Do we really do it ?

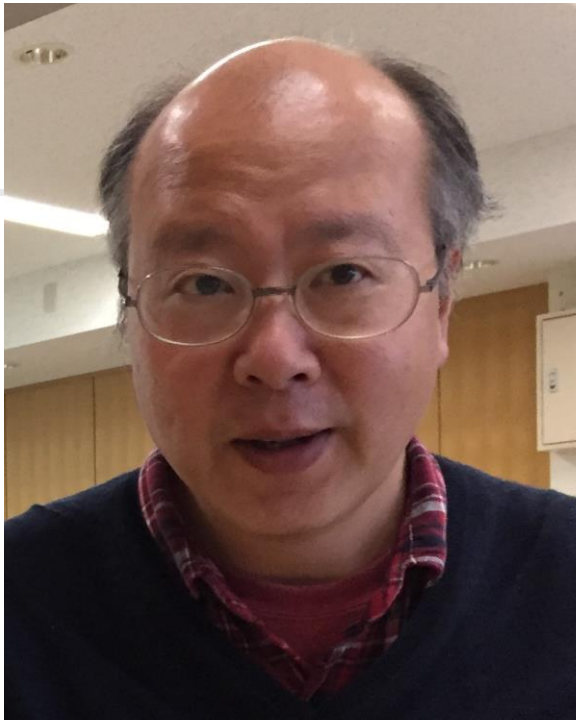
(comment)
Eccentric Lidov-Kozai effect & planetary orbits

Takashi Ito (CfCA, NAOJ)

- the Lidov-Kozai effect
- classic (e′=0) L-K
- eccentric (e′>0) L-K
- summary

(*Not* atmospheric/oceanic science at all)

a strict order from prof. Ishiwatari



"Give a talk! I'll give you 10 min. Tell us something about orbital dynamics."

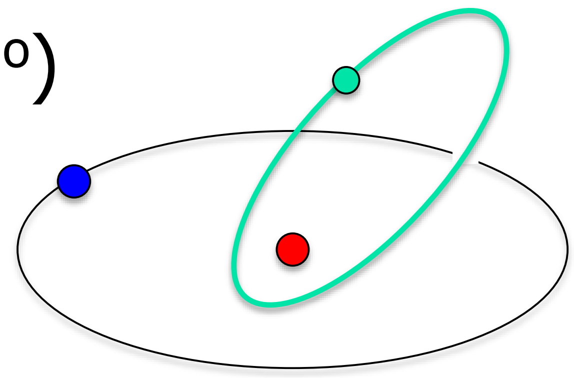
"Is something that has nothing to do with your meeting subject fine?"

"Very fine, as long as it is interesting."

"Hmm..." 😰

the Lidov-Kozai effect

- in hierarchical (restricted) 3-body problems
- when orbital inclination is large
- the perturbed body's eccentricity+inclination can oscillate with a large amplitude
  - with libration of argument of pericenter
- the orbit sometimes flips ($i > 90^o$)
  - when perturber's orbit is elliptic

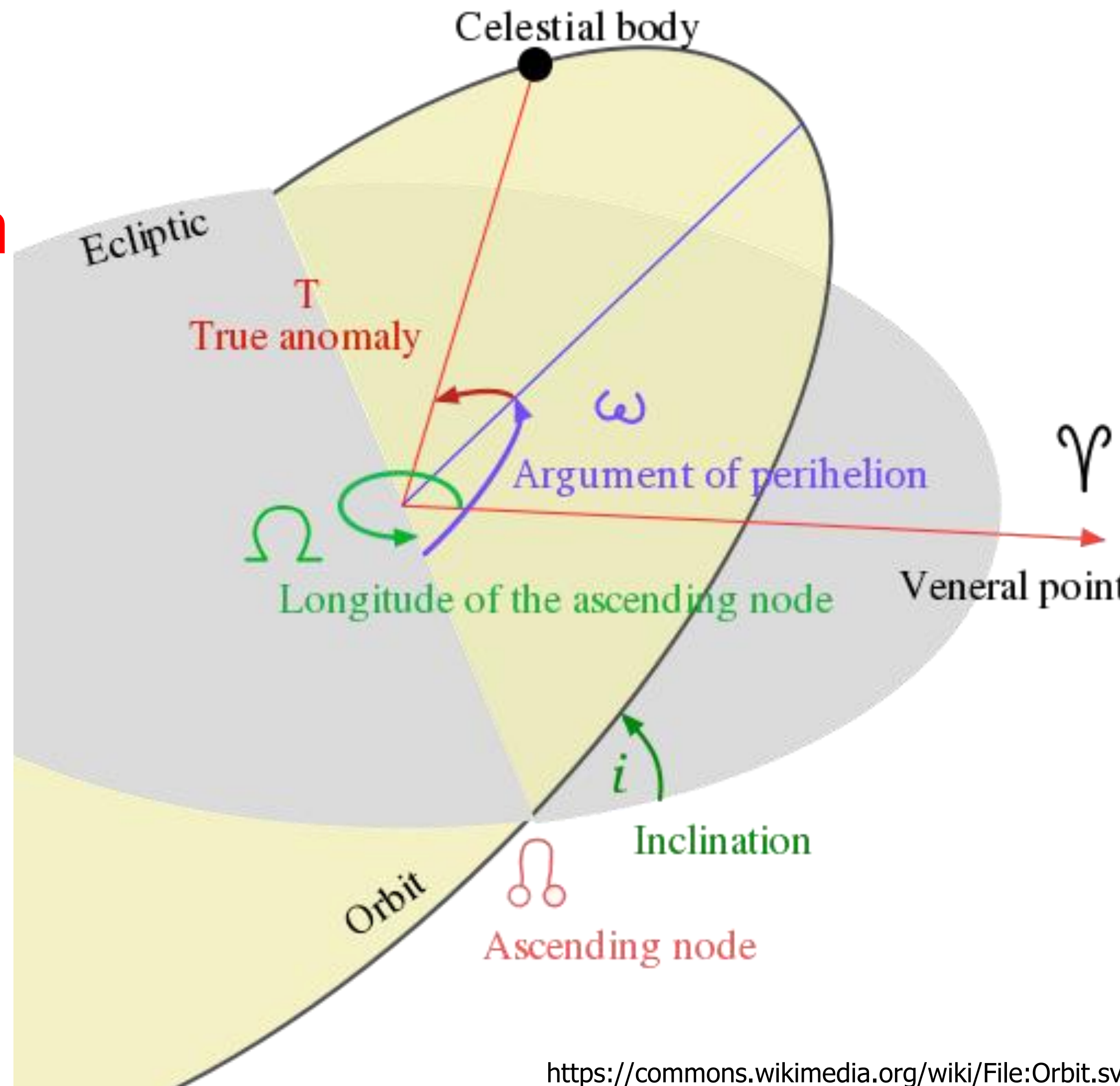


orbital elements

- semimajor axis → a
- eccentricity → e
- inclination → i
- argument of pericenter → *g*

Perturber's elements

- a′, e′, ...



https://commons.wikimedia.org/wiki/File:Orbit.svg

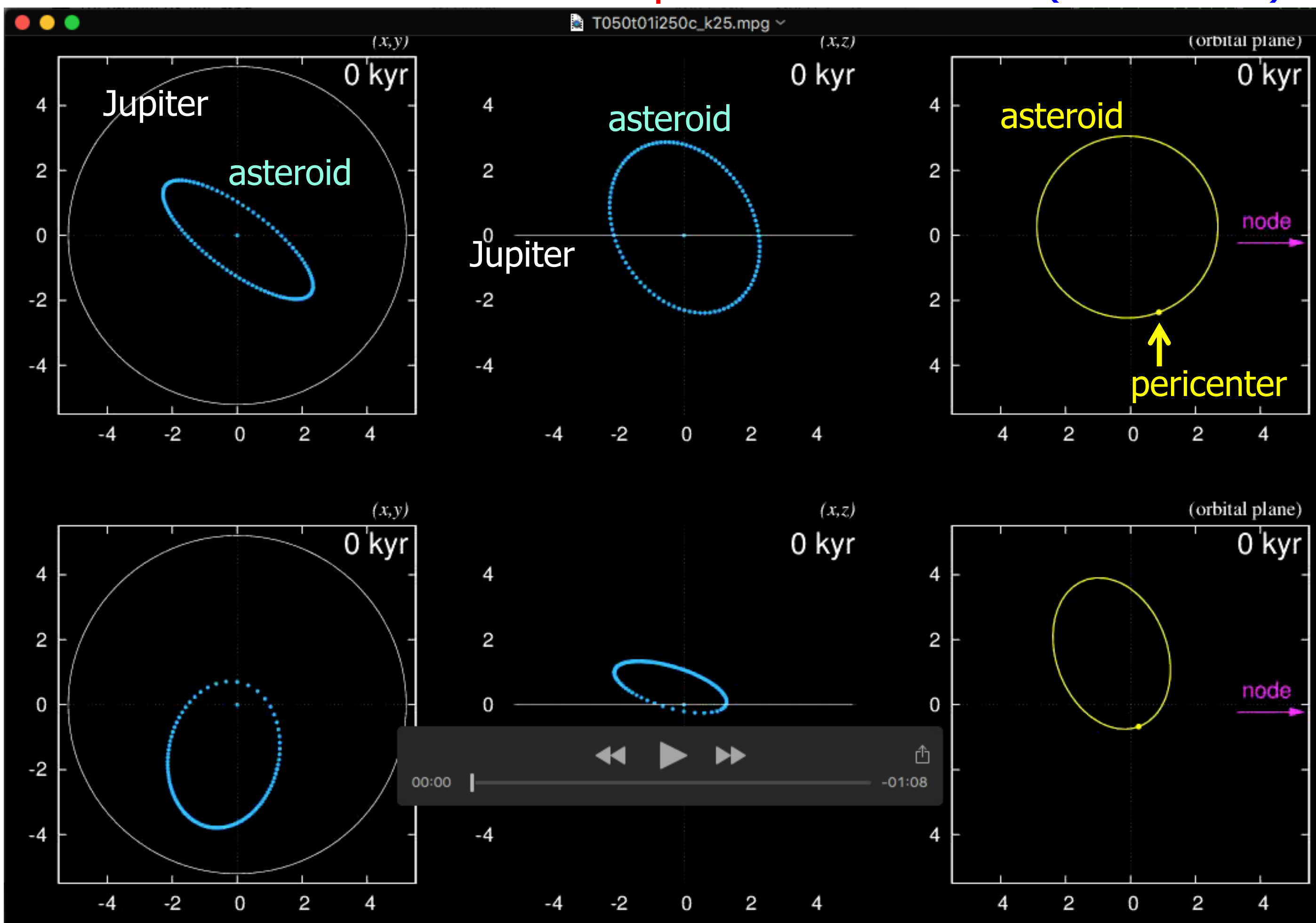
classic L-K (e′=0)

on asteroid's orbital plane (node fixed)

the "northern" view

the "equatorial" view

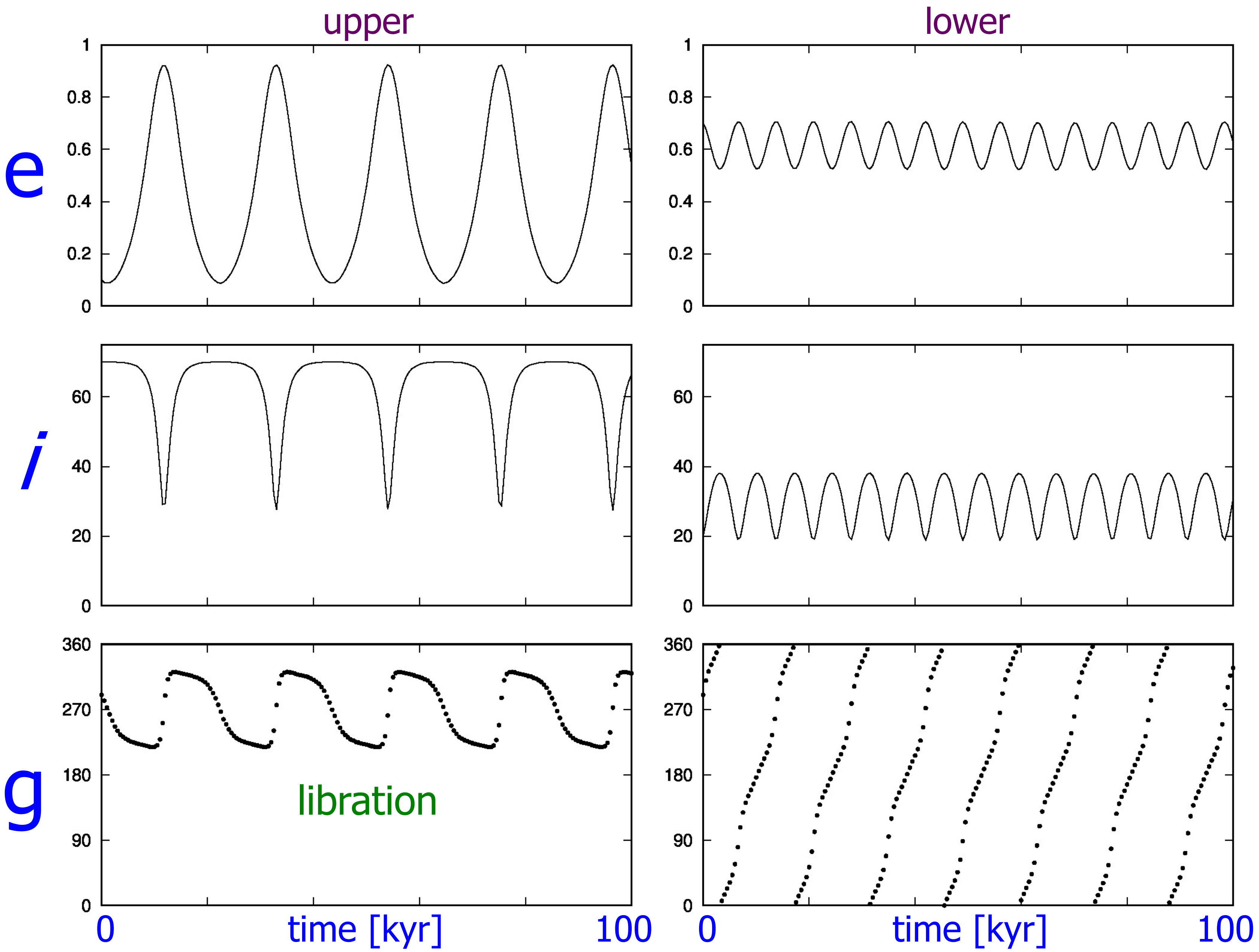
Sun
+ Jupiter (e′=0)
+ an asteroid



ascending node

Sun
+ Jupiter (e′=0)
+ another asteroid

orbital elements

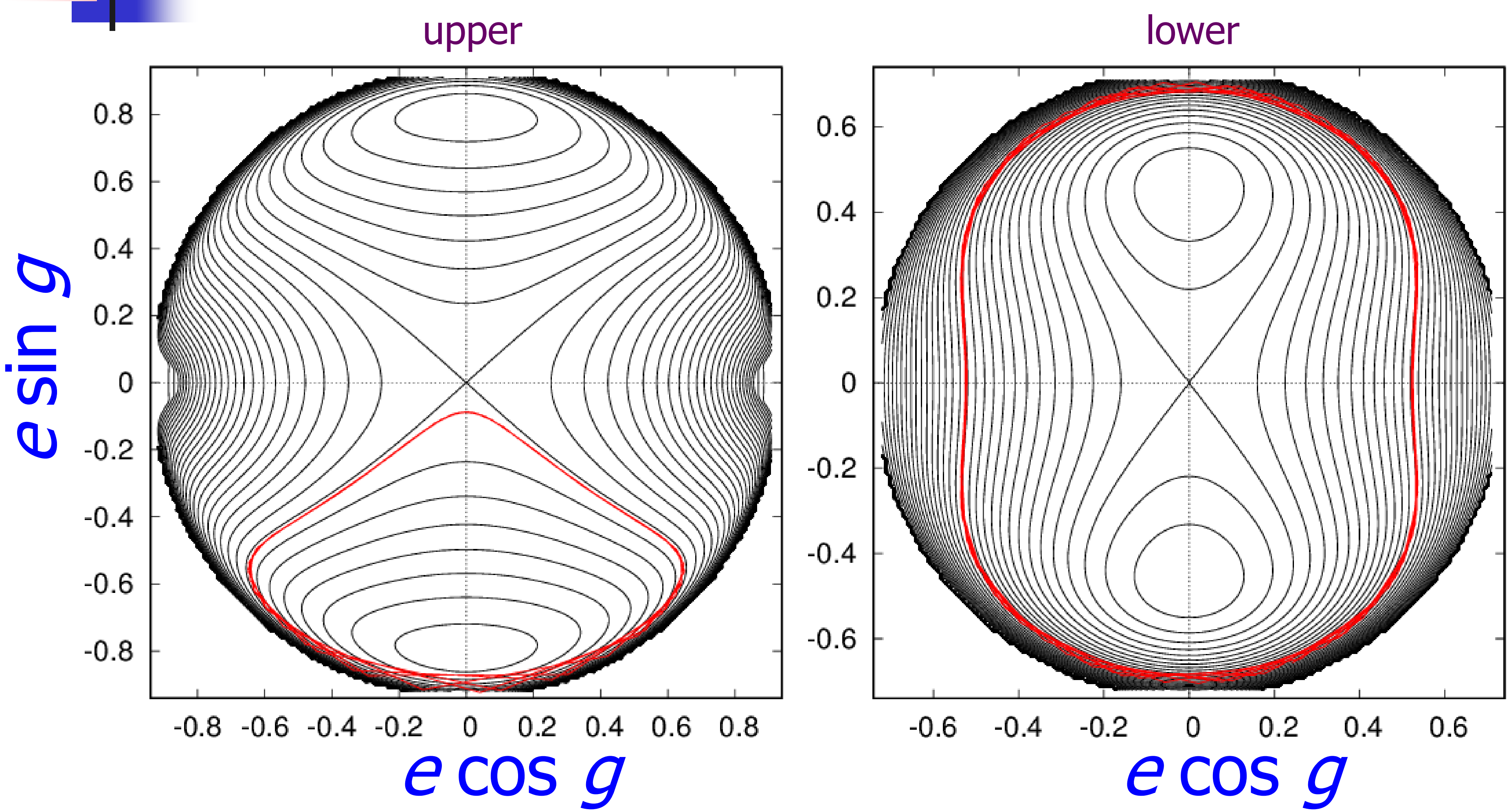


reducing degrees of freedom (standard procedure)

- if $e'=0$ (circular restricted 3-body system)
  - disturbing potential is axisymmetric
    - $(1-e^2)\cos^2 i = L_z^2$ is conserved
  - fast-moving angles can be averaged out
    - averaged disturbing potential R is conserved
- degrees of freedom → 1
  - system becomes integrable $R(e,g) = \text{const.}$
  - can draw 2D equi-potential contours

equi-potential contours

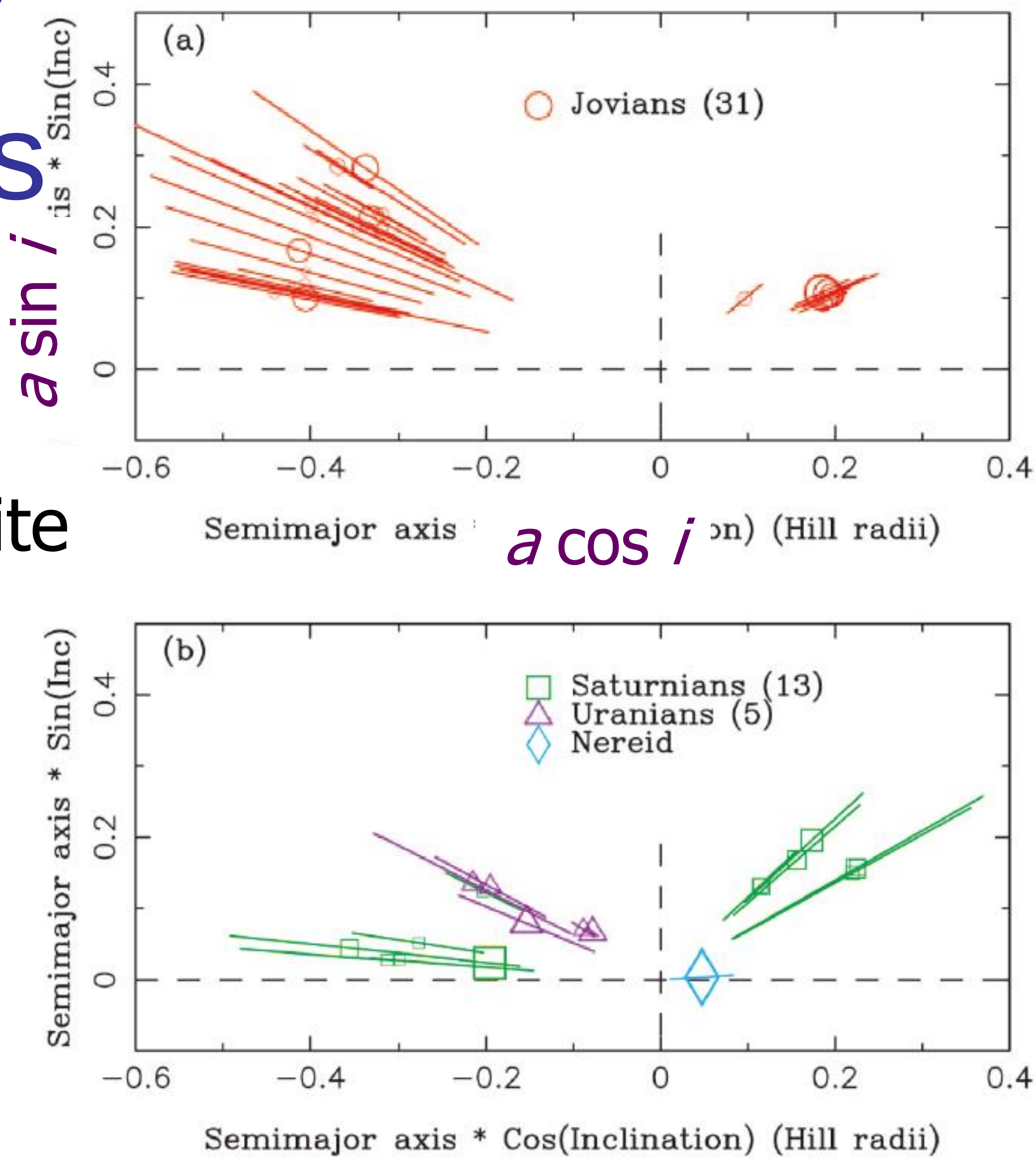
on the (e cos g, e sin g) plane



examples in the real world

- near-Earth asteroids
- irregular satellites of jovian planets
- Pluto and TNOs
- Oort cloud comets
- artificial satellites around the Earth
- examples in exoplanetary systems
- examples in stellar dynamics

irregular satellites



No irregular satellite with large *i*

(their *e* becomes very large too)

Nesvorny+ (2003)

ADS search result 1.

keywords:
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in abstract

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Affiliation:	AA(University of Chicago, Chicago, IL, United States nbaskin@uchicago.edu), AB(University States abbot@uchicago.edu)
Publication:	American Geophysical Union, Fall Meeting 2015, abstract #P31D-2087
Publication Date:	12/2015
Origin:	AGU
Keywords:	0325 Evolution of the atmosphere, ATMOSPHERIC COMPOSITION AND STRUCTURE, 0406 ASTROBIOLOGY, 6296 Extra-solar planets, PLANETARY SCIENCES: SOLAR SYSTEM OBJEC
Bibliographic Code:	2015AGUFM.P31D2087B

Abs

In our search for habitable exoplanets, it is important to understand how planetary habitability is influenced by observational surveys have revealed the prevalence of planetary systems around binary stars. Within these syst (referred to as Kozai Cycles) on timescales as short as thousands of years. The resulting fluctuations in stellar f implications for the planet's habitability prospects. We investigate this research problem using two steps. First, under the gravitational influence of a stellar companion. Second, we run a coupled Global Climate Model (GCM) renders the planet uninhabitable. This work will allow us to better understand how Kozai cycles influence the bo

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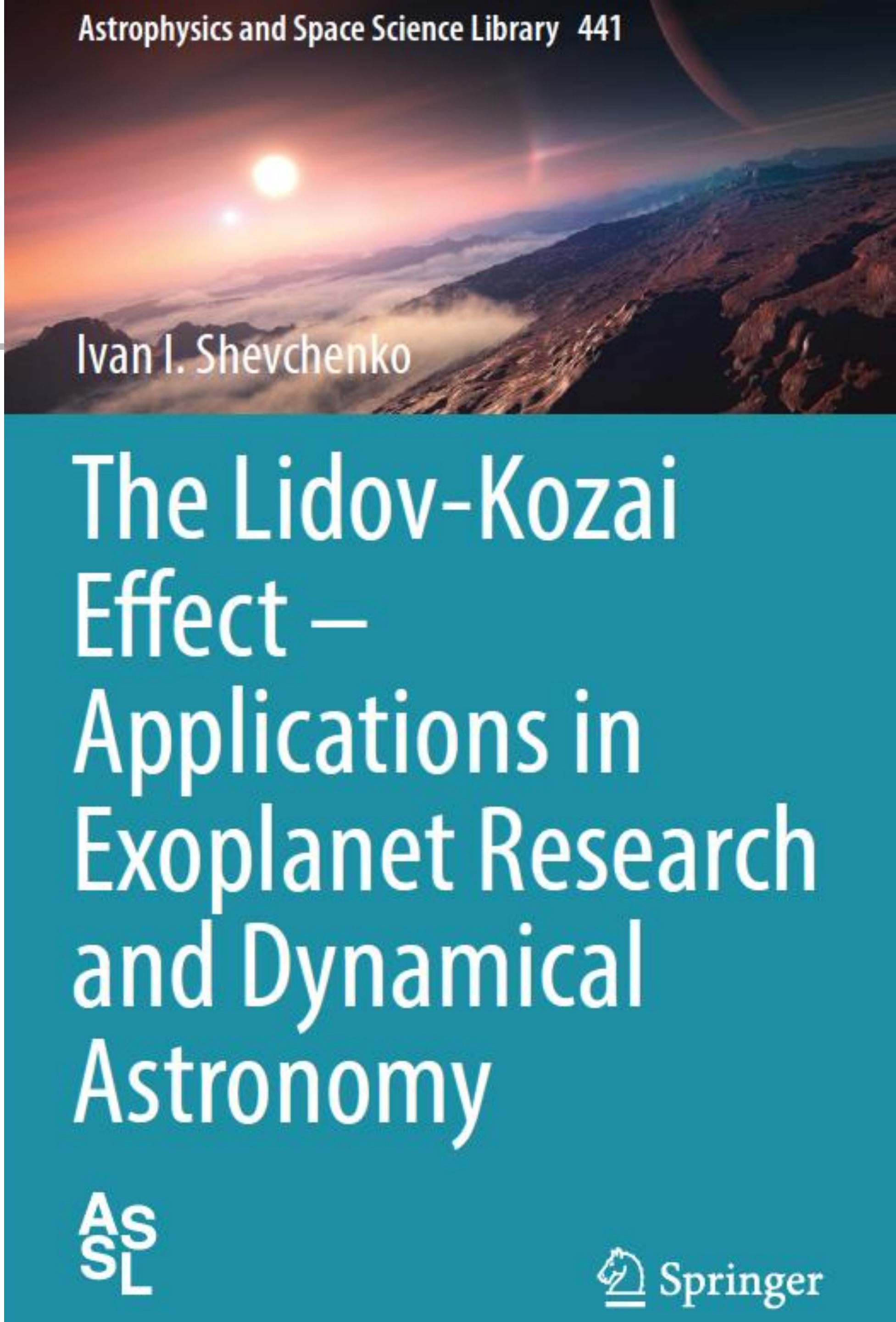
Title:	Insolation patterns on synchronous exoplanets with obliquity
Authors:	Dobrovolskis, Anthony R.
Affiliation:	AA(Lick Observatory, U. C. Santa Cruz, 245-3 NASA Ames Research C
Publication:	Icarus, Volume 204, Issue 1, p. 1-10. (Icarus Homepage)
Publication Date:	11/2009
Origin:	ELSEVIER
Abstract Copyright:	(c) 2009 Elsevier Inc.
DOI:	10.1016/j.icarus.2009.06.007
Bibliographic Code:	2009Icar..204....1D

A previous paper [Dobrovolskis, A.R., 2007. Icarus 192, 1-23] showed that eccentricity can ha
obliquity can have comparable effects. The known exoplanets exhibit a wide range of orbital e
attributed to the dissipation of tides in the planets. Tides in a planet affect its spin even more
identical to their orbital periods. The canonical example of synchronous spin is the way that o
between its spin and orbital angular velocities). However, orbit precession can cause the rotat
an obliquity of about 6.7° with respect to its orbit about the Earth. In comparison, stable Cass
mutual inclinations, such as are produced by scattering or by the Kozai mechanism. This work
over the planet's surface, particularly near its poles. For β=0, one hemisphere bakes in perpe

textbooks

e.g.
Shevchenko (2017)



eccentric L-K (e’>0)

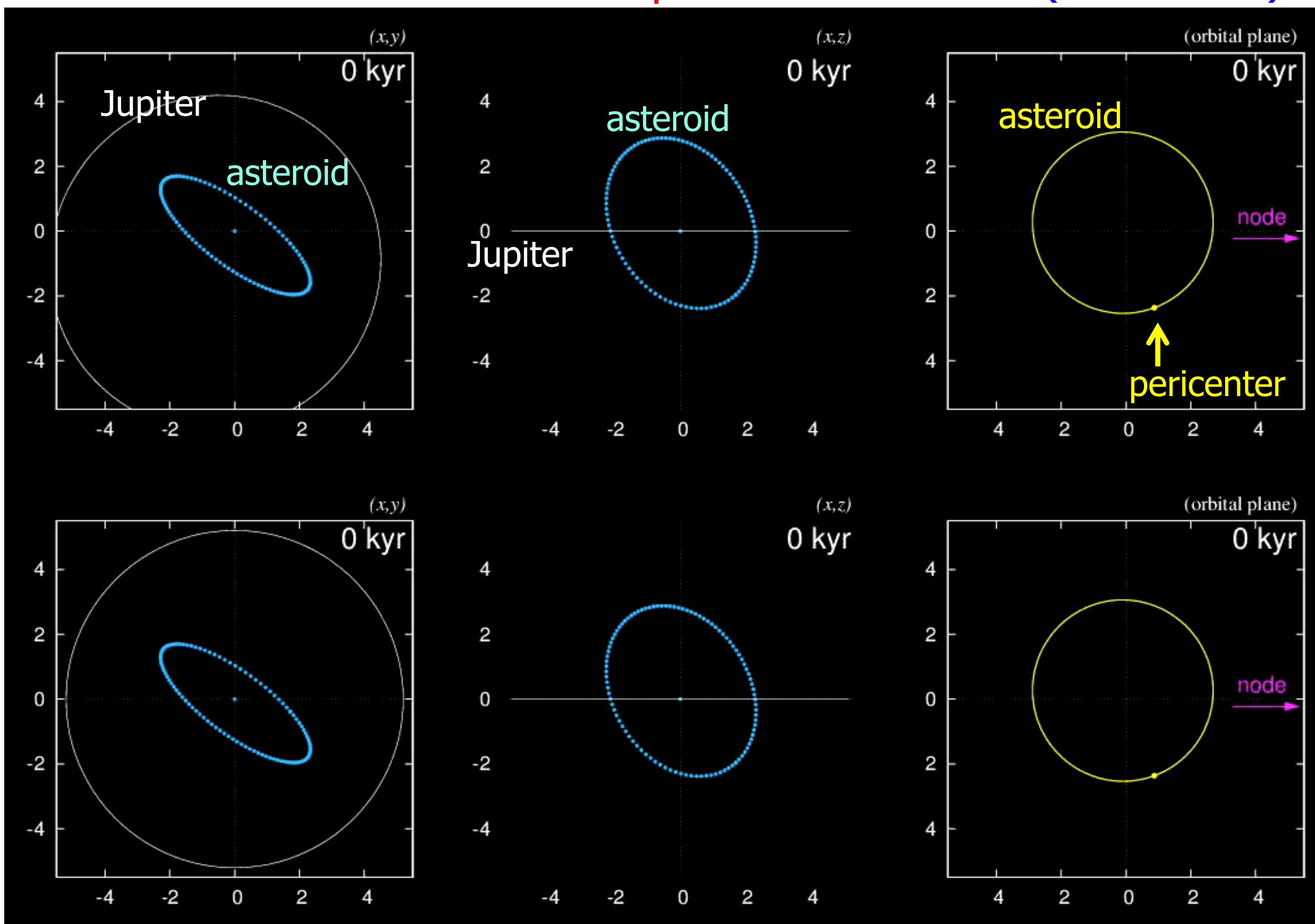
on asteroid’s orbital plane (node fixed)

the “northern” view

the “equatorial” view

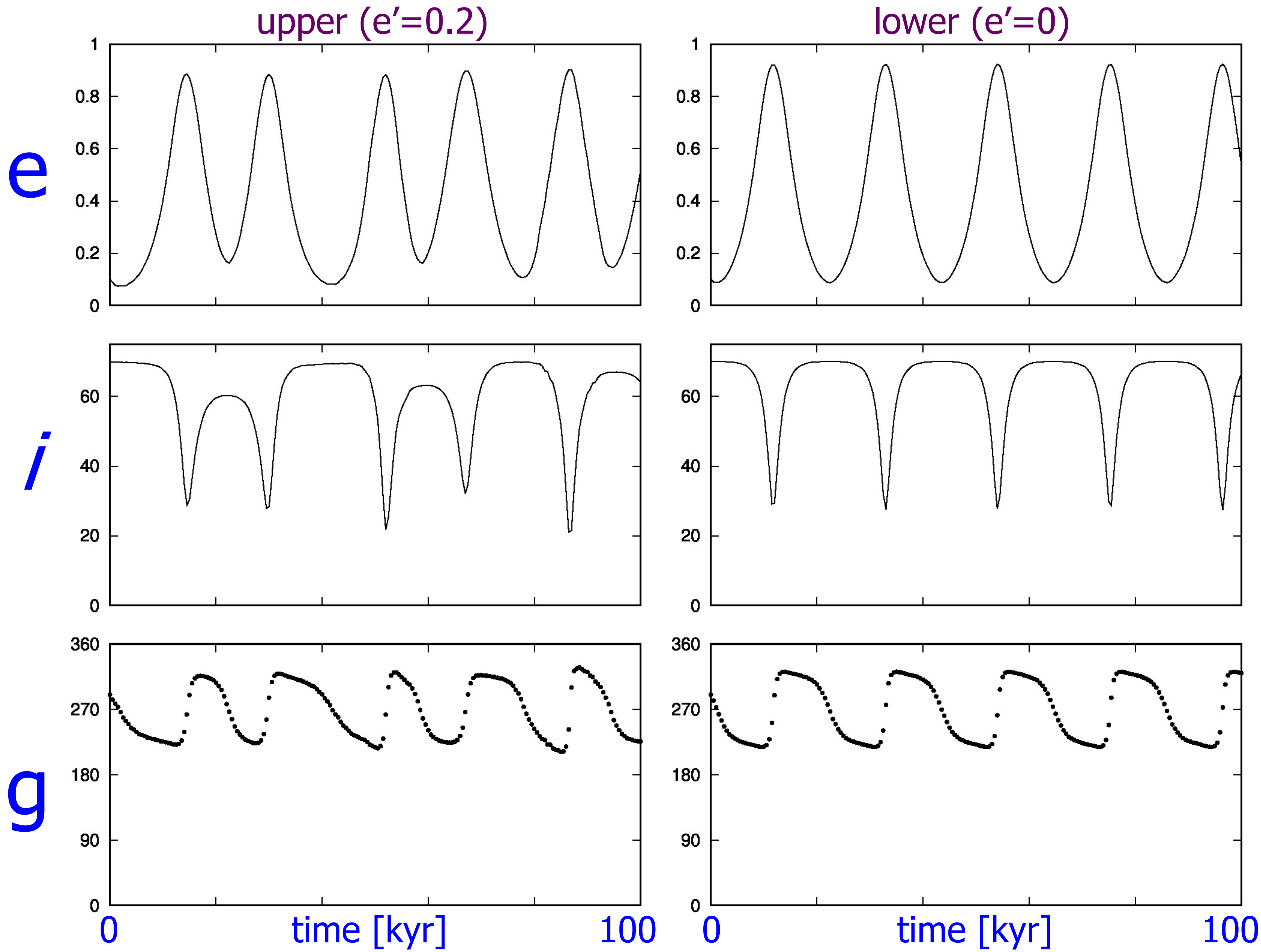
Sun
+ Jupiter (e’=0.2)
+ an asteroid

Sun
+ Jupiter (e’=0)
+ the same asteroid

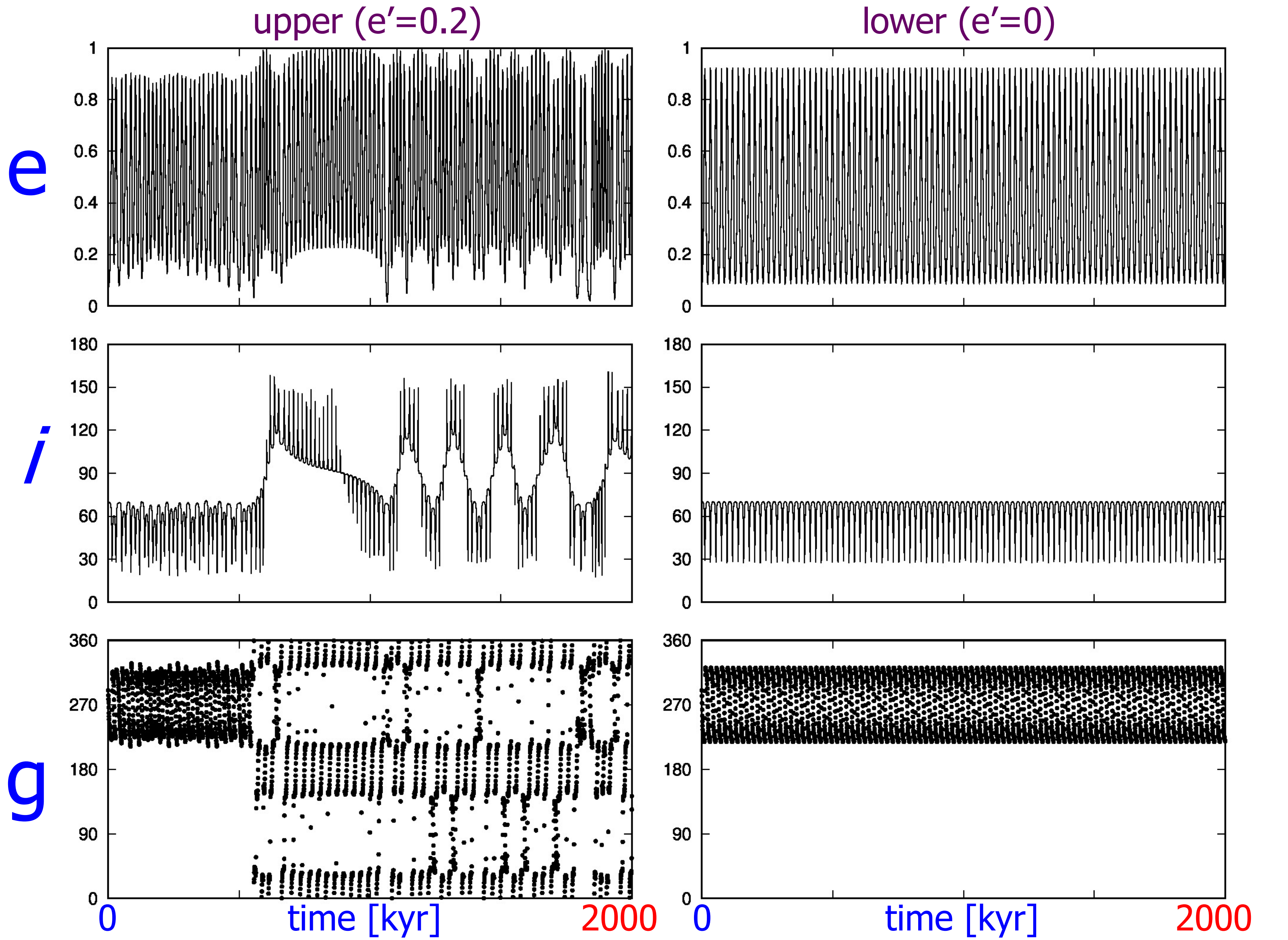


ascending node

orbital elements



orbital elements (zoom out x 20)



not integrable anymore

- disturbing potential is not axisymmetric
  - $(1-e^2)\cos^2 i = L_z^2$ is not conserved
- cannot draw 2D equi-potential contours

- things happen stochastically
- orbits sometimes flip ($i > 90^o$), and flip back
- e closely approaches 1

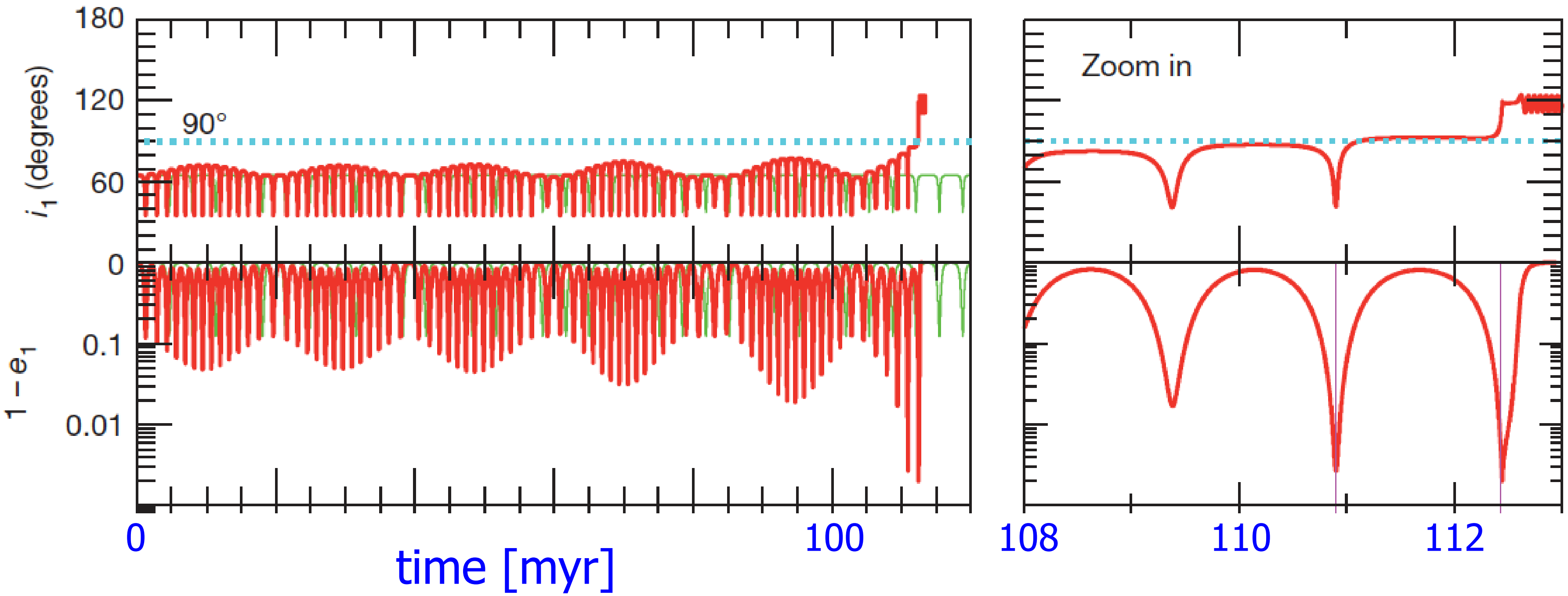
- theory is not established yet (2011-)

examples in the real world

- retrograde SSSBs (NEAs, comets, ...)
- irregular satellites of jovian planets
- retrograde hot jupiters
- many other examples in
  - exoplanetary systems
  - stellar dynamics
  - compact object dynamics (white dwarfs, neutron stars, black holes, ...)

retrograde hot jupiters

- orbit flip by eLK → tidal circularization
  - origin of retrograde hot jupiters (~25%)



Naoz+ (2011)

a review article

Naoz (2016, ARAA)

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The Eccentric Kozai-Lidov Effect and Its Applications

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comments for meteologists in the real world

- the L-K effect often causes instability
  - your planets may not survive for a long time
- usually there are more than 3 bodies
  - real dynamics is more complicated
    - but the 3-body approx. works out in most cases
- no discussion on rotational dynamics, but
  - it is more significant than orbital dynamics
  - you must assume/calculate it separately
    - resonance, precession/nutation, tide, whatever
    - the calculation would be far more complicated

done

thank you