# The Temporal Variation of the Rate of Interplanetary Enhancements seen in Association with Asteroids 2201 Oljato and 138175 at Earth: Evidence for Co-orbital Material Disturbed by Gravitational Interactions

M. Connors, H.R. Lai, H.Y. Wei, C.T. Russell

SSERVI Meeting
1555-1610, Monday, July 21, 2014
Parallel Session #2, Bldg 152, Side Room
Ames Research Center
July 2014

# Collisions in Space

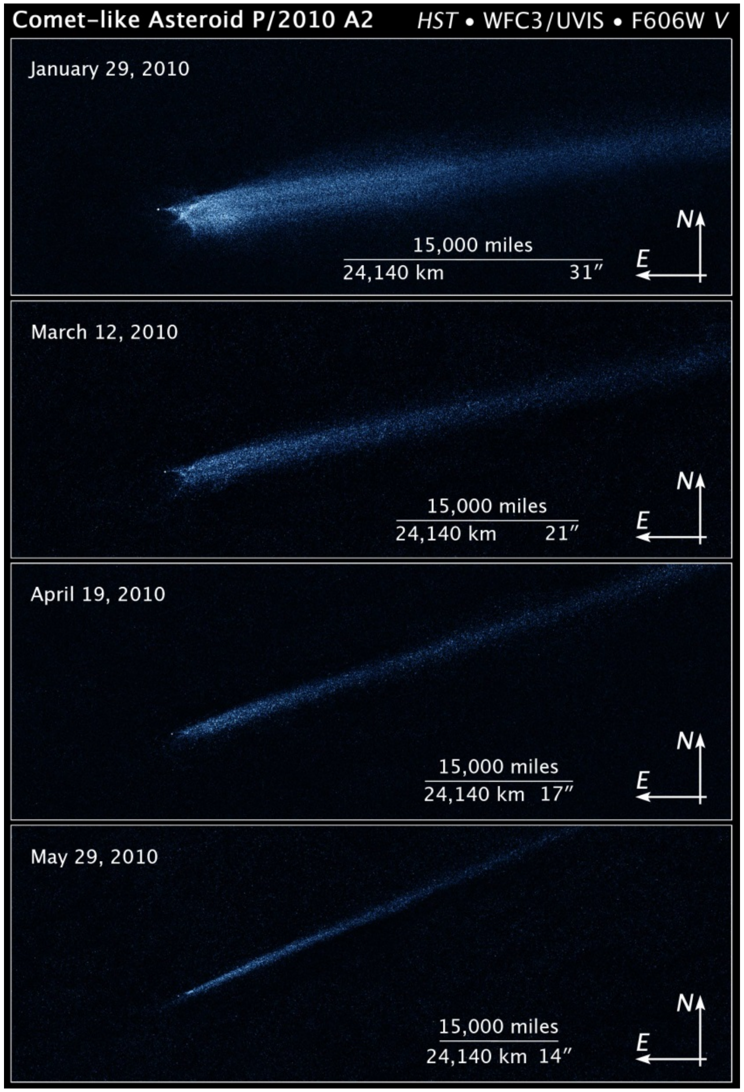
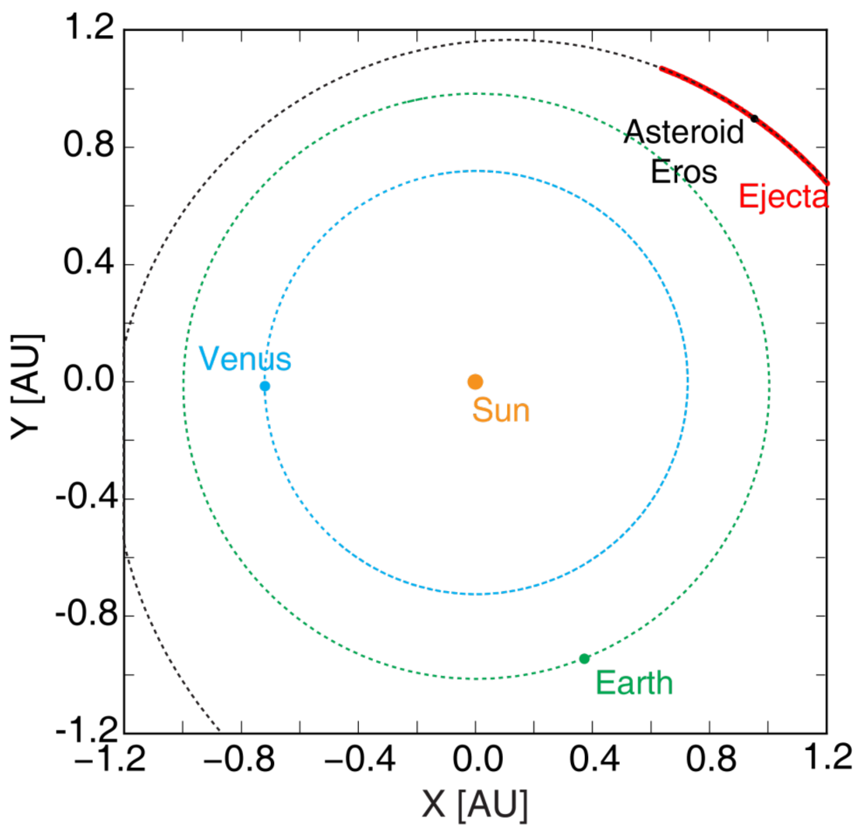



**Illustration Credit:** NASA, ESA, Z. Levay (STScI)
**Science Credit:** NASA, ESA, D. Jewitt

- Near 1AU the typical collision speed of meteoroids and asteroids is 20km/s. At this speed an impactor can completely disrupt a body $10^6$ times more massive.
- Objects that are large enough to be observed optically from the Earth are rarely seen to suffer destructive collisions.
- Non-destructive collisions with such large objects can produce co-orbiting debris.
- Since the number of impactors grows rapidly with decreasing size, the co-orbiting debris encounters destructive collisions much more frequently. We will give an example of this collisional removal of debris near the end of this talk.

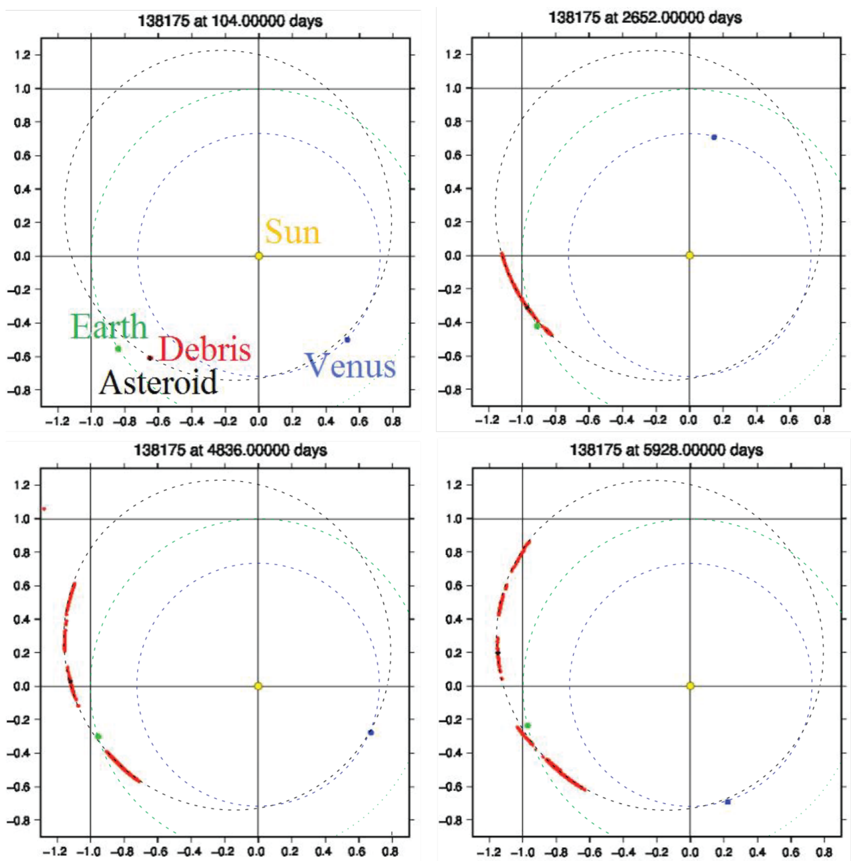
# Orbital Evolution of Co-orbitals by Gravity Perturbation: Eros with No Close Encounters




NOTE: Test case only. Eros is not known to have a debris trail.

- In the simulation, we assume that debris is ejected from the parent body forward and backward.
- If the debris has no close encounters with any planets as we see here for Eros, the debris remains in a continuous stream leading and trailing the parent body.

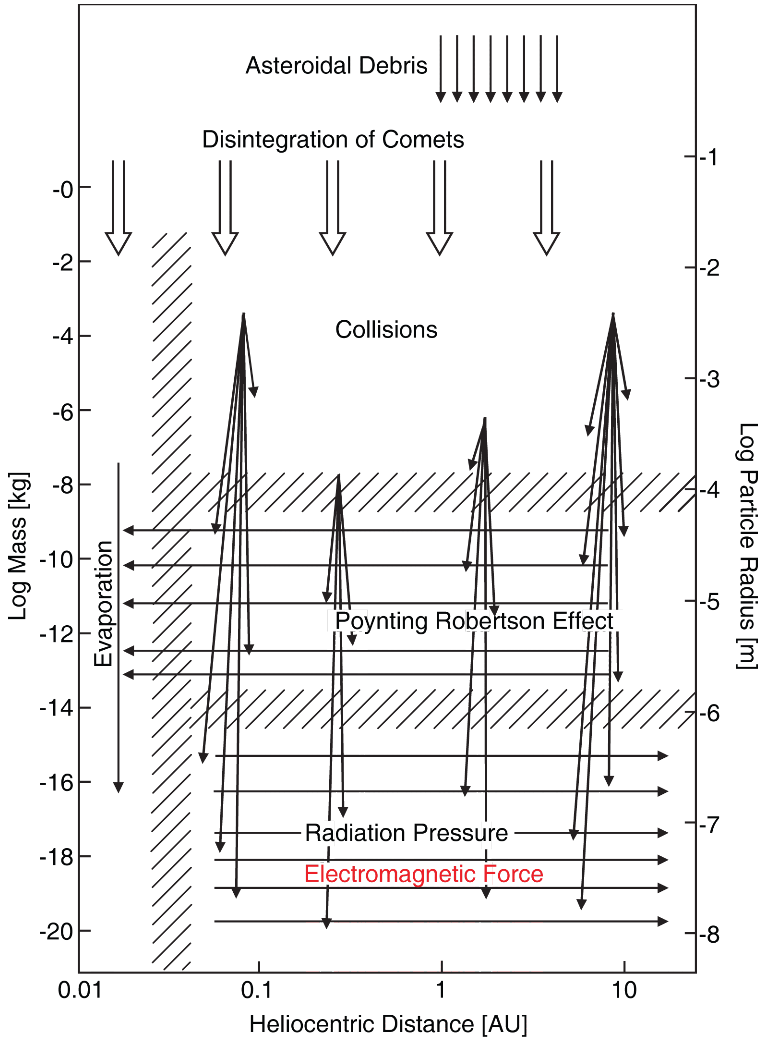
# Orbital Evolution of Co-orbitals by Gravity Perturbation: 138175 with Close Planetary Encounters




See Connors, Russell, Lai, MNRAS Lett. 443(1), 2014,, for similar results at 1 m/s

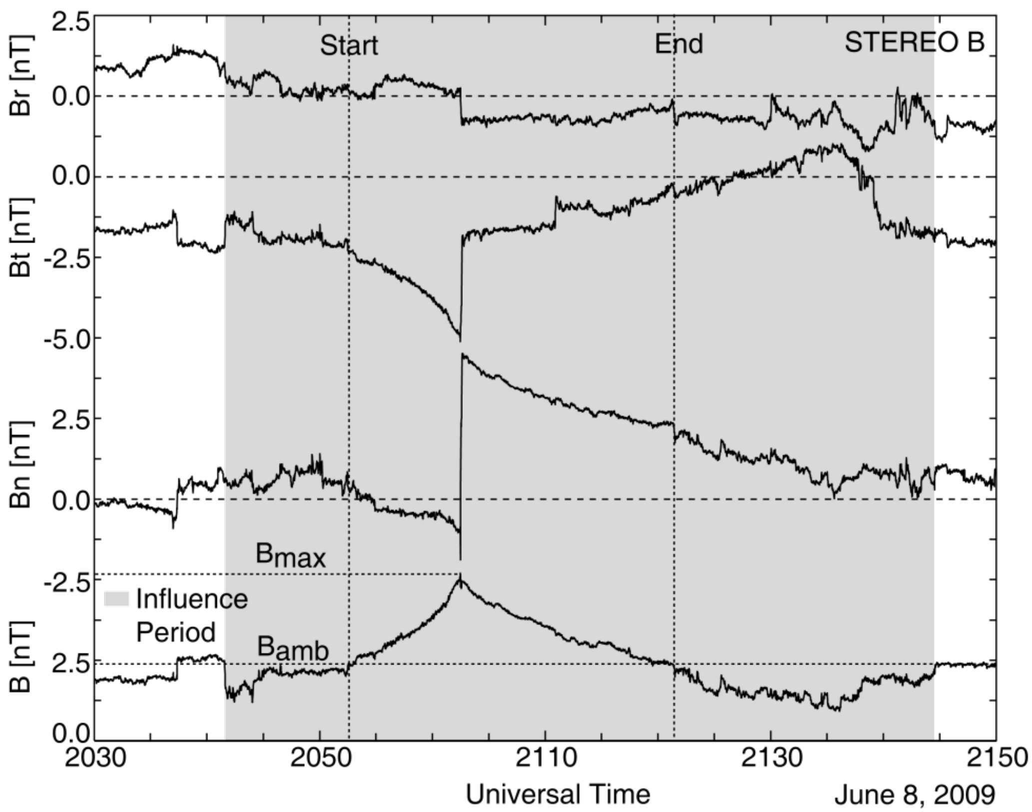
- If the debris has close approaches with a planet, it can be scattered along and across the orbits of the parent bodies.
- Gaps can be formed in the debris trail when it approaches the planet even though the parent body is far away.
- Therefore the debris trail is potentially hazardous to Earth even if the parent bodies have no close encounters in thousands of years.
- As we will show in the next talk the size of material in these debris trails is in the very hazardous size range.

# Collisional Cascade of Asteroids



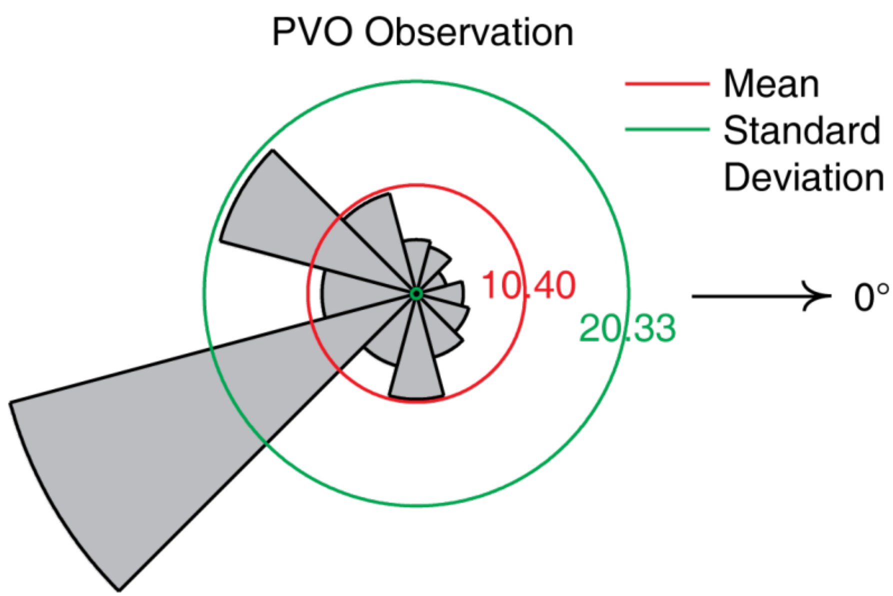

- The lifecycle of near-Earth objects (NEOs) involves a collisional cascade that produces ever smaller debris.
- Co-orbiting debris in the hazardous range can be destroyed by the numerous small meteoroids down to tens of cm in diameter.
- A large amount of nano-scale dust and gas particles are produced in the disruptive collisions
- When the solar wind passes through that cloud of nanoscale dust, it can pick up the dust coherently

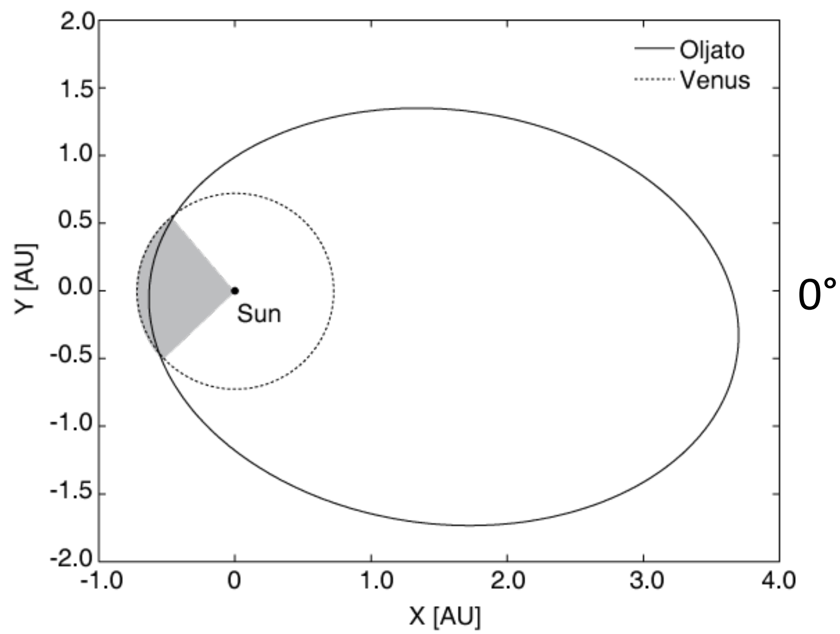
# Collisional Signatures in the Solar Wind: Interplanetary Field Enhancements

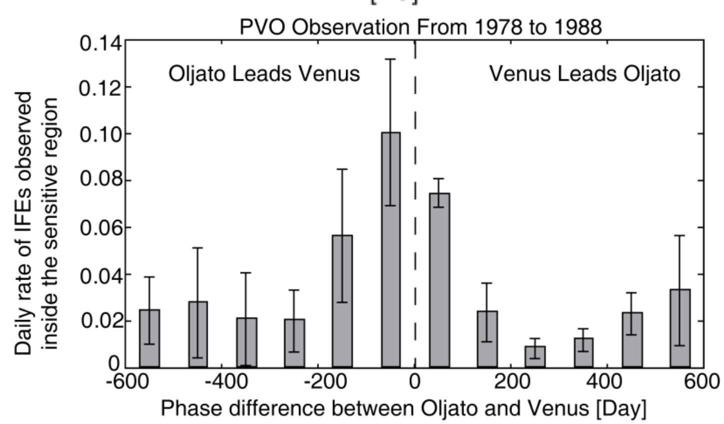



- IFEs are unique and readily identifiable structures in the solar wind
- They have enhanced magnetic field and central current sheets and travel with the solar wind
- At half an hour long in a 400 km/s flow, the scale size is of the order of million km

# Discovery of IFEs: Oljato Visits Venus

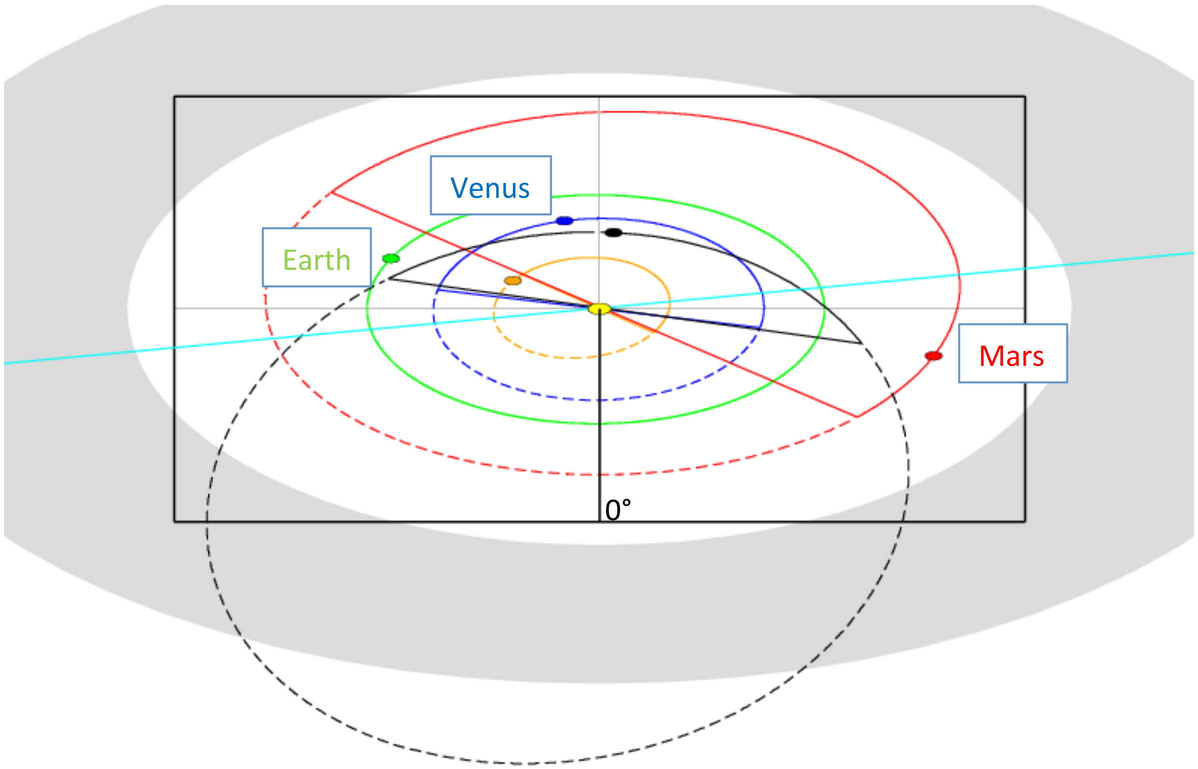



- Pioneer Venus Orbiter (PVO), in the 1980s, observed IFEs in the solar wind, at a longitudinal range where the orbit of asteroid 2201 Oljato was inside that of Venus.
- This is consistent with a disturbance created in Oljato's orbit either leading or trailing the asteroid, and being carried outward.
- We concluded that co-orbitals of Oljato were responsible for the IFEs seen by PVO.

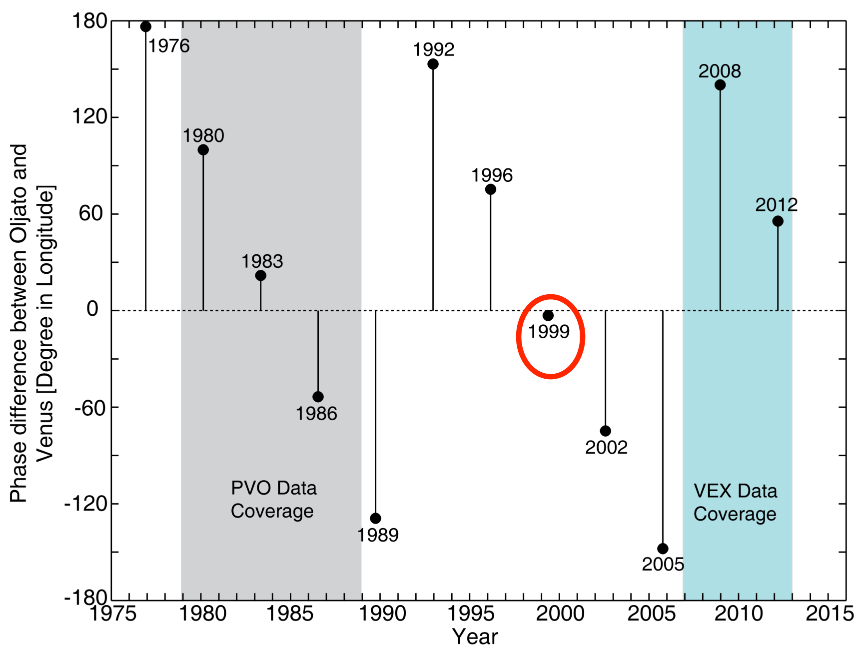
# Oljato: A Collisionally-active Asteroid



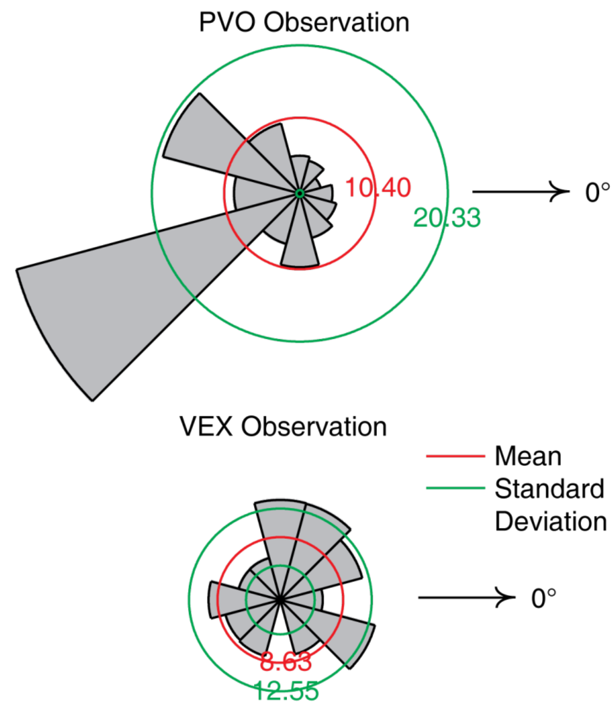

- Oljato is an asteroid with some comet-like signatures (e.g., possible UV emission). Therefore it was suggested to be a collisionally-active asteroid.
- It has an eccentric, low inclination orbit with close approaches to Earth, Venus, and Mars. Debris in its orbit thus has a fair chance of eventually experiencing gravitational scattering.

# Temporal Change of IFE Occurrence Rate

Oljato's period is 5.2 Venus years so phase difference between Oljato and Venus changes. The length of the vertical lines shows this phase difference.

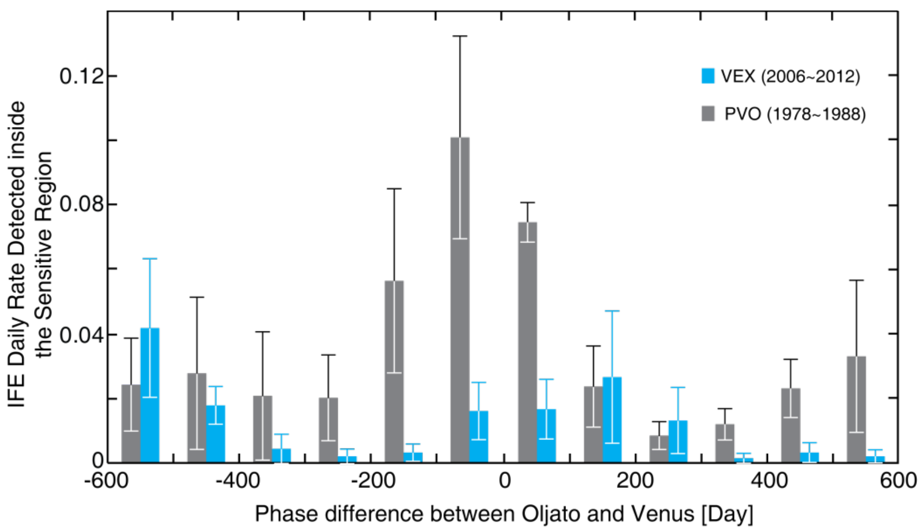


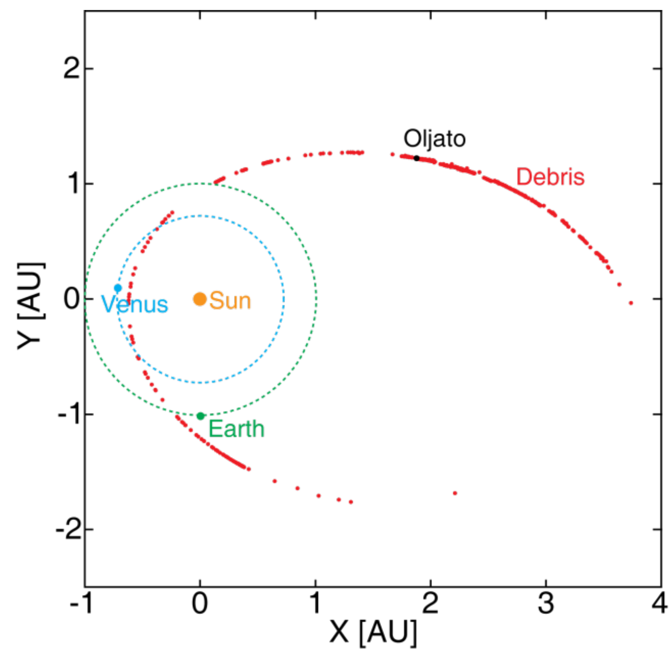

In 1999 when we were not making measurements, the phase difference was small so Venus could have perturbed the densest region of the co-orbitals.




- More than two decades after PVO entered the Venus atmosphere, Venus Express (VEX) arrived to provide new magnetic-field measurements at Venus.
- During the observation period of VEX, the orbital geometry of Venus and Oljato was similar to the ones in the 1980s.
- However, the distribution of IFEs inside the sensitive region was quite different in 2008 and 2012.

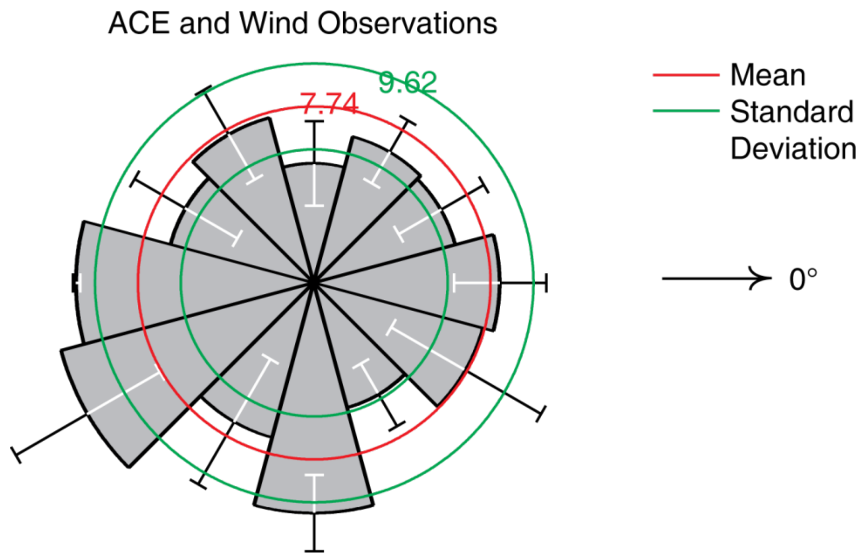
# Possible Loss Mechanisms for Co-orbiting Debris of Oljato

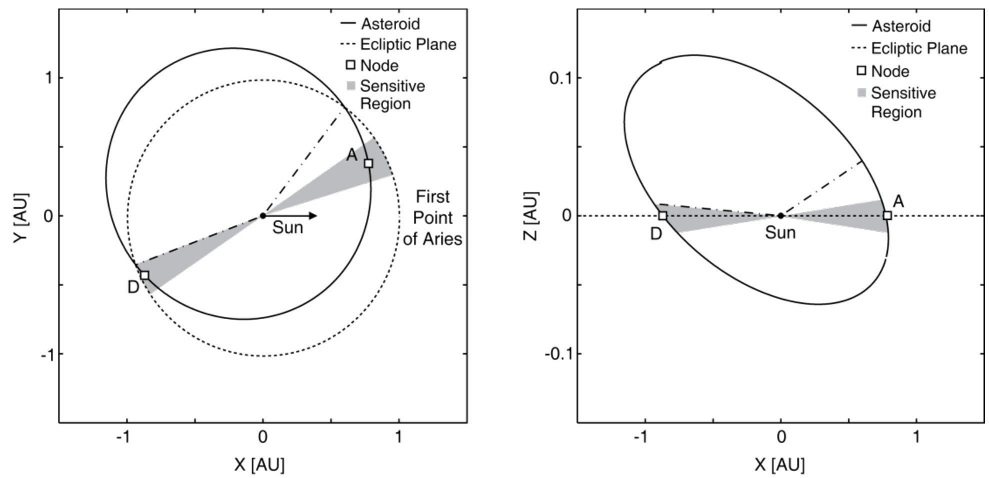


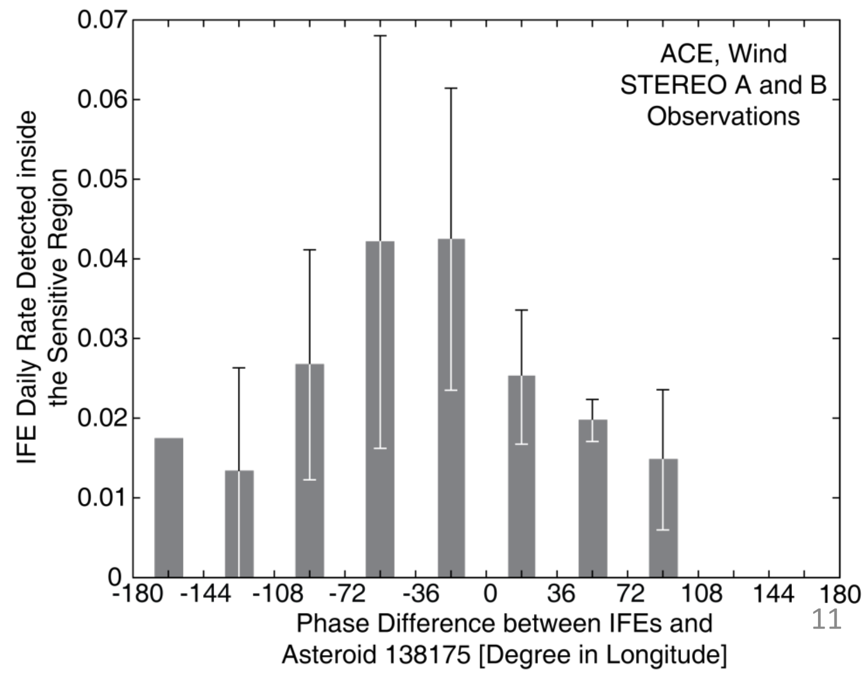

- Due to gravitational perturbations from Earth and Venus, gaps can be formed in the otherwise continuous debris streams.
- If the material responsible for IFEs was scattered from the debris trail in the later close encounters, a decrease in the IFE occurrence rate would occur.

# Another IFE-producing Asteroid



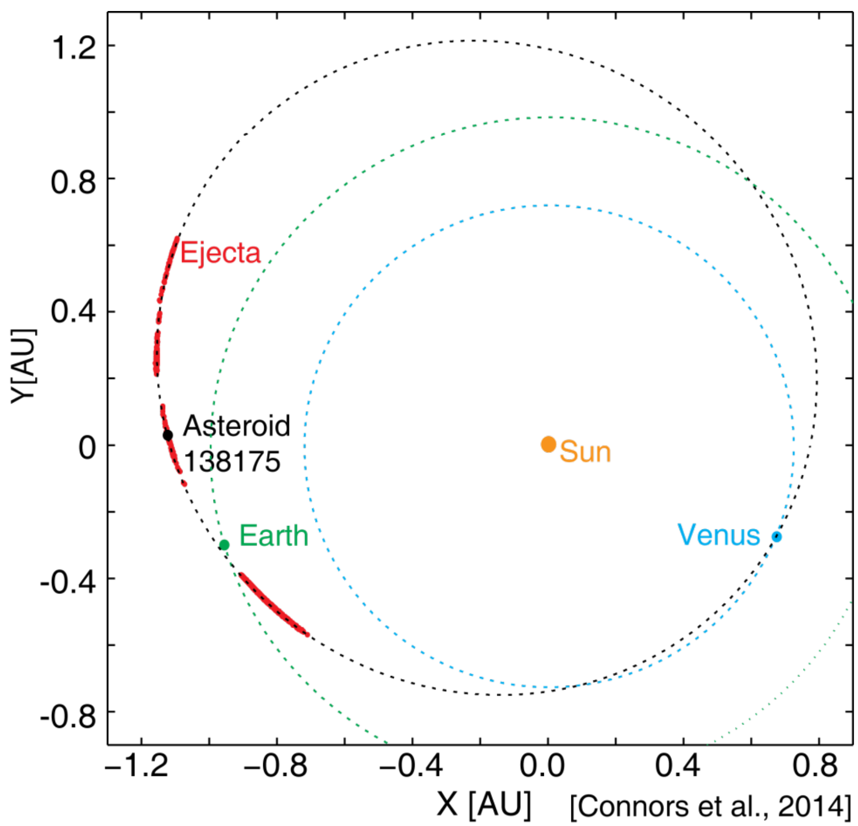




- The material accompanying asteroid 138175 produces IFEs near both its descending and ascending node near 1AU



# Soon-to-be Earth Co-orbital 138175

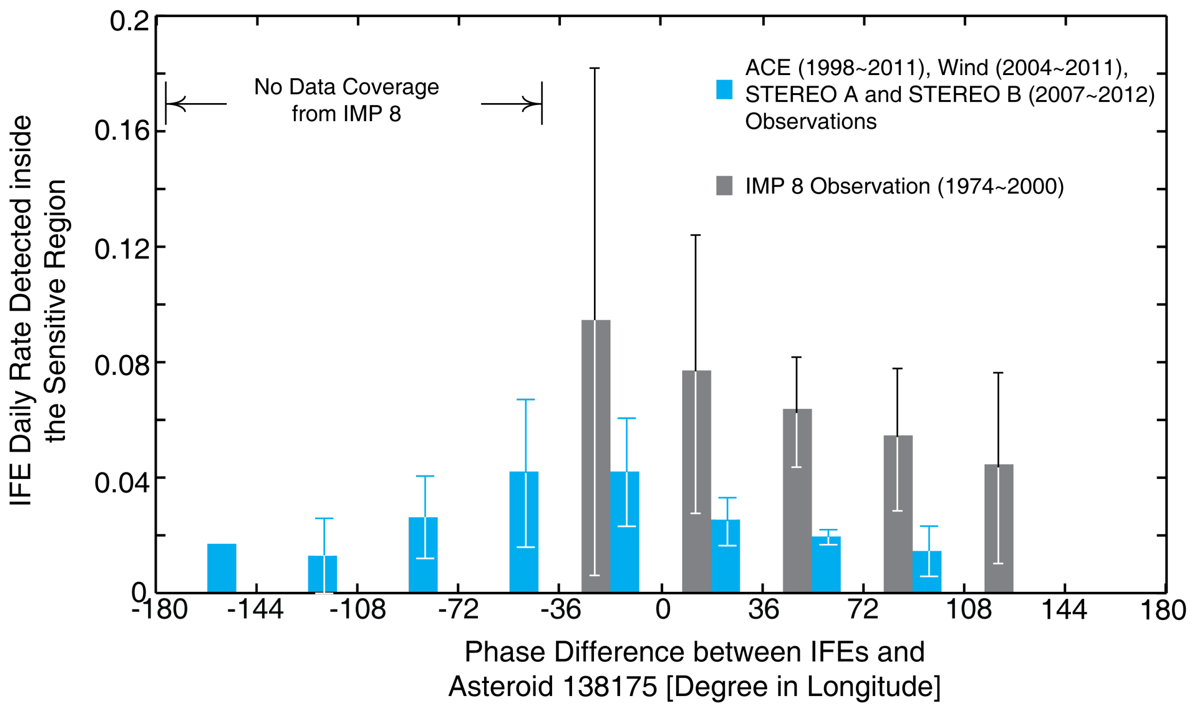
a=1.005 AU e=0.293 i=5° Earth-crossing Venus-orbit-grazing 0.5 km asteroid




- Nodes just inside Earth's orbit allowing radial outward motion of IFEs toward Earth
- Has close encounters to Earth and Venus occasionally
- If the IFEs are due to a debris trail it will be a *resonant* debris trail
- The asteroid with its co-orbitals is also subject to gravitational perturbations from Venus and the Earth, making gaps.

See Connors, Russell, Lai, MNRAS Lett. 2014, 443(1), L109

# Temporal Changes in IFEs Associated with Co-orbitals of 138175




- The decrease in the IFE occurrence suggests that asteroid 138175 has lost its co-orbiting material.
- Unlike 2201 Oljato, this temporal change is consistent with collisional destruction of the debris trail.
- More details are the subject of the next talk (Lai et al.)

# Summary

- The detection of IFEs provides indirect evidence of debris streams associated with inner solar system asteroids. These streams consist of material of hazardous sizes.
- Based on IFE observations, material co-orbiting with asteroid Oljato was identified from PVO observations at 0.72AU and co-orbitals of asteroid 138175 were identified from modern spacecraft observations near 1AU.
- Temporal variations of IFEs have been inferred from the decreasing IFE occurrence rate inside the sensitive region where the asteroid orbit is inside that of the observing spacecraft.
- Oljato's orbit is a good candidate for the gravitational scattering of debris while 138175 appears to have evolved through collisional destruction.
- In both cases it is important to be monitoring the density and location of the co-orbitals.