NEOWISE/WISE Characterization Results

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NEOWISE Science Team

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NEOWISE

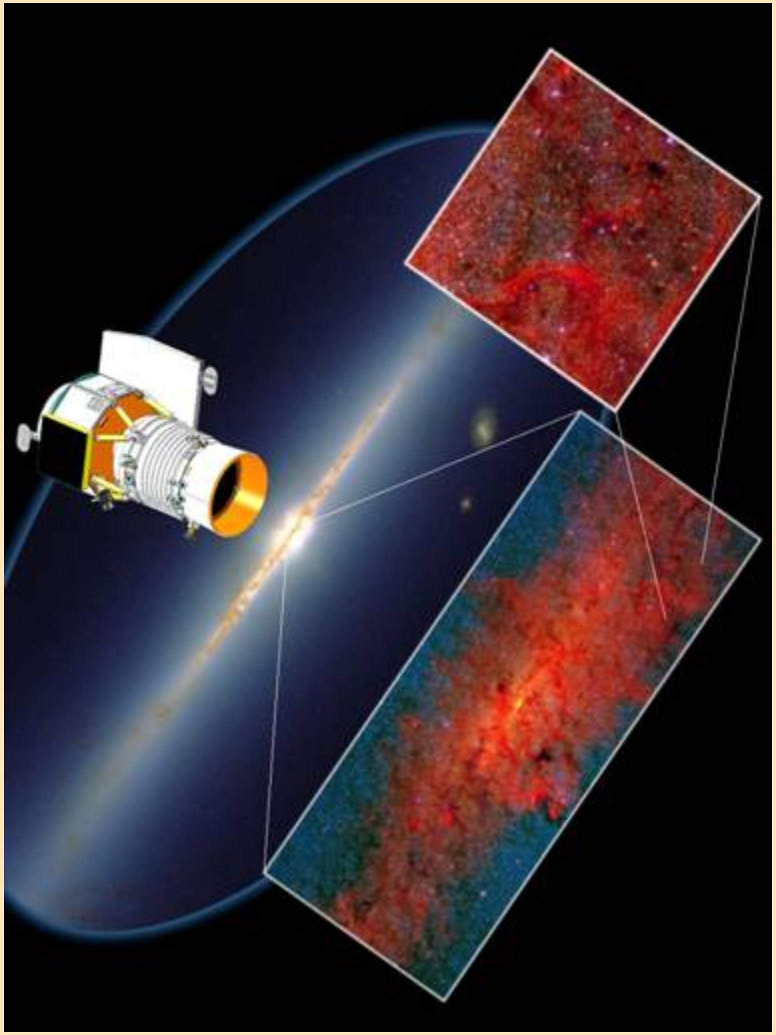
<u>*Salient Features*</u>

- *Uses the WISE spacecraft*
- *Terminator – following pole-to-pole orbit*
- *4 imaging channels cryo, 2 channels post-cryo & restart:*
  - *<u>3.4, 4.6,</u> 12 & 22 mm*
- *40 cm telescope*
- *Surveyed entire sky, 1/14/10 – 2/1/11*
- *Restarted Survey 12/23, 2013*
- *NEOWISE planetary component of prime mission and sole component of restarted mission.*

<u>*NEO Science Observations Summary*</u>

- *Sensitive all sky survey with ~10X redundancy*
- *135 NEOs discovered during WISE prime mission,*
  - *21 PHAs*
  - *585 NEOs detected.*
- *> 207 NEOs observed since restart (w/o stacking),*
  - *33 discovered*
  - *~25% PHAs*

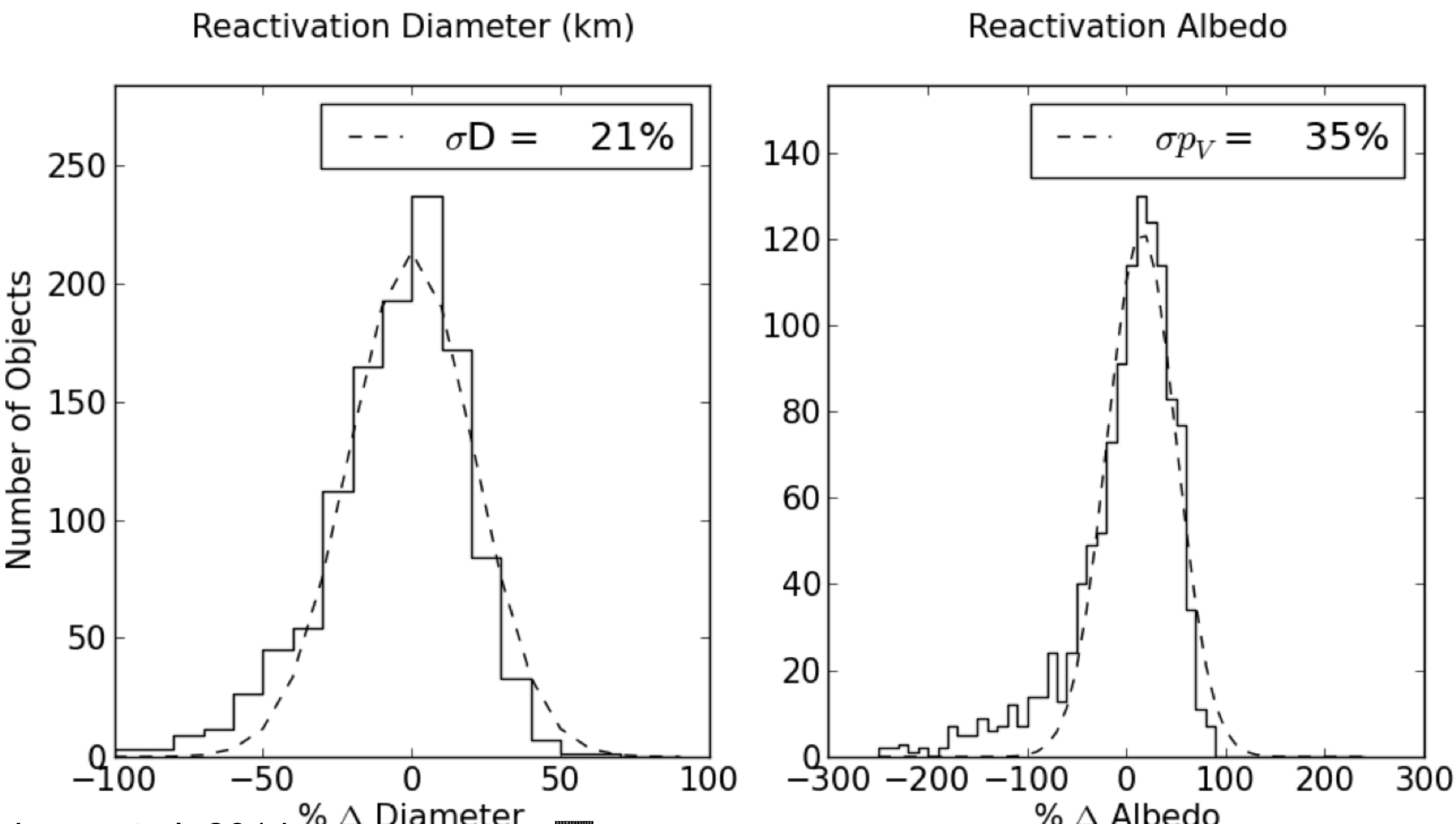
Wide Field Infrared Survey Explorer



Status: Moving Object Processing

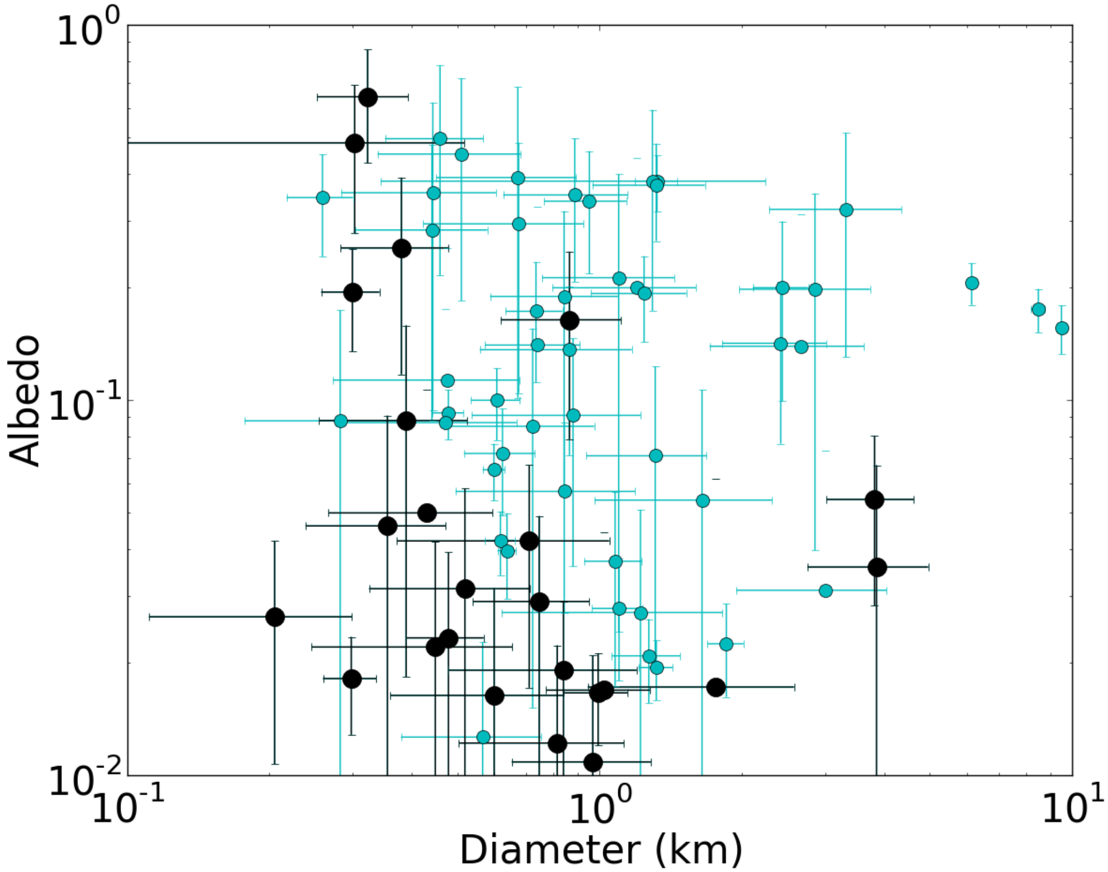
- Routine processing of data using moving object processing software began late December, 2013
  - First new NEO discovered 6 days later: 2013 YP139
- Regular deliveries to Minor Planet Center (MPC) being made
- Pipeline running at SNR=4.5
- Running 3x per week
- Currently detecting ~0.7 NEO/day out of ~31 minor planets/day in single-frame images (no stacking)

Preliminary Thermal Fits: Cryo vs. Restart



Mainzer et al. 2014

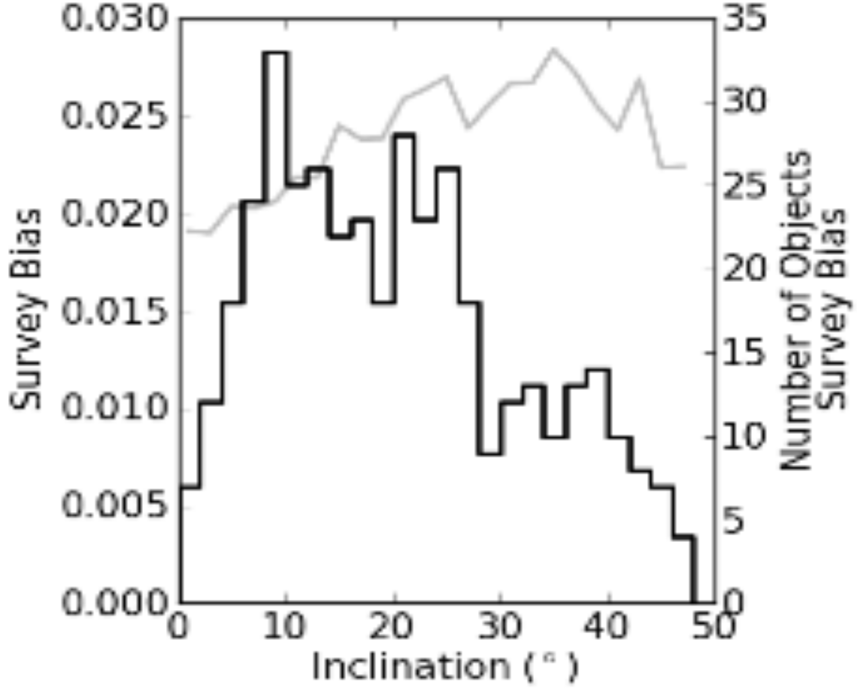
Large and Dark NEOs

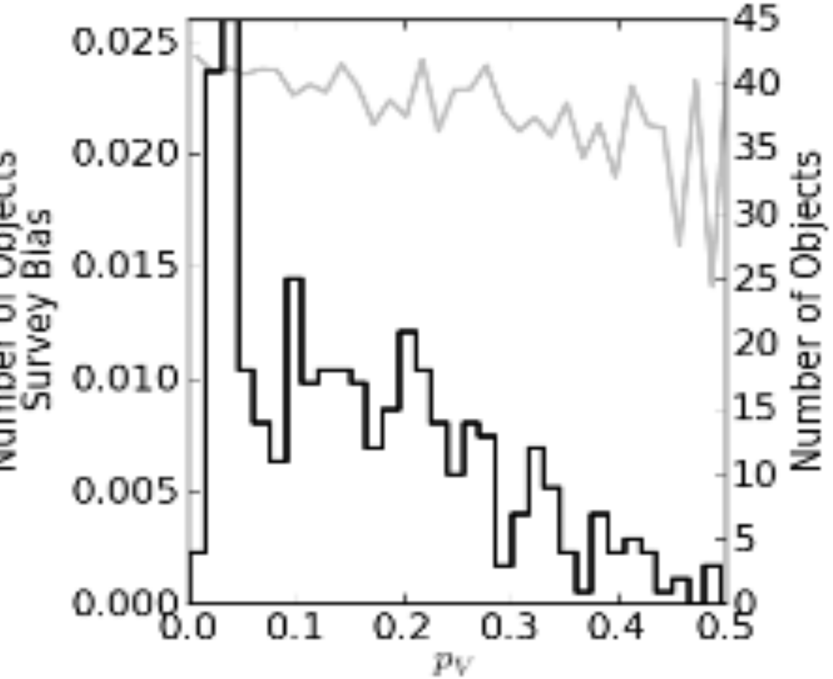


- NEO discoveries are large, dark; 25% potentially hazardous asteroids

Mainzer et al. 2014

Survey Biases



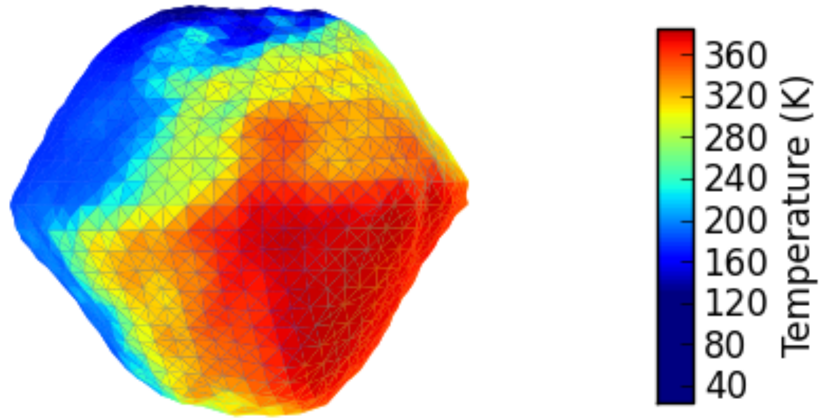


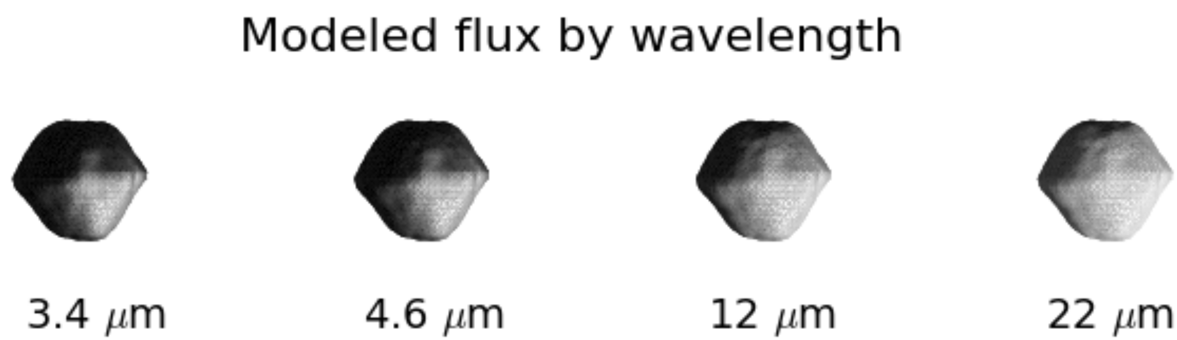
- NEOWISE is ~unbiased w.r.t. albedo and inclination

Leads: Mainzer & Grav

NEOWISE thermophysical modeling

- 3-dimensional heat conduction
- Self-heating and reflection
- Modeling over seasonal + diurnal length scales (steps every 10 minutes over 1/4 of orbit)

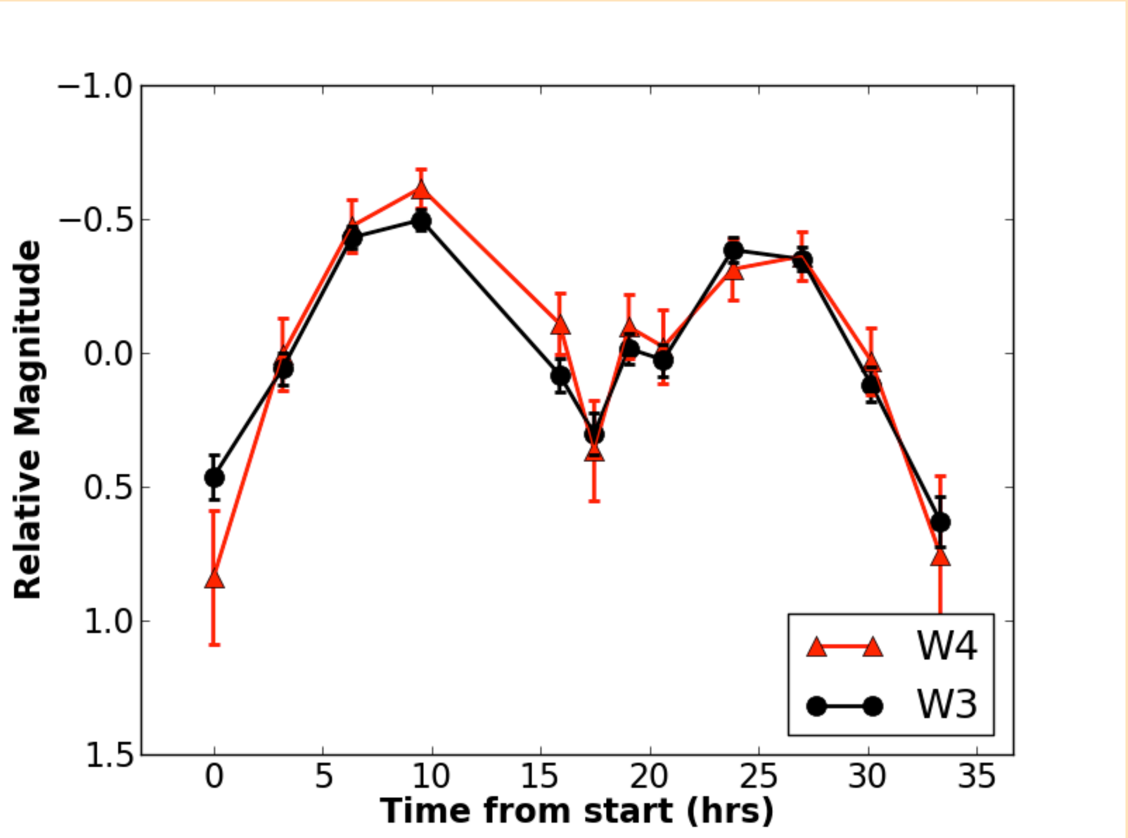




NEA 2008 EV5
Radar-based shape model, Busch et al., 2011
Thermophysical model, Nugent et al., in prep

High-order TMM Lead: Nugent

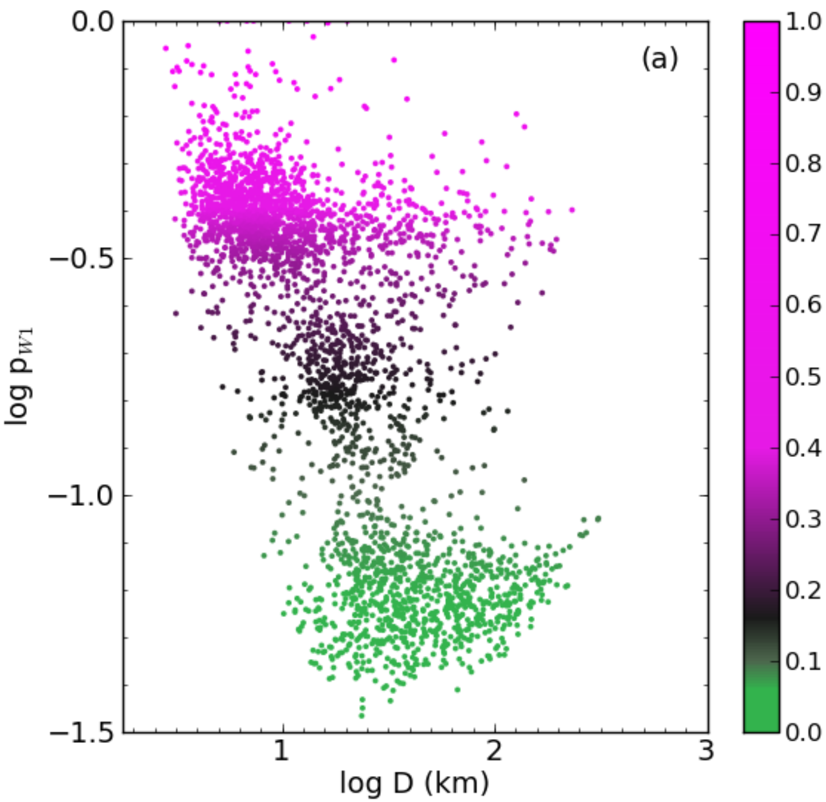
Search for Binary Signatures



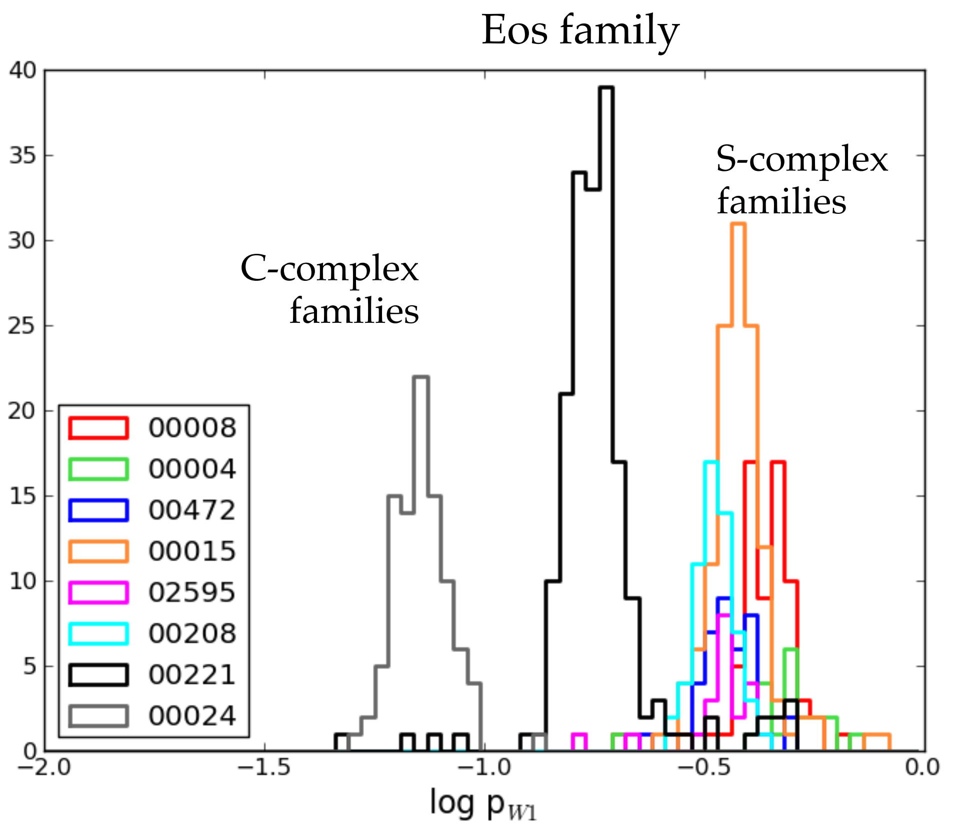
Ongoing Search in Hilda and Jupiter Trojan populations based on NEOWISE Light Curves (Sonnett, Grav et al. 2014, Submitted)

Asteroid Families – Recent Results

NEOWISE 3.4 micron albedos of all Main Belt asteroids. These measurements provide a better constraint on asteroid taxonomy than visible albedos, including identification of three distinct reflectance groups



Figures from Masiero et al. (2014)



Asteroid families show narrow distributions of 3.4 micron albedos, tracing the three groupings seen in the overall MBAs. Of note is the (221) Eos family, which shows a moderate 3.4 micron albedo unique among all asteroid families which is similar to shock-blackened chondrites

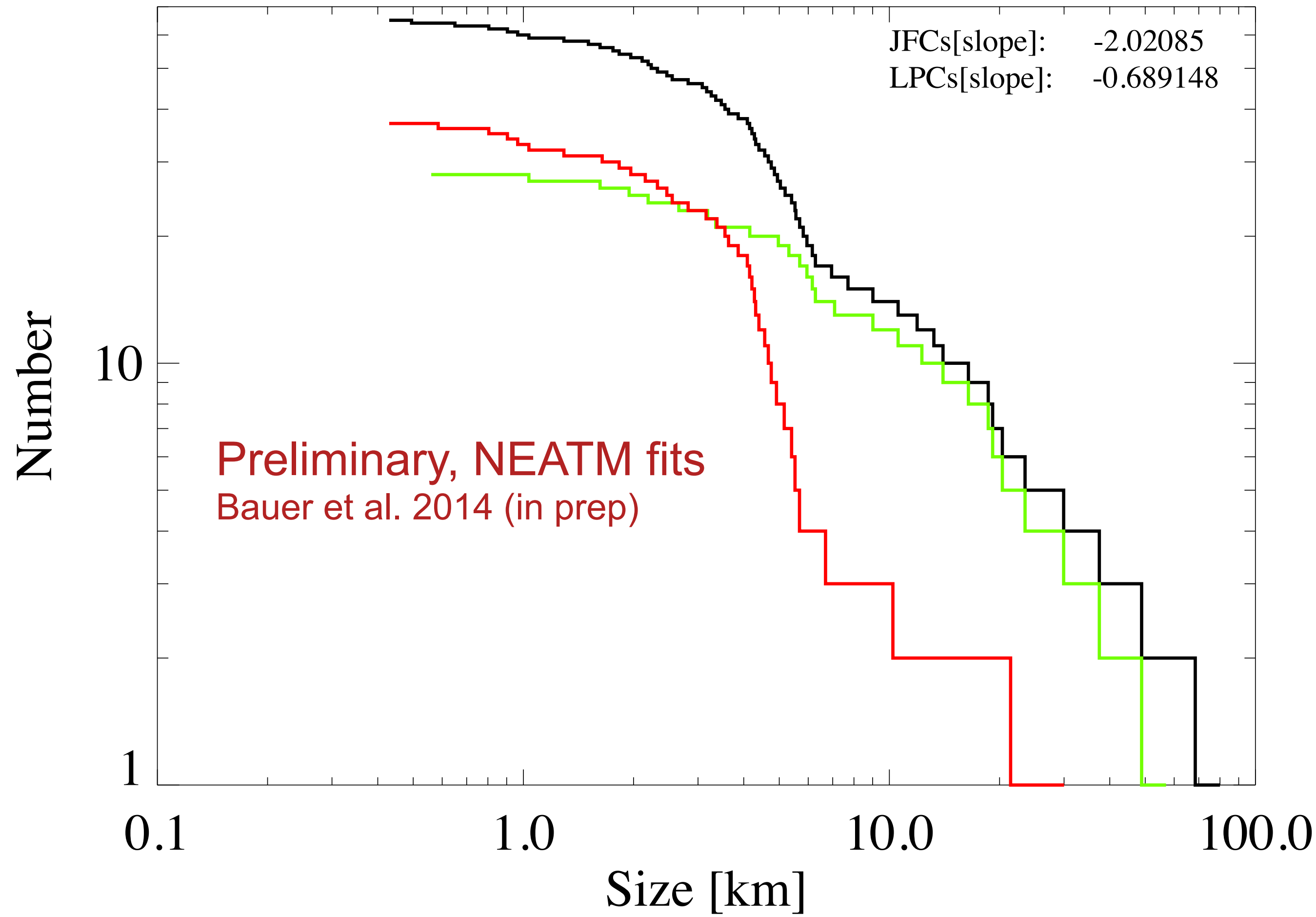
Comet Science Observations

- ✧ Sensitive all sky survey with ~10X redundancy
- ✧ 160 comets detected during WISE prime mission,
  - 1/3rd LPCs, 2/3rd SPCs
  - 80 will yield nuclei
- ✧ More than 50 observed since restart,
  - half LPCs
  - About 2/3rds CO/CO_2 active (4.6 mm band excess)
  - 3 Comet Discoveries so far…
- ✧ Comets observed at multiple epochs

NEOWISE – Derived Properties for Small Potentially Active Bodies

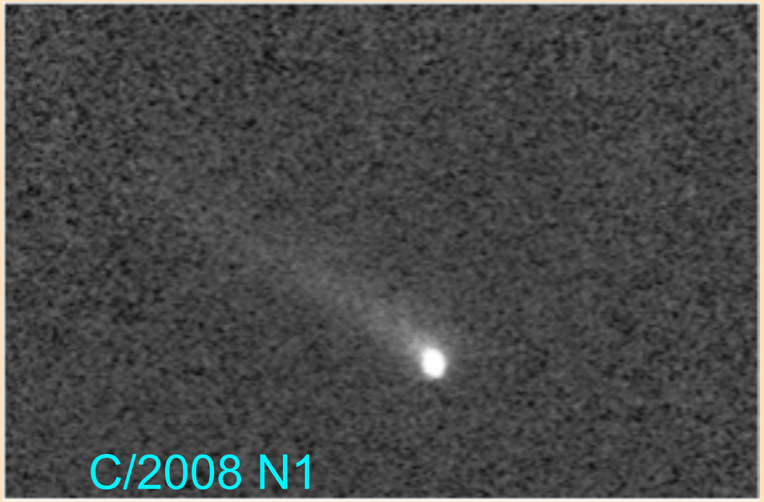
- Nucleus
  - Size
  - Temperature
  - Thermal Inertia & related properties (like beaming parameters)
  - Albedo (with optical measurements)
  - Rotation Properties (light curves)
    -including shape, period, & pole
- Dust Properties (e.g. Particle Size Distribution, Temperature, Reflectance, Dust mass loss rate)
  - Coma & Tail – photometry & morphology
  - Trail dust – width and photometry
- Gas (production rates)
  - CO/CO_2 emission lines

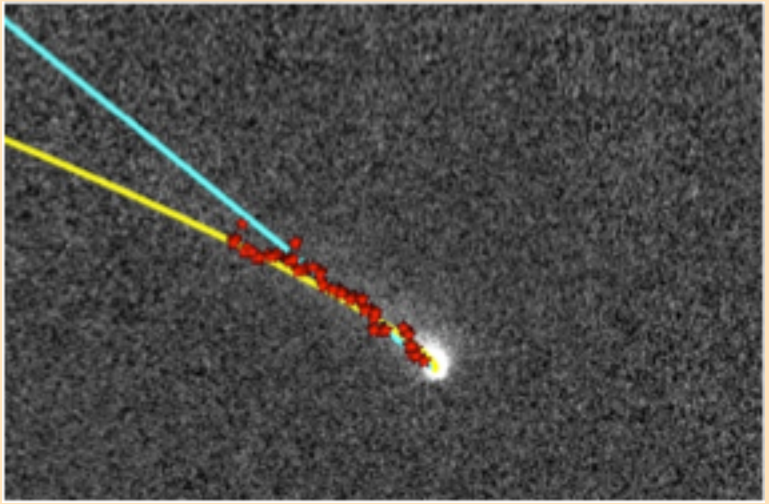
Cumulative Size Distribution From 64 NEOWISE comets



- **Not de-biased**; 29 LPCs (green), 35 JFCs (red), total (black).
- From thermal measurements of nuclei (cryo-mission).
- Observed LPCs nearly 2 times as large as JFC population.

Dust tails in the WISE data

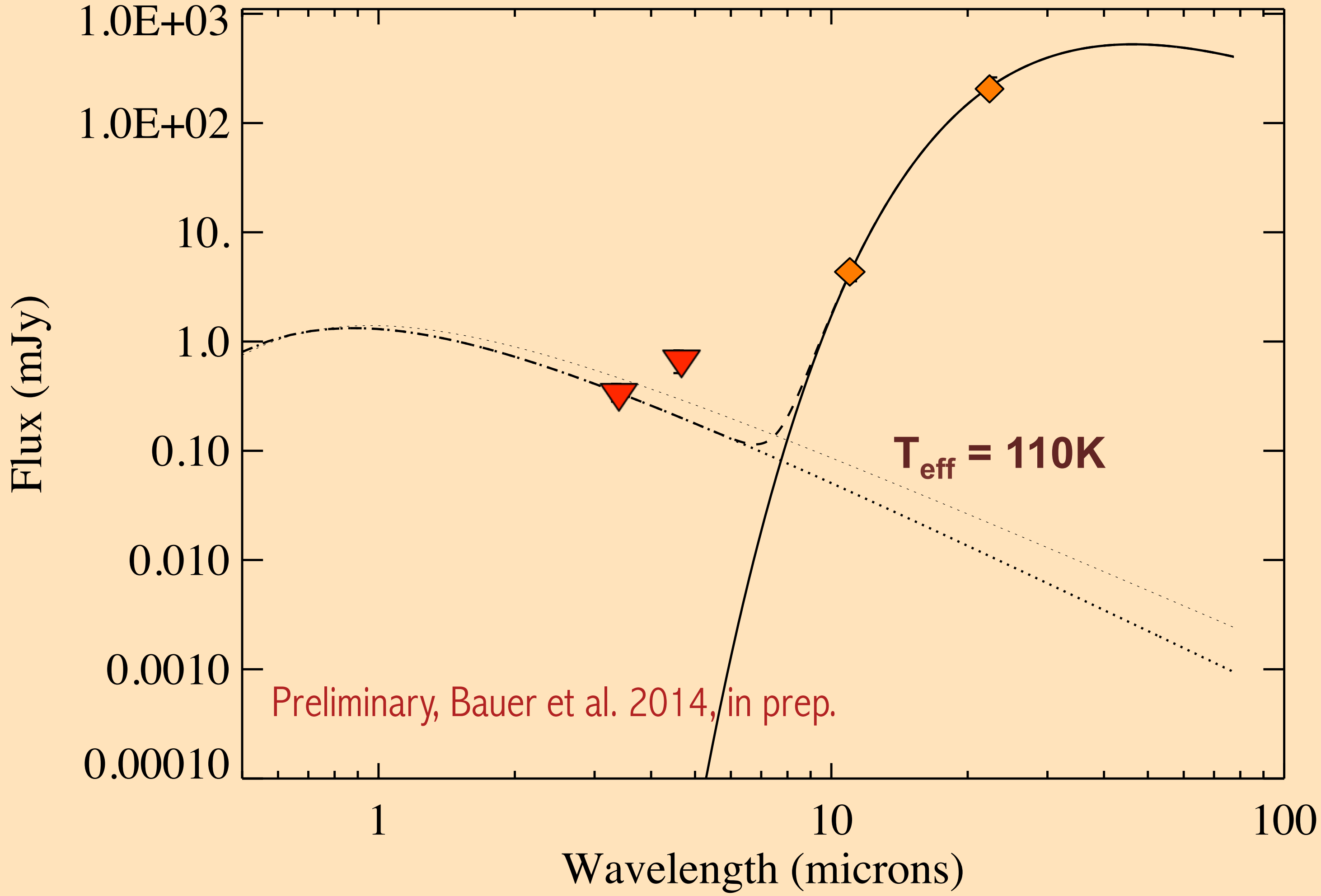




- Over half of the comets seen had dust tails (89/160)
- Dynamical models are used to constrain the size and age of the particles, with the best models selected using a novel analytical tail fitting method
- For both LPCs and SPCs, most comets had dust tails comprised of ~mm to cm sized particles
- Most 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)

Kramer et al. 2014 (based on PhD thesis work)

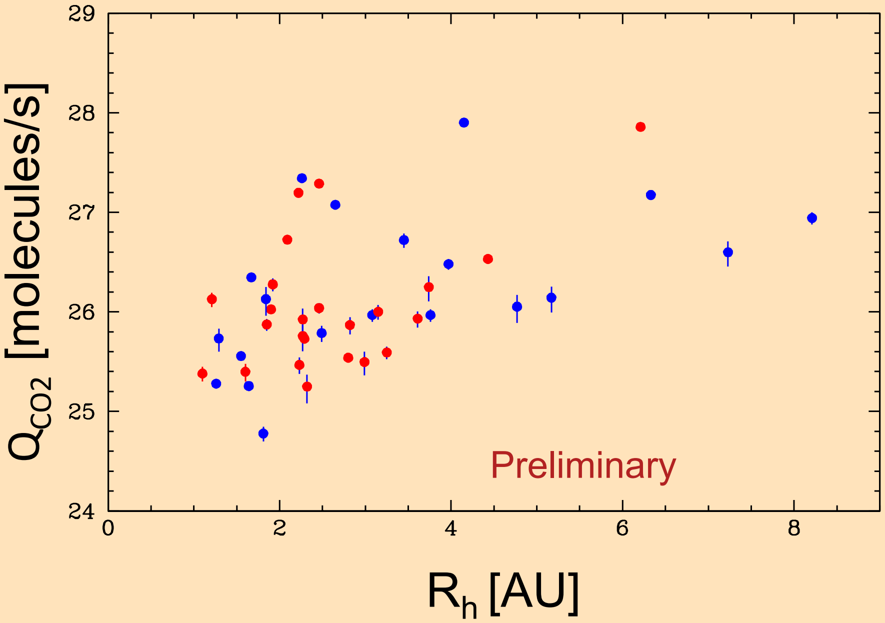
Cryo CO2 Analysis (with thermal bands)



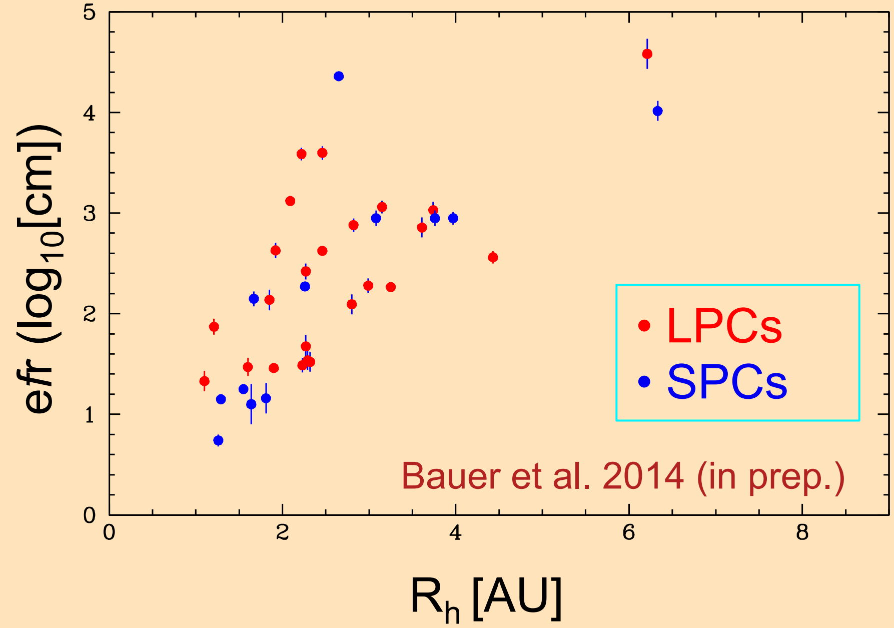
WISE 4.6mm band (W2) contains CO 4.7mm and CO2 4.3mm emission lines. C/2009 P1 Garradd's 4.6 mm band excess not consistent with reflected or thermal contributions of coma or nucleus, but are with CO_2 & CO emission.

Total Prime Mission Sample

4.6 mm Excess

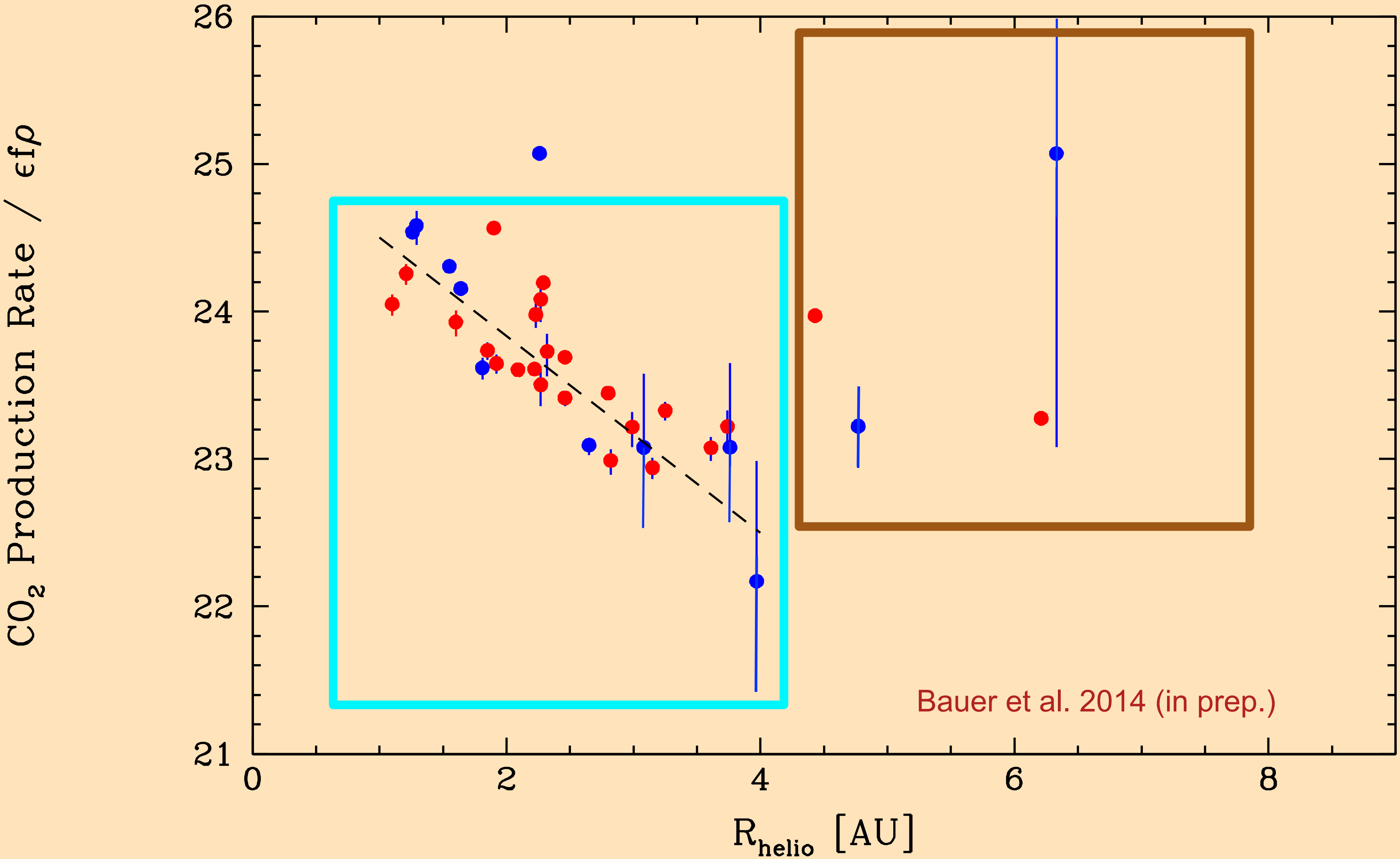


Dust (thermal)



- During the WISE cryo mission, 60 comets with significant W2 signal,
- 39 with W2 excess consistent with CO/CO2 emission,
- LPCs and SPCs have similar distributions,
- Can normalize with respect to dust production.

CO_2 / Dust



26
25
24
23
22
21
0
2
4
6
8
CO_2 Production Rate / εfρ
R_{helio} [AU]
Bauer et al. 2014 (in prep.)

NEOWISE observations of C/2013 A1 (Siding Spring)

Rachel Stevenson, James Bauer, Amy Mainzer, Roc Cutri, & Frank Masci

Comet Science Summary

- The NEOWISE Prime mission sample of 160 comets provides a rich data set of sizes, beaming parameters, and CO/CO_2 production for SPC and LPC alike.
- 25% of prime-mission comets exhibit 4.6 mm channel excess (B2E), attributable to CO or CO_2 production. SPCs and LPCs show similar overall dispersions.
- Most of the B2E comets show excess that, when divided by dust production values, exhibits a R_H^{-2} behavior.
- NEOWISE continues to acquire CO/CO2 production rates for active comets, over 50 observed to date, and will likely surpass the sample from the prime mission by the end of its 3-year restarted survey.

Data Access & Use

- All NEOWISE data from Prime Mission have been publicly released & are available through NASA's Infrared Science Archive (IRSA):
  - Diameters & albedos in team papers (heading to PDS)
  - irsa.ipac.caltech.edu

- First NEOWISE Restart data release March 2015; annually thereafter
  - neowise.ipac.caltech.edu

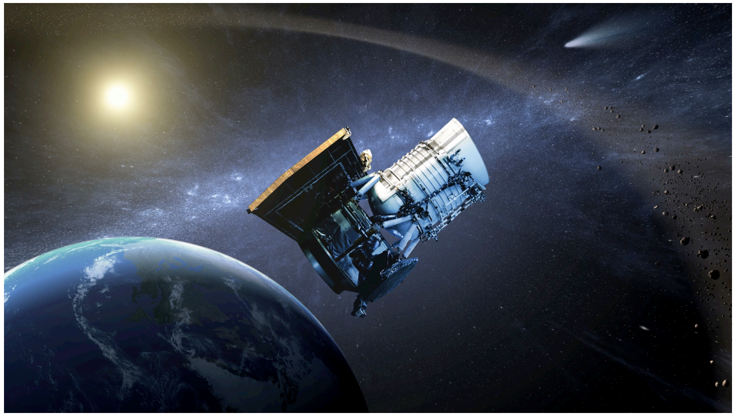
- >100 peer-reviewed papers spanning wide range of topics

Conclusions

- ✧ Survey operations begun Dec. 23, 2013; science data processing begun
- ✧ Follow-up observations needed, particularly in southern hemisphere
  - Thanks to LCOGT, Bob Holmes, Alan Gilmore, & amateur observers
- ✧ First data release March 2015; annually thereafter
  - neowise.ipac.caltech.edu
- ✧ Will return ~double the number of NEO physical properties known, + tens of thousands of Main Belt asteroids and rich comet characterization results, with the largest survey of comets in the IR.

Thank You!!

WISE at 5: Legacy and Prospects



February 10-12, 2015
Beckman Institute Auditorium, California Institute of Technology
http://wise5.ipac.caltech.edu
Twitter hashtag: #wise5

WISE was launched into orbit 5 years ago, and by the time of the conference will be on its fifth pass over the sky. This conference will celebrate what has been done with WISE, what is being done with NEOWISE, and what will be done in the future.

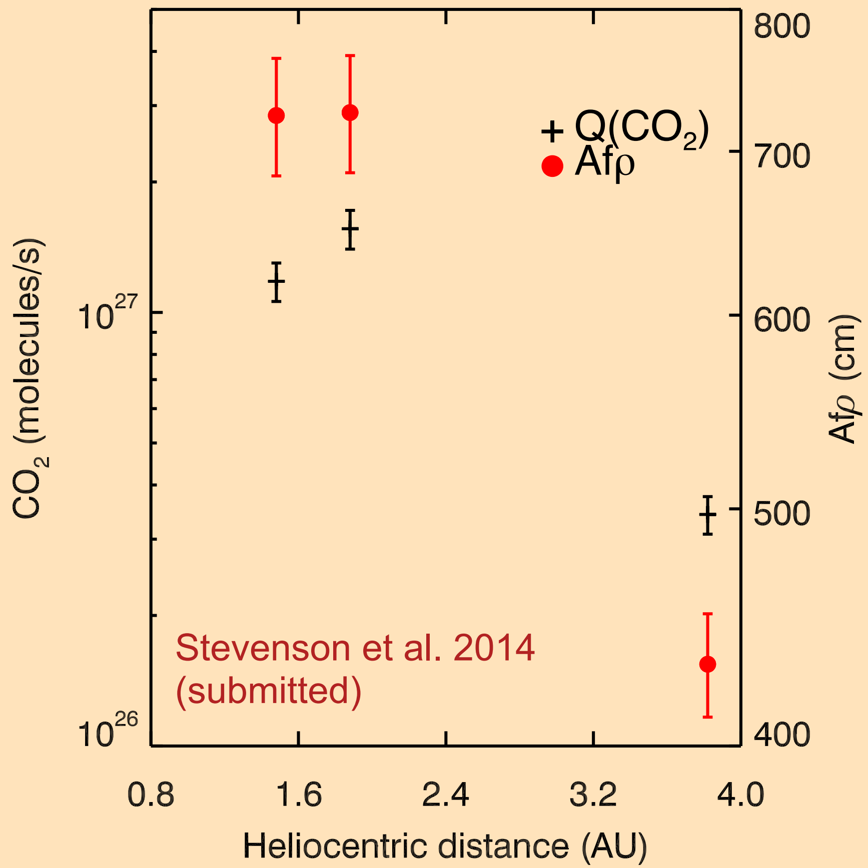
WISE/NEOWISE topics to be covered include:

- Discoveries
- Data Tips and Techniques
- Extreme Sources
- Synergy with Other Surveys
- Time Domain
- Follow-up Observations
- Future Uses

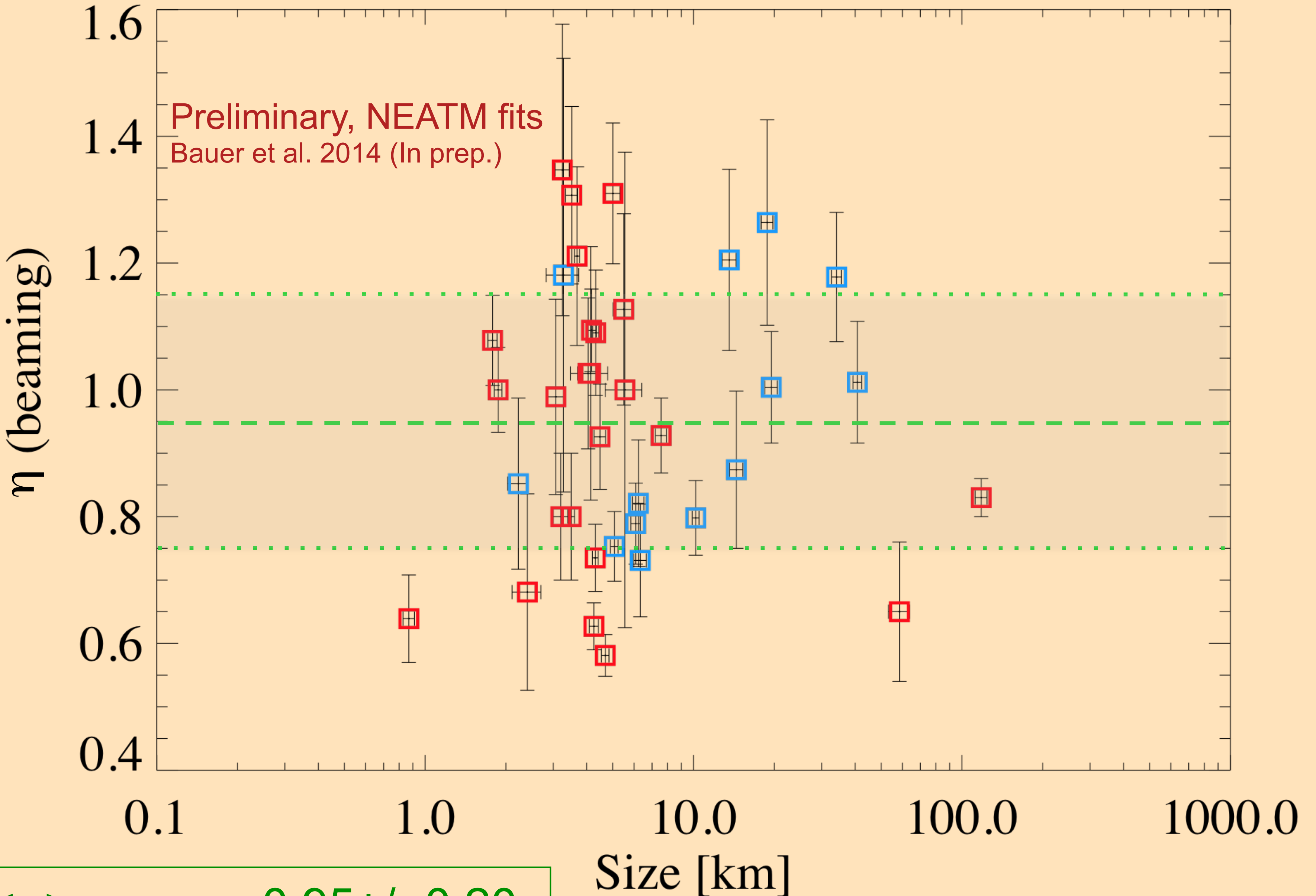
Confirmed speakers include:

- Ned Wright (UCLA)
- Amy Mainzer (JPL)
- Kevin Luhman (Penn State)
- Nadia Zakamska (Johns Hopkins)
- Željko Ivezić (U. Washington)

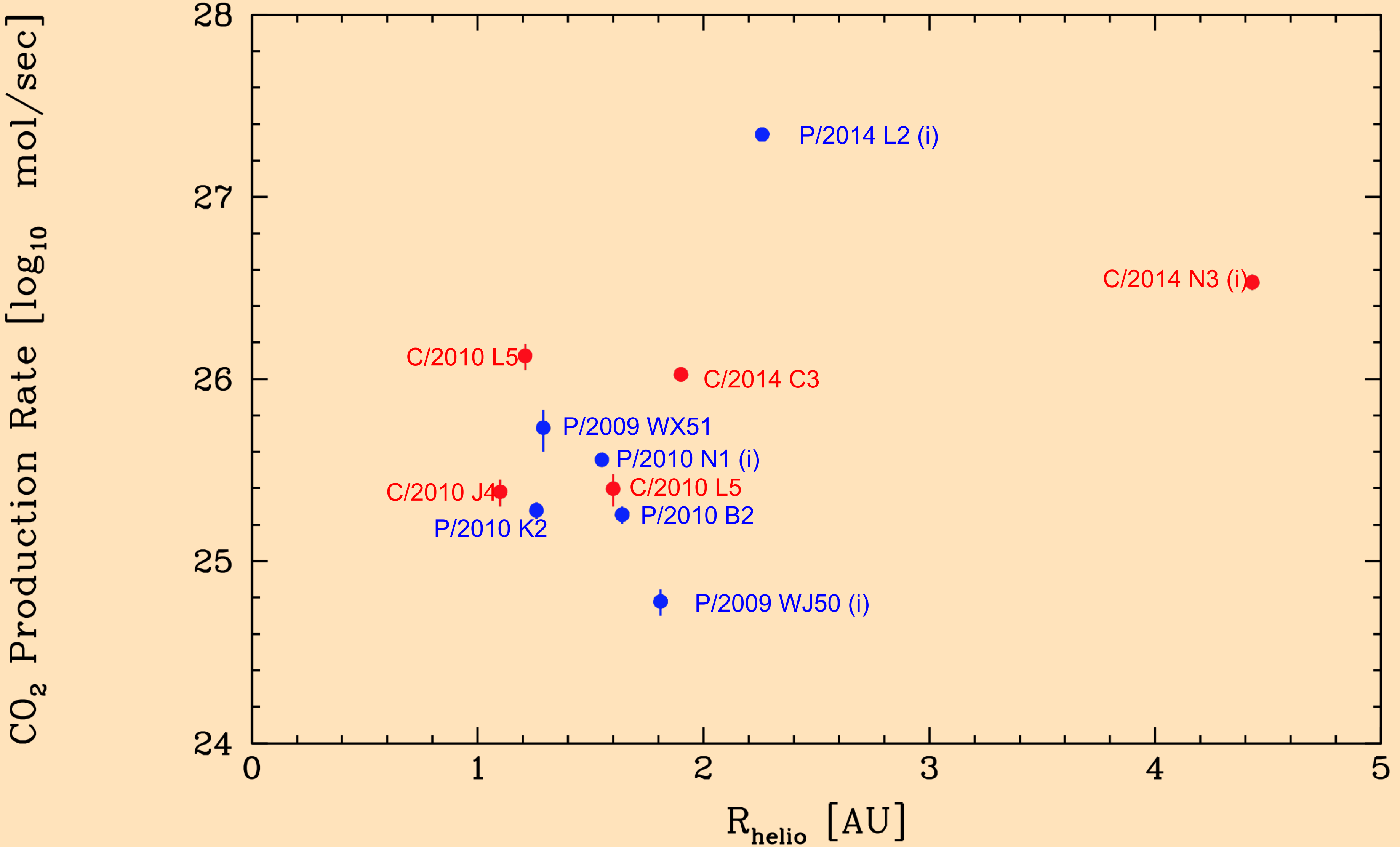
Siding Spring CO_2 Production



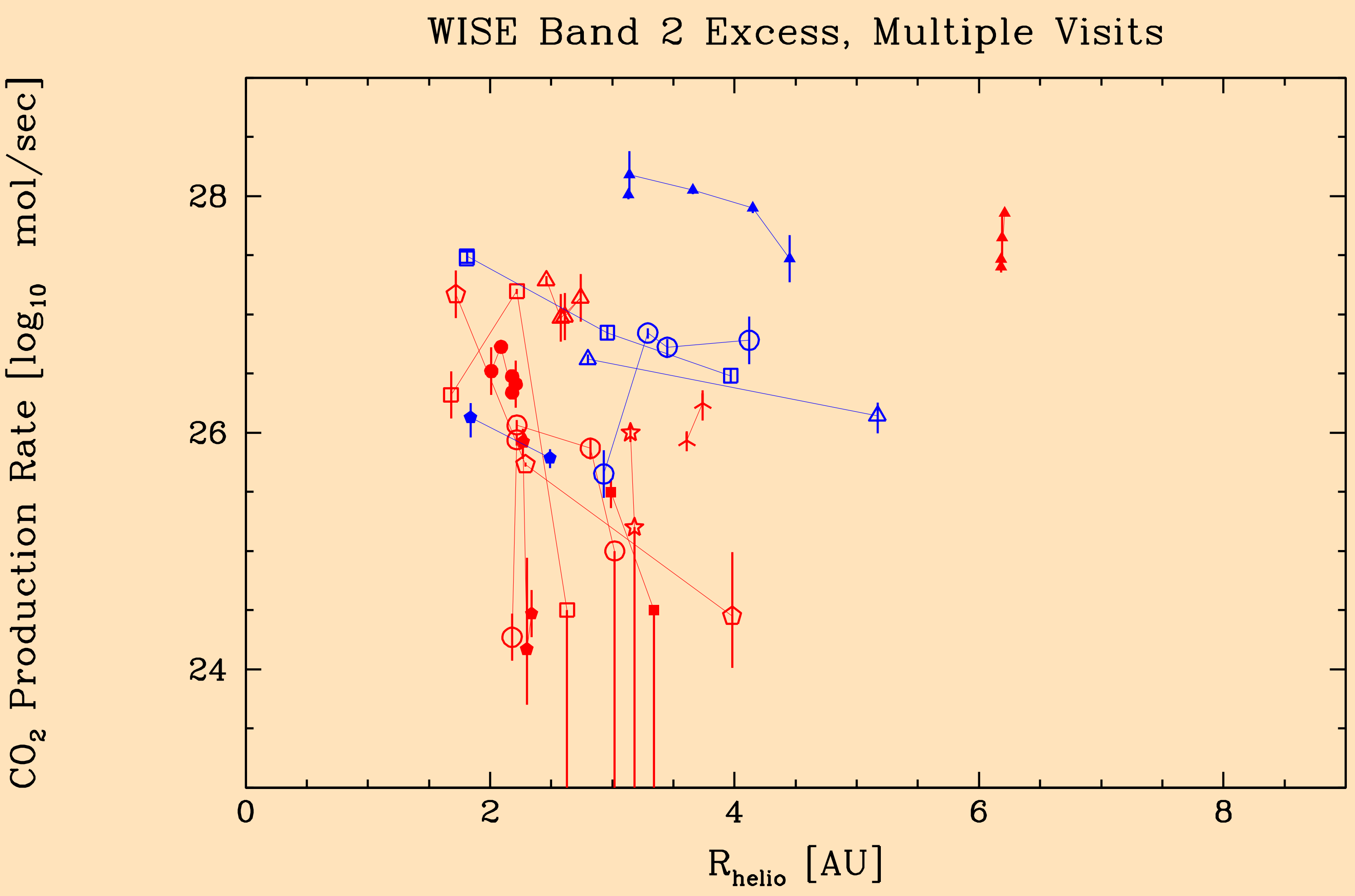
- From January to July, increase matched $\sim R_H^{-2}$
- CO_2 Diminished between July and late September.



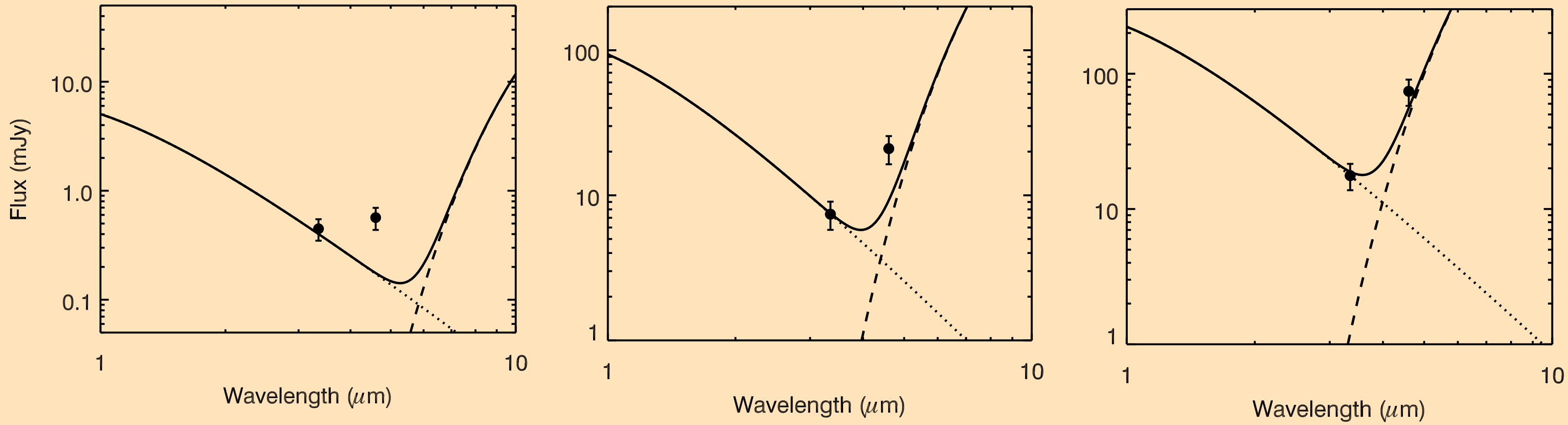
$\langle\eta\rangle_{SPC,LPC}$ = 0.95+/- 0.20



Bauer et al. 2014 (in prep.)

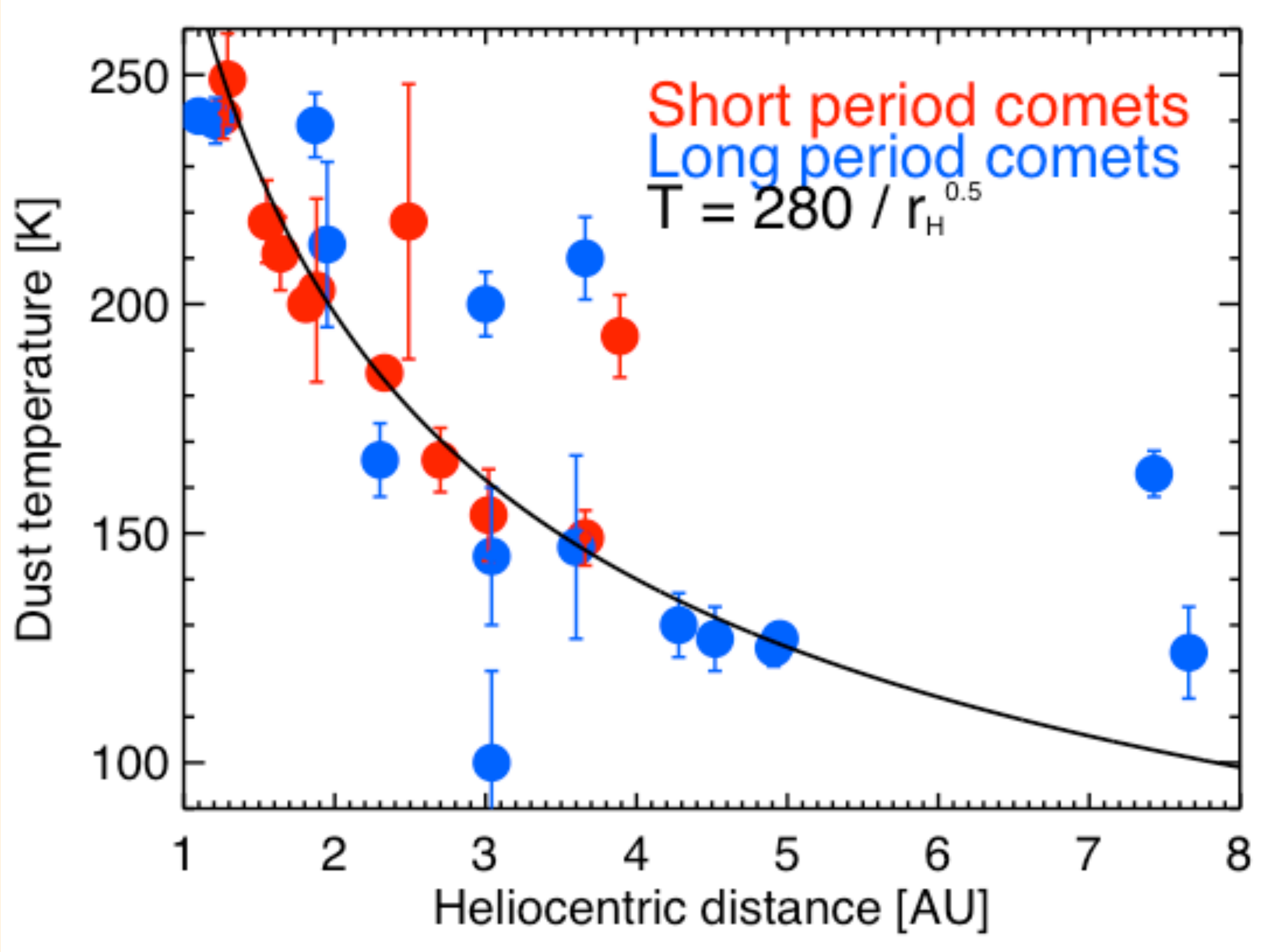

WISE Band 2 Excess, Multiple Visits
CO_2 Production Rate [$\log_{10}$ mol/sec]
28
26
24
0
2
4
6
8
R_{helio} [AU]

Siding Spring CO_2 Analysis



Stevenson et al. 2014 (submitted)

- Dust thermal signal grows with decreasing R_H.
- CO_2 in late September very weak signal above modeled dust thermal signal.



Stevenson et al. 2014