



# Methods for Simulating Comet Populations in Preparation for the Near-Earth Object Surveyor Mission

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NEO Surveyor Mission Investigation Team

**Introduction:** The Near-Earth Object Surveyor Mission (NEO Surveyor) will provide unprecedented detection, tracking and characterization of Near-Earth Objects (NEOs) using high-cadence imaging from a space-based infrared telescope.

We present updates to our comet simulation methods:

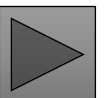
- (1) [Orbital distributions](#)
- (2) [Nuclei size frequency distributions](#)
- (3) [Dust comae activity behaviors](#)
- (4) [CO+CO<sub>2</sub> comae](#)
- (5) [Tails/trails](#)



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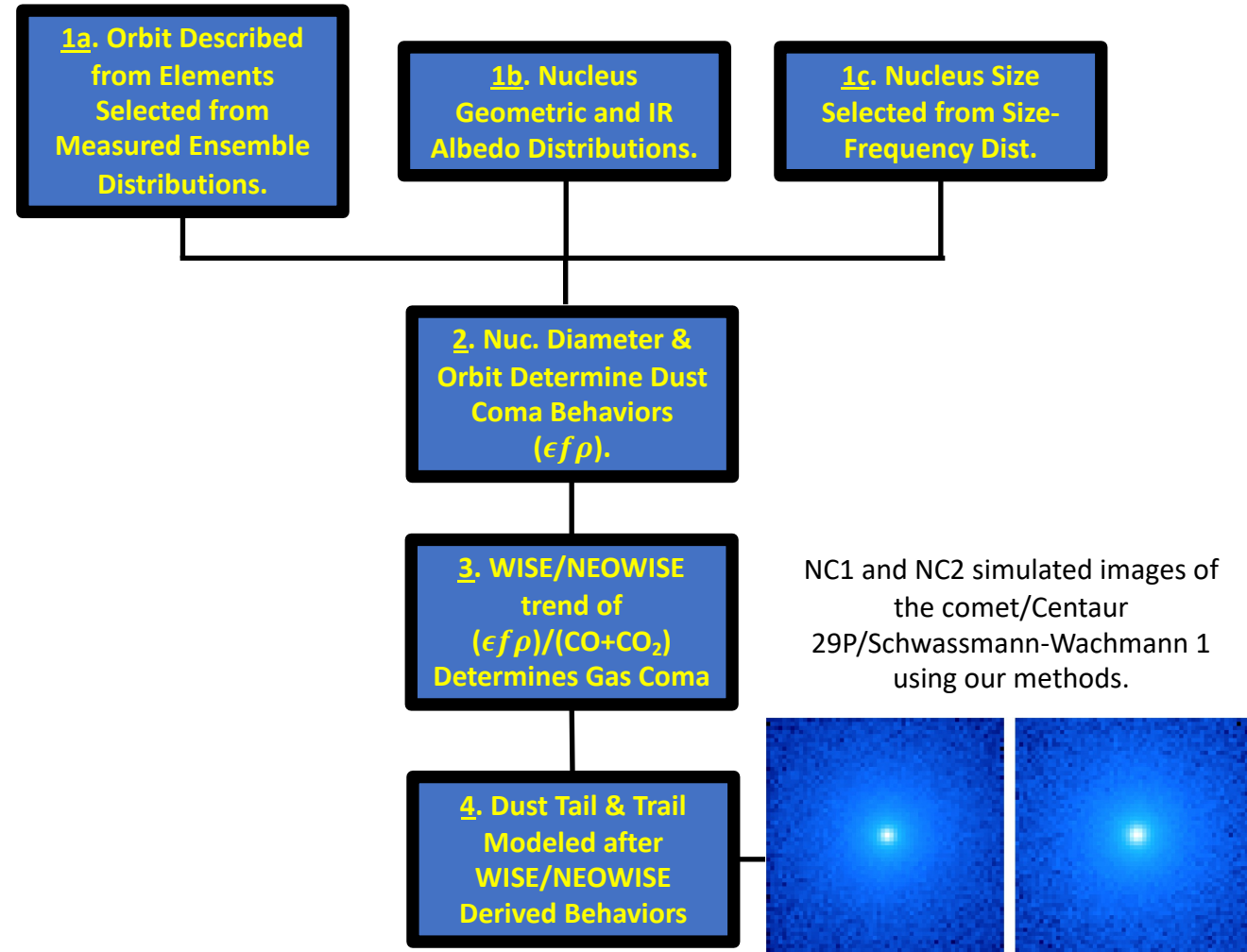
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# Mission Overview

- The NEO Surveyor Mission is a NASA funded space-based IR telescope with the direction to detect, track, and characterize near-Earth objects.
- Its two detectors will produce images at bandpasses of 4-5.2 microns (NC1) and 6-10 microns (NC2).
- Planning for the NEO Surveyor requires an accurate model of the Solar System's small body populations in order to develop efficient operational survey strategies and to assess survey performance once in-flight operations have commenced.
- We are currently developing the NEO Surveyor Survey Simulator (NSS) and the Reference Small Body Population Model (RSBPM) that will simulate the Solar System and the survey's detection efficiencies.
- For this model's development we are developing methods to accurately represent the 2-D surface-brightness(nucleus + coma) characteristics of the comet populations.

# Flow Chart of JFC Simulation Methods



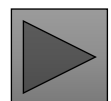
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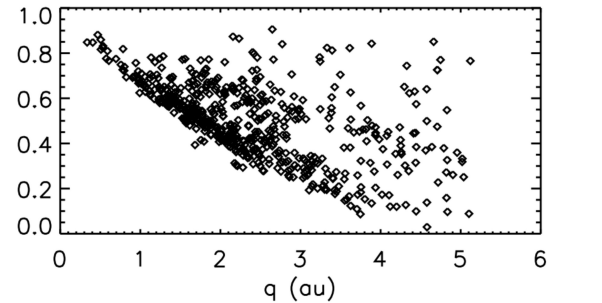
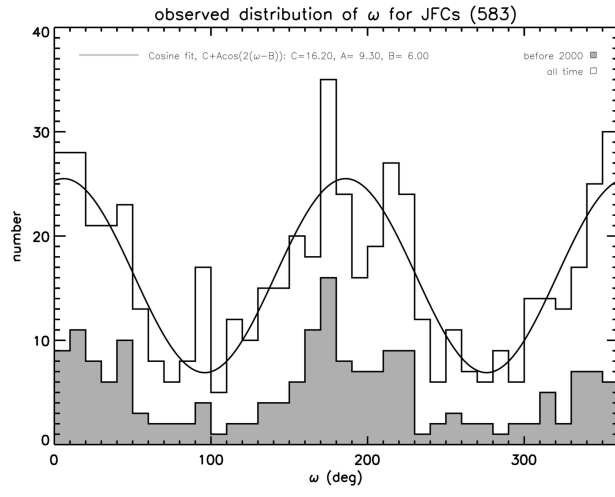
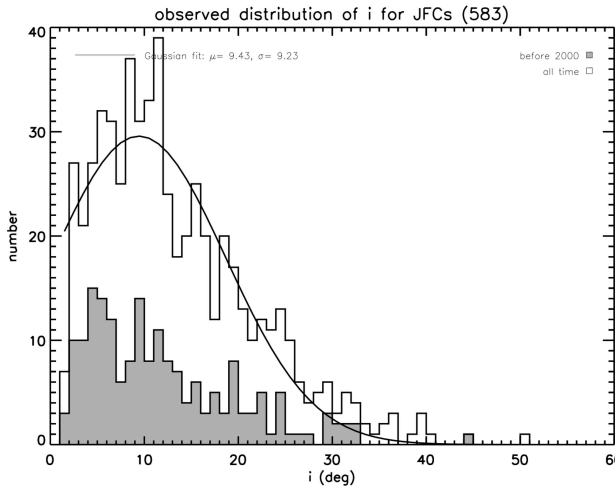
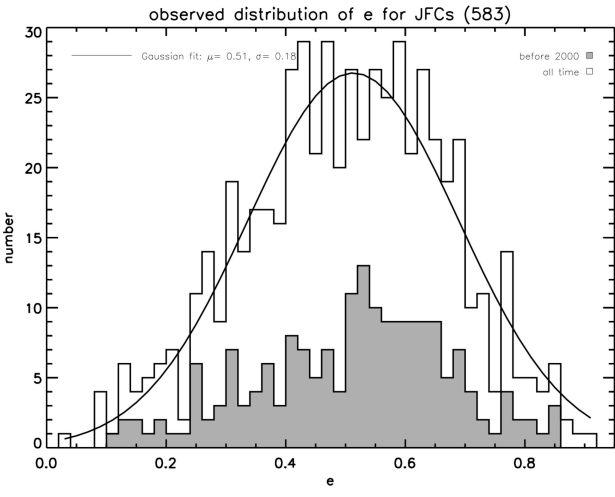
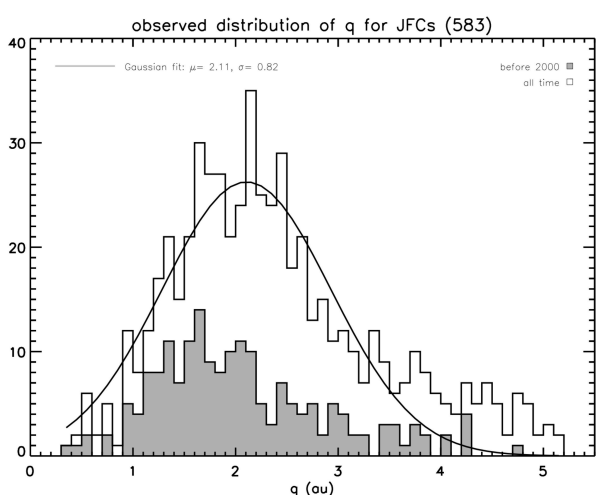
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# 1a. Selection from JFCs Orbital Element Distributions.

- For each of the comet populations (JFCs, LPCs, Halley type, etc.) a database of comets is generated based on Markov-Chain Monte Carlo sampling from observed orbital elements distributions.
- We show here a compiled list of orbital elements based on currently known JFCs [cite] from which we base our sampling.

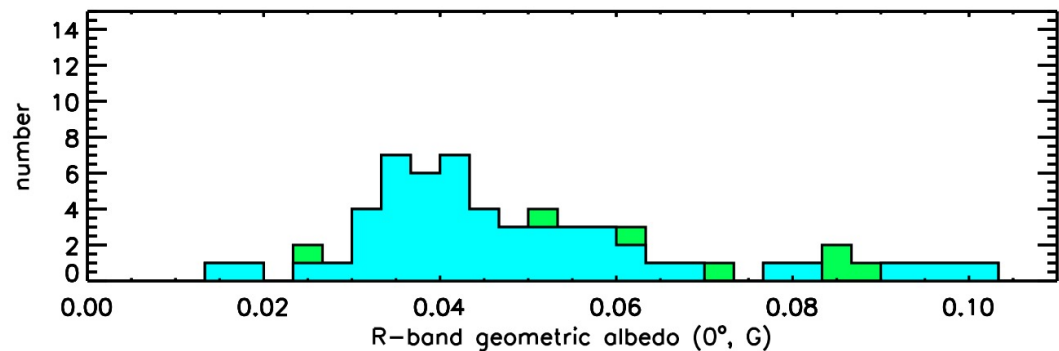
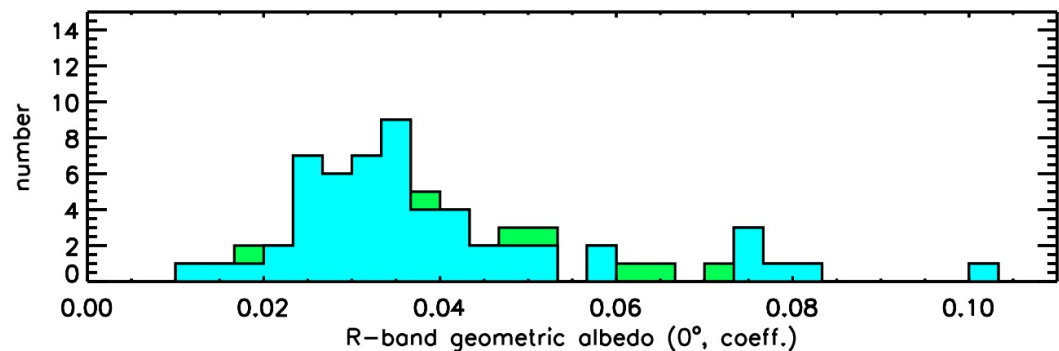


- Once inflight operations have commenced, we will be able to help debias the JFCs orbital element distributions for smaller diameter nuclei based on the survey's detections.



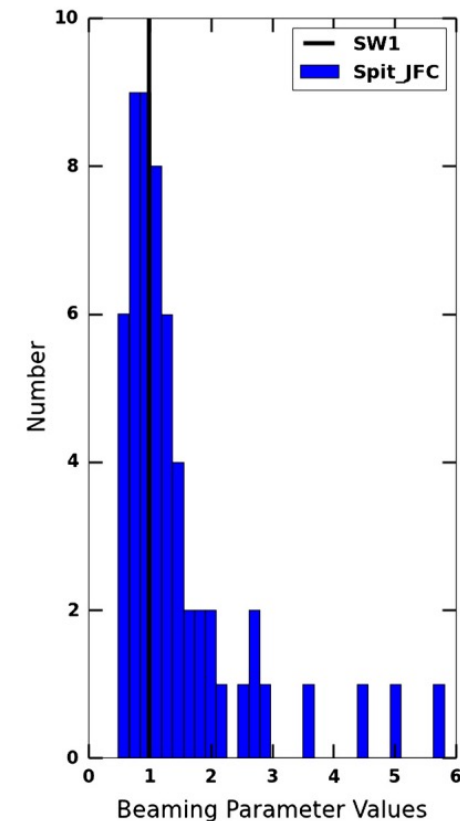
# 1b. Selection from JFCs Albedo Distributions.

- Each comet in the simulated population will be assigned a geometric albedo, IR albedo, and beaming parameter based on the observed distributions.



Geometric albedo distribution (Yan Fernández (SEPPCoN), personal communication)

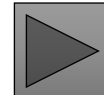
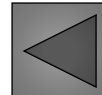
- Left: the geometric albedo will be assigned to each comet based on MCMC sampling.
- Right: Similarly, each nucleus will be assigned an infrared beaming parameter based on the observed distribution (Fig. credit: []).
- IR albedos will be based on the observed distributions from the WISE/NEOWISE database.



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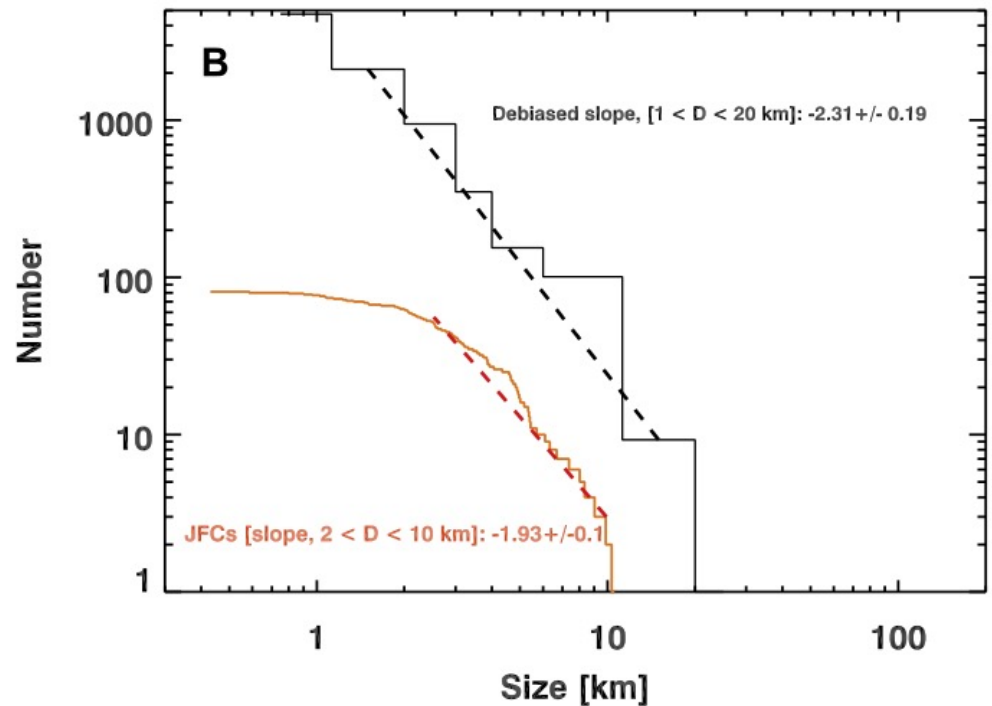
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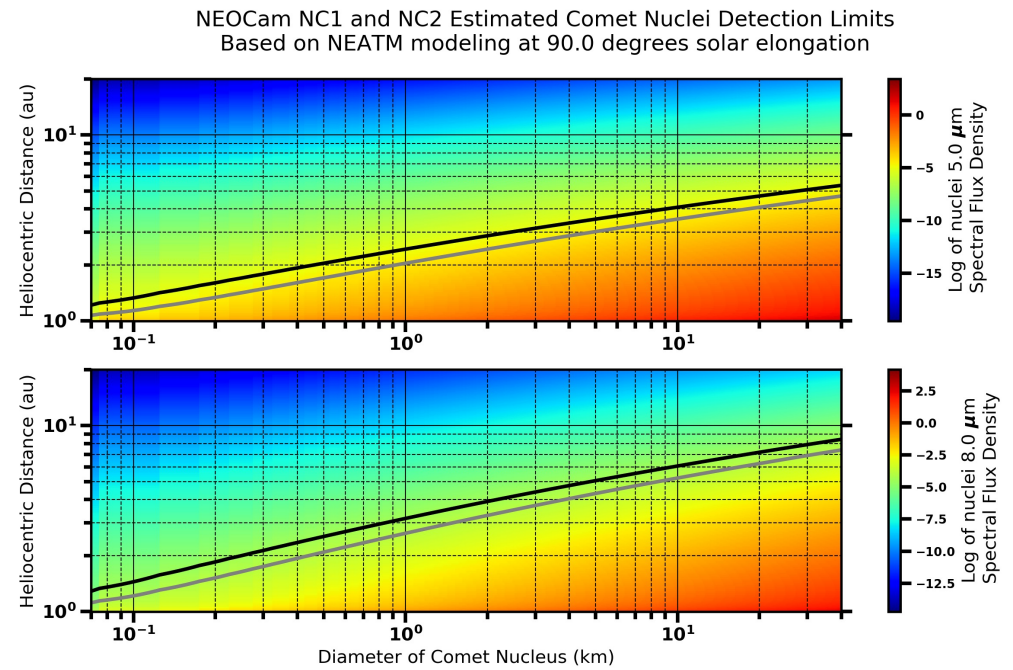
# 1b. Selection from JFCs Nuclei Size-Frequency Distributions



- Each comet in the simulated population will be assigned an effective spherical nucleus diameter following the size-frequency distributions based on WISE/NEOWISE [10] & SEPPCoN [4].



WISE/NEOWISE (Bauer et al. 2017)



- Using expected detector's sensitivities, we can estimate the heliocentric detection limits based on nuclei diameter.
- Expected NEO Surveyor Detection limits  $R_H$  vs Nucleus Diameter for low (black contour) and high (gray contour) zodiacal backgrounds



# 2. Dust Comae Simulation Methods

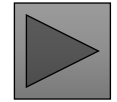
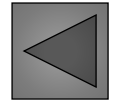
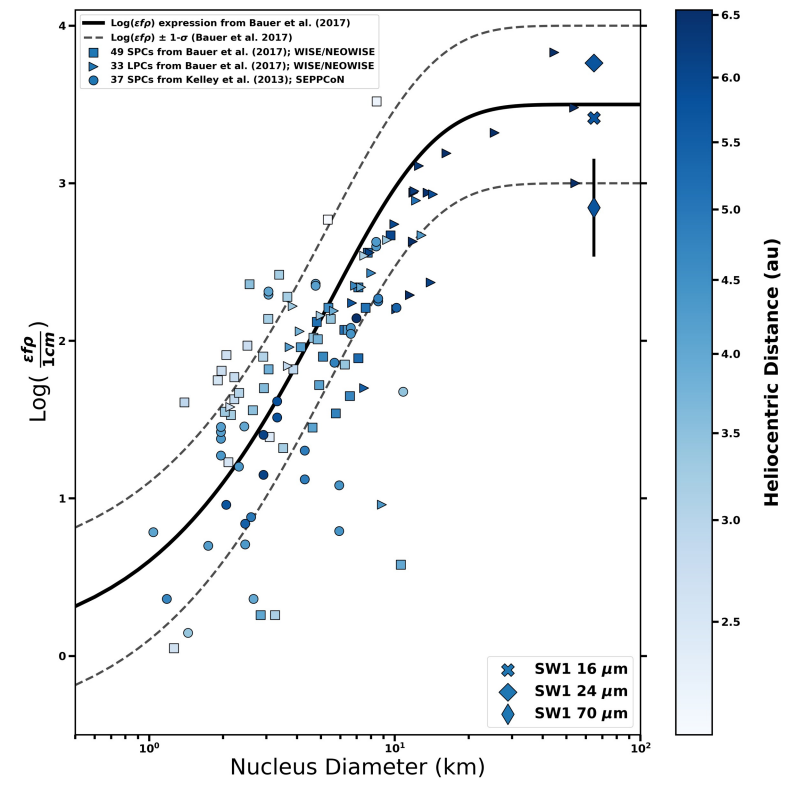
The level of dust coma activity for a particular comet has been notoriously difficult to predict. To accurately represent the comet populations into the RSBPM methods of determining whether a particular comet to be simulated is displaying dust activity during the epoch of simulation, and the extent of this activity, must be developed. Our approach of predicting the presence and level of dust comae activity makes use of ensemble behaviors of comet derived from their  $\epsilon f \rho$  measurement based on the WISE/NEOWISE data [10]. The  $\epsilon f \rho$  parameter is an often-used proxy for dust comae activity based on thermal emission for micron sized and larger dust grains. activity of activity behaviors from other infrared surveys. Dust coma activity based on the NEOWISE derived formula for  $\epsilon f \rho$  [10]:

$$\log \frac{\epsilon f \rho}{1 \text{ cm}} = 3.5 \left( 1 - \exp \left( - \frac{D_N}{5.3 \text{ km}} \right) \right) + N(0,0.25)$$

where  $N(0, 0.25)$  is a random number generated from a normal distribution with mean of 0 and variance of 0.25. Below, we compare this functional relationship with respect to various parameters searching for an correlations.

This dust activity level will be linked to a particular orbital position (e.g., perihelion distance) of the individual comet and scaled based on the comet's actual orbital position during the simulated NEOSM detection.

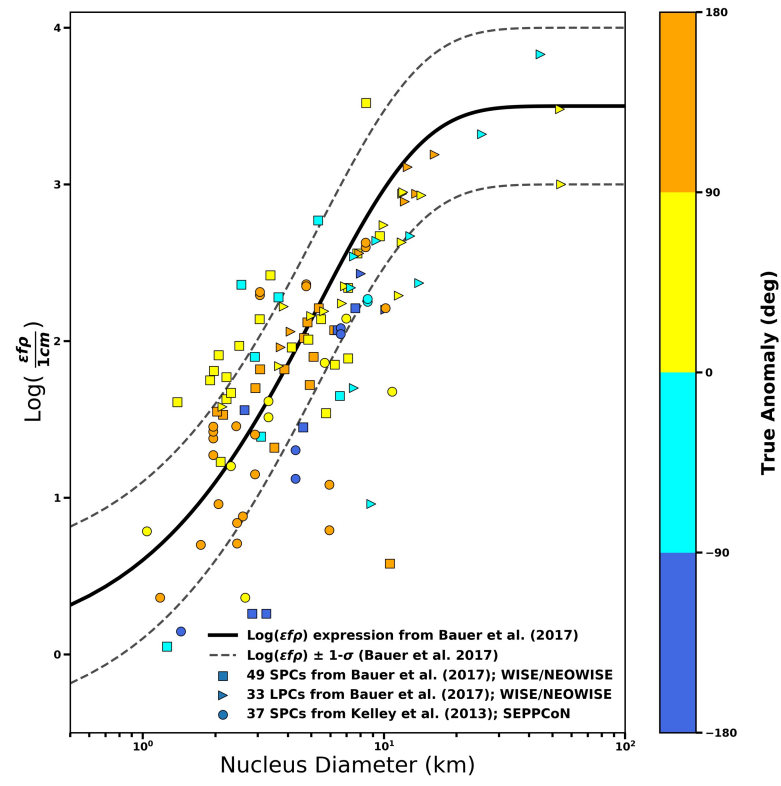
Comparison of  $\epsilon f \rho$  vs. nucleus diameter for SPCs and LPCs based on the SEPPCoN [4] and WISE/NEOWISE [10] surveys.  $R_H$  is indicated by the marker color as indicated by the colorbar to the right.





# 2. Dust Comae Simulation Methods

Similar to the previous slide's figure, but colormap indicates true anomaly (TA) of the comet during the epoch of observations. Negative TA values indicate pre-perihelion and positive values indicate post-perihelion positions.



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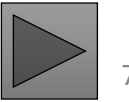
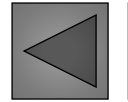
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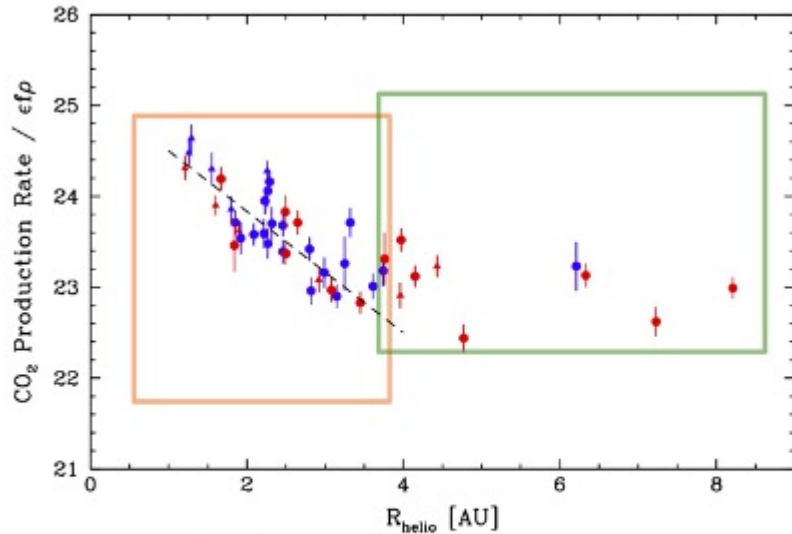
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# Future Work: Gas Comae & Tails/Trails Simulations



- The WISE/NEOWISE derived properties for comets indicated that there are relationships between  $\epsilon_{fp}$  and  $CO+CO_2$  gas production rate. We are analyzing these data in more detail to develop methods of estimating a particular comet's  $CO$ - and  $CO_2$ -production rates.



**Figure 9.**  $\text{Log}(Q_{CO_2}/\epsilon_{fp})$  as a function of  $R_h[\text{AU}]$ . LPCs are represented by red symbols, SPCs blue. Note the two dissimilar groupings of behavior (orange and green boxes) inside and outside 4 AU. The latter may be  $CO$  production driven activity, and includes 29P at 6.2 AU, and C/2009 P1 (Garradd) at 6.3 AU.

- $CO$  or  $CO_2$ ?: We are investigating known abundance ratios for  $CO/CO_2$  measured for comets to properly incorporate the spatial profile for gas comae in NC2 images.
- Tails and Trails will be modeled after the ensemble properties detected based on the WISE/NEOWISE population.

# Acknowledgments & References



- Acknowledgements:

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- References:

- [1] Lilly (Schunova) et al., 2020, AAS Meeting Abstracts, 385.04.
- [2] Lisse et al., 2002, IAU Colloq. 181, Vol. 15, 259.
- [3] Ootsubo et al., 2012, *ApJ*, **752**:15.
- [4] Fernandez et al., 2013, *Icarus*, 226, Issue 1.
- [5] Denneau et al., 2013, *PASP*, 125:926.
- [6] Masci et al., 2019, *PASP*, 131:995.
- [7] Tonry et al., 2018, *PASP*, 130:988.
- [8] Mainzer et al., 2011, *ApJ*, 731:53.
- [9] Kelley et al., 2013, *Icarus*, 225:475.
- [10] Bauer et al., 2015, *ApJ*, 814:85.

**Thank You For Your Attention!**

**Feedback via email  
([charles.schambeau@ucf.edu](mailto:charles.schambeau@ucf.edu))  
on the simulation methods are  
appreciated.**



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