Solar System Science

David Jewitt, UCLA

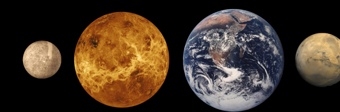
Tuesday, 10:10 am, Pasadena Hilton

My Charge: "Provide overview of solar system science in the context of space-based IR surveys & WFIRST"

Topics:
- Structure of solar system (Oort cloud, Kuiper belt, comets)
- Processes (impact, rotational disruption, capture, debris production, binary formation, endogenic activity)

Background

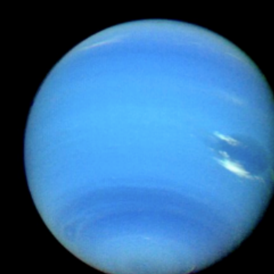
Three Domains of the Solar System:



- Terrestrial planets: Mercury - Mars (asteroids)

- Giant planets: Jupiter - Neptune

- Comets: Oort Cloud, Kuiper belt

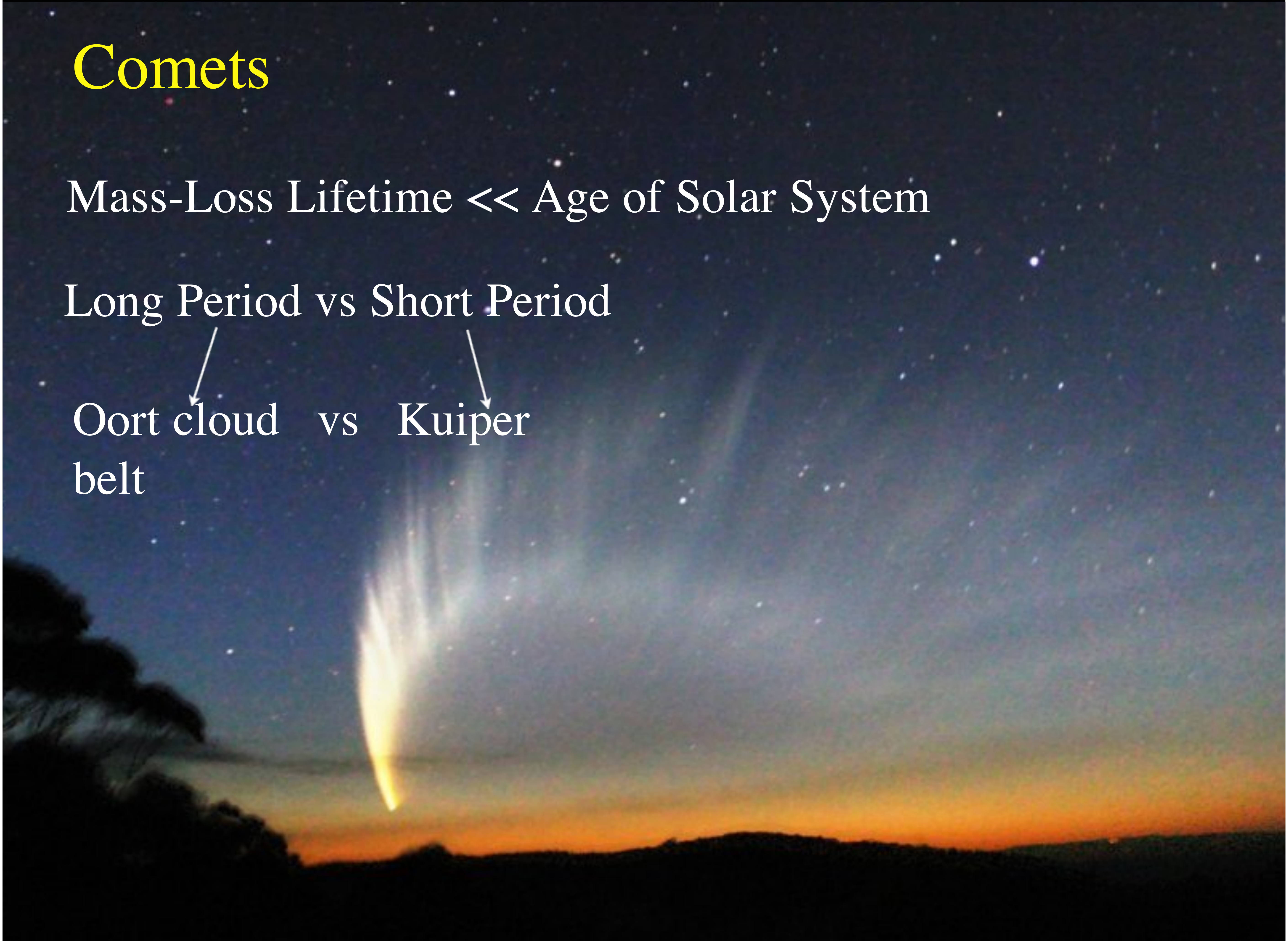


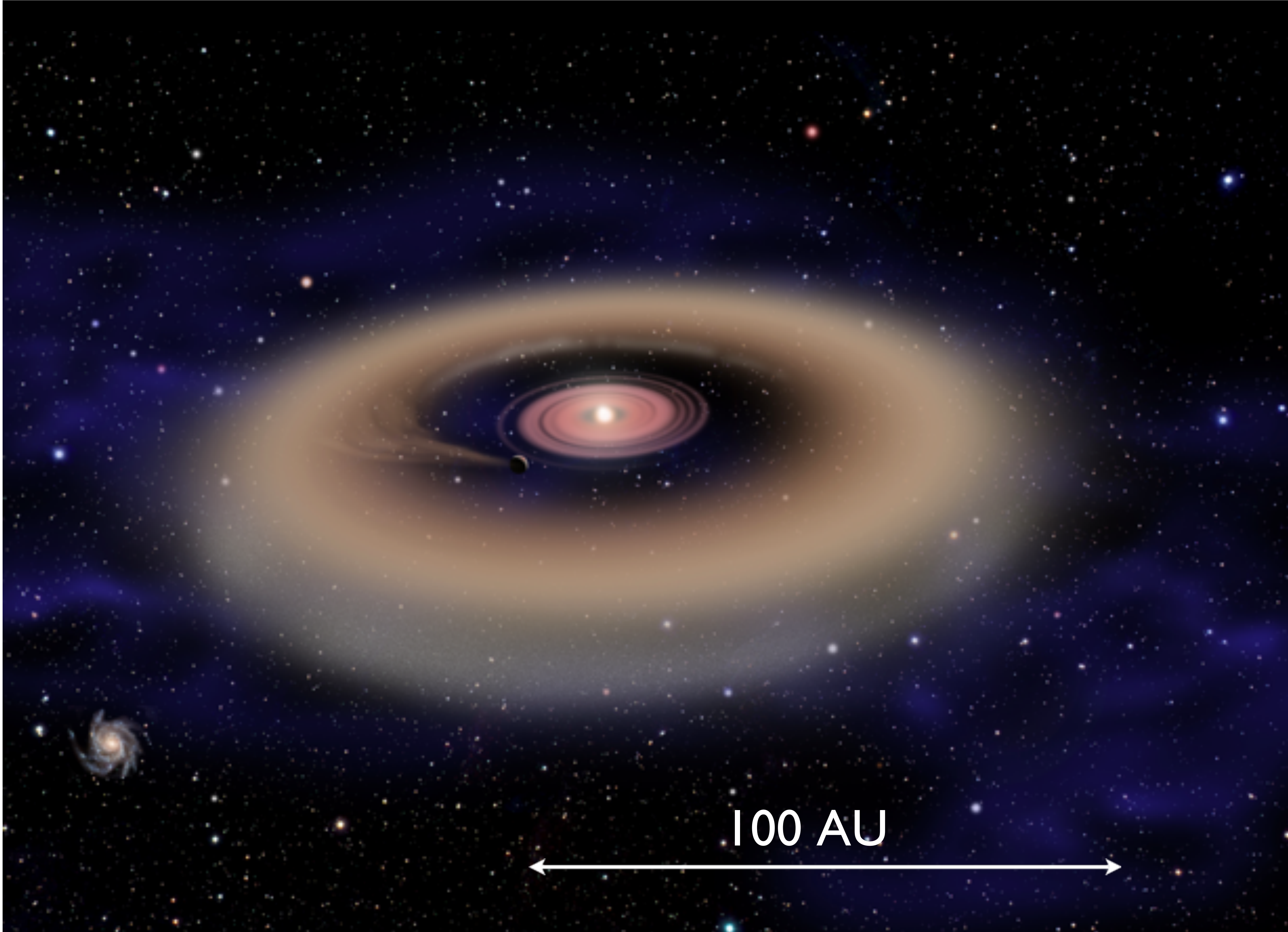
Comets

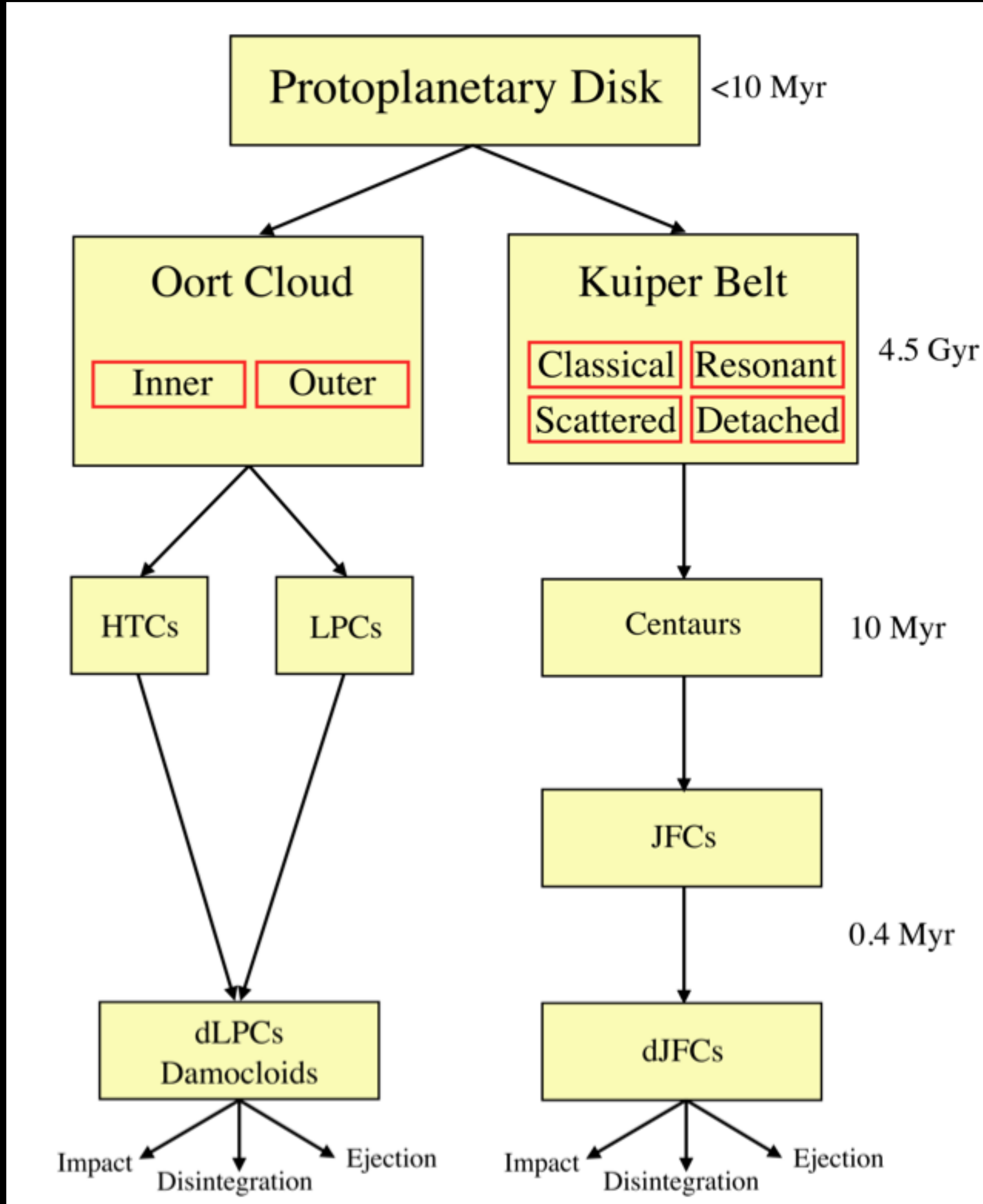
Mass-Loss Lifetime << Age of Solar System

Long Period vs Short Period

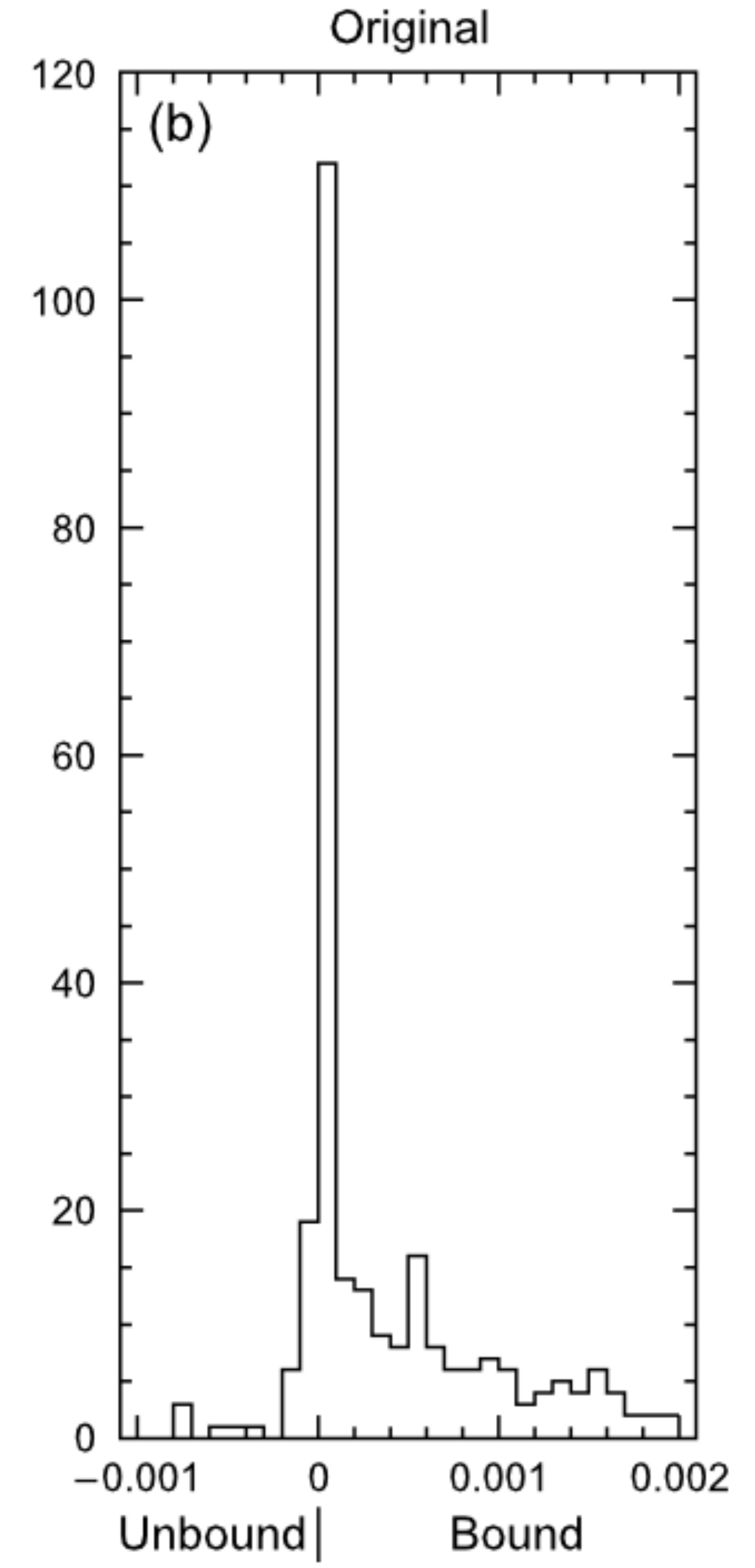
Oort cloud vs Kuiper belt




100 AU


Protoplanetary Disk
<10 Myr
Oort Cloud
Inner
Outer
Kuiper Belt
Classical
Resonant
Scattered
Detached
4.5 Gyr
HTCs
LPCs
Centaurs
10 Myr
JFCs
0.4 Myr
dLPCs
Damocloids
dJFCs
Impact
Disintegration
Ejection
Impact
Disintegration
Ejection

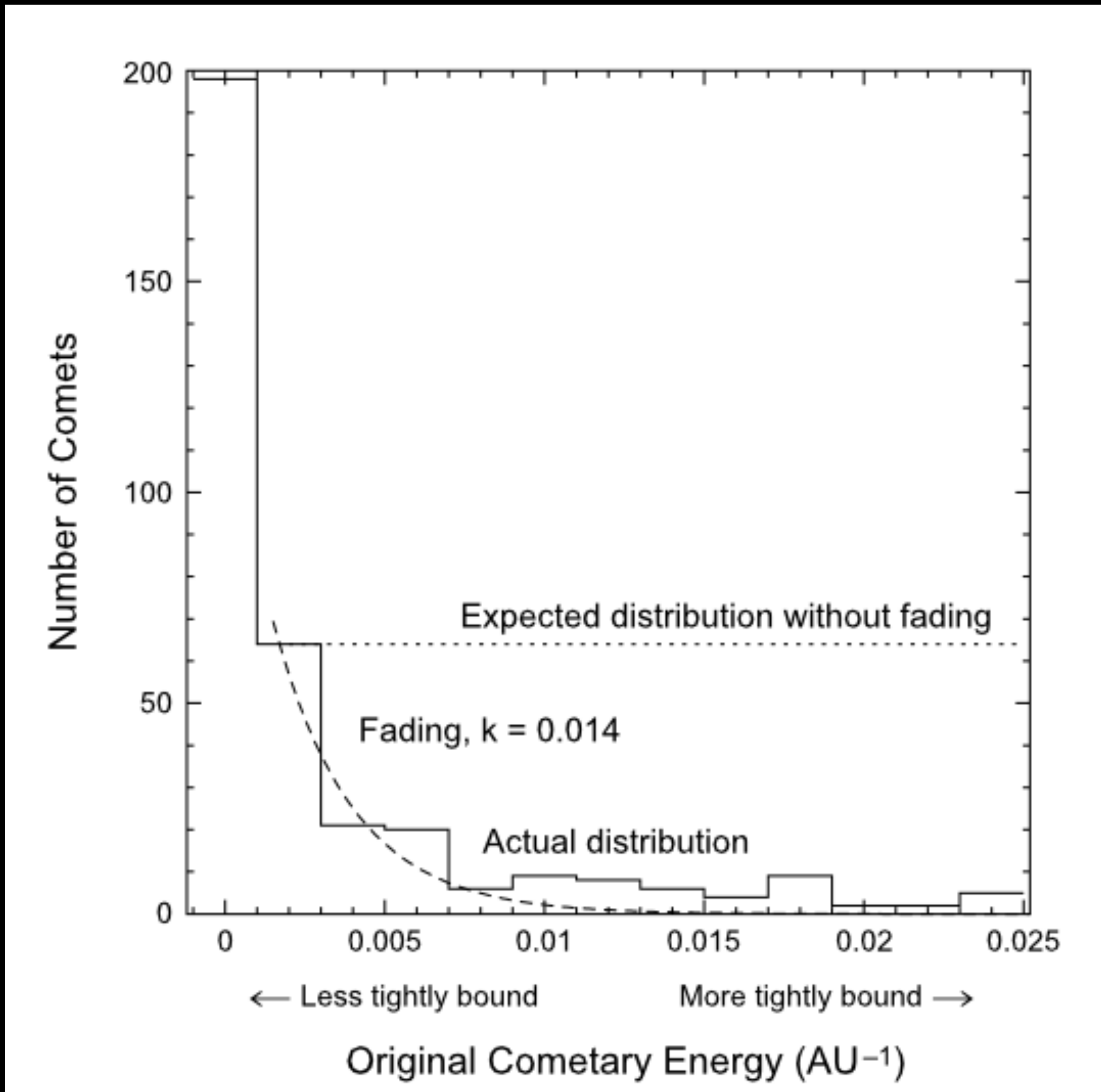
Oort Cloud



Oort Cloud

- No strong hyperbolics
- Width of peak < ΔE_J
- Comets in the peak are first arrivals
- Too many first arrivals relative to Nth arrivals. Why?

Oort Cloud



Dones et al. (2004)

- Dynamics alone cannot explain the distribution of orbital energies.

- Oort introduced a "fading parameter" to reduce the number of returning comets relative to 1st arrivals.

Oort Cloud

$r \sim 50{,}000$ AU

$V_K \sim 100\ m\ s^{-1}$

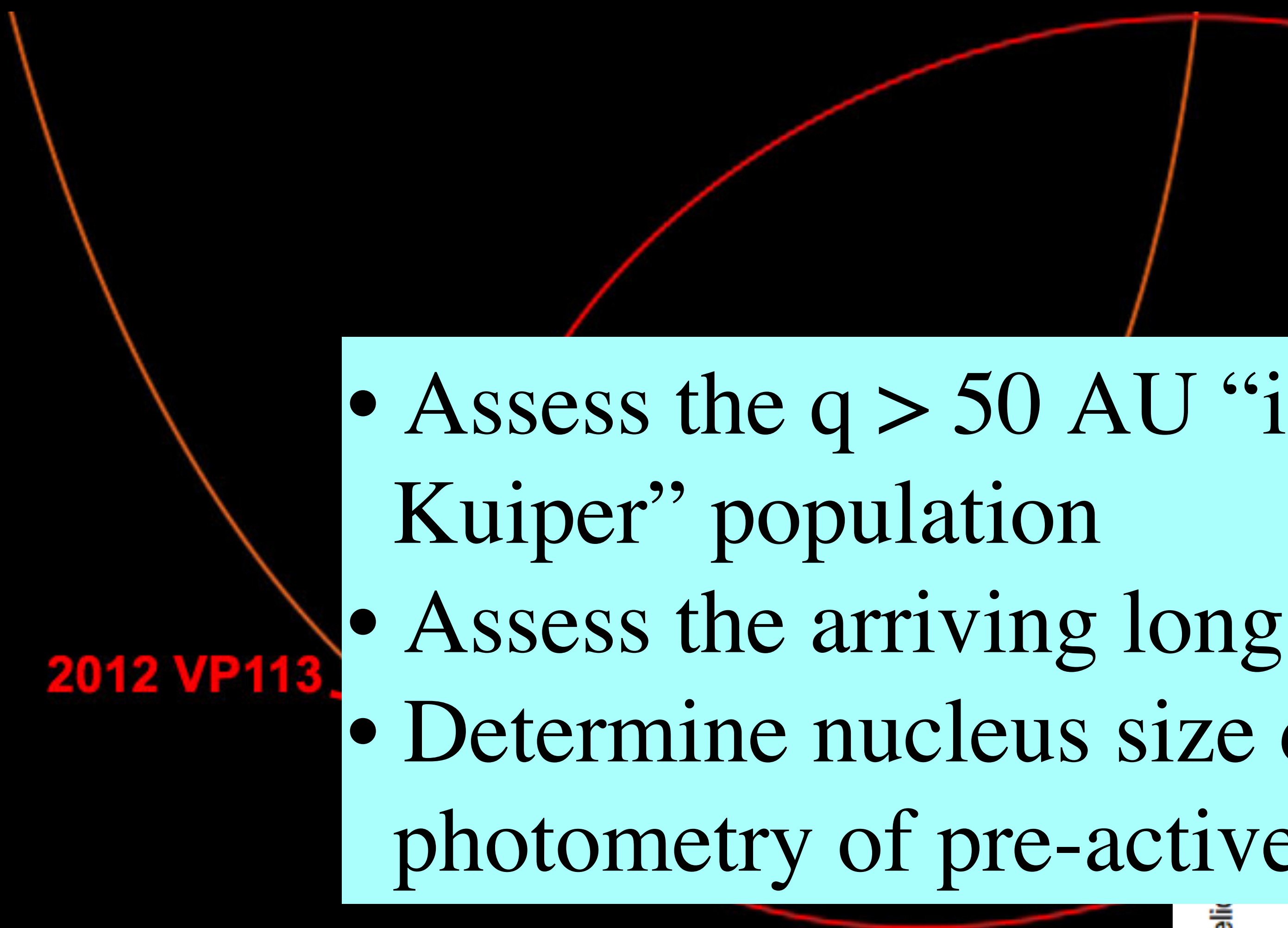
$N \sim 10^{11} - 10^{12}$

$M \sim 1 - 10\ M_E$

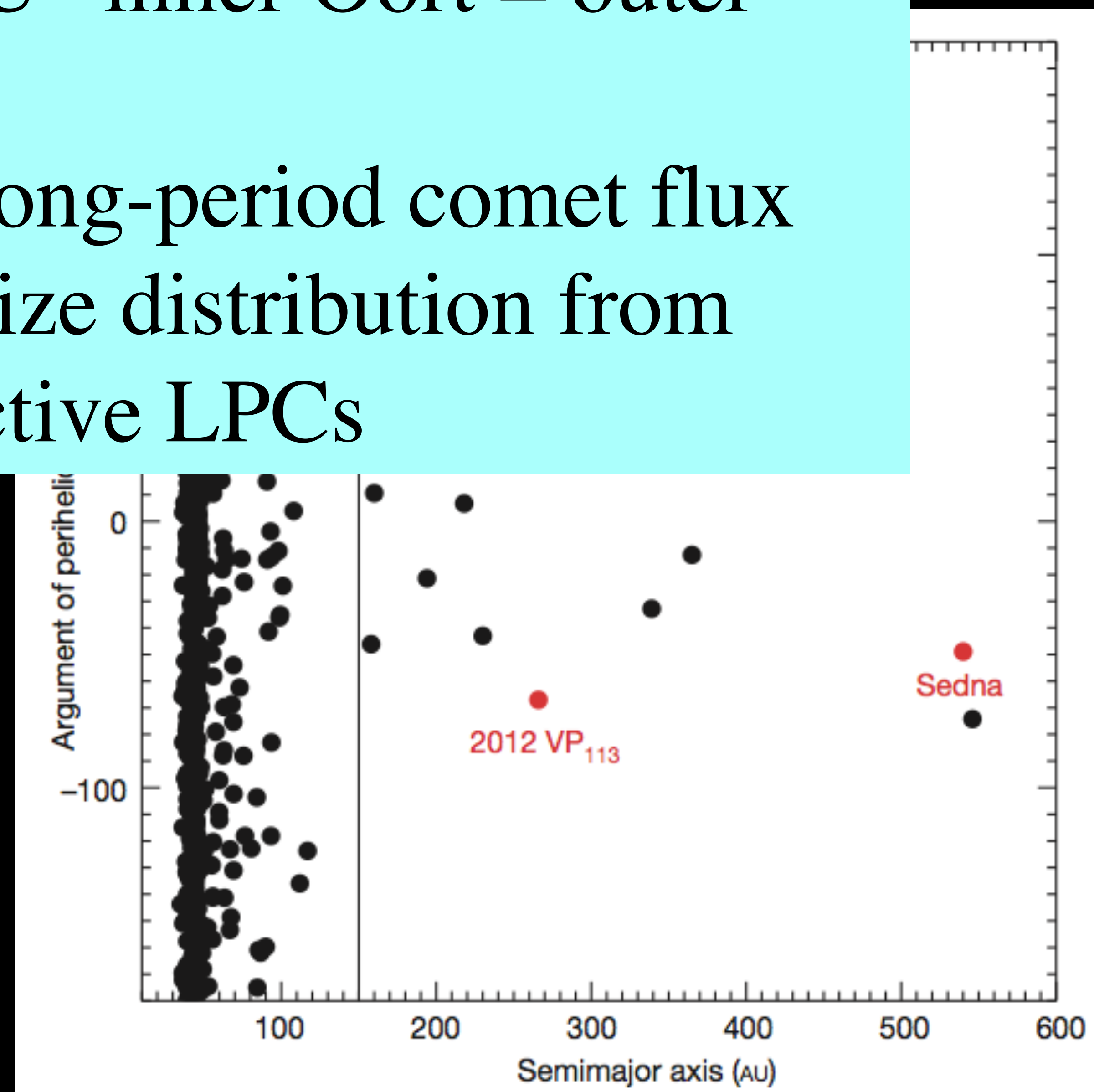
Isotropized ~ 1 Gyr

Hot Topics

- Two-step formation (emplacement efficiency =1-10%)
- Comet-sharing between stars in birth cluster?
- Existence/population of inner Oort Cloud?
- Nature of the fading parameter? (is it real?)
- Can OC be directly observed? How?



- Assess the q > 50 AU “inner Oort = outer Kuiper” population
- Assess the arriving long-period comet flux
- Determine nucleus size distribution from photometry of pre-active LPCs

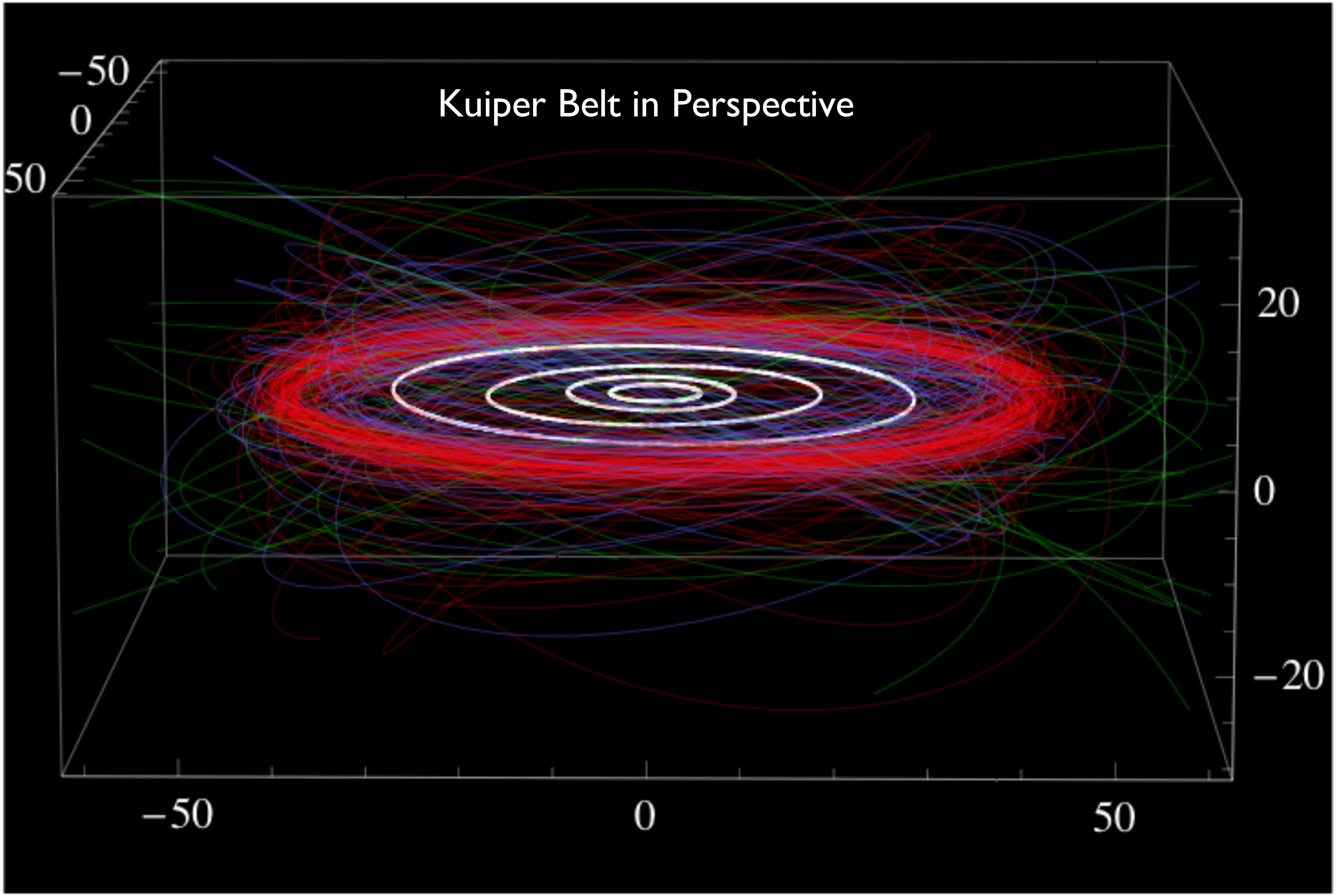


Trujillo & Sheppard 2014

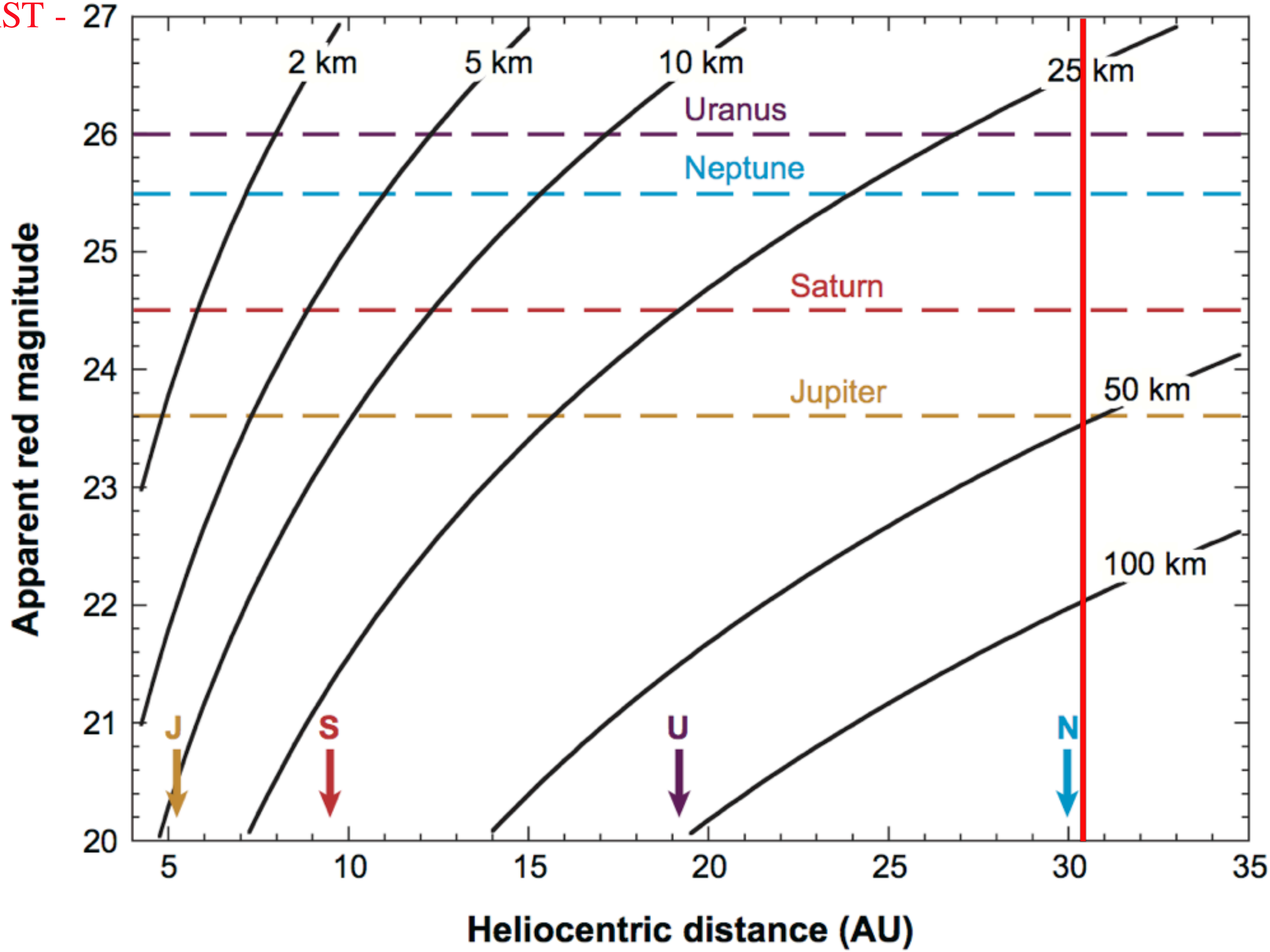
Detection of large perihelion objects

Planet	V(1,1,0)	R (V=27) AU
Earth	-3.9	1230
Jupiter	-9.3	4300
Neptune	-6.9	2500
Pluto	-1.0	630

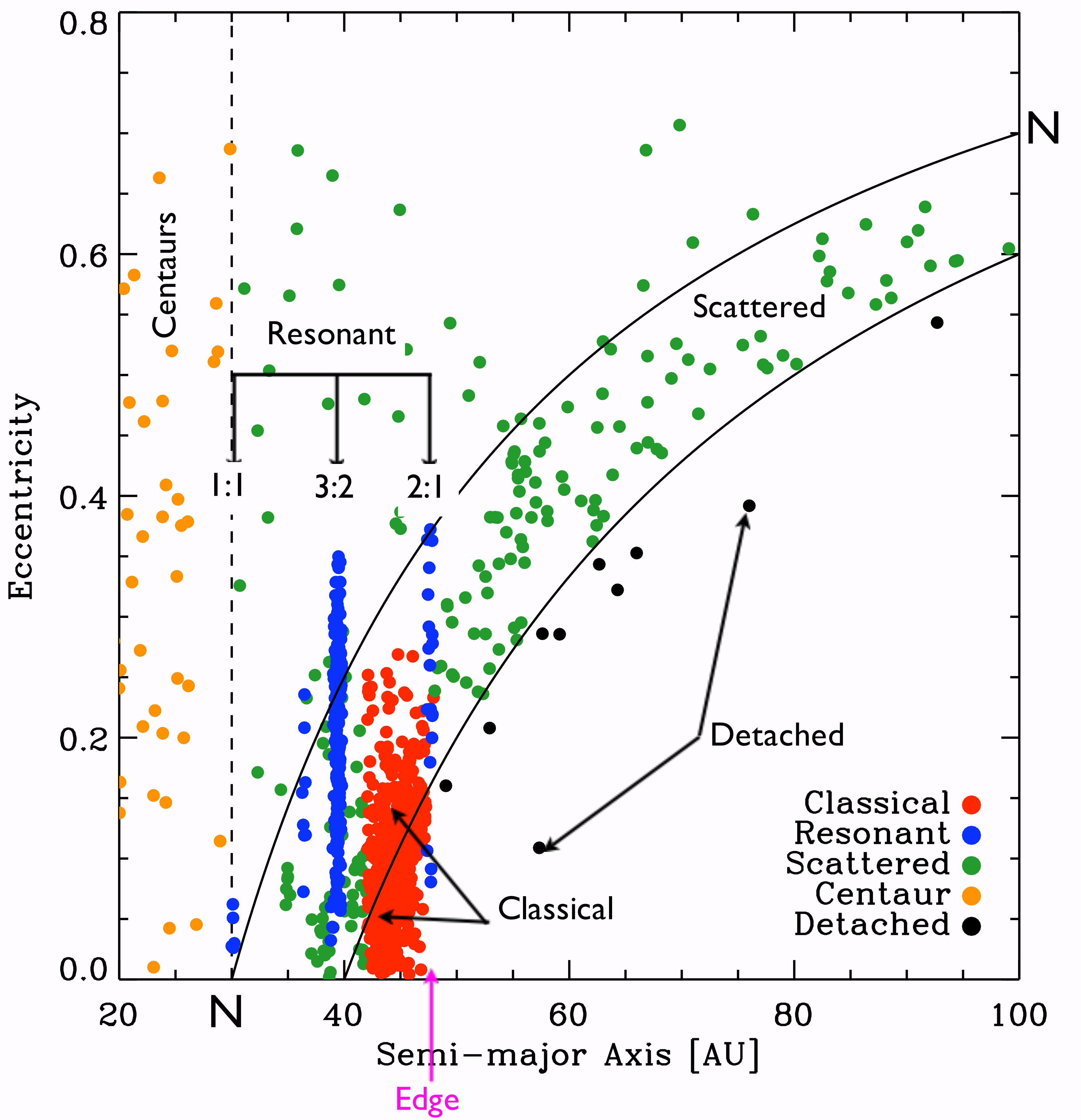
Kuiper Belt


Kuiper Belt in Perspective
−50
0
50
20
0
−20
−50
0
50

WFIRST -



Jewitt & Haghighipour (2008)



Jewitt & Luu (2002)

Kuiper Belt

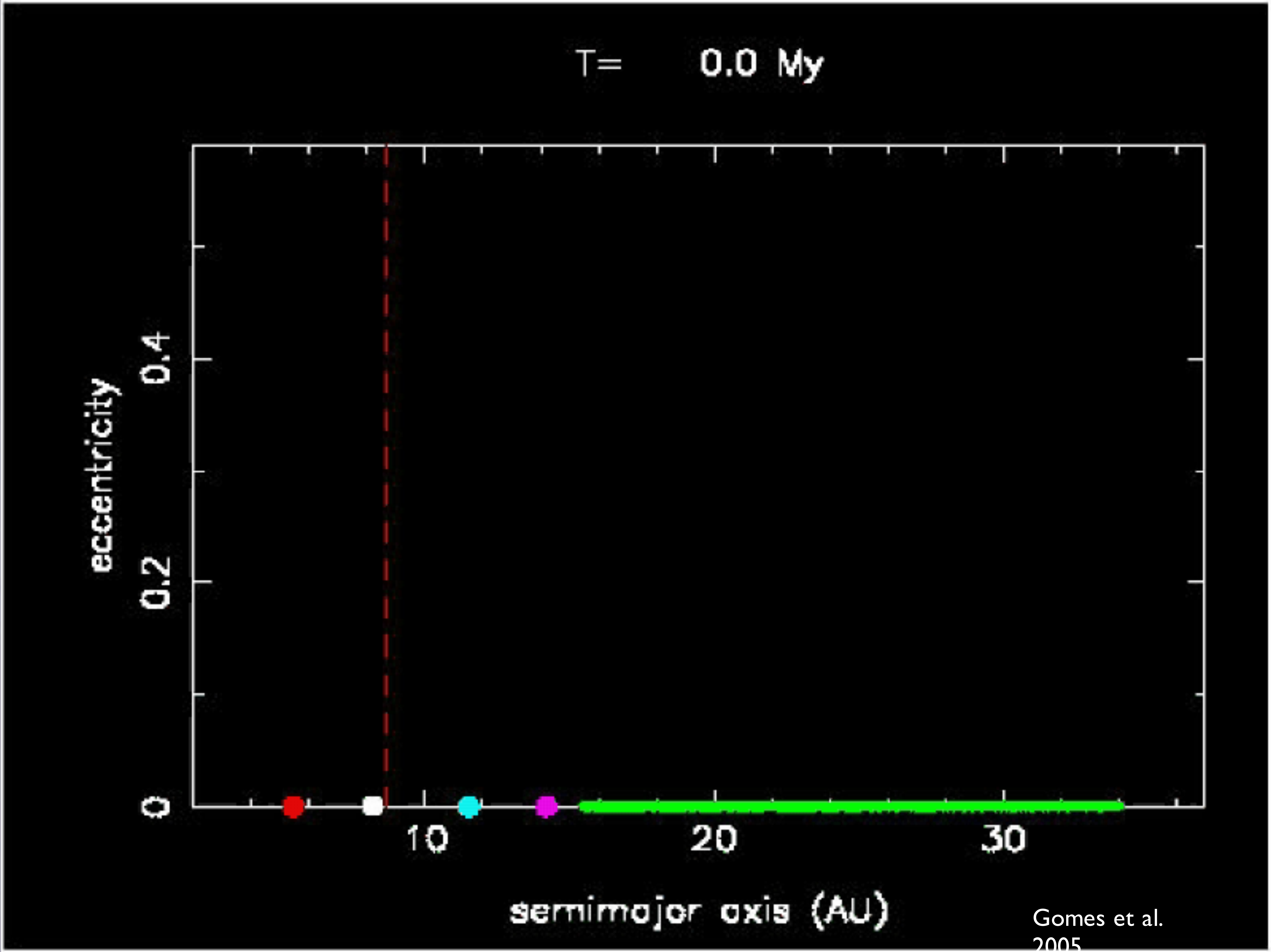
$r \sim 30 - 2000$ AU

$V_K \leq 5$ km s^{-1}

N (a > 1km) $\sim 10^9 - 10^{10}$

$M \sim 0.1\ M_E$ (now, 10 - 50 originally)

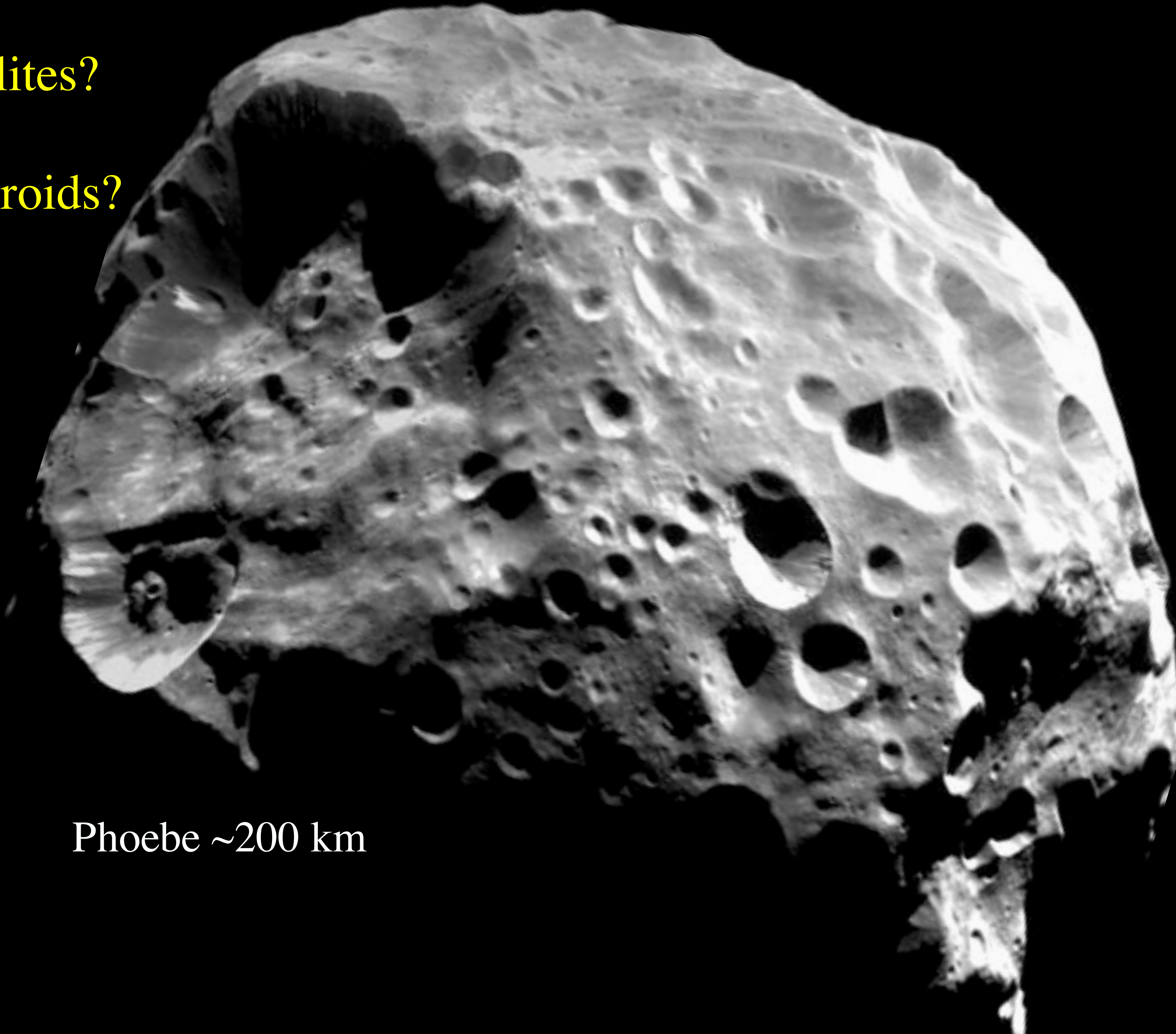
Dynamical fossil



Gomes et al. 2005

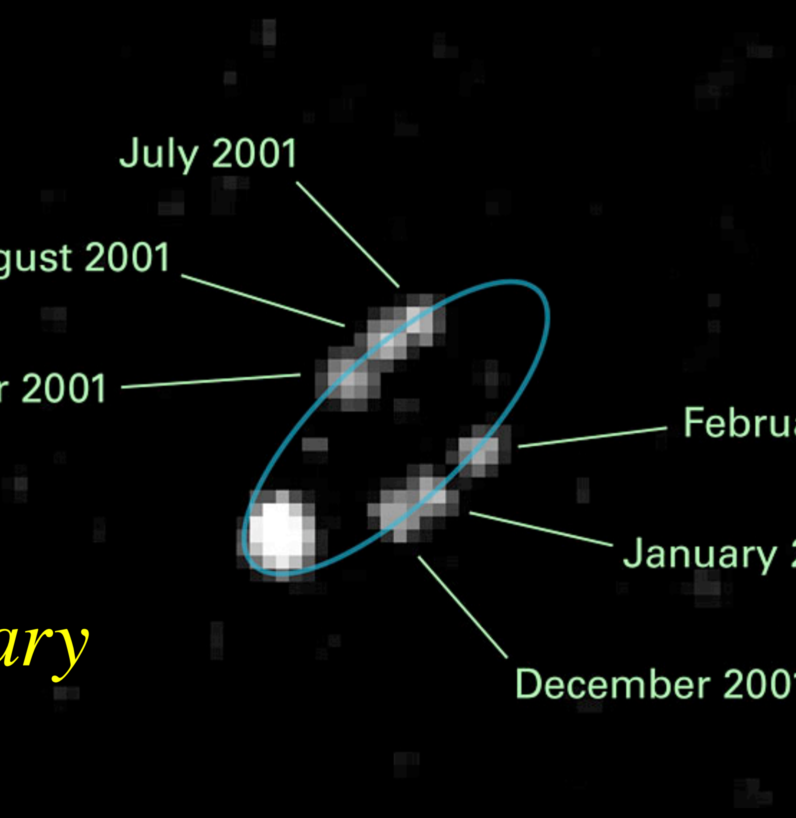
Scattering is a Potential Source of Other Populations

- Irregular Satellites?
- Trojans?
- Outer-belt asteroids?
- Late-Heavy?



Phoebe ~200 km

Binaries

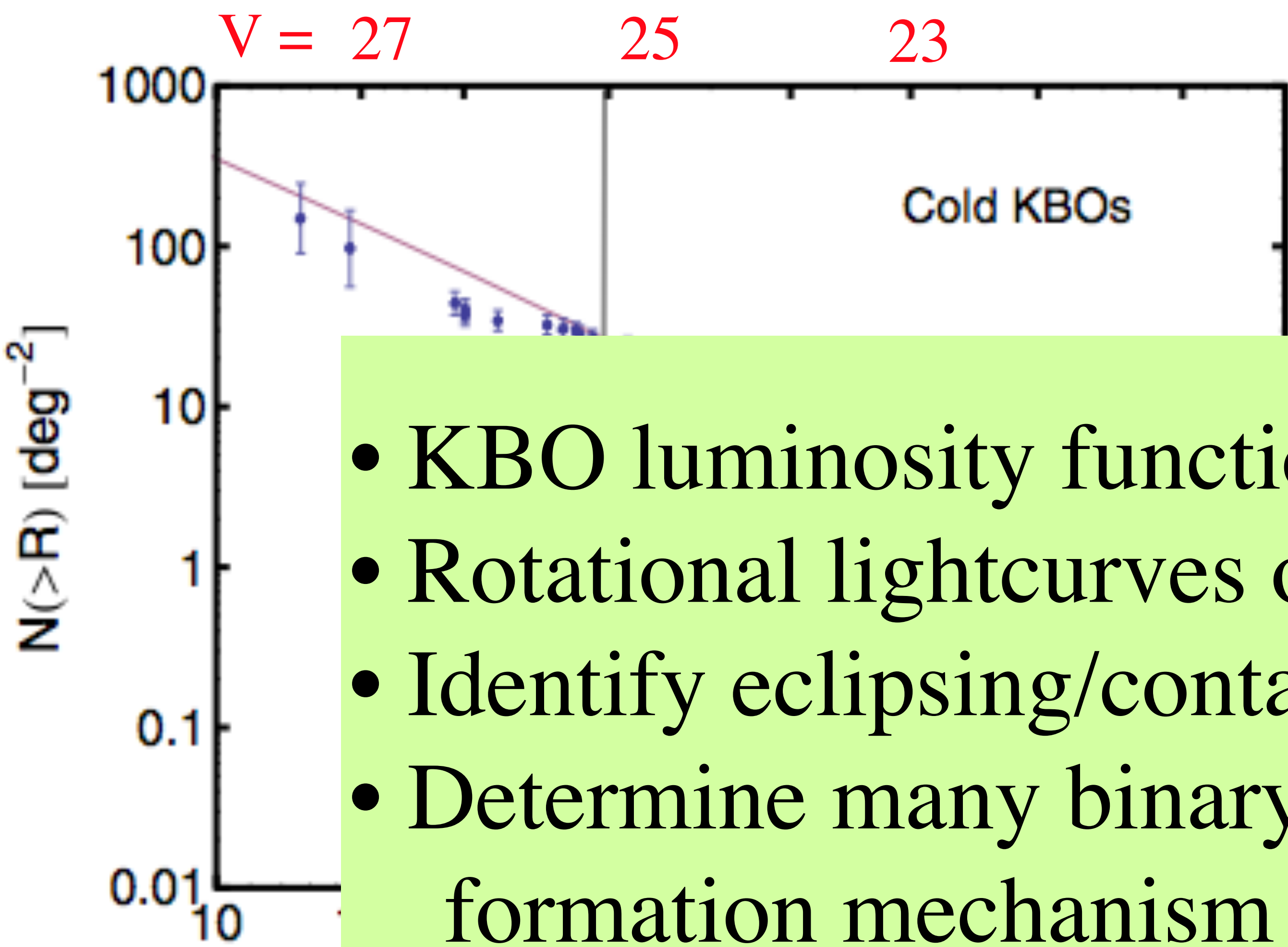


wide binary

High abundance of KBO binaries (>10%) attests to dense, dynamically cold environment unlike that now observed (N-body interactions, dynamical friction etc)

contact binary

Model by Pedro Lacerda



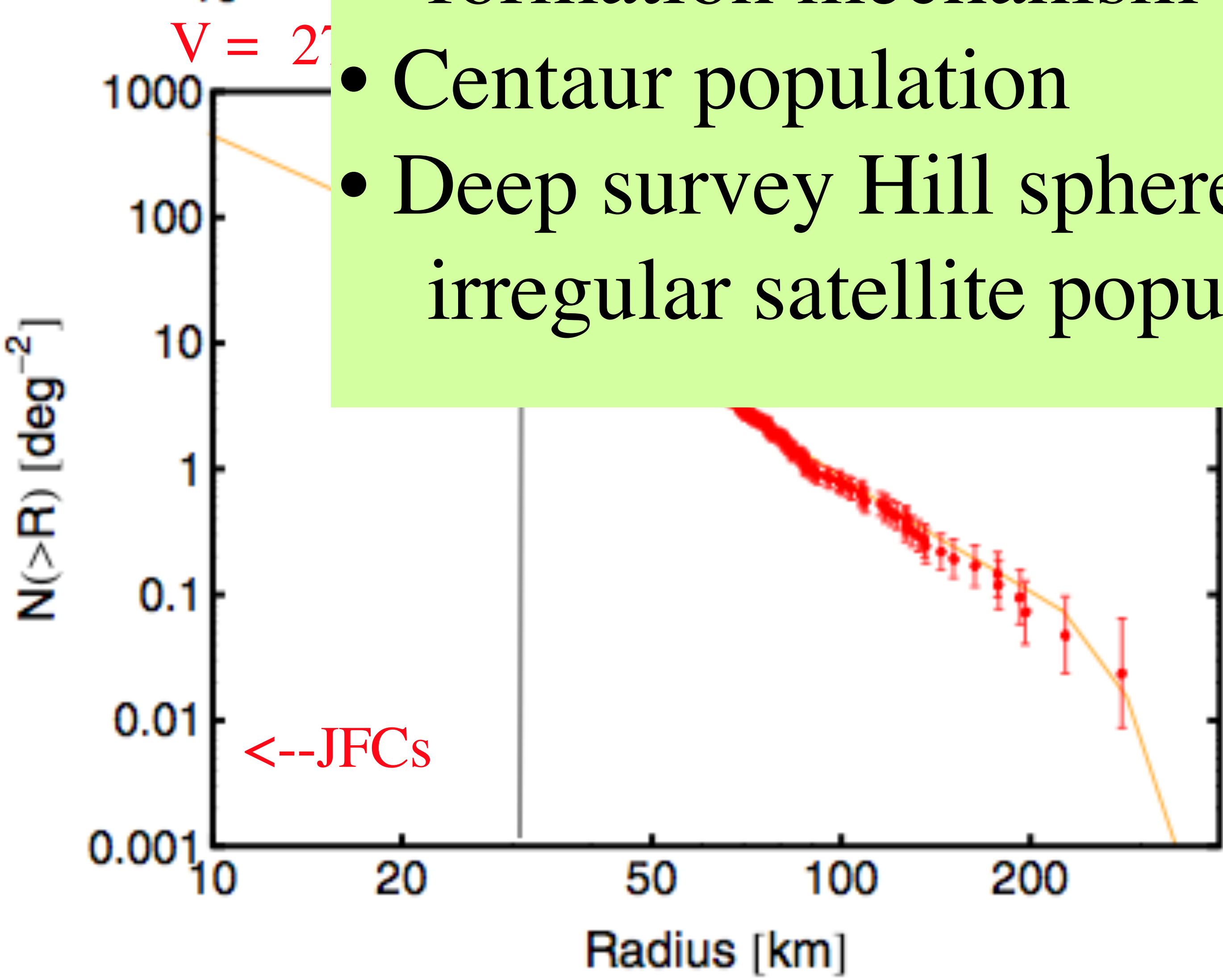
- KBO luminosity function to 10km scales
- Rotational lightcurves of 5000+ KBOs
- Identify eclipsing/contact binary population
- Determine many binary orbits - constrain formation mechanism
- Centaur population
- Deep survey Hill spheres of the giants for irregular satellite populations

V = 27

m

deg^{-2}

~ 25



1

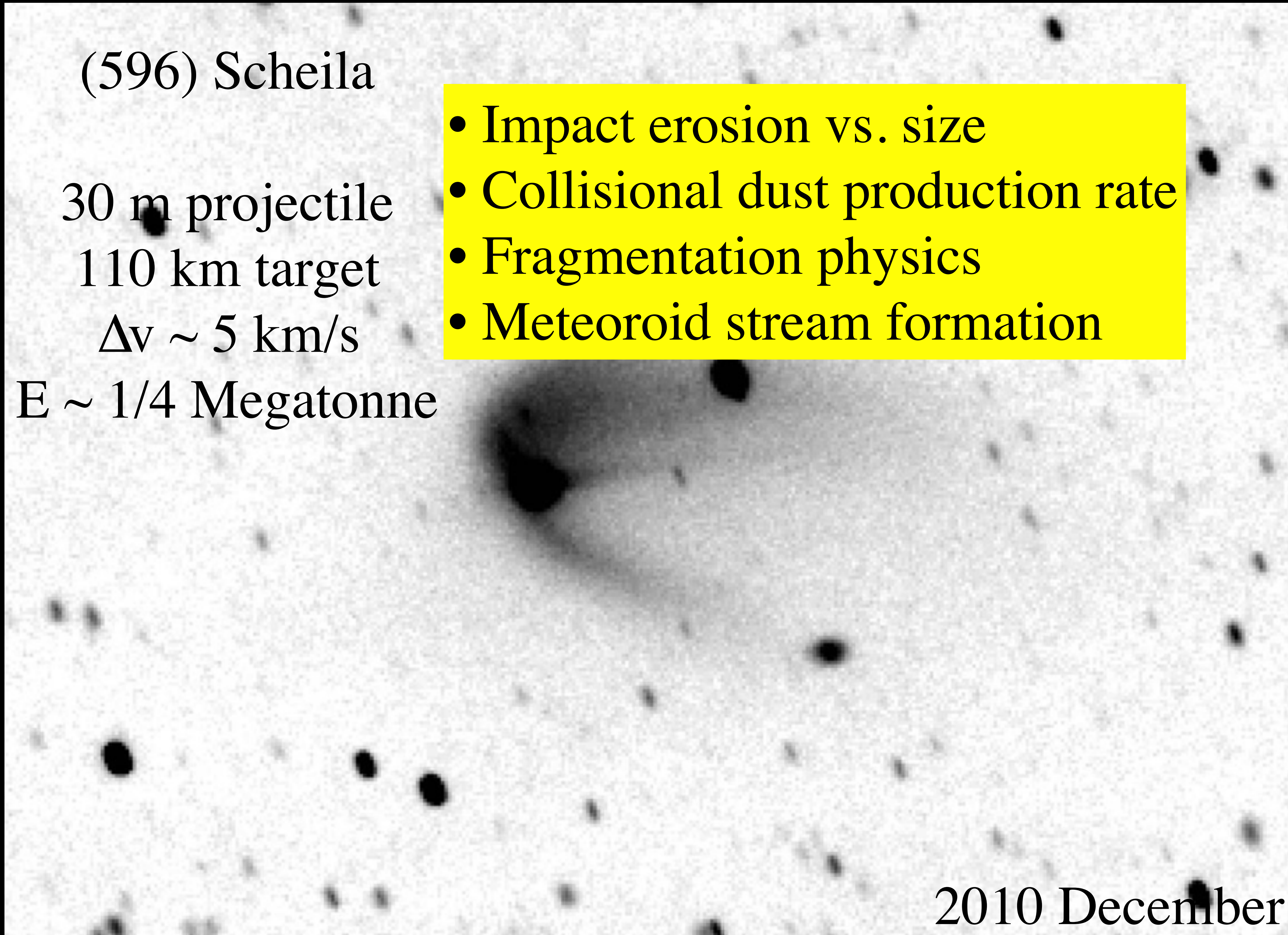
r < 30 km - Collisionally modified

Gould (2012) Schlichting et al. (2013)

Transients

Impact
Radiation torques - YORP
Crystallization energy
Endogenic activity

Impact

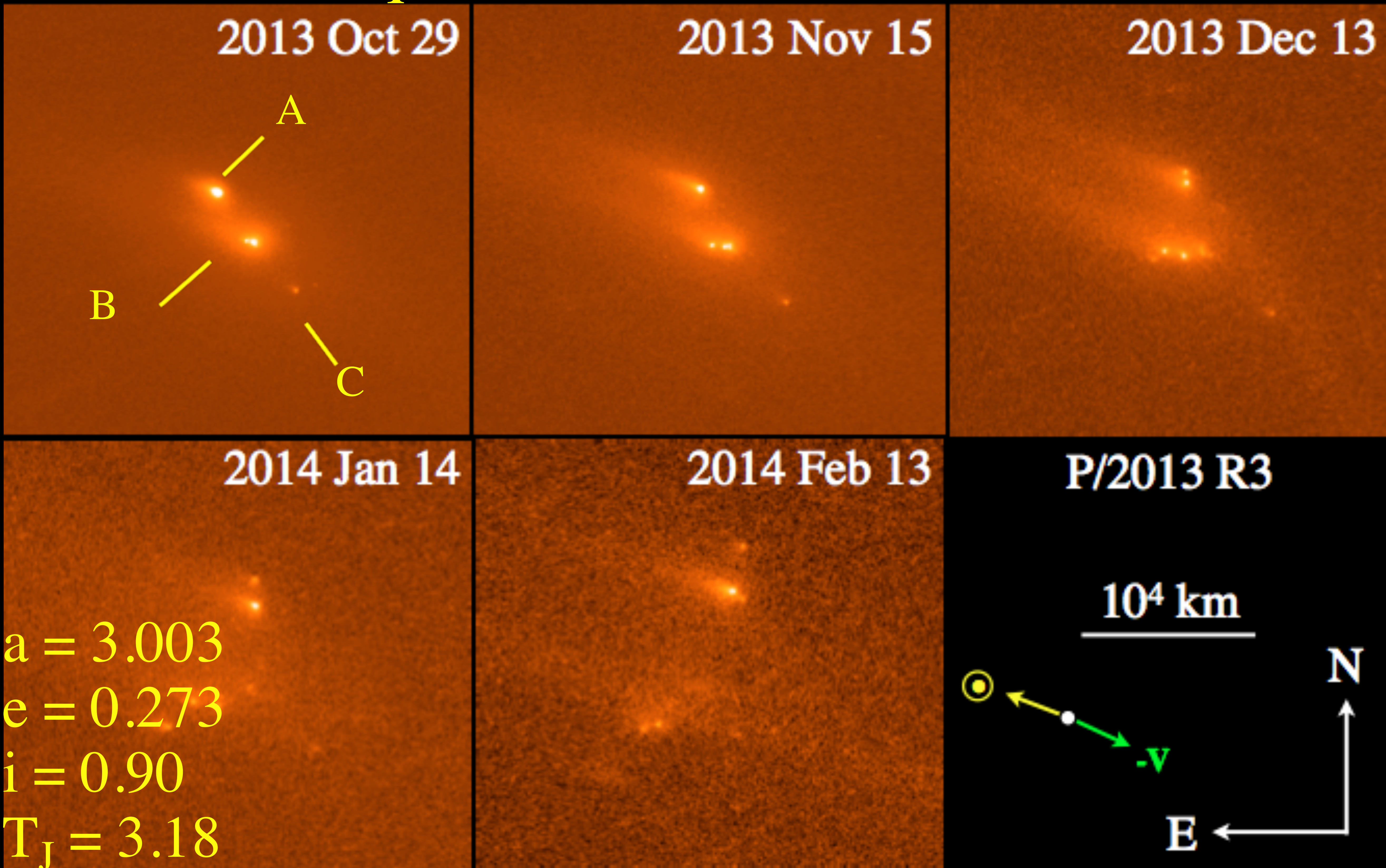


Jewitt et al. (2011)

Steve Larson, LPL

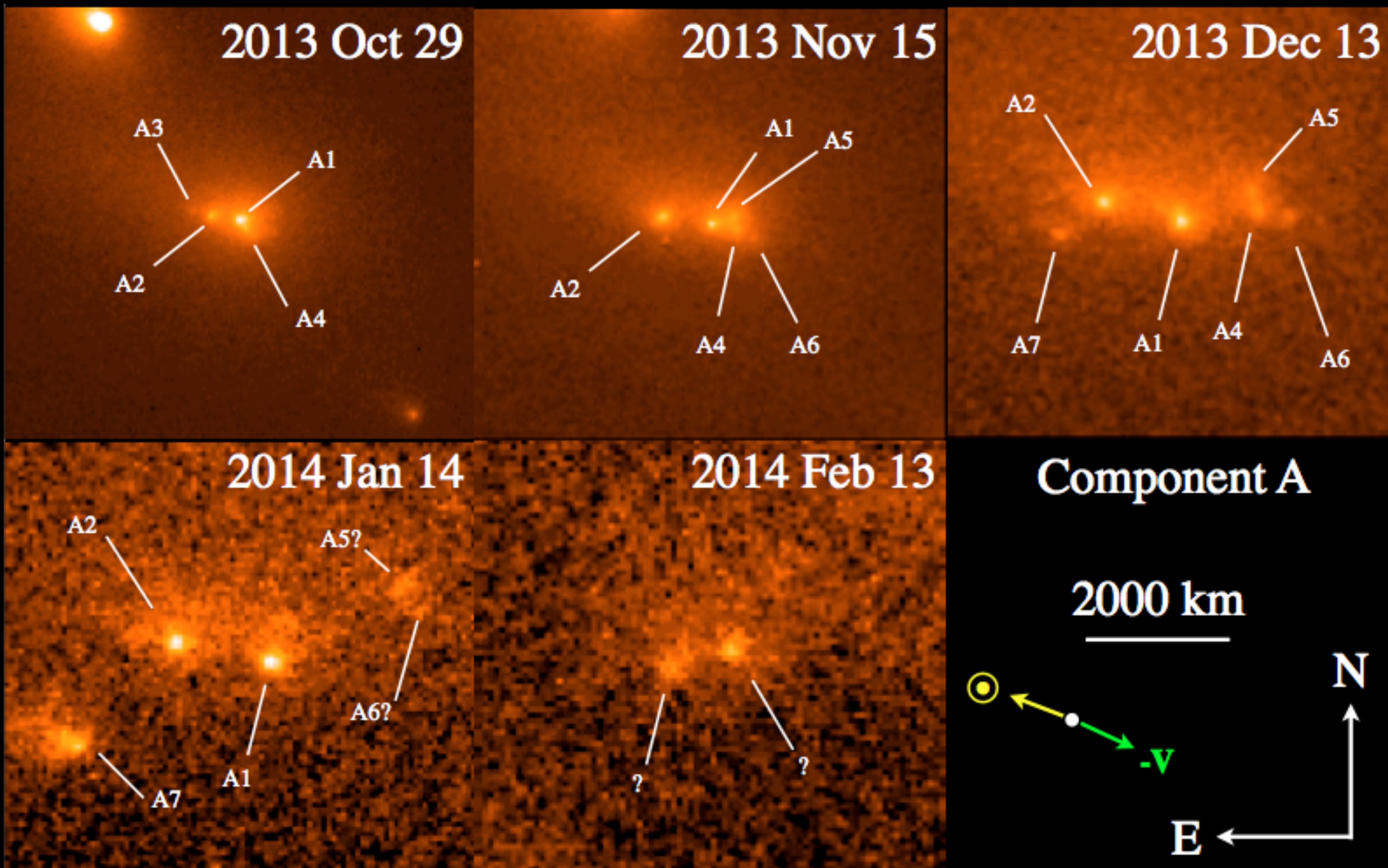
Radiation torques

Asteroid P/2013 R3



Jewitt et al. (2014)

P/2013 R3 - Zoomed

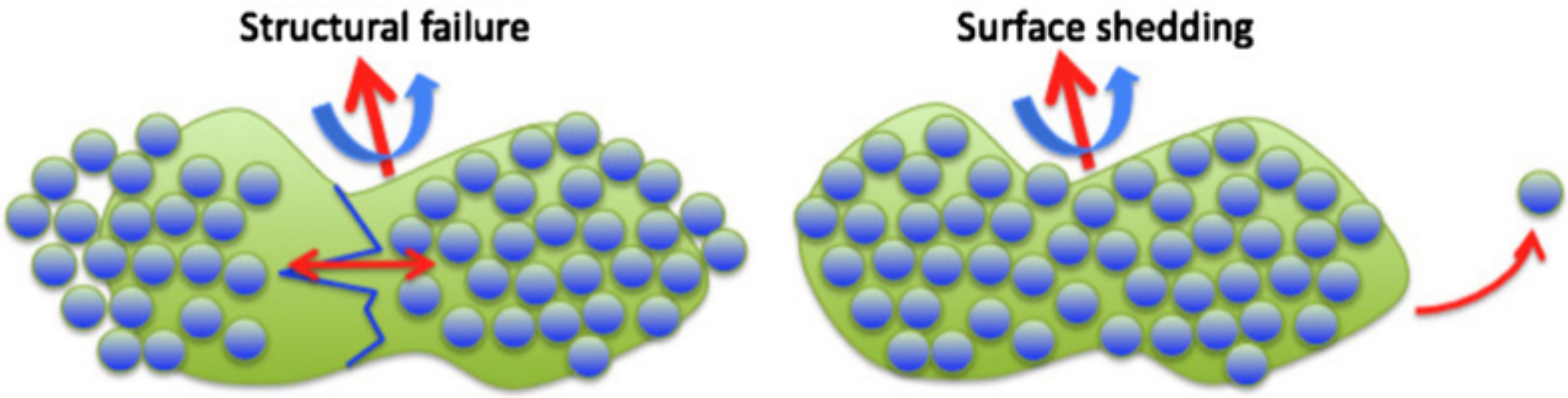


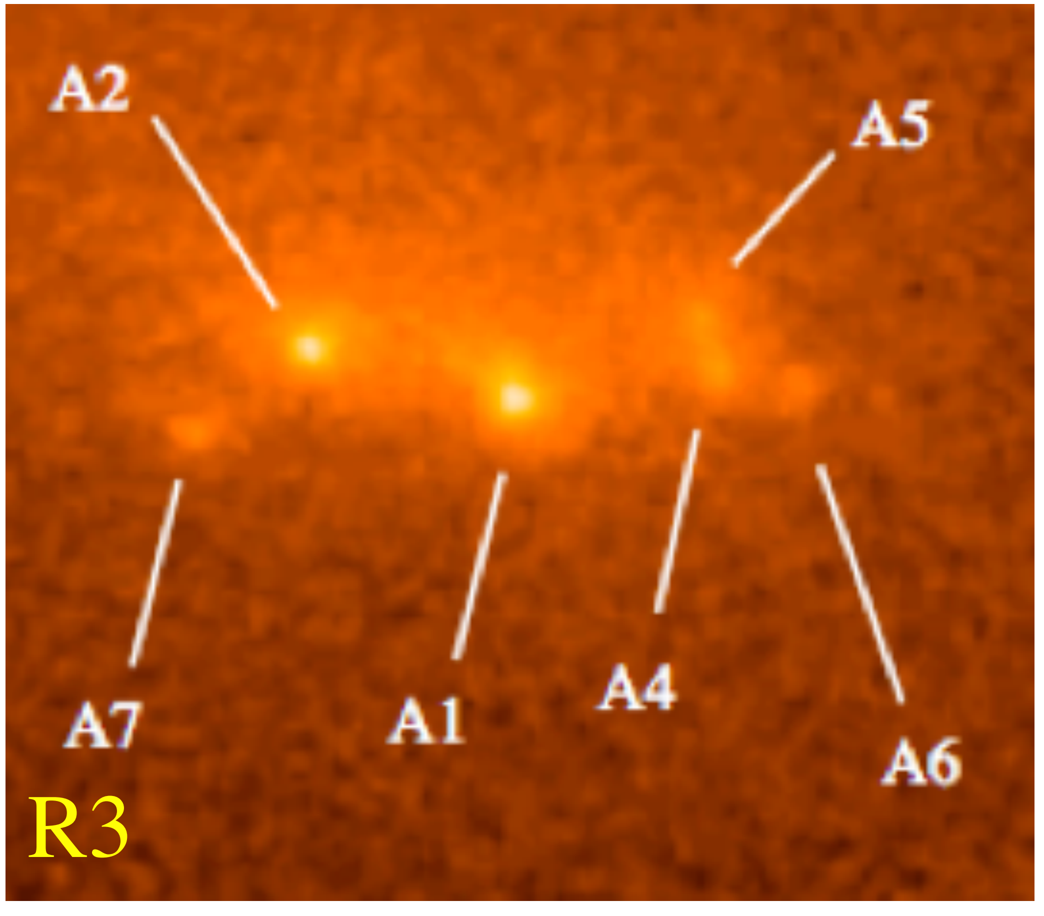
$a = 3.003$, $e = 0.273$, $i = 0.90$, $T_J = 3.18$

Shedding & Satellite Formation by YORP spin-up

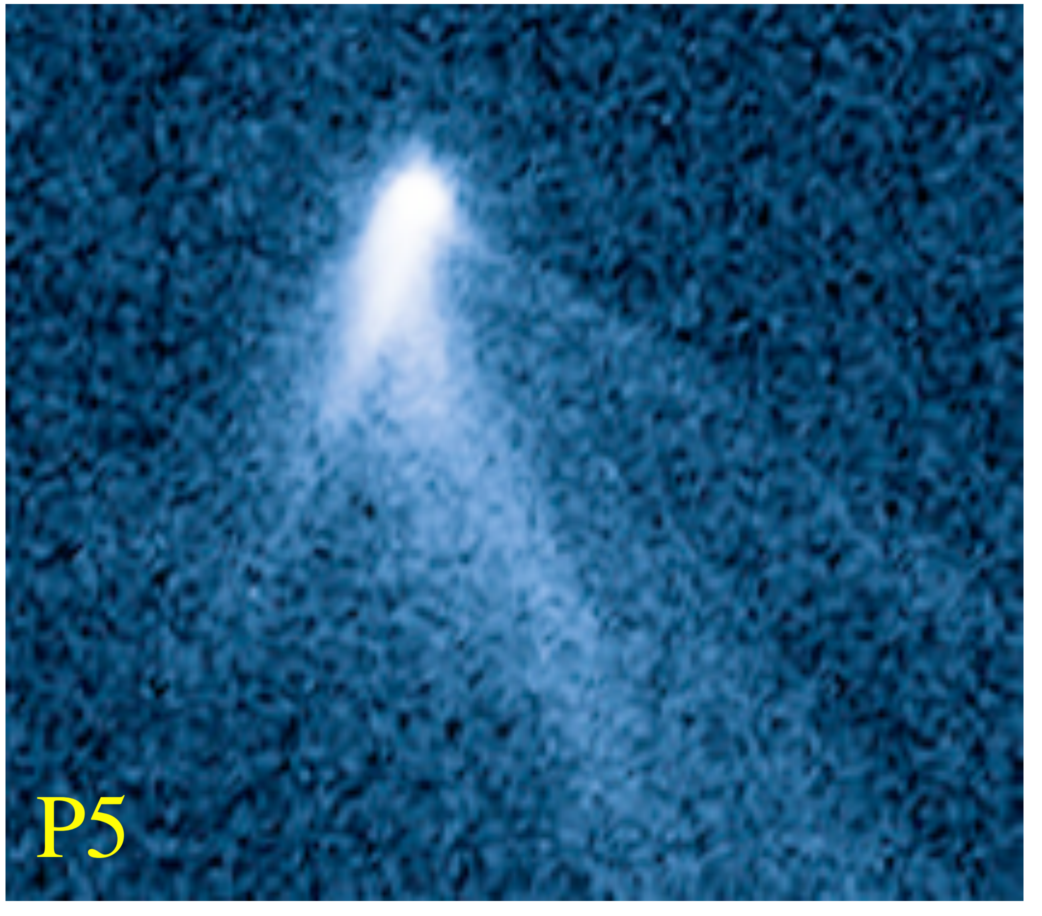
Kevin Walsh and Patrik Michel Observatoire de la Cote d'Azur (OCDA)

Hirabayashi et al (2014)

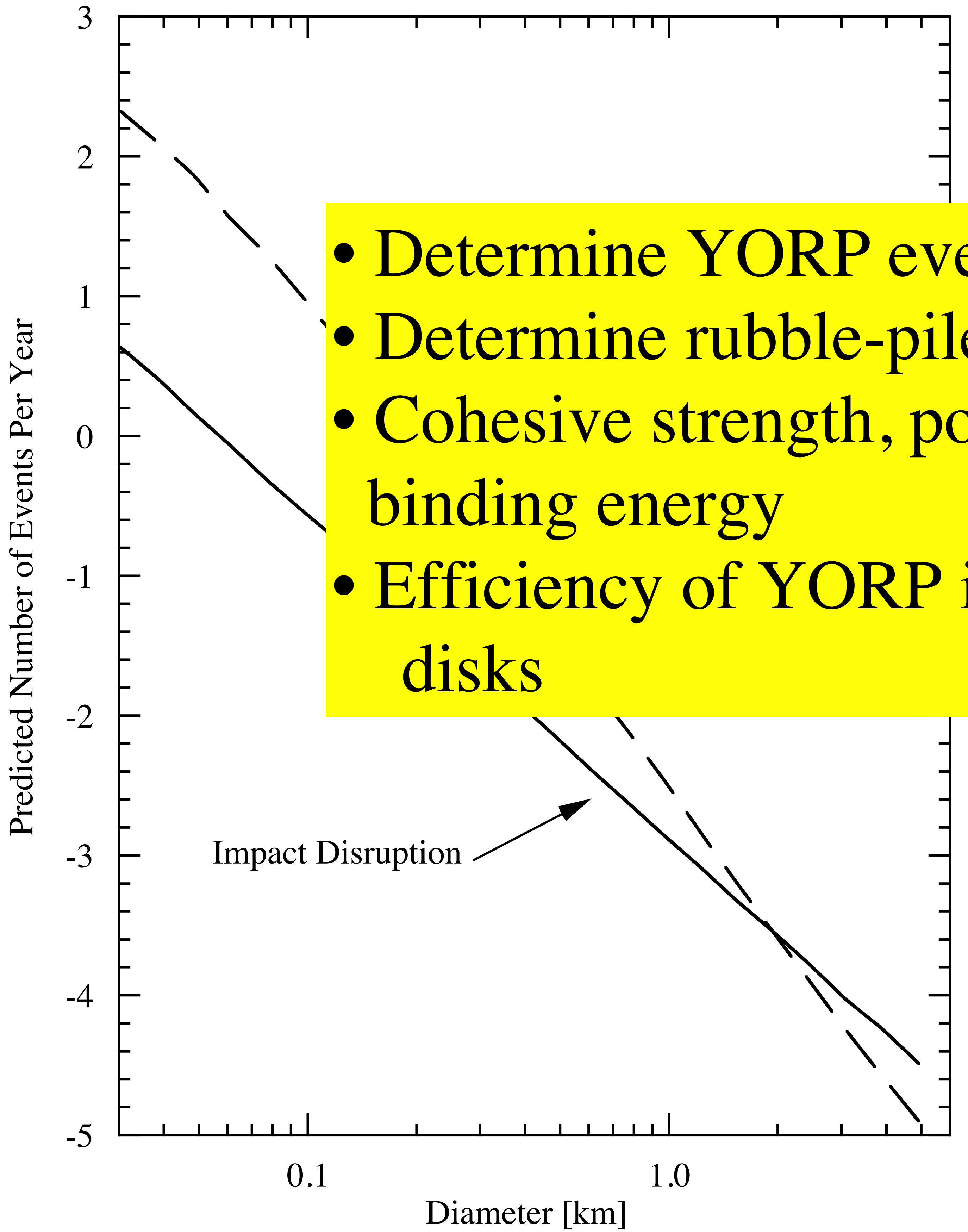




Jewitt et al. (2014)



Jewitt et al. (2013)



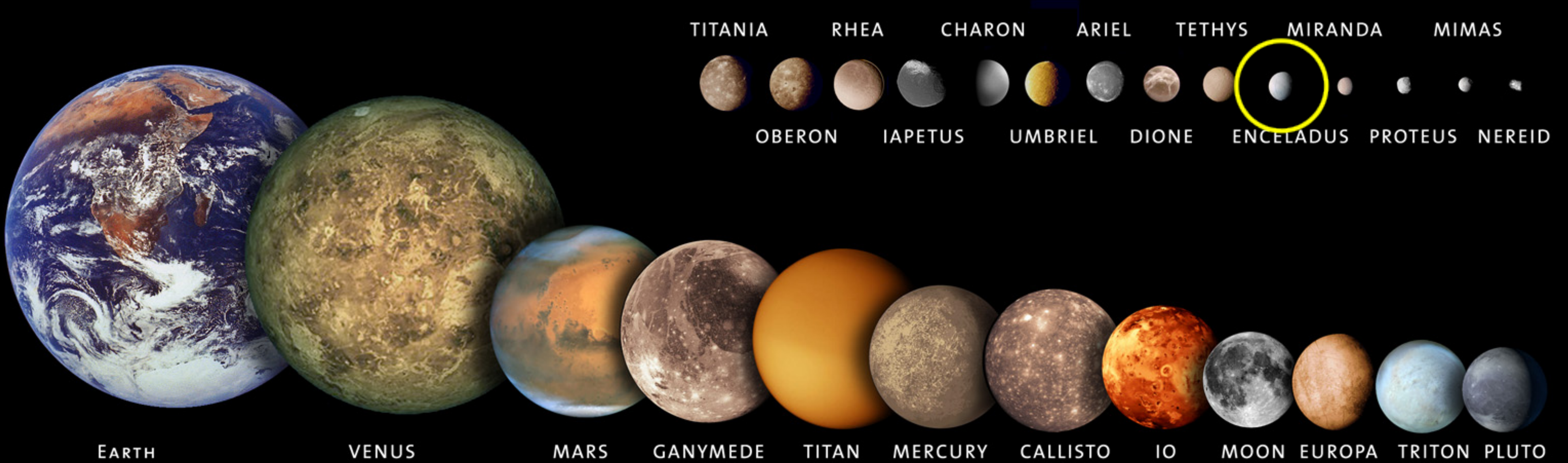
- Determine YORP event rate
- Determine rubble-pile physics
- Cohesive strength, porosity, binding energy
- Efficiency of YORP in debris disks

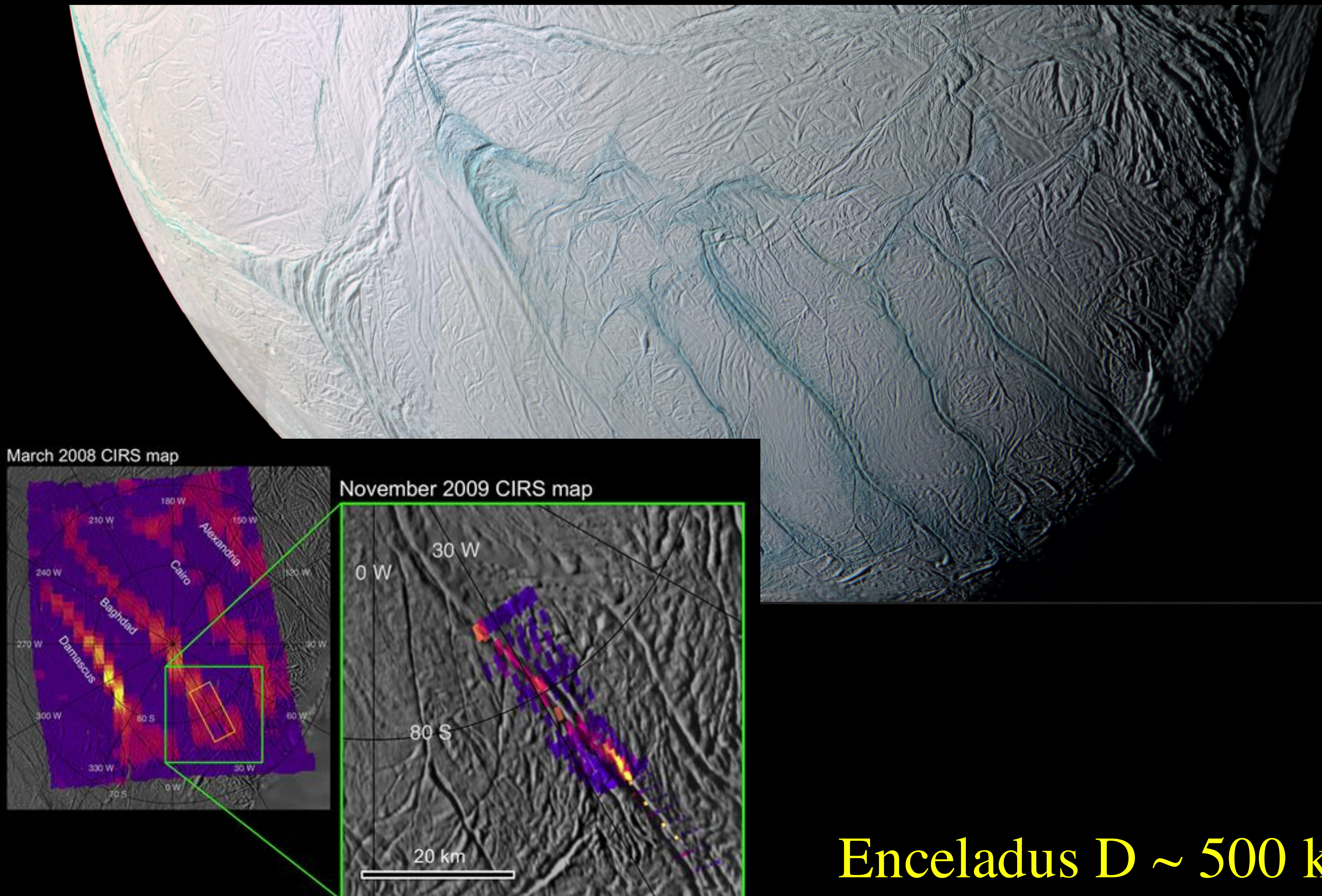
- Radiation torques may dominate collisional ... on in the asteroid ... sub-km ...)

... may apply for ... production around other stars

Marzari et al. (2011), Veras et al. (2014)

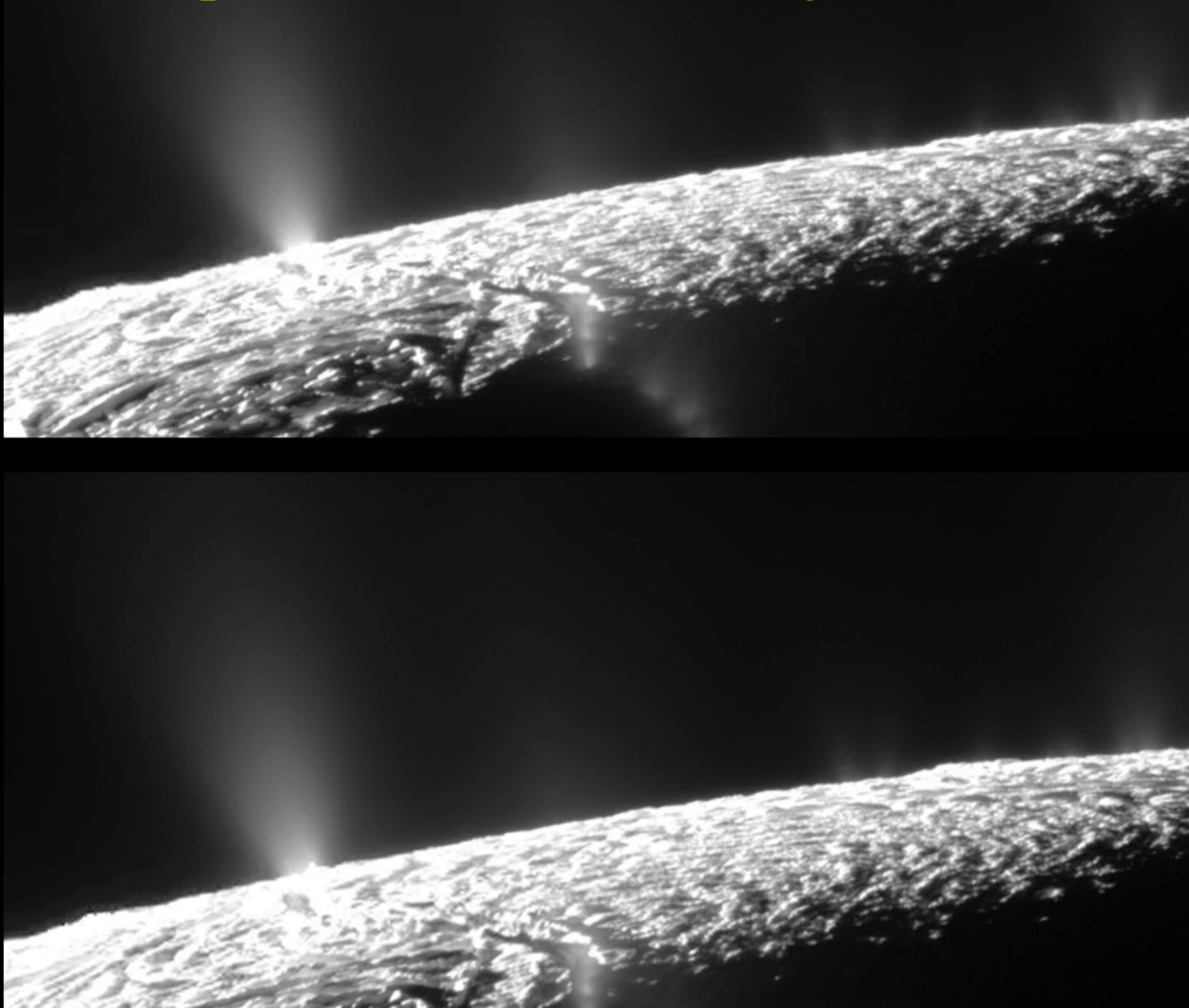
Endogenic activity

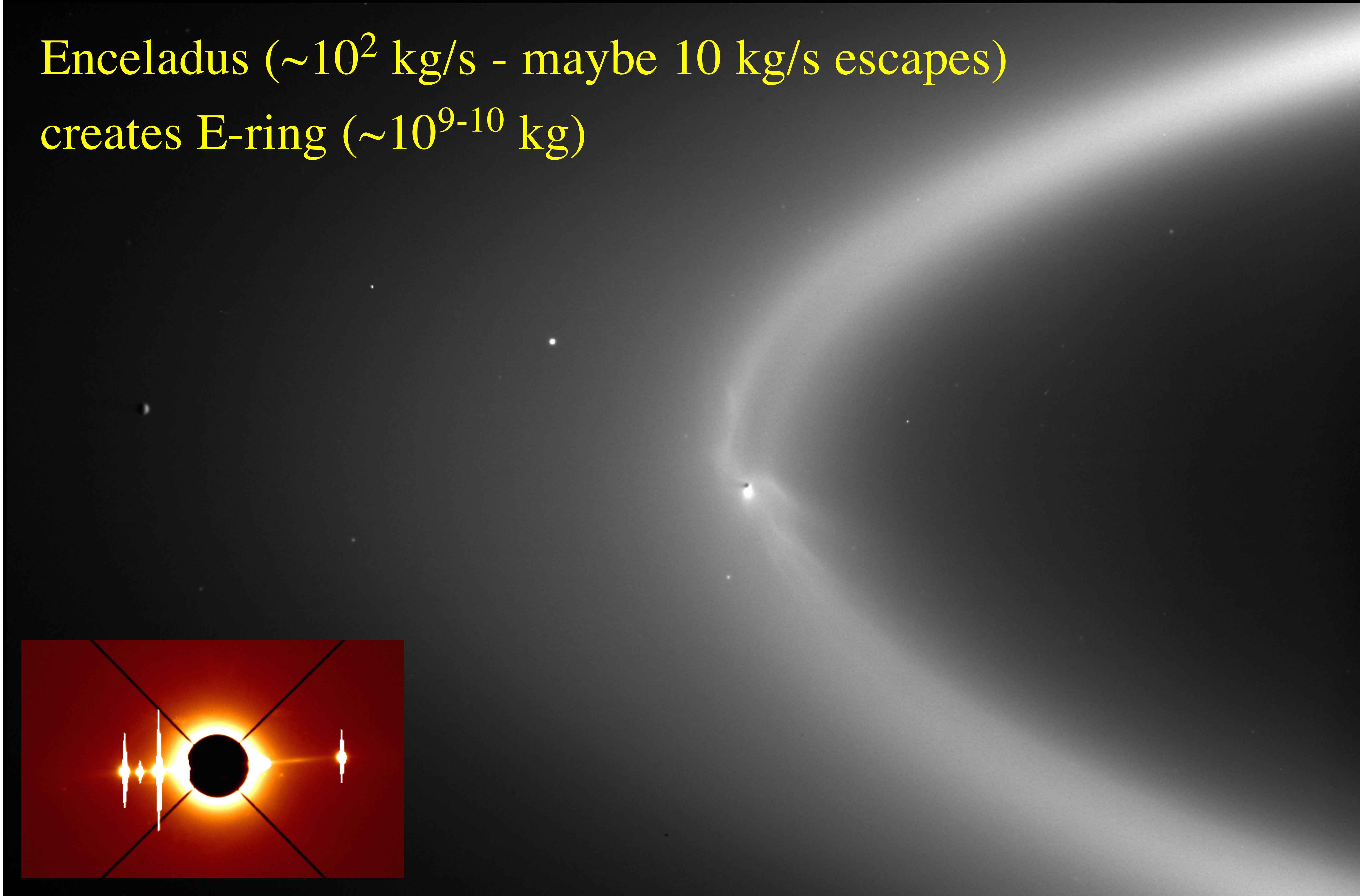




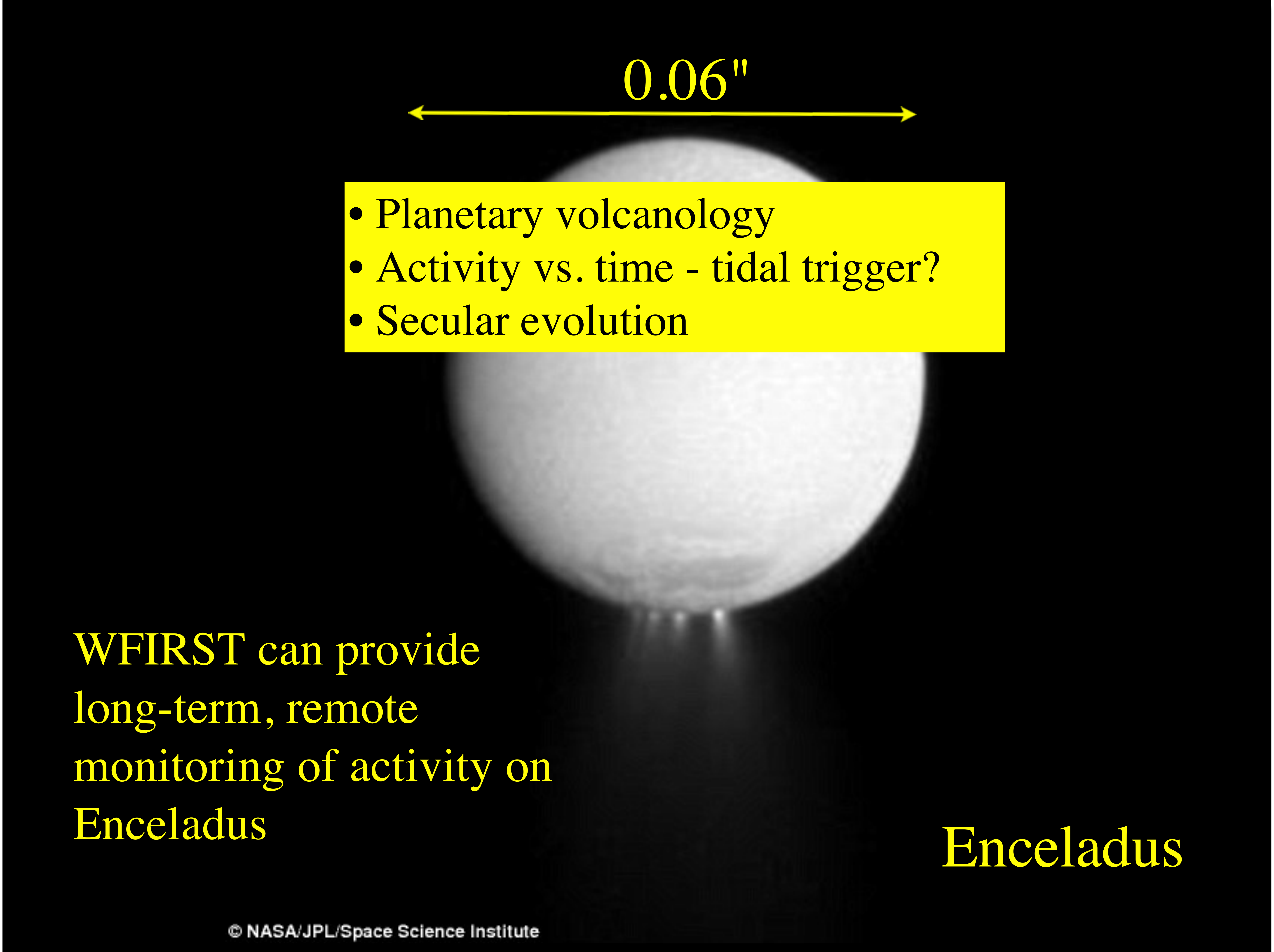
Enceladus D ~ 500 km

Enceladus production ~few x 100 kg/s





Cassini/ISS/Cyclops


0.06"
• Planetary volcanology
• Activity vs. time - tidal trigger?
• Secular evolution
WFIRST can provide long-term, remote monitoring of activity on Enceladus
Enceladus
© NASA/JPL/Space Science Institute

Summary

My Charge: "Provide overview of solar system science in the context of space-based IR surveys & WFIRST"

Expect science impacts in

- Structure of solar system (Kuiper belt, Oort Cloud, Centaurs, Trojans, comets)

- Distribution & origin of binaries

- Active Objects (hypervelocity impact clouds, rotational instabilities, weird volcanism)

BUT the most exciting science will come unexpectedly, not from detailed planning and anticipation

END