XVIII Jornadas de Trabajo en Mecánica Celeste

Haro, 19 - 21 junio, 2019

Programa, Resúmenes y Lista de Participantes

Programa

Miércoles 19 de junio:

09:45-10:00 Inauguración de las Jornadas.

10:00-13:30 **Sesión:** I. **Moderador:** Mercè Ollé

10:00-11:00 J. A. Docobo:"Sistemas estelares dobles y múltiples (y sus huéspenes) en la era GAIA".

11:00-11:30 M. Andrade: "On the computation of dynamical parallaxes and individual masses of visual systems".

11:30-12:00 Pausa para el café.

12:00-12:30 D. Arnas: "Invariantes en la definición nominal de constelaciones de satélites y su relación con Walker y Flower Constellations".

12:30-13:00 D. Casanova: "Deterministic and Heuristic methods to compute a synthetic population of space debris".

13:00-13:30 G. Gómez: "State and Parameter Estimation of GEO Satellites Using Jet Transport".

14:00 Comida en el restaurante La Vega, situado a 150 m de la sede de las Jornadas.

16:30-18:00 **Sesión:** II. **Moderador:** Jesús Palacián

16:30-17:00 E. Barrabés: "Stacked Central Configurations of the five body problem".

17:00-17:30 J.M. Cors: "Right cuadrilaterals central configurations".

17:30-18:00 O. Rodríguez: "Regularization Techniques and Ejection-collision Orbits in the RTBP".

Jueves 20 de junio:

9:30-13:30 **Sesión:** III. **Moderador:** Antonio Elipe

9:30-10:30 M. Álvarez: "The Hamiltonian with Armbruster-Guckenheimer-Kim potential".

10:30-11:00 V. Lanchares: "Normal forms, averaging and periodic orbits in a rotating Hénon-Heiles system".

11:00-11:30 Pausa para el café.

11:30-12:00 M. Ollé: "Some questions and some (partial) answers about the atom of hydrogen in a CP microwave field".

12:00-12:30 F. Salazar: "Design of homoclinic and heteroclinic orbits for the exploration of the south pole of Enceladus".

12:30-13:00 B. Bardin: "On orbital stability of periodic pendulum-like motion of a heavy rigid body with a fixed point in the case of identical resonance".

13:00-13:30 P. Yanguas: "Lie stability of L_4 in the spatial restricted circular three-body problem".

14:00 Comida en el restaurante La Vega.

16:30 Visita guiada a Bodegas Bilbaínas.

19:00 Visita guiada por Haro.

21:00 Cena de las Jornadas en el Restaurante El Claustro, en el Hotel Los Agustinos.

Viernes 21 de junio:

10:00-13:30 **Sesión:** IV. **Moderador:** Manuel Iñarrea

10:00-11:00 L. Rández: "Algunos métodos y técnicas para la integración numérica de problemas de Mecánica Celeste."

11:00-11:30 J.P. Salas: "Nonlinear dynamics of Neutral atoms in optical dipole traps".

11:30-12:00 Pausa para el café.

12:00-12:30 J.J. Morales–Ruiz: "Integrabilidad de procesos estocásticos de nacimiento-muerte vía Teoría de Galois diferencial"

12:30-13:00 J. Palacián: "Normalisation through invariants in n-dimensional Kepler problems".

13:00-13:30 L. Floría: "On Constants of Motion of Some Gyldén-Type Systems".

13:30 Clausura de las Jornadas.

14:00 Comida en el restaurante La Vega.

Conferencias plenarias y comunicaciones

XVIII Jornadas de Trabajo en Mecánica Celeste.
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The Hamiltonian with Armbruster-Guckenheimer-Kim potential

Martha Álvarez Ramírez[(1)]

Abstract

This talk deals with the Armbruster-Guckenheimer-Kim quartic potential, and the associated Hamiltonian given by

$$H(x,y) = \frac{1}{2}(y_1^2 + y_2^2) - \frac{\mu}{2}(x_1^2 + x_2^2) - \frac{a}{4}(x_1^2 + x_2^2)^2 - \frac{b}{2}x_1^2 x_2^2,$$

where μ, a and b are three real parameters.

We present several results related to non-integrability applying Morales-Ramis theory, and the existence and stability of periodic solutions in a neighbourhood of elliptic equilibrium points using reduction and averaging theory.

This is based on joint works with P. Acosta-Humánez, A. García, T. Stuchi and J. Vidarte.

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Sistemas estelares dobles y múltiples (y sus huéspedes) en la era GAIA

J. A. Docobo[(1)]

Abstract

Las estrellas dobles y múltiples constituyen una extraordinaria fuente de información astronómica. Pueden ser también consideradas como escaparates que permiten estudiar en ellas distintos fenómenos físicos, pudiéndose modelizar matemáticamente muchos de ellos, pero para ello necesitamos tener órbitas muy precisas. En esta presentación se describirán, en primer lugar, los distintos tipos de binarias y los fundamentos básicos. Hablaremos también someramente de técnicas de observación de binarias visuales que proporcionen la base de todo este campo de investigación: observaciones de gran calidad.

Después de recordar algunos de los métodos ms representativos para el cálculo de órbitas, nos adentraremos en determinados resultados recientes del OARMA, como por ejemplo el poder determinar la órbita 3D de una binaria espectroscópica con una sola medida interferométrica, o cómo tener una estimación de la distancia angular entre las componentes de una binaria espectroscópica para intentar su resolución óptica. Recordaremos así mismo ciertos resultados de interés relacionados con la pérdida de masa de las componentes.

Referente a dinámica de los sistemas múltiples, es preciso tener en cuenta los distintos trabajos realizados en tesis doctorales tanto en Zaragoza como en Santiago de Compostela, y más recientemente en otra tesis en preparación con la aplicación de TIDES al problema jerarquizado de tres cuerpos. Ya en relación con esto, entramos de lleno en el estudio de la dinámica de exoplanetas en torno a una componente, o a las dos, de un sistema binario, a lo que se puede añadir la existencia de exomoons en el escenario.

La enorme precisión que se espera de los datos obtenidos por la misión espacial Gaia, en especial de las paralajes, motivan el calcular cada vez órbitas más seguras, particularmente para las binarias a la vez visuales y espectroscópicas de doble línea ya que de sus órbitas se pueden deducir las denominadas paralajes orbitales que pueden servir de test para las medidas por Gaia y, en todo caso, para calcular con la mayor fiabilidad posible las masas individuales de las componentes.

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Algunos métodos y técnicas para la integración numérica de problemas de Mecánica Celeste

L. Rández[(1)]

Abstract

En esta presentación haremos un resumen de algunos de los problemas diferenciales más icónicos que aparecen en Mecánica Celeste y veremos algunos de los métodos numéricos y distintas técnicas empleadas para propagación de órbitas

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On the computation of dynamical parallaxes and individual masses of visual systems

Manuel Andrade[(1)]

Abstract

A theory that allows to obtain accurate dynamical parallaxes and individual masses of visual binaries, even in the case of a large difference of luminosities between both components, is presented. This has been accomplished using a new nonlinear mass-luminosity relation (valid throughout the entire main sequence) for whose choice the second-order Akaike information criterion (AIC_c) was used. Since the fundamental equation of the method cannot be solved by factorization into radicals, thus it is solved using the Brent-Dekker method. In addition, reliable uncertainties in parallaxes and masses are computed by means of Monte Carlo simulations.

A synthetic sample of 10^3 binary systems has been used to assess the accuracy of the theory using a linear regression model. Moreover, dynamical parallaxes and individual masses have been calculated for the set of 19 main-sequence VB+SB2 systems with "definitive" visual orbits and compared with those obtained from astrometric and spectroscopic observations.

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Invariantes en la definición nominal de constelaciones de satélites y su relación con Walker y Flower Constellations

D. Arnas[(1)], **D. Casanova**[(1)]

Abstract

Este trabajo se centra en el diseño nominal de constelaciones de satélites para diferentes aplicaciones. En concreto, se presenta una metodología para la definición de distributiones de satélites que permanecen invariantes bajo la acción del potencial gravitatorio terrestre. Esto incluye no sólo la perturbación producida por el achatamiento terrestre J_2, sino también por los términos zonales y teserales del potencial.

Para lograr este fin, la metodología propuesta se basa en las Ground-Track Constellations, un modelo de definición de constelaciones basado en las distancias entre satélites respecto a un sistema de referencia rotante cualquiera. En este caso, el sistema escogido es el ligado a tierra con el fin de beneficiarse de la periodicidad que la dinámica presenta en dicho sistema.

A su vez, y con el objeto de extender esta metodología a otras definiciones de constelaciones de satélites, se presentan todas las transformaciones biyectivas existentes entre las formulaciones de Walker, Flower, 2D Lattice Flower, y 2D Necklace Flower Constellations. Esto proporciona la herramienta necesaria para encontrar todas las distribuciones equivalentes en las distintas formulaciones de constelación.

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On orbital stability of periodic pendulum-like motion of a heavy rigid body with a fixed point in the case of identical resonance

Boris Bardin[(1)]

Abstract

We study the problem of orbital stability for pendulum-like oscillations and rotations of a rigid body with a fixed point in a uniform gravitational field. The mass geometry of the body corresponds to the Hess case. The Hamiltonian for the canonical system of equations of perturbed motion depends on three parameters. Two of them describe the mass geometry of the body and the third one parameterizes the family of the periodic orbits.

The system of motion equations, linearized in a neighborhood of periodic orbit, can be solved in quadratures. We calculate its monodromy matrix in an explicit form and perform the stability study analytically. It appears that in the case of pendulum rotations the characteristic equation of the linear system always has a root with modulus more then 1. Thus, the pendulum rotations are orbital unstable for any values of parameters. In the case of the pendulum oscillations the characteristic equation of the linear system always has double root, which is equal to 1. It means that for any values of parameters the first order resonance occurs in the linear system. In such a case we say that the so-called identical resonance takes place in the stability problem. In three-dimensional space of parameters we have constructed the surface where the Jordan normal form of the monodromy matrix is diagonal. For parameters values corresponding to the above surface the pendulum-like oscillations are orbitally stable in linear approximation and outside of this surface the pendulum-like oscillations are orbitally unstable in linear approximation.

We show that the nonlinear problem of orbital stability for pendulum-like oscillations cannot be solve by taking into account terms of any finite order, that is the so-called transcendental case takes place. To solve the nonlinear problem of orbital stability we use the method developed in [1]. It has allowed us to prove the that pendulum-like oscillations are orbitally unstable in the sense of Lyapunov.

This work was carried out at the Moscow Aviation Institute (National Research University) within the framework of the state assignment (project No 3.3858.2017/4.6).

References

[1] Bardin B. S., *On the Stability of a Periodic Hamiltonan System with One Degree of Freedom in a Transcendental Case* // Doklady Mathematics, 2018, vol. 97, no. 2, pp. 161–163.

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Stacked Central Configurations of the five body problem

Esther Barrabés[(1)]

Abstract

Stacked central configurations (SCC) are central configurations of the n-body problem such that a proper subset is also a central configuration. In the case $n = 5$, all the SCC found in the literature up to now are concave, except one family that is convex, but non-strictly ([2]), and all of them are symmetric. Several questions arise from these observations: there exist strictly convex SCC? Can we characterize the non-strictly convex SCC? Are there non-symmetric SCC? We analytically prove that the answers of the first two questions are no and yes, respectively. We use two important results for central configurations: a theorem of Cheng and Hsiao (see Theorem 6.1 in [1]) and the Perpendicular Bisector Theorem (see [3]). With respect the symmetry, we show a numerical example of a non-symmetric concave SCC.

This is a work in collaboration with J.M. Cors (U. Politècnica de Catalunya), A.C. Fernandes (U. Federal de Itajubá) and C. Vidal (U. Bío-Bío).

References

[1] Chen, K. C., Hsiao, J. S.: Strictly convex central configurations of the planar five–body problem. Trans. Amer. Math. Soc. **310**, 1907–1924, (2018).

[2] Gidea, M., Llibre, J.: Symmetric planar central configurations of five bodies: Euler plus two, Celest. Mech. Dyn. Astronom. **106**, 89–107 (2010).

[3] Moeckel, R.: On central configurations. Math. Z. **205**, 499–517 (1990).

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Deterministic and Heuristic methods to compute a synthetic population of space debris

D. Casanova[1,2], **A. Petit**[3]

Abstract

Space debris objects have increased drastically in the last decades, and have become a hot topic in Astrodynamics. Unfortunately, just a small fraction of the biggest and brightest objects are visible (by means of radar and optical telescopes) and later cataloged. In particular, in the geostationary region we can observe and track only those objects with a size about 1 meter, and consequently, many efforts have been made to simulate the complete space debris population orbiting in this region. In this work, we propose different ways to create a synthetic population of space debris in the geostationary region. The global characteristics of the designed popu- lation are as similar as possible to the real one. We consider two main approaches; a deterministic and an heuristic approach. The first one try to simulate the real situation by considering all the breakup events that took place in the previous years. The heuristic approach try to improve the simulation by including new objects, by adjusting the simulation with new data (both by using the Iterative Proportional Fitting method), or by using Particle Swarm Optimization or Simulated Annealing algorithms to determine in a better way the parameters of each breakup event by knowing the current situation.

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Right quadrilaterals central configurations

Josep M. Cors[(1)]

Abstract

In the framework of the four-body problem we study central configurations of convex quadrilaterals with one right angle, that is, right quadrilaterals. Using cartesian coordinates, we show that the set of four-body right quadrilaterals central configurations with positive masses is a two-dimensional surface where the family of right kites is on its boundary. We say that the bodies are *ordered sequentially* if they are numbered consecutively while traversing the boundary of the quadrilateral (either clockwise or counter-clockwise). For a given sequential order of the bodies, we also study how some specific order of the masses values determines the geometry of the configuration, namely right quadrilaterals with two obtuse angles and one acute angle, or right quadrilaterals with one obtuse angle and two acute angles. We also prove the existence of non-symmetric right quadrilaterals central configurations with two adjacent pairs of equal masses.

This is a work in progress in collaboration with Martha Álvarez (UAM-I).

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On Constants of Motion of Some Gyldén–Type Systems

L. Floría[(1)], **J. Oliveros**[(1)]

Abstract

We consider the *time–dependent gravitational two–body problem*. According to Deprit, a *Gyldén system* is a Keplerian system with a time–varying Keplerian coupling parameter $\mu(t)$. In principle, no hypotheses are made concerning the causes of the time variations of μ: changes of the mass of at least one of the two bodies (variable–mass two–body problem), changes of the "constant of gravitation" $\mathcal{G}$ in time (Kepler–Dirac problem), or the joint effect of both phenomena.

Since the Gyldén problem is still a central–force problem, the orbital angular momentum is a constant of motion. However, as a result of the aforesaid explicit time dependence, a Gyldén system does not possesses some of the classical first integrals of the conventional Kepler problem any more; for instance, the total energy of the system and the Laplace vector are no longer conserved quantities in a Gyldén problem.

In the present contributed paper we consider some cases of the Gyldén problem in which some additional constant of motion can be found.

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State and Parameter Estimation of GEO Satellites Using Jet Transport

J. Chen[(1,3)], **J.J. Masdemont**[(1)], **G. Gómez**[(2)], **J. Duan**[(3)]

Abstract

We consider the problem of state and parameter estimation for geostationary spacecraft in an accurate and efficient way. For this purpose we implement a Jet Transport Taylor technique in two coordinate representations, analyzing the impact of using different orders in the computations. Then, under the assumption of a Gaussian distribution, we evaluate the mean vectors and covariance matrices corresponding to estimated states and parameters. These are incorporated into a high order Kalman filter where the estimates are updated sequentially. The performances on the orbit determination and parameter estimation are discussed by a series of numerical simulations which are compared with a classical implementation of the filter.

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Normal forms, averaging and periodic orbits in a rotating Hénon-Heiles system

V. Lanchares[1], **A.I. Pascual**[1], **M. Iñarrea**[2], **J.P. Salas**[2], **J. Palacián**[3], **P. Yanguas**[3]

Abstract

Hénon-Heiles system is probably one of the most studied dynamical systems, because it can be used to model different physical problems and also to highlight different properties inherent to most of two degrees of freedom nonlinear Hamiltonian systems. It arose as a simple model to find additional conservation laws in galactic potentials with axial symmetry . In the context of galactic dynamics, to study stellar orbits, the rotation of the galaxy must be taken into account so that it makes sense to consider a generalized Hénon-Heiles system in a rotating frame. Our aim is to prove the existence of periodic orbits in a neighborhood of the origin for appropriate values of the rotating frequency. To this end, we use normal form theory and averaging to demonstrate that the number of periodic orbits is in correspondence with the equilibrium solutions of the original system, with the same type of stability.

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Integrabilidad de procesos estocásticos de nacimiento-muerte vía Teoría de Galois diferencial

Juan J. Morales-Ruiz[(1)]

Abstract

Algunos procesos estocásticos relevantes de Markov de dinámica de poblaciones en tiempo continuo son regidos por sistemas de infinitas ecuaciones diferenciales ordinarias acopladas. Estos sistemas se transforman en ecuaciones en derivadas parciales de tipo difusión mediante la función generatriz asociada al sistema (transformada Z). EL objetivo de esta charla es estudiar la integrabilidad mediante la teoría de Galois diferencial de dos ecuaciones en derivadas parciales de ese tipo que modelizan dos procesos estocásticos de nacimiento y muerte en dinámica de poblaciones. (trabajo conjunto con Primitivo B. Acosta-Humánez y José A. Capitán)

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Some questions and some (partial) answers about the atom of hydrogen in a CP microwave field

A. Delshams[(1)], **M. Ollé**[(1)], **J. R. Pacha**[(1)]

Abstract

We will explain what we do and do not know about the dynamical behavior of an electron surrounding a proton, when this atom is submitted to a circularly polarized microwave field. We want to analyse both local and global behavior. Some comparisons with the well known planar circular RTBP will also be discussed.

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Normalisation through invariants in n-dimensional Kepler problems

J. Palacián[(1)], **P. Yanguas**[(1)], **K. R. Meyer**[(2)]

Abstract

We present a procedure for the normalization of perturbed Keplerian problems in n dimensions based on Moser regularization of the Kepler problem and on the invariants associated to the reduction process. The approach allows us, not only to circumvent the problems introduced by certain classical variables used in the normalization of this kind of problems, but also to do both the normalization and the reduction in one step. The technique is introduced for any dimensions and is illustrated for $n = 2, 3$ by relating Moser coordinates with Delaunay-like variables [1].

References

[1] K.R. Meyer, J.F. Palacián, P. Yanguas, *Normalization through invariants in n-dimensional Kepler problems*, Regular and Chaotic Dynamics 23, 389–417 (2018).

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Regularization Techniques and Ejection-collision Orbits in the RTBP

Óscar Rodríguez[(1)]

Abstract

In this talk, we discuss the advantages and disadvantages of Levi-Civita and McGehee regularizations. In particular, we use them to study ejection-collision orbits.

As it is well known, for any value of the mass parameter $\mu \in (0, 0.5]$ and sufficiently restricted Hill regions, there are exactly four ejection-collison orbits. We check their existence and extend numerically these four orbits for $\mu \in (0, 0.5]$ and for less restrictive values of the Jacobi constant. In addition we extend this result for the n-ejection-collision orbits.

We consider the possible evolutions of the ejection orbits and the mechanisms of the creation and bifurcations of new types of ejection-collision orbits for $\mu \in (0, 0.5]$ and suitable values of the Jacobi constant.

This is joint work with Mercè Ollé and Jaume Soler.

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Nonlinear dynamics of Neutral atoms in optical dipole traps

J. P. Salas[(1)], **M. Iñarrea**[(1)], **R. González-Férezi**[(2)], **P. Schmelcher**[(3)]

Abstract

The simplest optical trap of neutral atoms consists of a single strongly focused Gaussian laser beam. In this case, there is only tight confinement in the plane perpendicular to the propagation of the beam axis. For a tight confinement of atomic ensembles in the three spatial dimensions, the so-called crossed-beam trap is commonly used. This trap consists of two Gaussian laser beams with orthogonal polarizations propagating along perpendicular directions.

In particular, for a thermal atomic cloud, but also in a more general context, the description of the optical trapping mechanism via the corresponding classical dynamics is a relevant issue. Indeed, the non-linear nature of the optical trapping makes these systems very attractive for such classical studies.

In this talk we present a rigorous study on the classical dynamics of optically trapped neutral atoms. The talk is organized in four parts. In the first part we establish the three degree of freedom Hamiltonian governing the dynamics of an atom in a crossed-beam trap. In the second, we study the critical points of this system and its fundamental families of periodic orbits. In the third part we study the nonlinear dynamics of the system by means of a fast chaos indicator. The last part is devoted to investigate the dynamics of an atomic beam in free motion which is suddenly exposed to a crossed-beam trap.

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Design of homoclinic and heteroclinic orbits for the exploration of the south pole of Enceladus

F. Salazar[(1)], **E. Fantino**[(1)], **E. M. Alessi**[(2)]

Abstract

In the framework of the future generation of solar system exploration missions, high priority is given to the observation of the so-called Inner Larger Moons of Saturn, namely, Mimas, Enceladus, Tethys and Dione. In particular, the discovery made by Cassini of geyser-like jets in the Enceladus' south polar surface has placed this moon among the targets to search for life and habitability features. This investigation proposes a set of orbits in the Saturn-Enceladus circular restricted three-body problem, and analyses their performance for the exploration of the south polar re- gion of the moon. Families of northern Halo orbits around the L_1 and L_2 libration points of the system are considered because of their significant out-of-plane mo- tion. Then, the stable and unstable hyperbolic invariant manifolds of these orbits are propagated inside the Hill region of Enceladus, and homoclinic and heteroclinic connections are sought. The dynamical properties of the connections are analysed and presented, and observational parameters such as orbital periods, distances from the surface, orbital inclinations and relative speeds are computed and discussed. The periodic character of the Halo orbits makes them suitable parking orbits within of an observation tour of Enceladus, in which several homoclinic and heteroclinic paths are followed consecutively. Finally, the same Halo orbits can be employed as departure gates to the nearby moons.

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Lie stability of L_4 in the spatial restricted circular three-body problem

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Abstract

In this talk we extend previous studies [1, 3] on the well-known problem of the nonlinear stability of L_4 and L_5 in the spatial restricted circular three-body problem.

In the framework of nonlinear stability of elliptic equilibria in Hamiltonians with n degrees of freedom we use a criterion to obtain a kind of formal stability called Lie stability. In case of formally stable systems we bound the solutions near the equilibrium over exponentially long times. The underlying idea of our criterion is exploiting the algebraic structure of the linear part of the equation [2].

References

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