Found 87 Records

CONTROL ID: 2971686
TITLE: Dynamics of multiple bodies in a corotation resonance
CONTACT (NAME ONLY): Joseph A'Hearn
CONTACT (INSTITUTION ONLY): University of Idaho
ABSTRACT BODY:
Abstract (2,250 Maximum Characters): The orbital evolution of multiple massive bodies trapped in the same corotation resonance site has not yet been studied in depth, but could be relevant to the origins and history of small moons like Saturn's moon Aegaeon. We conduct numerical simulations of multiple bodies trapped within a corotation resonance and examine what happens to these bodies when they have close encounters. Compared to simulations with equal mass bodies, simulations with one body more massive than the others may be more likely to feature an asymmetry in the phase space of semi-major axis and mean longitude. That is, bodies on one side of phase space have a slightly greater tendency to lose angular momentum, while bodies on the other side gain angular momentum. With this asymmetry, the transfer of angular momentum during gravitational encounters makes it more likely for the most massive body rather than other bodies to approach the center of the corotation site. More work is needed to determine if this sort of process can significantly affect the orbital evolution of small moons like Aegaeon.
AUTHORS (FIRST NAME INITIAL, LAST NAME): J. A'Hearn[1], M. Hedman[1]
AUTHORS/INSTITUTIONS: J. A'Hearn, M. Hedman, University of Idaho, Moscow, Idaho, UNITED STATES|
SESSION TITLE: Flat Cats Instead of Spherical Cows
PRESENTATION TYPE: Oral
CURRENT CATEGORY:

CONTROL ID: 2967526

TITLE: The Stability of Tidal Equilibrium for Hierarchical Star-Planet-Moon Systems

CONTACT (NAME ONLY): Fred Adams

CONTACT (INSTITUTION ONLY): University of Michigan

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Motivated by the current search for exomoons, this talk considers the stability of tidal equilibrium for hierarchical three-body systems containing a star, a planet, and a moon. In this treatment, the energy and angular momentum budgets include contributions from the planetary orbit, lunar orbit, stellar spin, planetary spin, and lunar spin. The goal is to determine the optimized energy state of the system subject to the constraint of constant angular momentum. Due to the lack of a closed form solution for the full three-body problem, however, we must use use an approximate description of the orbits. We first consider the Keplerian limit and find that the critical energy states are saddle points, rather than minima, so that these hierarchical systems have no stable tidal equilibrium states. We then generalize the calculation so that the lunar orbit is described by a time-averaged version of the circular restricted three-body problem. In this latter case, the critical energy state is a shallow minimum, so that a tidal equilibrium state exists. In both cases, however, the lunar orbit for the critical point lies outside the boundary (roughly half the Hill radius) where (previous) numerical simulations indicate dynamical instability.

AUTHORS (FIRST NAME INITIAL, LAST NAME): F. C. Adams[1]

AUTHORS/INSTITUTIONS: F.C. Adams, Physics , University of Michigan, Ann Arbor , Michigan, UNITED STATES|

SESSION TITLE: Stability, or Instability, That is the QuestionDynamics of Planetary System Stability

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974680

TITLE: Teetering Stars: Resonant Excitation of Stellar Obliquities by Hot and Warm Jupiters with External Companions

CONTACT (NAME ONLY): Kassandra Anderson

CONTACT (INSTITUTION ONLY): Cornell University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Stellar spin-orbit misalignments (obliquities) in hot Jupiter systems have been extensively probed in recent years thanks to Rossiter-McLaughlin observations. Such obliquities may reveal clues about hot Jupiter dynamical and migration histories. Common explanations for generating stellar obliquities include high-eccentricity migration, or primordial disk misalignment. This talk investigates another mechanism for producing stellar spin-orbit misalignments in systems hosting a close-in giant planet with an external, inclined planetary companion. Spin-orbit misalignment may be excited due to a secular resonance, occurring when the precession rate of the stellar spin axis (due to the inner orbit) becomes comparable to the precession rate of the inner orbital axis (due to the outer companion). Due to the spin-down of the host star via magnetic braking, this resonance may be achieved at some point during the star's main sequence lifetime for a wide range of giant planet masses and orbital architectures. We focus on both hot Jupiters (with orbital periods less than ten days) and warm Jupiters (with orbital periods around tens of days), and identify the outer perburber properties needed to generate substantial obliquities via resonant excitation, in terms of mass, separation, and inclination. For hot Jupiters, the stellar spin axis is strongly coupled to the orbital axis, and resonant excitation of obliquity requires a close perturber, located within 1-2 AU. For warm Jupiters, the spin and orbital axes are more weakly coupled, and the resonance may be achieved for more distant perturbers (at several to tens of AU). Resonant excitation of the stellar obliquity is accompanied by a decrease in the planets' mutual orbital inclination, and can thus erase high mutual inclinations in two-planet systems. Since many warm Jupiters are known to have outer planetary companions at several AU or beyond, stellar obliquities in warm Jupiter systems may be common, regardless of the formation/migration mechanism. Future observations probing warm Jupiter obliquities may indicate the presence of a hitherto undetected outer companion.

AUTHORS (FIRST NAME INITIAL, LAST NAME): K. Anderson[1], D. Lai[1]

AUTHORS/INSTITUTIONS: K. Anderson, D. Lai, Cornell University, Ithaca, New York, UNITED STATES|

SESSION TITLE: An Oblique Reference to Pop Culture

Dynamics of Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974974

TITLE: Probing the parameters of the HAT-P-2 system

CONTACT (NAME ONLY): Elizabeth Bailey

CONTACT (INSTITUTION ONLY): Caltech

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The HAT-P-2 system contributes an exceptional set of parameters to the exoplanetary inventory. HAT-P-2b weighs in at approximately 9 Jupiter masses, residing on one of the most eccentric, close-in orbits of any hot Jupiter (e~0.5, a~0.07). The identification of an RV trend points to the existence of an additional, long-period companion, which may have facilitated Kozai-Lidov cycles in the system over its multi-Gyr history. The well-constrained parameters of HAT-P-2b present an opportunity to predict the parameters of the perturber, and furthermore, to assess the tidal dissipation involved in the system's evolution. In this work, we employ an octupole-level secular model to account for the interaction of the two massive planets, thus classifying the system's deviations away from purely quadrupolar dynamics.

AUTHORS (FIRST NAME INITIAL, LAST NAME): E. Bailey[1], S. Naoz[2], K. Batygin[1]

AUTHORS/INSTITUTIONS: E. Bailey, K. Batygin, Caltech, Pasadena, California, UNITED STATES|S. Naoz, UCLA, Los Angeles, California, UNITED STATES|

SESSION TITLE: An Oblique Reference to Pop Culture

Dynamics of Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974939

TITLE: Schrödinger Evolution of Self-Gravitating Disks

CONTACT (NAME ONLY): Konstantin Batygin

CONTACT (INSTITUTION ONLY): California Institute of Technology

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): An understanding of the long-term evolution of self-gravitating disks ranks among the classic problems of dynamical astronomy. In this talk, I will describe an intriguing connection between the secular inclination dynamics of a Lagrange-Laplace disk and the time-dependent Schrödinger equation. Within the context of this formalism, nodal bending waves correspond to the eigen-modes of a quasiparticle's wavefunction, confined in an infinite square well with boundaries given by the radial extent of the disk. I will further show that external secular perturbations upon self-gravitating disks exhibit a mathematical similarity to quantum scattering theory, yielding an analytic criterion for the gravitational rigidity of a nearly-Keplerian disk under external perturbations.

AUTHORS (FIRST NAME INITIAL, LAST NAME): K. Batygin[1]

AUTHORS/INSTITUTIONS: K. Batygin, Division of Geological & Planetary Sciences, California Institute of Technology, Pasadena, California, UNITED STATES|

SESSION TITLE: Flat Cats Instead of Spherical Cows

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971068

TITLE: Forming Hot Jupiters: Observational Constraints on Gas Giant Formation and migration

CONTACT (NAME ONLY): Juliette Becker

CONTACT (INSTITUTION ONLY): University of Michigan

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Since the first extrasolar planets were detected, the existence of hot Jupiters has challenged prevailing theories of planet formation. The three commonly considered pathways for hot Jupiter formation are in situ formation, runaway accretion in the outer disk followed by disk migration, and tidal migration (occurring after the disk has dissipated). None of these explains the entire observed sample of hot Jupiters, suggesting that different selections of systems form via different pathways. The way forward is to use observational data to constrain the migration pathways of particular classes of systems, and subsequently assemble these results into a coherent picture of hot Jupiter formation. We present constraints on the migratory pathway for one particular type of system: hot Jupiters orbiting cool stars (T< 6200 K). Using the full observational sample, we find that the orbits of most wide planetary companions to hot Jupiters around these cool stars must be well aligned with the orbits of the hot Jupiters and the spins of the host stars. The population of systems containing both a hot Jupiter and an exterior companion around a cool star thus generally exist in roughly coplanar configurations, consistent with the idea that disk-driven migratory mechanisms have assembled most of this class of systems. We then discuss the overall applicability of this result to a wider range of systems and the broader implications on planet formation.

AUTHORS (FIRST NAME INITIAL, LAST NAME): J. Becker[1], A. Vanderburg[2], F. C. Adams[1], T. Khain[1], M. Bryan[3]

AUTHORS/INSTITUTIONS: J. Becker, F.C. Adams, T. Khain, University of Michigan, Ann Arbor, Michigan, UNITED STATES|A. Vanderburg, University of Texas, Austin, Texas, UNITED STATES|M. Bryan, Caltech, Pasadena, California, UNITED STATES|

SESSION TITLE: In the Beginning There Was Chaos

Dynamics of Planet Formation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970275

TITLE: Assessing Backwards Integration as a Method of KBO Family Finding

CONTACT (NAME ONLY): Nathan Benfell

CONTACT (INSTITUTION ONLY): Brigham Young University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The age of young asteroid collisional families can sometimes be determined by using backwards n-body integrations of the solar system. This method is not used for discovering young asteroid families and is limited by the unpredictable influence of the Yarkovsky effect on individual specific asteroids over time. Since these limitations are not as important for objects in the Kuiper belt, Marcus et al. 2011 suggested that backwards integration could be used to discover and characterize collisional families in the outer solar system. But various challenges present themselves when running precise and accurate 4+ Gyr integrations of Kuiper Belt objects. We have created simulated families of Kuiper Belt Objects with identical starting locations and velocity distributions, based on the Haumea Family. We then ran several long-term test integrations to observe the effect of various simulation parameters on integration results. These integrations were then used to investigate which parameters are of enough significance to require inclusion in the integration. Thereby we determined how to construct long-term integrations that both yield significant results and require manageable processing power. Additionally, we have tested the use of backwards integration as a method of discovery of potential young families in the Kuiper Belt.

AUTHORS (FIRST NAME INITIAL, LAST NAME): N. Benfell[1], D. Ragozzine[1]

AUTHORS/INSTITUTIONS: N. Benfell, D. Ragozzine, Physics & Astronomy, Brigham Young University, PROVO, Utah, UNITED STATES|

SESSION TITLE: Never Tell Me the Odds

Dynamics of the Kuiper Belt

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2973063

TITLE: Transit Duration Variations due to Secular Interactions in Systems with Tightly-packed Inner Planets

CONTACT (NAME ONLY): Aaron Boley

CONTACT (INSTITUTION ONLY): The University of British Columbia

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Secular interactions among planets in multi-planet systems will lead to variations in orbital inclinations and to the precession of orbital nodes. Taking known system architectures at face value, we calculate orbital precession rates for planets in tightly-packed systems using classical second-order secular theory, in which the orientation of the orbits can be described as a vector sum of eigenmodes and the eigenstructure is determined only by the masses and semi-major axes of the planets. Using this framework, we identify systems that have fast precession frequencies, and use those systems to explore the range of transit duration variation that could occur using amplitudes that are consistent with tightly-packed planetary systems. We then further assess how transit duration variations could be used in practice.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. Boley[1], C. Van Laerhoven[1], A. Granados Contreras[1]

AUTHORS/INSTITUTIONS: A. Boley, C. Van Laerhoven, A. Granados Contreras, Physics and Astronomy, The University of British Columbia, Vancouver, British Columbia, CANADA|

SESSION TITLE: Hot, Flat, and Crowded

Dynamics of Tightly-Packed Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974948

TITLE: The Sustainable Development of Space: Astro-environmental and dynamical considerations

CONTACT (NAME ONLY): Aaron Boley

CONTACT (INSTITUTION ONLY): The University of British Columbia

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The sustainable development of space is a global (and exo-global) challenge that is not limited by borders or research disciplines. Sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. While the development of space brings new economic and scientific possibilities, it also carries significant political, legal, and technical uncertainties. For example, the rapidly increasing accessibility of space is motivating states to unilaterally adopt legislation for the new era of space use, which may have significant unintended consequences, such as increased risks to space assets, disputes among state as well as non-state actors, and changes to unique astro-environments. Any policy or legal position must be informed by the dynamical and astrophysical realities of space use, creating complex and interwoven challenges. Here, we explore several of these potential challenges related to astro-environmentalism, space minining operations, and the associated dynamics.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. Boley[1], M. Byers[1], S. Russell[2]

AUTHORS/INSTITUTIONS: A. Boley, M. Byers, Physics and Astronomy, The University of British Columbia, Vancouver, British Columbia, CANADA|S. Russell, Natural History Museum, London, UNITED KINGDOM|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2974757

TITLE: Orbits of the inner satellites of Neptune

CONTACT (NAME ONLY): Marina Brozovic

CONTACT (INSTITUTION ONLY): Jet Propulsion Laboratory/California Institute of Technology

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We report on the numerically integrated orbits of seven inner satellites of Neptune, including S/2004 N1, the last moon of Neptune to be discovered by the Hubble Space Telescope (HST). The dataset includes Voyager imaging data as well as the HST and Earth-based astrometric data. The observations span time period from 1989 to 2016. Our orbital model accounts for the equatorial bulge of Neptune, perturbations from the Sun and the planets, and perturbations from Triton. The initial orbital integration assumed that the satellites are massless, but the residuals improved significantly as the masses adjusted toward values that implied that the density of the satellites is in the realm of 1 g/cm^3. We will discuss how the integrated orbits compare to the precessing ellipses fits, mean orbital elements, current orbital uncertainties, and the need for future observations.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. Brozovic[1], M. R. Showalter[2], R. A. Jacobson[1], R. S. French[2], I. de Pater[3], J. Lissauer[4]

AUTHORS/INSTITUTIONS: M. Brozovic, R.A. Jacobson, Jet Propulsion Laboratory/California Institute of Technology, Pasadena, California, UNITED STATES|M.R. Showalter, R.S. French, SETI Institute, Mountan View, California, UNITED STATES|I. de Pater, UC Berkley, Berkley, California, UNITED STATES|J. Lissauer, NASA Ames Research Center, Mountain View, California, UNITED STATES|

SESSION TITLE: Ringleaders and Fellow Travelers

Dynamics of Moons

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2972794

TITLE: Cellular Analysis of Boltzmann Most Probable Ideal Gas Statistics

CONTACT (NAME ONLY): Michael Cahill

CONTACT (INSTITUTION ONLY): U WI Milwaukee/Washington County

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Exact treatment of Boltzmann's Most Probable Statistics for an Ideal Gas of Identical Mass Particles having Translational Kinetic Energy gives a Distribution Law for Velocity Phase Space Cell j which relates the Particle Energy and the Particle Population according to

$B\ e(j) = A - \Psi(n(j) + 1)$

where A & B are the Lagrange Multipliers and Ψ is the Digamma Function defined by

$\Psi(x + 1) = d/dx \ln(x!)$

A useful sufficiently accurate approximation for Ψ is given by

$\Psi(x + 1) \approx \ln(e^{-\gamma} + x)$

where γ is the Euler constant (≈.5772156649) & so the above distribution equation is approximately

$B\ e(j) = A - \ln(e^{-\gamma} + n(j))$

which can be inverted to solve for n(j) giving

$n(j) = (e^{B\ (eH - e(j))} - 1)\ e^{-\gamma}$

where $B\ eH = A + \gamma$

& where B eH is a unitless particle energy which replaces the parameter A. The 2 approximate distribution equations imply that eH is the highest particle energy and the highest particle population is

$nH = (e^{B\ eH} - 1)\ e^{-\gamma}$

which is due to the facts that population becomes negative if e(j) > eH and kinetic energy becomes negative if n(j) > nH.

An explicit construction of Cells in Velocity Space which are equal in volume and homogeneous for almost all cells is shown to be useful in the analysis.

Plots for sample distribution properties using e(j) as the independent variable are presented.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. E. Cahill[1]

AUTHORS/INSTITUTIONS: M.E. Cahill, U WI Milwaukee/Washington County, West Bend, Wisconsin, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971575

TITLE: Meteoroid Orbits from Observations

CONTACT (NAME ONLY): Margaret Campbell-Brown

CONTACT (INSTITUTION ONLY): University of Western Ontario

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Millions of orbits of meteoroids have been measured over the last few decades, and they comprise the largest sample of orbits of solar system bodies which exists. The orbits of these objects can shed light on the distribution and evolution of comets and asteroids in near-Earth space (e.g. Neslusan et al. 2016). If orbits can be measured at sufficiently high resolution, individual meteoroids can be traced back to their parent bodies and, in principle, even to their ejection time (Rudawska et al. 2012). Orbits can be measured with multi-station optical observations or with radar observations.

The most fundamental measured quantities are the speed of the meteor and the two angles of the radiant, or point in the sky from which the meteor appears to come. There are many methods used to determine these from observations, but not all produce the most accurate results (Egal et al. 2017). These three measured quantities, along with the time and location of the observation, are sufficient to obtain an orbit (see, e.g., Clark & Wiegert 2011), but the measurements must be corrected for the deceleration of the meteoroid in the atmosphere before it was detected, the rotation of the Earth, and the gravitational attraction of the Earth (including higher order moments if great precision is necessary).

Once meteor orbits have been determined, studies of the age and origin of meteor showers (Bruzzone et al., 2015), the parent bodies of sporadic sources (Pokorny et al. 2014), and the dynamics of the meteoroid complex as a whole can be constrained.

Bruzzone, J. S., Brown, P., Weryk, R., Campbell-Brown, M., 2015. MNRAS 446, 1625.

Clark, D., Wiegert, P., 2011. M&PS 46, 1217.

Egal, A., Gural, P., Vaubaillon, J., Colas, F., Thuillot, W., 2017. Icarus 294, 43.

Neslusan, L., Vaubaillon, J., Hajdukova, M., 2016. A&A 589, id.A100.

Pokorny, P., Vokrouhlicky, D., Nesvorny, D., Campbell-Brown, M., Brown, P., 2014. ApJ 789, id.25.

Rudawska, R., Vaubaillon, J., Atreya, P., 2012. A&A 541, id.A2

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. Campbell-Brown[1]

AUTHORS/INSTITUTIONS: M. Campbell-Brown, Physics and Astronomy, University of Western Ontario, London, Ontario, CANADA|

SESSION TITLE: Pebble in the Sky: Meteoroids and Their Orbits

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2969417

TITLE: The structure of Jupiter's main ring from New Horizons: A comparison with other ring-moon systems

CONTACT (NAME ONLY): Robert Chancia

CONTACT (INSTITUTION ONLY): University of Idaho

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): During New Horizon's Jupiter flyby in 2007, the Long-Range Reconnaissance Imager (LORRI) took several images of the planet's main ring. The data set contains two extended image-movies of the main ring, along with several brief observations at varying ring azimuths, and a small set of high phase angle images. Thus far, the only published work on the New Horizons Jupiter rings data set found seven bright clumps with sub-km equivalent radii embedded in the main ring (Showalter et al. 2007 Science). In this work, we searched the inner region of the main ring for any structures that might be perturbed at the 3:2 resonances with the rotation of Jupiter's magnetic field or massive storms. We also examined the structure of the outer main ring in order to assess how it is shaped by the small moons Metis and Adrastea. Some of the features seen in Jupiter's main ring are similar to those found in other dusty rings around Saturn, Uranus, and Neptune. By comparing these different rings, we can gain a better understanding of how small moons sculpt tenuous rings.

AUTHORS (FIRST NAME INITIAL, LAST NAME): R. Chancia[1], M. Hedman[1]

AUTHORS/INSTITUTIONS: R. Chancia, M. Hedman, University of Idaho, Moscow, Idaho, UNITED STATES|

SESSION TITLE: The Astronomer Always Rings Twice, Dynamics of Planetary Rings

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2962638
TITLE: Saving the Inner Solar System with an Early Instability
CONTACT (NAME ONLY): Matthew Clement
CONTACT (INSTITUTION ONLY): University of Oklahoma
ABSTRACT BODY:
Abstract (2,250 Maximum Characters):

An orbital instability between the solar system's giant planets (the so-called Nice Model) has been shown to greatly disturb the orbits of the young terrestrial planets. Undesirable outcomes such as over-excitated orbits, ejections and collisions can be avoided if the instability occurs before the inner planets are fully formed. Such a scenario also has the advantage of limiting the mass and formation time of Mars when it occurs within several million years (Myr) of gas disk dissipation. The dynamical effects of the instability cause many small embryos and planetesimals to scatter away from the forming Mars, and lead to heavy mass depletion in the Asteroid Belt. We present new simulations of this scenario that demonstrate its ability to accurately reproduce the eccentricity, inclination and resonant structures of the Asteroid Belt. Furthermore, we perform simulations using an integration scheme which accounts for the fragmentation of colliding bodies. The final terrestrial systems formed in these simulations provide a better match to the actual planets' compact mass distribution and dynamically cold orbits. An early instability scenario is thus very successful at simultaneously replicating the dynamical state of both the inner and outer solar system.
AUTHORS (FIRST NAME INITIAL, LAST NAME): M. Clement[1], N. A. Kaib[1], S. N. Raymond[2], K. J. Walsh[3]
AUTHORS/INSTITUTIONS: M. Clement, N.A. Kaib, Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, UNITED STATES|S.N. Raymond, Laboratorie d'Astrophysique de Bordeaux, University Bordeaux, Pessac, FRANCE|K.J. Walsh, Southwest Research Institute, Boulder, Colorado, UNITED STATES|
SESSION TITLE: In the Beginning There Was Chaos
Dynamics of Planet Formation
PRESENTATION TYPE: Oral
CURRENT CATEGORY:

CONTROL ID: 3003058

TITLE: Electromagnetic Effices from Impacts on Spacecraft

CONTACT (NAME ONLY): Sigrid Close

CONTACT (INSTITUTION ONLY): Stanford University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Hypervelocity micro particles, including meteoroids and space debris with masses < 1 ng, routinely impact spacecraft and create dense plasma that expands at the isothermal sound speed. This plasma, with a charge separation commensurate with different species mobilities, can produce a strong electromagnetic pulse (EMP) with a broad frequency spectrum. Subsequent plasma oscillations resulting from instabilities can also emit significant power and may be responsible for many reported satellite anomalies. We present theory and recent results from ground-based impact tests aimed at characterizing hypervelocity impact plasma and show that impact-produced radio frequency (RF) emissions occurred in frequencies ranging from VHF through L-band and that these emissions were highly correlated with fast (> 20 km/s) impacts that produced a fully ionized plasma.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. Close[1]

AUTHORS/INSTITUTIONS: S. Close, Stanford University, Stanford, California, UNITED STATES|

SESSION TITLE: Pebble in the Sky: Meteoroids and Their Orbits

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971045

TITLE: Early Dynamics of the Moon's Core

CONTACT (NAME ONLY): Matija Cuk

CONTACT (INSTITUTION ONLY): SETI Institute

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The Moon has a small molten iron core (Williams et al. 2006). Remanent magnetization in lunar rocks likely derives from a past lunar dynamo (Wieczorek 2018 and references therein), which may have been powered by differential precession between the mantle and the core. The rotations of the lunar mantle and core were largely decoupled for much of lunar history, with a large mutual offset during the Cassini State Transition (Meyer and Wisdom, 2011). It is likely that the past work underestimated lunar obliquities, and therefore core offsets, during early lunar history (Cuk et al. 2016).

Here we investigate the dynamics of the lunar core and mantle using a Lie-Poisson numerical integrator (Touma and Wisdom 2001) which includes interactions between triaxial core and mantle, as well as all gravitational and tidal effects included in the model of Cuk et al. (2016). Since we assume a rigid triaxial mantle, this model is applicable to the Moon only once it has acquired its current shape, which probably happened before the Moon reached 25 Earth radii. While some details of the core dynamics depend on our assumptions about the shape of the lunar core-mantle boundary, we can report some robust preliminary findings. The presence of the core does not change significantly the evolutionary scenario of Cuk et al. (2016). The core and mantle are indeed decoupled, with the core having a much smaller obliquity to the ecliptic than the mantle for almost all of the lunar history. The core was largely in an equivalent of Cassini State 2, with the vernal equinoxes (wrt the ecliptic) of the core and the mantle being anti-aligned. The core-mantle spin axis offset has been very large during the Moon's first billion years (this is true both in canonical and high-inclination tidal evolution), causing the lunar core to be sub-synchronous. If the ancient lunar magnetic dipole was rotating around the core axis that was inclined to the Moon's spin axis, then the magnetic poles would move across the lunar surface as the mantle rotates independently. This relative motion would dilute the average dipole field over much of the lunar surface, and would would restrict meaningful average fields to low lunar latitudes.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. Cuk[1], D. Hamilton[2], S. T. Stewart[3]

AUTHORS/INSTITUTIONS: M. Cuk, Carl Sagan Center, SETI Institute, Mountain View, California, UNITED STATES|D. Hamilton, University of Maryland, College Park, Maryland, UNITED STATES|S.T. Stewart, University of California, Davis, California, UNITED STATES|

SESSION TITLE: Party in the Spin Room

Dynamics of Rotation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2965143

TITLE: Full Two-Body Problem Mass Parameter Observability Explored Through Doubly Synchronous Systems

CONTACT (NAME ONLY): Alex Davis

CONTACT (INSTITUTION ONLY): University of Colorado at Boulder

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The full two-body problem (F2BP) is often used to model binary asteroid systems, representing the bodies as two finite mass distributions whose dynamics are influenced by their mutual gravity potential. The emergent behavior of the F2BP is highly coupled translational and rotational mutual motion of the mass distributions. For these systems the doubly synchronous equilibrium occurs when both bodies are tidally-locked and in a circular co-orbit. Stable oscillations about this equilibrium can be shown, for the nonplanar system, to be combinations of seven fundamental frequencies of the system and the mutual orbit rate. The fundamental frequencies arise as the linear periods of center manifolds identified about the equilibrium which are heavily influenced by each body's mass parameters. We leverage these eight dynamical constraints to investigate the observability of binary asteroid mass parameters via dynamical observations. This is accomplished by proving the nonsingularity of the relationship between the frequencies and mass parameters for doubly synchronous systems. Thus we can invert the relationship to show that given observations of the frequencies, we can solve for the mass parameters of a target system. In so doing we are able to predict the estimation covariance of the mass parameters based on observation quality and define necessary observation accuracies for desired mass parameter certainties. We apply these tools to 617 Patroclus, a doubly synchronous Trojan binary and flyby target of the LUCY mission, as well as the Pluto and Charon system in order to predict mutual behaviors of these doubly synchronous systems and to provide observational requirements for these systems' mass parameters

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. B. Davis[1], D. Scheeres[1]

AUTHORS/INSTITUTIONS: A.B. Davis, D. Scheeres, Aerospace Engineering Sciences, University of Colorado at Boulder, Boulder, Colorado, UNITED STATES|

SESSION TITLE: 'N SyncDynamics of Resonant Objects

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971879

TITLE: Terrestrial Planet Formation from an Annulus -- Revisited

CONTACT (NAME ONLY): Rogerio Deienno

CONTACT (INSTITUTION ONLY): Southwest Research Institute - SwRI

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Numerous recent theories of terrestrial planet formation suggest that, in order to reproduce the observed large Earth to Mars mass ratio, planets formed from an annulus of material within 1 au. The success of these models typically rely on a Mars sized embryo being scattered outside 1 au (to ~1.5 au) and starving, while those remaining inside 1 au continue growing, forming Earth and Venus. In some models the scattering is instigated by the migration of giant planets, while in others an embryo-instability naturally occurs due to the dissipation of the gaseous solar nebula. While these models can typically succeed in reproducing the overall mass ratio among the planets, the final angular momentum deficit (AMD) of the present terrestrial planets in our Solar System, and their radial mass concentration (RMC), namely the position where Mars end up in the simulations, are not always well reproduced. Assuming that the gas nebula may not be entirely dissipated when such an embryo-instability happens, here, we study the effects that the time of such an instability can have on the final AMD and RMC. In addition, we also included energy dissipation within embryo-embryo collisions by assuming a given coefficient of restitution for collisions. Our results show that: i) dissipation within embryo-embryo collisions do not play any important role in the final terrestrial planetary system; ii) the final AMD decreases only when the number of final planets formed increases; iii) the RMC tends to always be lower than the present value no matter the number of final planets; and iv) depending on the time that the embryo-instability happen, if too early, with too much gas still present, a second instability will generally happen after the dissipation of the gas nebula.

AUTHORS (FIRST NAME INITIAL, LAST NAME): R. Deienno[1], K. J. Walsh[1], K. A. Kretke[1], H. F. Levison[1]

AUTHORS/INSTITUTIONS: R. Deienno, K.J. Walsh, K.A. Kretke, H.F. Levison, Department of Space Studies, Southwest Research Institute - SwRI, Boulder, Colorado, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2971869

TITLE: Exciting an Initially Cold Asteroid Belt Through a Planetary Instability

CONTACT (NAME ONLY): Rogerio Deienno

CONTACT (INSTITUTION ONLY): Southwest Research Institute - SwRI

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The main asteroid belt (MB) is low in mass but dynamically excited, with much larger eccentricities and inclinations than the planets. In recent years, the Grand Tack model has been the predominant model capable of reconciling the formation of the terrestrial planets with a depleted but excited MB. Despite this success, the Grand Tack is still not generally accepted because of uncertainties in orbital migration. It was recently proposed that chaotic early evolution of Jupiter and Saturn could excite the initially cold MB. However, hydrodynamical simulations predict that the giant planets should generally emerge from the gas disk phase on orbits characterized by resonant and regular motion. Here we propose a new mechanism to excite the MB during the giant planets' ('Nice model') instability, which is expected to have included repeated close encounters between Jupiter and one or more ice giants ('Jumping Jupiter' -- JJ). We show that when Jupiter temporarily reaches a high enough level of excitation, both in eccentricity and inclination, it induces strong forced vectors of eccentricity and inclination within the MB region. Because during the JJ instability Jupiter's orbit 'jumps' around, forced vectors keep changing both in magnitude and phase throughout the whole MB region. The entire cold primordial MB can thus be excited as a natural outcome of the JJ instability. Furthermore, we show that the subsequent evolution of the Solar System is capable of reshaping the resultant MB to its present day orbital state, and that a strong mass depletion is always associated to the JJ instability phase.

AUTHORS (FIRST NAME INITIAL, LAST NAME): R. Deienno[1], A. Izidoro[2], A. Morbidelli[3], R. Gomes[4], D. Nesvorny[1], S. N. Raymond[5]

AUTHORS/INSTITUTIONS: R. Deienno, D. Nesvorny, Department of Space Studies, Southwest Research Institute - SwRI, Boulder, Colorado, UNITED STATES|A. Izidoro, Universidade Estadual Paulista, Guaratingueta, Sao Paulo, BRAZIL|A. Morbidelli, Observatorie de la Côte d'Azur, Nice, FRANCE|R. Gomes, Observatorio Nacional, Rio de Janeiro, Rio de Janeiro, BRAZIL|S.N. Raymond, Laboratoire d’Astrophysique de Bordeaux, Bordeaux, FRANCE|

SESSION TITLE: In the Beginning There Was Chaos

Dynamics of Planet Formation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974881

TITLE: Asteroids and Meteorites from Venus? Only the Earth Goddess Knows

CONTACT (NAME ONLY): Henry Dones

CONTACT (INSTITUTION ONLY): Southwest Research Institute

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): No meteorites from Venus have been found; indeed, some find their existence unlikely because of the perceived difficulty of launching rocks at speeds above 10 km/s and traversing the planet's 93 bar atmosphere. [1] Nonetheless, we keep hope alive, since cosmochemists say they can identify Cytherean meteorites, should candidates be found [2]. Gladman et al. [3] modeled the exchange of impact ejecta between the terrestrial planets, but did not consider meteorites launched from Venus in any detail. At the time of Gladman's work, no asteroids that remained entirely within Earth's orbit were known. 14 such Earth-interior objects with good orbits have now been discovered, and are known as Atiras, for the Pawnee goddess of the Earth. The largest known member of the class is 163693 Atira, a binary whose components have diameters of approximately 4.8 and 1 km. Discovery of Atiras is very incomplete because they can only be seen at small solar elongations [4]. Greenstreet et al. [5] modeled the orbital distribution of Atiras from main-belt asteroidal and cometary source regions, while Ribeiro et al. [6] mapped the stability region of hypothetical Atiras and integrated the orbits of clones of 12 real Atiras for 1 million years. 97% of the clones survived for 1 Myr; impact with Venus was the most common fate of those that met their ends. We have performed orbital integrations of 1000 clones of each of the known Atiras, and of hypothetical ejecta that escape Venus after asteroid impacts, for 10-100 Myr. The latter calculations use techniques like those of Alvarellos et al. [7] and Zahnle et al. [8] for transfer amongst Jupiter's galilean satellites. Our goals are to estimate the fraction of Atiras that are ejecta launched from Venus, the time spent in space by hypothetical meteorites from Venus, and the rate at which such meteorites strike the Earth.

[1] Gilmore M., et al (2017). Space Sci. Rev. 212, 1511. [2] Jourdan F., Eroglu E. (2017). MAPS 52, 884. [3] Gladman B.J., et al. (1996). Science 271, 1387. [4] Masi G. (2003). Icarus 163, 389. [5] Greenstreet S., Ngo H., Gladman B. (2012). Icarus 217, 355. [6] Ribeiro A.O., et al. (2016). MNRAS 458, 4471. [7] Alvarellos, J.L., et al. (2008). Icarus 194, 636. [8] Zahnle, K., et al. (2008). Icarus 194, 660.

AUTHORS (FIRST NAME INITIAL, LAST NAME): H. Dones[1], K. J. Zahnle[2], J. L. Alvarellos[3]

AUTHORS/INSTITUTIONS: H. Dones, Southwest Research Institute, BOULDER, Colorado, UNITED STATES|K.J. Zahnle, NASA Ames Research Center, Moffett Field, California, UNITED STATES|J.L. Alvarellos, SSL, Palo Alto, California, UNITED STATES|

SESSION TITLE: Pebble in the Sky: Meteoroids and Their Orbits

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974774

TITLE:

Derivation of the Torque Associated to Tesseral Resonances

CONTACT (NAME ONLY): Maryame El Moutamid

CONTACT (INSTITUTION ONLY): Cornell University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters):

A so-called m+1:m Tesseral Resonance is simply equivalent to an inner m+1:m Lindblad Resonance or an outer Lindblad Resonance, where m is an integer. They are generated between a gravity anomaly that rotates with the primary and a test particle evolving around this primary, instead of being caused by a secondary, meaning that in this case the particle and the secondary do not share the same orbit. We show in this work that the torque is stronger for small values of |m|; as |m| tends to infinity, the torque tends to zero and that the Lagrange points are displaced away from the usual triangular configuration. These simple results have interesting implications on Saturn, Chariklo and Mars.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. El Moutamid[1]

AUTHORS/INSTITUTIONS: M. El Moutamid, Cornell University, Ithaca, New York, UNITED STATES|

SESSION TITLE: The Astronomer Always Rings Twice, Dynamics of Planetary Rings

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2987819

TITLE: The Realm of Close-in Planets

CONTACT (NAME ONLY): Daniel Fabrycky

CONTACT (INSTITUTION ONLY): University of Chicago

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The space within about 1 AU of other stars in the Galaxy is an exciting place to be a planet. The categories of "hot Jupiters", "super-Earths", "sub-Neptunes", and recently terrestrial analogues, have been revealed by Doppler programs and space-based transit missions. In this talk, we review how N-body modelling of the data teach us the properties of these planets and their orbital architectures. We also review the major dynamical ideas about the formation and evolution of these systems.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. C. Fabrycky[1]

AUTHORS/INSTITUTIONS: D.C. Fabrycky, Astronomy & Astrophysics, University of Chicago, Chicago, Illinois, UNITED STATES|

SESSION TITLE: Vera Rubin Prize Lecture

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971825

TITLE: Coevolution of Binaries and Circumbinary Gaseous Disks

CONTACT (NAME ONLY): David Fleming

CONTACT (INSTITUTION ONLY): University of Washington

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The recent discoveries of circumbinary planets by Kepler raise questions for contemporary planet formation models. Understanding how these planets form requires characterizing their formation environment, the circumbinary protoplanetary disk, and how the disk and binary interact. The central binary excites resonances in the surrounding protoplanetary disk that drive evolution in both the binary orbital elements and in the disk. To probe how these interactions impact both binary eccentricity and disk structure evolution, we ran N-body smooth particle hydrodynamics (SPH) simulations of gaseous protoplanetary disks surrounding binaries based on Kepler 38 for 10^4 binary orbital periods for several initial binary eccentricities. We find that nearly circular binaries weakly couple to the disk via a parametric instability and excite disk eccentricity growth. Eccentric binaries strongly couple to the disk causing eccentricity growth for both the disk and binary. Disks around sufficiently eccentric binaries strongly couple to the disk and develop an m = 1 spiral wave launched from the 1:3 eccentric outer Lindblad resonance (EOLR). This wave corresponds to an alignment of gas particle longitude of periastrons. We find that in all simulations, the binary semi-major axis decays due to dissipation from the viscous disk.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Fleming[1], T. R. Quinn[1]

AUTHORS/INSTITUTIONS: D. Fleming, T.R. Quinn, Astronomy, University of Washington, Seattle, Washington, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2962710

TITLE: On the Lack of Circumbinary Planets Orbiting Isolated Binary Stars

CONTACT (NAME ONLY): David Fleming

CONTACT (INSTITUTION ONLY): University of Washington

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): To date, no binary star system with an orbital period less than 7.5 days has been observed to host a circumbinary planet (CBP), a puzzling observation given the thousands of binary stars with orbital periods < 10 days discovered by the Kepler mission (Kirk et al., 2016) and the observational biases that favor their detection (Munoz & Lai, 2015). We outline a mechanism that explains the observed lack of CBPs via coupled stellar-tidal evolution of isolated binary stars. Tidal forces between low-mass, short-period binary stars on the pre-main sequence slow the stellar rotations, transferring rotational angular momentum to the orbit as the stars approach the tidally locked state. This transfer increases the binary orbital period, expanding the region of dynamical instability around the binary, and destabilizing CBPs that tend to preferentially orbit just beyond the initial dynamical stability limit. After the stars tidally lock, we find that angular momentum loss due to magnetic braking can significantly shrink the binary orbit, and hence the region of dynamical stability, over time impacting where surviving CBPs are observed relative to the boundary. We perform simulations over a wide range of parameter space and find that the expansion of the instability region occurs for most plausible initial conditions and that in some cases, the stability semi-major axis doubles from its initial value. We examine the dynamical and observable consequences of a CBP falling within the dynamical instability limit by running N-body simulations of circumbinary planetary systems and find that typically, at least one planet is ejected from the system. We apply our theory to the shortest period Kepler binary that possesses a CBP, Kepler-47, and find that its existence is consistent with our model. Under conservative assumptions, we find that coupled stellar-tidal evolution of pre-main sequence binary stars removes at least one close-in CBP in 87% of multi-planet circumbinary systems.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Fleming[1, 2], R. Barnes[1, 2], D. E. Graham[1], R. Luger[1, 2], T. R. Quinn[1, 2]

AUTHORS/INSTITUTIONS: D. Fleming, R. Barnes, D.E. Graham, R. Luger, T.R. Quinn, Astronomy, University of Washington, Seattle, Washington, UNITED STATES|D. Fleming, R. Barnes, R. Luger, T.R. Quinn, NASA Astrobiology Institute - Virtual Planetary Laboratory Lead Team, Seattle, Washington, UNITED STATES|

SESSION TITLE: An Oblique Reference to Pop Culture

Dynamics of Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974825

TITLE: Dynamical Upheaval in Ice Giant Formation: A Solution to the Fine-tuning Problem in the Formation Story

CONTACT (NAME ONLY): Renata Frelikh

CONTACT (INSTITUTION ONLY): UC Santa Cruz

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We report on our recent theoretical work, where we suggest that a protoplanetary disk dynamical instability may have played a crucial role in determining the atmospheric size of the solar system's ice giants. In contrast to the gas giants, the intermediate-size ice giants never underwent runaway gas accretion in a full gas disk. However, as their substantial core masses are comparable to those of the gas giants, they would have gone runaway, given enough time. In the standard scenario, the ice giants stay at roughly their current size for most of the disk lifetime, undergoing period of slow gas accretion onto ~full-sized cores that formed early-on. The gas disk dissipates before the ice giants accumulate too much gas, but we believe this is fine tuned. A considerable amount of solids is observed in outer disks in mm-to-cm sized particles (pebbles). Assisted by gas drag, these pebbles rapidly accrete onto cores. This would cause the growing ice giants to exceed their current core masses, and quickly turn into gas giants. To resolve this problem, we propose that Uranus and Neptune stayed small for the bulk of the disk lifetime. They only finished their core and atmospheric growth in a short timeframe just as the disk gas dissipated, accreting most of their gas from a disk depleted to ~1% of its original mass. The ice giants have atmospheric mass fractions comparable to the disk gas-to-solid ratio of this depleted disk. This coincides with a disk dynamical upheaval onset by the depletion of gas. We propose that the cores started growing closer-in, where they were kept small by proximity to Jupiter and Saturn. As the gas cleared, the cores were kicked out by the gas giants. Then, they finished their core growth and accreted their atmospheres from the remaining, sparse gas at their current locations. We predict that the gas giants may play a key role in forming intermediate-size atmospheres in the outer disk.

AUTHORS (FIRST NAME INITIAL, LAST NAME): R. Frelikh[1], R. Murray-Clay[1]

AUTHORS/INSTITUTIONS: R. Frelikh, R. Murray-Clay, UC Santa Cruz, Santa Cruz, California, UNITED STATES|

SESSION TITLE: In the Beginning There Was Chaos

Dynamics of Planet Formation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970582

TITLE: Orbital stability of compact three-planets systems.

CONTACT (NAME ONLY): Sacha Gavino

CONTACT (INSTITUTION ONLY): Université de Bordeaux

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Recent discoveries unveiled a significant number of compact multi-planetary systems, where the adjacent planets orbits are much closer to those found in the Solar System. Studying the orbital stability of such compact systems provides information on how they form and how long they survive. We performed a general study of three Earth-like planets orbiting a Sun-mass star in circular and coplanar prograde orbits. The simulations were performed over a wide range of mutual Hill radii and were conducted for virtual times reaching at most 10 billion years. Both equally-spaced and unequally spaced planet systems are investigated. We recover the results of previous studies done for systems of planets spaced uniformly in mutual Hill radius and we investigate mean motion resonances and test chaos. We also study systems with different initial spacing between the adjacent inner pair of planets and the outer pair of planets and we displayed their lifetime on a grid at different resolution. Over 45000 simulations have been done. We then characterize isochrones for lifetime of systems of equivalent spacing. We find that the stability time increases significantly for values of mutual Hill radii beyond 8. We also study the affects of mean motion resonances, the degree of symmetry in the grid and test chaos.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. Gavino[1, 2], J. Lissauer[3]

AUTHORS/INSTITUTIONS: S. Gavino, Laboratoire d'Astrophysique de Bordeaux, Université de Bordeaux, Paris, FRANCE|S. Gavino, Laboratoire d'Astrophysique de Bordeaux, Pessac, FRANCE|J. Lissauer, NASA Ames Research Center, Moffett Field, California, UNITED STATES|

SESSION TITLE: Stability, or Instability, That is the QuestionDynamics of Planetary System Stability

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2986926

TITLE: The Barred Inner Region of the Milky Way

CONTACT (NAME ONLY): Ortwin Gerhard

CONTACT (INSTITUTION ONLY): Max Planck Institue for Ex. Physics

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The central few kpc of our Galaxy, the Milky Way, are dominated by the gravitational field of the Galactic bar. This talk describes dynamical models of the bar and box/peanut bulge, and what we have learnt from them about the dynamical structure, the distribution of stellar and dark matter mass, and the spatial and orbital distributions of the Galactic stellar populations. Finally I discuss models for the formation of galaxies like ours, and how Milky Way studies enlighten galaxy formation theories in general.

AUTHORS (FIRST NAME INITIAL, LAST NAME): O. Gerhard[1]

AUTHORS/INSTITUTIONS: O. Gerhard, Max Planck Institue for Ex. Physics, Garching, Bavaria, GERMANY|

SESSION TITLE: Dirk Brouwer Award Lecture

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974984

TITLE: The prevalence of resonances among large-a transneptunian objects

CONTACT (NAME ONLY): Brett Gladman

CONTACT (INSTITUTION ONLY): University of British Columbia

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The detached population consists of transneptunian objects (TNOs) with large semi-major axes and sufficiently high perihelia (roughly q>38 au, but there is no simple cut). However, what constitutes 'large semi-major axis' has been, and continues to be, unclear. Once beyond the apehlia of the classical Kuiper Belt (which extends out to about 60 au), objects with semimajor axes from a=60-150 au can be detached, but there are a reasonable number of objects in this range known to be in mean-motion resonances with Neptune. Beyond a=150 au, however, it is a widely-held belief that resonances become `unimportant', and that a q>38 au cut (or sometimes q>50 au) with a>150 au isolates a set of large semimajor axis detached objects. However, once semimajor axes become this large, the orbit determination of the object discovered near perihelion becomes a much harder task then for low-a TNOs. Because small velocity differences near the perihelion of large-a orbits cause large changes the fitted orbital in semimajor axis, extremely good and long baseline astrometry is required to reduce the semimajor axis uncertainty to be smaller than the few tenths of an astronomical unit widths of mean motion resonances. By carefully analyzing the astrometric data of all known large semimajor axis objects, we show that a very large fraction of the objects are in fact likely in high-order mean-motion resonances with Neptune. This prevealence for actually being resonant with Neptune would imply that hypothesized planets are problematic as they would remove the detached objects from these resonances. Instead, we favor a view in which the large-a population is the surviving remnant of a massive early scattering disk, whose surviving members are sculpted mostly by diffusive gravitational interactions with the four giant planets over the last four gigayears, but whose initial emplacement mechanism (in particular: perihelion lifting mechanism) is still unclear but of critical importance to the early Solar System's evolution.

AUTHORS (FIRST NAME INITIAL, LAST NAME): B. Gladman[1], K. Volk[2], C. Van Laerhoven[1]

AUTHORS/INSTITUTIONS: B. Gladman, C. Van Laerhoven, Physics and Astronomy, University of British Columbia, Vancouver, British Columbia, CANADA|K. Volk, University of Arizona, Tucson, Arizona, UNITED STATES|

SESSION TITLE: 'N SyncDynamics of Resonant Objects

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974745

TITLE: The formation of co-orbital planets and their resulting transit signatures

CONTACT (NAME ONLY): Agueda Granados Contreras

CONTACT (INSTITUTION ONLY): The University of British Columbia

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Systems with Tightly-packed Inner Planets (STIPs) are metastable, exhibiting sudden transitions to an unstable state that can potentially lead to planet consolidation. When these systems are embedded in a gaseous disc, planet-disc interactions can significantly reduce the frequency of instabilities, and if they do occur, disc torques alter the dynamical outcomes. We ran a suite of N-body simulations of synthetic 6-planet STIPs using an independent implementation of IAS15 that includes a prescription for gaseous tidal damping. The algorithm is based on the results of disc simulations that self-consistently evolve gas and planets. Even for very compact configurations, the STIPS are resistant to instability when gas is present. However, instability can still occur, and in some cases, the combination of system instability and gaseous damping leads to the formation of co-orbiting planets that are stable even when gas damping is removed. While rare, such systems should be detectable in transit surveys, although the dynamics of the system can make the transit signature difficult to identify.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. P. Granados Contreras[1], A. Boley[1]

AUTHORS/INSTITUTIONS: A.P. Granados Contreras, A. Boley, Physics and Astronomy, The University of British Columbia, Vancouver, British Columbia, CANADA|

SESSION TITLE: An Oblique Reference to Pop Culture

Dynamics of Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2975035

TITLE: Stability considerations of packed multi-planet systems

CONTACT (NAME ONLY): Pierre Gratia

CONTACT (INSTITUTION ONLY): Northwestern University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): I will present our first results of the outcomes of five packed, Earth-mass planetary simulations around a Sun-like star, whose initial separations in terms of their semi-major axes is determined by a multiple of their mutual Hill radius, the parameter beta. In our simulations, we will vary beta between 3.5 and and 9, with a special emphasis on the region around 8.5, where stability times are wildly different for small increments of beta. While the zero initial eccentricity case has been investigated before, we expand on it by allowing for initial nonzero eccentricities of one or more planets. Furthermore, we increase the simulated time by up to one order of magnitude reaching billions of orbits. This of course will determine more accurately the fate of systems that take a long time to go unstable. Both of these investigations have not been done before, thus our findings improve our understanding of the stabilities of closely-spaced planetary systems.

AUTHORS (FIRST NAME INITIAL, LAST NAME): P. Gratia[1, 2], J. Lissauer[2]

AUTHORS/INSTITUTIONS: P. Gratia, Northwestern University, Evanston, Illinois, UNITED STATES|P. Gratia, J. Lissauer, NASA Ames Research Center, Mountain View, California, UNITED STATES|

SESSION TITLE: Stability, or Instability, That is the QuestionDynamics of Planetary System Stability

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970254

TITLE: A Resonance Overlap Criterion for the Onset of Chaos in Systems of Two Eccentric Planets

CONTACT (NAME ONLY): Sam Hadden

CONTACT (INSTITUTION ONLY): Harvard-Smithsonian CfA

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): I will desrcribe a new analytic criterion to predict the onset of chaos in systems consisting of two massive, eccentric planets. Given a planet pair's spacing and masses, the criterion predicts the eccentricities at which the onset of large-scale chaos occurs. The onset of chaos is predicted based on overlap of mean motion resonances as in Wisdom (1980)'s pioneering work. Whereas Wisdom's work was limited to the overlap of first-order resonance and therefore to nearly circular planets, we account for resonances of all orders. This allows us to consider resonance overlap for planets with arbitrary eccentricities (up to orbit-crossing). Our results show excellent agreement with numerical simulations.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. Hadden[1], Y. Lithwick[2]

AUTHORS/INSTITUTIONS: S. Hadden, Harvard-Smithsonian CfA, Cambridge, Massachusetts, UNITED STATES|Y. Lithwick, Northwestern University, Evanston, Illinois, UNITED STATES|

SESSION TITLE: Hot, Flat, and Crowded

Dynamics of Tightly-Packed Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974913

TITLE: Deadly Sunflower Orbits

CONTACT (NAME ONLY): Douglas Hamilton

CONTACT (INSTITUTION ONLY): University of Maryland

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Solar radiation pressure is usually very effective at removing hazardous millimeter-sized debris from distant orbits around asteroids and other small solar system bodies (Hamilton and Burns 1992). The primary loss mechanism, driven by the azimuthal component of radiation pressure, is eccentricity growth followed by a forced collision with the central body. One large class of orbits, however, neatly sidesteps this fate. Orbits oriented nearly perpendicular to the solar direction can maintain their face-on geometry, oscillating slowly around a stable equilibrium orbit. These orbits, designated sunflower orbits, are related to terminator orbits studied by spacecraft mission designers (Broschart etal. 2014).

Destabilization of sunflower orbits occurs only for particles small enough that radiation pressure is some tens of percent the strength of the central body's direct gravity. This greatly enhanced stability, which follows from the inability of radiation incident normal to the orbit to efficiently drive eccentricities, presents a threat to spacecraft missions, as numerous dangerous projectiles are potentially retained in orbit. We have investigated sunflower orbits in support of the New Horizons, Aida, and Lucy missions and find that these orbits are stable for hazardous particle sizes at asteroids, comets, and Kuiper belt objects of differing dimensions. We investigate the sources and sinks for debris that might populate such orbits, estimate timescales and equilibrium populations, and will report on our findings.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. P. Hamilton[1]

AUTHORS/INSTITUTIONS: D.P. Hamilton, University of Maryland, College Park, Maryland, UNITED STATES|

SESSION TITLE: Danger, Will Robinson! Danger! Dynamics of Hazardous Asteroids

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2968907

TITLE: NEA impactors: what direction to they come from?

CONTACT (NAME ONLY): Alan Harris

CONTACT (INSTITUTION ONLY): MoreData!

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): One might expect, if Earth-crossing NEAs are "thermalized" by prior close scattering encounters with the Earth, that final impact trajectories would be isotropic in direction. But orbital perturbations and other sources of entry and exit to the Earth-crossing zone are faster acting that thermalization, so the actual distribution of impacting orbits is quite anisotropic. I have studied impactor directions by adjusting the orbits of known Earth-crossing PHAs slightly to put them on intersecting orbits and then computed the direction of approach to the Earth. This arguably suffers from "looking under the lamp post", since NEAs are mostly discovered close to the opposition direction, so I also took the distribution of NEA orbits recently derived by Granvik and others and extracted, from a set of 100,000 synthetic orbits they provided, a subset of Earth-crossing PHAs and similarly adjusted them to be intersecting orbits. This should represent an unbiased set of orbits. I then weighted the impact directions by the individual Opik impact probability to obtain a distribution of impact directions weighted by actual impact probabilities. The result was that more than 40% of incoming trajectories clustered within 60 degrees of the opposition direction, and a similar fraction come from within 60 degrees of the solar direction. Thus ~80% of impactors come from only about 1/3 of the sky area, with almost none coming from 60-120 degrees solar elongation. The message is that existing ground-based surveys can hardly be improved upon by greater sky coverage with respect to detecting "death plunge" objects, and even space-based instruments offer very little improvement due to the very low solar elongation of most objects approaching from the solar direction.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. Harris[1]

AUTHORS/INSTITUTIONS: A. Harris, MoreData!, La Canada, California, UNITED STATES|

SESSION TITLE: Danger, Will Robinson! Danger! Dynamics of Hazardous Asteroids

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2968763

TITLE: Axisymmetric Density Waves in Saturn's Rings

CONTACT (NAME ONLY): Matthew Hedman

CONTACT (INSTITUTION ONLY): University of Idaho

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Density waves in Saturn's rings are typically tightly wrapped spiral patterns generated by resonances with either Saturn's moons or structures inside the planet. However, between the Barnard and Bessel Gaps in the Cassini Division (i.e. between 120,240 and 120,300 km), there are density variations that appear to form an axisymmetric density wave, which consists of concentric regions of varying density that propagate radially through the rings. Such a wave requires some process that forces ring particles at all longitudes to pass through pericenter at the same time, and so cannot be generated by satellite resonances. Instead this particular wave appears to be excited by interference between a nearby satellite resonance and normal mode oscillations on the inner edge of the Barnard Gap. Similar axisymmetric waves may exist within the Dawes ringlet and the outermost part of the B ring, which are also just interior to resonantly confined edges that exhibit a large number of normal modes. These waves may therefore provide new insights into how resonant perturbations near an edge can propagate through a disk of material.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. Hedman[1], P. Nicholson[2]

AUTHORS/INSTITUTIONS: M. Hedman, University of Idaho, Moscow, Idaho, UNITED STATES|P. Nicholson, Cornell University, Ithaca, New York, UNITED STATES|

SESSION TITLE: The Astronomer Always Rings Twice, Dynamics of Planetary Rings

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2975090
TITLE:
Supermassive Black Holes as Revealed by LISA: How Gravitational Wave Astronomy Will be a Game Changer
CONTACT (NAME ONLY): Kelly Holley-Bockelmann
CONTACT (INSTITUTION ONLY): Vanderbilt University
ABSTRACT BODY:
Abstract (2,250 Maximum Characters):

Astronomers now know that supermassive black holes are in nearly every galaxy.
Though these black holes are an observational certainty, nearly every aspect of their evolution -- from their birth, to their fuel source, to their basic dynamics -- is a matter of lively debate. Fortunately, LISA, a space-based gravitational wave observatory set to launch in 2034, will revolutionize this field by providing data that is complementary to electromagnetic observations as well as data in regimes that are electromagnetically dark. This talk will touch on our current understanding of how SMBHs form, evolve, and alter their galaxy host, and will outline the theoretical, computational and observational work needed to make the most of LISA observations.
AUTHORS (FIRST NAME INITIAL, LAST NAME): K. Holley-Bockelmann[1]
AUTHORS/INSTITUTIONS: K. Holley-Bockelmann, Astronomy, Vanderbilt University, Nashville, Tennessee, UNITED STATES|
SESSION TITLE: The Good, the Bad, the Ugly: How Do Simulations Compare Their Data to Observers and How Can They Do It Better?
PRESENTATION TYPE: Invited
CURRENT CATEGORY:

CONTROL ID: 2972016

TITLE: Orbital Dynamics of Exomoons During Planet–Planet Scattering

CONTACT (NAME ONLY): Yu-Cian Hong

CONTACT (INSTITUTION ONLY): Astronomy, Cornell University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters):

Planet–planet scattering is the leading mechanism to explain the broad eccentricity distribution of observed giant exoplanets. Here we study the orbital stability of primordial giant planet moons in this scenario. We use N-body simulations including realistic oblateness and evolving spin evolution for the giant planets. We find that the vast majority (~80%–90% across all our simulations) of orbital parameter space for moons is destabilized. There is a strong radial dependence, as moons past are systematically removed. Closer-in moons on Galilean-moon-like orbits (<0.04 R_{Hill}) have a good (~20%–40%) chance of survival. Destabilized moons may undergo a collision with the star or a planet, be ejected from the system, be captured by another planet, be ejected but still orbiting its free-floating host planet, or survive on heliocentric orbits as "planets." The survival rate of moons increases with the host planet mass but is independent of the planet's final (post-scattering) orbits. Based on our simulations, we predict the existence of an abundant galactic population of free-floating (former) moons.

AUTHORS (FIRST NAME INITIAL, LAST NAME): Y. Hong[2], J. I. Lunine[2], P. Nicholson[2], S. N. Raymond[1]

AUTHORS/INSTITUTIONS: S.N. Raymond, Laboratoire d'Astrophysique de Bordeaux, Pessac, FRANCE|Y. Hong, J.I. Lunine, P. Nicholson, Astronomy, Cornell University, Ithaca, New York, UNITED STATES|

SESSION TITLE: In the Beginning There Was Chaos

Dynamics of Planet Formation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970455

TITLE: Dynamics of the retrograde 1/1 mean motion resonance

CONTACT (NAME ONLY): Yukun Huang

CONTACT (INSTITUTION ONLY): Tsinghua University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Mean motion resonances are very common in the solar system. Asteroids in mean motion resonances with giant planets have been studied for centuries. But it was not until recently that asteroids in retrograde mean motion resonances with Jupiter and Saturn were discovered. The newly discovered asteroid, 2015 BZ509 is confirmed to be the first asteroid in retrograde 1:1 mean motion resonance (or retrograde co-orbital resonance) with Jupiter, which gives rise to our interests in its unique resonant dynamics. In this study, we thoroughly investigate the phase-space structure of the retrograde 1:1 resonance within the framework of the circular restricted three-body problem. We begin by constructing a simple integrable approximation for the planar retrograde resonance with the Hamiltonian approach and show that the variables definition of the retrograde resonance is very different to the prograde one. When it comes to the disturbing function, we abandon the classical series expansion approach, whereas numerically carry out the averaging process on the disturbing function in closed form. The phase portrait of the retrograde 1:1 resonance is depicted with the level curves of the averaged Hamiltonian. We find that the topological structure of phase space for the retrograde 1:1 resonance is very different to other resonances, due to the consistent existence of the collision separatrix. And the surprising bifurcation of equilibrium point around 180° (i.e., the apocentric libration center) has never been found in any other mean motion resonances before. We thoroughly analyze the novel apocentric librations and find that close encounter with the planet does not always lead to the disruption of a stable apocentric libration. Afterwards, we examine the Kozai dynamics inside the mean motion resonance with the similar Hamiltonian approach and explain why the exact resonant point does not exist in the 3D retrograde 1:1 resonance model.

AUTHORS (FIRST NAME INITIAL, LAST NAME): Y. Huang[1], M. Li[1], J. Li[1], S. Gong[1]

AUTHORS/INSTITUTIONS: Y. Huang, M. Li, J. Li, S. Gong, School of Aerospace Engineering, Tsinghua University, Beijing, Beijing, CHINA|

SESSION TITLE: 'N SyncDynamics of Resonant Objects

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2973002

TITLE: Constraints on the Mass and Location of Planet 9 set by Range and VLBI Observations of Cassini

CONTACT (NAME ONLY): Robert Jacobson

CONTACT (INSTITUTION ONLY): Jet Propulsion Laboratory

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Batygin and Brown, 2016 AJ, found that Kuiper belt objects (KBOs) with well determined orbits having periods greater than 4000 years are apsidally aligned. They attribute this orbital clustering to the existence of a distant planet, Planet 9, well beyond Neptune, with a mass roughly ten times that of Earth. If such a planet exists, it would affect the motion of the known solar system planets, in particular Saturn, which is well observed with radiometric ranging from the Cassini spacecraft and VLBI observations of Cassini. The current planetary ephemerides do not account for the postulated Planet 9, yet their fit to the observational data shows no obvious effect that could be attributed to neglecting that planet. However, it is possible that the effect could be absorbed by the estimated parameters used to determine the ephemerides. Those parameters include the planetary orbital elements, mass of the Sun, and the masses of the asteroids that perturb the Martian orbit. We recently updated the Cassini data set and extended it through the end of the mssion in 2017 September. We analyze the sensitivity of these data to the tidal perturbations caused by the postulated Planet 9 for a range of positions on the sky and tidal parameters (the ratio of the mass of Planet 9 to the cube of its distance from Saturn). We determine an upper bound on the tidal parameter and the most probable directions consistent with the observational data.

AUTHORS (FIRST NAME INITIAL, LAST NAME): R. A. Jacobson[1], W. Folkner[1], R. Park[1], J. Williams[1]

AUTHORS/INSTITUTIONS: R.A. Jacobson, W. Folkner, R. Park, J. Williams, Jet Propulsion Laboratory, La Crescenta, California, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2972839

TITLE: A shower look-up table to trace the dynamics of meteoroid streams and their sources

CONTACT (NAME ONLY): Petrus Jenniskens

CONTACT (INSTITUTION ONLY): SETI Institute

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Meteor showers are caused by meteoroid streams from comets (and some primitive asteroids). They trace the comet population and its dynamical evolution, warn of dangerous long-period comets that can pass close to Earth's orbit, outline volumes of space with a higher satellite impact probability, and define how meteoroids evolve in the interplanetary medium. Ongoing meteoroid orbit surveys have mapped these showers in recent years, but the surveys are now running up against a more and more complicated scene. The IAU Working List of Meteor Showers has reached 956 entries to be investigated (per March 1, 2018). The picture is even more complicated with the discovery that radar-detected streams are often different, or differently distributed, than video-detected streams. Complicating matters even more, some meteor showers are active over many months, during which their radiant position gradually changes, which makes the use of mean orbits as a proxy for a meteoroid stream's identity meaningless. The dispersion of the stream in space and time is important to that identity and contains much information about its origin and dynamical evolution. To make sense of the meteor shower zoo, a Shower Look-Up Table was created that captures this dispersion. The Shower Look-Up Table has enabled the automated identification of showers in the ongoing CAMS video-based meteoroid orbit survey, results of which are presented now online in near-real time at http://cams.seti.org/FDL/. Visualization tools have been built that depict the streams in a planetarium setting. Examples will be presented that sample the range of meteoroid streams that this look-up table describes. Possibilities for further dynamical studies will be discussed.

AUTHORS (FIRST NAME INITIAL, LAST NAME): P. Jenniskens[1]

AUTHORS/INSTITUTIONS: P. Jenniskens, SETI Institute, Mountain View, California, UNITED STATES|

SESSION TITLE: Pebble in the Sky: Meteoroids and Their Orbits

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974947

TITLE: Dynamical Constraints on Non-Transiting Planets at Trappist-1

CONTACT (NAME ONLY): Daniel Jontof-Hutter

CONTACT (INSTITUTION ONLY): University of the Pacific

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The outermost of the seven known planets of Trappist-1 orbits six times closer to its host star than Mercury orbits the sun. The architecture of this system beyond 0.07 AU remains unknown. While the presence of additional planets will ultimately be determined by observations, in the meantime, some constraints can be derived from dynamical models.

We will firstly look at the expected signature of additional planets at Trappist-1 on the transit times of the known planets to determine at what distances putatuve planets can be ruled out.

Secondly, the remarkably compact configuration of Trappist-1 ensures that the known planets are secularly coupled, keeping their mutual inclinations very small and making their cotransiting geometry likely if Trappist-1h transits. We determine the range of masses and orbital inclinations of a putatuve outer planet that would make the observed configuration unlikely, and compare these to these constraints to those expected from radial velocity observations.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Jontof-Hutter[1], V. Truong[1], E. Ford[2, 3], P. Robertson[2, 3], R. Terrien[4]

AUTHORS/INSTITUTIONS: D. Jontof-Hutter, V. Truong, University of the Pacific, Stockton, California, UNITED STATES|E. Ford, P. Robertson, Pennsylvania State University, University Park, Pennsylvania, UNITED STATES|E. Ford, P. Robertson, Center for Exoplanets and Habitable Worlds, University Park, Pennsylvania, UNITED STATES|R. Terrien, Carleton College, Northfield, Minnesota, UNITED STATES|

SESSION TITLE: An Oblique Reference to Pop Culture

Dynamics of Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970136

TITLE: Using Real and Simulated TNOs to Constrain the Outer Solar System

CONTACT (NAME ONLY): Nathan Kaib

CONTACT (INSTITUTION ONLY): University of Oklahoma

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Over the past 2-3 decades our understanding of the outer solar system's history and current state has evolved dramatically. An explosion in the number of detected trans-Neptunian objects (TNOs) coupled with simultaneous advances in numerical models of orbital dynamics has driven this rapid evolution. However, successfully constraining the orbital architecture and evolution of the outer solar system requires accurately comparing simulation results with observational datasets. This process is challenging because observed datasets are influenced by orbital discovery biases as well as TNO size and albedo distributions. Meanwhile, such influences are generally absent from numerical results. Here I will review recent work I and others have undertaken using numerical simulations in concert with catalogs of observed TNOs to constrain the outer solar system's current orbital architecture and past evolution.

AUTHORS (FIRST NAME INITIAL, LAST NAME): N. Kaib[1]

AUTHORS/INSTITUTIONS: N. Kaib, Physics and Astronomy, University of Oklahoma, Norman, Oklahoma, UNITED STATES|

SESSION TITLE: The Good, the Bad, the Ugly: How Do Simulations Compare Their Data to Observers and How Can They Do It Better?

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2965724

TITLE: The Generation of the Distant Kuiper Belt by Planet Nine from an Initially Broad Perihelion Distribution

CONTACT (NAME ONLY): Tali Khain

CONTACT (INSTITUTION ONLY): University of Michigan

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The observation that the orbits of long-period Kuiper Belt objects are anomalously clustered in physical space has recently prompted the Planet Nine hypothesis - the proposed existence of a distant and eccentric planetary member of our Solar System. Within the framework of this model, a Neptune-like perturber sculpts the orbital distribution of distant Kuiper Belt objects through a complex interplay of resonant and secular effects, such that the surviving orbits get organized into apsidally aligned and anti-aligned configurations with respect to Planet Nine's orbit. We present results on the role of Kuiper Belt initial conditions on the evolution of the outer Solar System using numerical simulations. Intriguingly, we find that the final perihelion distance distribution depends strongly on the primordial state of the system, and demonstrate that a bimodal structure corresponding to the existence of both aligned and anti-aligned clusters is only reproduced if the initial perihelion distribution is assumed to extend well beyond 36 AU. The bimodality in the final perihelion distance distribution is due to the permanently stable objects, with the lower perihelion peak corresponding to the anti-aligned orbits and the higher perihelion peak corresponding to the aligned orbits. We identify the mechanisms that enable the persistent stability of these objects and locate the regions of phase space in which they reside. The obtained results contextualize the Planet Nine hypothesis within the broader narrative of solar system formation, and offer further insight into the observational search for Planet Nine.

AUTHORS (FIRST NAME INITIAL, LAST NAME): T. Khain[1], K. Batygin[2], M. E. Brown[2]

AUTHORS/INSTITUTIONS: T. Khain, University of Michigan, Ann Arbor, Michigan, UNITED STATES|K. Batygin, M.E. Brown, California Institute of Technology, Pasadena, California, UNITED STATES|

SESSION TITLE: Never Tell Me the Odds

Dynamics of the Kuiper Belt

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971589

TITLE:

Interior properties of the inner Saturnian moons from space astrometry data

CONTACT (NAME ONLY): Valery Lainey

CONTACT (INSTITUTION ONLY): JPL

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): During thirteen years in orbit around Saturn before its final plunge, the Cassini spacecraft provided more than ten thousand astrometric measurements. Such large amounts of accurate data enable the search for extremely faint signals in the orbital motion of the moons. Among those, the detection of the dynamical feedback of the rotation of the inner moons of Saturn on their respective orbits becomes possible. Using all the currently available astrometric data associated with Atlas, Prometheus, Pandora, Janus and Epimetheus, we provide a detailed analysis of the ISS data, with special emphasis on their statistical behavior and source of biases. Then, we try quantifying the physical librations of Prometheus, Pandora, Epimetheus and Janus from the monitoring of their orbits. Last, we show how introducing measurements directly derived from imaging can provide tighter constraints on these quantities.

AUTHORS (FIRST NAME INITIAL, LAST NAME): V. Lainey[1, 2], B. Noyelles[3], N. Cooper[4], C. Murray[4], R. Park[1], N. Rambaux[5, 2]

AUTHORS/INSTITUTIONS: V. Lainey, R. Park, JPL, Pasadena, California, UNITED STATES|V. Lainey, N. Rambaux, IMCCE, Paris, FRANCE|B. Noyelles, UNamur, Namur, BELGIUM|N. Cooper, C. Murray, QMUL, London, UNITED KINGDOM|N. Rambaux, UPMC, Paris, FRANCE|

SESSION TITLE: Ringleaders and Fellow Travelers

Dynamics of Moons

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971904

TITLE: Neptune's 5:2 mean motion resonance in the Kuiper Belt

CONTACT (NAME ONLY): Lei Lan

CONTACT (INSTITUTION ONLY): The University of Arizona

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Recent observations of distant Kuiper belt objects (KBOs) in Neptune's 5:2 mean motion resonance (MMR) present two dynamical puzzles: this third order MMR, located at a semi-major axis of about 55 AU, hosts a surprisingly large population, comparable to the well-known and prominent populations of Plutinos and Twotinos in the 3:2 and the 2:1 MMRs, respectively; secondly, the eccentricities of these resonant KBOs are concentrated near ~0.4. To shed light on these puzzles, we investigate the phase space structure near this resonance with use of Poincaré sections of the circular planar restricted three body model, for the full range of eccentricities, (0—1). With this non-perturbative numerical analysis, we find that the resonance width in semi-major axis is narrow for very small eccentricities, but widens dramatically for eccentricities ≥ 0.2. The resonance width reaches a maximum near eccentricity 0.4, where it is similar to the maximum widths of the 2:1 and 3:2 MMRs. We confirm these results with numerical simulations of the three dimensional N-body problem of KBOs in the gravitational field of the Sun and the four giant planets; our simulations include a wide range of orbital inclinations of the KBOs relative to the solar system's invariable plane. From these simulations, we find that the boundaries of the stable zone of the 5:2 MMR in the semimajor axis—eccentricity plane are very similar to those found with the simplified circular planar restricted three body model of the Sun-Neptune-KBO, with the caveat that orbits of eccentricity above ~0.55 are long term unstable; such orbits, which have perihelion distance less than ~25 AU, are phase-protected from close encounters with Neptune but not from destabilizing encounters with Uranus. Additionally, the numerical simulations show that the long term stability of KBOs in Neptune's 5:2 MMR is only mildly sensitive to KBO inclination. We conclude that the two dynamical puzzles presented by the observations of the KBOs in Neptune's 5:2 MMR can be understood fairly naturally in light of the phase space structure of this resonance combined with basic considerations of their long term stability.

AUTHORS (FIRST NAME INITIAL, LAST NAME): L. Lan[1], R. Malhotra[1]

AUTHORS/INSTITUTIONS: L. Lan, R. Malhotra, The University of Arizona, Tucson, Arizona, UNITED STATES|

SESSION TITLE: 'N SyncDynamics of Resonant Objects

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2962964

TITLE: Long-lived Eccentric modes in Protoplanetary Disks

CONTACT (NAME ONLY): Wing-Kit Lee

CONTACT (INSTITUTION ONLY): Northwestern University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): A theory is developed to understand global eccentric modes that are slowly precessing in protoplanetary disks. Using the typical self-similar density profiles, we found that these modes are trapped in the disk and are not sensitive to the uncertain boundary condition at the disk edge. This is contrary to common wisdom that the modes can only exist in disks with very sharp outer edge. Because of their discrete spectrum, once excited, a perturbed disk can stay eccentric for a long time until the mode is viscously damped. The physics behind the mode trapping depends ultimately on the relative importance of gas pressure and self-gravity, which is characterized by g = 1/ (Q h), where h is the disk aspect ratio and Q is the Toomre stability parameter. A very low mass disk (g << 1) is pressure-dominated and supports pressure modes, in which the eccentricity is highest at the disk edge. The modes are trapped by a turning point due to the density drop in the outer disk. For a more massive disk with g of order of unity (Q~1/h~10-100), prograde modes are supported. Unlike the pressure modes, these modes are trapped by Q-barriers and result in a bump in the radial eccentricity profile. As the mode trapping is a generic phenomenon for typical disk profiles, the free linear eccentric modes are likely to be present in protoplanetary disks with a wide range of disk mass.

AUTHORS (FIRST NAME INITIAL, LAST NAME): W. Lee[1], A. M. Dempsey[1], Y. Lithwick[1]

AUTHORS/INSTITUTIONS: W. Lee, A.M. Dempsey, Y. Lithwick, CIERA, Northwestern University, Evanston, Illinois, UNITED STATES|

SESSION TITLE: Flat Cats Instead of Spherical Cows

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2963267

TITLE: Stability of Multi-Planet Systems Orbiting in the Alpha Centauri AB System

CONTACT (NAME ONLY): Jack Lissauer

CONTACT (INSTITUTION ONLY): NASA Ames Research Center

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We evaluate how closely-spaced planetary orbits in multiple planet systems can be and still survive for billion-year timescales within the alpha Centauri AB system. Although individual planets on nearly circular, coplanar orbits can survive throughout the habitable zones of both stars, perturbations from the companion star imply that the spacing of such planets in multi-planet systems must be significantly larger than the spacing of similar systems orbiting single stars in order to be long-lived. Because the binary companion induces a forced eccentricity upon circumstellar planets, stable orbits with small initial eccentricities aligned with the binary orbit are possible to slightly larger initial semimajor axes than are initially circular orbits. Initial eccentricities close to the appropriate forced eccentricity can have a much larger affect on how closely planetary orbits can be spaced, on how many planets may remain in the habitable zones, although the required spacing remains significantly higher than for planets orbiting single stars.

AUTHORS (FIRST NAME INITIAL, LAST NAME): J. Lissauer[1]

AUTHORS/INSTITUTIONS: J. Lissauer, NASA Ames Research Center, Moffett Field, California, UNITED STATES|

SESSION TITLE: Stability, or Instability, That is the QuestionDynamics of Planetary System Stability

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974702

TITLE: DAVs: Red Edge and Outbursts

CONTACT (NAME ONLY): Jing Luan

CONTACT (INSTITUTION ONLY): UC Berkeley

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): As established by ground based surveys, white dwarfs with hydrogen atmospheres pulsate as they cool across the temperature range, $12500K< Teff < 10800K $. Known as DAVs or ZZ Ceti stars, their oscillations are attributed to overstable g-modes excited by convective driving. The effective temperature at the blue edge of the instability strip is slightly lower than that at which a surface convection zone appears. The temperature at the red edge is a two-decade old puzzle. Recently, Kepler discovered a number of cool DAVs exhibiting sporadic outbursts separated by days, each lasting several hours, and releasing $\sim 10^{33}-10^{34} {erg}$. We provide quantitative explanations for both the red edge and the outbursts. The minimal frequency for overstable modes rises abruptly near the red edge. Although high frequency overstable modes exist below the red edge, their photometric amplitudes are generally too small to be detected by ground based observations. Nevertheless, these overstable parent modes can manifest themselves through nonlinear mode couplings to damped daughter modes which generate limit cycles giving rise to photometric outbursts.

AUTHORS (FIRST NAME INITIAL, LAST NAME): J. Luan[1]

AUTHORS/INSTITUTIONS: J. Luan, UC Berkeley, Berkeley, CHINA|

SESSION TITLE: The Fault in Our Stars

Dynamics of Stars and Black Holes

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971160

TITLE: Dynamical Classifications of the Kuiper Belt

CONTACT (NAME ONLY): Steven Maggard

CONTACT (INSTITUTION ONLY): Brigham Young University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The Minor Planet Center (MPC) contains a plethora of observational data on thousands of Kuiper Belt Objects (KBOs). Understanding their orbital properties refines our understanding of the formation of the solar system. My analysis pipeline, BUNSHIN, uses Bayesian methods to take the MPC observations and generate 30 statistically weighted orbital clones for each KBO that are propagated backwards along their orbits until the beginning of the solar system. These orbital integrations are saved as REBOUND SimulationArchive files (Rein & Tamayo 2017) which we will make publicly available, allowing many others to perform statistically-robust dynamical classification or complex dynamical investigations of outer solar system small bodies.

This database has been used to expand the known collisional family members of the dwarf planet Haumea. Detailed orbital integrations are required to determine the dynamical distances between family members, in the form of "Delta v" as measured from conserved proper orbital elements (Ragozzine & Brown 2007). Our preliminary results have already ~tripled the number of known Haumea family members, allowing us to show that the Haumea family can be identified purely through dynamical clustering.

We will discuss the methods associated with BUNSHIN and the database it generates, the refinement of the updated Haumea family, a brief search for other possible clusterings in the outer solar system, and the potential of our research to aid other dynamicists.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. Maggard[1], D. Ragozzine[1]

AUTHORS/INSTITUTIONS: S. Maggard, D. Ragozzine, Physics & Astronomy, Brigham Young University, Prosper, Texas, UNITED STATES|

SESSION TITLE: Never Tell Me the Odds

Dynamics of the Kuiper Belt

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2967554

TITLE: Gravity Does it: Redshift of Light from the Galaxies Yes, Expanding Universe NO!

CONTACT (NAME ONLY): Satish Malhotra

CONTACT (INSTITUTION ONLY): free lance researcher, no affiliation

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): In the history of physics, ideas on space and time have changed the course of physics a number of times; this is another such event. We postulate 'space and time' as a flow of quantum gravity energy, having the absolute velocity c (same as velocity of light), where time is the delay in the spread of space (delay from infinite velocity flow, when there would be no time), such a flow has to have a reverse cycle, as energy creating it (howsoever large it might be has to be limited and limited energy can only create a limited space and time energy spread) and the reverse cycle is that of the creation of fundamental particles. This explanation of the universe tells us that the idea of an expanding universe is only an appearance, the argument, in brief, is as follows: One, the universe is so large that we cannot see the edges, light from the edges, the reality is non-observable. Two, the process is dark, it is beyond observation, the process of creation of charge (the reflection of light starts with it), the space energy flow process is in the range of invisible (before charge emerged); it is the elusive dark energy of the universe; we never connected space and time to flow of energy, and so did not find its connection either to its limitedness or to its dark nature (dark energy). Three, the space energy flow has a reverse process which leads to the formation of fundamental particles we have not included it in the totality of the processes of the universe, the former is the dark energy and the initial part of the reverse process—till it reaches the state of ionisation-- is dark matter. In the continuity of the cycle of space flow and its reversal to matter forms, ionisation happens at a particular point and visibility comes through along with; ionisation here is a later event (which is a part of the reverse process, enters visibility).It is this reverse process which creates fundamental particles (no big bang creation. With no idea of space as energy flow and no idea of the reverse process, physicists could never take the step in the direction of the correct understanding of the 'dark energy' or 'dark matter'.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. Malhotra[1]

AUTHORS/INSTITUTIONS: S. Malhotra, free lance researcher, no affiliation, CHANDIGARH, Chandigarh, INDIA|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2988494

TITLE: A View into Saturn through its Natural Seismograph

CONTACT (NAME ONLY): Christopher Mankovich

CONTACT (INSTITUTION ONLY): University of California Santa Cruz

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Saturn's nonradial oscillations perturb the orbits of ring particles. The C ring is fortuitous in that it spans several resonances with Saturn's fundamental acoustic (f-) modes, and its moderate optical depth allows the characterization of wave features using stellar occultations. The growing set of C-ring waves with precise pattern frequencies and azimuthal order m measured from Cassini stellar occultations (Hedman & Nicholson 2013, 2014; French et al. 2016) provides new constraints on Saturn's internal structure, with the potential to aid in resolving long-standing questions about the planet's distribution of helium and heavier elements, its means of internal energy transport, and its rotation state.

We construct Saturn interior models and calculate mode eigenfrequencies, mapping the planet mode frequencies to resonant locations in the rings to compare with the locations of observed spiral density and vertical bending waves in the C ring. While spiral density waves at low azimuthal order (m=2-3) appear strongly affected by resonant coupling between f-modes and deep g-modes (Fuller 2014), the locations of waves with higher azimuthal order can be fit with a spectrum of pure f-modes for Saturn models with adiabatic envelopes and realistic equations of state. Notably, several newly observed density waves and bending waves (Nicholson et al., in preparation) align with outer Lindblad and outer vertical resonances for non-sectoral (m!=l) Saturn f-modes of relatively high angular degree, and we present normal mode identifications for these waves. We assess the range of resonance locations in the C and D rings allowed for the spectrum of f-modes given gravity field constraints, point to other resonance locations that should experience strong forcing, and use the full set of observed waves to estimate Saturn's bulk rotation rate.

AUTHORS (FIRST NAME INITIAL, LAST NAME): C. Mankovich[1]

AUTHORS/INSTITUTIONS: C. Mankovich, Astronomy & Astrophysics, University of California Santa Cruz, Santa Cruz, California, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 3003991

TITLE: The Discovery and Characterization of Interstellar Object 1I/'Oumuamua

CONTACT (NAME ONLY): Karen Meech

CONTACT (INSTITUTION ONLY): University of Hawaii

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): On October 19, 2017 the Pan-STARRS1 telescope discovered a rapidly moving object. Additional astrometry obtained with pre-discovery observations on October 18 through data obtained with the Canada-France- Hawaii-Telescope on October 22 showed that the object had the highest hyperbolic eccentricity ever detected, confirming that this object clearly originated from outside the solar system. By October 30, the orbital eccentricity was 1.1956±0.006 – a 100-sigma confirmation of the hyperbolic nature and was given the designation 1I/2017 U1, and the official name of ‘Oumuamua, meaning visitor from the distant past, was approved by the IAU. Beginning on October 22 there was an intense effort to secure observing resources to characterize the object. 1I/2017 U1 passed perihelion on September 9, 2017 and had made its Earth close approach at 63 lunar radii on October 14. Because it was receding rapidly from the Earth and Sun, within a week of discovery the brightness had dropped by a factor of 10 and in less than a month it had dropped by a factor of 100. Thus, there was a period of just over a

week where the target could be relatively easily characterized. Deep images of ‘Oumuamua showed no hint of cometary activity, with limits on the amount of dust that could be present at less than 7-8 orders of magnitude that of a typical comet at similar distances. Light curve observations showed that the object was rotating with an instantaneous rotation period of 7.34 hours, and a light curve range of 2.5 magnitudes, implying an extremely elongated axis ratio perhaps as large as 10:1. Assuming a low albedo typical of comets (4%) this implies a size of 800x80x80. However, as more time series data were obtained, it was evident that ‘Oumuamua was in an excited spin state with the long axis precessing around the total angular momentum vector with an average period of 8.67±0.34 hr. If in a LAM rotation state the most likely rotation period around the long axis is 54.58 hr, but there are also two possible SAM rotation states where ‘Oumuamua oscillates around the long axis with periods at 13.15 and 54.48 hours.

AUTHORS (FIRST NAME INITIAL, LAST NAME): K. Meech[1]

AUTHORS/INSTITUTIONS: K. Meech, Institute for Astronomy, University of Hawaii, Honolulu, Hawaii, UNITED STATES|

SESSION TITLE: 1I/`Oumuamua: the First Known Interstellar Asteroid

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2971058

TITLE: On the Obliquities of Planets in Close-in, Compact Systems

CONTACT (NAME ONLY): Sarah Millholland

CONTACT (INSTITUTION ONLY): Yale University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Secular spin-orbit resonances can be encountered when planets sweep through commensurabilities between nodal and spin-axis precession frequencies, for example, during disk-driven migration. These encounters can induce significant planetary spin-axis misalignment and capture into a “Cassini state”, a configuration involving synchronous precession of the planetary spin and orbital angular momentum vectors. We show that typical extrasolar systems – exemplified by the Kepler close-in, coplanar multiple-planet systems – frequently have nodal and spin-axis precession frequencies that are near-commensurable. This implies that obliquity-pumping should be common if the planets undergo any migration. We present analytic and numerical models of the spin evolution of typical Kepler-multi-type systems subject to the influences of disk migration, the quadrupole potential of an oblate young star, and tidal dissipation. Among other consequences of large obliquities, we find that the several orders of magnitude enhancement in tidal dissipation strength at non-zero obliquity may be able to generate the observed excess of planet pairs with period ratios just wide of 2:1 and 3:2. Though tidal origins of these excesses have previously been discussed, tidal dissipation is insufficient to reproduce the observations unless planets have non-negligible obliquities at some time in their history.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. Millholland[1], G. Laughlin[1]

AUTHORS/INSTITUTIONS: S. Millholland, G. Laughlin, Yale University, New Haven, Connecticut, UNITED STATES|

SESSION TITLE: An Oblique Reference to Pop Culture

Dynamics of Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2969333

TITLE: The formation and early evolution of meteoroid streams

CONTACT (NAME ONLY): Althea Moorhead

CONTACT (INSTITUTION ONLY): NASA Marshall Space Flight Center

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Meteor showers occur when the Earth encounters a stream of particles liberated from the surface of a comet or, more rarely, an asteroid. Initially, meteoroids follow a trajectory that is similar to that of their parent comet but modified by both the outward flow of gas from the nucleus and radiation pressure. Sublimating gases impart an “ejection velocity” to solid particles in the coma; this ejection velocity is larger for smaller particles but cannot exceed the speed of the gas itself. Radiation pressure provides a repulsive force that, like gravity, follows an inverse square law, and thus effectively reduces the central potential experienced by small particles. Depending on the optical properties of the particle, the speed of the particle may exceed its effective escape velocity; such particles will be unbound and hence excluded from meteoroid streams and meteor showers. These processes also modify the heliocentric distance at which meteoroid orbits cross the ecliptic plane, and can thus move portions of the stream out of range of the Earth. This talk presents recent work on these components of the early evolution of meteoroid streams and their implications for the meteoroid environment seen at Earth.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. Moorhead[1]

AUTHORS/INSTITUTIONS: A. Moorhead, NASA Marshall Space Flight Center, Huntsville, Alabama, UNITED STATES|

SESSION TITLE: Pebble in the Sky: Meteoroids and Their Orbits

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2975008

TITLE: Reconstructing the Dwarf Galaxy Progenitor from Tidal Streams Using MilkyWay@home

CONTACT (NAME ONLY): Heidi Newberg

CONTACT (INSTITUTION ONLY): Rensselaer Polytechnic Institute

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We attempt to reconstruct the mass and radial profile of stars and dark matter in the dwarf galaxy progenitor of the Orphan Stream, using only information from the stars in the Orphan Stream. We show that given perfect data and perfect knowledge of the dwarf galaxy profile and Milky Way potential, we are able to reconstruct the mass and radial profiles of both the stars and dark matter in the progenitor to high accuracy using only the density of stars along the stream and either the velocity dispersion or width of the stream in the sky. To perform this test, we simulated the tidal disruption of a two component (stars and dark matter) dwarf galaxy along the orbit of the Orphan Stream. We then created a histogram of the density of stars along the stream and a histogram of either the velocity dispersion or width of the stream in the sky as a function of position along the stream. The volunteer supercomputer MilkyWay@home was given these two histograms, the Milky Way potential model, and the orbital parameters for the progenitor. N-body simulations were run, varying dwarf galaxy parameters and the time of disruption. The goodness-of-fit of the model to the data was determined using an Earth-Mover Distance algorithm. The parameters were optimized using Differential Evolution. Future work will explore whether currently available information on the Orphan Stream stars is sufficient to constrain its progenitor, and how sensitive the optimization is to our knowledge of the Milky Way potential and the density model of the dwarf galaxy progenitor, as well as a host of other real-life unknowns.

AUTHORS (FIRST NAME INITIAL, LAST NAME): H. Newberg[1], S. Shelton[1]

AUTHORS/INSTITUTIONS: H. Newberg, S. Shelton, Rensselaer Polytechnic Institute, Albany, New York, UNITED STATES|

SESSION TITLE: Stretched Out Dwarfs

Dynamics of Galaxies

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2987159

TITLE: Stellar Occultations by Saturn's Rings

CONTACT (NAME ONLY): Philip Nicholson

CONTACT (INSTITUTION ONLY): Cornell University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters):

On 15 September 2017 the Cassini mission came to an end when the spacecraft made a controlled entry into the planet's atmosphere. Over the preceding 13 years the Visual and Infrared Mapping Spectrometer (VIMS) instrument successfully observed over 170 stellar occultations by Saturn's rings, greatly increasing the available data set for high-resolution studies of the rings' structure and dynamics. Ring opening angles, $B_\ast$ ranged from 1.06° to 74.18°, while spacecraft ranges varied from 220,000 to 3,014,000~km. The effective radial resolution of the data is determined by a combination of Fresnel diffraction, stellar diameter and sampling rate, but is typically 150--300~m. We will briefly review the overall data set, before looking at examples of dynamical studies carried out with it over the past decade. These include modeling the geometry of self-gravity wakes in the A and B rings, evidence for viscous over-stability in the inner A ring, studies of eccentric, inclined and more complex orbital perturbations on the edges of isolated ringlets and narrow gaps, identification of density and bending waves in the C ring driven by both internal oscillations and gravity anomalies in Saturn, and the first reliable estimates of surface mass density in the central B ring.

{\bf References:} French \etal\ (2016a, 2016b, 2017), Hedman \etal\ (2007, 2010, 2014), Hedman \& Nicholson (2013, 2014, 2016), Nicholson \& Hedman (2010, 2016), Nicholson \etal\ (2014a, 2014b).

AUTHORS (FIRST NAME INITIAL, LAST NAME): P. Nicholson[1], M. Hedman[2], R. G. French[3], T. Ansty[1]

AUTHORS/INSTITUTIONS: P. Nicholson, T. Ansty, Astronomy, Cornell University, Ithaca, New York, UNITED STATES|M. Hedman, University of Idaho, Moscow, Idaho, UNITED STATES|R.G. French, Wellesley College, Wellesley, Massachusetts, UNITED STATES|

SESSION TITLE: The Astronomer Always Rings Twice, Dynamics of Planetary Rings

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2968567

TITLE: Formation of Close-in Super-Earths in an Evolving Disk Due to Disk Winds

CONTACT (NAME ONLY): Masahiro Ogihara

CONTACT (INSTITUTION ONLY): National Astronomical Observatory of Japan

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Planets with masses larger than Mars mass undergo rapid inward migration (type I migration) in a standard protoplanetary disk. Recent magnetohydrodynamical simulations revealed the presence of magnetically-driven disk winds, which would alter the disk profile and the type I migration in the close-in region ($r<1$ au). We investigate orbital evolution of planetary embryos in a disk that viscously evolves under effects of magnetically-driven disk winds. The aim is to examine whether observed distributions of close-in super-Earths can be reproduced by simulations. We find that the type I migration is significantly suppressed in a disk with flat surface density profile. After planetary embryos undergo slow inward migration, they are captured in a resonant chain. The resonant chain undergoes late orbital instability during the gas depletion, leading to a non-resonant configuration. We also find that observed distributions of close-in super-Earths (e.g., period ratio, mass ratio) can be reproduced by results of simulations.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. Ogihara[1], E. Kokubo[1], T. Suzuki[2], A. Morbidelli[3]

AUTHORS/INSTITUTIONS: M. Ogihara, E. Kokubo, Division of Theoretical Astronomy, National Astronomical Observatory of Japan, Tokyo, JAPAN|T. Suzuki, University of Tokyo, Tokyo, JAPAN|A. Morbidelli, Observatoire de la Côte d'Azur, Nice, FRANCE|

SESSION TITLE: In the Beginning There Was Chaos

Dynamics of Planet Formation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974648

TITLE: More Sophisticated Fits of the Oribts of Haumea's Interacting Moons

CONTACT (NAME ONLY): William Oldroyd

CONTACT (INSTITUTION ONLY): Brigham Young University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Since the discovery of Haumea's moons, it has been a challenge to model the orbits of its moons, Hi'iaka and Namaka. With many precision HST observations, Ragozzine & Brown 2009 succeeded in calculating a three-point mass model which was essential because Keplerian orbits were not a statistically acceptable fit. New data obtained in 2010 could be fit by adding a J2 and spin pole to Haumea, but new data from 2015 was far from the predicted locations, even after an extensive exploration using Bayesian Markov Chain Monte Carlo methods (using emcee). Here we report on continued investigations as to why our model cannot fit the full 10-year baseline of data. We note that by ignoring Haumea and instead examining the relative motion of the two moons in the Hi'iaka centered frame leads to adequate fits for the data. This suggests there are additional parameters connected to Haumea that will be required in a full model. These parameters are potentially related to photocenter-barycenter shifts which could be significant enough to affect the fitting process; these are unlikely to be caused by the newly discovered ring (Ortiz et al. 2017) or by unknown satellites (Burkhart et al. 2016). Additionally, we have developed a new SPIN+N-bodY integrator called SPINNY that self-consistently calculates the interactions between n-quadrupoles and is designed to test the importance of other possible effects (Haumea C22, satellite torques on the spin-pole, Sun, etc.) on our astrometric fits. By correctly determining the orbit of Haumea's satellites we develop a better understanding of the physical properties of each of the objects with implications for the formation of Haumea, its moons, and its collisional family.

AUTHORS (FIRST NAME INITIAL, LAST NAME): W. J. Oldroyd[1], D. Ragozzine[1], S. Porter[2]

AUTHORS/INSTITUTIONS: W.J. Oldroyd, D. Ragozzine, Physics and Astronomy, Brigham Young University, Provo, Utah, UNITED STATES|S. Porter, Southwest Research Institute, Boulder, Colorado, UNITED STATES|

SESSION TITLE: Ringleaders and Fellow Travelers

Dynamics of Moons

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971506

TITLE: Titan Crossing a 5:1 MMR with Iapetus : Constraining the Tidal Recession of Titan and Giving an Explanation for Lapetus' Current Orbit

CONTACT (NAME ONLY): William POLYCARPE

CONTACT (INSTITUTION ONLY): IMCCE

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Iapetus orbits Saturn with an orbtial eccentricity of 3% and possesses an constant tilt to its local Laplace plane of around 7°, both elements are today poorly explained. The objective of the this work is to investigate if these orbtial characteristics may be explained in the frame of rapid tidal migration in the saturnian system [Lainey et al., 2012, 2017] [Fuller et al. 2016]. We present several sets of numerical simulations of a past 5:1 mean motion resonance crossing between Titan and Iapetus. Iapetus was placed initially on its local Laplace plane with a circular orbit. Simulations show that the outcomes of this resonance are very dependent on the migration speed of Titan, and therefore on the effective quality factor Q of Saturn. Iapetus will generally be ejected of the system due to this resonance when the migration is too slow, typically Q higher than 1500. Lower values allow Iapetus to survive with an eccentricity of a few percent, consistent with today's value. This resonance would also act on the inclination and can bring the tilt up to several degrees, and even reach 7° and more on rare occasions. It seems, in general, that the current value of the eccentricity can be easily explained by this resonance. On the other hand the tilt is more difficult to obtain for fast tidal migration (Q lower than 20), but high values are possible for medium migration rate (typically Q between 200 and 1500).

AUTHORS (FIRST NAME INITIAL, LAST NAME): W. POLYCARPE[1], V. Lainey[2], A. Vienne[1], B. Noyelles[3], M. Saillenfest[1], N. Rambaux[1]

AUTHORS/INSTITUTIONS: W. POLYCARPE, A. Vienne, M. Saillenfest, N. Rambaux, IMCCE, Paris, FRANCE|V. Lainey, JPL, Pasadena, California, UNITED STATES|B. Noyelles, Namur University, Namur, BELGIUM|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2971819

TITLE: Merging black holes in non-spherical nuclear star clusters

CONTACT (NAME ONLY): Cristobal Petrovich

CONTACT (INSTITUTION ONLY): Canadian Institute for Theoretical Astrophysics

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The Milky Way and a significant fraction of galaxies are observed to host a central Massive Black Hole (MBH) embedded in a non-spherical nuclear star cluster. I will discuss the orbital evolution of stellar binaries in these environments and argue that their merger rates are expected to be greatly enhanced when the effect from cluster potential is taken into account in the binary-MBH triple system. I will apply our results to compact-object binary mergers mediated by gravitational wave radiation and show that this merger channel can contribute significantly to the LIGO/Virgo detections.

AUTHORS (FIRST NAME INITIAL, LAST NAME): C. Petrovich[1]

AUTHORS/INSTITUTIONS: C. Petrovich, Canadian Institute for Theoretical Astrophysics, Toronto, Ontario, CANADA|

SESSION TITLE: The Fault in Our Stars

Dynamics of Stars and Black Holes

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2974749

TITLE: Using Ice and Dust Lines to Constrain the Surface Densities of Protoplanetary Disks

CONTACT (NAME ONLY): Diana Powell

CONTACT (INSTITUTION ONLY): UC Santa Cruz

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The surface density of protoplanetary disks is a fundamental parameter that still remains largely unconstrained due to uncertainties in the dust-to-gas ratio and CO abundance. In this talk I will present a novel method for determining the surface density of protoplanetary disks through consideration of disk “dust lines,” which indicate the observed disk radial scale at different observational wavelengths. I will provide an initial proof of concept of our model through an application to the disk TW Hya where we are able to estimate the disk dust-to-gas ratio, CO abundance, and accretion rate in addition to the total disk surface density. We find that our derived surface density profile and dust-to-gas ratio are consistent with the lower limits found through measurements of HD gas. We further apply our model to a large parameter space of theoretical disks and find three observational diagnostics that may be used to test its validity. Using this method we derive disks that may be much more massive than previously thought, often approaching the limit of gravitational stability.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Powell[1], R. Murray-Clay[1], H. Schlichting[2, 3]

AUTHORS/INSTITUTIONS: D. Powell, R. Murray-Clay, UC Santa Cruz, Santa cruz, California, UNITED STATES|H. Schlichting, UCLA, Los Angeles, California, UNITED STATES|H. Schlichting, MIT, Cambridge, Massachusetts, UNITED STATES|

SESSION TITLE: Flat Cats Instead of Spherical Cows

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971008

TITLE: Modeling the Dynamical Structure of the Haumea Family

CONTACT (NAME ONLY): Benjamin Proudfoot

CONTACT (INSTITUTION ONLY): Brigham Young University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters):

Collisions are known to be critical in explaining the full story of the outer Solar System. The dwarf planet Haumea provides a unique empirical view into this, as Haumea is the only known example of a collisional family in the Kuiper Belt. Although there have been many Haumea formation hypotheses presented in the literature, none are fully self-consistent. In particular, it is challenging to explain the low ejection velocity of the family. With the addition of many new Haumea family members (Maggard & Ragozzine 2018, in prep.), we further investigate how we can use collision models to recreate the current dynamical distribution of Haumea family members in (proper) a-e-i-dv-H space. Using synthetic families created using different collision models, we use a Bayesian methodology to infer the posterior distribution of our model parameters that best matches the current family. Our newest results continue to exclude the planar distribution of family members that would result from a 'graze-and-merge' type collision (e.g., Leinhardt et al. 2010) based on a lack of a-e-i correlation (Proudfoot & Ragozzine, DPS 2017, DDA 2017). We present here our results from more models. We have also validated a statistical method for automatically and self-consistently identifying interlopers from the background population.

AUTHORS (FIRST NAME INITIAL, LAST NAME): B. Proudfoot[1], D. Ragozzine[1]

AUTHORS/INSTITUTIONS: B. Proudfoot, D. Ragozzine, Brigham Young University, Provo, Utah, UNITED STATES|

SESSION TITLE: Never Tell Me the Odds

Dynamics of the Kuiper Belt

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970265

TITLE: Dynamics of Circumbinary Planets Near the Stability Limit

CONTACT (NAME ONLY): Billy Quarles

CONTACT (INSTITUTION ONLY): University of Oklahoma

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The stability limit for circumbinary planets (CBPs) is not well defined and carries uncertainty that depends on the orbital parameters of the stellar binary and possible planets. Previous work by Holman & Wiegert (1999, AJ 117, 621) developed a two parameter fitting formula for CBPs. We update the coefficients for this formula and introduce a grid interpolation method that is based on ~150 million full N-body simulations of systems with Jupiter-mass planets on initially circular, coplanar orbits. We find an improvement in the accuracy in estimating the inner boundary of stability and use planet packing to identify the relative proximity of the Kepler CBPs to their respective stability limits. As a result, 55% of the Kepler CBPs could host a planet at the stability limit in addition to the innermost observed planet. The results of our simulations and python tools to determine the stability limit are available to the CBP community on Zenodo and GitHub, respectively.

AUTHORS (FIRST NAME INITIAL, LAST NAME): B. Quarles[1], S. Satyal[2], V. Kostov[3], N. Kaib[1], N. Haghighipour[4]

AUTHORS/INSTITUTIONS: B. Quarles, N. Kaib, Physics & Astronomy, University of Oklahoma, Norman, Oklahoma, UNITED STATES|S. Satyal, University of Texas at Arlington, Arlington, Texas, UNITED STATES|V. Kostov, NASA Goddard Space Flight Center, Greenbelt, Maryland, UNITED STATES|N. Haghighipour, Institute for Astronomy - University of Hawaii-Manoa, Honolulu, Hawaii, UNITED STATES|

SESSION TITLE: Stability, or Instability, That is the QuestionDynamics of Planetary System Stability

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2973131

TITLE: On the Detectability of Interstellar Objects Like 1I/'Oumuamua

CONTACT (NAME ONLY): Darin Ragozzine

CONTACT (INSTITUTION ONLY): Brigham Young University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Almost since Oort's 1950 hypothesis of a tenuously bound cloud of comets, planetary formation theorists have realized that the process of planet formation must have ejected very large numbers of planetesimals into interstellar space. Unforunately, these objects are distributed over galactic volumes, while they are only likely to be detectable if they pass within a few AU of Earth, resulting in an incredibly sparse detectable population. Furthermore, hypotheses for the formation and distribution of these bodies allows for uncertainties of orders of magnitude in the expected detection rate: our analysis suggested LSST would discover 0.01-100 objects during its lifetime (Cook et al. 2016). The discovery of 1I/'Oumuamua by a survey less powerful that LSST indicates either a low probability event and/or that properties of this population are on the more favorable end of the spectrum. We revisit the detailed detection analysis of Cook et al. 2016 in light of the detection of 1I/'Oumuamua. We use these results to better understand 1I/'Oumuamua and to update our assessment of future detections of interstellar objects. We highlight some key questions that can be answered only by additional discoveries.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Ragozzine[1]

AUTHORS/INSTITUTIONS: D. Ragozzine, Physics and Astronomy, Brigham Young University, Provo, Utah, UNITED STATES|

SESSION TITLE: 1I/`Oumuamua: the First Known Interstellar Asteroid

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2974914

TITLE: HNBody: A Simulation Package for Hierarchical N-Body Systems

CONTACT (NAME ONLY): Kevin Rauch

CONTACT (INSTITUTION ONLY): University of Maryland

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): HNBody (http://www.hnbody.org/) is an extensible software package for integrating the dynamics of N-body systems. Although general purpose, it incorporates several features and algorithms particularly well-suited to systems containing a hierarchy (wide dynamic range) of masses. HNBody version 1 focused heavily on symplectic integration of nearly-Keplerian systems. Here I describe the capabilities of the redesigned and expanded package version 2, which includes: symplectic integrators up to eighth order (both leap frog and Wisdom-Holman type methods), with symplectic corrector and close encounter support; variable-order, variable-timestep Bulirsch-Stoer and Störmer integrators; post-Newtonian and multipole physics options; advanced round-off control for improved long-term stability; multi-threading and SIMD vectorization enhancements; seamless availability of extended precision arithmetic for all calculations; extremely flexible configuration and output. Tests of the physical correctness of the algorithms are presented using JPL Horizons ephemerides (https://ssd.jpl.nasa.gov/?horizons) and previously published results for reference. The features and performance of HNBody are also compared to several other freely available N-body codes, including MERCURY (Chambers), SWIFT (Levison & Duncan) and WHFAST (Rein & Tamayo).

AUTHORS (FIRST NAME INITIAL, LAST NAME): K. P. Rauch[1]

AUTHORS/INSTITUTIONS: K.P. Rauch, Astronomy, University of Maryland, College Park, Maryland, UNITED STATES|

SESSION TITLE: The Fault in Our Stars

Dynamics of Stars and Black Holes

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971223

TITLE: The Stability of Resonant Chains of Moons

CONTACT (NAME ONLY): Thomas Rimlinger

CONTACT (INSTITUTION ONLY): University of MD, College Park

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Unlike other giant planets, Saturn has a satellite system that is dominated by a single massive body, Titan, which features an unusually large inclination and eccentricity. Its origin has yet to be satisfactorily explained; neither in situ formation nor capture from heliocentric orbit can easily produce all of its measured properties. We argue that dynamical instability and subsequent mergers within a resonant chain of satellites analogous to the Galilean moons could be responsible for Titan's unusual features.

To explore this idea, we perform simulations in which we vary a wide range of parameters, including the number of satellites, their masses, their spacings, and their tidal migration and eccentricity damping rates. In our preliminary modeling, we initialize our simulations with three moons in the 1:2:4 mean-motion resonance (currently occupied by Io, Europa, and Ganymede at Jupiter) and study how varying each parameter affects the resonant stability. We find that in some cases, the satellites do indeed escape from this three-body resonance, while in others, the bodies' period ratios remain locked. We study the evolution of these systems and seek a deeper understanding of the competing mechanisms responsible for resonant capture and escape.

Accordingly, we investigate the role that specific two-body eccentricity and inclination resonances play in determining stability conditions. For three satellites in a 1:2:4 resonance, there exist four nearby first-order eccentricity resonances along with many other weaker eccentricity and inclination resonances. In our simulations, we track entrance into and exit from these resonances to provide a more cohesive picture of how the system evolves and find that this evolution depends sensitively on the masses and damping rates. We will report further details of our findings and will discuss their implications for the stability of resonant chains of moons.

AUTHORS (FIRST NAME INITIAL, LAST NAME): T. Rimlinger[1], D. Hamilton[1]

AUTHORS/INSTITUTIONS: T. Rimlinger, D. Hamilton, University of MD, College Park, Manassas, Virginia, UNITED STATES|

SESSION TITLE: 'N SyncDynamics of Resonant Objects

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974658

TITLE: Why is it so difficult to tilt Uranus?

CONTACT (NAME ONLY): Zeeve Rogoszinski

CONTACT (INSTITUTION ONLY): University of Maryland

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The leading hypothesis for the origin of Uranus' large obliquity (98°) is a polar strike from an Earth sized object, but to tilt Saturn similarly would require an impactor roughly 10x as massive. A more likely cause for Saturn's tilt (27°) is a spin-orbit resonance with Neptune (Ward & Hamilton, 2004; Hamilton & Ward, 2004); might the same process work for Uranus? It initially seems unlikely, as at its current location Uranus' axial precession period is too long to resonate with any of the giant planets' orbital precession frequencies. If we place Uranus between Jupiter and Saturn, however, then Uranus' spin axis would precess much more quickly. Thommes et al. (1999, 2002, 2003) first postulated that Uranus and Neptune were formed between Jupiter and Saturn because the conditions there allow the ice giants to be built rapidly. A resonance for our closer Uranus still requires a distant planet, nevertheless, a condition that can be satisfied if Neptune is ejected from Jupiter and Saturn first with Uranus following significantly later. This scenario, while contrived, is consistent with at least some versions of the Nice model and allows us to fully test the resonance hypothesis. We discovered that even with these optimistic assumptions, i) a resonance capture requires a migration timescale on the order of 100 Myr, and ii) it is impossible to tilt Uranus past 90°. Increasing Neptune's migration speed precludes resonant capture, and instead results in a resonance kick. In the most favorable cases, a resonance kick could raise Uranus' obliquity by 40° on a time span of about 50 Myr. We conclude that even in our best scenario, a resonance cannot fully account for Uranus' tilt. We have investigated some scenarios that include both resonances and collisions, and will report on our findings.

AUTHORS (FIRST NAME INITIAL, LAST NAME): Z. Rogoszinski[1], D. Hamilton[1]

AUTHORS/INSTITUTIONS: Z. Rogoszinski, D. Hamilton, University of Maryland, Cheverly, Maryland, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2986976

TITLE: Chaotic Transport in Circumterrestrial Orbits

CONTACT (NAME ONLY): Aaron Rosengren

CONTACT (INSTITUTION ONLY): University of Arizona

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The slow deformation of circumterrestrial orbits in the medium region, subject to lunisolar secular resonances, is well approximated by a Hamiltonian system with 2.5 degrees of freedom. This dynamical model is referred to in the astrophysical and celestial dynamics communities as the quadrupolar, secular, hierarchical three-body problem, and, in the non-autonomous case, gives rise to the classical Kozai-Lidov mechanism. In the time-dependent model, brought about in our case by the Moon's perturbed motion, the action variables of the system may experience chaotic variations and large drifts due to the possible overlap of nearby resonances. Using variational chaos indicators, we compute high-resolution portraits of the action space, revealing the existence of tori and structures filling chaotic regions. Our refined and elaborate calculations allow us to isolate precise initial conditions near specific areas of interest and to study their asymptotic behavior in time. We highlight in particular how the drift in phase space is mediated by the complement of the numerically detected KAM tori. Despite their reputed normality, Earth satellite orbits can possess an extraordinarily rich spectrum of dynamical behaviors, and, like the small body remnants of Solar system formation, they have all the complications that make them very interesting candidates for testing the modern tools of chaos theory.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. J. Rosengren[1]

AUTHORS/INSTITUTIONS: A.J. Rosengren, Aerospace and Mechanical Engineering, University of Arizona, Tucson, Arizona, UNITED STATES|

SESSION TITLE: Danger, Will Robinson! Danger! Dynamics of Hazardous Asteroids

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974942

TITLE: How Turbulence Can Set the Radial Distribution of Gas Giants Formed by Pebble Accretion

CONTACT (NAME ONLY): Mickey Rosenthal

CONTACT (INSTITUTION ONLY): University of California, Santa Cruz

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): I discuss how turbulence impacts the orbital separation at which the cores of gas giants can form via pebble accretion. While pebble accretion is extremely rapid for massive planets, I demonstrate that pebble accretion is inhibited at protoplanet masses, an effect which is strongly enhanced in a turbulent disk. Using these considerations I derive a “minimum” mass, past which pebble accretion proceeds on timescales less than the disk lifetime. By considering core formation where early growth to this minimum mass proceeds by gravitational focusing of planetesimals, I demonstrate that the the semi-major axes where gas giants can form are more restricted as the strength of the nebular turbulence increases — e.g. formation can only occur at distances < 30 AU for α > 10^-2. I also examine the implications of turbulence on the mass gas giants can reach before opening a substantial gap and halting growth. I find that while weak turbulence allows gas giants to form far out in the disk, the masses of these planets are substantially lower (< 1 Jupiter mass), which would preclude them from having been detected by the current generation of direct imaging surveys.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. M. Rosenthal[1], R. Murray-Clay[1]

AUTHORS/INSTITUTIONS: M.M. Rosenthal, R. Murray-Clay, Astronomy and Astrophysics, University of California, Santa Cruz, Santa Cruz, California, UNITED STATES|

SESSION TITLE: In the Beginning There Was Chaos

Dynamics of Planet Formation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971787

TITLE: Science with Synthetic Stellar Surveys

CONTACT (NAME ONLY): Robyn Sanderson

CONTACT (INSTITUTION ONLY): Caltech

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): A new generation of observational projects is poised to revolutionize our understanding of the resolved stellar populations of Milky-Way-like galaxies at an unprecedented level of detail, ushering in an era of precision studies of galaxy formation. In the Milky Way itself, astrometric, spectroscopic and photometric surveys will measure three-dimensional positions and velocities and numerous chemical abundances for stars from the disk to the halo, as well as for many satellite dwarf galaxies. In the Local Group and beyond, HST, JWST and eventually WFIRST will deliver pristine views of resolved stars. The groundbreaking scale and dimensionality of this new view of resolved stellar populations in galaxies challenge us to develop new theoretical tools to robustly compare these surveys to simulated galaxies, in order to take full advantage of our new ability to make detailed predictions for stellar populations within a cosmological context. I will describe a framework for generating realistic synthetic star catalogs and mock surveys from state-of-the-art cosmological-hydrodynamical simulations, and present several early scientific results from, and predictions for, resolved stellar surveys of our Galaxy and its neighbors.

AUTHORS (FIRST NAME INITIAL, LAST NAME): R. E. Sanderson[1]

AUTHORS/INSTITUTIONS: R.E. Sanderson, TAPIR, Caltech, Pasadena, California, UNITED STATES|

SESSION TITLE: The Good, the Bad, the Ugly: How Do Simulations Compare Their Data to Observers and How Can They Do It Better?

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2964634

TITLE: Stability Limits for Rubble Pile Asteroid Shapes

CONTACT (NAME ONLY): Daniel Scheeres

CONTACT (INSTITUTION ONLY): University of Colorado

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The stability of rubble pile asteroids are explored analytically, using simple models for their constituent components. Specifically, we look at the stability of spherical components resting and potentially rolling on each other as a function of their relative sizes, configuration and number. This talk will present some recent results in this problem. Of specific interest is a 5:1 limit on the elongation of a rubble pile body for stability, which is interestingly the same extreme elongation found for the first interstellar object. This limit is for a rubble pile consisting of stacked spheres, resting on each other in a straight line. If there are 5 or less bodies resting on each other in this configuration, there is an interval of spin rates for which the configuration is stable. If there are 6 or more bodies stacked as such, the spin rate for it to stabilize is beyond the spin rate at which it fissions. The talk will also explore additional results for different configurations of bodies resting on each other.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Scheeres[1]

AUTHORS/INSTITUTIONS: D. Scheeres, Aerospace Engineering Sciences, University of Colorado, Boulder, Colorado, UNITED STATES|

SESSION TITLE: 1I/`Oumuamua: the First Known Interstellar Asteroid

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2967112

TITLE: The Feasibility and Benefits of In Situ Exploration of `Oumuamua-like objects

CONTACT (NAME ONLY): Darryl Seligman

CONTACT (INSTITUTION ONLY): Yale University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): A rapid accumulation of observations and interpretation have followed in the wake of 1I `Oumuamua's passage through the inner Solar System. We outline the consequences that this first detection of an interstellar asteroid implies for the planet-forming process, and we assess the near-term prospects for detecting and observing (both remotely and \textit{in situ}) future Solar System visitors of this type. Drawing on detailed heat-transfer calculations that take both `Oumuamua's unusual shape and its chaotic tumbling into account, we affirm that the lack of a detectable coma in deep images of the object very likely arises from the presence of a radiation-modified coating of high molecular weight material (rather than a refractory bulk composition). Assuming that `Oumuamua is a typical representative of a larger population with a kinematic distribution similar to Population I stars in the local galactic neighborhood, we calculate expected arrival rates, impact parameters and velocities of similar objects and assess their prospects for detection using operational and forthcoming facilities. Using `Oumuamua as a proof-of-concept, we assess the prospects for missions that intercept ISOs using conventional chemical propulsion. Using a ``launch on detection'' paradigm, we estimate wait times of order a year between favorable mission opportunities with the detection capabilities of the Large-Scale Synoptic Survey Telescope (LSST), a figure that will be refined as the population of interstellar asteroids becomes observationally better constrained.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Seligman[1], G. Laughlin[1]

AUTHORS/INSTITUTIONS: D. Seligman, G. Laughlin, Astronomy, Yale University, New Haven, Connecticut, UNITED STATES|

SESSION TITLE: 1I/`Oumuamua: the First Known Interstellar Asteroid

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2972725

TITLE: The Dynamical Imprint of Lost Protoplanets on the Trans-Neptunian Populations, and Limits on the Primordial Size Distribution of Trans-Neptunian Objects at Pluto and Larger Sizes.

CONTACT (NAME ONLY): Andrew Shannon

CONTACT (INSTITUTION ONLY): The Pennsylvania State University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Planet formation remains a poorly understood process, in part because of our limited access to the intermediate phases of planetesimal and protoplanet growth. Today, the vast majority of the accessible remaining planetesimals and protoplanets reside within the Hot Trans-Neptunian Object population. This population has been depleted by 99% - 99.9% over the course of the Solar system's history, and as such the present day size-number distribution may be incomplete at the large size end. We show that such lost protoplanets would have left signatures in the dynamics of the present-day Trans-Neptunian Populations, and their primordial number can thus be statistically limited by considering the survival of ultra-wide binary TNOs, the Cold Classical Kuiper belt, and the resonant populations. We compare those limits to the predicted size-number distribution of various planetesimal and proto-planet growth models.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. B. Shannon[1], R. Dawson[1]

AUTHORS/INSTITUTIONS: A.B. Shannon, R. Dawson, Department of Astronomy & Astrophysics, The Pennsylvania State University, University Park, Pennsylvania, UNITED STATES|

SESSION TITLE: Flat Cats Instead of Spherical Cows

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971737

TITLE: High-Velocity Cloud Complex H and Weaver's "Jet": Two candidate dwarf satellite galaxies for which dark matter halo models indicate distances of ~27 kpc and ~108 kpc

CONTACT (NAME ONLY): S. Simonson

CONTACT (INSTITUTION ONLY): None

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Two anomalous-velocity H I features, High-Velocity Cloud Complex H (HVC H) (Blitz et al. 1999), and Weaver's "jet" (Weaver 1974), appear to be good candidates for dwarf satellites. In this work they are modeled as H I disks in dark matter halos that move in 3D orbits in the combined time-dependent gravitational fields of the Milky Way and M31. As they orbit in the Local Group they develop tidal distortions and produce debris. The current l,b,V appearance of the tidal features as they approach the Milky Way indicate distances of 27 ± 9 kpc for HVC H and 108 ± 36 kpc for Weaver's "jet". As these are within the distances to known Milky Way satellites, finding stellar components would be of interest for the star formation history of the Milky Way. This work uses recent Hubble Space Telescope results on M31 (van der Marel et al. 2012) to calculate the center-of-mass (COM) locations and the dark matter mass distributions of the Milky-Way—M31 system since the Big Bang. Time-dependent COM orbits of the satellites have been computed in 3D, along with rings of test particles representing their disks. Tidal effects that develop on these rings have been compared with published 21-cm line data from Lockman (2003) and Simonson (1975). For HVC H at l = 130.5°, b = +1.5°, V = -200 km/s, the dark matter mass (in solar masses) is estimated as 5.2 ± 3.5E8. The previously estimated H I mass is 6.4E6, or 1.2% of the newly derived satellite mass. For Weaver's "jet", which covers 2° by 7° at l = 197.3°, b = +2.1°, V = -30 to -87 km/s, the dark matter mass is estimated as 1.8 ± 0.6E9. The H I mass is 1.8 ± 1.1E8, or 6% to 12% of the satellite mass. In the case of HVC H, owing to its disk angle of 45°, tidal debris is thrown upward. This would presumably contribute to a halo star stream. In the case of Weaver's "jet", the streamer represents accreting material for the disk. I am grateful to Leo Blitz for bringing Lockman's work on HVC H to my attention and for many helpful discussions and suggestions over the course of several years. Blitz, L., et al. 1999, ApJ, 514, 818. Lockman, F. J. 2003, ApJ, 591, L33. Simonson, S. C. 1975, ApJ, 201, L103. Van der Marel, R. P., et al. 2012, ApJ, 753, 8. Weaver, H. 1974, in IAU Symp. 60, 573.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. C. Simonson[1]

AUTHORS/INSTITUTIONS: S.C. Simonson, None, Los Altos, California, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970870

TITLE: Episodic Spin-up and Spin-down Torque on Earth

CONTACT (NAME ONLY): Victor Slabinski

CONTACT (INSTITUTION ONLY): U.S. Naval Observatory

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Variations in Earth rotation angle are traditionally expressed by the time difference (ΔT=TT-UT1) between Terrestrial Time (TT) as told by atomic clocks and Universal Time UT1, the time variable used by the Earth-rotation formula. A plot of ΔT versus TT over the past 160 years shows a continuous curve with approximate straight-line segments with different spans of order ~20 years. Removing the tidal and seasonal variations from the data gives these line segments which represent the "decadal variations" in Earth rotation.

The slope of a straight-line segment is proportional to the departure of Earth rotation rate from a reference value at the time. The change in slope over the relatively short time between segments indicates an episodic spin-up or spin-down in Earth rotation. The daily combination of VLBI, SLR, and other modern data available since 1973 gives us accurate, daily values of ΔT and the corresponding LOD (Length Of Day) values during these episodes. These allow us to determine the rotational acceleration occurring then.

The three largest spin-speed changes found during the VLBI era have the following characteristics:

Episode ____________ Duration__ ΔLOD__LOD Rate
1983 Dec 30-1984 Jan 28 ... 29 d ...-0.65 ms ..-8.3 ms/y ....spin-up
1989 Mar 15-1989 May 23 ...69 d ....0.68 ....+3.6 ....spin-down
1994 Jan 21-2001 Apr 01 ... 6.5 y ...-2.2 ....-0.36 ..extended spin-up

For the first two episodes listed, we find the acceleration grows from zero (or at least a relatively small value) to its extreme value in ~1 day, stays approximately constant at this value for 29 or 69 days, and then decays back to zero over ~1 day. The acceleration, while it occurs, gives an LOD rate much greater than the 0.02 ms/y rate from tidal friction.

The third episode shows that occasionally a several-year-long episode occurs. The acceleration magnitude is smaller but can make a larger total change in LOD (and spin rate). Tidal friction requires >100 y to equal the LOD magnitude change from this episode.

We do not know the cause or trigger for the episodes.

AUTHORS (FIRST NAME INITIAL, LAST NAME): V. J. Slabinski[1], A. A. Mendonca[2]

AUTHORS/INSTITUTIONS: V.J. Slabinski, Earth Orientation, U.S. Naval Observatory, Washington, District of Columbia, UNITED STATES|A.A. Mendonca, Winston Churchill High School, Potomac, Maryland, UNITED STATES|

SESSION TITLE: Party in the Spin Room

Dynamics of Rotation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2966421

TITLE: The Resilience of Kepler Multi-systems to Stellar Obliquity

CONTACT (NAME ONLY): Christopher Spalding

CONTACT (INSTITUTION ONLY): California Institute of Technology

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The Kepler mission and its successor K2 have brought forth a cascade of transiting planets. Many of these planetary systems exhibit multiple transiting members. However, a large fraction possesses only a single transiting planet. This high abundance of singles, dubbed the "Kepler Dichotomy," has been hypothesized to arise from significant mutual inclinations between orbits in multi-planet systems. Alternatively, the single-transiting population truly possesses no other planets in the system, but the true origin of the overabundance of single systems remains unresolved. In this work, we propose that planetary systems typically form with a coplanar, multiple-planetary architecture, but that quadrupolar gravitational perturbations from their rapidly-rotating host star subsequently disrupt this primordial coplanarity. We demonstrate that, given sufficient stellar obliquity, even systems beginning with 2 planetary constituents are susceptible to dynamical instability soon after planet formation, as a result of the stellar quadrupole moment. This mechanism stands as a widespread, yet poorly explored pathway toward planetary system instability. Moreover, by requiring that observed multi-systems remain coplanar on Gyr timescales, we are able to place upper limits on the stellar obliquity in systems such as K2-38 (obliquity < 20 degrees), where other methods of measuring spin-orbit misalignment are not currently available.

AUTHORS (FIRST NAME INITIAL, LAST NAME): C. Spalding[1], N. W. Marx[2], K. Batygin[1]

AUTHORS/INSTITUTIONS: C. Spalding, K. Batygin, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California, UNITED STATES|N.W. Marx, Calabasas High School, Calabasas, California, UNITED STATES|

SESSION TITLE: An Oblique Reference to Pop Culture

Dynamics of Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971150

TITLE: Predicting Instability Timescales in Closely-Packed Planetary Systems

CONTACT (NAME ONLY): Daniel Tamayo

CONTACT (INSTITUTION ONLY): University of Toronto at Scarborough

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Many of the multi-planet systems discovered around other stars are maximally packed. This implies that simulations with masses or orbital parameters too far from the actual values will destabilize on short timescales; thus, long-term dynamics allows one to constrain the orbital architectures of many closely packed multi-planet systems. A central challenge in such efforts is the large computational cost of N-body simulations, which preclude a full survey of the high-dimensional parameter space of orbital architectures allowed by observations. I will present our recent successes in training machine learning models capable of reliably predicting orbital stability a million times faster than N-body simulations. By engineering dynamically relevant features that we feed to a gradient-boosted decision tree algorithm (XGBoost), we are able to achieve a precision and recall of 90% on a holdout test set of N-body simulations. This opens a wide discovery space for characterizing new exoplanet discoveries and for elucidating how orbital architectures evolve through time as the next generation of spaceborne exoplanet surveys prepare for launch this year.

AUTHORS (FIRST NAME INITIAL, LAST NAME): D. Tamayo[1], S. Hadden[4], N. Hussain[3], A. Silburt[2], C. Gilbertson[2], H. Rein[1], K. Menou[1]

AUTHORS/INSTITUTIONS: D. Tamayo, H. Rein, K. Menou, University of Toronto at Scarborough, Scarborough, Ontario, CANADA|A. Silburt, C. Gilbertson, Pennsylvania State University, State College, Pennsylvania, UNITED STATES|N. Hussain, University of Toronto, Toronto, Ontario, CANADA|S. Hadden, Harvard Smithsonian Center for Astrophysics, Cambridge, Massachusetts, UNITED STATES|

SESSION TITLE: Hot, Flat, and Crowded

Dynamics of Tightly-Packed Exoplanets

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2971049

TITLE: Estimatining biases in the stellar dynamical black hole mass measurements in barred galaxies and prospects for measuring SMBH masses with JWST

CONTACT (NAME ONLY): Monica Valluri

CONTACT (INSTITUTION ONLY): University of Michigan

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Although 60% of disk galaxies are barred, stellar dynamical measurements of the masses of supermassive black holes (SMBH) in barred galaxies have always been obtained under the assumption that the bulges are axisymmetric. We use N-body simulations with self-consistently grown SMBHs in barred and unbarred galaxies to create a suite of mock Integral Field Spectrographic (IFS) datasets for galaxies with various observed orientations. We then apply an axisymmetric orbit superposition code to these mock IFS datasets to assess the reliability with which SMBH masses can be recovered. We also assess which disk and bar orientations give rise to biases. We use these simulations to assess whether or not existing SMBH measurements in barred galaxies are likely to be biased. We also present a brief preview of our JWST Early Release Science proposal to study the nuclear dynamics of nearby Seyfert I galaxy NGC 4151 with the NIRSpec Integral Field Spectrograph and describe how simulations of disk galaxies will used to create mock NIRSpec data to prepare for the real data.

AUTHORS (FIRST NAME INITIAL, LAST NAME): M. Valluri[1], E. Vasiliev[2, 3], M. Bentz[4], J. Shen[5]

AUTHORS/INSTITUTIONS: M. Valluri, Astronomy, University of Michigan, Ann Arbor, Michigan, UNITED STATES|E. Vasiliev, University of Cambridge, Cambridge, UNITED KINGDOM|E. Vasiliev, Lebedev Physical Institute, Moscow, RUSSIAN FEDERATION|M. Bentz, Georgia State University, Atlanta, Georgia, UNITED STATES|J. Shen, Shanghai Astronomical Observatory, Shanghai, CHINA|

SESSION TITLE: Stretched Out Dwarfs

Dynamics of Galaxies

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974768

TITLE: Determining The Plane of The Kuiper Belt with OSSOS

CONTACT (NAME ONLY): Christa Van Laerhoven

CONTACT (INSTITUTION ONLY): University of British Columbia

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We present the OSSOS-based measurement of the semi-major axes dependent orientation of the Kuiper Belt plane. A Kuiper Belt object's (KBO's) inclination can be broken down into a forced component and a free component. The inclination and longitude of ascending node of the forced inclination define the 'forced plane,' the plane about which the KBO's inclination will precess. Secular theory predicts that this forced plane should depend on semi-major axis. For example, the nu18 secular resonance should create a significant warp in the forced planet near 40.5 au (Chiang and Choi 2008). Not predicted by secular theory is a warp in the distant Kuiper Belt (semi-major axes greater than 50 au) seen by Volk and Malhotra 2016 using KBOs from the Minor Planet Catalog. We investigate what the inclination distribution is for objects beyond Neptune as a function of semi-major axis using the OSSOS characterized sample. Through use of the OSSOS survey simulator we test various underlying orbital distributions and compare how the survey would have observed those populations to the actual observed sample. In particular, we test various widths for the inclination distribution about various local forcing planes for the kernel, stirred, and hot classical Kuiper Belt. We find that the forced plane in matches well with the expected forced plane from secular theory. Through most of the main Kuiper Belt (between the 3:2 and 2:1 resonances), we can reject both the ecliptic plane and the invariable plane as the true forced plane. Only as the expected secularly forced plane approaches the invariable plane does the invariable plane become non-rejectable. In the outer Kuiper Belt we reject the nominal mean-plane measured by Volk and Malhotra, but smaller warps are still allowed by the data.

AUTHORS (FIRST NAME INITIAL, LAST NAME): C. Van Laerhoven[1], J. Kavelaars[2], K. Volk[3], B. Gladman[1], J. Petit[4]

AUTHORS/INSTITUTIONS: C. Van Laerhoven, B. Gladman, Physics and Astronomy, University of British Columbia, Vancouver, British Columbia, CANADA|J. Kavelaars, National Research Council of Canada, Herzberg, Victoria, British Columbia, CANADA|K. Volk, University of Arizona, Tucson, Arizona, UNITED STATES|J. Petit, CNRS / Observatoire De Besançon, Besançon, FRANCE|

SESSION TITLE: Never Tell Me the Odds

Dynamics of the Kuiper Belt

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2972711

TITLE: Two objects in Neptune's 9:1 resonance -- implications for resonance sticking in the scattering population

CONTACT (NAME ONLY): Kathryn Volk

CONTACT (INSTITUTION ONLY): The University of Arizona

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We discuss the detection in the Outer Solar System Origins Survey (OSSOS) of two objects in Neptune's distant 9:1 mean motion resonance at semimajor axis a≈130 au. Both objects are securely resonant on 10 Myr timescales, with one securely in the 9:1 resonance's leading asymmetric libration island and the other in either the symmetric or trailing asymmetric island. These two objects are the largest semimajor axis objects known with secure resonant classifications, and their detection in a carefully characterized survey allows for the first robust population estimate for a resonance beyond 100 au. The detection of these two objects implies a population in the 9:1 resonance of 1.1×10^4 objects with Hr<8.66 (D > 100 km) on similar orbits, with 95% confidence range of $\sim0.4-3\times10^4$. Integrations over 4 Gyr of an ensemble of clones chosen from within the orbit fit uncertainties for these objects reveal that they both have median resonance occupation timescales of ~1 Gyr. These timescales are consistent with the hypothesis that these two objects originate in the scattering population but became transiently stuck to Neptune's 9:1 resonance within the last ~1 Gyr of solar system evolution. Based on simulations of a model of the current scattering population, we estimate the expected resonance sticking population in the 9:1 resonance to be 1000--5000 objects with Hr<8.66; this is marginally consistent with the OSSOS 9:1 population estimate. We conclude that resonance sticking is a plausible explanation for the observed 9:1 population, but we also discuss the possibility of a primordial 9:1 population, which would have interesting implications for the Kuiper belt's dynamical history.

AUTHORS (FIRST NAME INITIAL, LAST NAME): K. Volk[1], R. Murray-Clay[2], B. Gladman[3], S. Lawler[4], T. Yu[5], M. Alexandersen[6], M. Bannister[7], Y. Chen[6], R. Dawson[8], S. Greenstreet[9], S. Gwyn[4], J. Kavelaars[4, 10], H. Lin[11, 12], P. Lykawka[13], J. Petit[14]

AUTHORS/INSTITUTIONS: K. Volk, The University of Arizona, Tucson, Arizona, UNITED STATES|R. Murray-Clay, University of California Santa Cruz, Santa Cruz, California, UNITED STATES|B. Gladman, University of British Columbia, Vancouver, British Columbia, CANADA|S. Lawler, S. Gwyn, J. Kavelaars, NRC-Herzberg Astronomy and Astrophysics, Victoria, British Columbia, CANADA|T. Yu, University of California Los Angeles, Los Angeles, California, UNITED STATES|M. Alexandersen, Y. Chen, Institute of Astronomy and Astrophysics, Academia Sinica, Taipei, TAIWAN|M. Bannister, Queen's University Belfast, Belfast, UNITED KINGDOM|R. Dawson, Pennsylvania State University, University Park, Pennsylvania, UNITED STATES|S. Greenstreet, Las Cumbres Observatory, Santa Barbara, California, UNITED STATES|J. Kavelaars, University of Victoria, Victoria, British Columbia, CANADA|H. Lin, National Central University, Taoyuan, TAIWAN|H. Lin, University of Michigan, Ann Arbor, Michigan, UNITED STATES|P. Lykawka, Kindai University, Higashiosaka City, JAPAN|J. Petit, Univ. Bourgogne Franche-Comté, Besançon, FRANCE|

SESSION TITLE: 'N SyncDynamics of Resonant Objects

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2987041

TITLE: The influence of dynamical friction and mean motion resonances on terrestrial planet growth

CONTACT (NAME ONLY): Spencer Wallace

CONTACT (INSTITUTION ONLY): University of Washington

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We present a set of high-resolution direct N-body simulations of planetesimal coagulation at 1 AU. We follow the evolution of of 1 million planetesimals in a ring though the runaway and oligarchic growth phases. During oligarchic growth, the size frequency distribution (SFD) of planetesimals develops a bump at intermediate masses, which we argue is due to dynamical friction acting through mean motion resonances, heating the low mass planetesimals and inhibiting their growth. This feature is similar to the bump seen in the SFD of asteroid belt and Kuiper belt objects and we argue that a careful treatment of the dynamics of planetesimal interactions is required in order to adequately explain the observed SFD. Although our model does not account for fragmentation, our results show that a similar feature can be produced without it, which is in contention with previous studies.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. C. Wallace[1], T. R. Quinn[1]

AUTHORS/INSTITUTIONS: S.C. Wallace, T.R. Quinn, Astronomy, University of Washington, Seattle, Washington, UNITED STATES|

SESSION TITLE: Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations|Poster Presentations

PRESENTATION TYPE: Poster

CURRENT CATEGORY:

CONTROL ID: 2971007

TITLE: High Resolution N-Body Simulations of Terrestrial Planet Growth

CONTACT (NAME ONLY): Spencer Wallace

CONTACT (INSTITUTION ONLY): University of Washington

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): We investigate planetesimal accretion with a direct N-body simulation of an annulus at 1 AU around a 1 M_sun star. The planetesimal ring, which initially contains $N = 10^6$ bodies is evolved through the runaway growth stage into the phase of oligarchic growth. We find that the mass distribution of planetesimals develops a bump around 10^{22} g shortly after the oligarchs form. This feature is absent in previous lower resolution studies. We find that this bump marks a boundary between growth modes. Below the bump mass, planetesimals are packed tightly enough together to populate first order mean motion resonances with the oligarchs. These resonances act to heat the tightly packed, low mass planetesimals, inhibiting their growth. We examine the eccentricity evolution of a dynamically hot planetary embryo embedded in an annulus of planetesimals and find that dynamical friction acts more strongly on the embryo when the planetesimals are finely resolved. This effect disappears when the annulus is made narrow enough to exclude most of the mean motion resonances. Additionally, we find that the 10^{22} g bump is significantly less prominent when we follow planetesimal growth with a skinny annulus.This feature, which is reminiscent of the power law break seen in the size distribution of asteroid belt objects may be an important clue for constraining the initial size of planetesimals in planet formation models.

AUTHORS (FIRST NAME INITIAL, LAST NAME): S. C. Wallace[1], T. R. Quinn[1]

AUTHORS/INSTITUTIONS: S.C. Wallace, T.R. Quinn, Astronomy, University of Washington, Seattle, Washington, UNITED STATES|

SESSION TITLE: In the Beginning There Was Chaos

Dynamics of Planet Formation

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2974664

TITLE: Tidal Disruption Events from Eccentric Nuclear Disks

CONTACT (NAME ONLY): Heather Wernke

CONTACT (INSTITUTION ONLY): University of Colorado Boulder

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): Stars that get too close to a supermassive black hole are in danger of being tidally disrupted. Stellar two-body relaxation is commonly assumed to be the main driver of these events. Recent work has shown, however, that secular gravitational torques from eccentric nuclear disks can push stars to extreme eccentricities at much higher rates than predicted by two-body relaxation. This work did not include the effects of general relativity, however, which could quench secular torques via rapid apsidal precession. Here we show that, for a star in danger of disruption, general relativity acts on a timescale of less than an orbital period. This short timescale means that general relativity does not have enough time to have a major effect on the orbit. When driven by secular torques from eccentric nuclear disks, tidal disruption event rates are not affected by general relativity.

AUTHORS (FIRST NAME INITIAL, LAST NAME): H. N. Wernke[1], A. Madigan[1]

AUTHORS/INSTITUTIONS: H.N. Wernke, A. Madigan, Astrophysical and Planetary Sciences, University of Colorado Boulder, Boulder, Colorado, UNITED STATES|

SESSION TITLE: The Fault in Our Stars

Dynamics of Stars and Black Holes

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2972840

TITLE: Implications of Stellar Feedback for Dynamical Modeling of the Milky Way and Dwarf Galaxies

CONTACT (NAME ONLY): Andrew Wetzel

CONTACT (INSTITUTION ONLY): University of California, Davis

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): I will present recent results on dynamical modeling of stellar populations from the FIRE cosmological zoom-in baryonic simulations of Milky Way-like and dwarf galaxies. First, I will discuss the dynamical formation of the Milky Way, including the origin of thin+thick stellar disk morphology. I also will discuss the curious origin of metal-rich stars on halo-like orbits near the Sun, as recently measured by Gaia, with new insights from FIRE simulations on stellar radial migration/heating. Next, I will discuss role of stellar feedback in generating non-equilibrium fluctuations of the gravitational potential in low-mass 'dwarf' galaxies, which can explain the origin of cores in their dark-matter density profiles. In particular, we predict significant observable effects on stellar dynamics, including radial migration, size fluctuations, and population gradients, which can provide observational tests of feedback-driven core formation. Finally, this scenario can explain the formation of newly discovered 'ultra-diffuse' galaxies.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. Wetzel[1]

AUTHORS/INSTITUTIONS: A. Wetzel, Physics, University of California, Davis, Davis, California, UNITED STATES|

SESSION TITLE: Stretched Out Dwarfs

Dynamics of Galaxies

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2970208

TITLE: The first retrograde Trojan asteroid

CONTACT (NAME ONLY): Paul Wiegert

CONTACT (INSTITUTION ONLY): University of Western Ontario

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): There are about six thousand asteroids which share Jupiter's orbit around the Sun. Called the 'Trojan asteroids', they co-exist easily with this giant planet because they travel in the same direction as it ('direct' or 'prograde' motion), and remain roughly 60 degrees ahead of or behind it in its orbit. Newly discovered asteroid 2015 BZ509 is on a retrograde orbit, but is nonetheless in a state dynamically analogous to that of the prograde Trojans. The discovery circumstances and the nature of the motion of this curious asteroid -the first of its kind- will be outlined.

AUTHORS (FIRST NAME INITIAL, LAST NAME): P. Wiegert[1, 2], M. Connors[3], C. Veillet[4]

AUTHORS/INSTITUTIONS: P. Wiegert, University of Western Ontario, London, Ontario, CANADA|P. Wiegert, Centre for Planetary Science and Exploration (CPSX), London, Ontario, CANADA|M. Connors, Athabasca University, Athabasca, Alberta, CANADA|C. Veillet, Large Binocular Telescope Observatory, Tucson, Arizona, UNITED STATES|

SESSION TITLE: 'N SyncDynamics of Resonant Objects

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2968362

TITLE: Stellar Angular Momentum Distributions and Preferential Radial Migration

CONTACT (NAME ONLY): Rosemary Wyse

CONTACT (INSTITUTION ONLY): Johns Hopkins University

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): I will present some results from our recent investigations into the efficiency of radial migration in stellar disks of differing angular momentum distributions, within a given adopted 2D spiral disk potential. We apply to our models an analytic criterion that determines whether or not individual stars are in orbits that could lead to radial migration around the corotation resonance. We couch our results in terms of the local stellar velocity dispersion and find that the fraction of stars that could migrate radially decreases as the velocity dispersion increases. I will discuss implications and comparisons with the results of other approaches.

AUTHORS (FIRST NAME INITIAL, LAST NAME): R. Wyse[1], K. J. Daniel[2]

AUTHORS/INSTITUTIONS: R. Wyse, Johns Hopkins University, Baltimore, Maryland, UNITED STATES|K.J. Daniel, Bryn Mawr College, Bryn Mawr, Pennsylvania, UNITED STATES|

SESSION TITLE: The Fault in Our Stars

Dynamics of Stars and Black Holes

PRESENTATION TYPE: Oral

CURRENT CATEGORY:

CONTROL ID: 2968910

TITLE: Telescopic and meteor observation of `Oumuamua, the first known interstellar asteroid

CONTACT (NAME ONLY): Quan-Zhi Ye

CONTACT (INSTITUTION ONLY): Caltech

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): 1I/2017 U1 ('Oumuamua), a recently discovered asteroid in a hyperbolic orbit, is the first macroscopic object of extrasolar origin identified in the solar system. I will present imaging and spectroscopic observations of 'Oumuamua as well as a search of meteor activity potentially linked to this object using the Canadian Meteor Orbit Radar. We find that 'Oumuamua exhibits a moderate spectral gradient of 10%+-6% per 100 nm, a value lower than that of outer solar system bodies, indicative of a formation and/or previous residence in a warmer environment. Imaging observation and spectral line analysis show no evidence that 'Oumuamua is presently active. Negative meteor observation is as expected, since ejection driven by sublimation of commonly known cometary species such as CO requires an extreme ejection speed of ~40 m/s at ~100 au in order to reach the Earth. No obvious candidate stars are proposed as the point of origin for 'Oumuamua. Given a mean free path of ~10^9 ly in the solar neighborhood, 'Oumuamua has likely spent a very long time in interstellar space before encountering the solar system.

AUTHORS (FIRST NAME INITIAL, LAST NAME): Q. Ye[1]

AUTHORS/INSTITUTIONS: Q. Ye, Caltech, Pasadena, California, UNITED STATES|

SESSION TITLE: 1I/`Oumuamua: the First Known Interstellar Asteroid

PRESENTATION TYPE: Invited

CURRENT CATEGORY:

CONTROL ID: 2974752

TITLE: Instability timescale for the inclination instability in the solar system

CONTACT (NAME ONLY): Alexander Zderic

CONTACT (INSTITUTION ONLY): University of Colorado Boulder

ABSTRACT BODY:

Abstract (2,250 Maximum Characters): The gravitational influence of small bodies is often neglected in the study of solar system dynamics. However, this is not always an appropriate assumption. For example, mutual secular torques between low mass particles on eccentric orbits can result in a self-gravity instability (`inclination instability'; Madigan & McCourt 2016). During the instability, inclinations increase exponentially, eccentricities decrease (detachment), and orbits cluster in argument of perihelion. In the solar system, the orbits of the most distant objects show all three of these characteristics (high inclination: Volk & Malhotra (2017), detachment: Delsanti & Jewitt (2006), and argument of perihelion clustering: Trujillo & Sheppard (2014)). The inclination instability is a natural explanation for these phenomena.

Unfortunately, full N-body simulations of the solar system are unfeasible ($N \approx O(10^{12})$), and the behavior of the instability depends on N, prohibiting the direct application of lower N simulations. Here we present the instability timescale's functional dependence on N, allowing us to extrapolate our simulation results to that appropriate for the solar system. We show that ~5 M_{Earth} of small icy bodies in the Sedna region is sufficient for the inclination instability to occur in the outer solar system.

AUTHORS (FIRST NAME INITIAL, LAST NAME): A. Zderic[1], A. Madigan[1], J. Fleisig[1]

AUTHORS/INSTITUTIONS: A. Zderic, A. Madigan, J. Fleisig, Astrophysical and Planetary Science, University of Colorado Boulder, Boulder, Colorado, UNITED STATES|

SESSION TITLE: Stability, or Instability, That is the QuestionDynamics of Planetary System Stability

PRESENTATION TYPE: Oral

CURRENT CATEGORY: