Solar and Planetary Destabilization of the Earth-Moon Triangular Lagrangian Points

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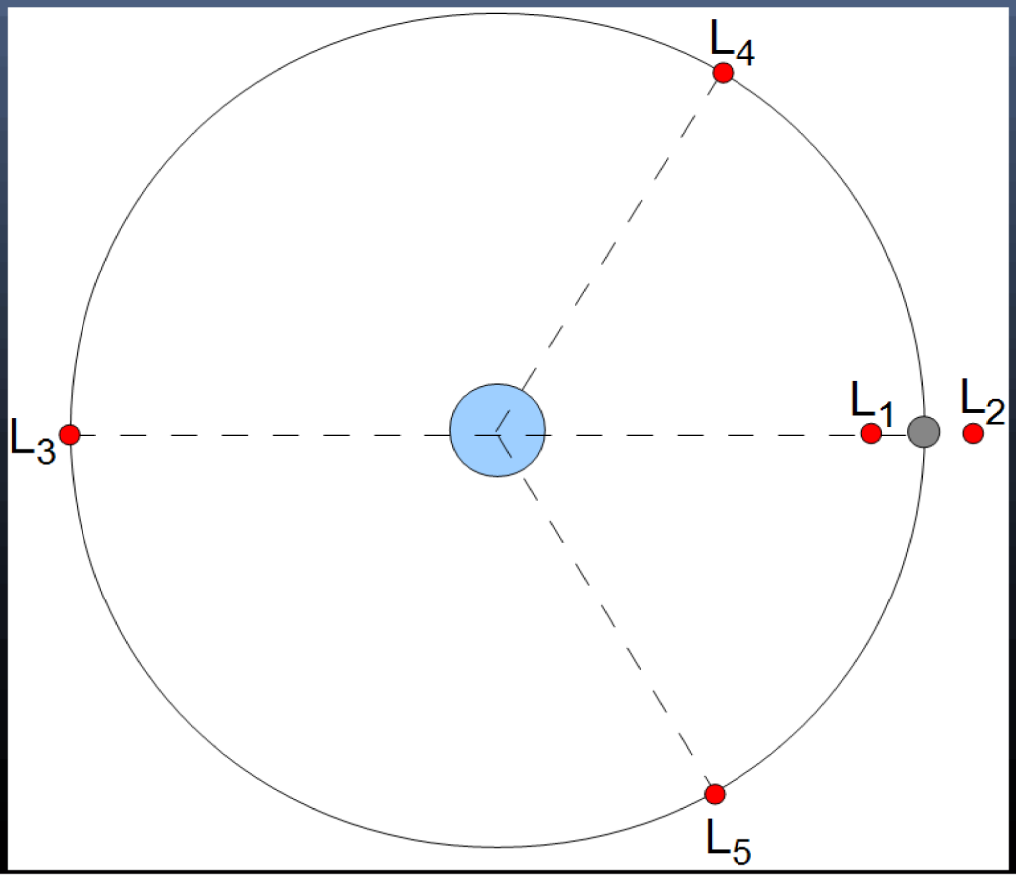
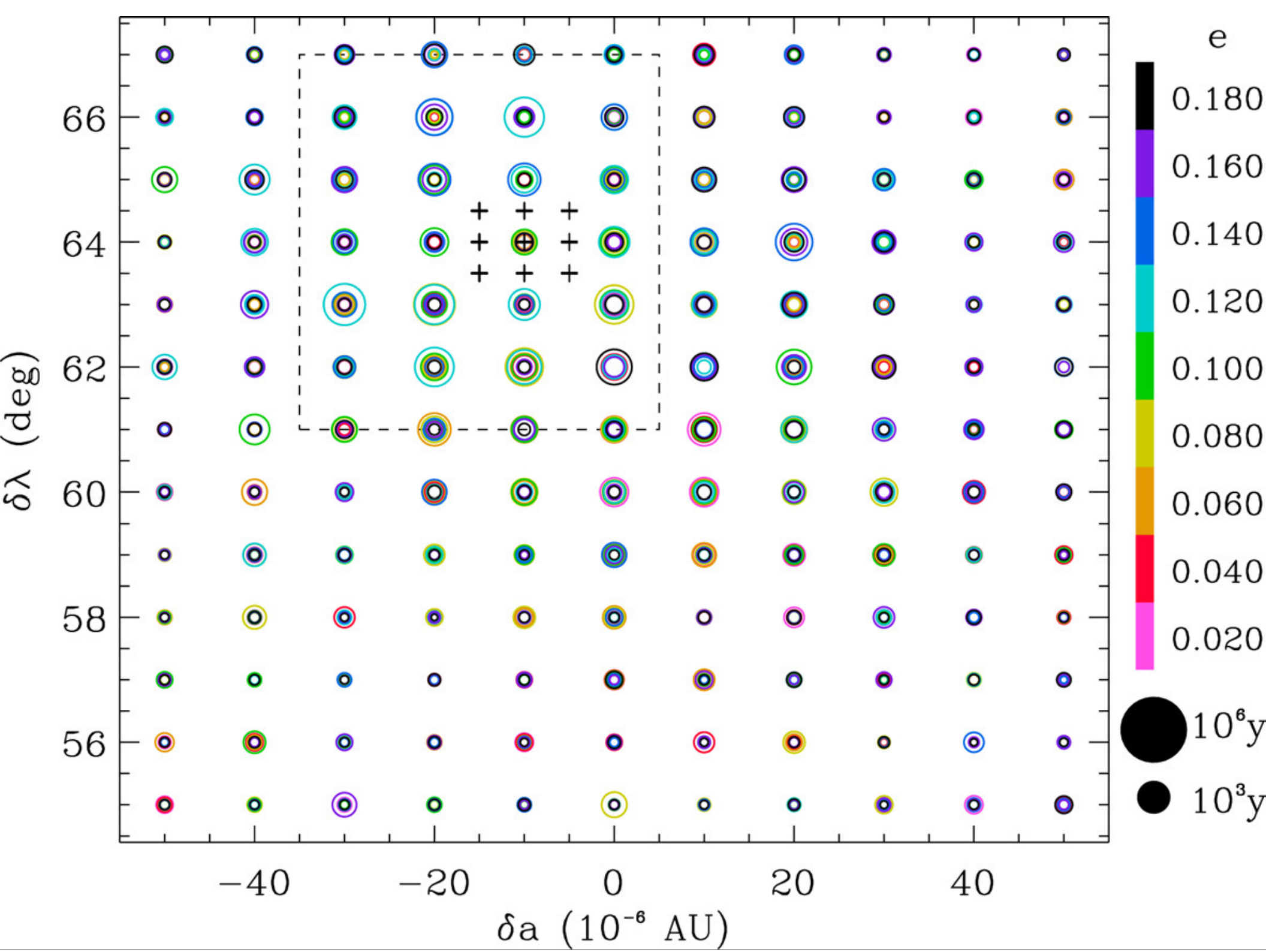
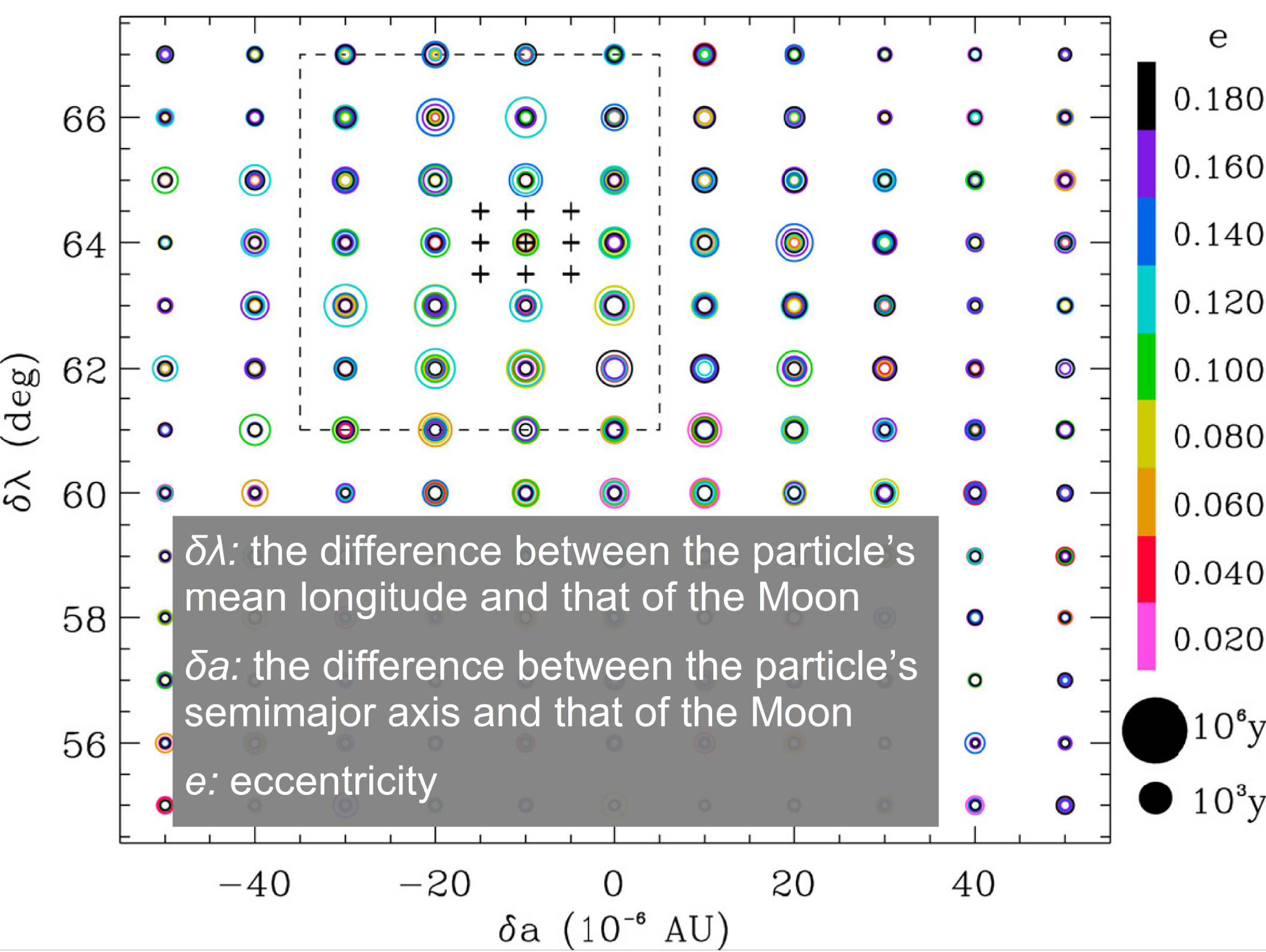
Sara Case – ASTR630 – TERPS Conference Fall 2010

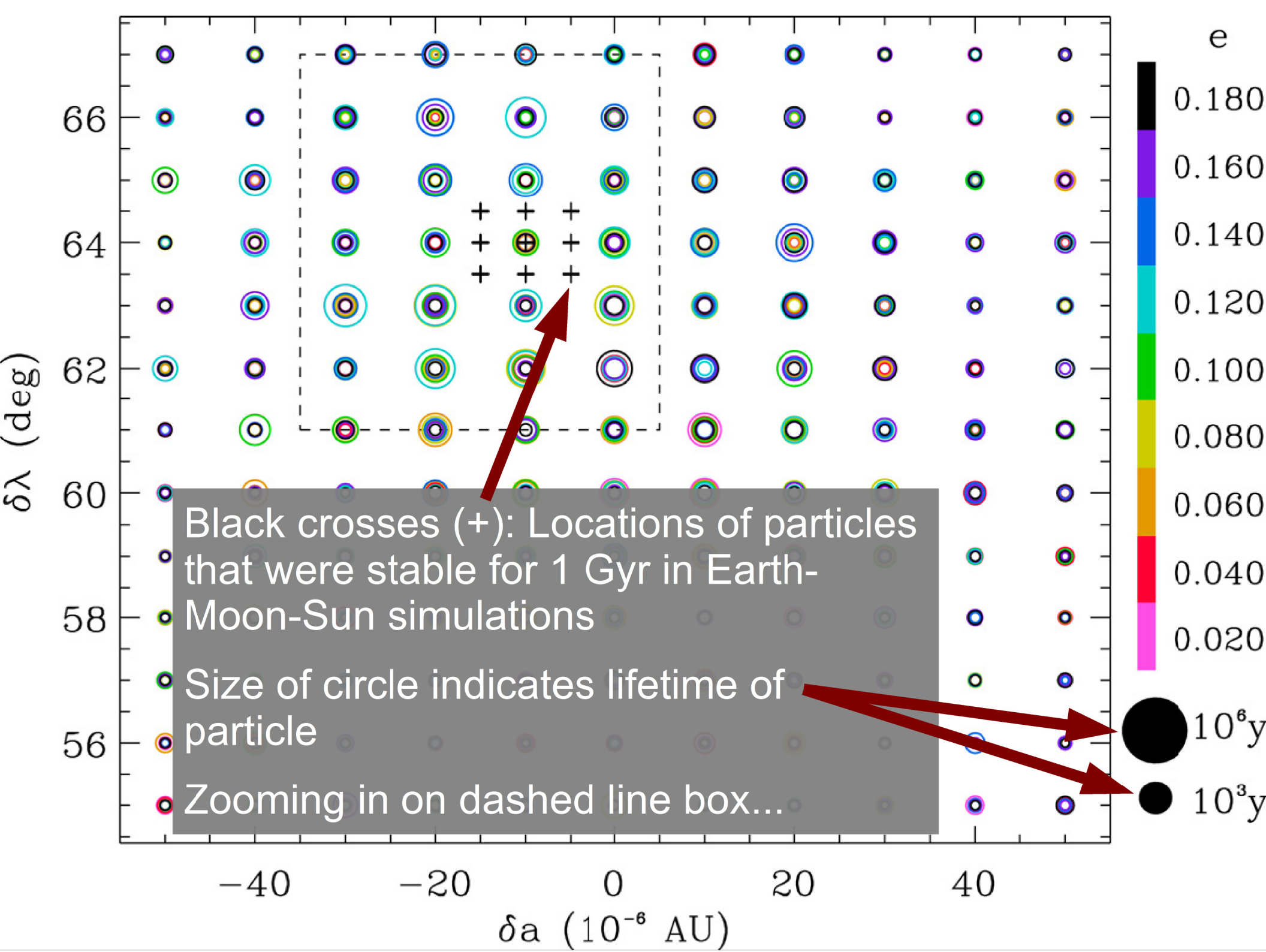


Why haven't any objects been discovered at Earth-Moon L_4/L_5?

- Triangular Lagrangian points (L_4 and L_5) are stable in the CRTBP
- Orbiters have been found in the Sun-Jupiter and Sun-Neptune systems and at L_4/L_5 of two of Saturn's moons
- In numerical integrations, Earth-Moon L_4/L_5 orbiters survived for over a billion years, even when Sun effects were included
- When planetary effects were added, no particles survived for more than 3 Myr


e
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
10^6y
10^3y
66
64
62
60
58
56
δλ (deg)
−40
−20
0
20
40
δa (10^{-6} AU)


δλ (deg)
66
64
62
60
58
56
−40
−20
0
20
40
δa (10⁻⁶ AU)
e
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
10⁶y
10³y
δλ: the difference between the particle's mean longitude and that of the Moon
δa: the difference between the particle's semimajor axis and that of the Moon
e: eccentricity


e
0.180
0.160
0.140
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10^6y
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δλ (deg)
−40
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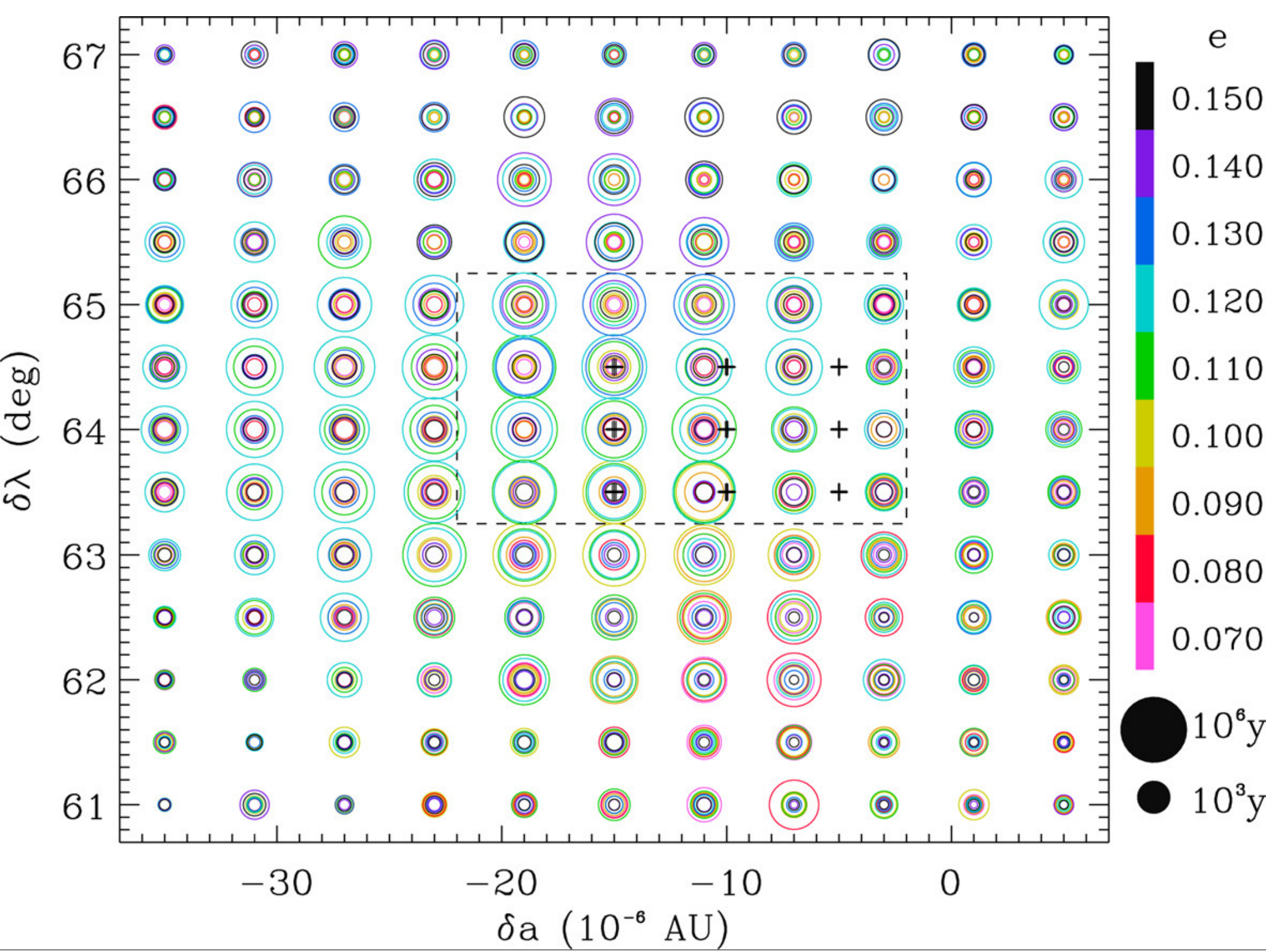
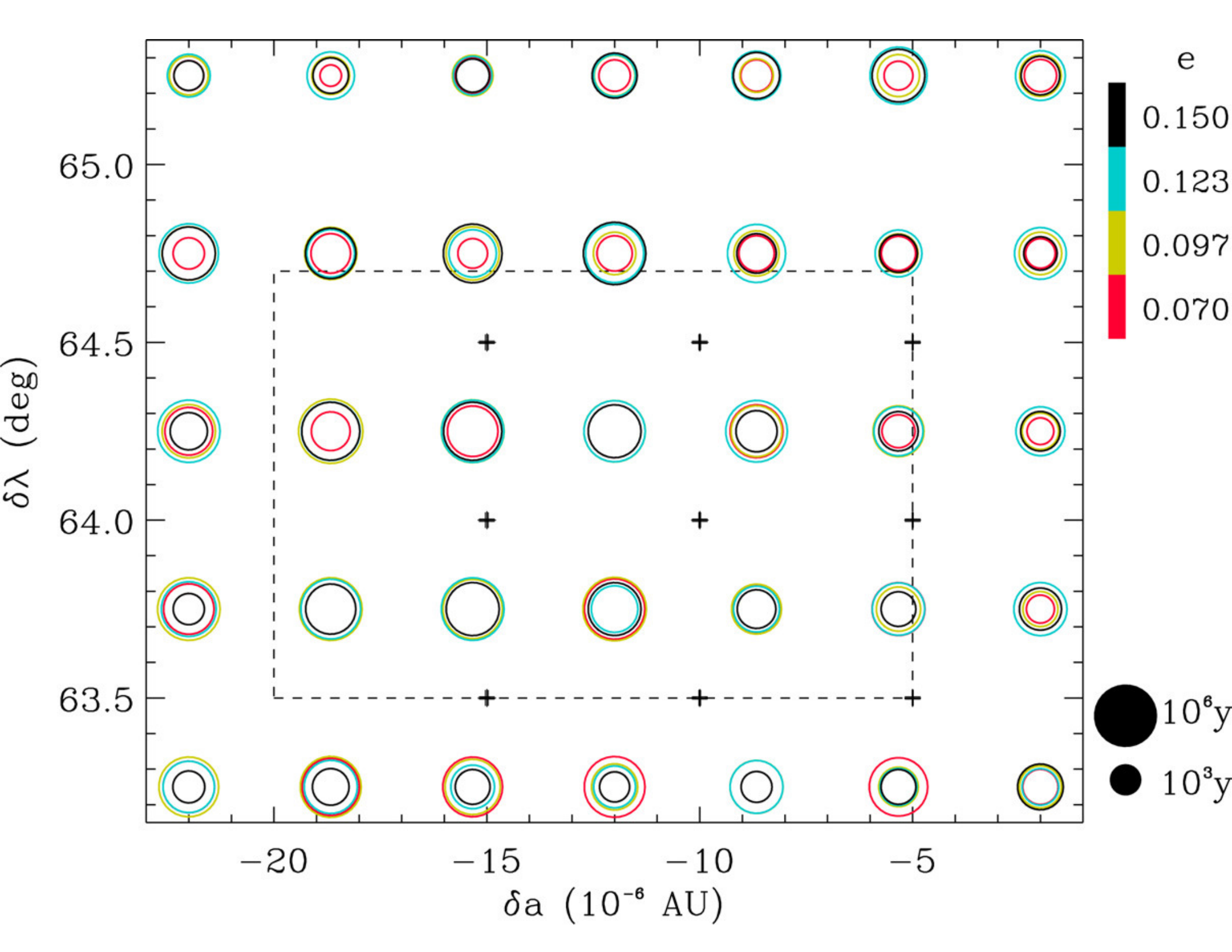
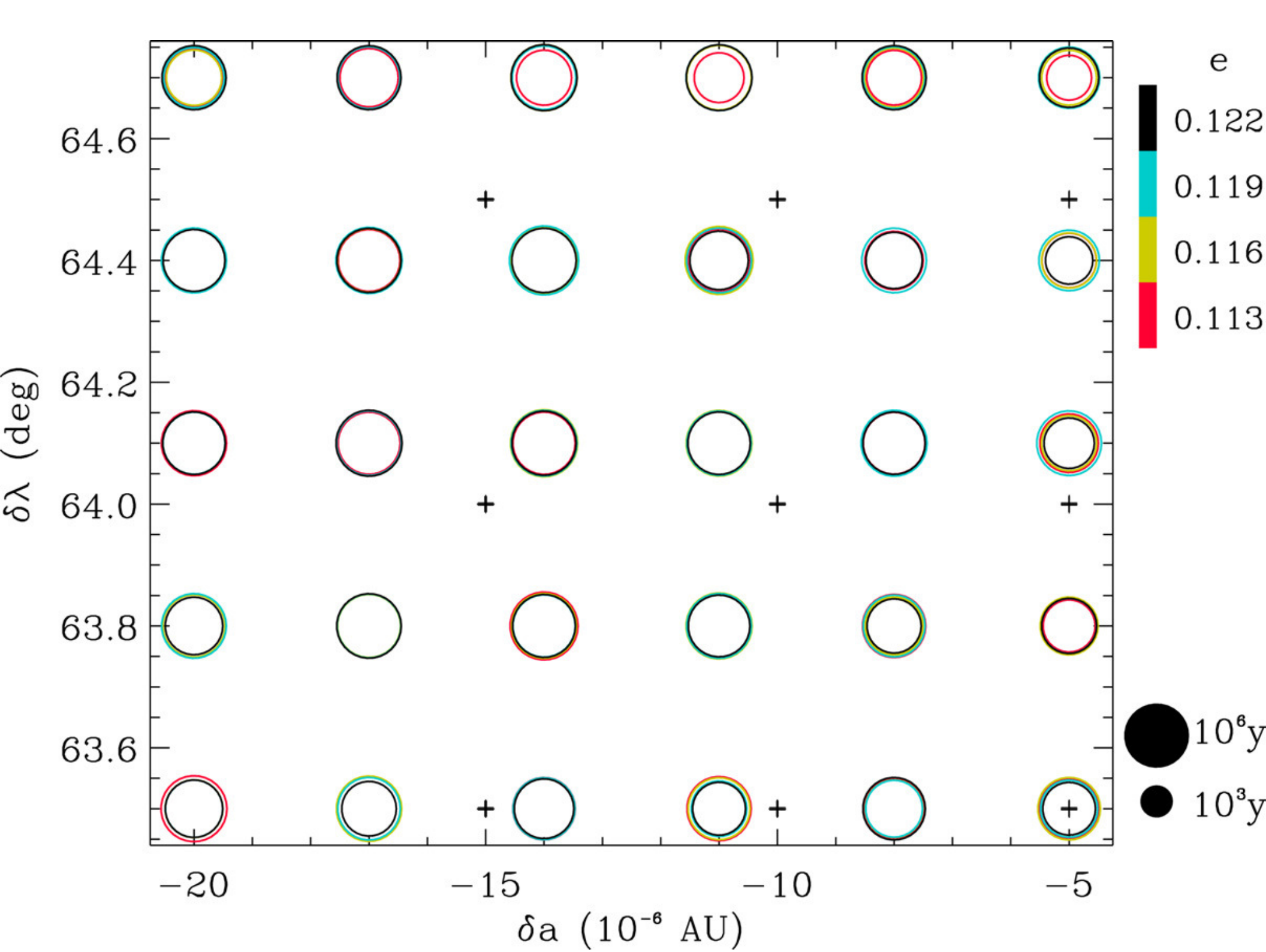
δa (10^{-6} AU)
Black crosses (+): Locations of particles that were stable for 1 Gyr in Earth-Moon-Sun simulations
Size of circle indicates lifetime of particle
Zooming in on dashed line box...


67
66
65
64
63
62
61
δλ (deg)
−30
−20
−10
0
δa (10⁻⁶ AU)
e
0.150
0.140
0.130
0.120
0.110
0.100
0.090
0.080
0.070
10⁶y
10³y


e
0.150
0.123
0.097
0.070
65.0
64.5
64.0
63.5
δλ (deg)
−20
−15
−10
−5
δa (10⁻⁶ AU)
10⁶y
10³y


e
0.122
0.119
0.116
0.113
64.6
64.4
64.2
64.0
63.8
63.6
δλ (deg)
−20
−15
−10
−5
δa (10⁻⁶ AU)
10⁶y
10³y

Possible explanations for short particle lifetimes?

- High eccentricity of the Earth's orbit
- Variations in Earth's eccentricity
- Direct effects from planetary resonances

Possible explanations for short particle lifetimes?

- High eccentricity of the Earth's orbit
  - Simulations with large but constant Earth eccentricity had particles that survived longer than 100 Myr
- Variations in Earth's eccentricity
- Direct effects from planetary resonances

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- ~~High eccentricity of the Earth's orbit~~
- Variations in Earth's eccentricity
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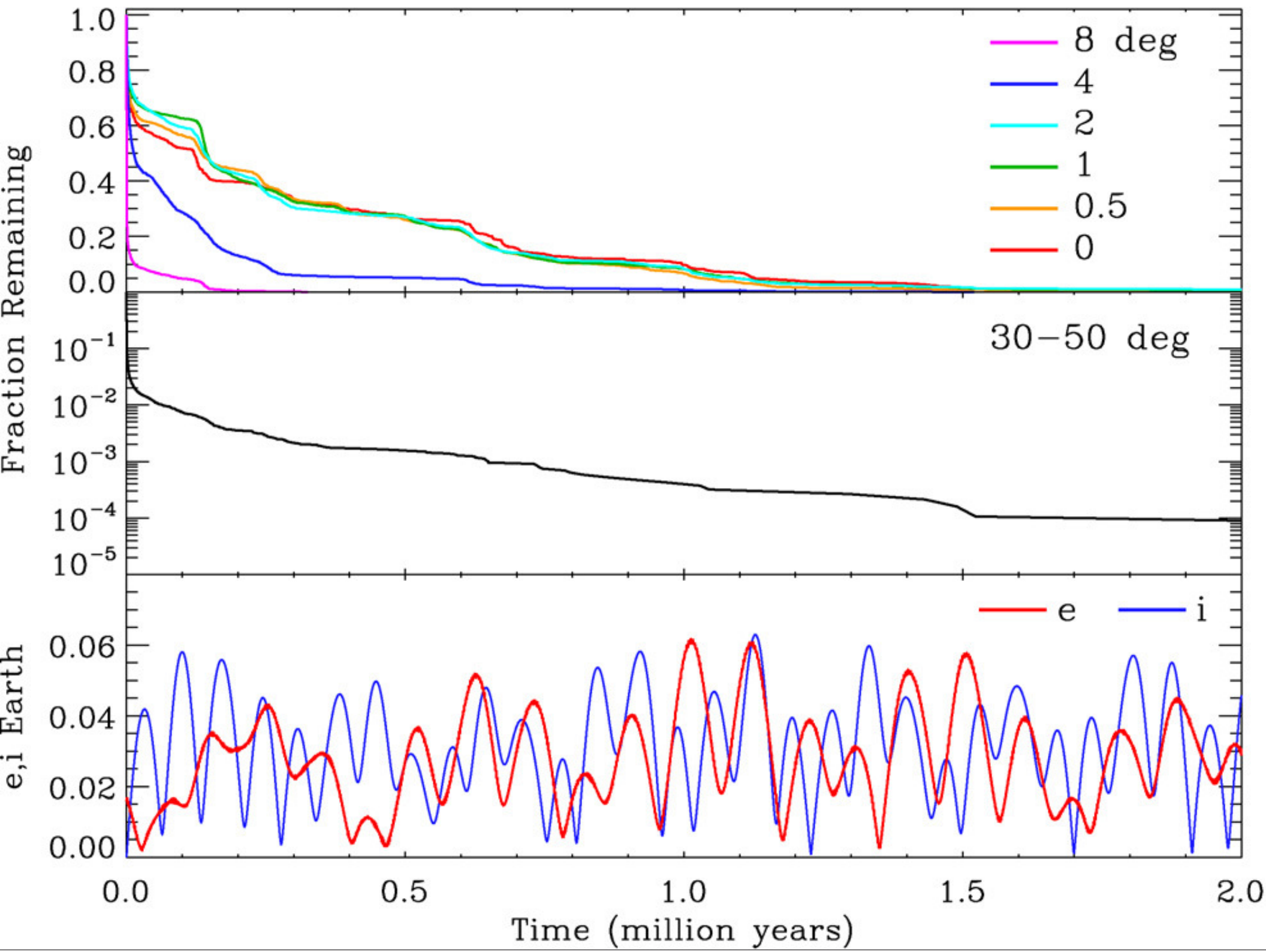
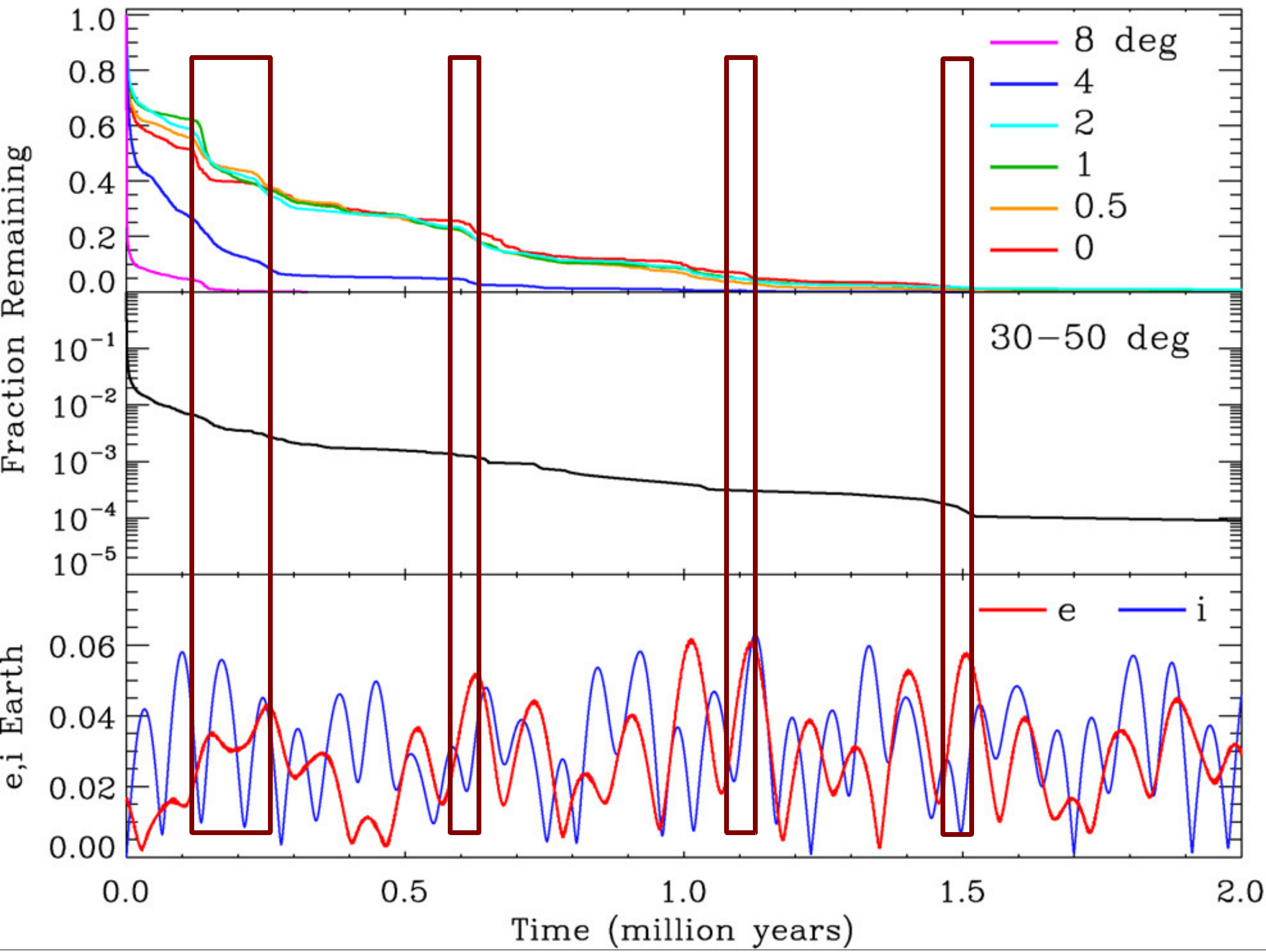
Possible explanations for short particle lifetimes?

- ~~High eccentricity of the Earth's orbit~~
- Variations in Earth's eccentricity
  - More particles appear to destabilize when Earth's eccentricity is increasing
- Direct effects from planetary resonances


Fraction Remaining
1.0
0.8
0.6
0.4
0.2
0.0
8 deg
4
2
1
0.5
0
30−50 deg
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
e,i Earth
0.06
0.04
0.02
0.00
e
i
0.0
0.5
1.0
1.5
2.0
Time (million years)


Fraction Remaining
1.0
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1
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10^{-1}
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10^{-5}
e,i Earth
0.06
0.04
0.02
0.00
e
i
0.0
0.5
1.0
1.5
2.0
Time (million years)

Conclusions

- Final simulation of Earth-Moon-Sun (not other planets)
  - Artificially increasing Earth's eccentricity
  - All particles lost within 830,000 years
- Third possibility (direct planetary resonance) was not investigated