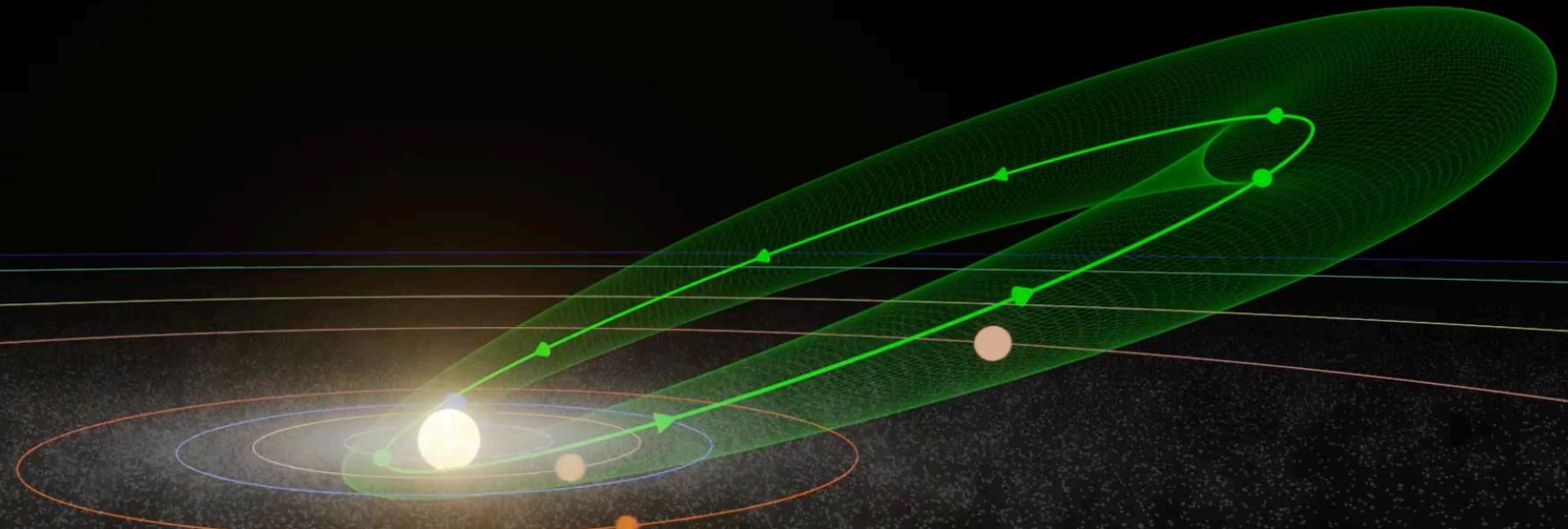
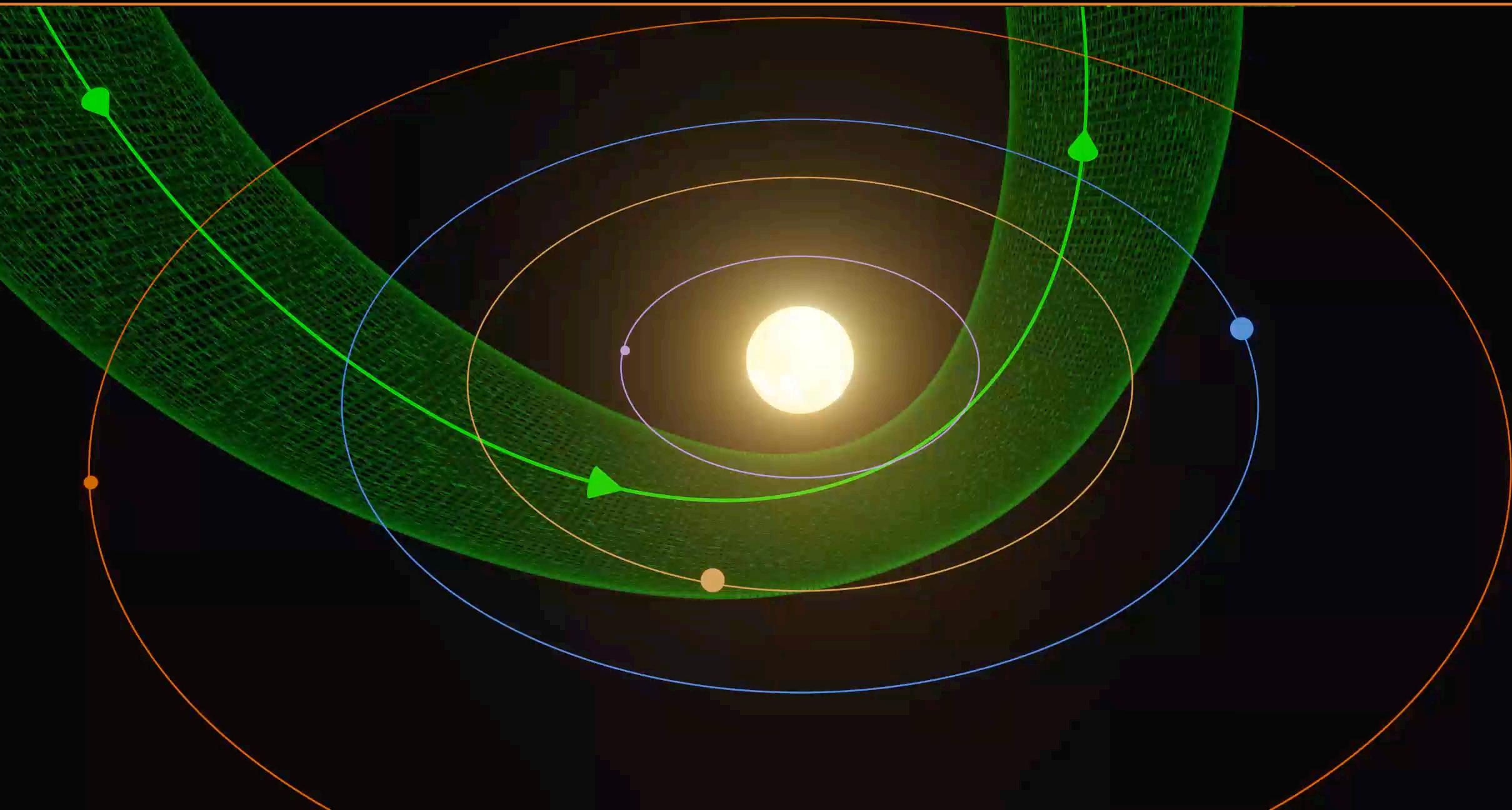


# Formation, Structure, and Detectability of the Geminids Meteoroid Stream

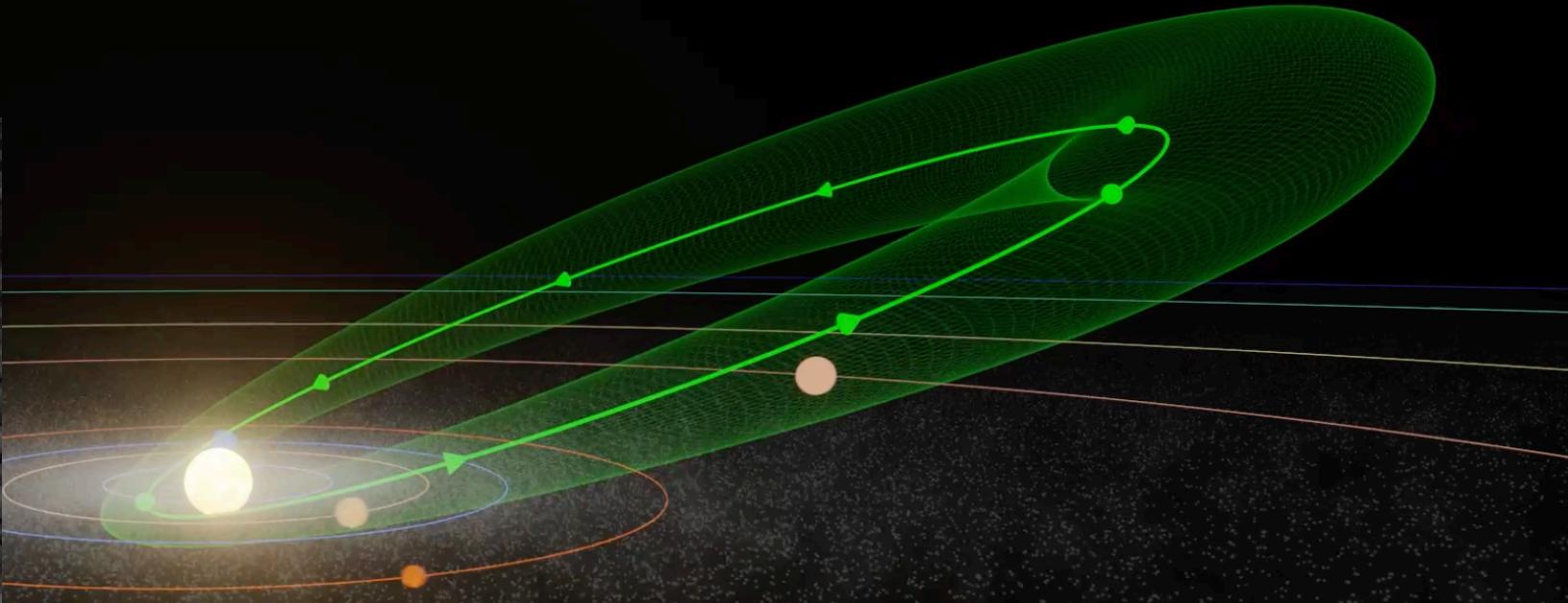
W. Cukier and J. R. Szalay



# The Geminids Shower



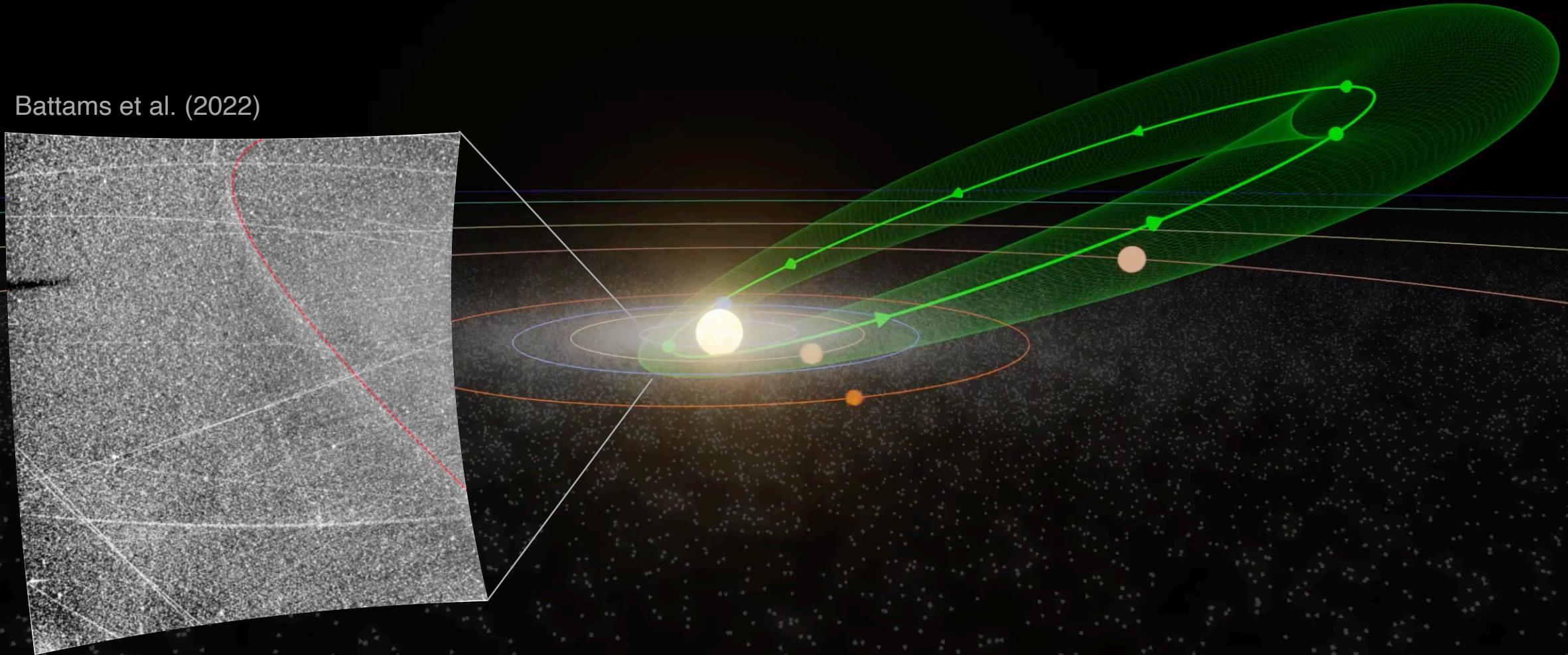
# (3200) Phaethon and the Geminids



# Geminids compared to (3200) Phaethon's Orbit

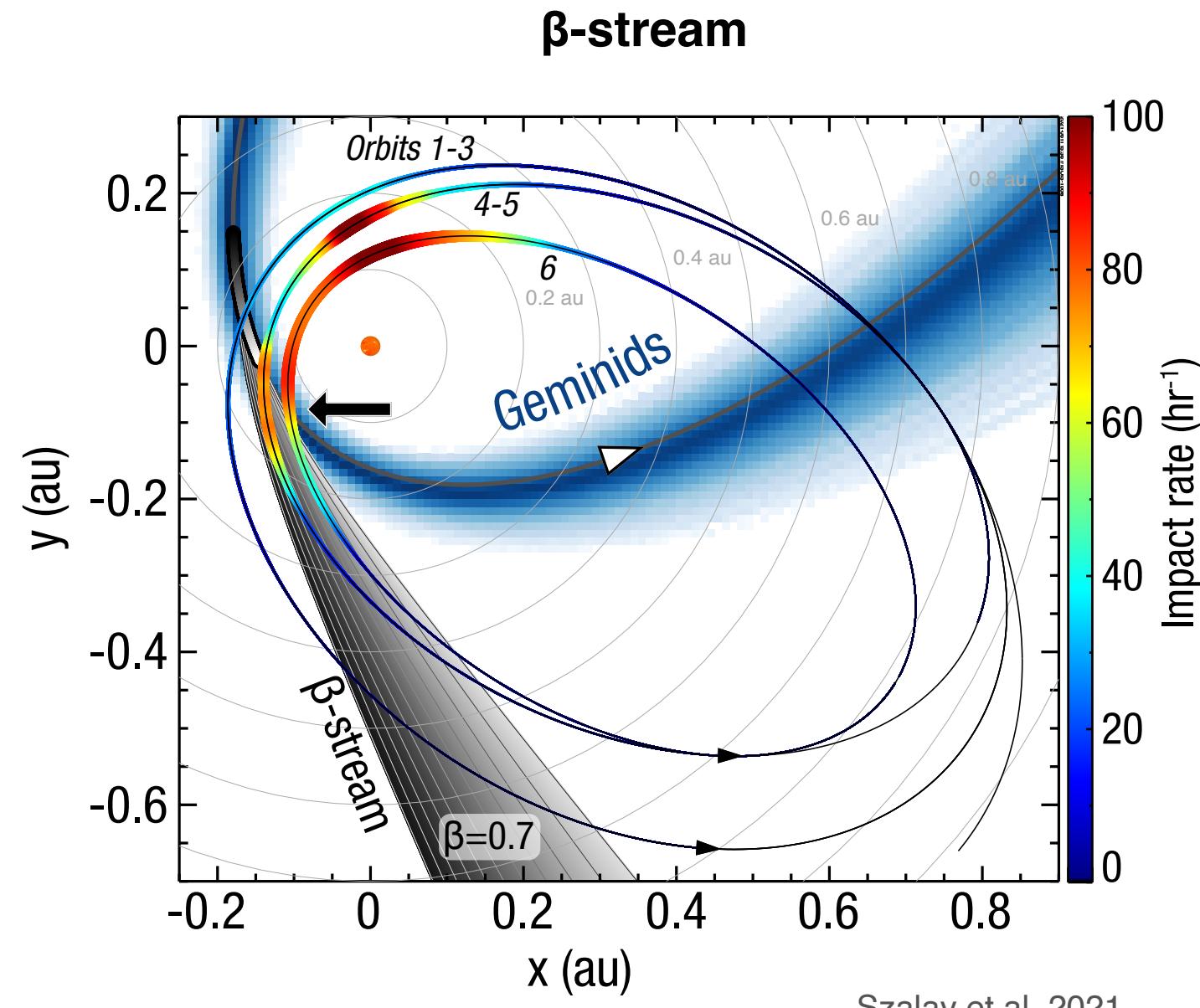
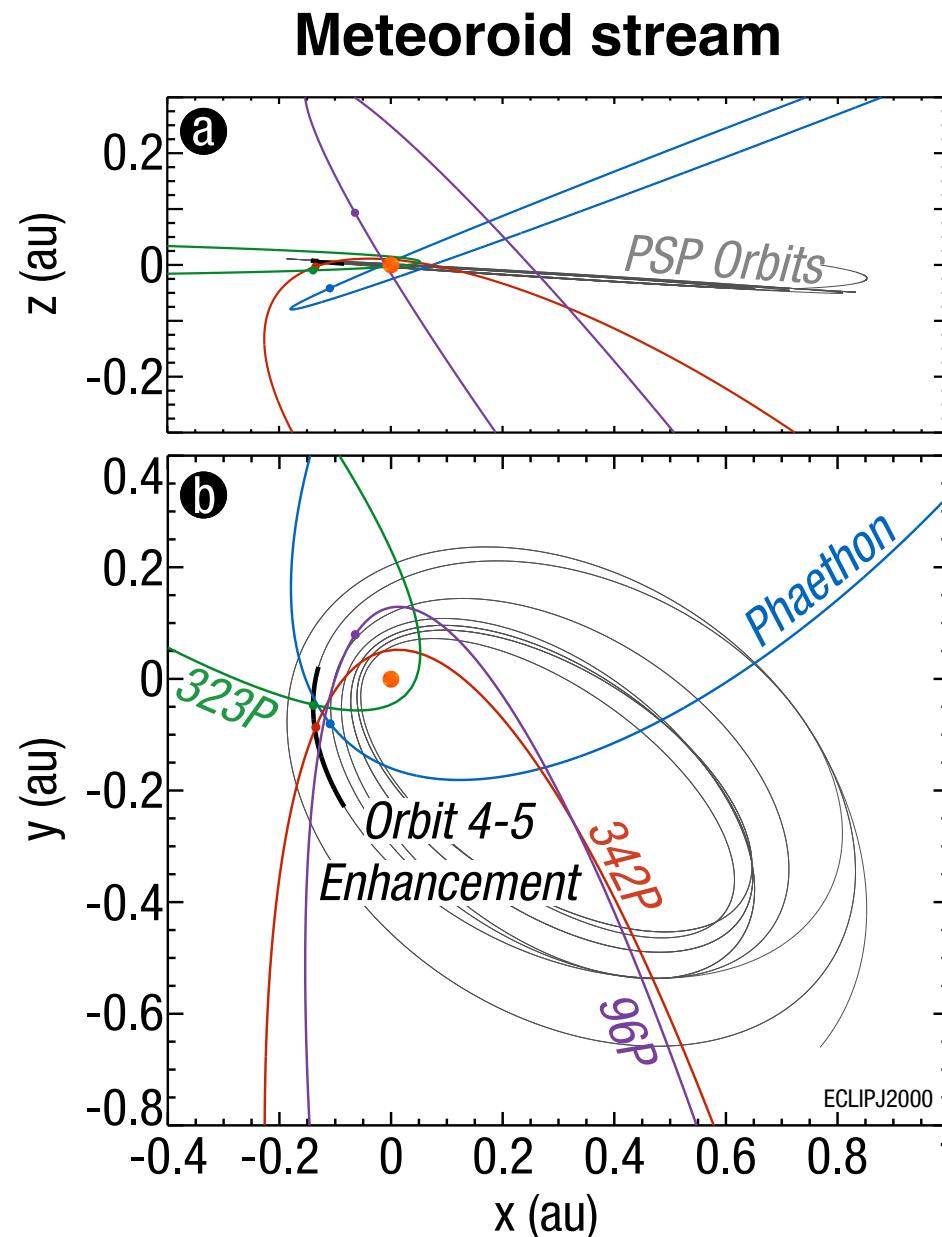


Battams et al. (2022)



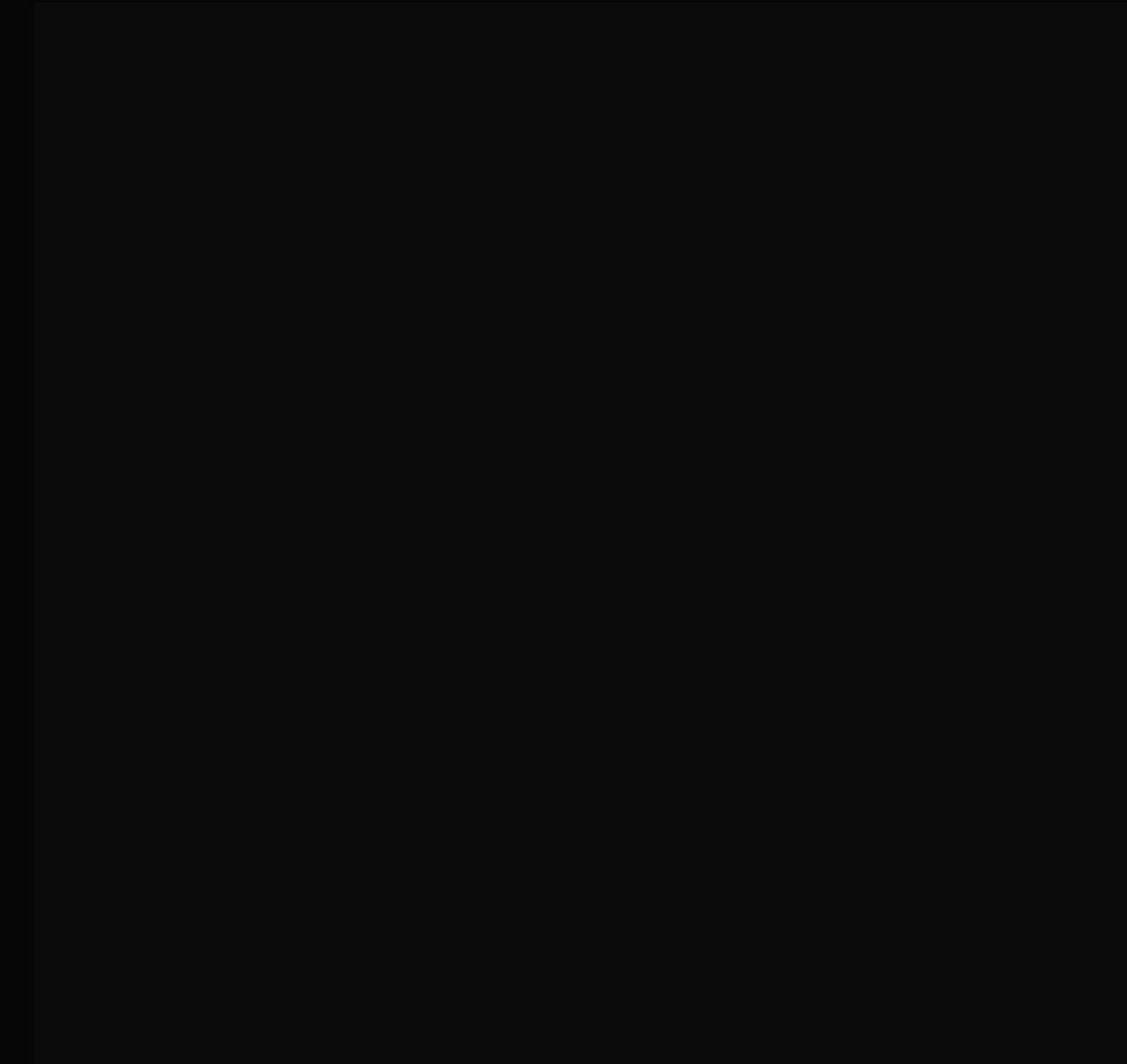
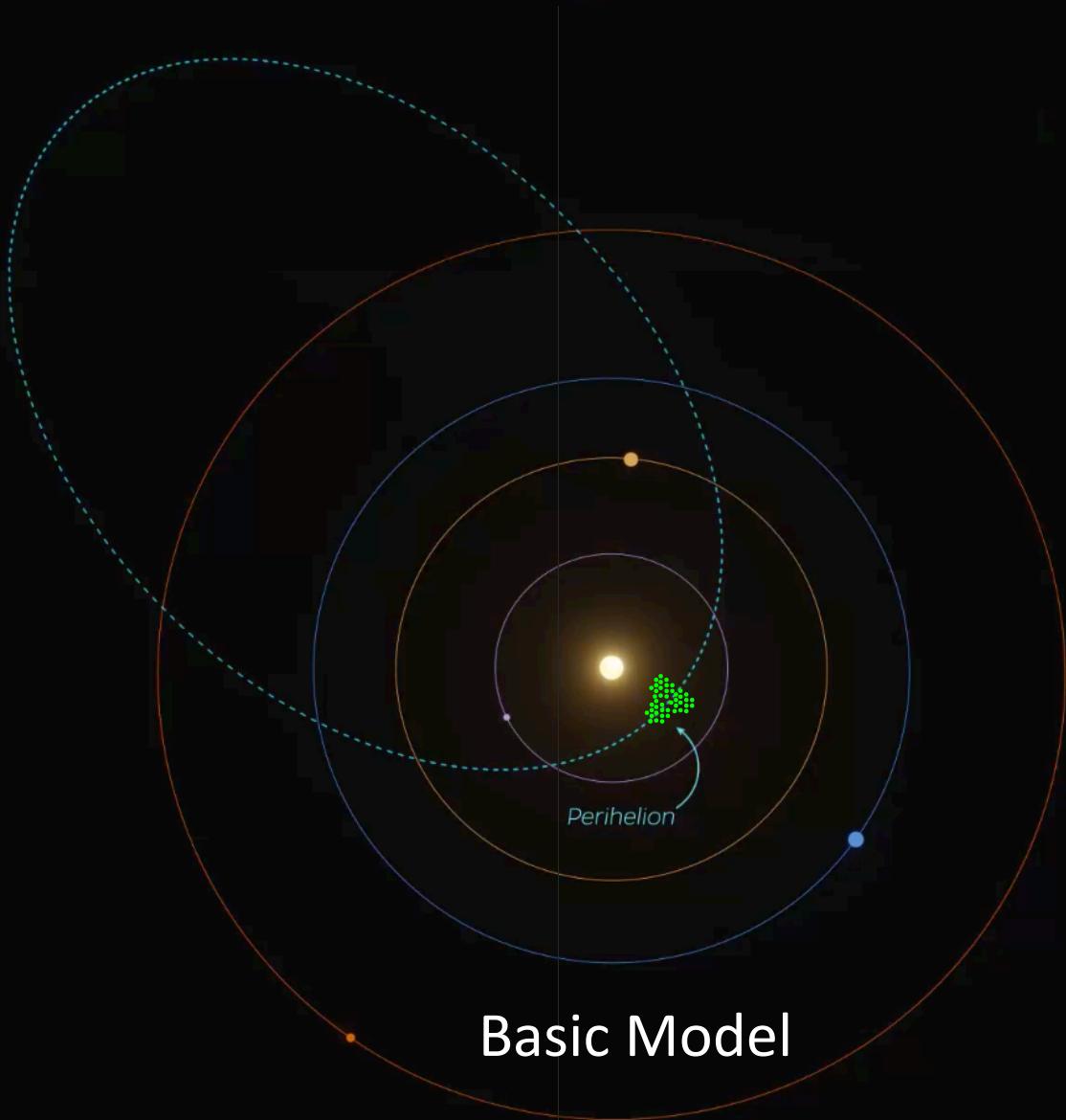


# Post-perihelion Enhancement



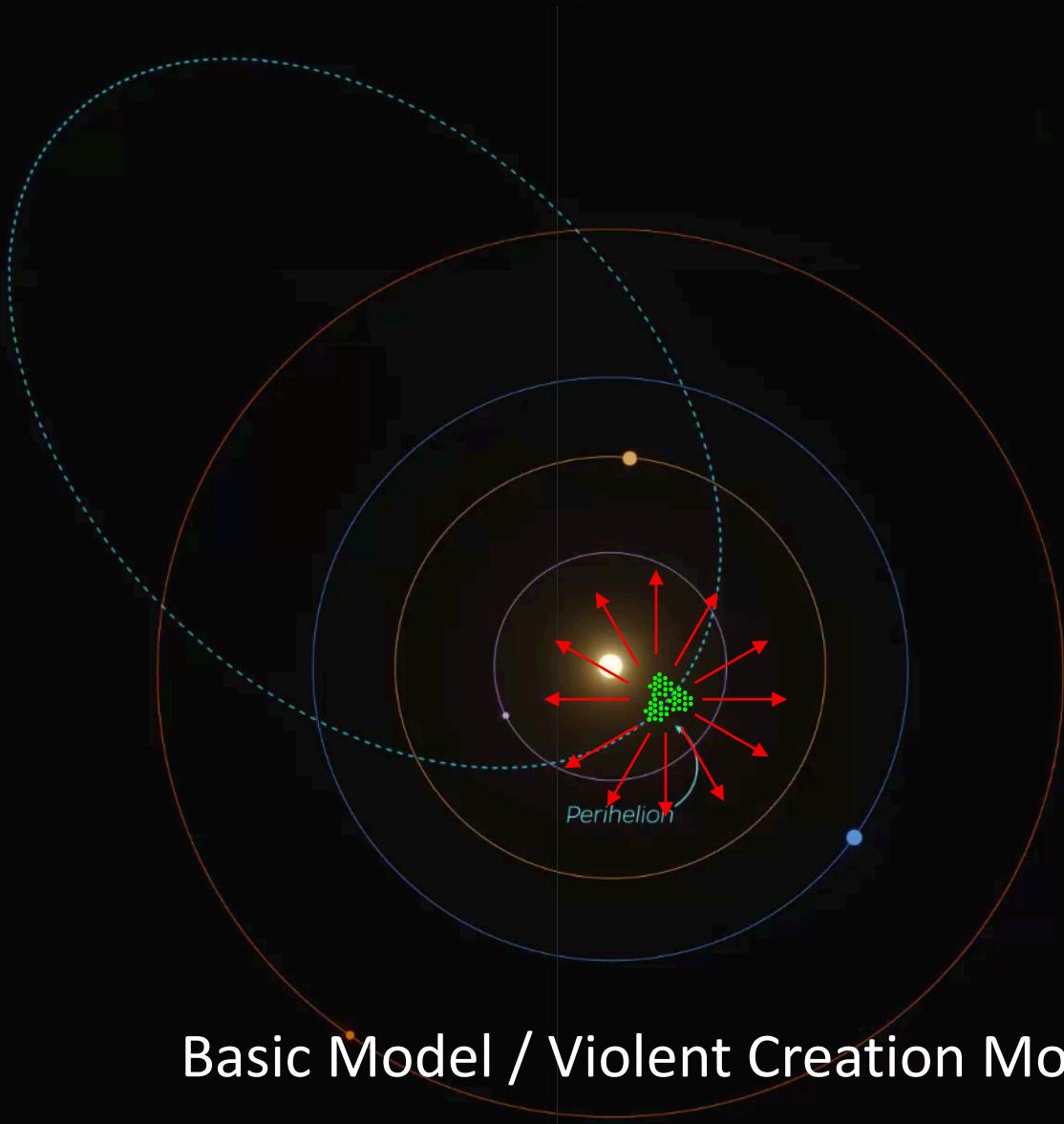


# Description of Models



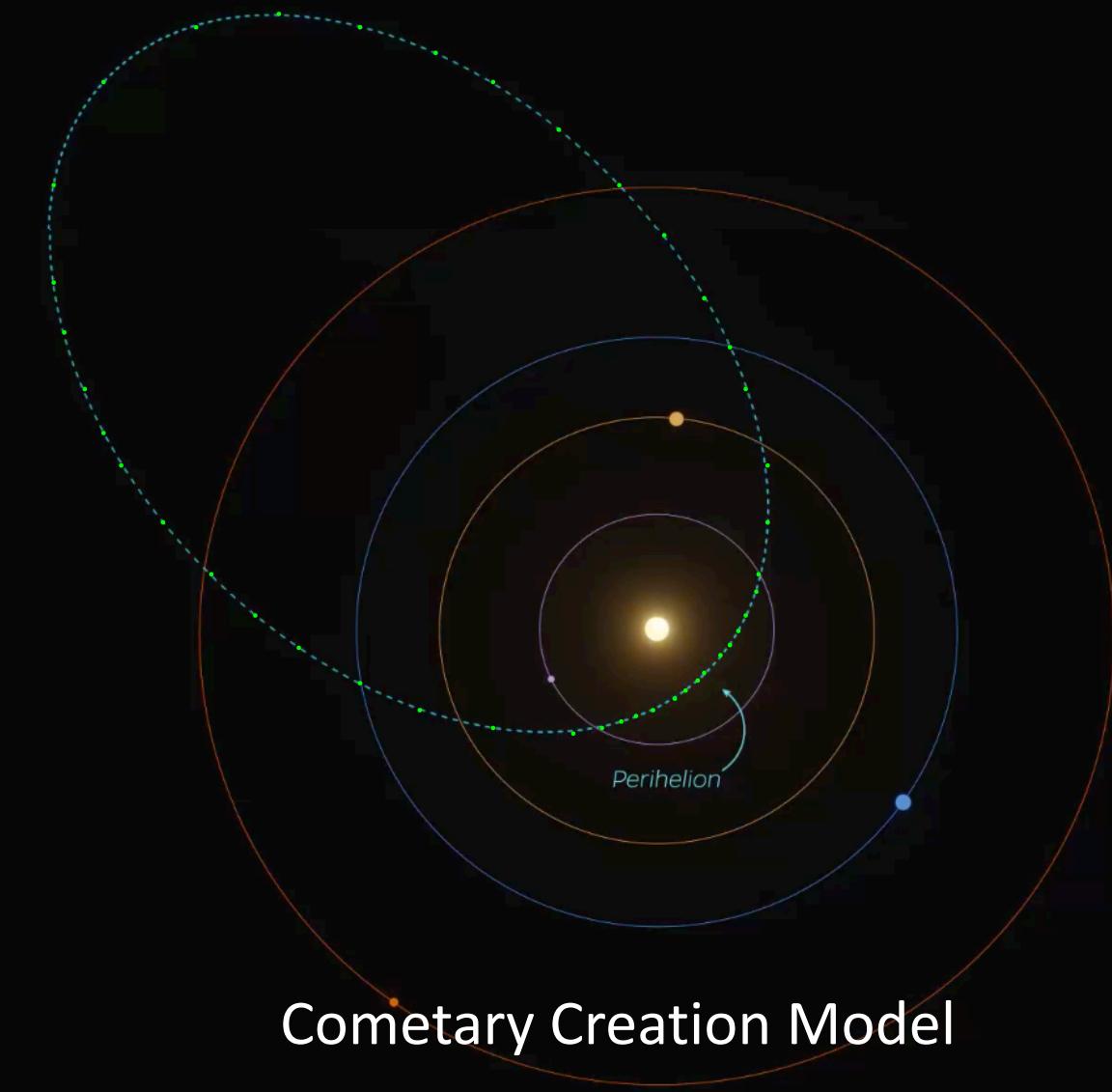
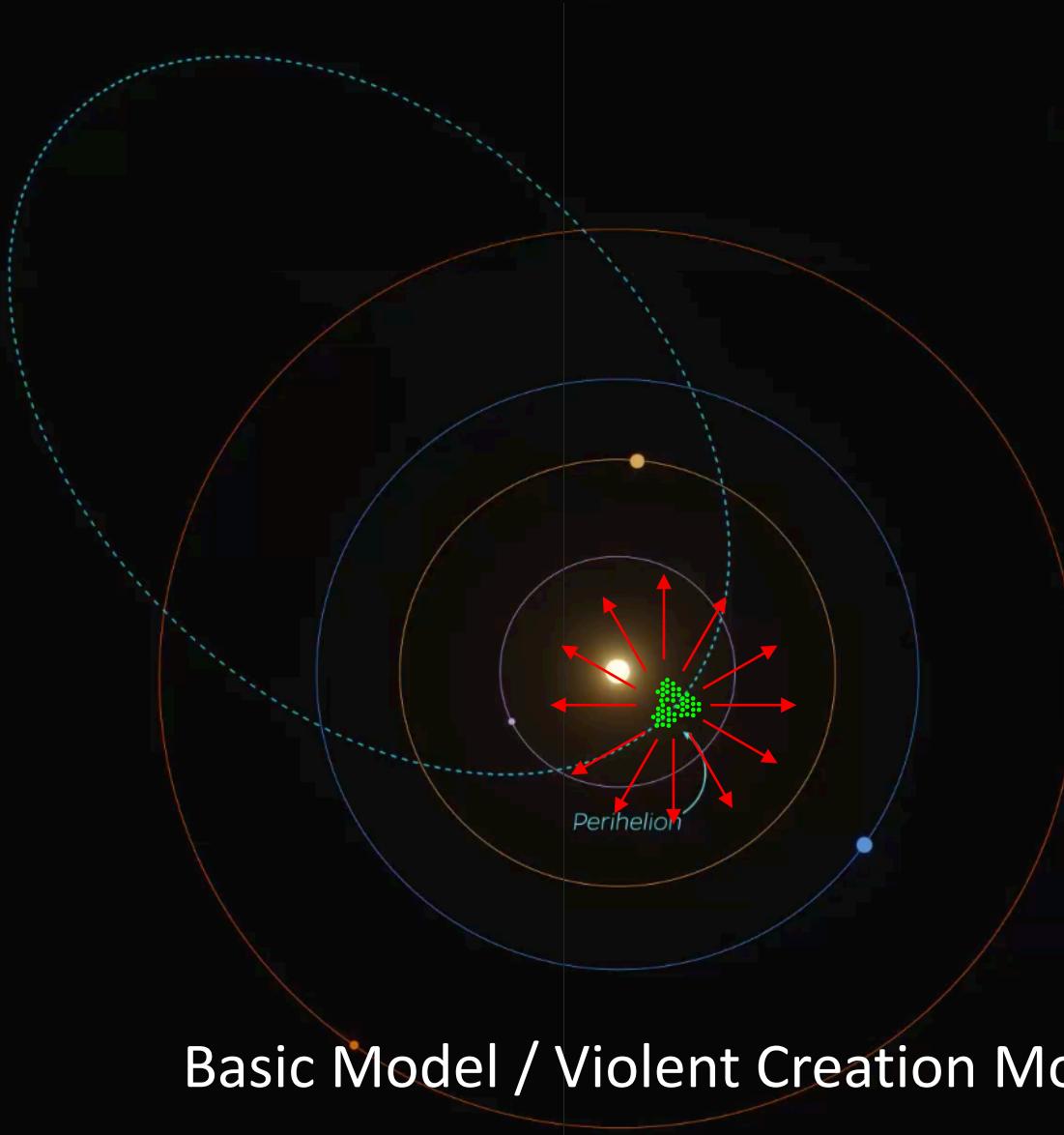


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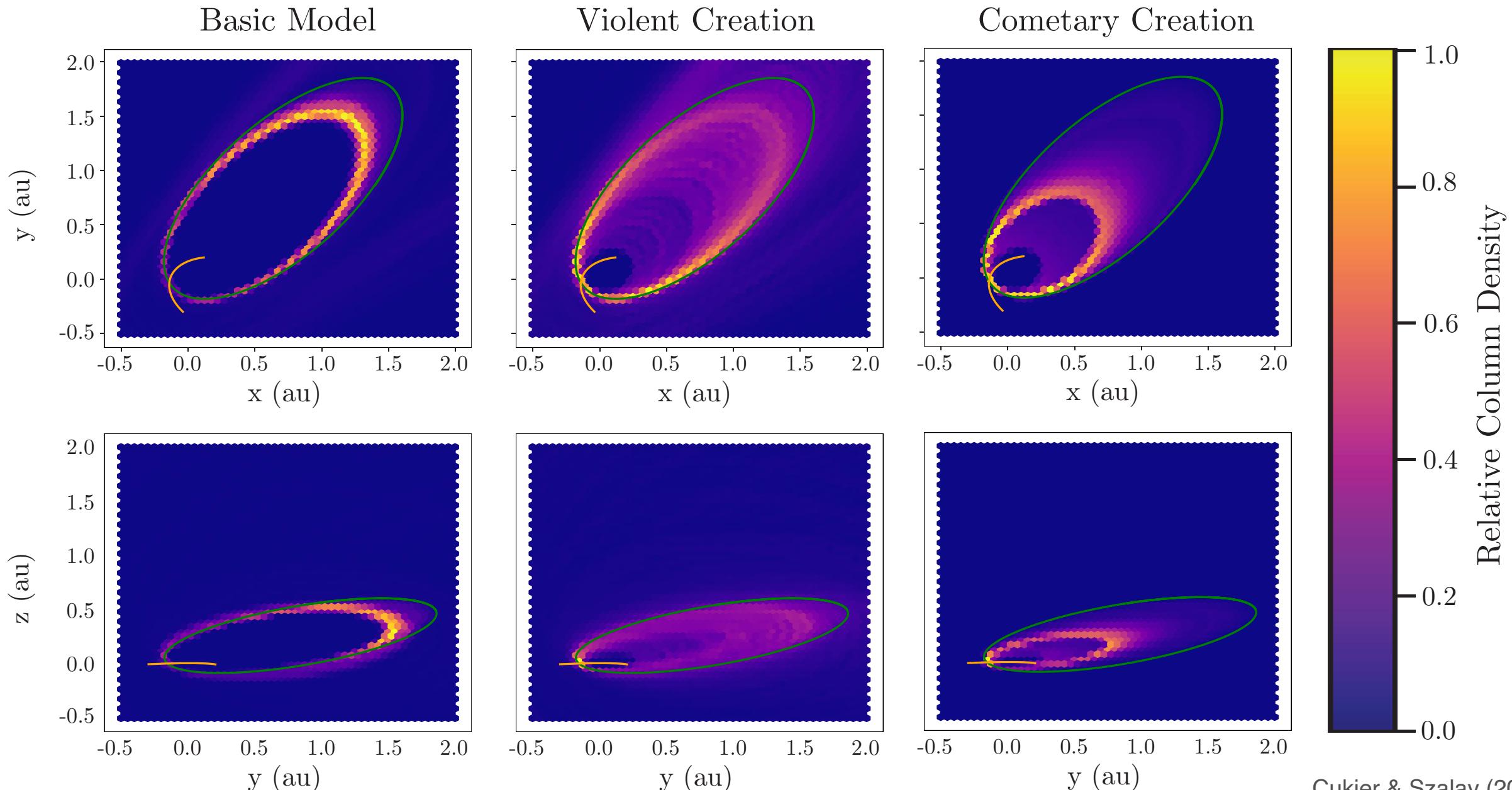


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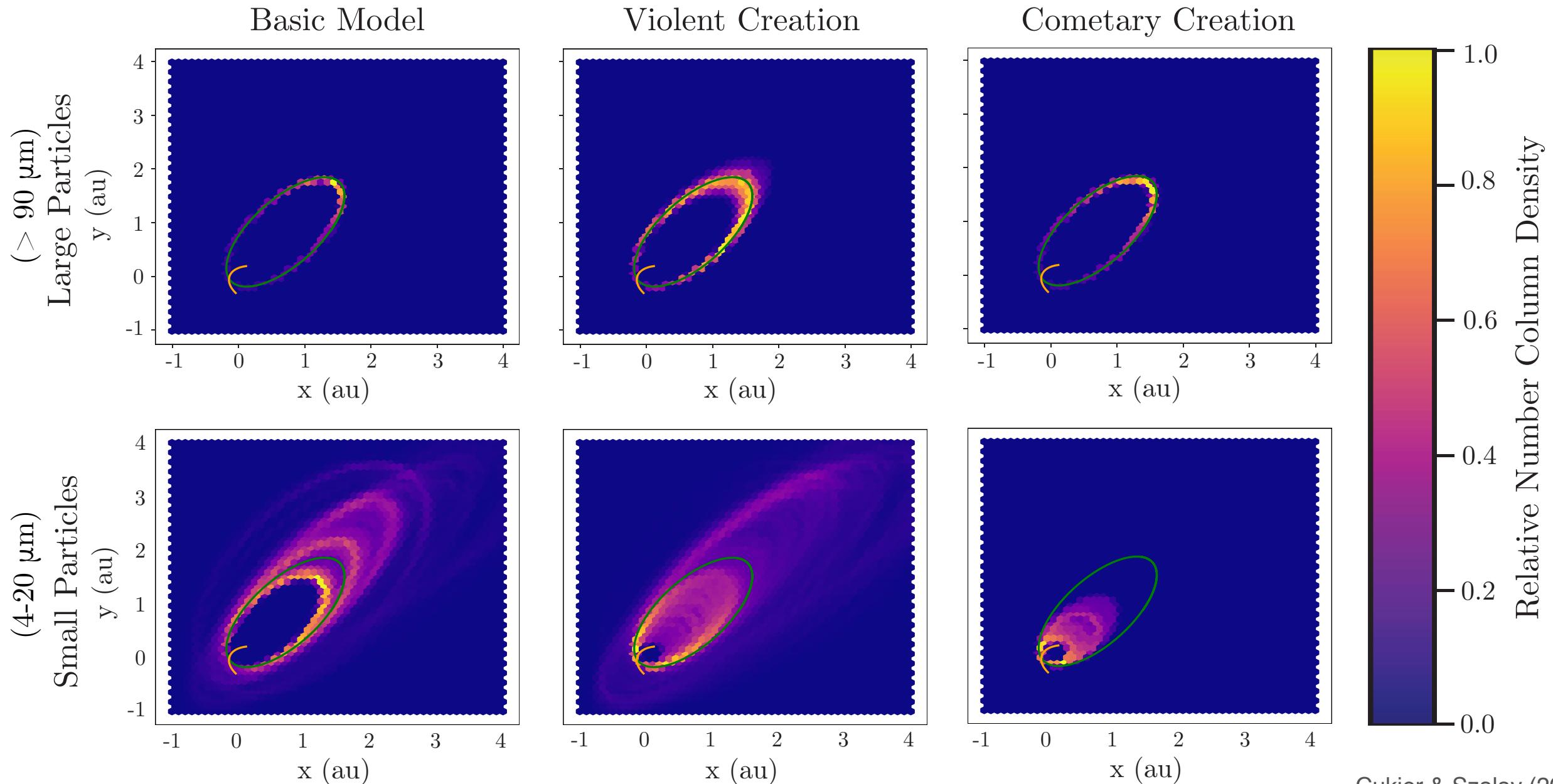


# Model Morphology



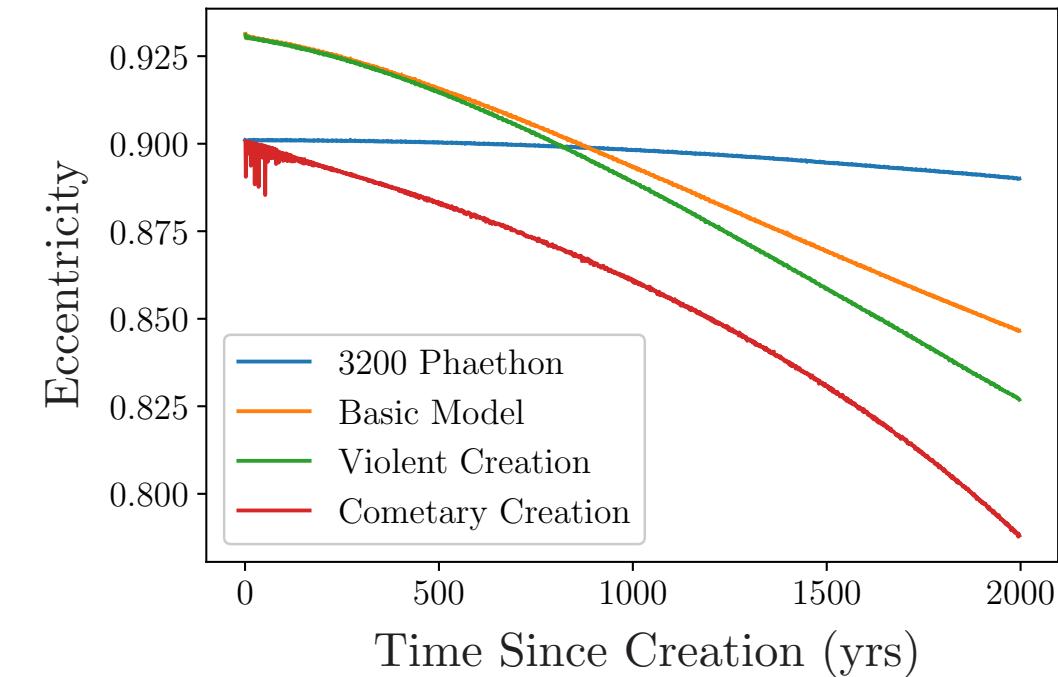
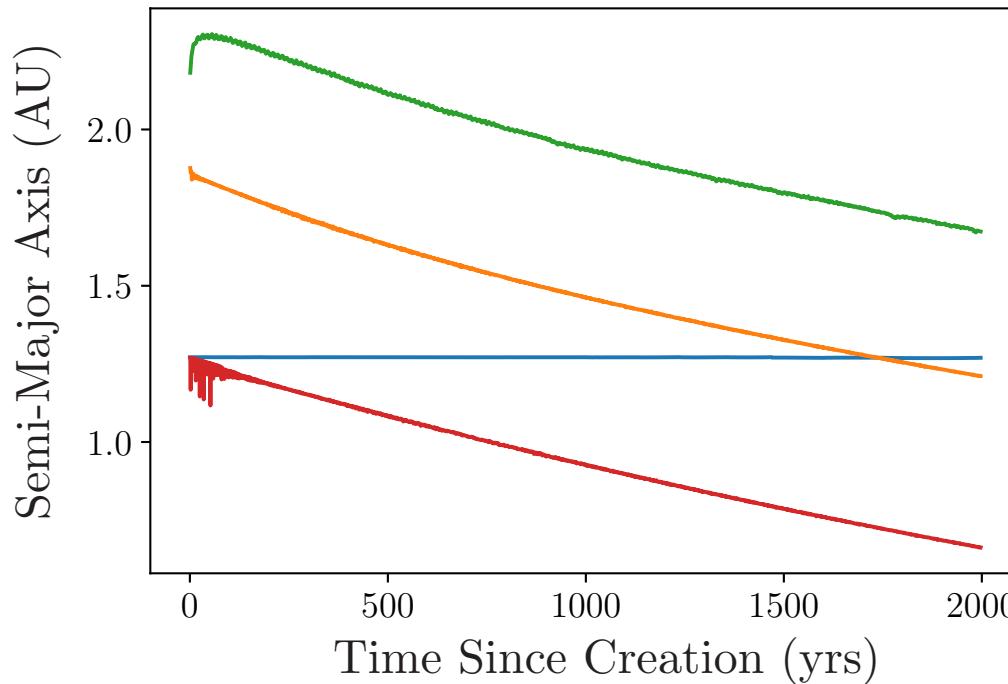


# Model Morphology

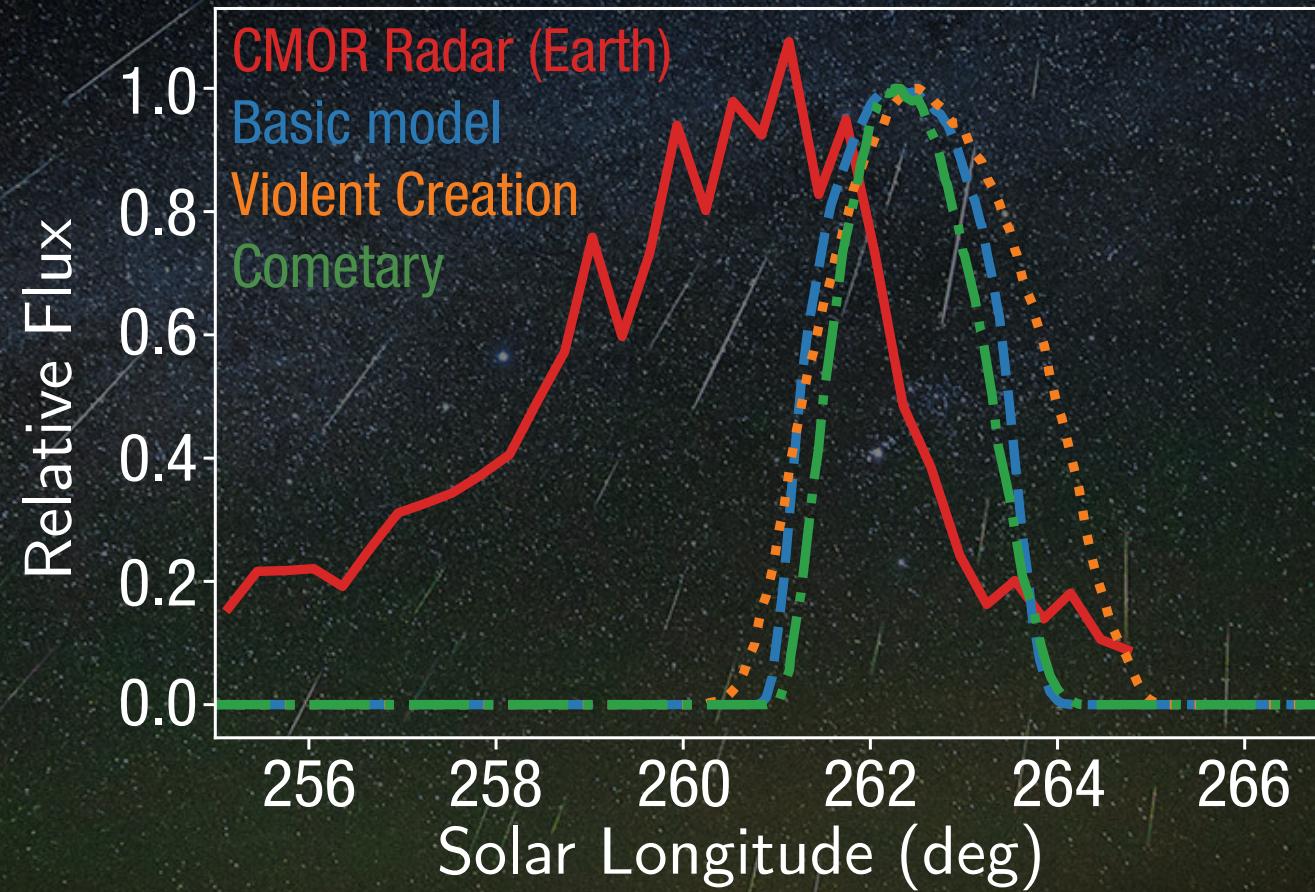




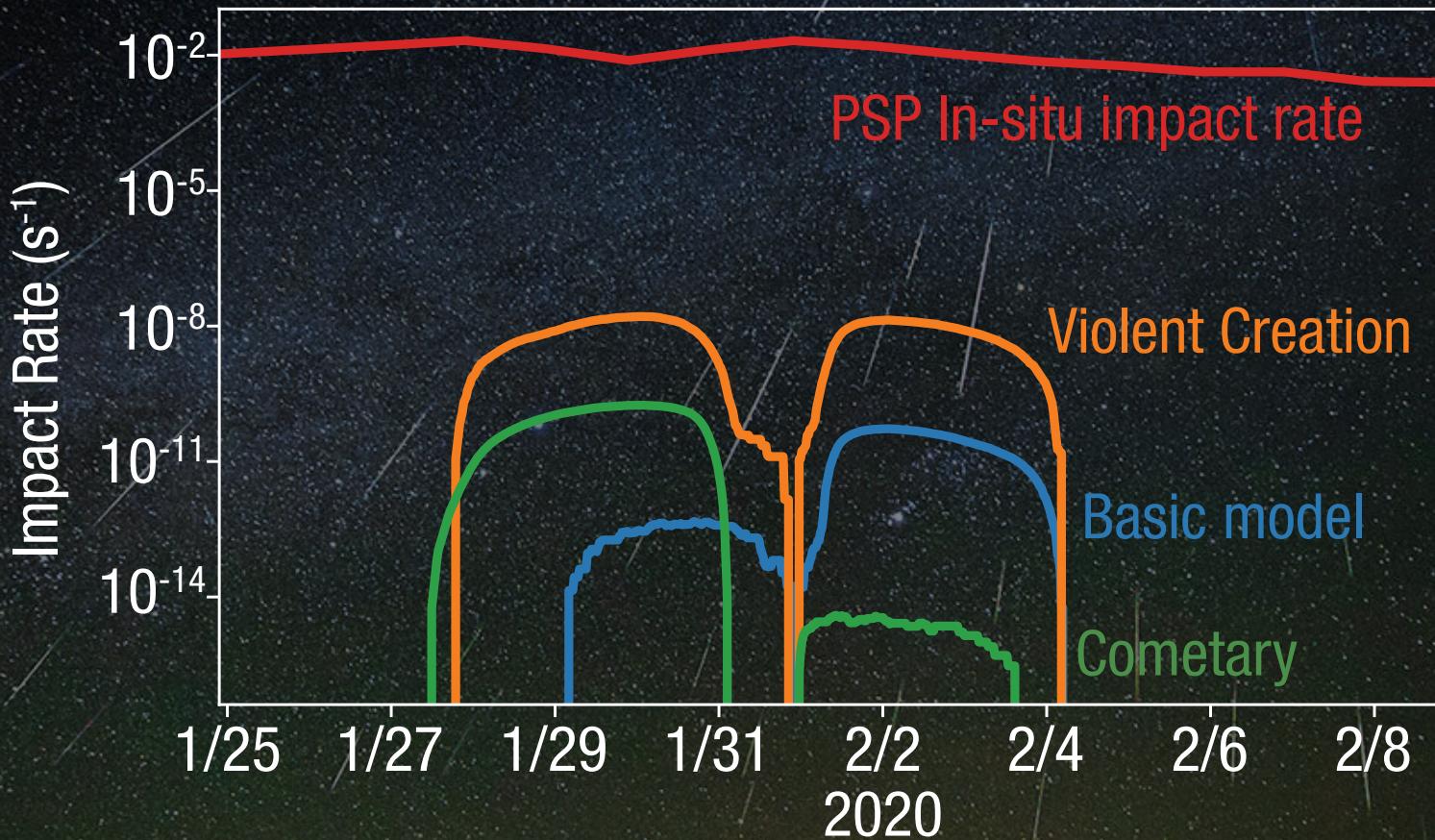
# Geminids Modeling



# Comparison to Geminids at Earth

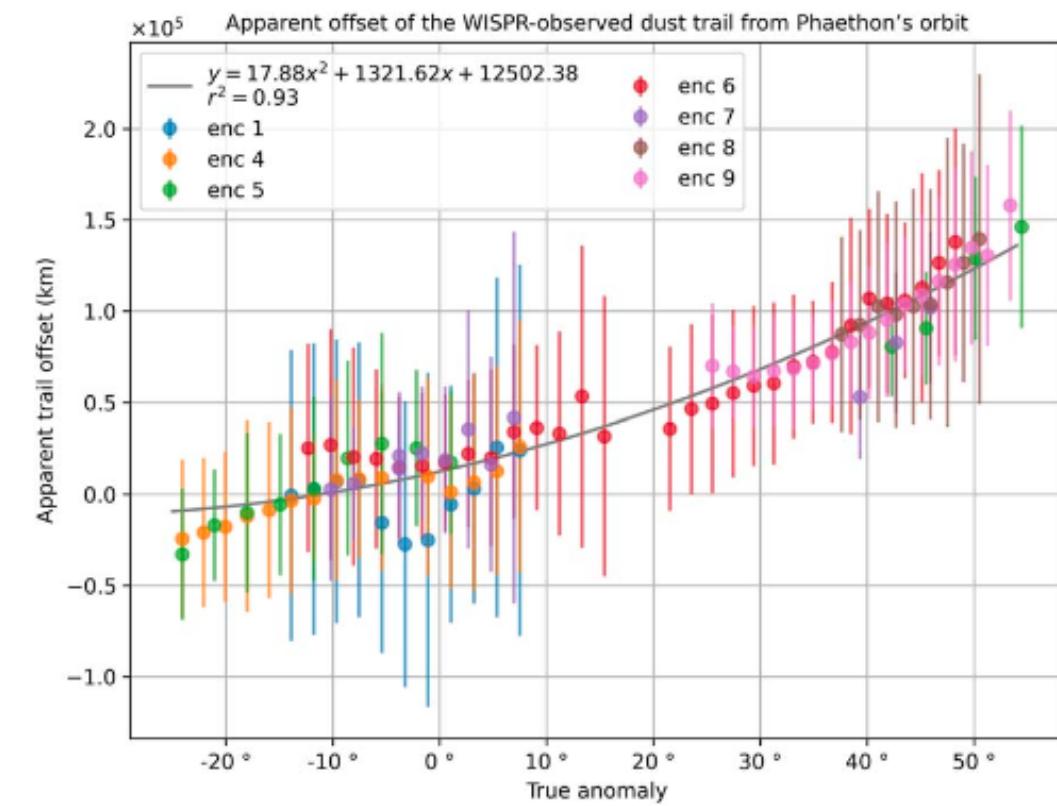
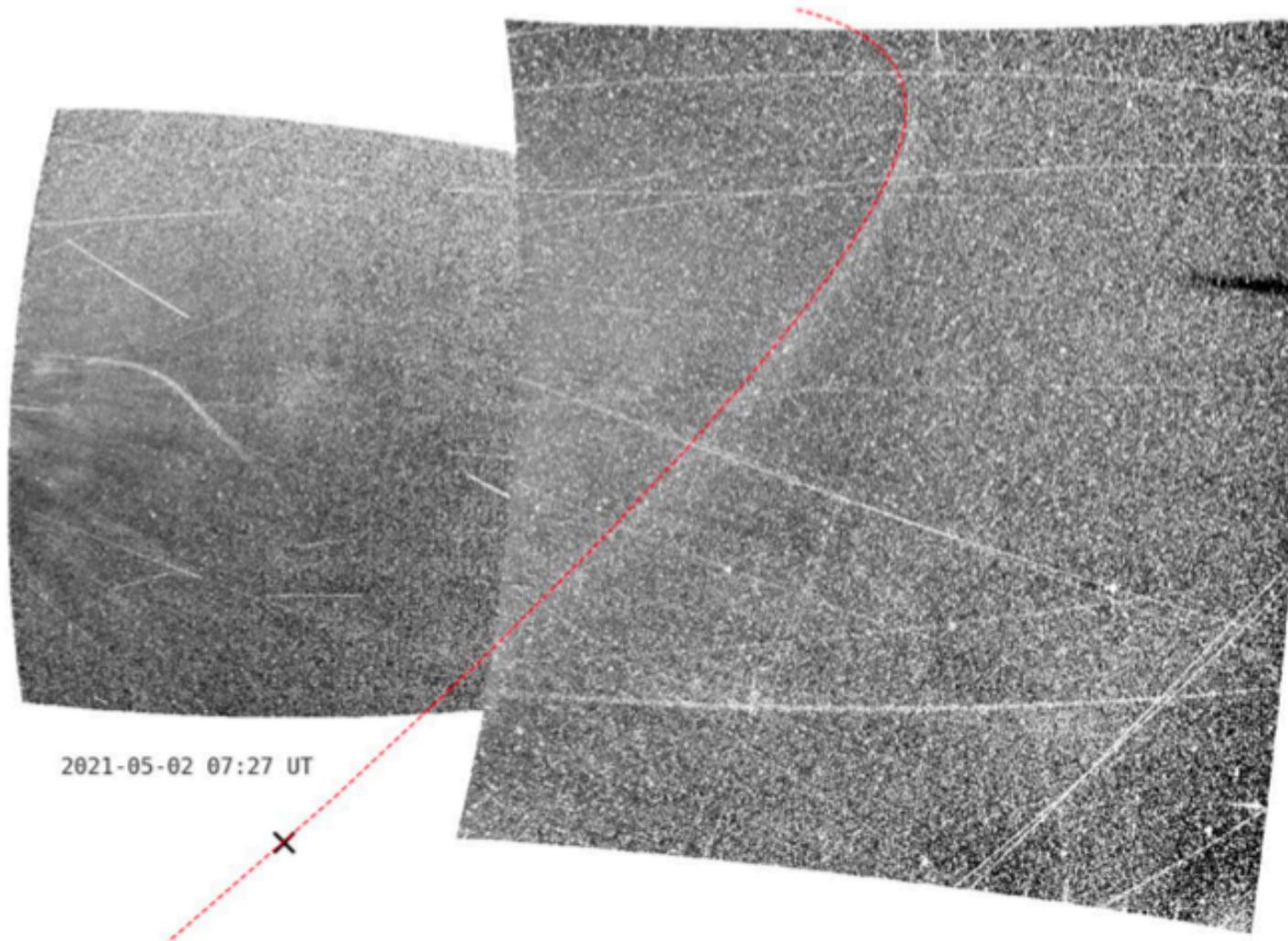


## Comparison to Geminids transits at Earth and PSP



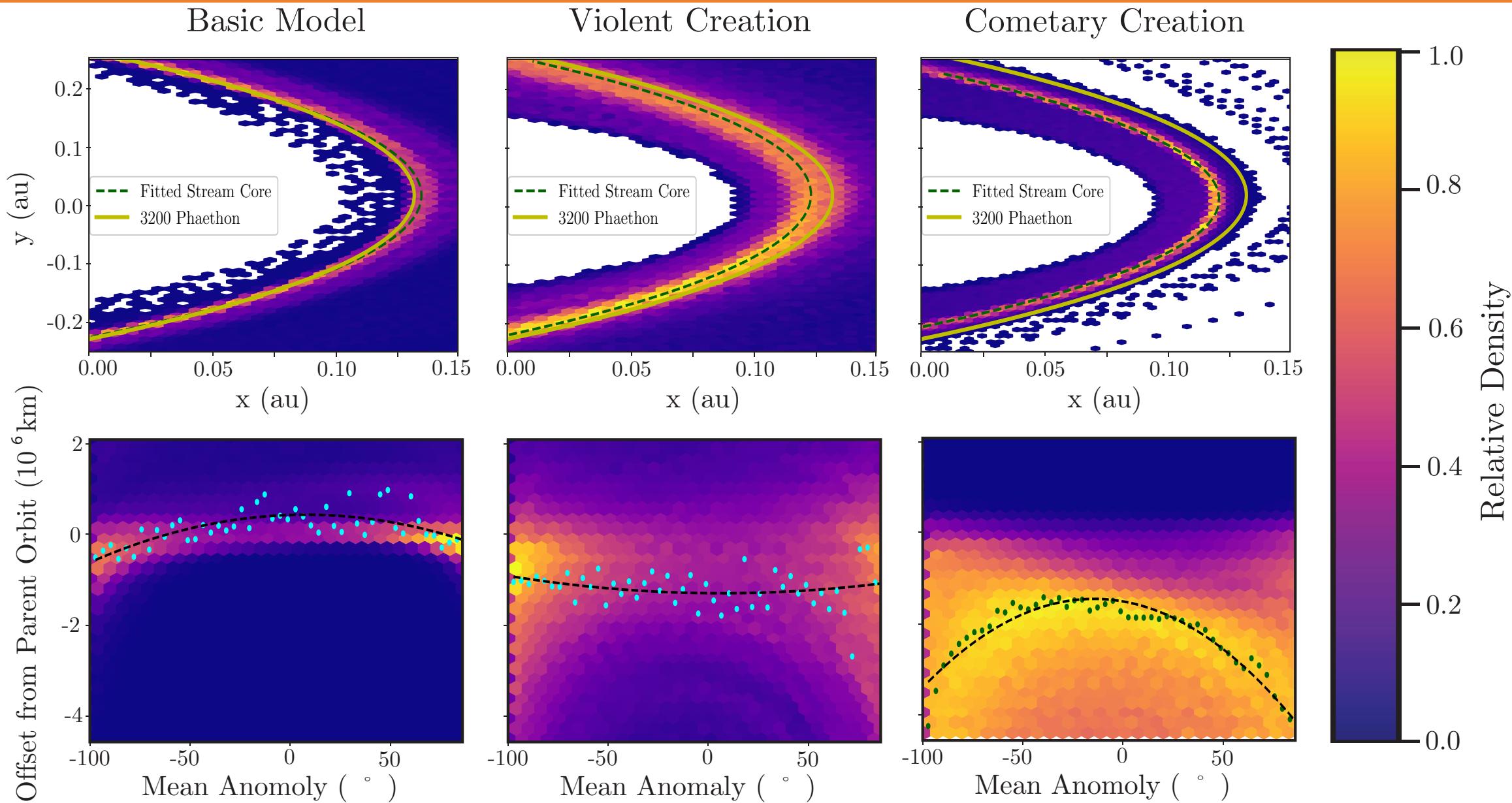
PSP is unable to directly observe the Geminids via impacts, still leaves the  $\beta$ -stream hypothesis.

## Geminids compared to (3200) Phaethon's Orbit

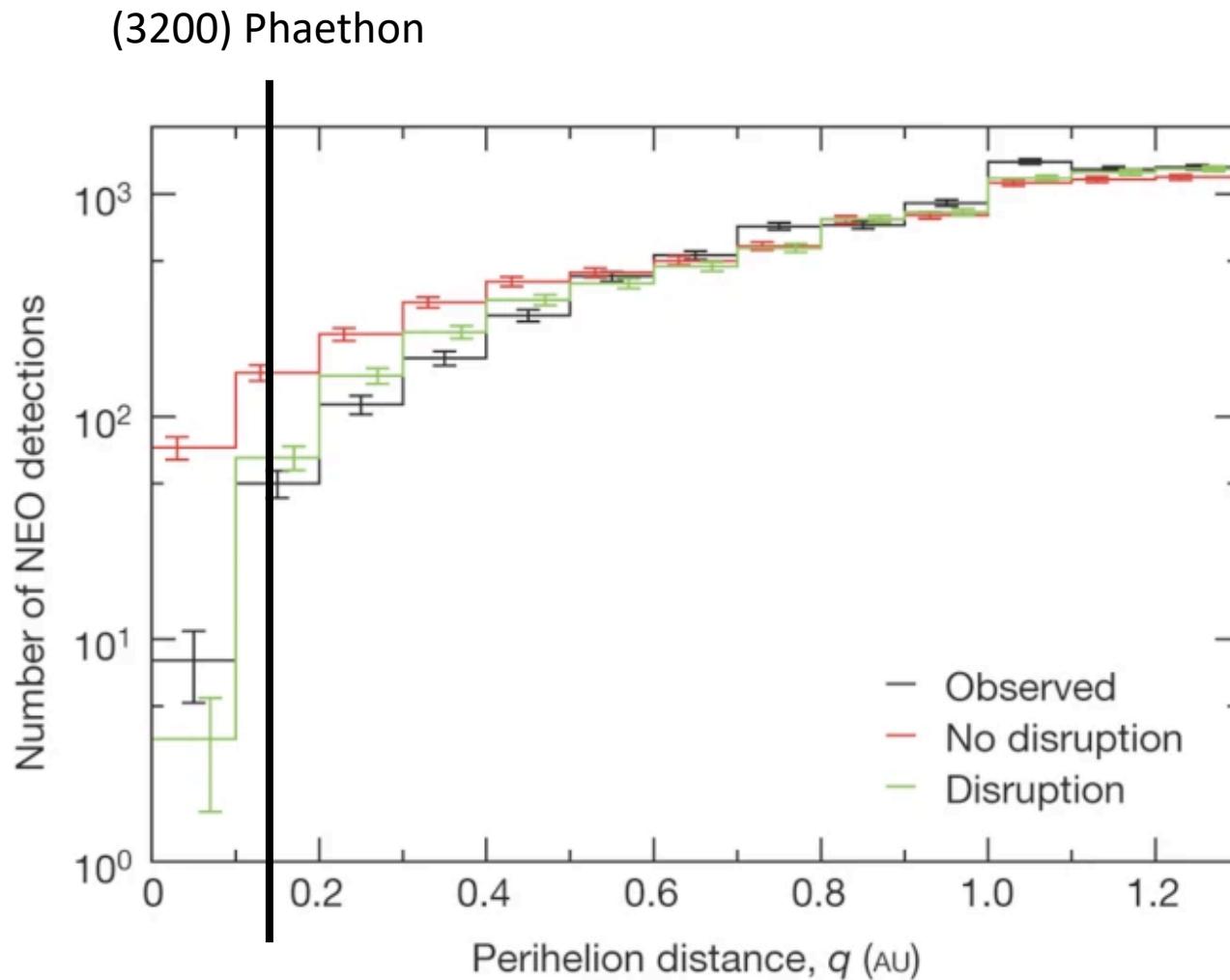




# Geminids Modeling



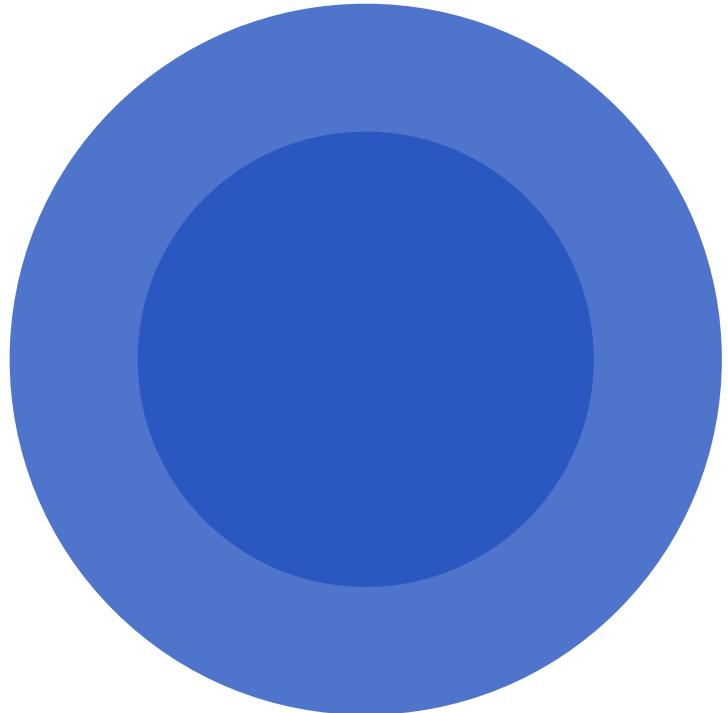
# Catastrophic Creation – Other Evidence



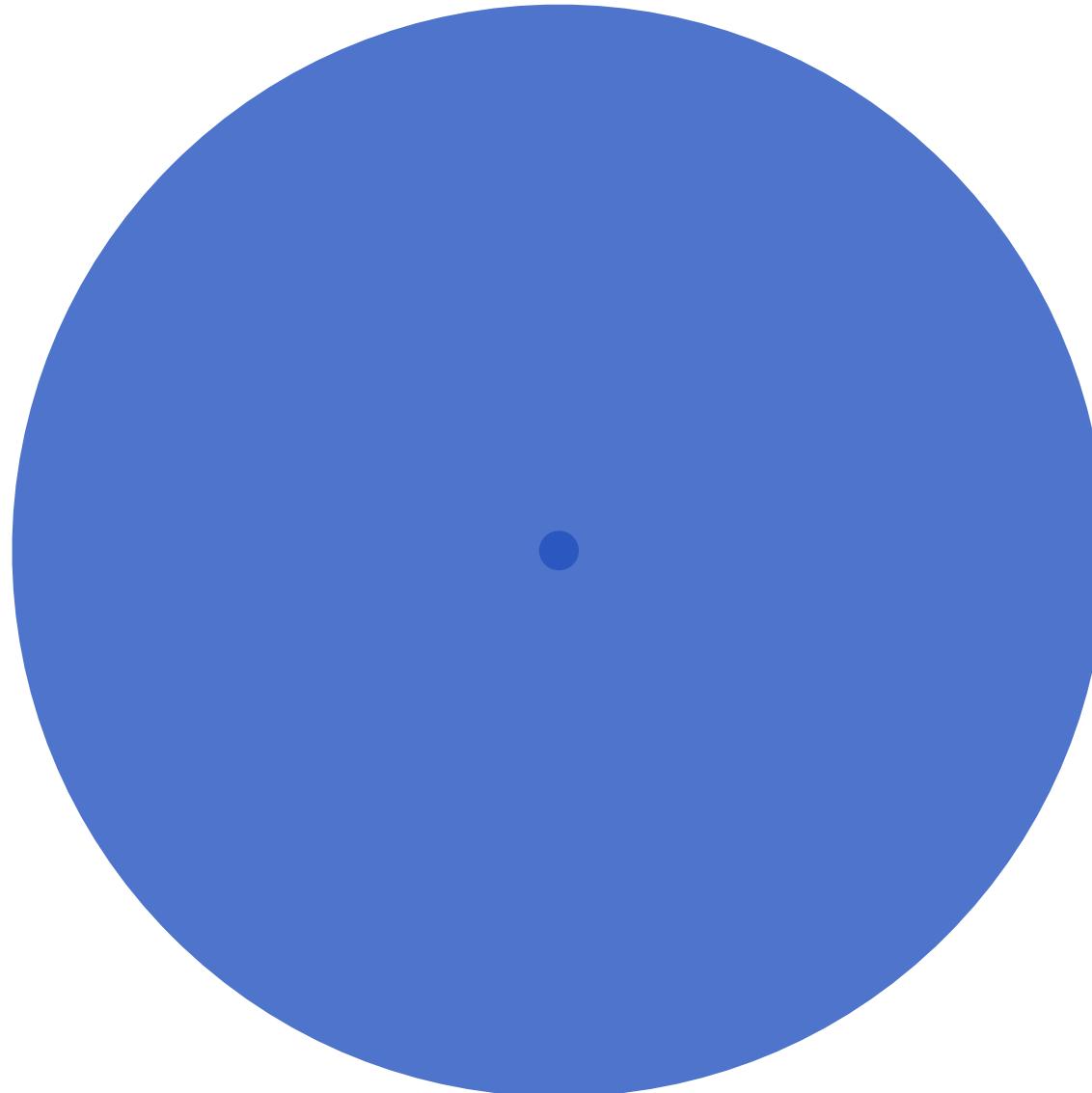
# Catastrophic Creation – Other Evidence



(3200) Phaethon



Geminids



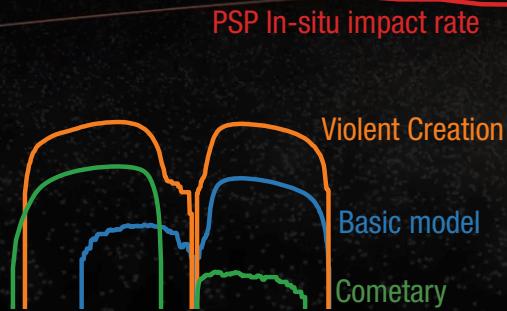
# DESTINY+ Mission



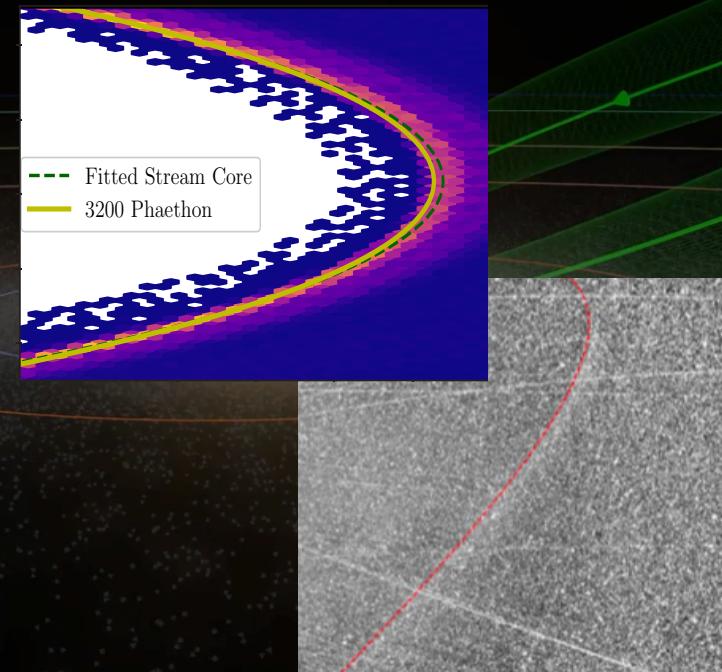


# Conclusions

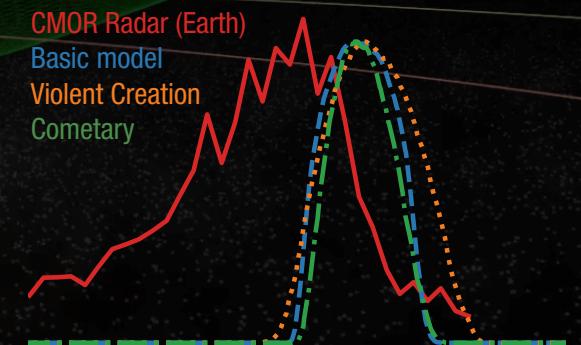
## Detectability by Spacecraft



## Stream origins & evolution



## Systemic Model Shortcomings





<https://doi.org/10.3847/PSJ/acd538>

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<https://doi.org/10.3847/PSJ/acd538>



## Formation, Structure, and Detectability of the Geminids Meteoroid Stream

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*Received 2022 October 6; revised 2023 May 11; accepted 2023 May 12; published 2023 June 15*

### Abstract

The Geminids meteoroid stream produces one of the most intense meteor showers at Earth. It is an unusual stream in that its parent body is understood to be an asteroid, (3200) Phaethon, unlike most streams, which are formed via ongoing cometary activity. Until recently, our primary understanding of this stream came from Earth-based measurements of the Geminids meteor shower. However, the Parker Solar Probe (PSP) spacecraft has transited near the core of the stream close to its perihelion and provides a new platform to better understand this unique stream. Here, we create a dynamical model of the Geminids meteoroid stream, calibrate its total density to Earth-based measurements, and compare this model to recent observations of the dust environment near the Sun by PSP. For the formation mechanisms considered, we find with the exception of very near perihelion the core of the meteoroid stream predominantly lies interior to the orbit of its parent body and we expect grains in the stream to be  $\gtrsim 10 \mu\text{m}$  in radius.

# Software Availability



[https://github.com/wcukier/Phaethon\\_Meteoroids](https://github.com/wcukier/Phaethon_Meteoroids)

# Software Acknowledgements



NumPy 

matplotlib 

SciPy 

REBOUNDx



SPICE

An Observation Geometry System  
for Space Science Missions

SpiceyPy

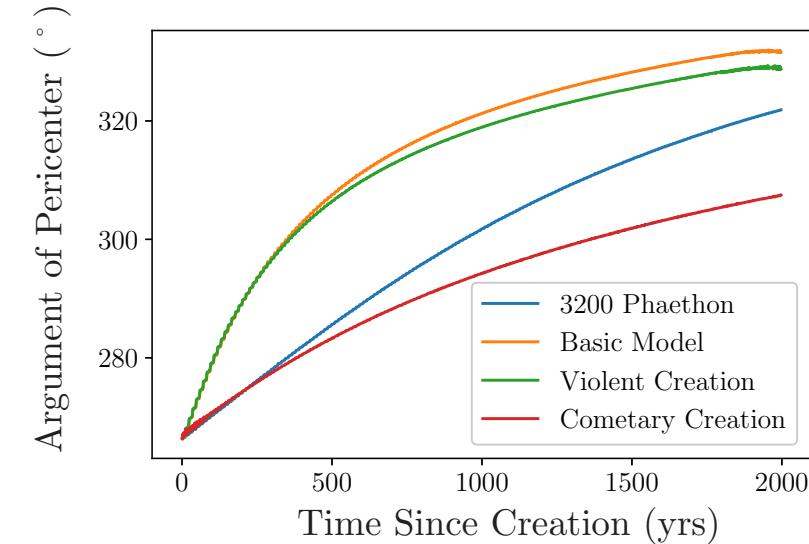
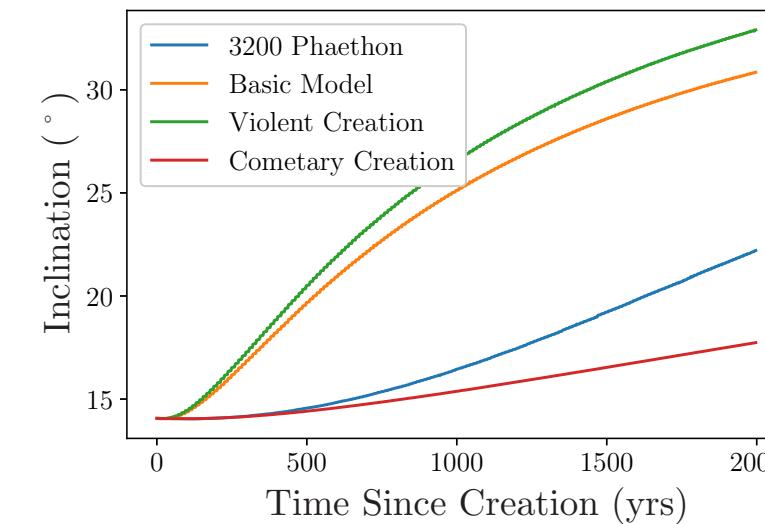
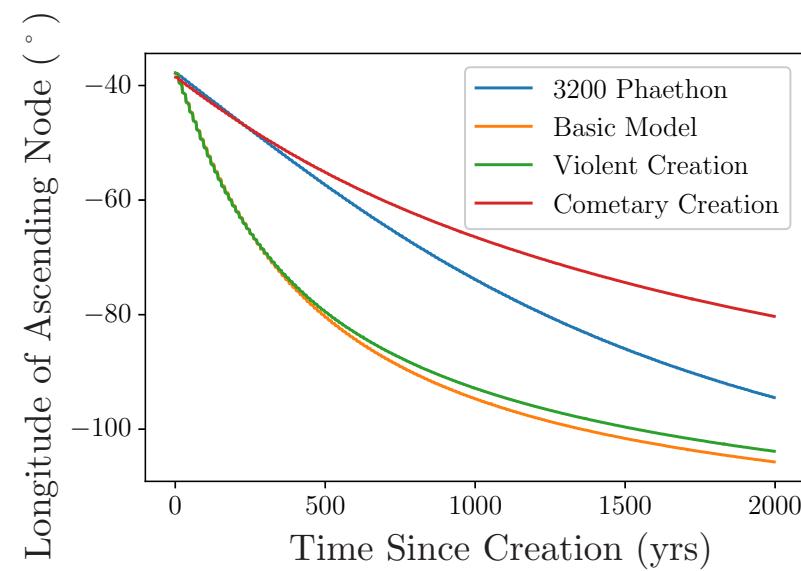
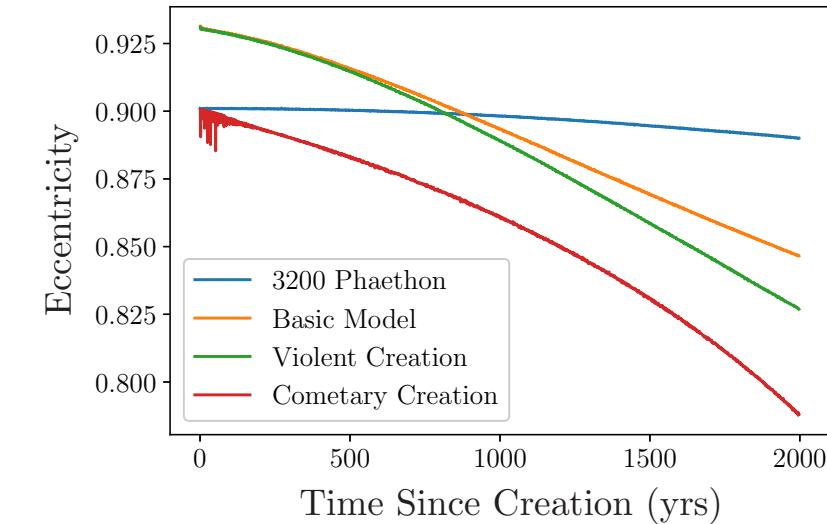
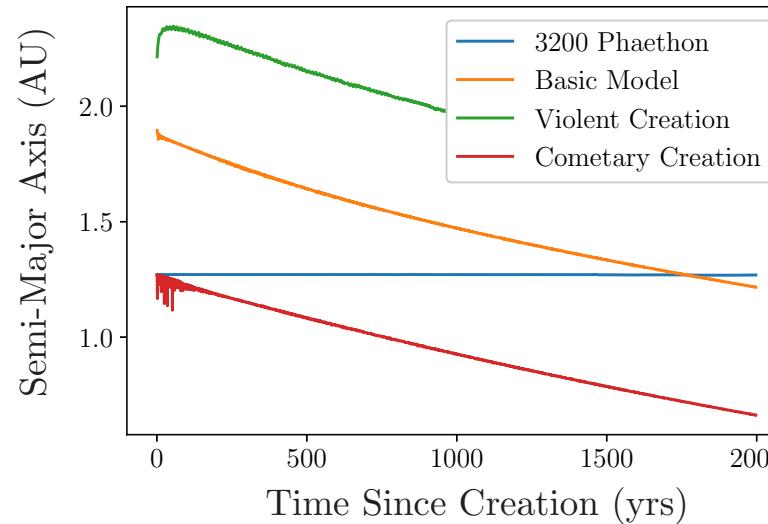
# Space Physics at Princeton



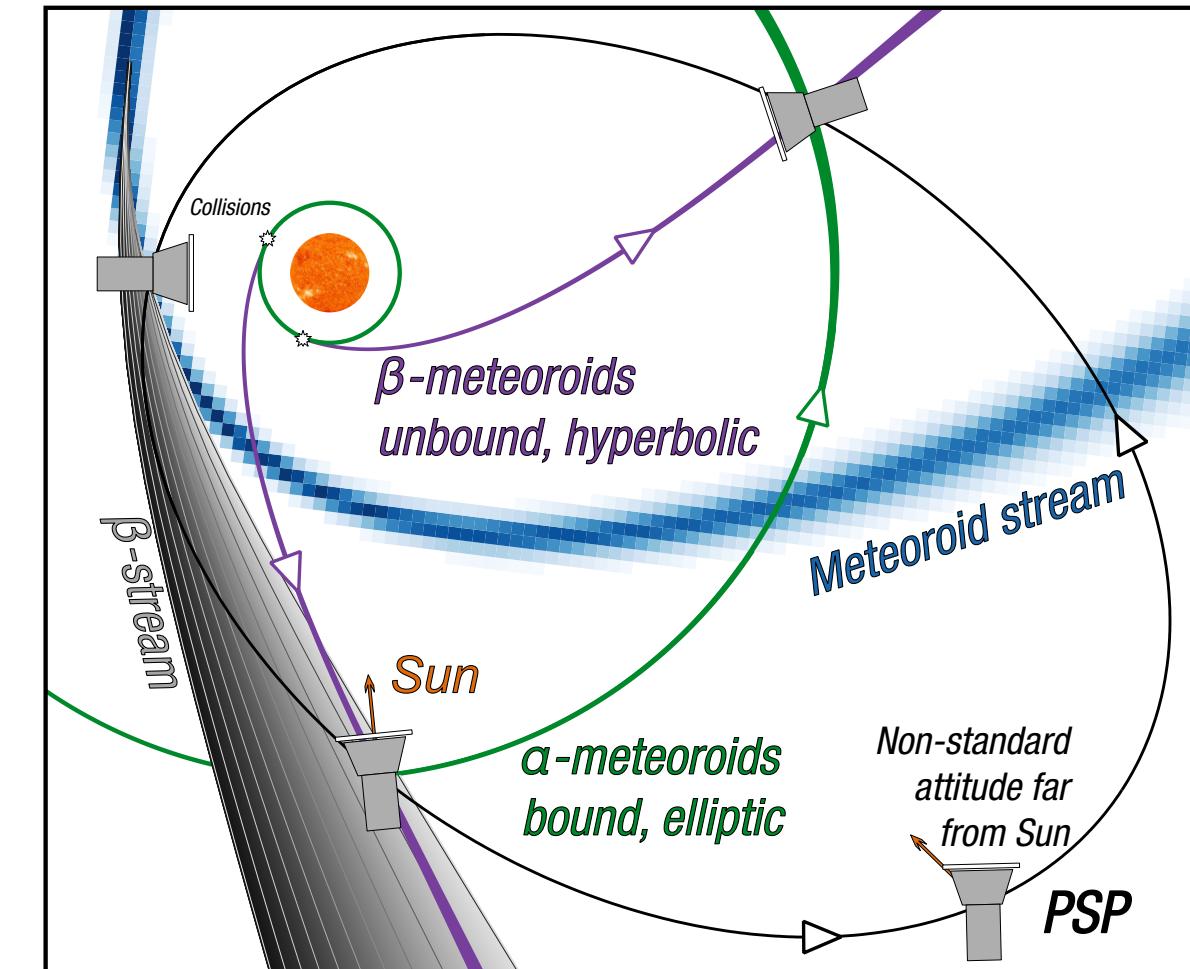
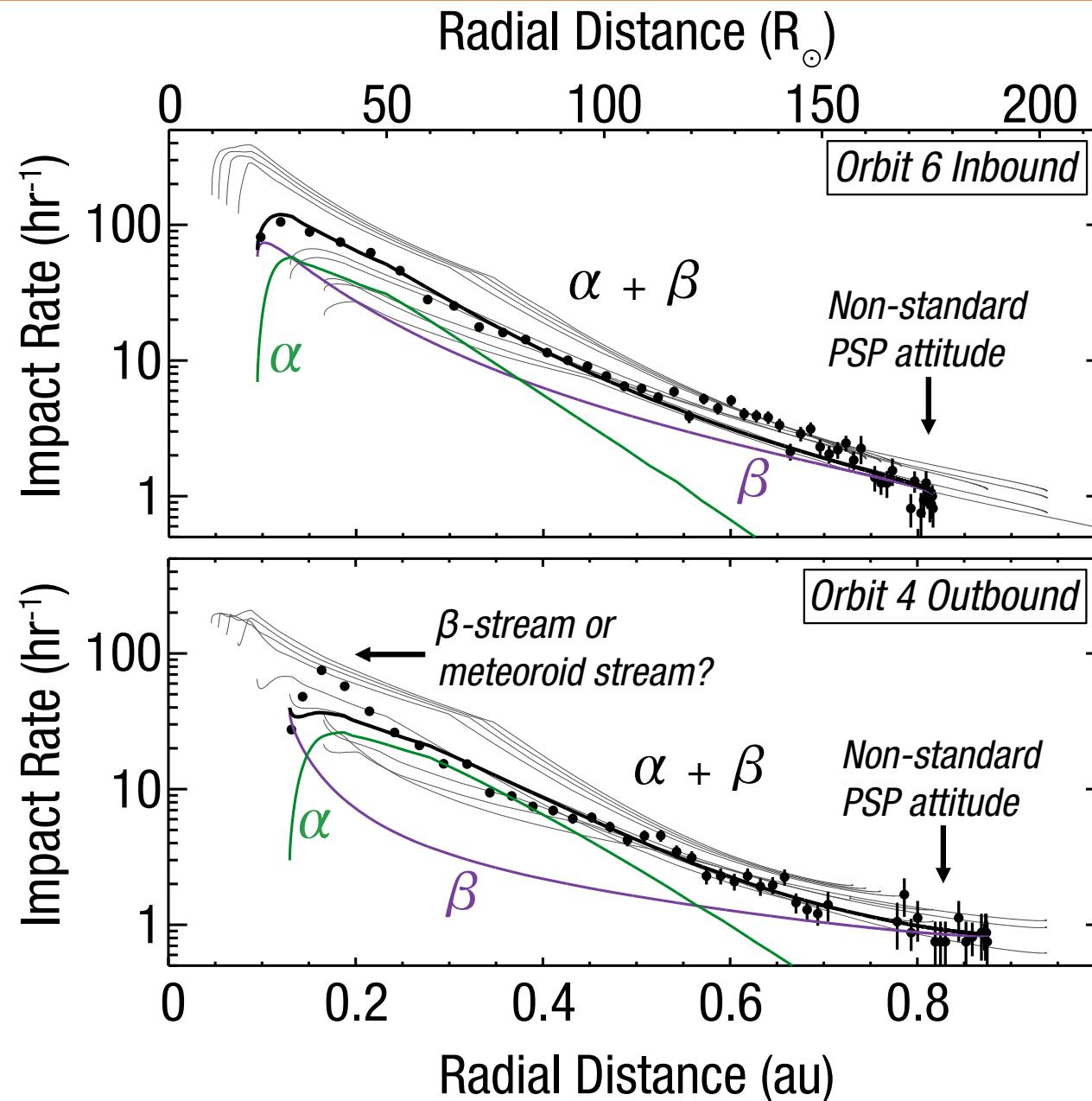




# Geminids Modeling

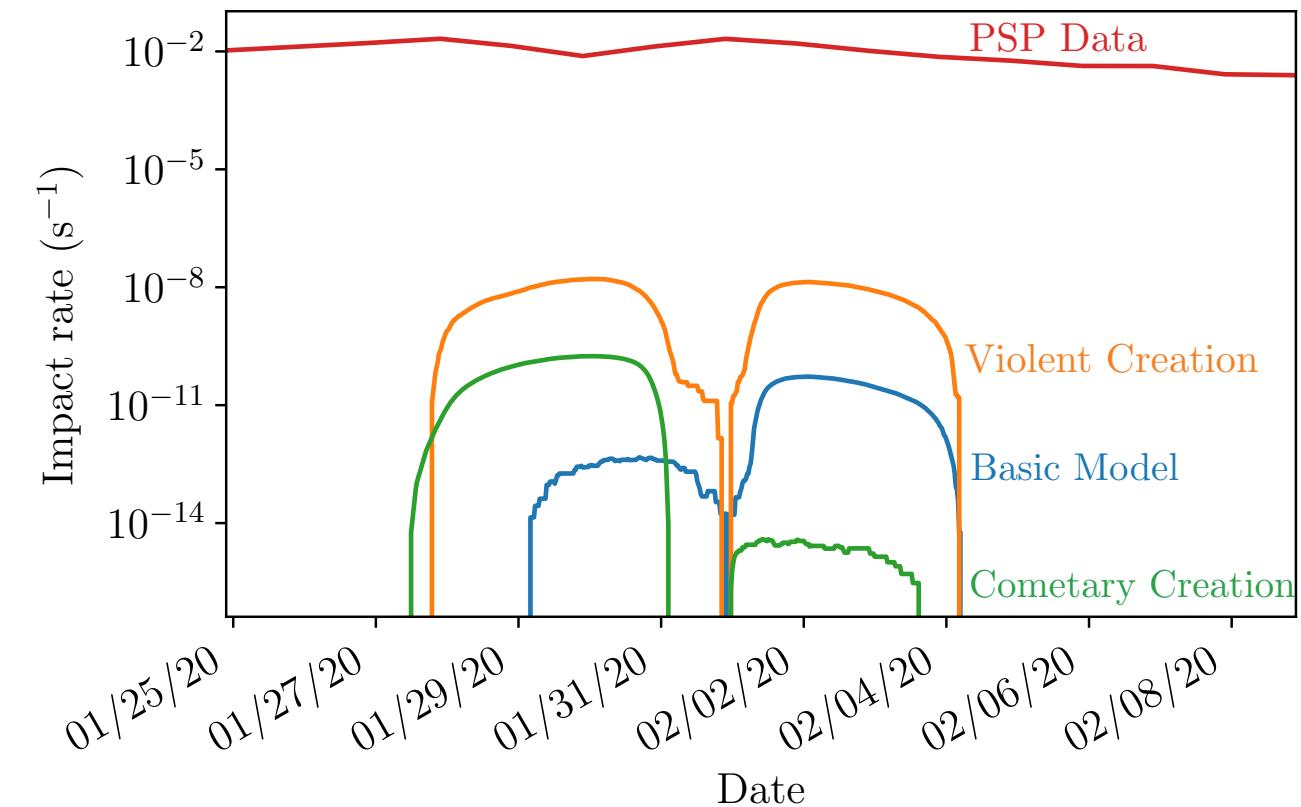
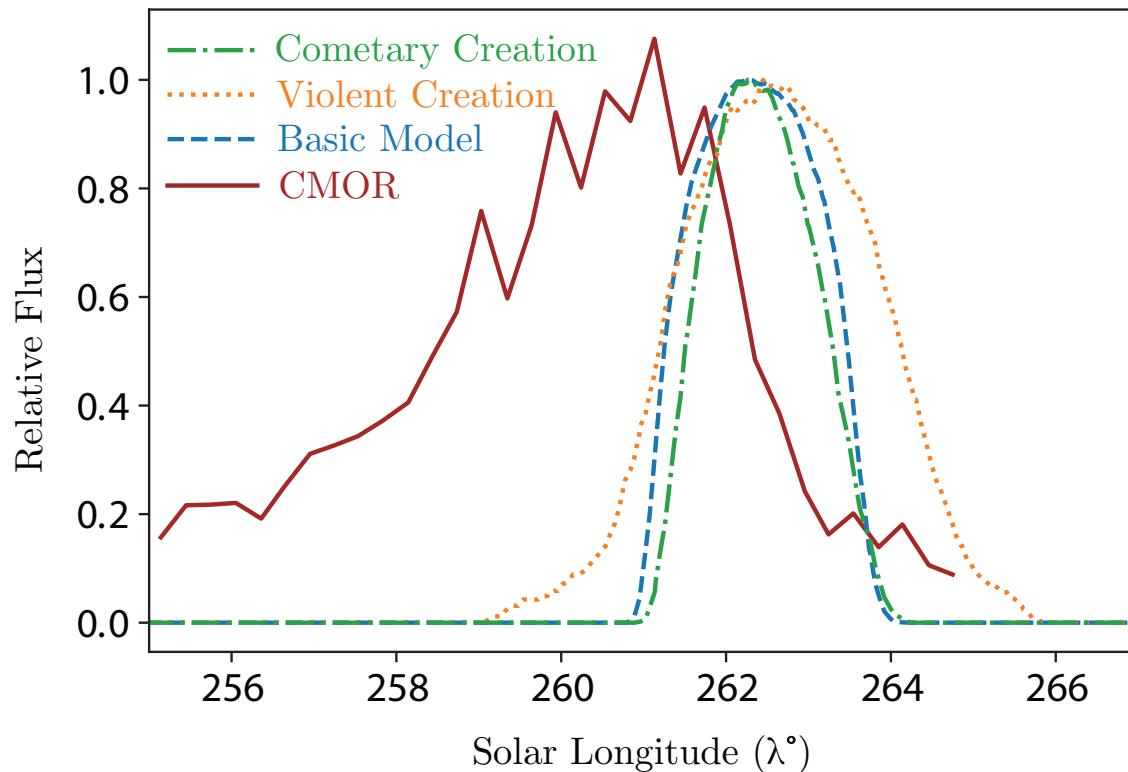


## Dust Environment of the Inner Solar System





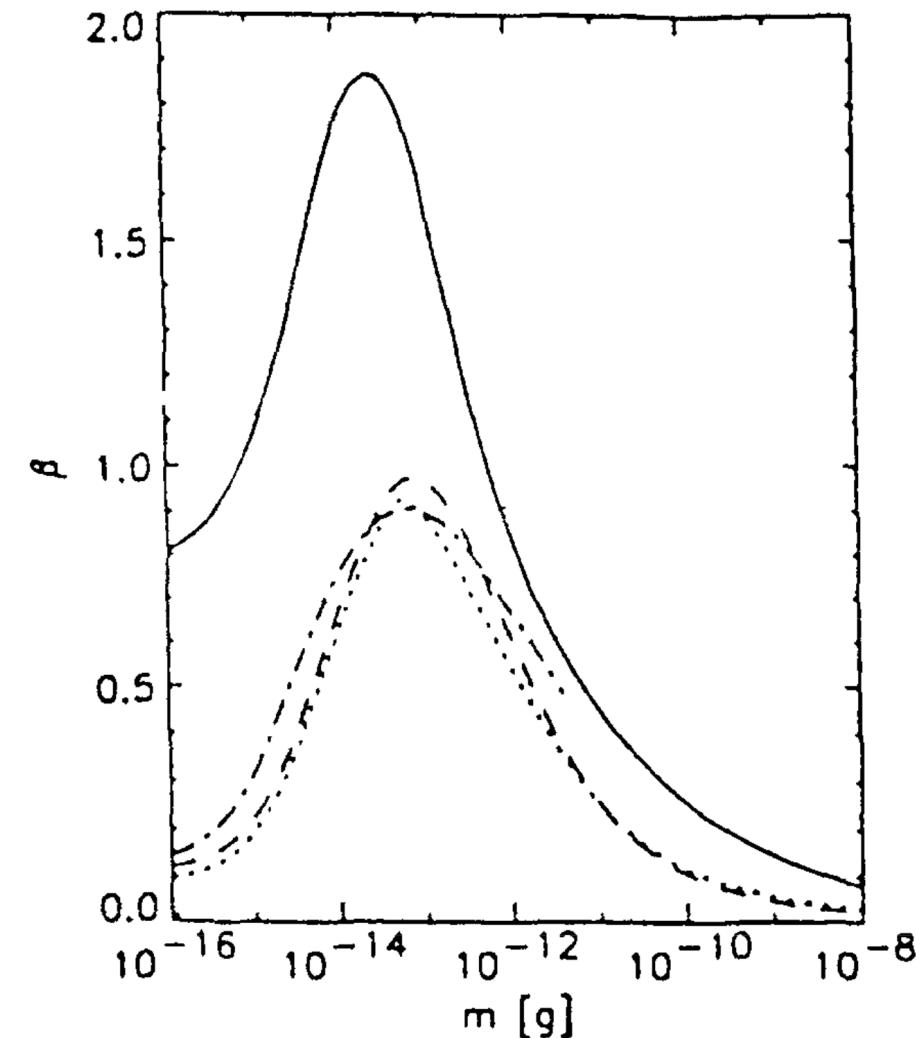
# Geminids Modeling



PSP is unable to directly observe the Geminids meteoroid stream, bolstering the  $\beta$ -stream hypothesis.



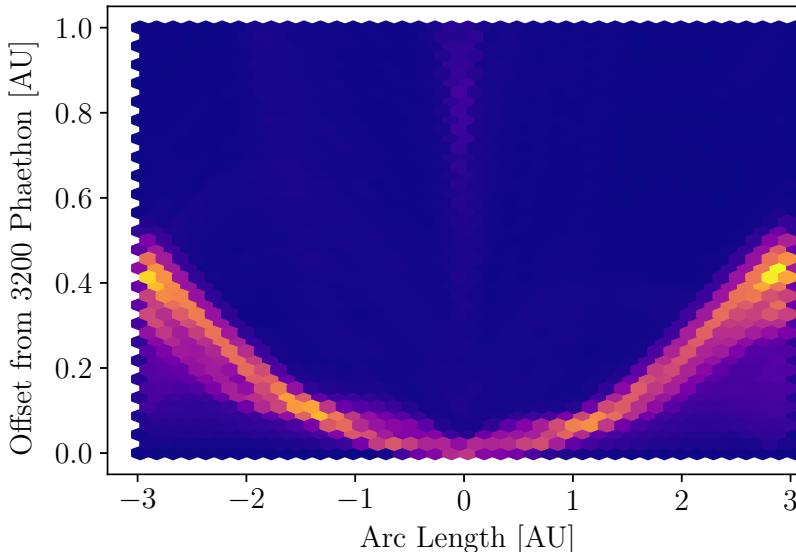
# Meteoroid Properties



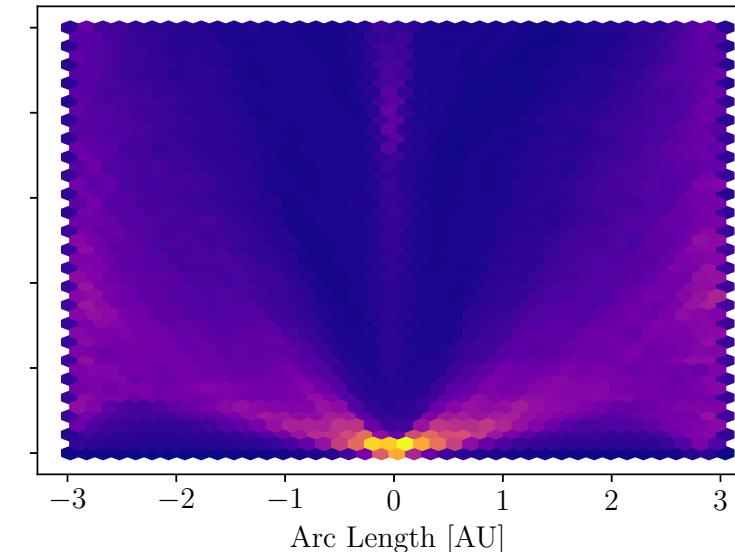
# Geminids Modeling



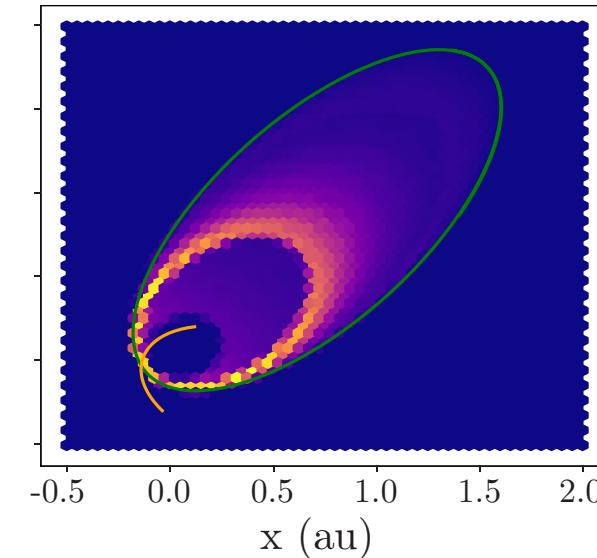
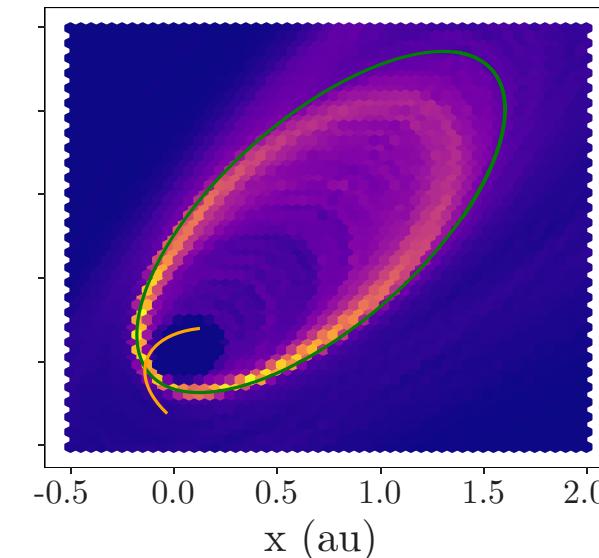
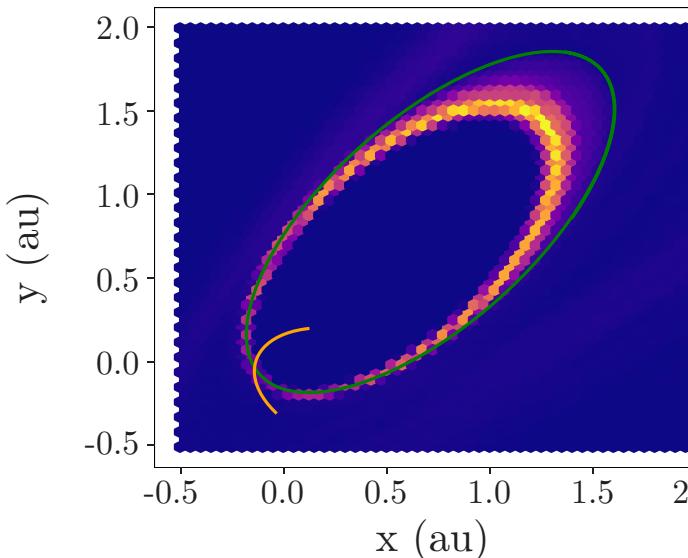
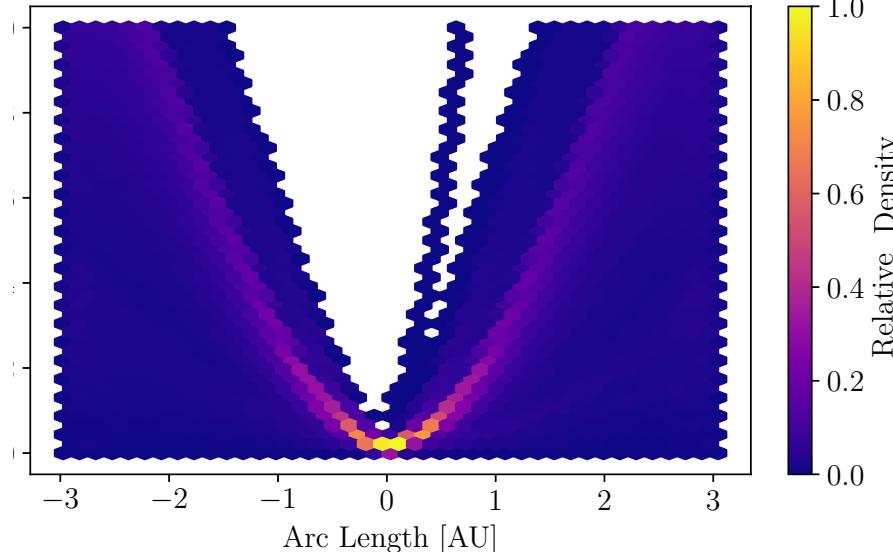
Base Model



Violent Creation

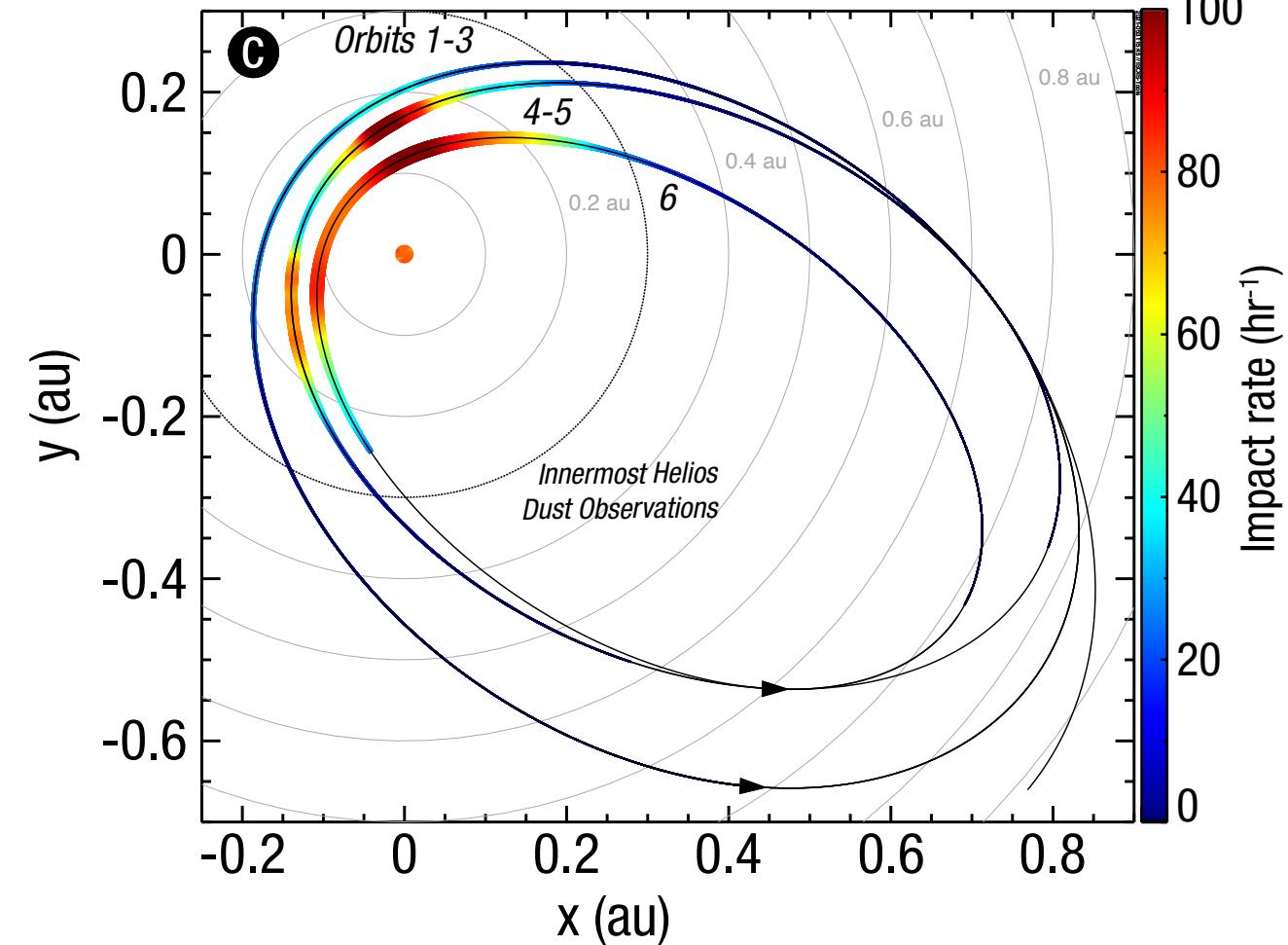
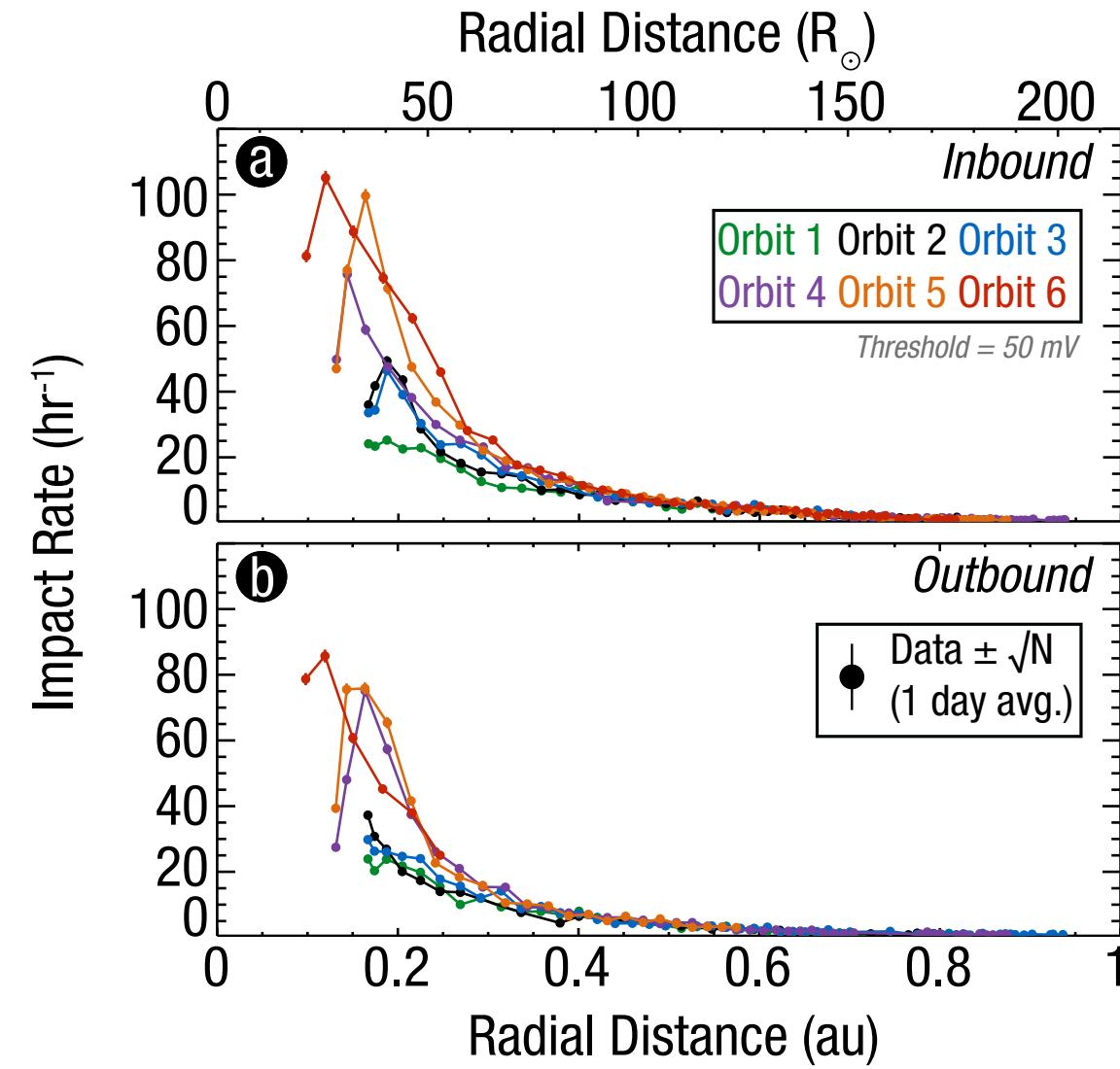


Cometary Creation





## Impact Rates

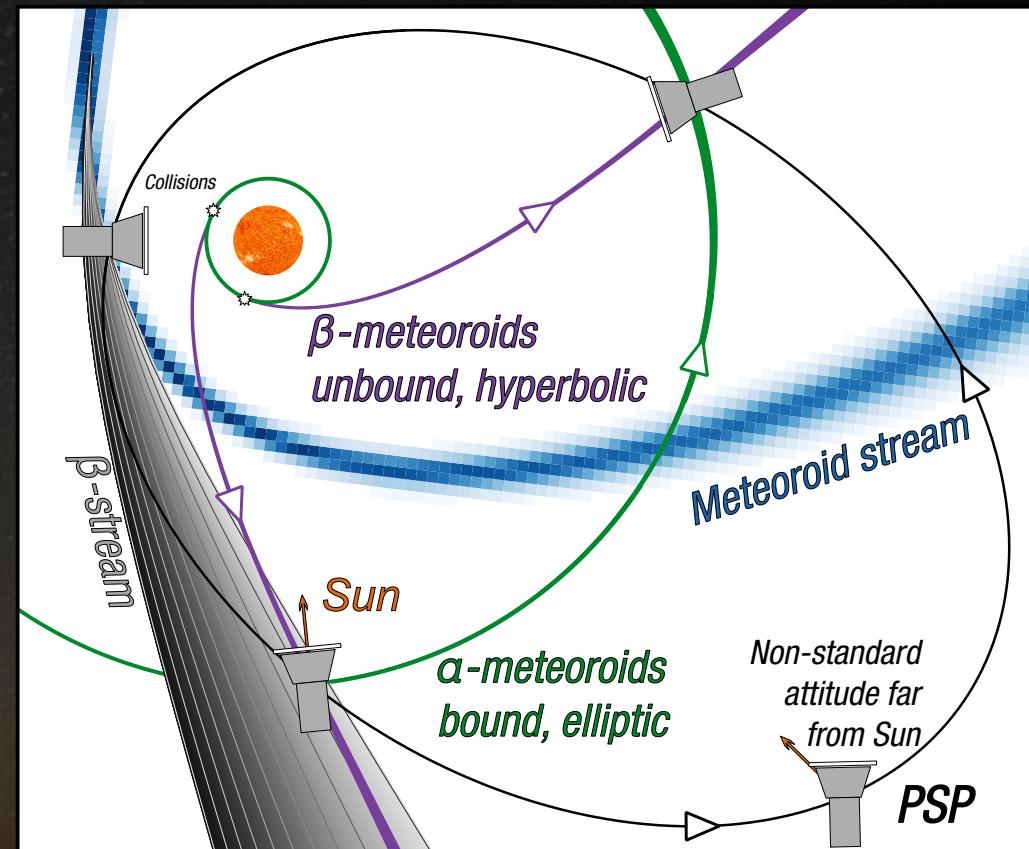




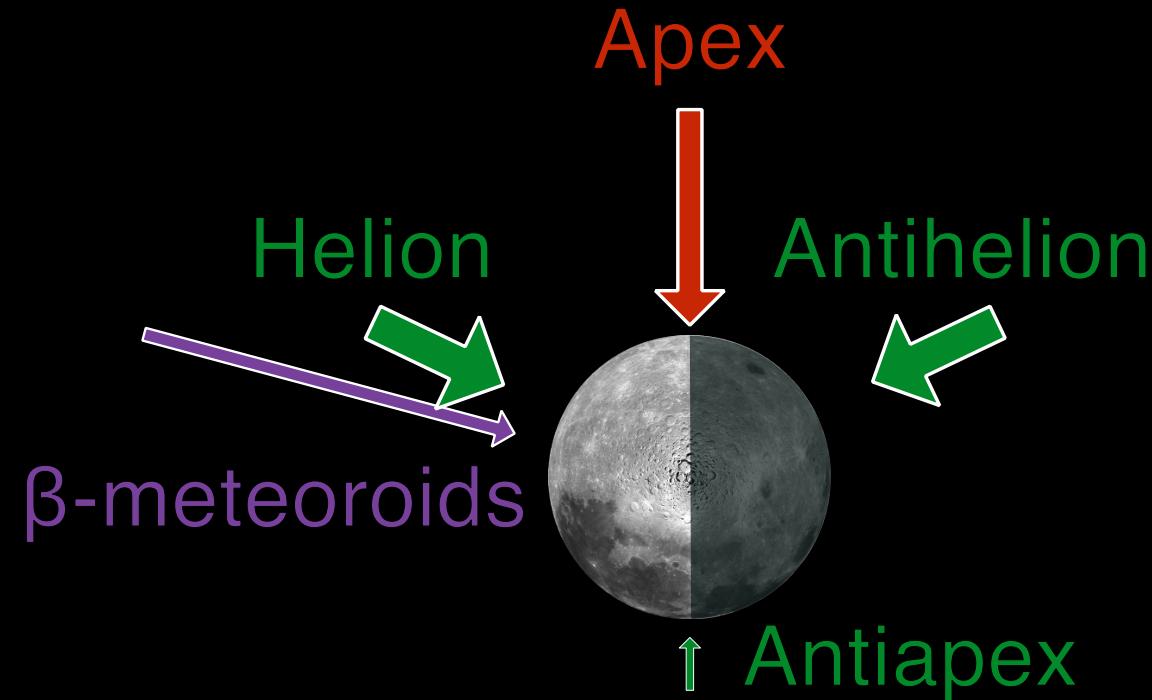
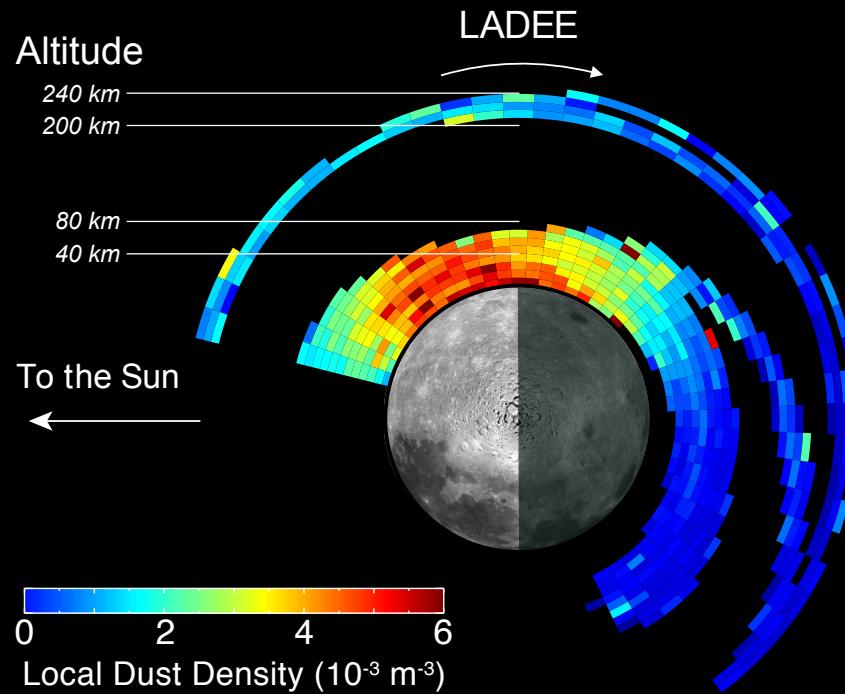
# Conclusions

- PSP impact rates due to  $\alpha$ -meteoroids,  $\beta$ -meteoroids, and a third impactor source likely related to meteoroid streams
- Geminids modeling suggests the primary meteoroid stream is not observable by PSP/FIELDS
- ISOIS experiences higher impact fluxes than predicted, which indicates retrograde meteoroids may be more abundant than expected. ISOIS is able to continue to make science measurements.
- Estimated zodiacal erosion rate of at least  $\sim 100 \text{ kg/s}$
- PSP provides a continuous monitor of  $\beta$ -meteoroid fluxes, informing on space weathering process at airless bodies
- If the inner source of PUIs is dust, must be from nanograins  $< 50 \text{ nm}$

Szalay et al. 2021



# $\beta$ -meteoroid fluxes to airless bodies



- $\beta$ -meteoroids may provide the missing source in the lunar dust ejecta cloud's asymmetry and could play an important role in space weather airless bodies.
- PSP will constrain the time variability of  $\beta$ -meteoroids over a solar cycle.