The exosphere of Mercury as a detector of Encke meteoroids

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ARMAGH OBSERVATORY

ICHEC
Irish Centre for High-End Computing

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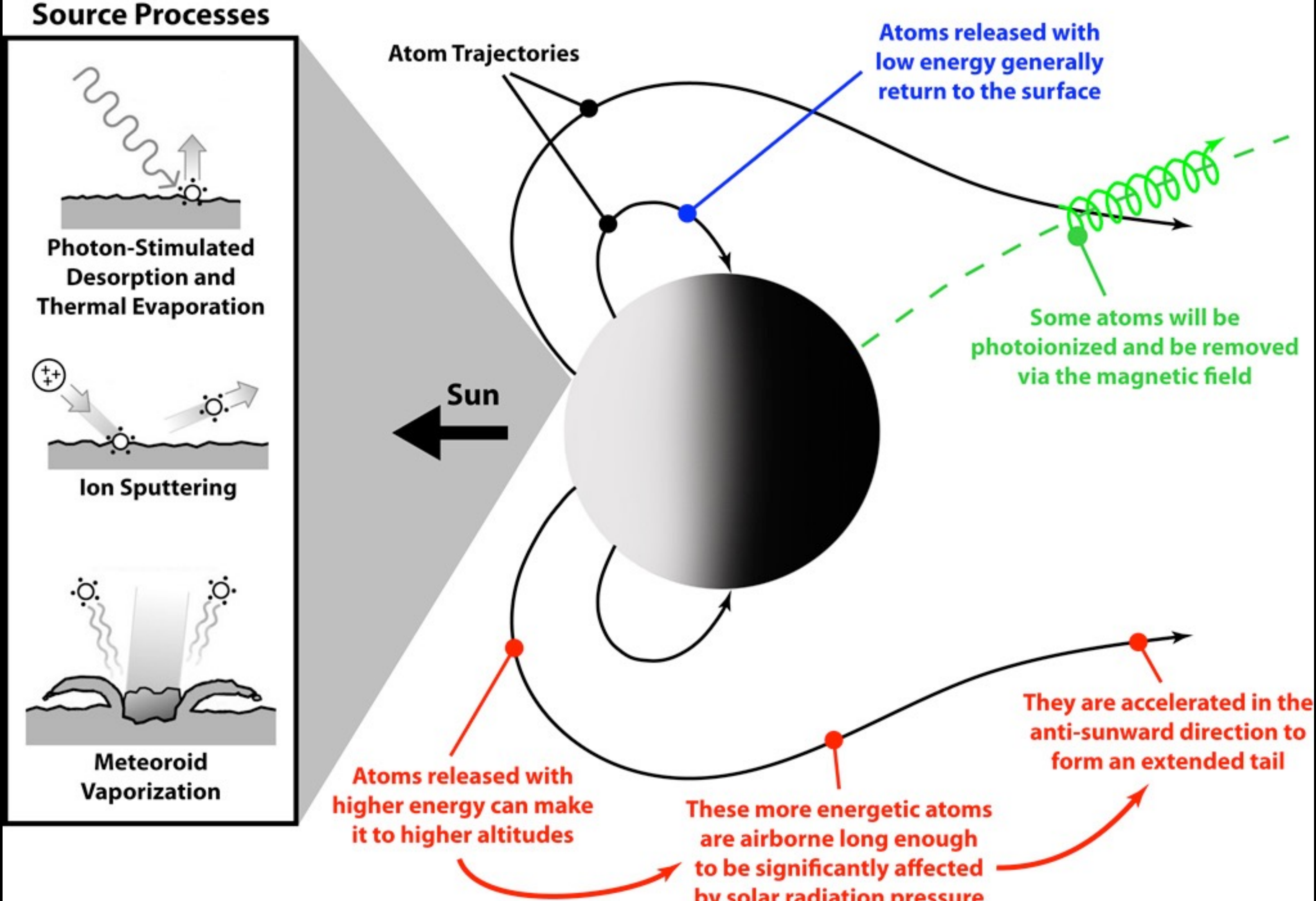
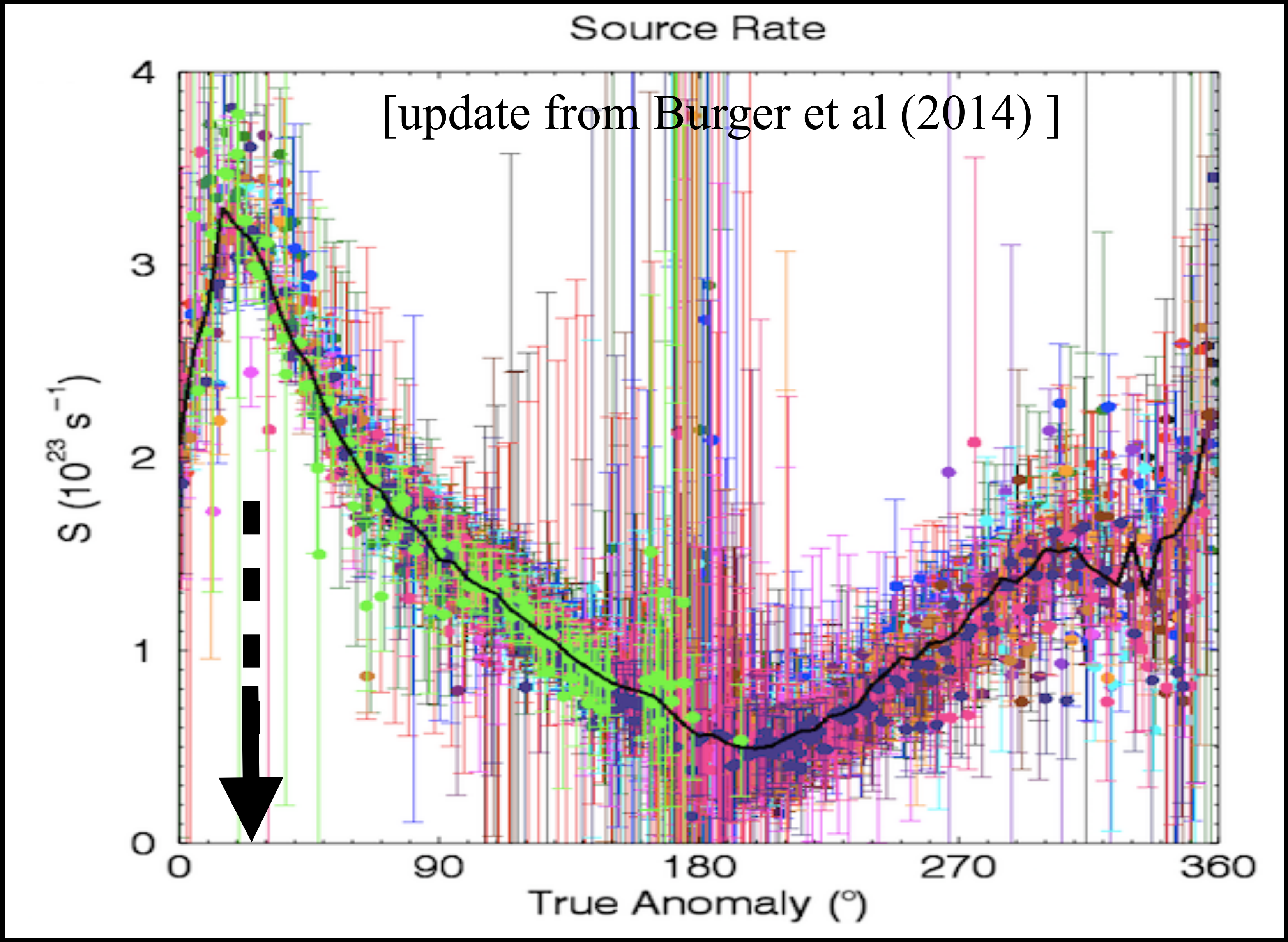
An Roinn Cultúir, Ealaíon agus Fóillíochta

Mercury's Surface-Bounded Exosphere



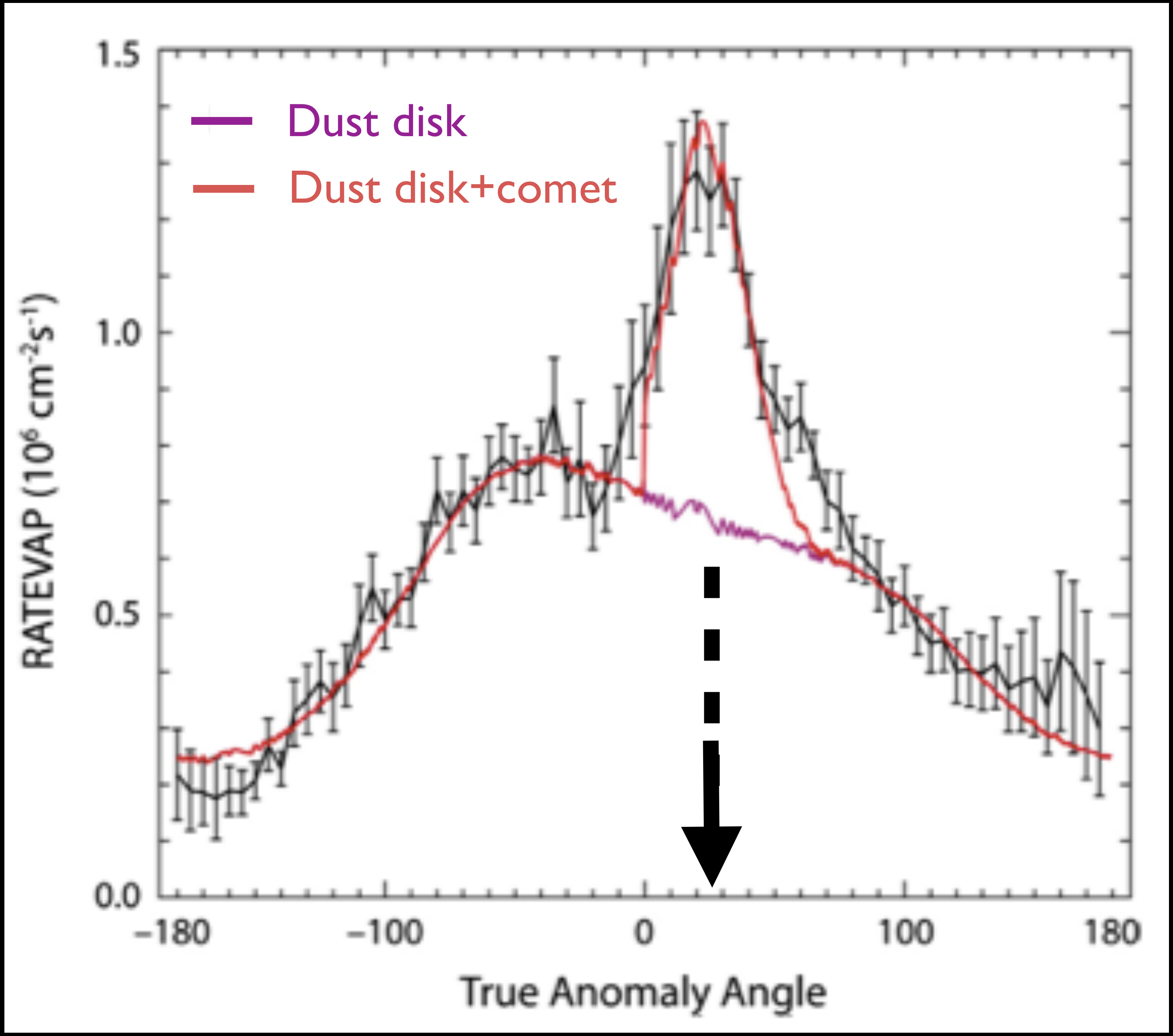
Calcium in Mercury's exosphere: MESSENGER MASCS observations



- Ca varies <u>seasonally</u>

- Ca Peak at True Anomaly Angle = $25^o \pm 5^o$

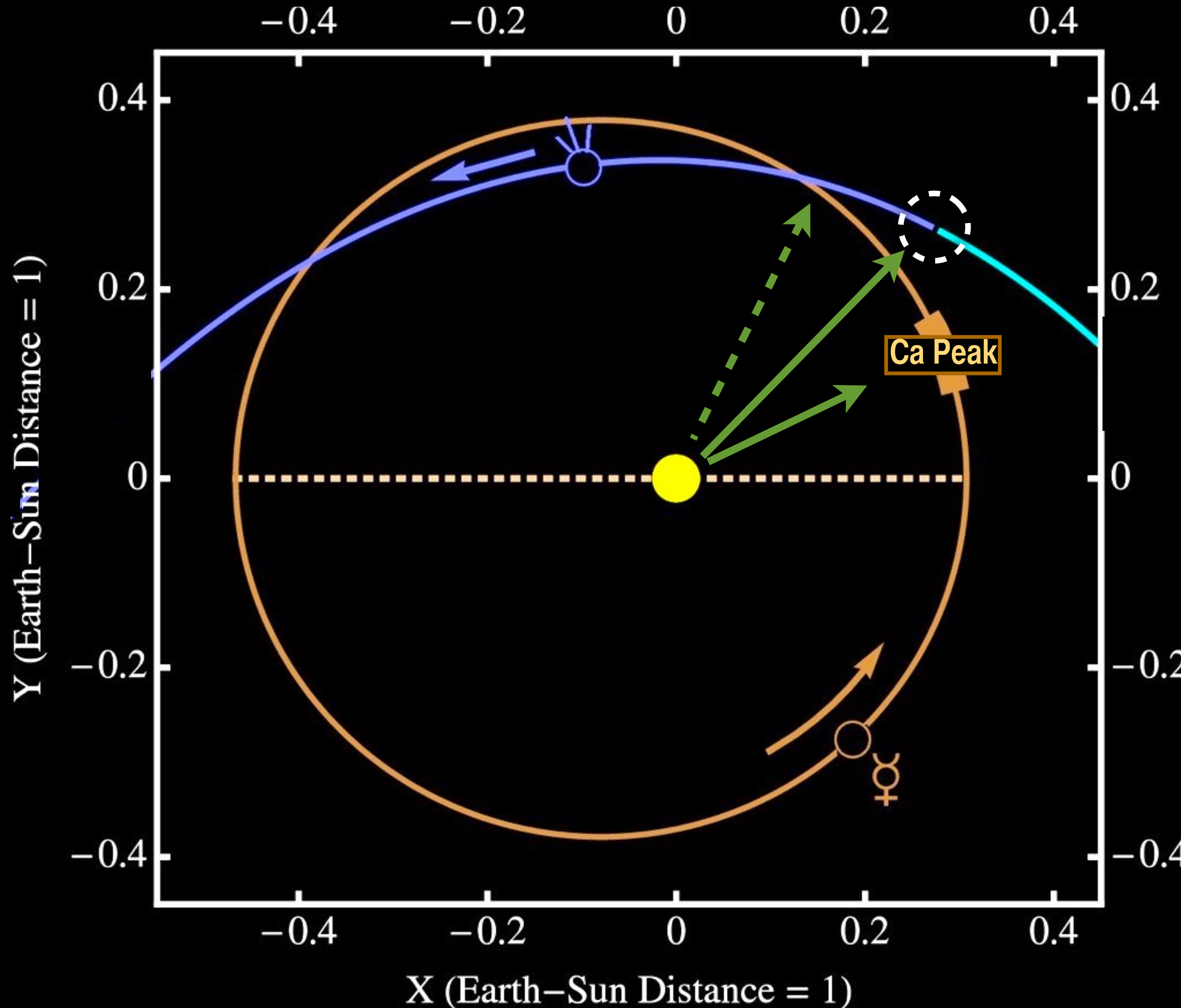
Killen & Hahn (2015) zodiacal cloud + comet stream at TAA = 25^0



``..seasonal variations in Mercury's exospheric Ca can be attributed to impacts by interplanetary dust grains plus <u>an additional localized contribution that could be a meteor stream from the nearby Comet Encke</u>.''

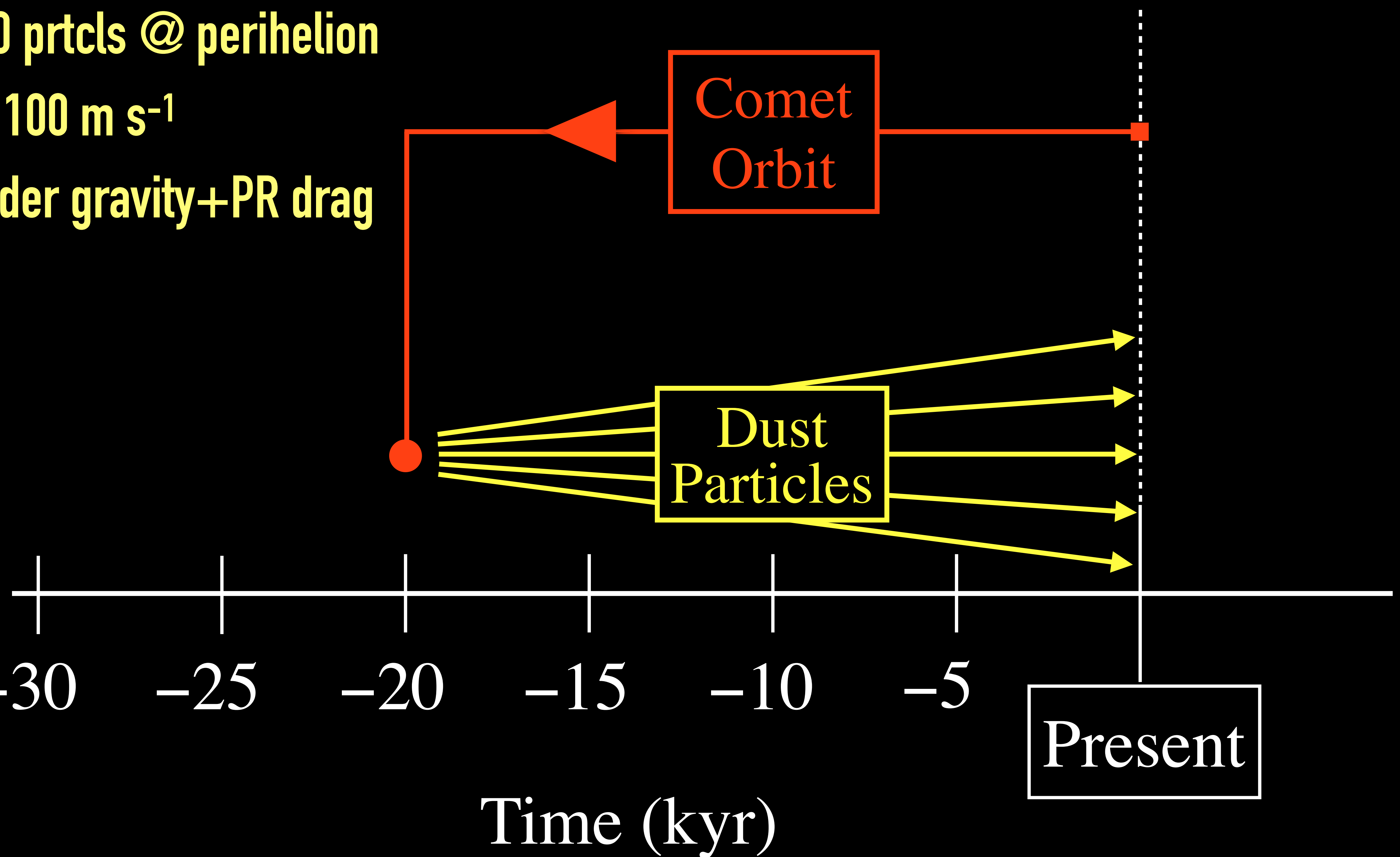
The problem: Ca peak is at TAA = 25°

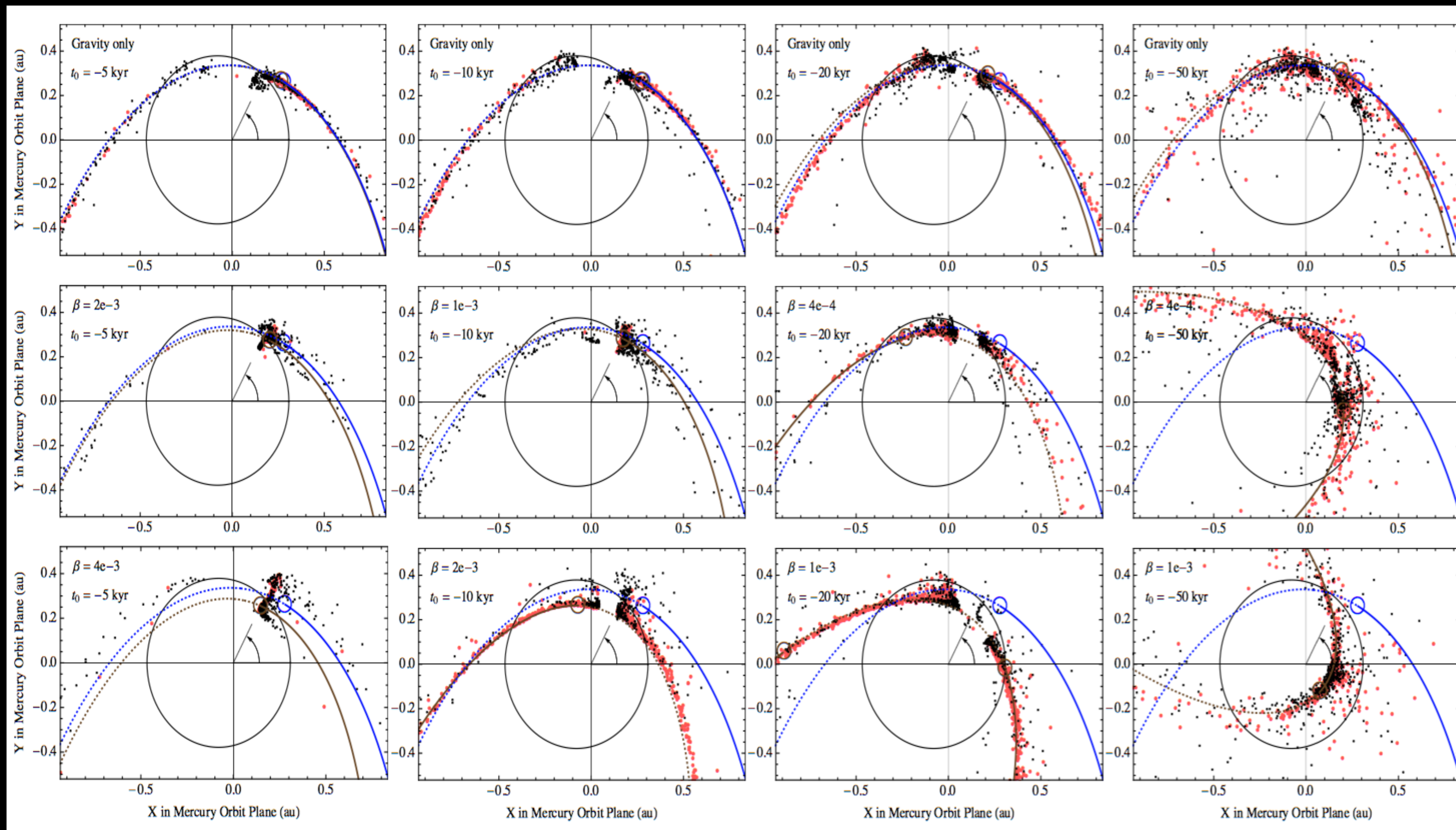
comet node is at TAA = 45°



Simulating the Encke stream

- Pick particle age & size
- eject 1000 prtcls @ perihelion
- Vej = 0 – 100 m s^{-1}
- evolve under gravity+PR drag




Gravity only
$t_0 = -5$ kyr
Gravity only
$t_0 = -10$ kyr
Gravity only
$t_0 = -20$ kyr
Gravity only
$t_0 = -50$ kyr
$\beta = 2e{-}3$
$t_0 = -5$ kyr
$\beta = 1e{-}3$
$t_0 = -10$ kyr
$\beta = 4e{-}4$
$t_0 = -20$ kyr
$\beta = 4e{-}4$
$t_0 = -50$ kyr
$\beta = 4e{-}3$
$t_0 = -5$ kyr
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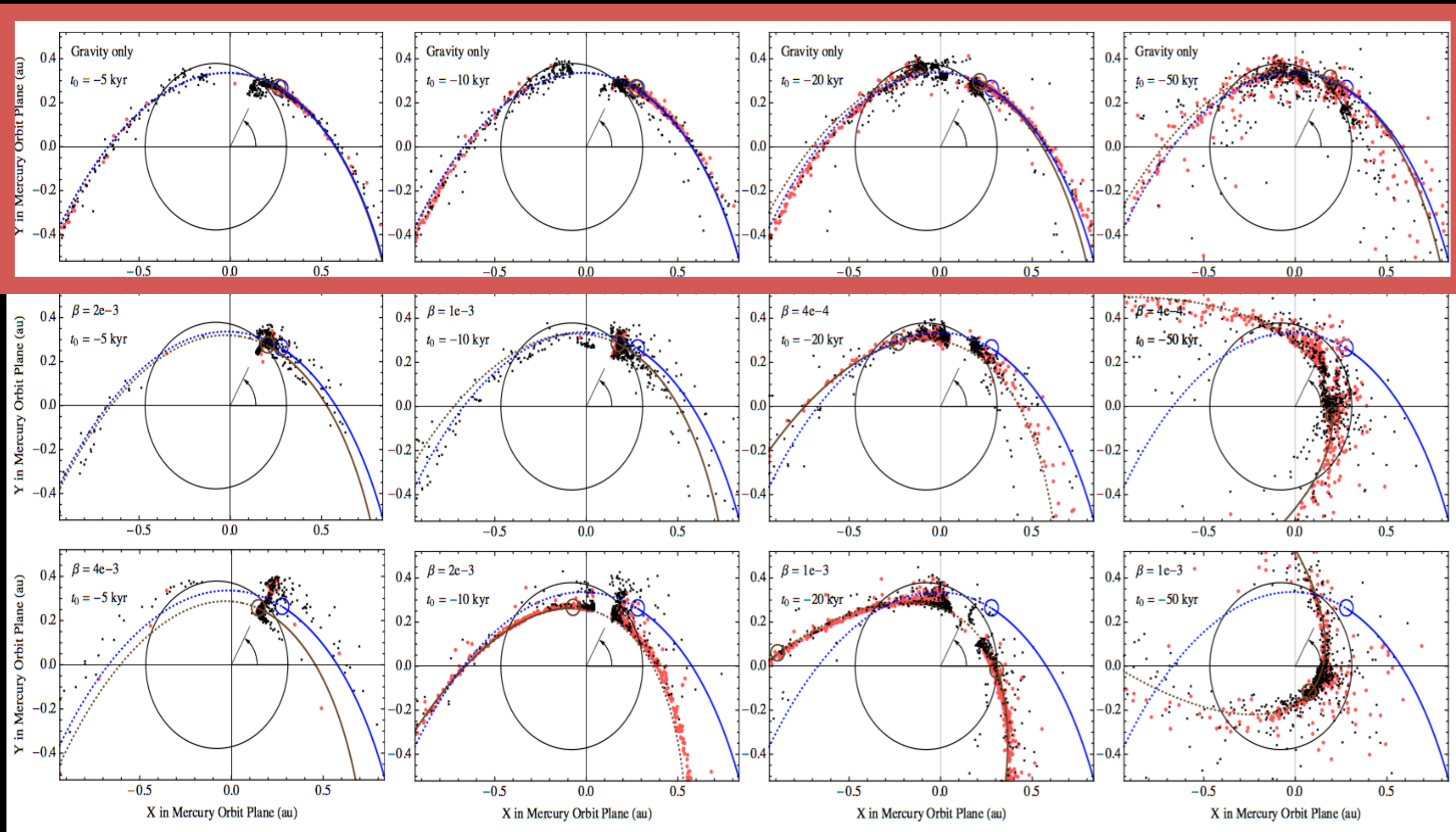
$t_0 = -10$ kyr
$\beta = 1e{-}3$
$t_0 = -20$ kyr
$\beta = 1e{-}3$
$t_0 = -50$ kyr
Y in Mercury Orbit Plane (au)
X in Mercury Orbit Plane (au)

β value

Age

β value


Gravity only
t0 = −5 kyr
Gravity only
t0 = −10 kyr
Gravity only
t0 = −20 kyr
Gravity only
t0 = −50 kyr
β = 2e−3
t0 = −5 kyr
β = 1e−3
t0 = −10 kyr
β = 4e−4
t0 = −20 kyr
β = 4e−4
t0 = −50 kyr
β = 4e−3
t0 = −5 kyr
β = 2e−3
t0 = −10 kyr
β = 1e−3
t0 = −20 kyr
β = 1e−3
t0 = −50 kyr
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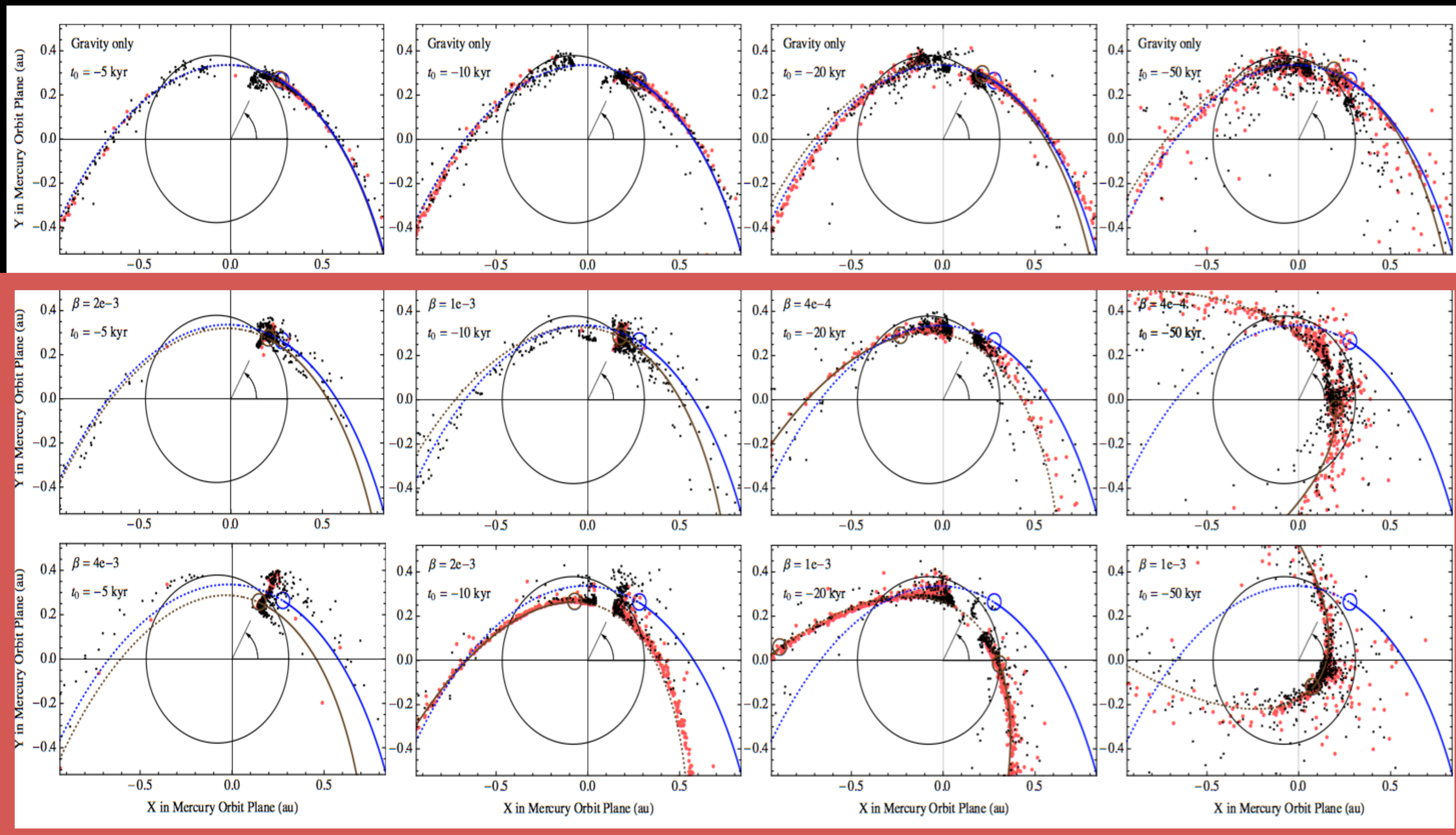
X in Mercury Orbit Plane (au)

Age

β value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$\beta = 2e{-}3$
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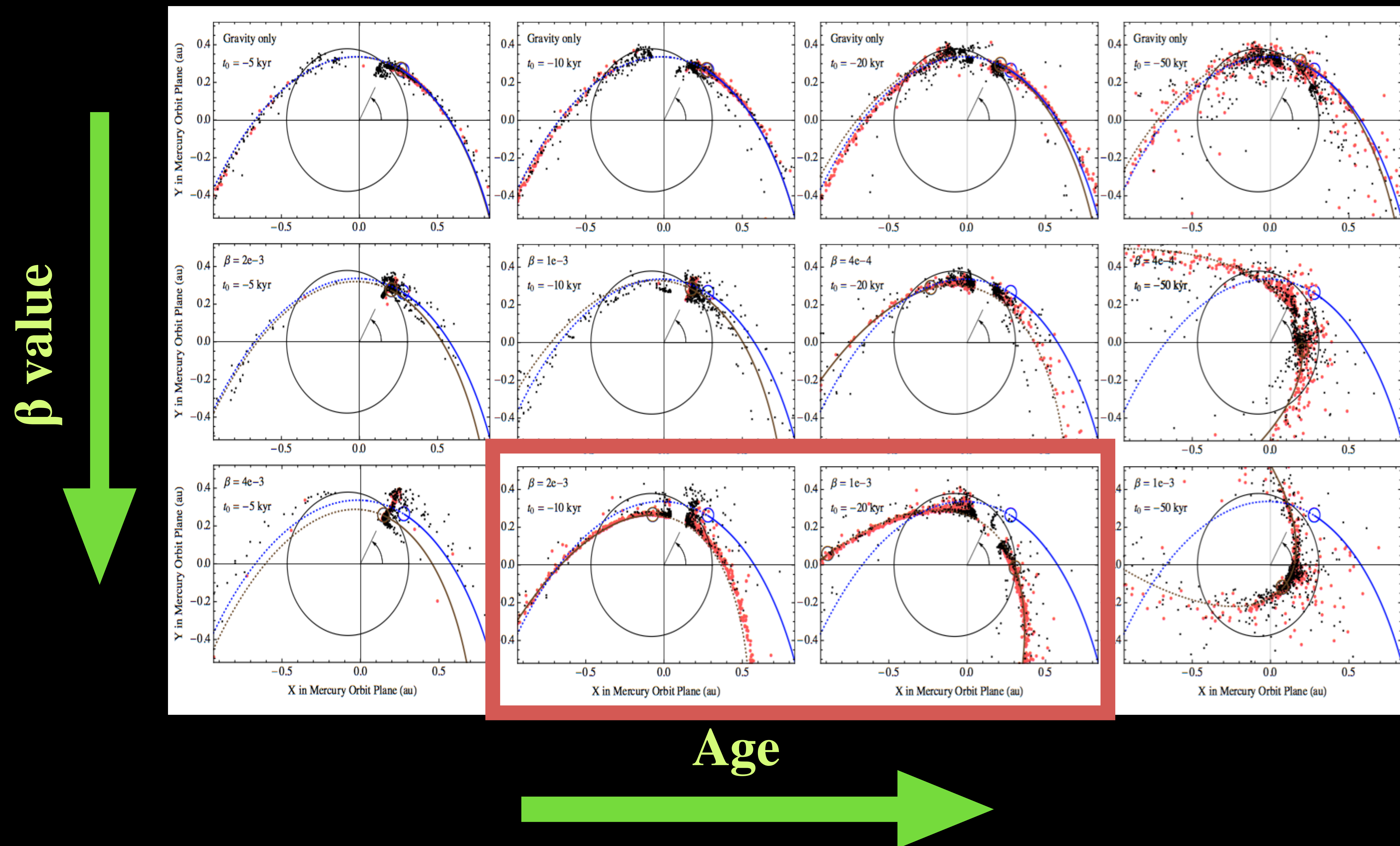
Age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Gravity only
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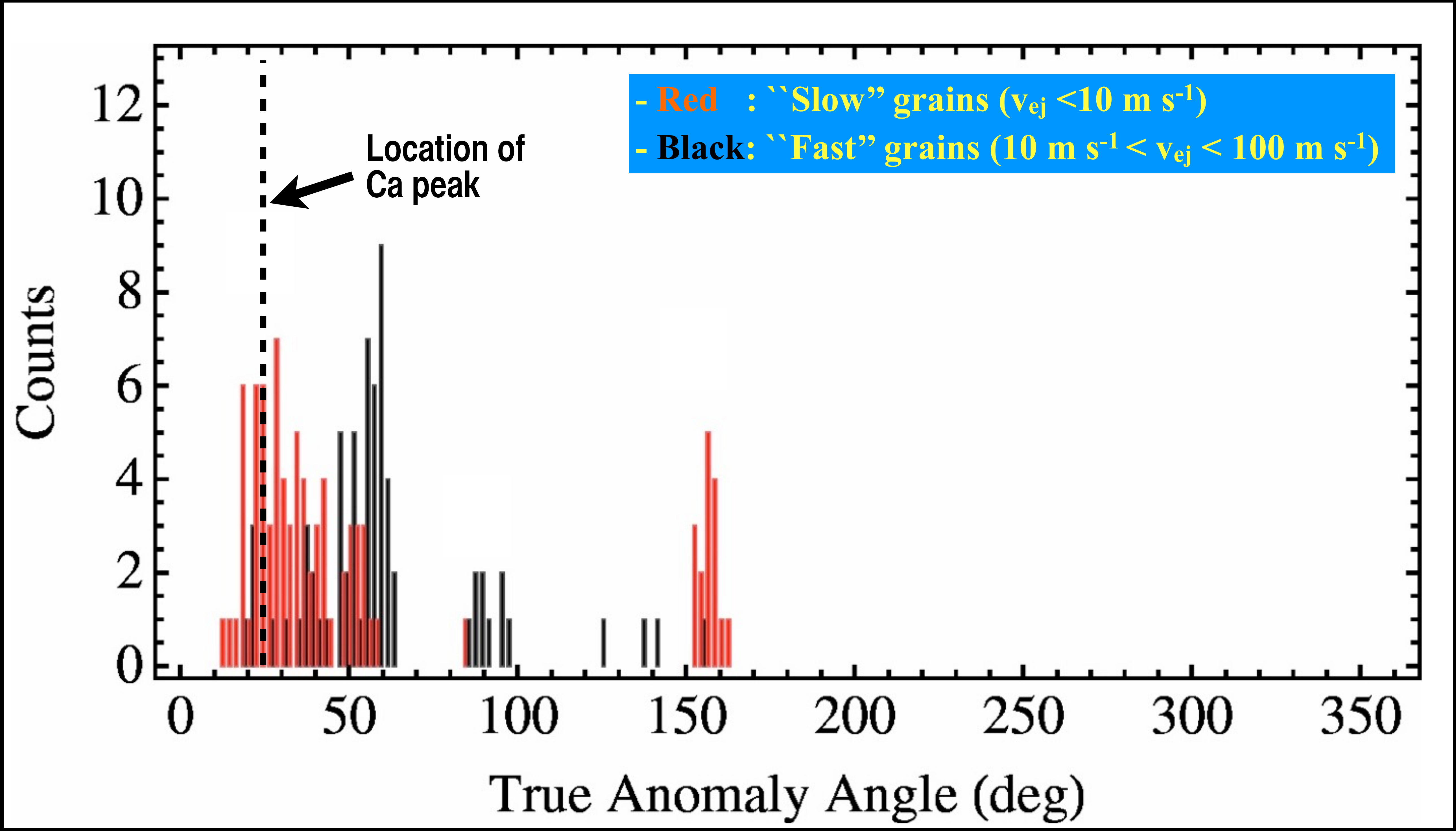
X in Mercury Orbit Plane (au)



$\beta = 2 \times 10^{-3}$ grains (D = 1 mm) ejected 10^4 yr ago

Main Result: Encke stream overlaps max Ca for 1-2 mm-sized grains ejected 10-20×10^3 yr at < 10 m s^{-1} and evolved under PR

Question: Why would that component of the stream dominate the flux at Mercury?

Argument #1: The physical lifetime of a comet is ~10^4 yr (Levison & Duncan, *Science*, 1997); a young, larger comet nucleus produces more dust

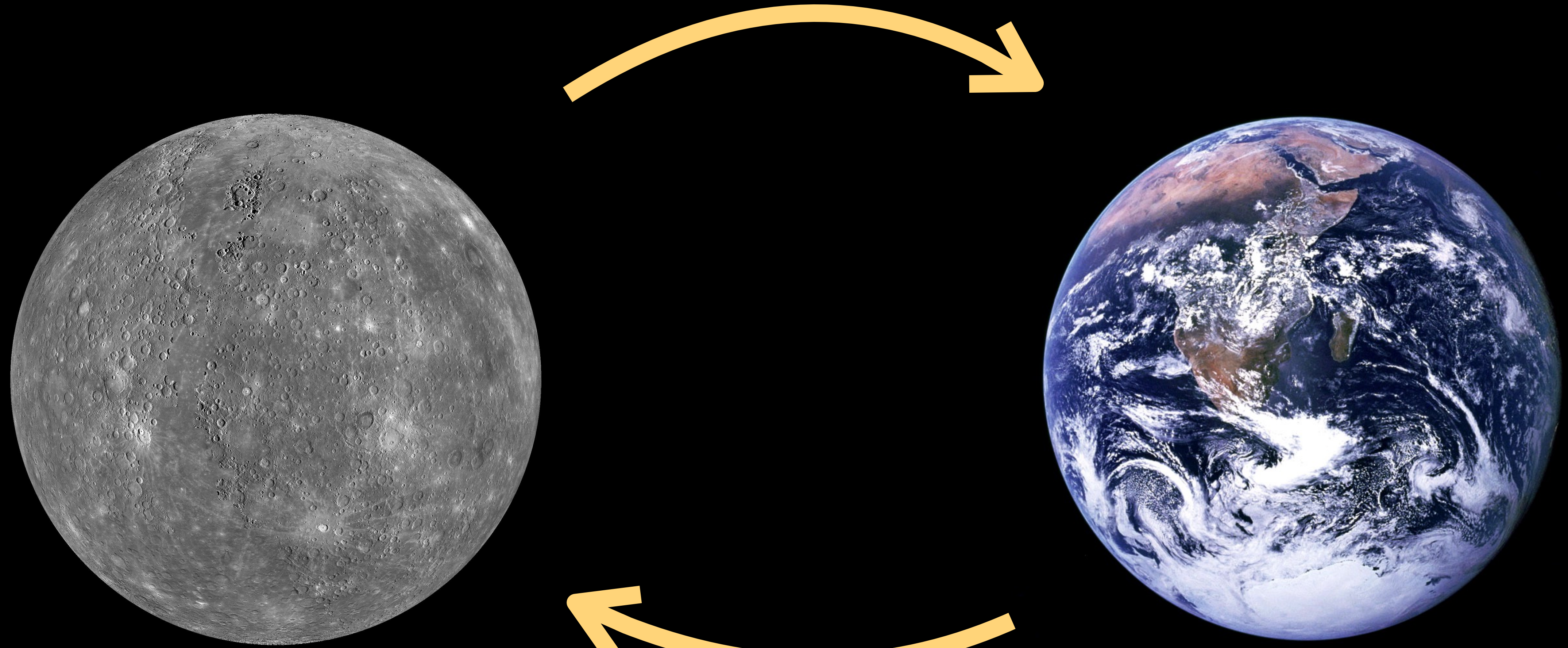
Argument #1a: The Taurid stream is old (8-18 kyr: Babadhzanov & Obrubhov, *CeMDA*, 1992; > 5 kyr: Jenniskens, *Proc. IAU 236*, 2007)

Argument #2: Comets break up (and generate dust!)

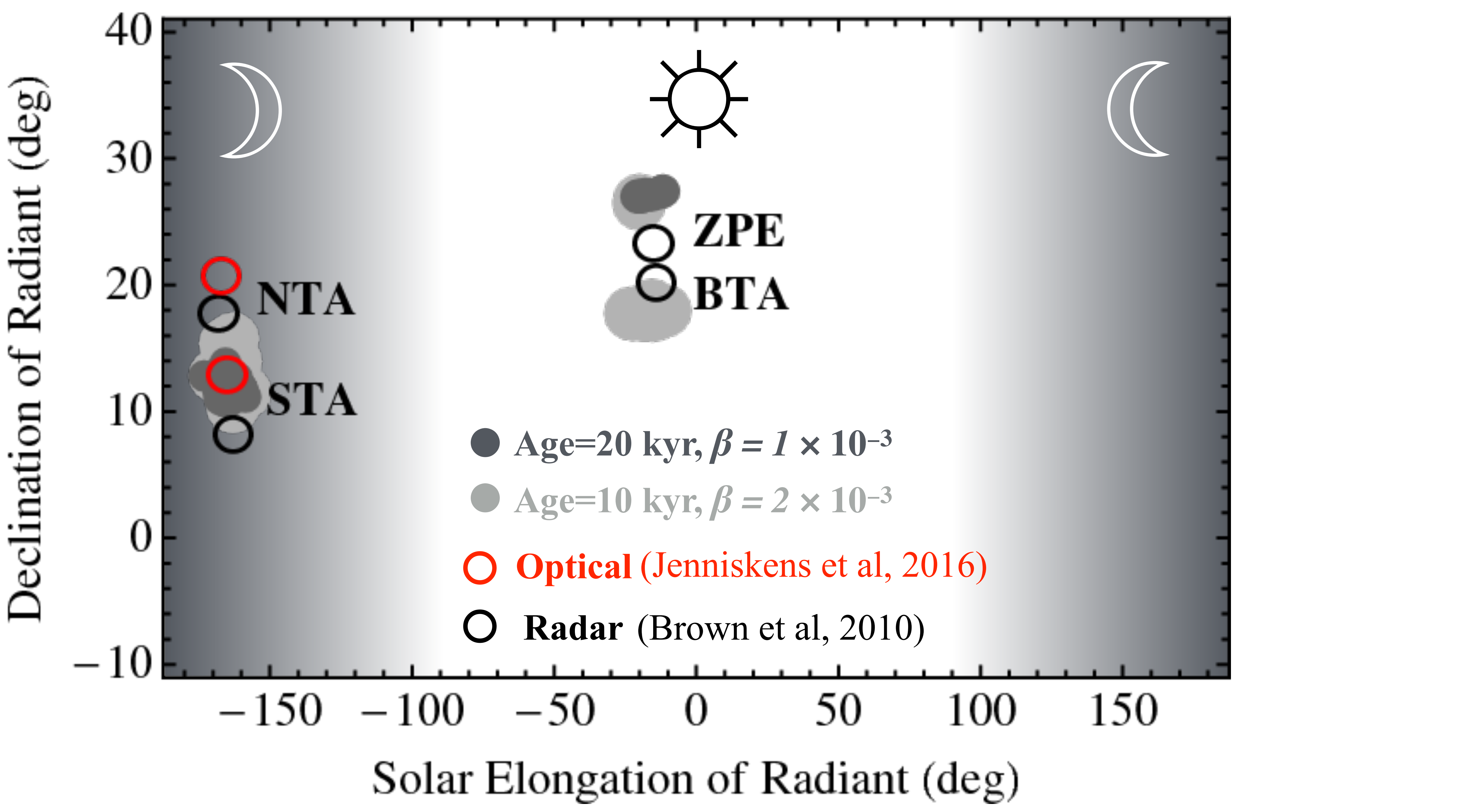
Encke defines its own ``complex" of asteroids: a fragmentation event 10s of kyr ago? Clube & Napier (*MNRAS*, 1984; updated by Jenniskens, *ESA SP-643*, 2007)

Evidence for substreams within Taurid shower (Jenniskens et al, Icarus, 2016)

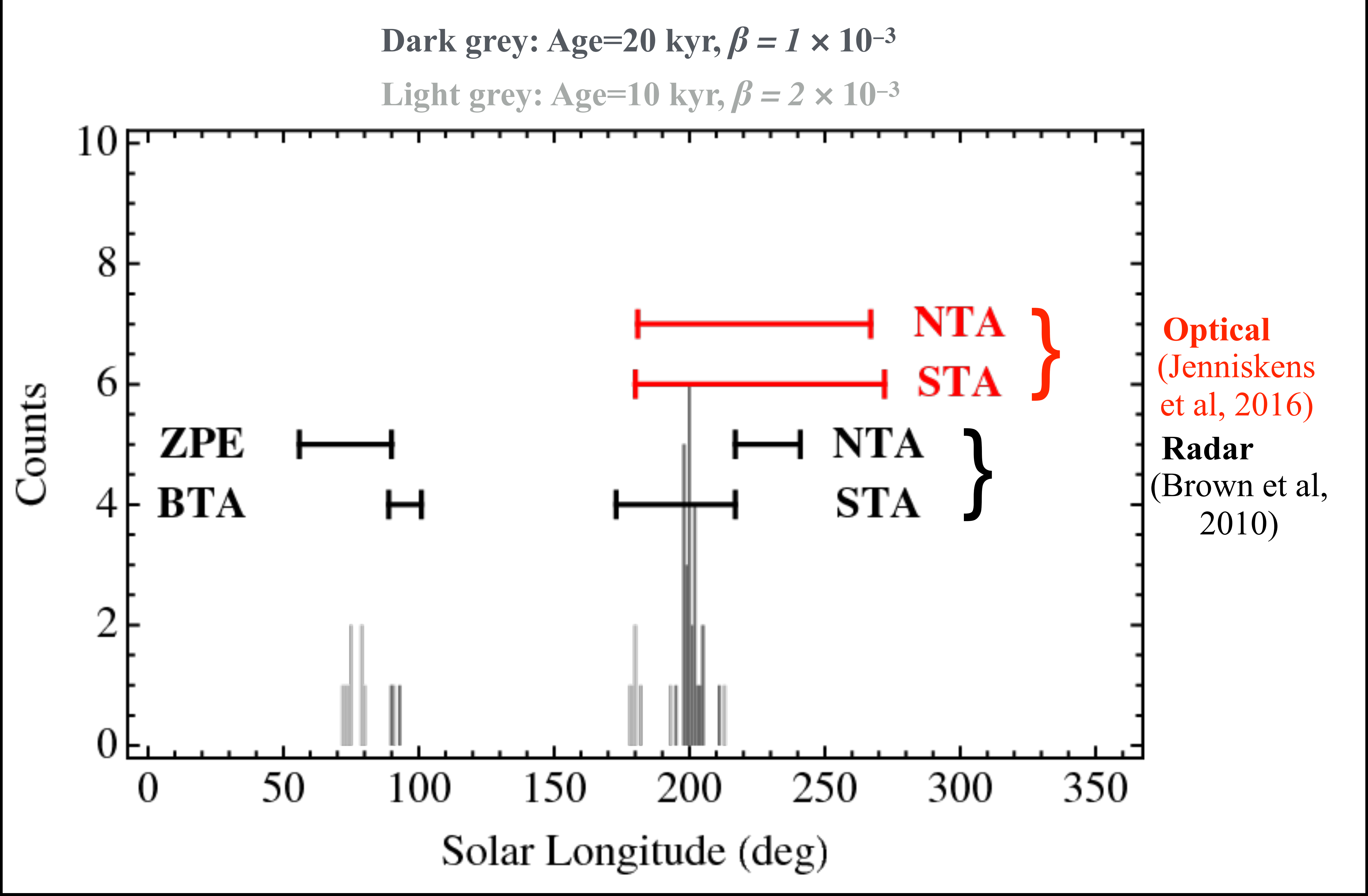
Earth-to-Mercury cross-checks



Check #1: **Radiants** of Mercury Taurids at Earth



Activity period of Mercury Taurids at Earth

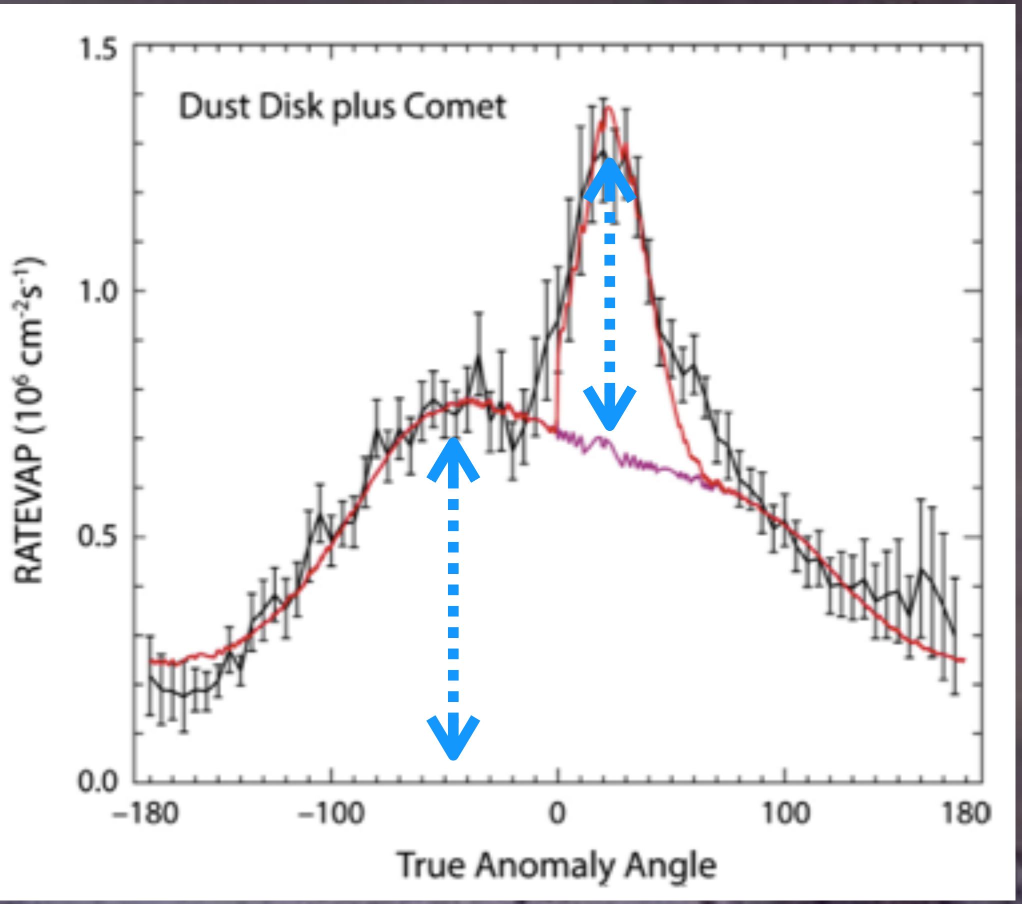


Check #2: Earth Taurid mass flux at Mercury

(stream peak density in mass interval 10^{-6} - 10^{2} g; Jenniskens 1994)

23 g sec^{-1} @ Earth

10 g sec^{-1} @ Mercury



(Ca evap. rate)$_{Encke}$ ≈ 0.5 (Ca Evap. Rate)$_{ZC}$

Summary

- Encke stream overlaps max Ca for $\beta \sim 10^{-3}$ grains ejected 10 - 20 kyr ago

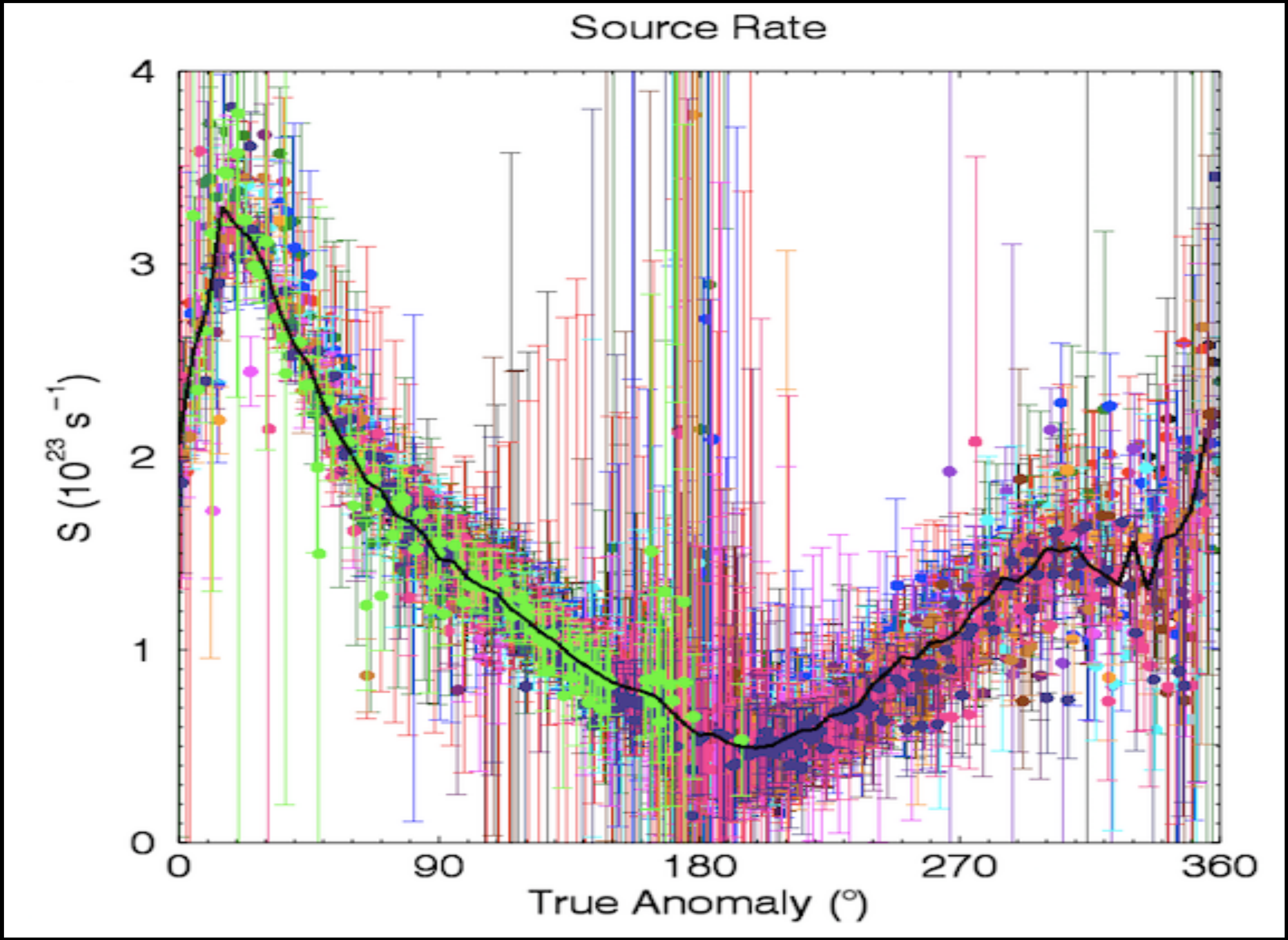
- consistent with: age of comet & meteor stream; fragmentation of a Taurid complex progenitor body

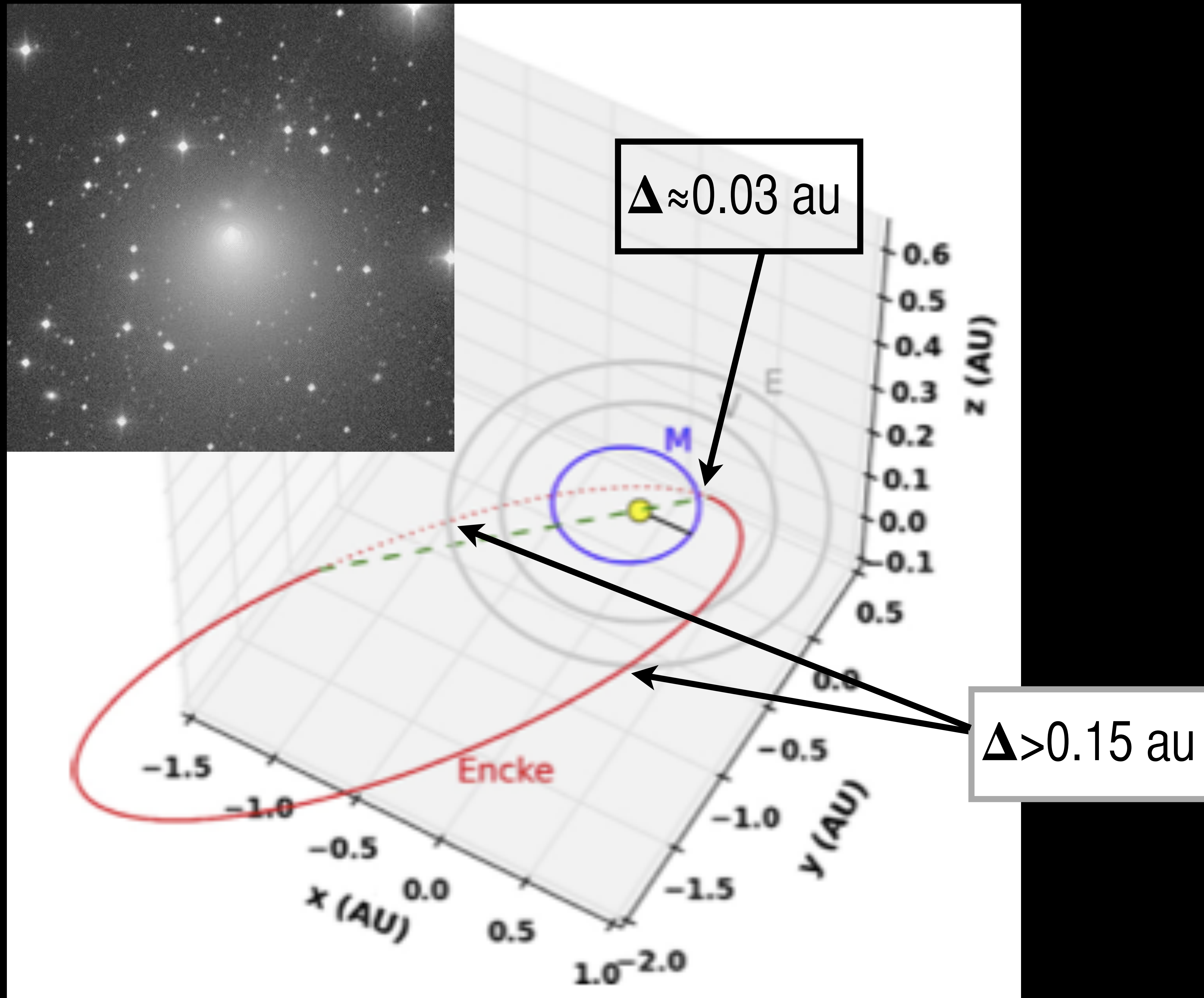
- a conundrum: Earth Taurid mass flux reproduces magnitude of Ca feature at Mercury; <u>but</u> delivered by particles within narrow range in β

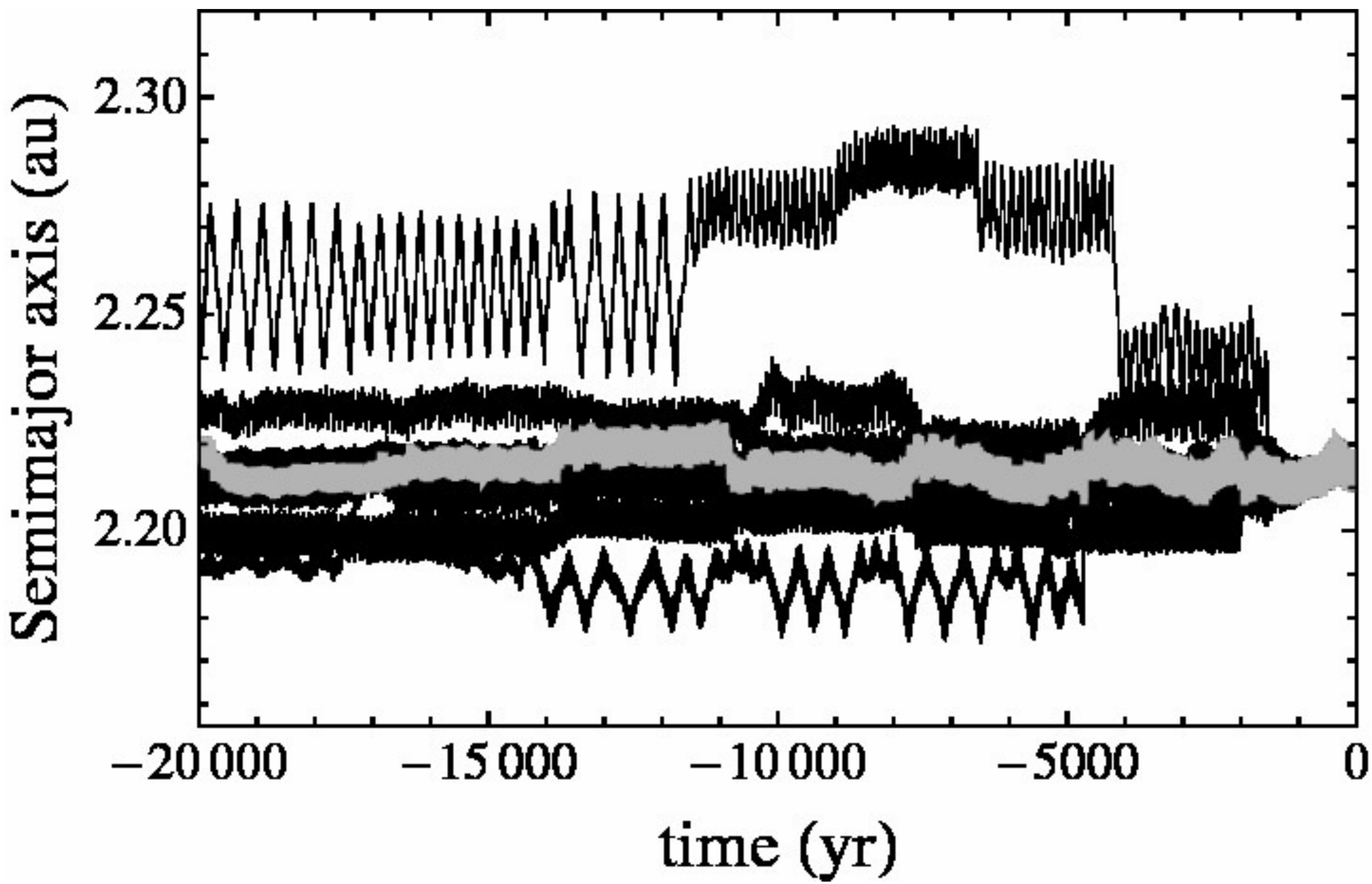
For details, see Christou, Killen & Burger, 2015, *GRL* **42**, 7311-7318

Additional Slides

Calcium in Mercury's exosphere: MESSENGER MASCS observations

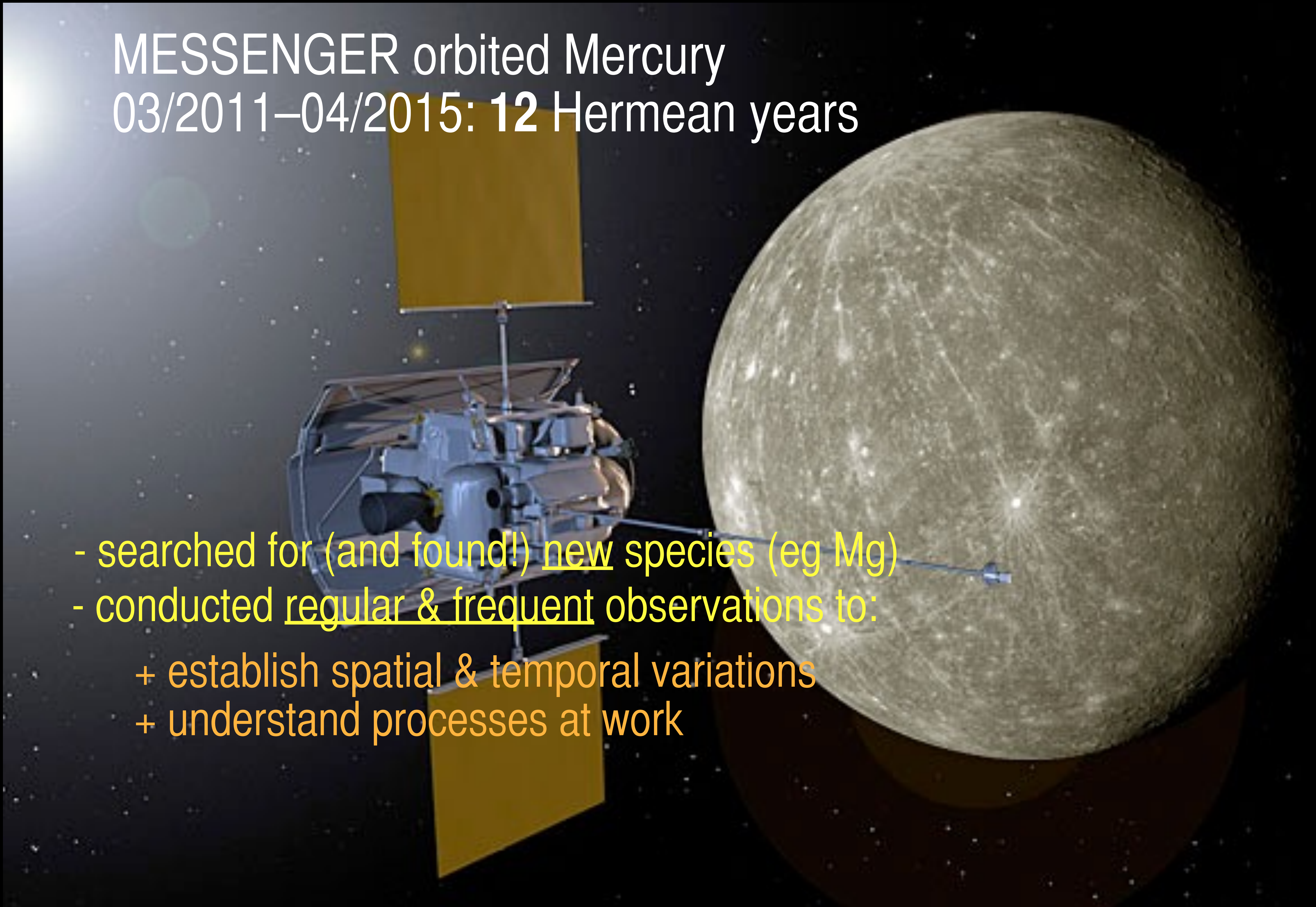



Δ≈0.03 au
Δ>0.15 au
E
M
Encke
x (AU)
−1.5
−1.0
−0.5
0.0
0.5
1.0
y (AU)
0.5
0.0
−0.5
−1.0
−1.5
−2.0
z (AU)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1


Semimajor axis (au)
2.30
2.25
2.20
−20 000
−15 000
−10 000
−5000
0
time (yr)


2P/Encke from MESSENGER
November 2013

MESSENGER orbited Mercury
03/2011–04/2015: **12** Hermean years



- searched for (and found!) <u>new</u> species (eg Mg)
- conducted <u>regular & frequent</u> observations to:
    + establish spatial & temporal variations
    + understand processes at work