Cometary Dust Tails in NEOWISE

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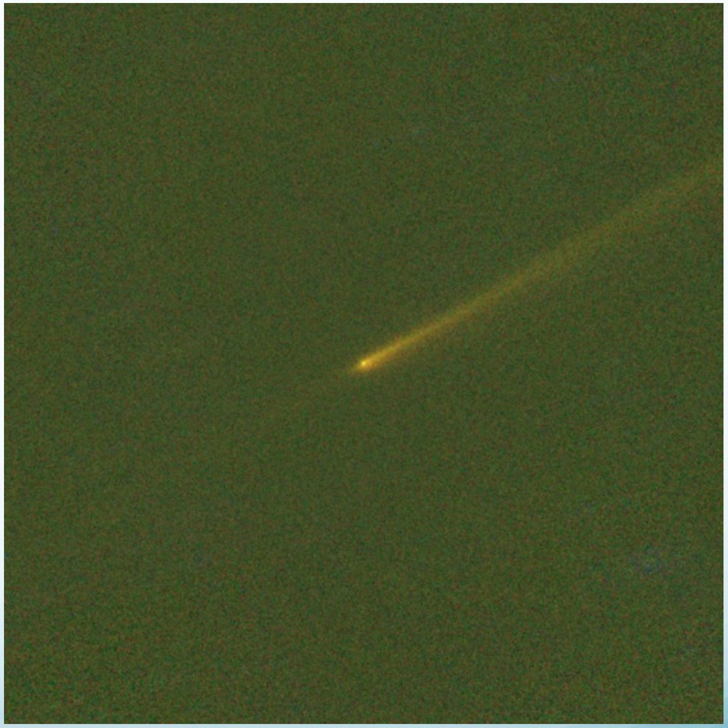
Introduction

- Definitions: nucleus, coma, tail, and trail

rosetta.jpl.nasa.gov



67P at 3.3 AU in Jan. 2010

Types of Comets

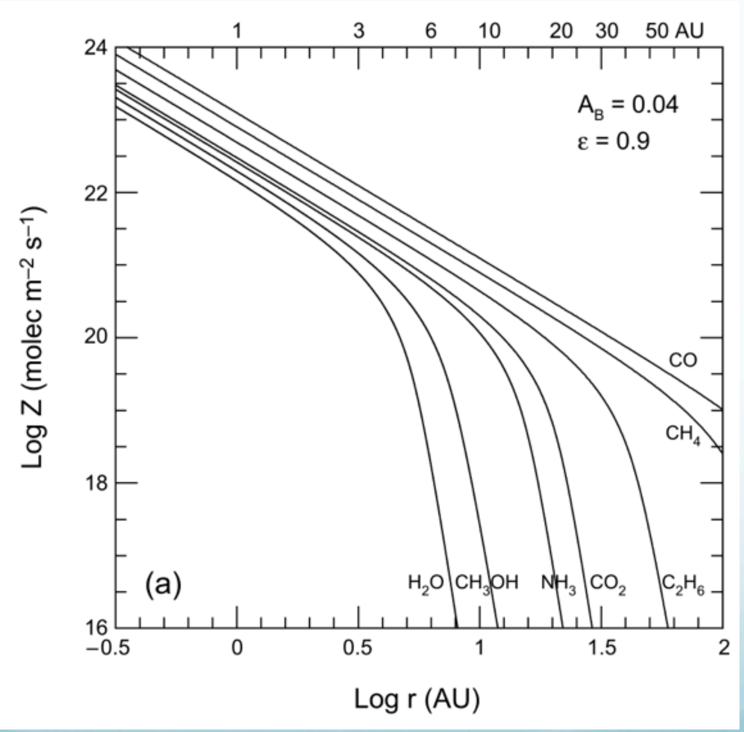
- LPC = Long Period Comet
  - Orbital Period >200 years, uniform inclination distribution
- SPC = Short Period Comet
  - Orbital Period <200 years, inclinations near ecliptic
  - Can be further split in to Jupiter Family Comets (JFCs P<20 years) and Halley Type Comets (HTCs, 20<P<200 years)

Why are comets interesting?

- Comets as tracers of protoplanetary disk conditions
- Mixing in the early disk
- Thermal evolution of different populations
- Potential hazards

Cometary Volatiles

- H_2O is most abundant, followed by CO_2 and CO
- Different volatiles have different "turn on" points



From Meech et al., 2004 in Comets II

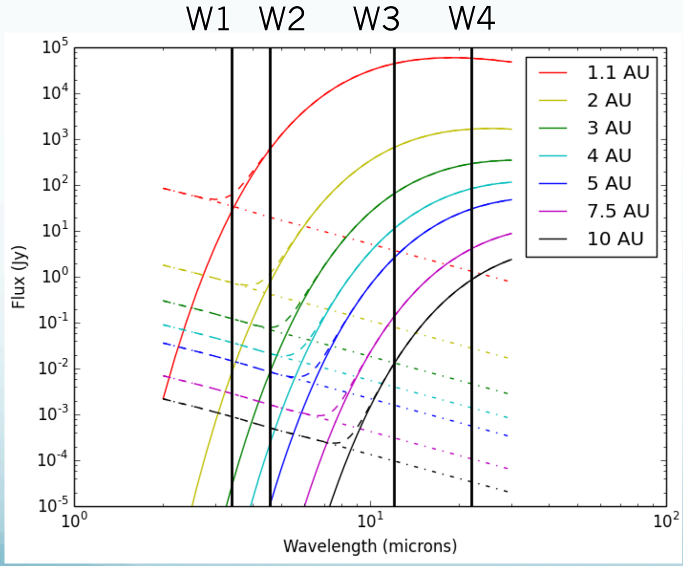
Cometary Dust

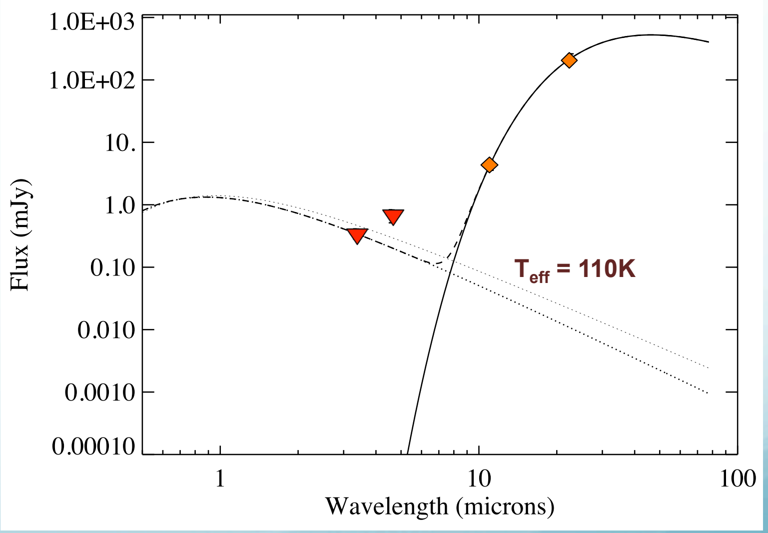
- Lifted off the comet's surface when volatiles sublimate
- From the Stardust sample return mission, we know that cometary dust is fractal and porous
- Made of refractory materials from the protoplanetary disk
- Can also be used as a tracer for volatile activity

http://stardust.jpl.nasa.gov

Cometary Dust in NEOWISE

- For comets, W1 is reflected sunlight, W3 and W4 is thermal emission, and W2 is a combination of those two and also contains emission from CO/CO_2

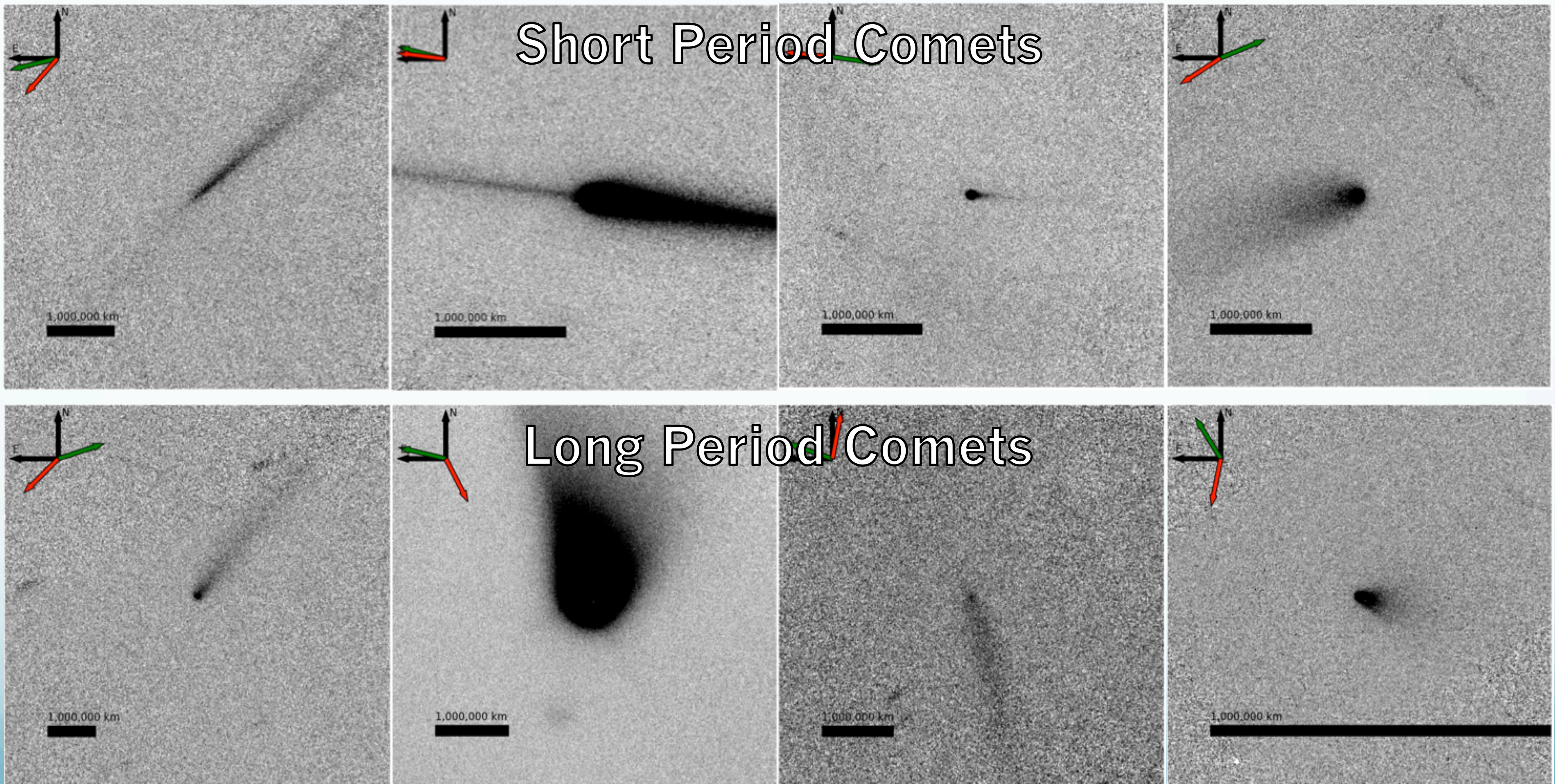




Comets detected by WISE, prime mission

- 160 comets detected
  - ~2/3 short-period
  - ~1/3 long-period
- 21 comets discovered (or activity discovered)
- 89 comets have a significant dust tail in W3/W4
- Each comet detected several times, for an average integration time of ~90s
- Images were stacked using AWAIC to increase the SNR, and interpolated to give a pixel scale of 1”/pixel

Representative comets



Kramer et al., WISE at 5, Pasadena, 2015

Dynamical Modeling

- Finson-Probstein modeling
  - Assumes that the only forces acting on a particle are solar radiation pressure and solar gravity

$$\beta = \frac{F_{radiation}}{F_{gravity}}$$

- In physical units

$$\beta = \frac{CQ_{pr}}{\rho_d a}$$

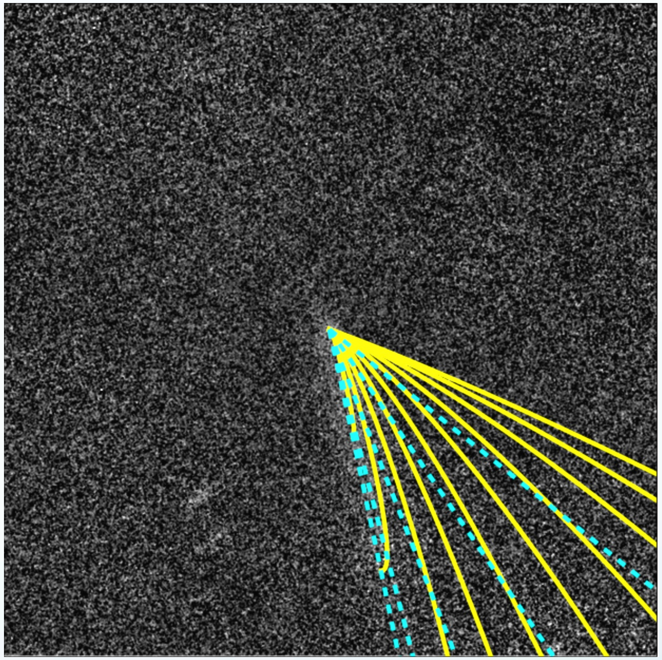
Finson and Probstein, 1968

Dynamical Modeling

- The radiation pressure essentially acts as a reduction to solar gravity, with smaller particles being more strongly affected than larger particles (β is inversely proportional to particle size)
- β is incorporated into the equation of motion for the dust particles
- Software takes in a set of β values and comet positions, and integrates the motion of the dust over a designated time interval
- Returns a matrix of points which can then be plotted as curves of constant β (syndynes), or curves of constant emission date (synchrones)

Dynamical Modeling

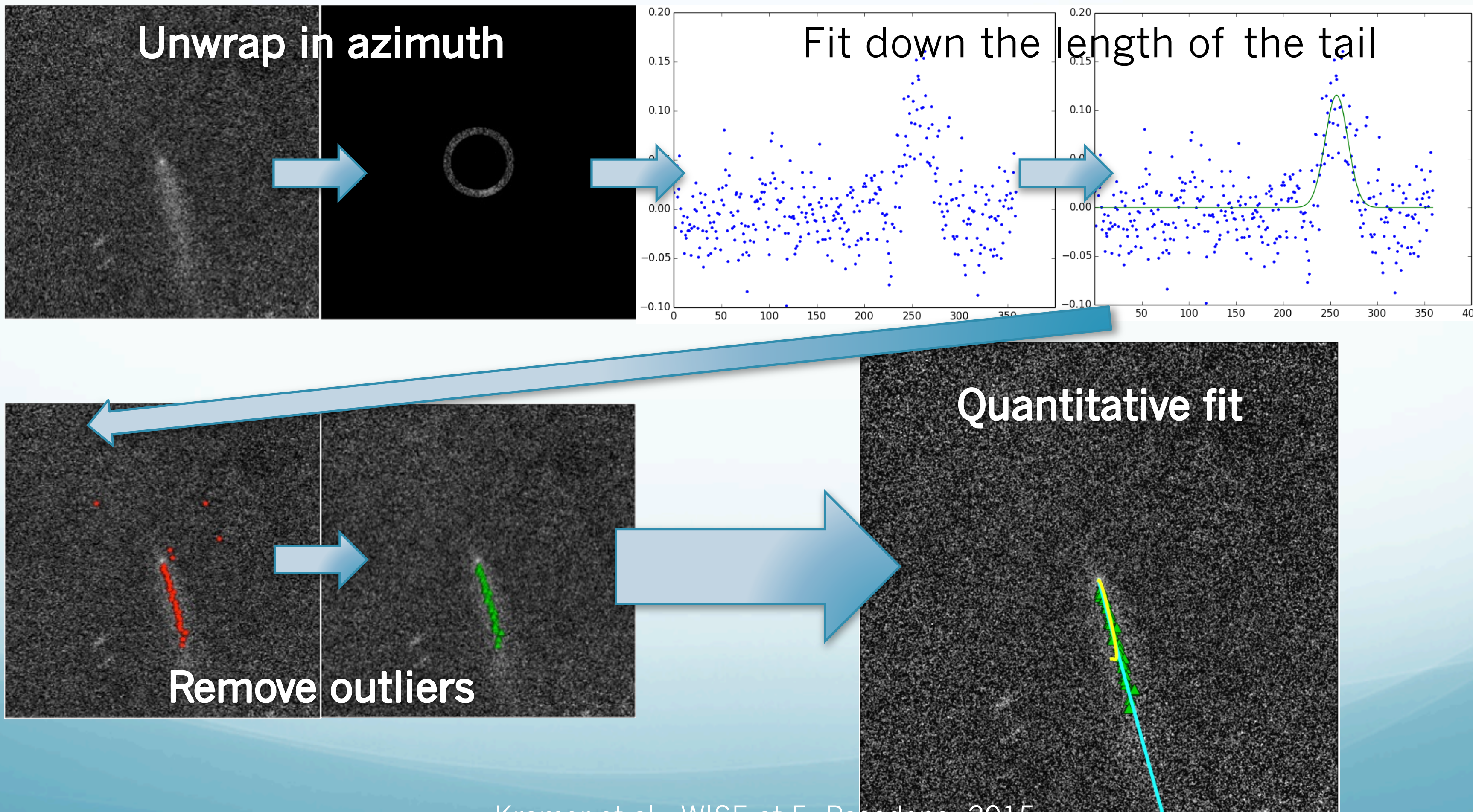
- Models give age and size of the particles in the dust tail
- Using the age of the particles, we can calculate the heliocentric distance at which strong emission occurred



Syndynes (yellow) and synchrones (cyan) for C/2008 T2 (Cardinal)

Tail fitting method

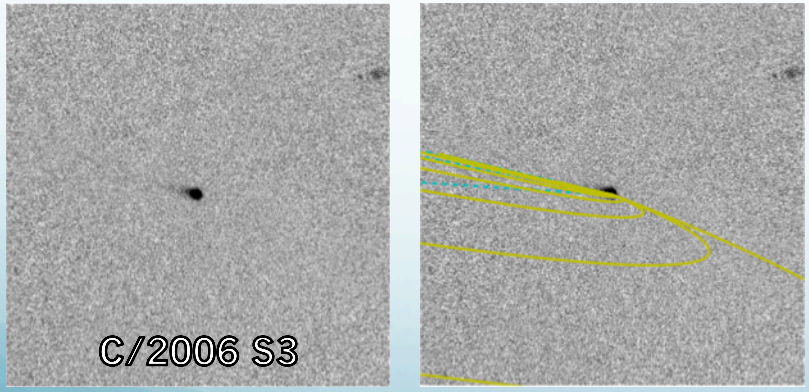
- Allows best-fit models to be chosen analytically

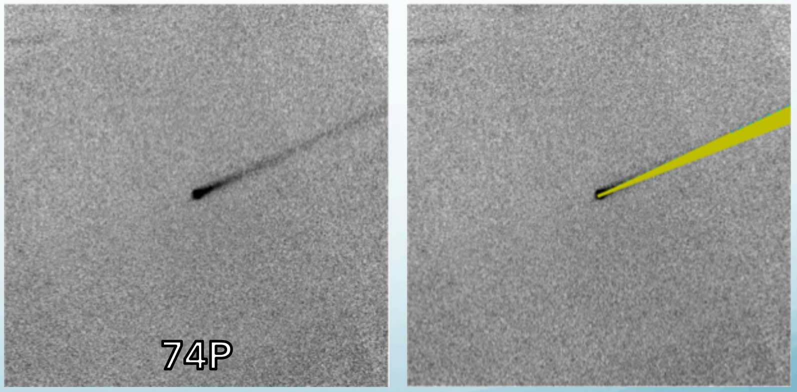


Kramer et al., WISE at 5, Pasadena, 2015

Tail fitting method

- Since this technique requires the tail to be relatively bright and long, comets with faint, short tails are selected against
- This also does not work well when there is significant background contamination, or for comets with very low orbit plane angle separation

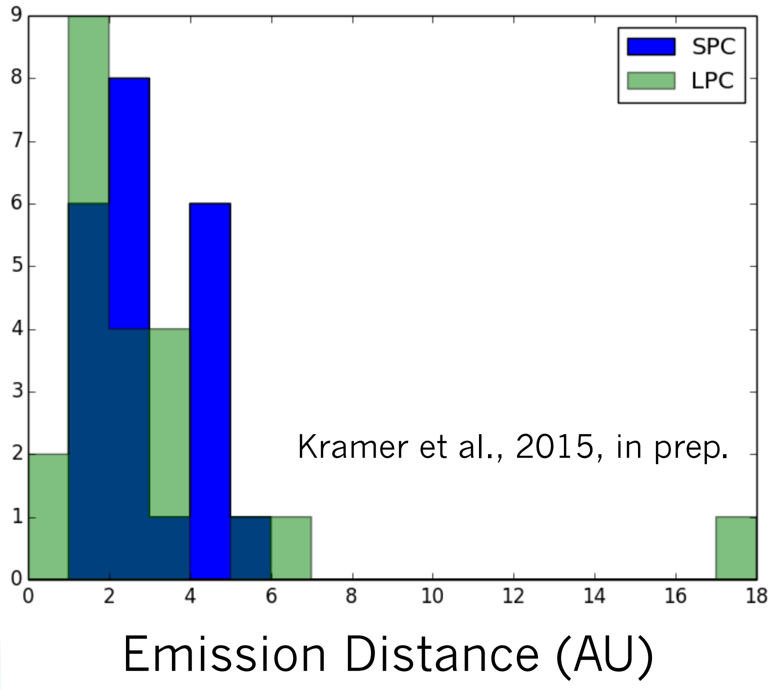


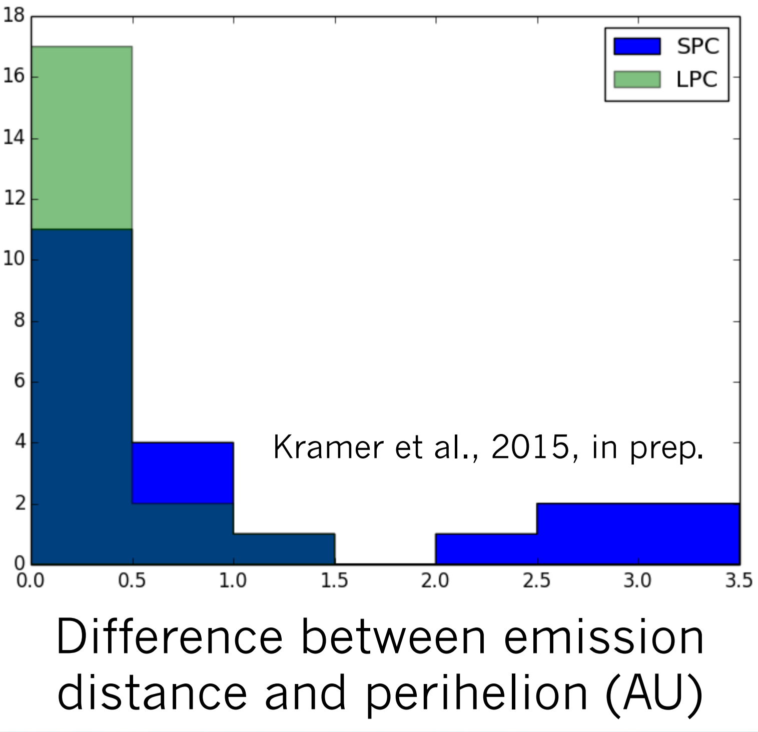


Words of Caution: Interpretation

- Synchrones are generally used to model outburst events. We are using them as a proxy for the onset of strong activity.
- The best-fit syndynes are actually an average particle size, since the particles in the middle of the tail are being modeled.
- We have limited the analysis to the 40 comets with well-fit tails, and only the W4 images (due to a higher SNR)

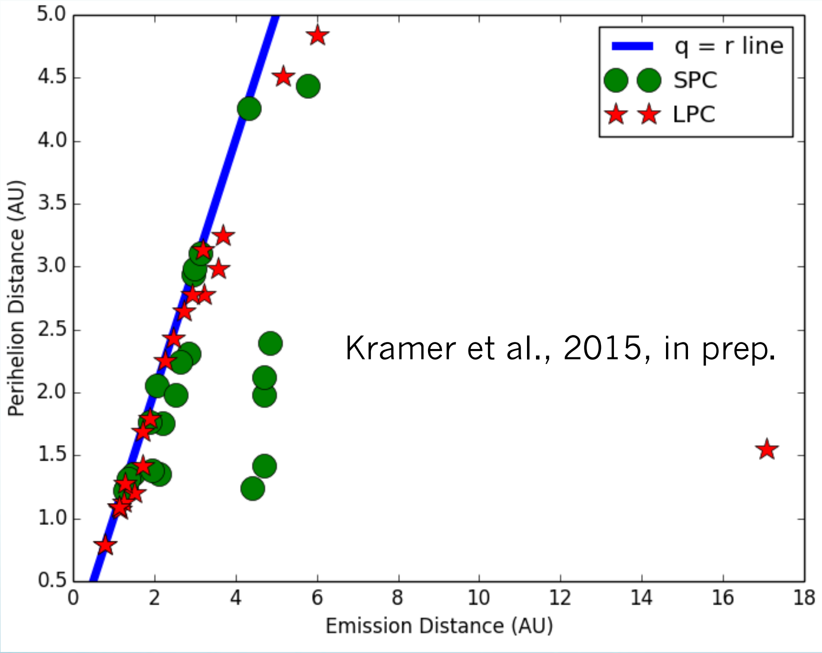
Heliocentric Distance at Emission

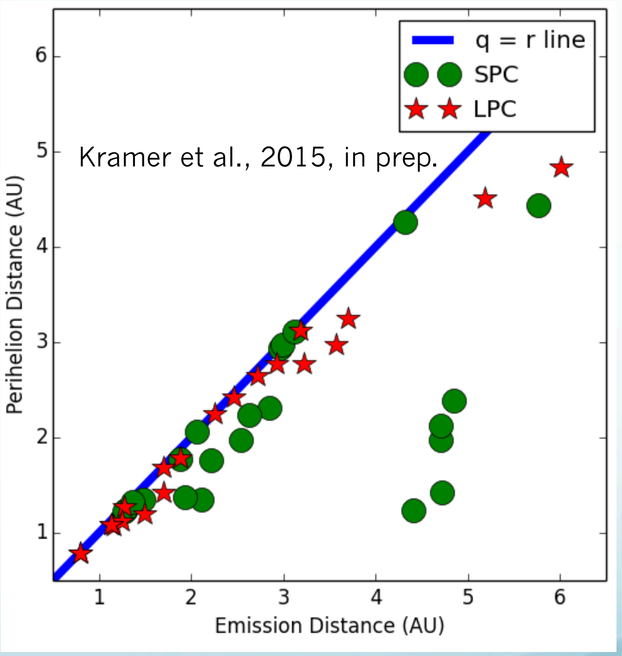




Heliocentric Distance at Emission

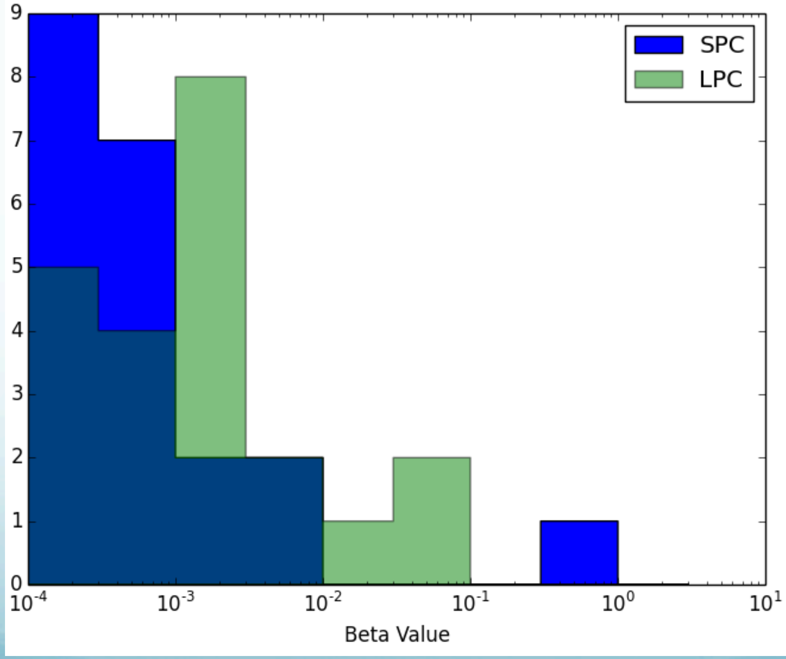
- For most comets, strong emission (which evolves into the tail we see in the images) occurred close to perihelion





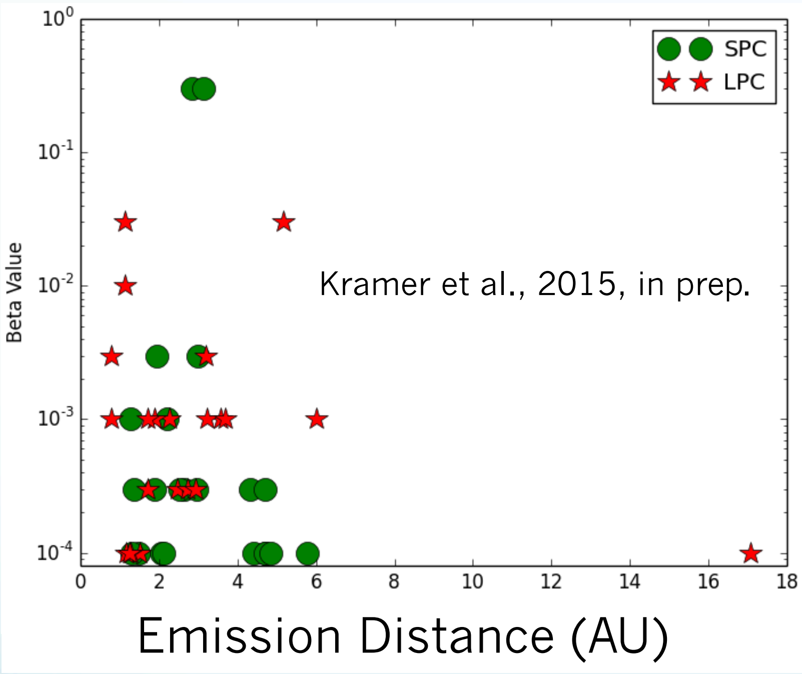
Particle Size

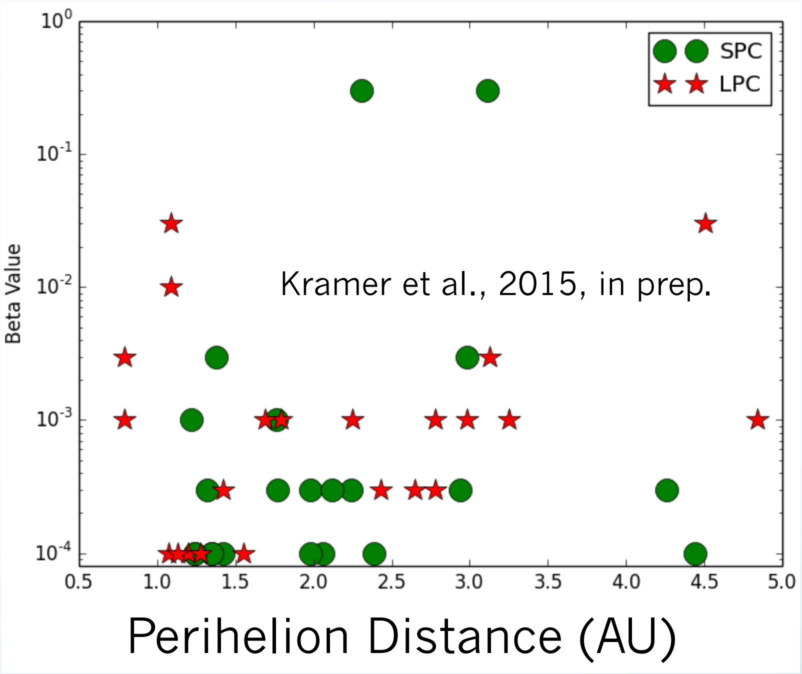
- Most of the tails are comprised of large (~mm to cm sized) particles
- We are sampling the large end of the particle size distribution



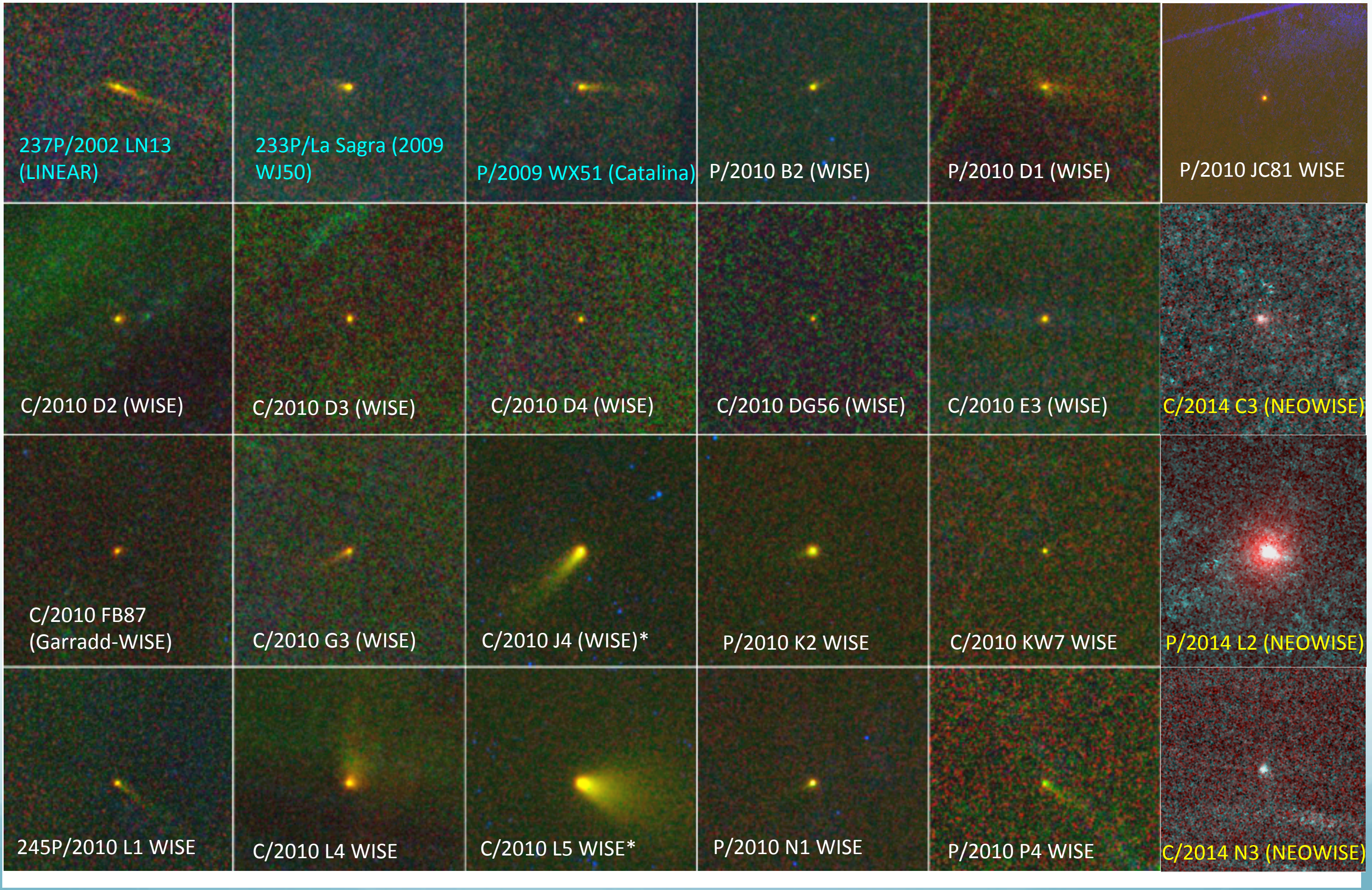
Kramer et al., WISE at 5, Pasadena, 2015

Relationship between β and heliocentric distances





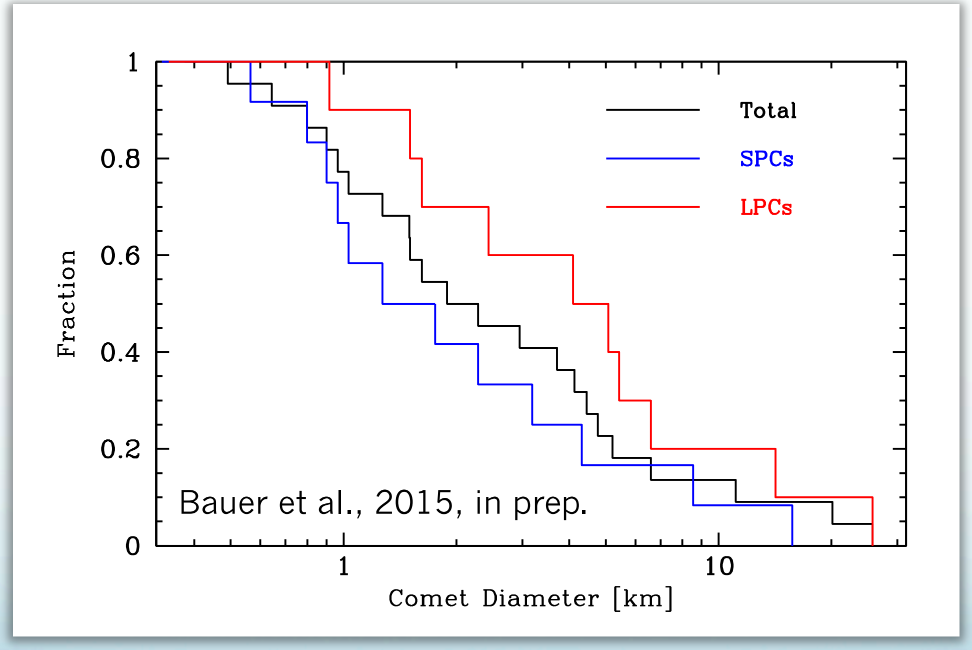
Comets Discovered by NEOWISE



Kramer et al., WISE at 5, Pasadena, 2015

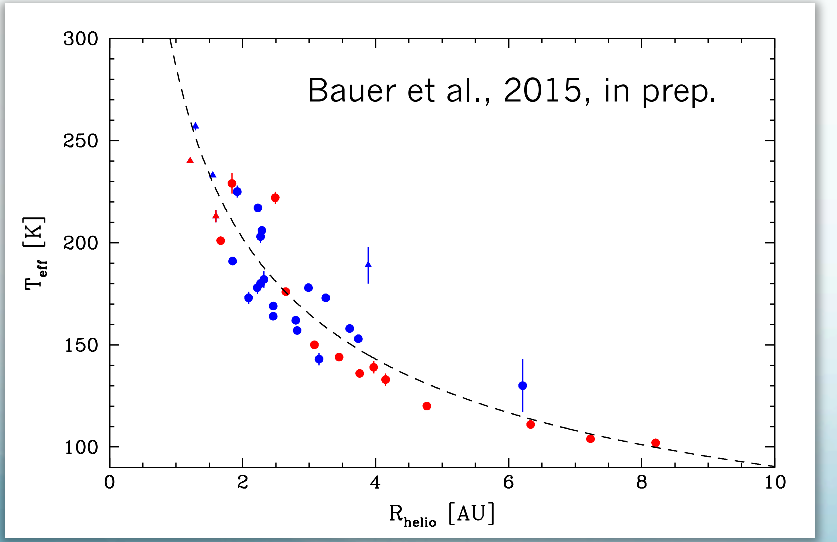
Discoveries: nucleus size

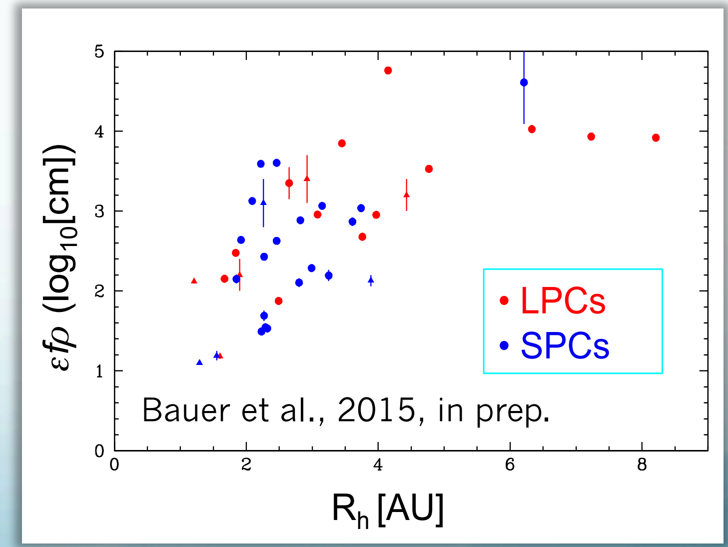
- Model and subtract dust coma, fit NEATM to extracted nucleus flux



Full set: dust temperature and quantity

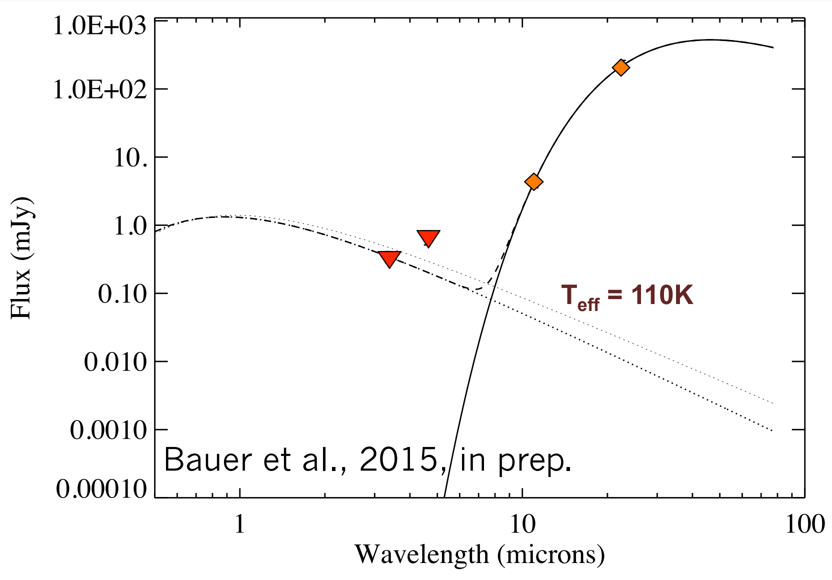
- Perform blackbody temperature fits to the W3 and W4 dust coma
- This also allows us to calculate $\varepsilon f \rho$ (a measure of dust quantity)

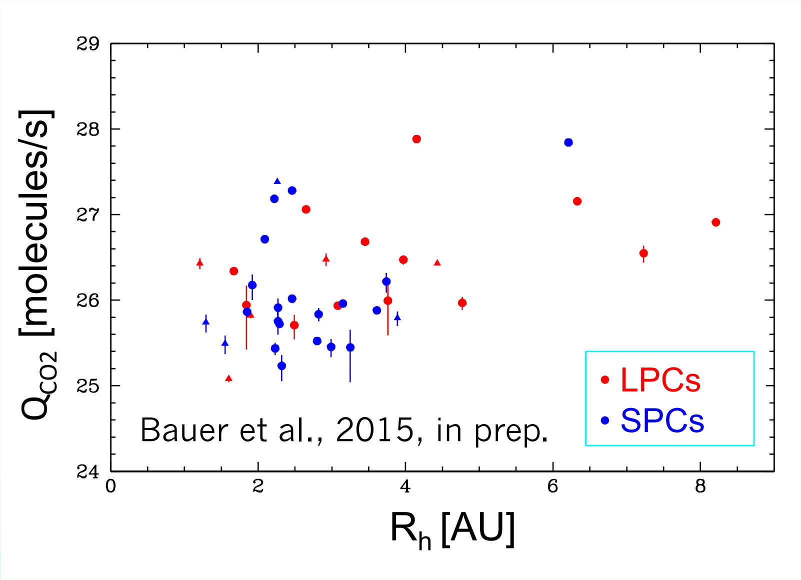




Full Set: CO_2 production

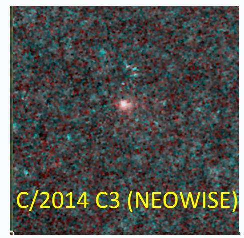
- Use W2 excess flux to calculate Q_{CO2} (CO_2 production)

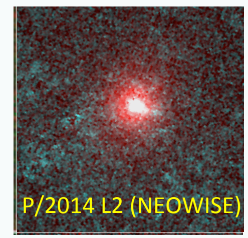


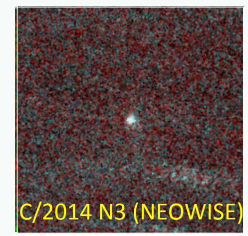


Comets detected in NEOWISE restart

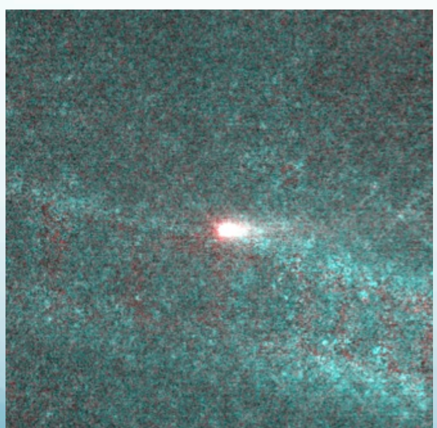
- 60+ comets detected
  - ~1/2 short-period
  - ~1/2 long-period
- 3 comets discovered

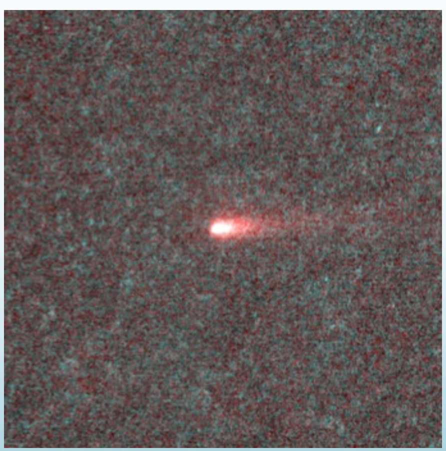


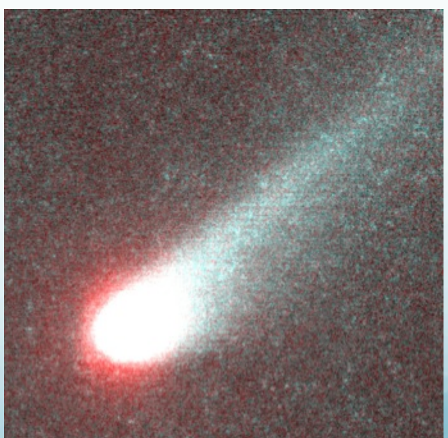




- Several comets have a significant dust tail







Conclusions

- There is a wide range of morphology and activity levels present in the dust tails of both SPCs and LPCs
- Most of the dust tails were several months to several years old
- All of the comets showed strong emission that begins at or before perihelion (i.e., none began post-perihelion)
- For both SPCs and LPCs, most had dust tails comprised of ~mm to cm sized particles
- No clear relationship between beta and emission distance or perihelion distance
- **In nearly all aspects of the analysis (except nucleus size), SPCs and LPCs are remarkably similar!**

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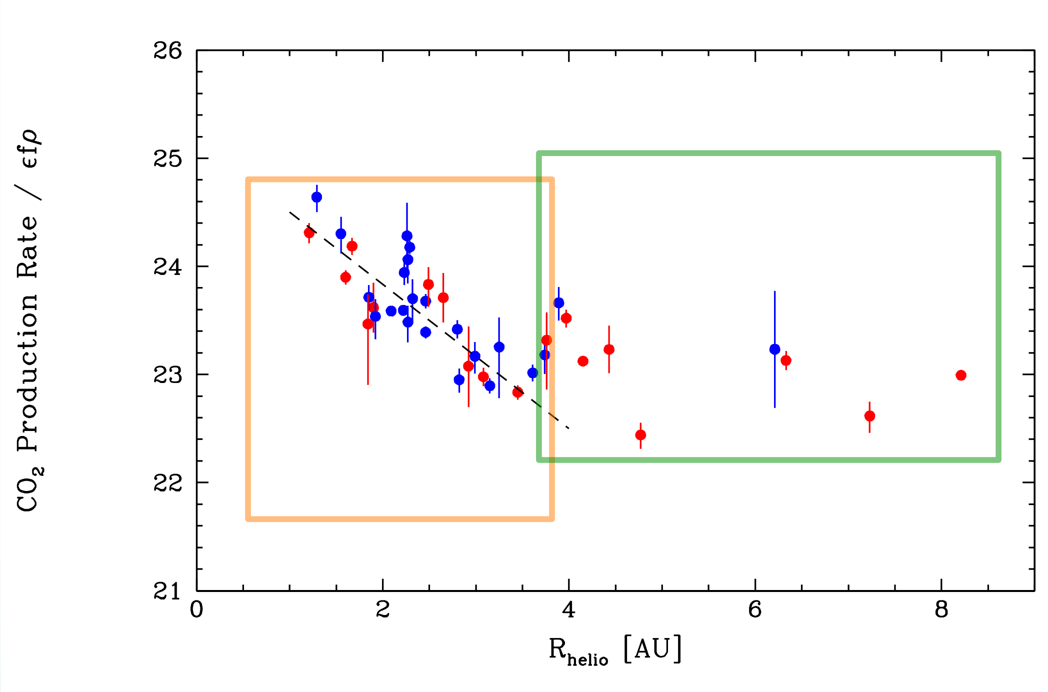
Full set: CO_2 normalized to dust production rate

- Two distinct regimes, due to different volatiles?

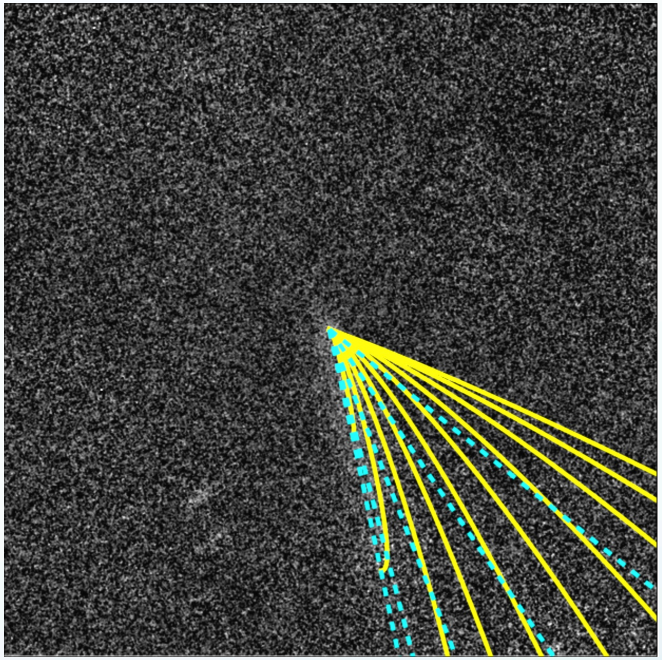


Modeling the dust tail

- Finson-Probstein modeling

$$\beta = \frac{F_{radiation}}{F_{gravity}}$$

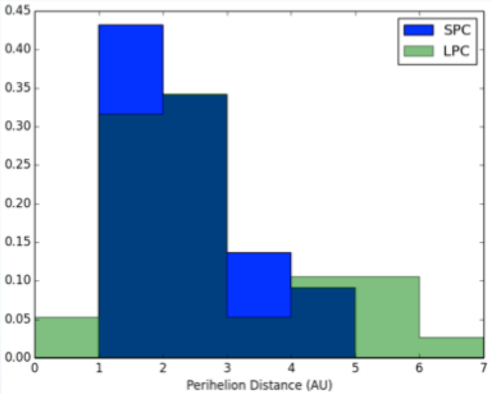
- Models give age and size of the particles
- Smaller beta corresponds to larger particles
- Syndynes: constant particle size
- Synchrones: constant emission date
- Models run for 5 years, $0.0001 < \beta < 3.0$

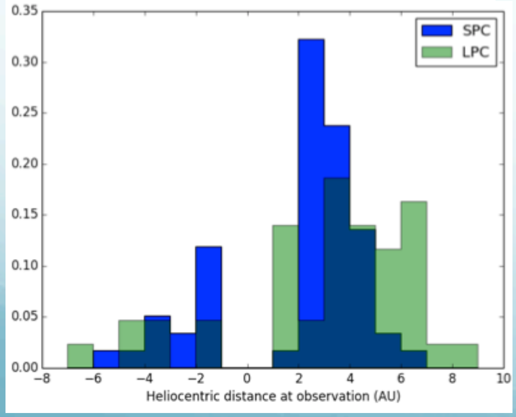


Syndynes (yellow) and synchrones (cyan) for C/2008 T2 (Cardinal)

Comets with a dust tail

- 89 with a dust tail
  - 34 LPC
  - 55 SPC





- 40 well-fit comets (described more later)
  - 19 LPC
  - 21 SPC