Gemini Observations of Active Asteroid 354P/LINEAR (2010 A2)

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Science & Evolution of Gemini Observatory
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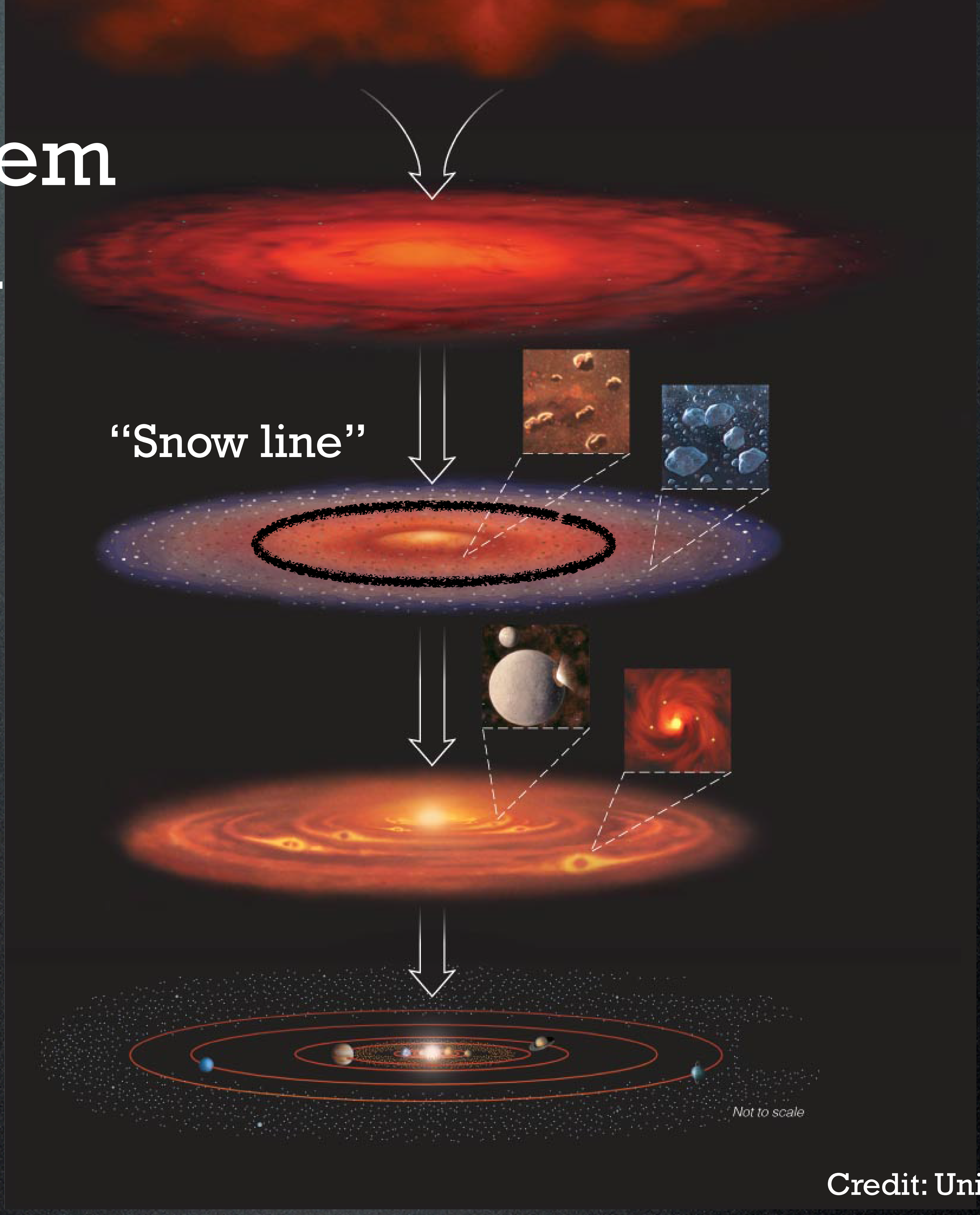
Contents

- Overview
- Active asteroids resulting from impacts
  - The case of 354P/LINEAR (2010 A2)
- Concluding remark

Overview

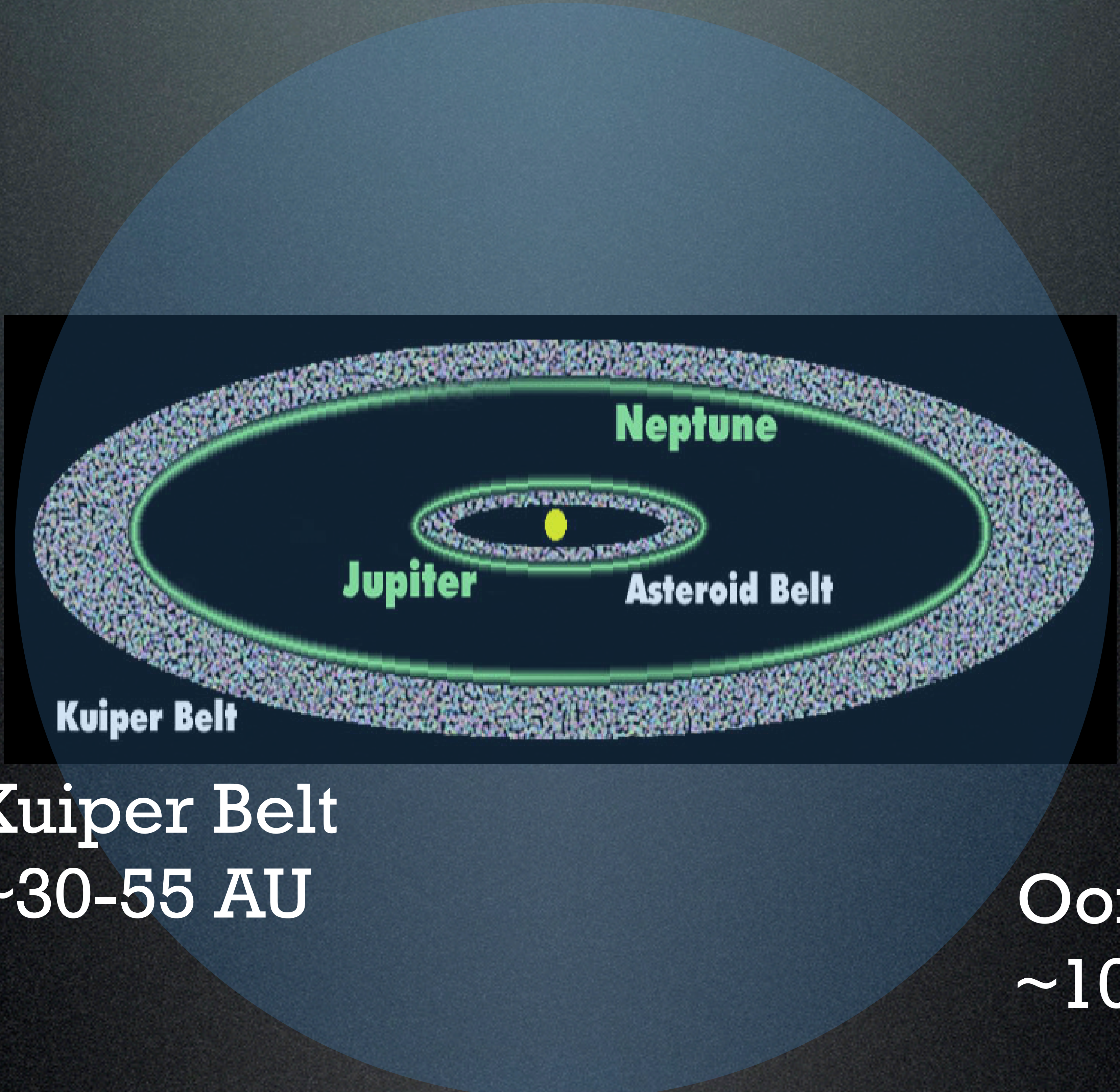
"Small Solar System bodies are primitive, but..."

Solar System Formation



Credit: Univ. of Hawaii

Primitive small bodies



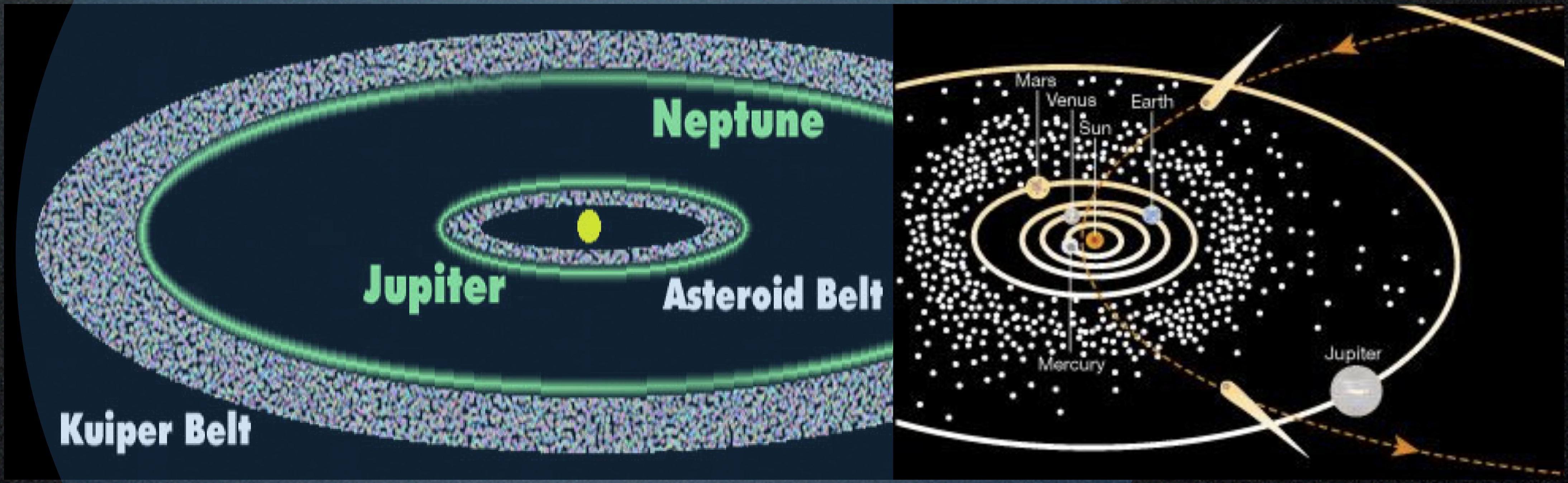
Kuiper Belt
~30-55 AU

Oort Cloud
~10^4-10^5 AU

Yeomans 2000

Primitive small bodies

(easy to observe) **are comets and asteroids**



Kuiper Belt
~30-55 AU

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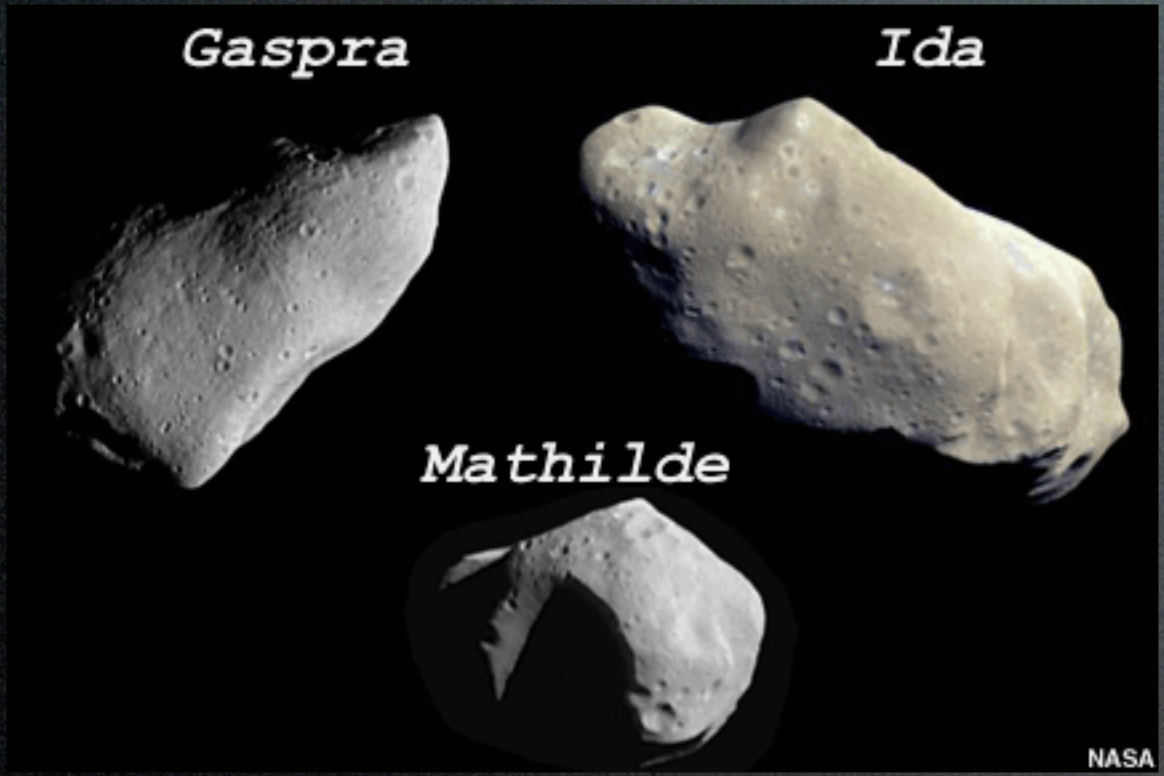
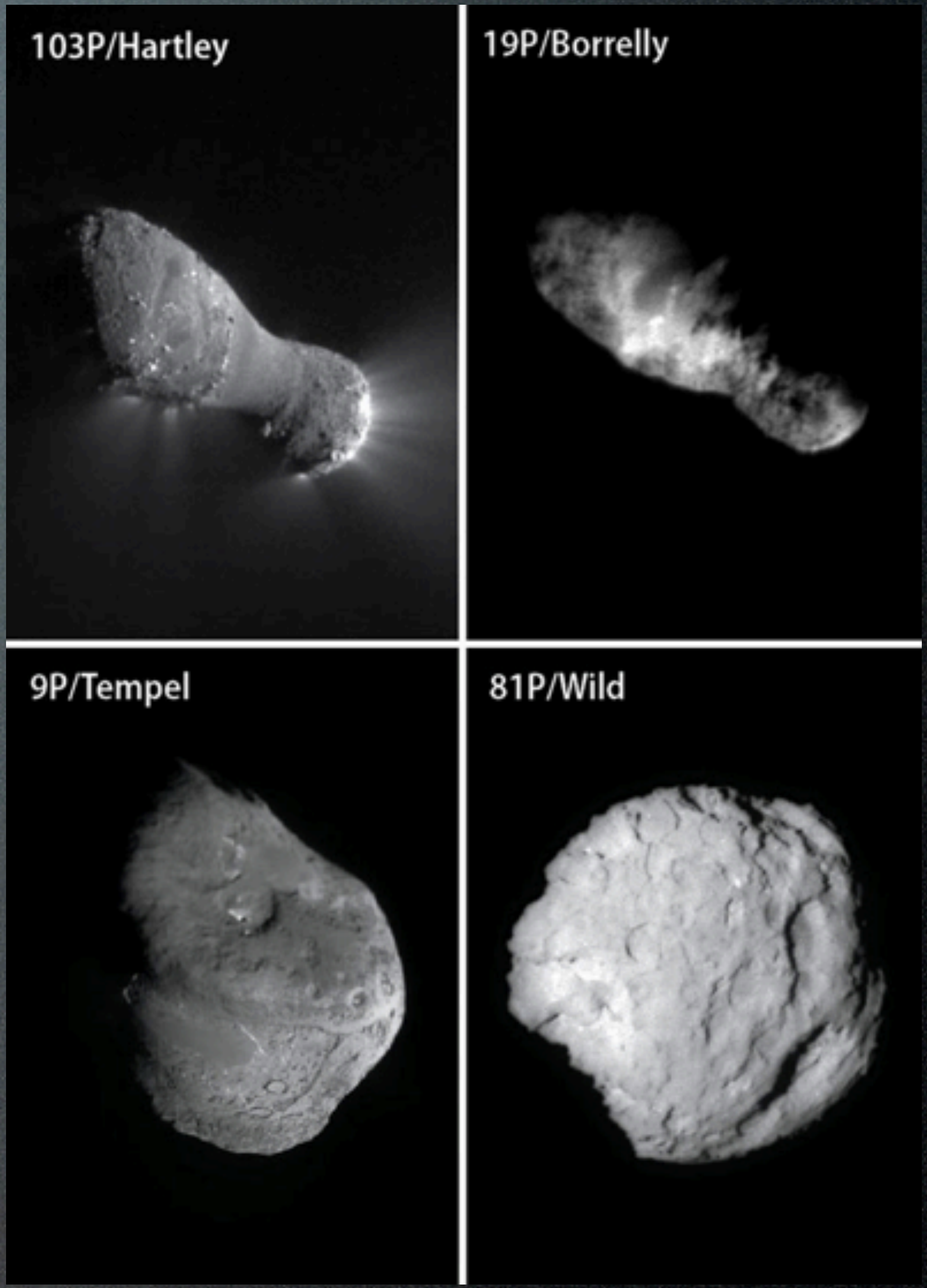
Yeomans 2000

but,

primitive small bodies
also evolved...



by impacts

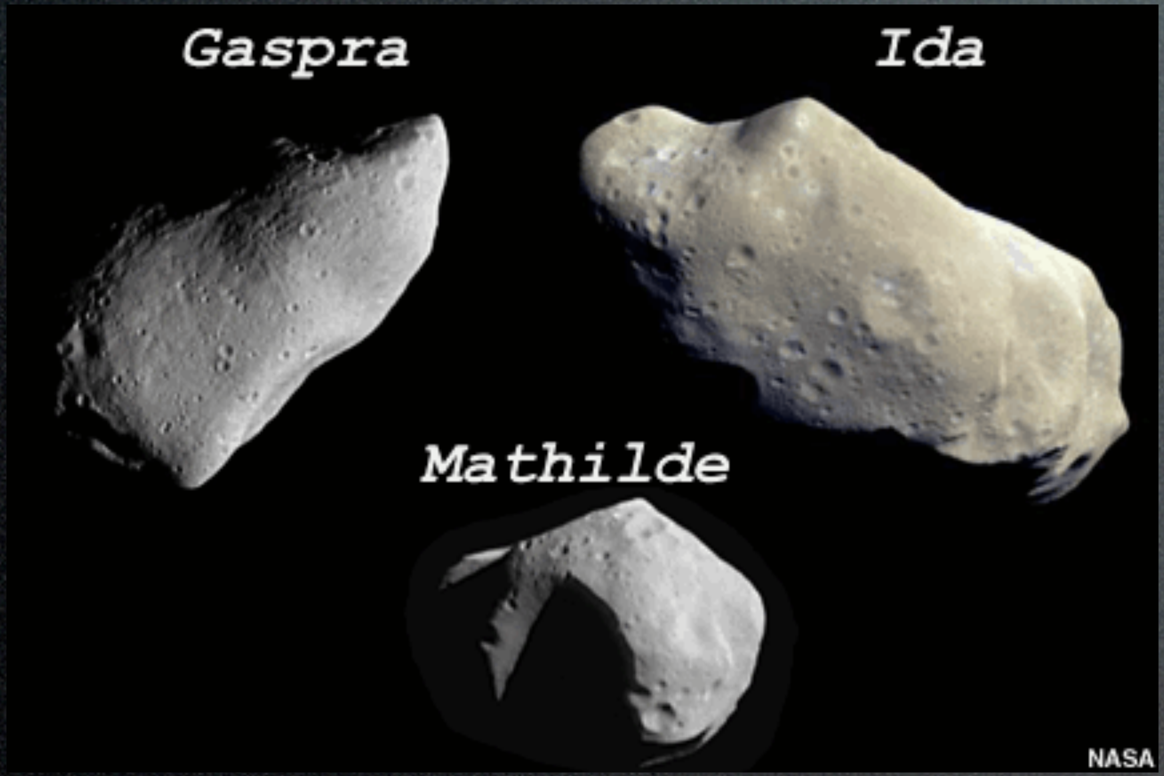


by solar radiative heating

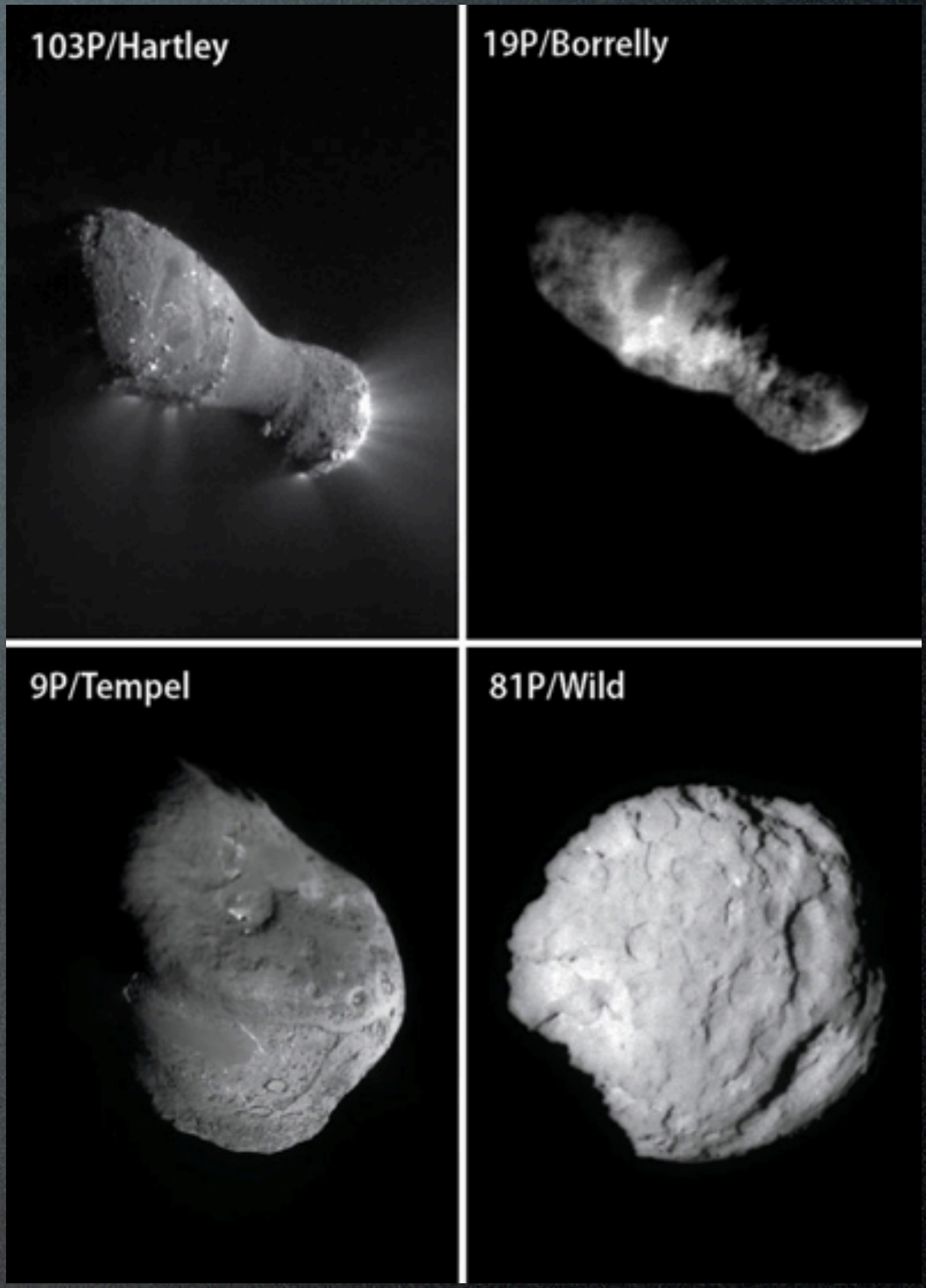
NASA/JPL/Univ. of Maryland

but,

primitive small bodies
also evolved...



by impacts



by solar radiative heating

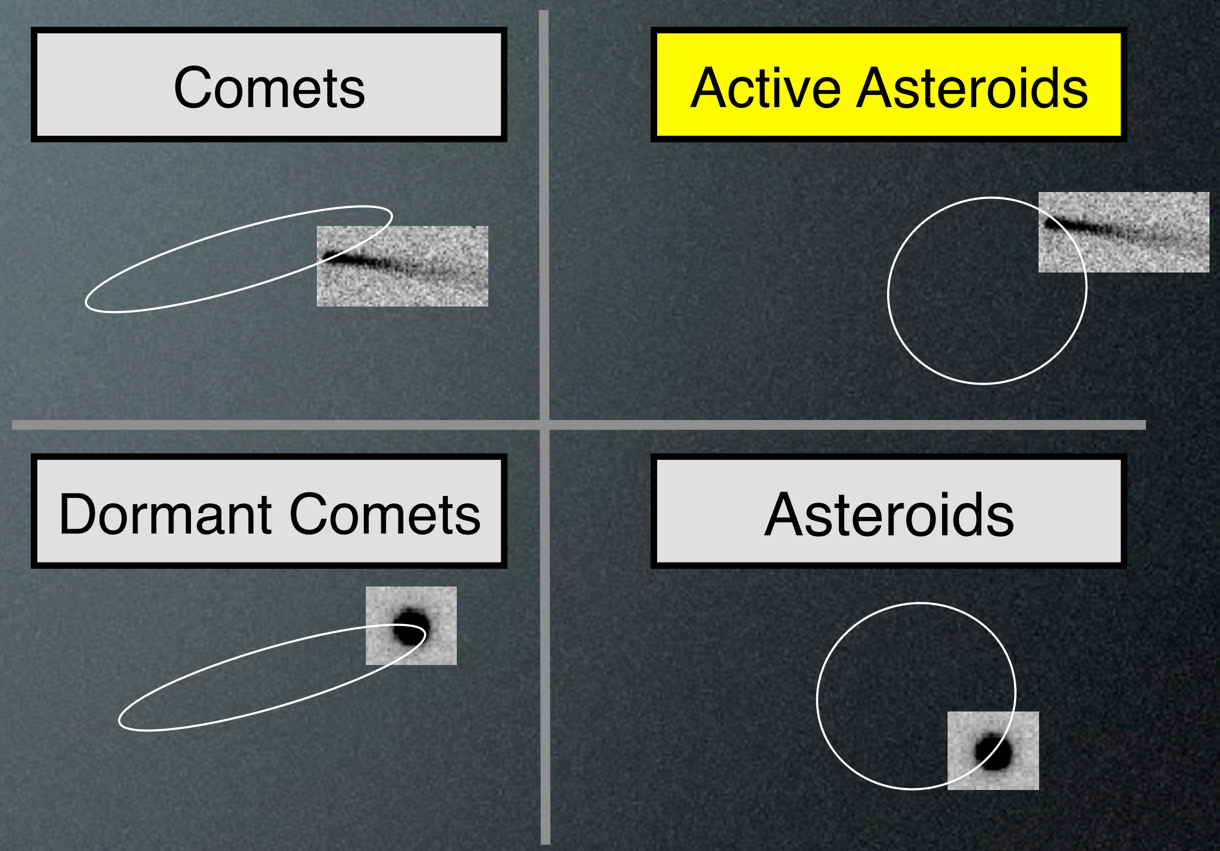
NASA/JPL/Univ. of Maryland

Purpose of this study

- We aim to figure out one of the major evolutionary processes in the Solar System (impacts) through observational studies of
  - Active asteroids resulting from impacts
    - The case of 354P/LINEAR (2010 A2)

Active asteroids resulting from impacts

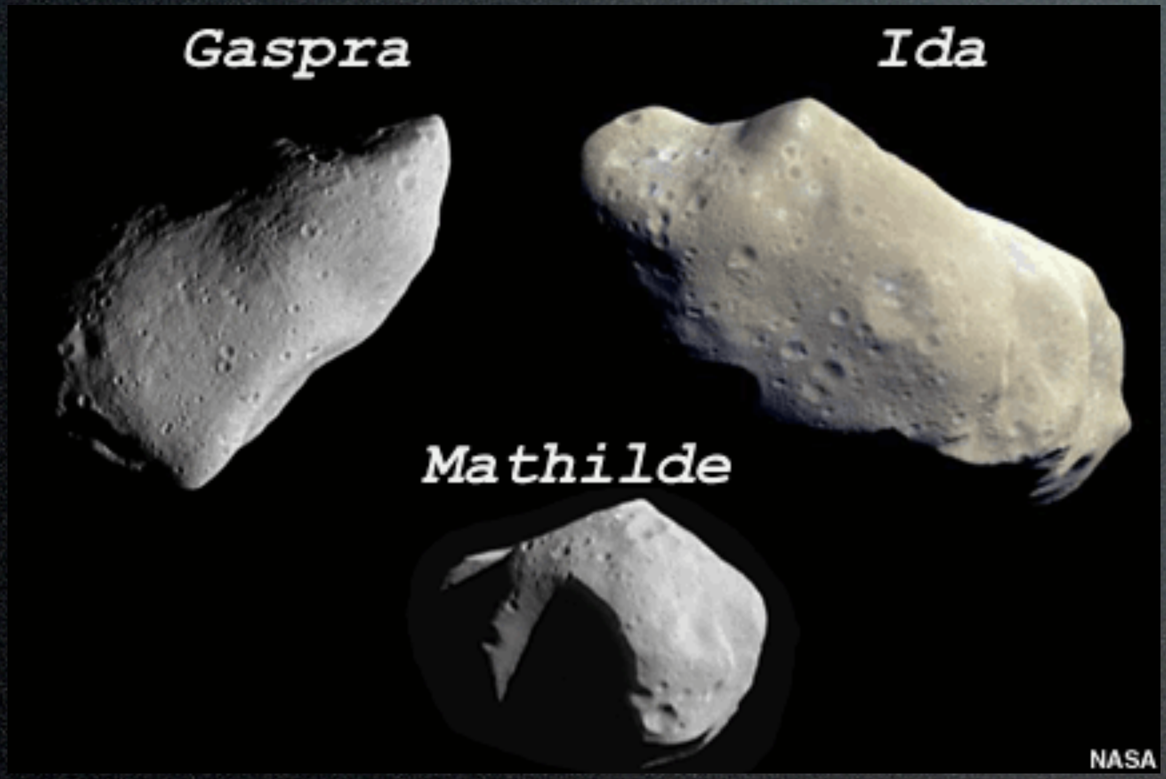
: The case of 354P/LINEAR (2010 A2)

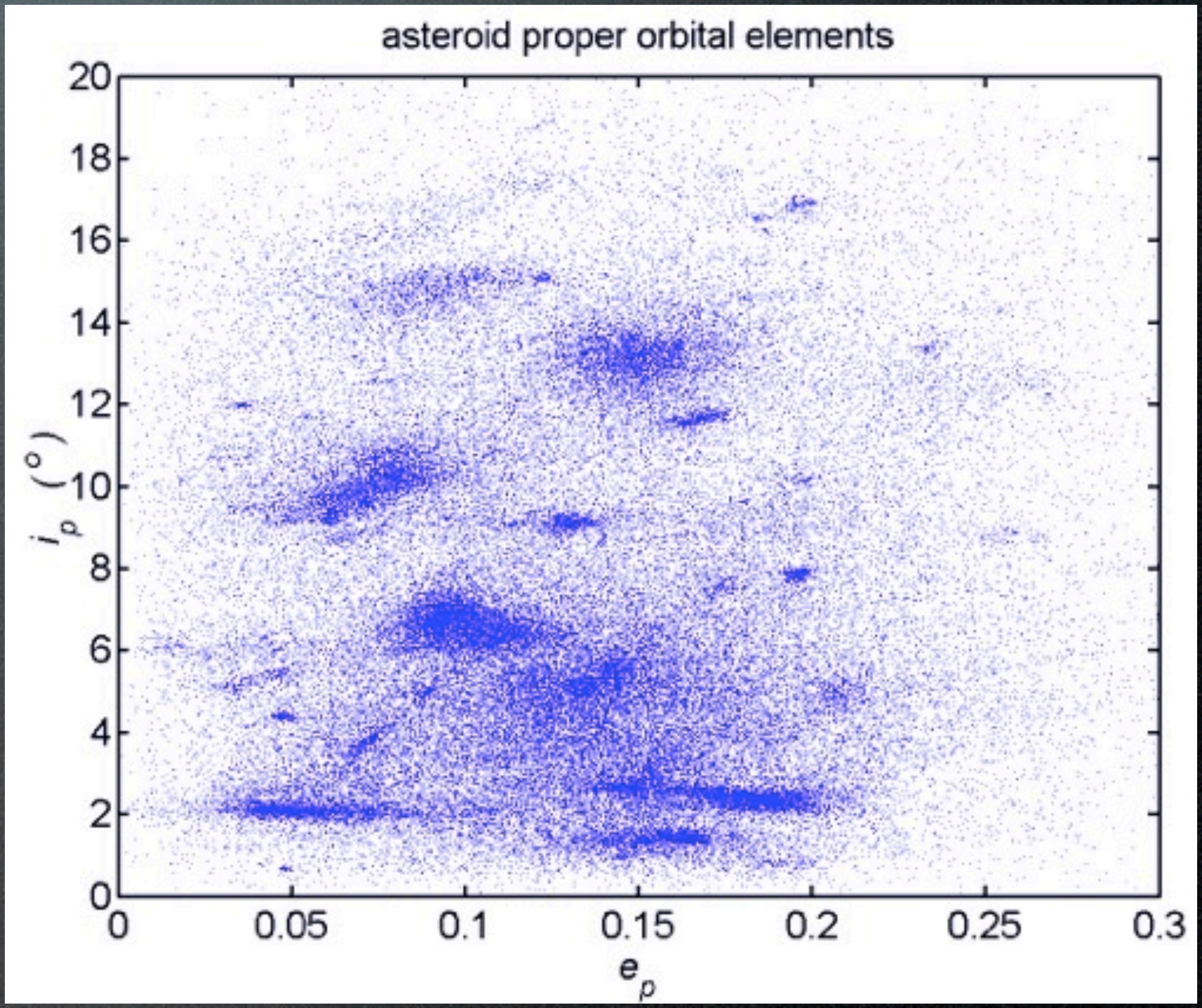


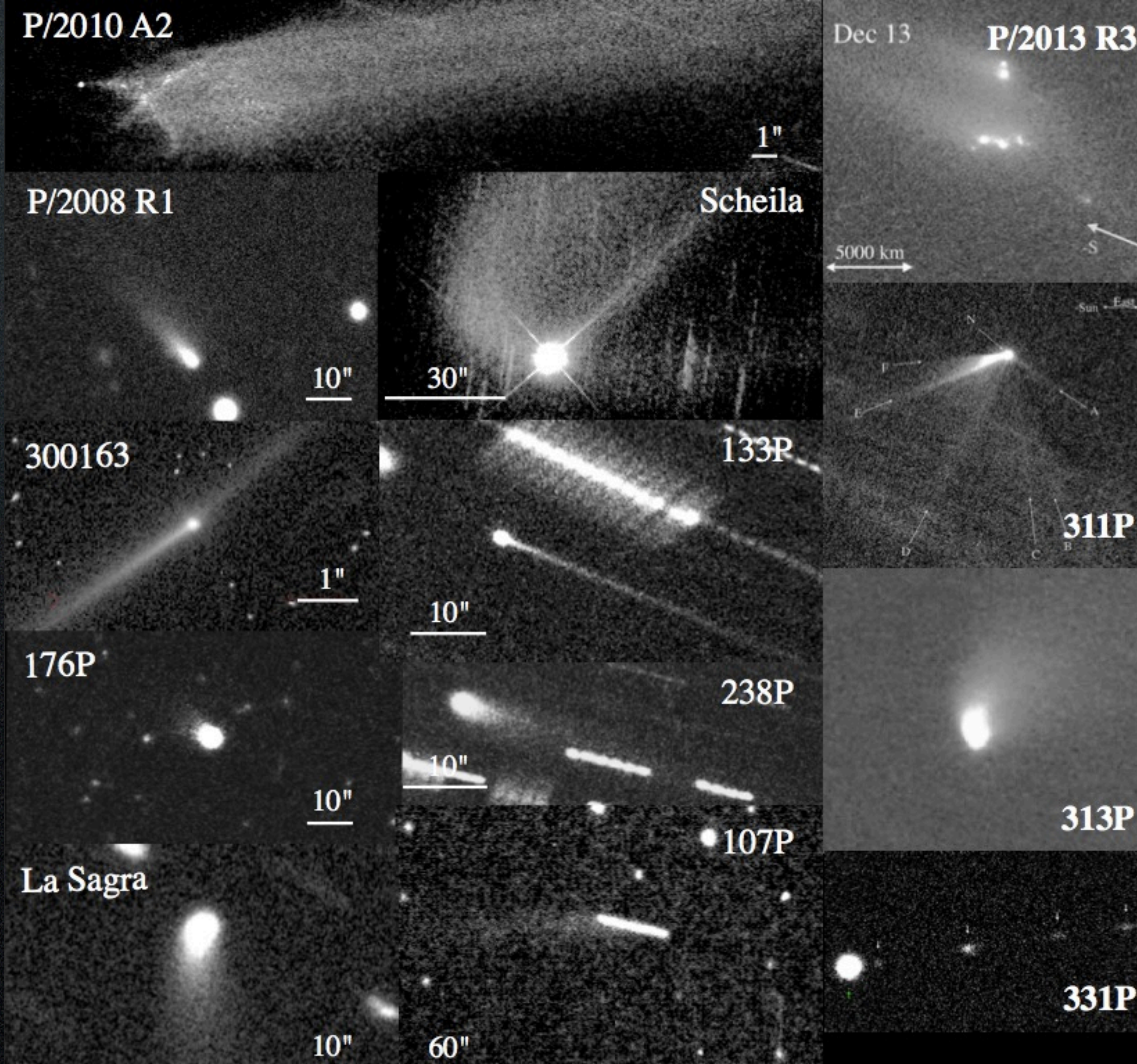
Kim, Y., Ishiguro, M., et al. 2017, AJ
Kim, Y., Ishiguro, M., & Lee, M. G. 2017, ApJL

Background

"Evidences of past impacts"

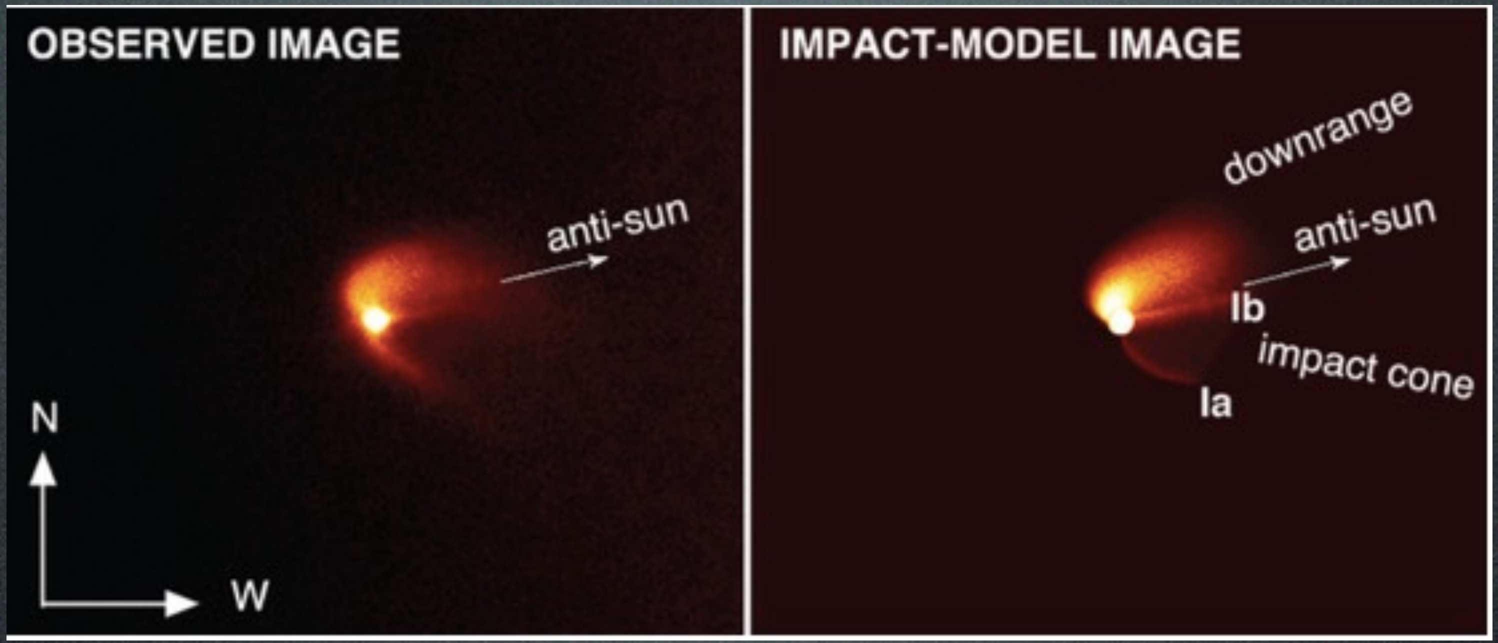


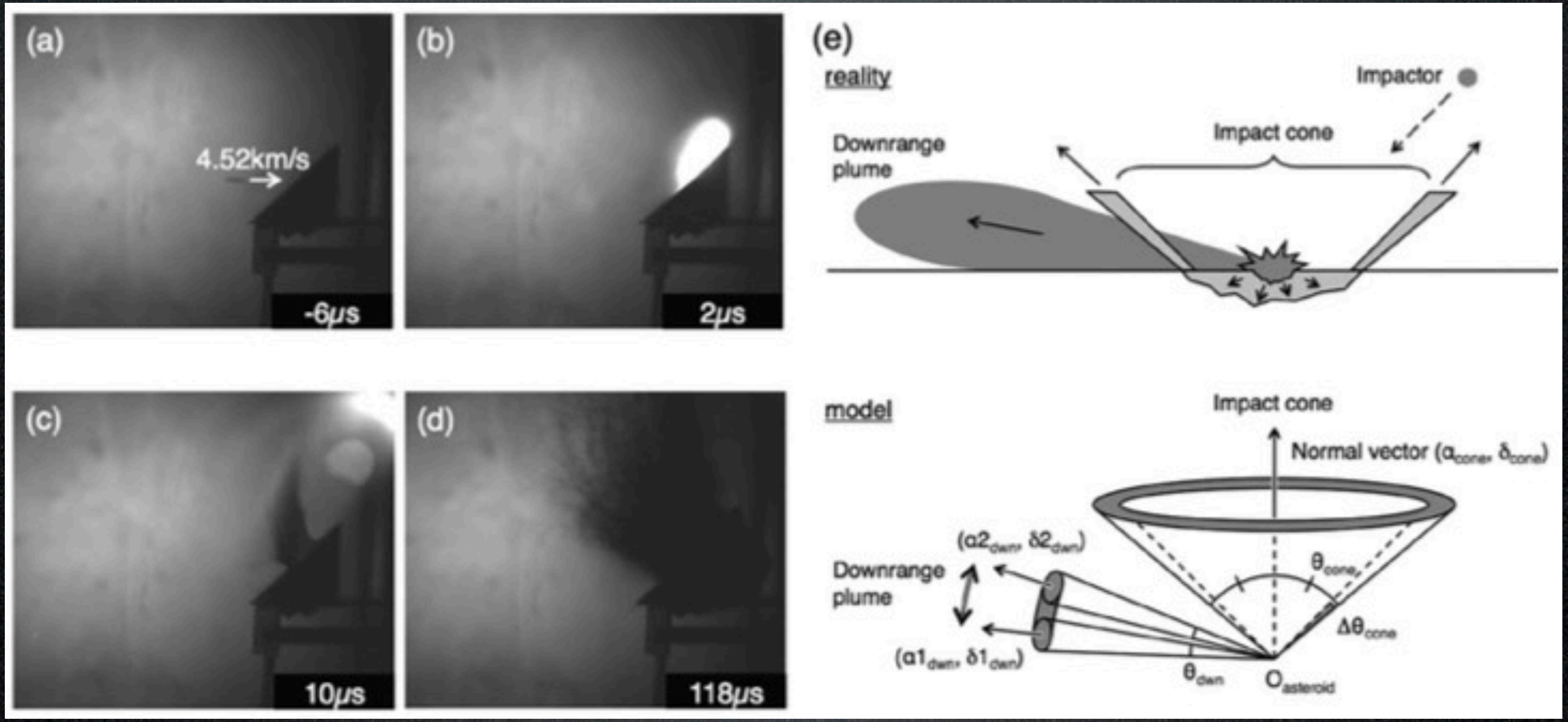




Credit: D. Jewitt

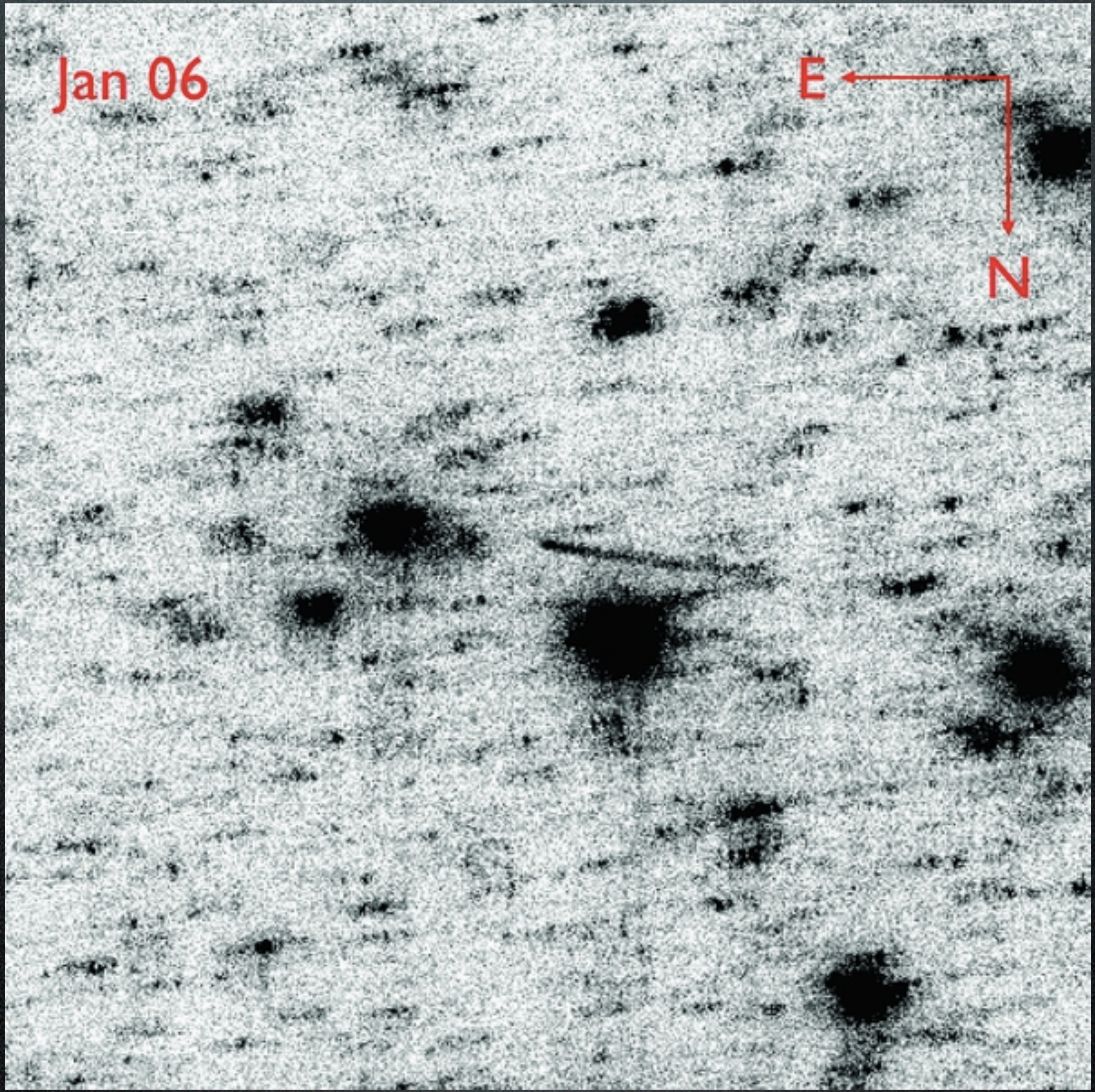
The case of (596) Scheila





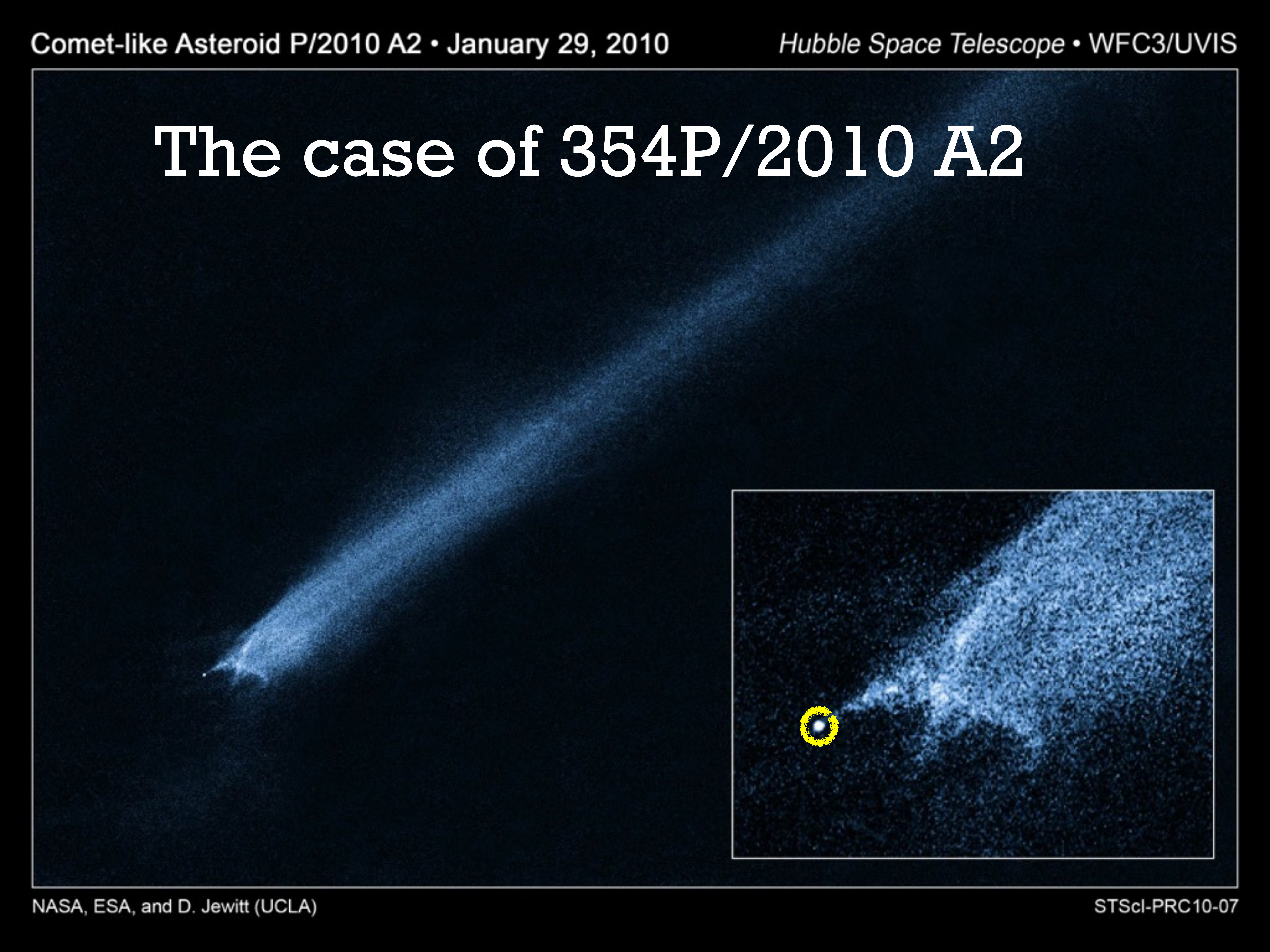
Ishiguro+2011

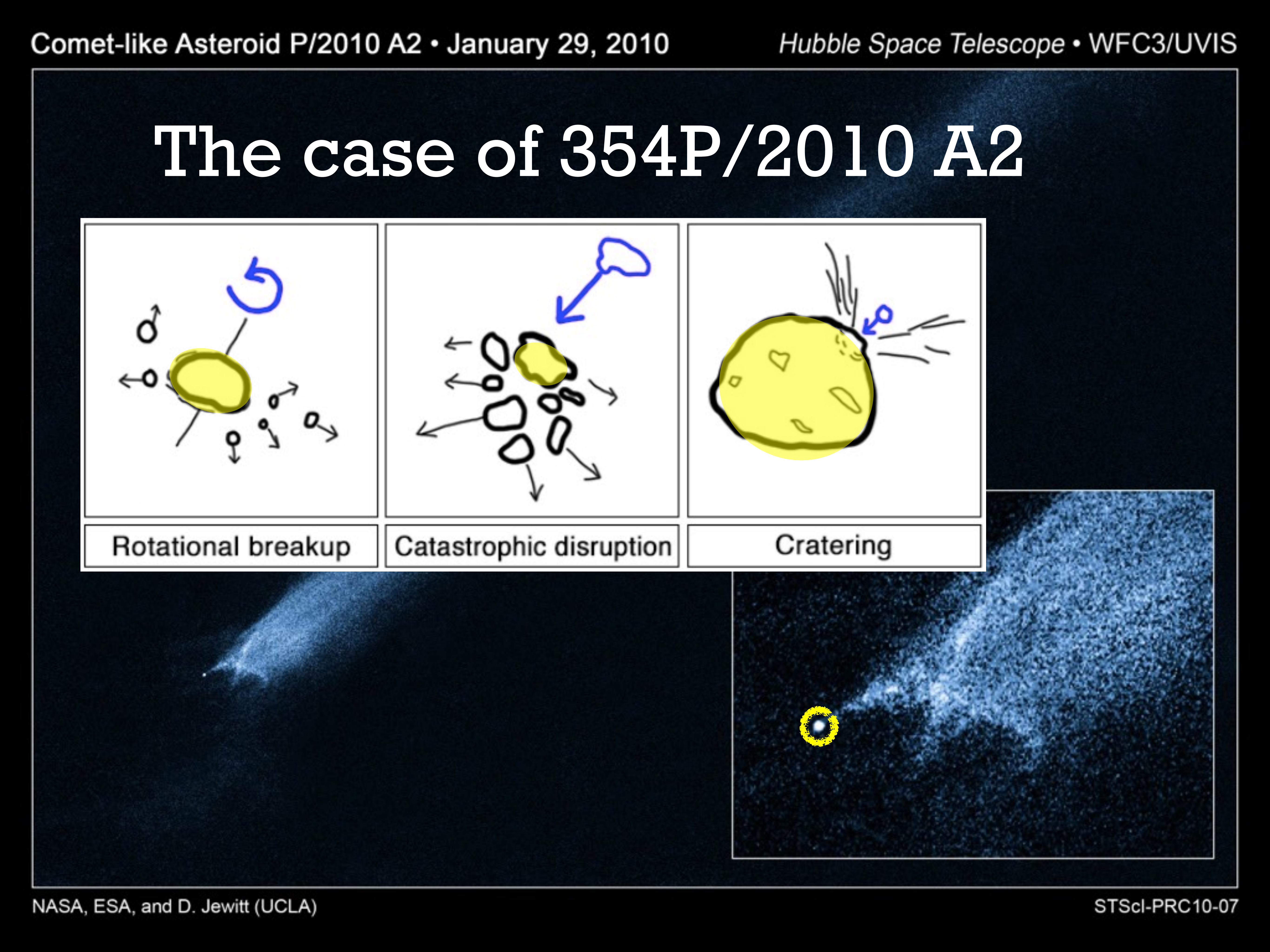
The case of 354P/2010 A2



Jewitt+2011

The case of 354P/2010 A2

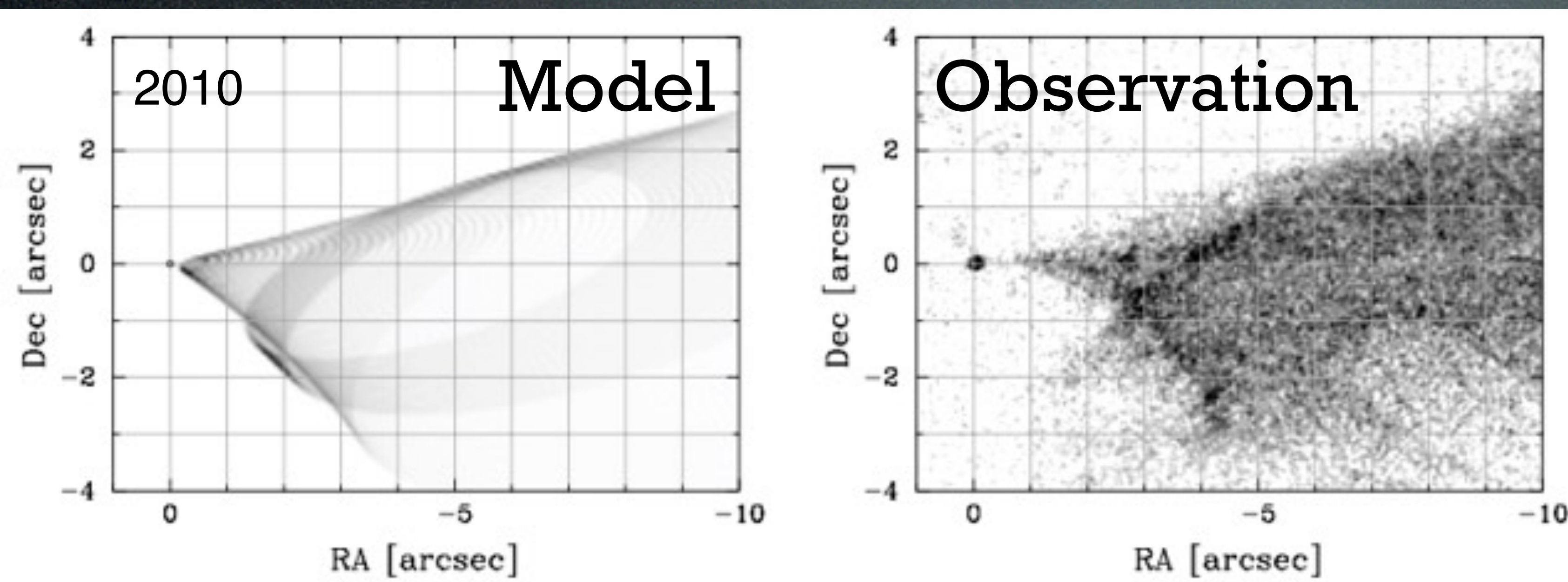



Comet-like Asteroid P/2010 A2 • January 29, 2010
Hubble Space Telescope • WFC3/UVIS
The case of 354P/2010 A2
Rotational breakup
Catastrophic disruption
Cratering
NASA, ESA, and D. Jewitt (UCLA)
STScI-PRC10-07

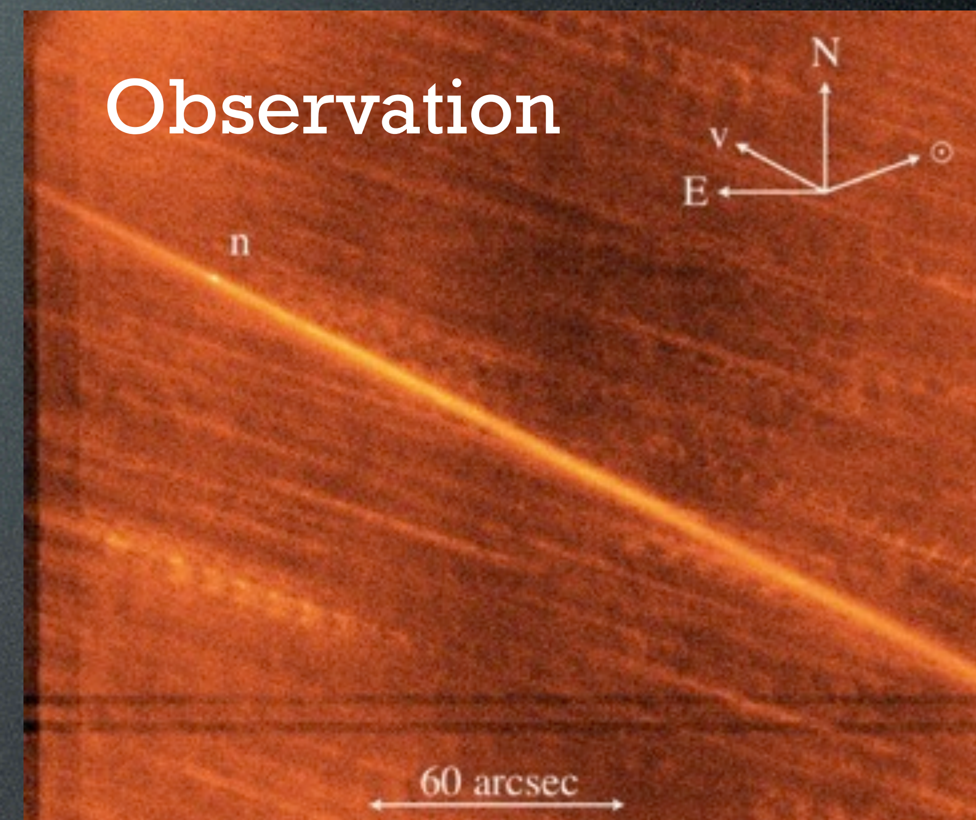
Previous modelings

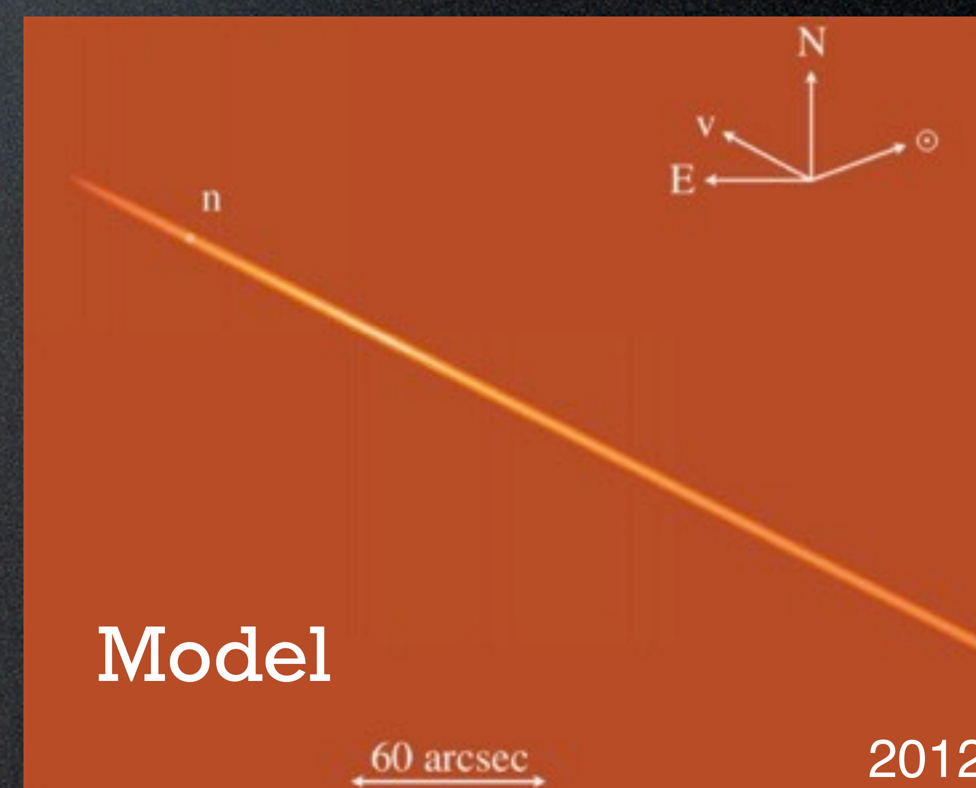
(Jewitt+10,13; Snodgrass+10; Hainaut+12; Agarwal+13; Kleyna+13)

Kleyna+2013

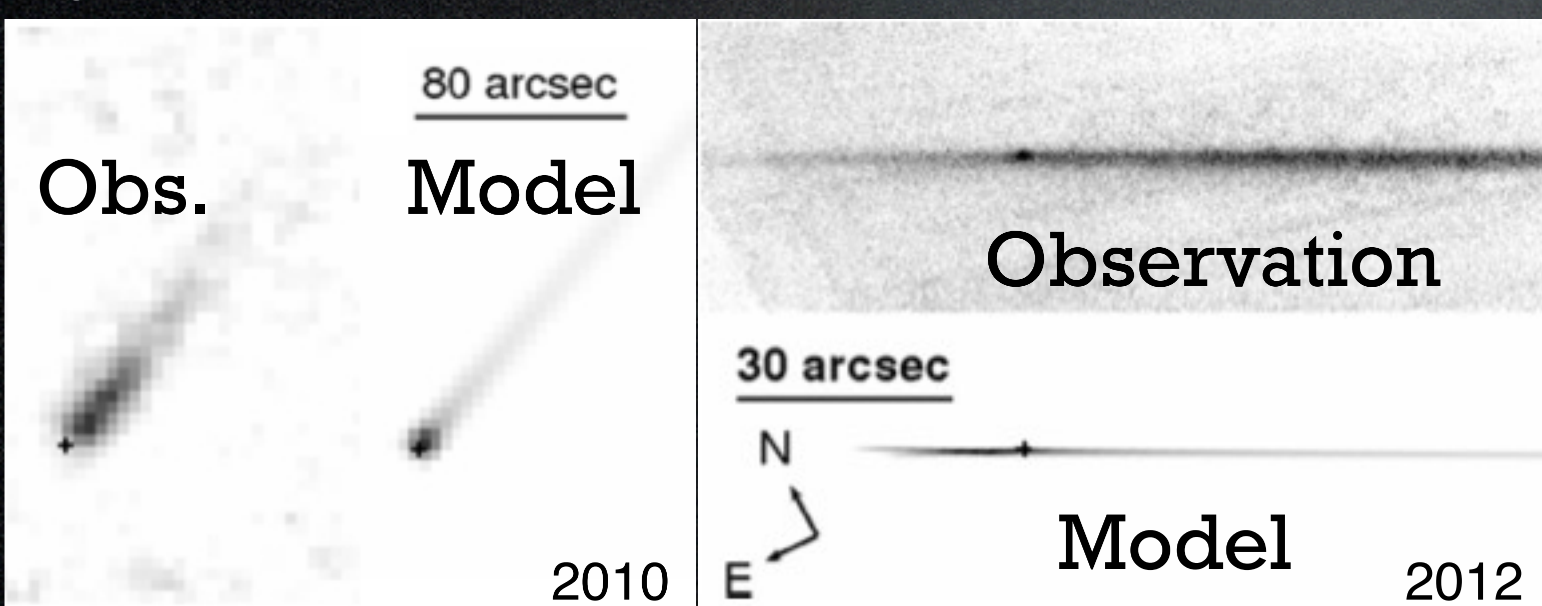


Jewitt+2013





Agarwal+2013



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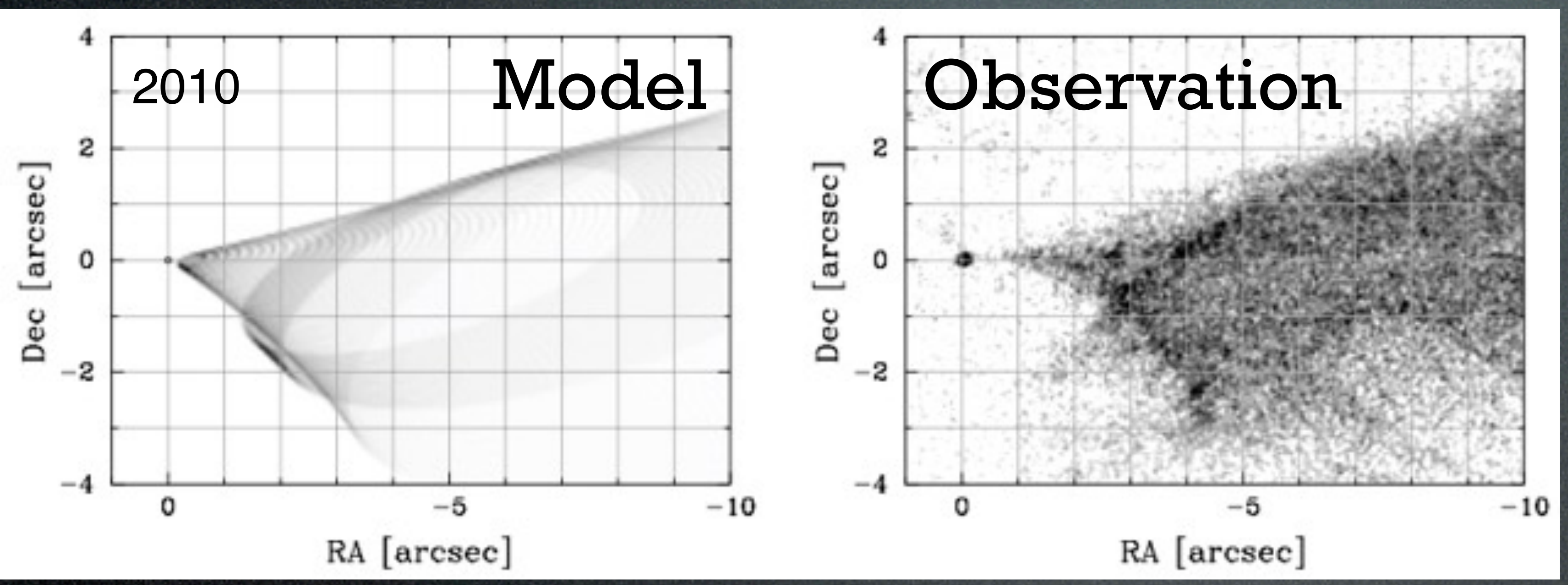
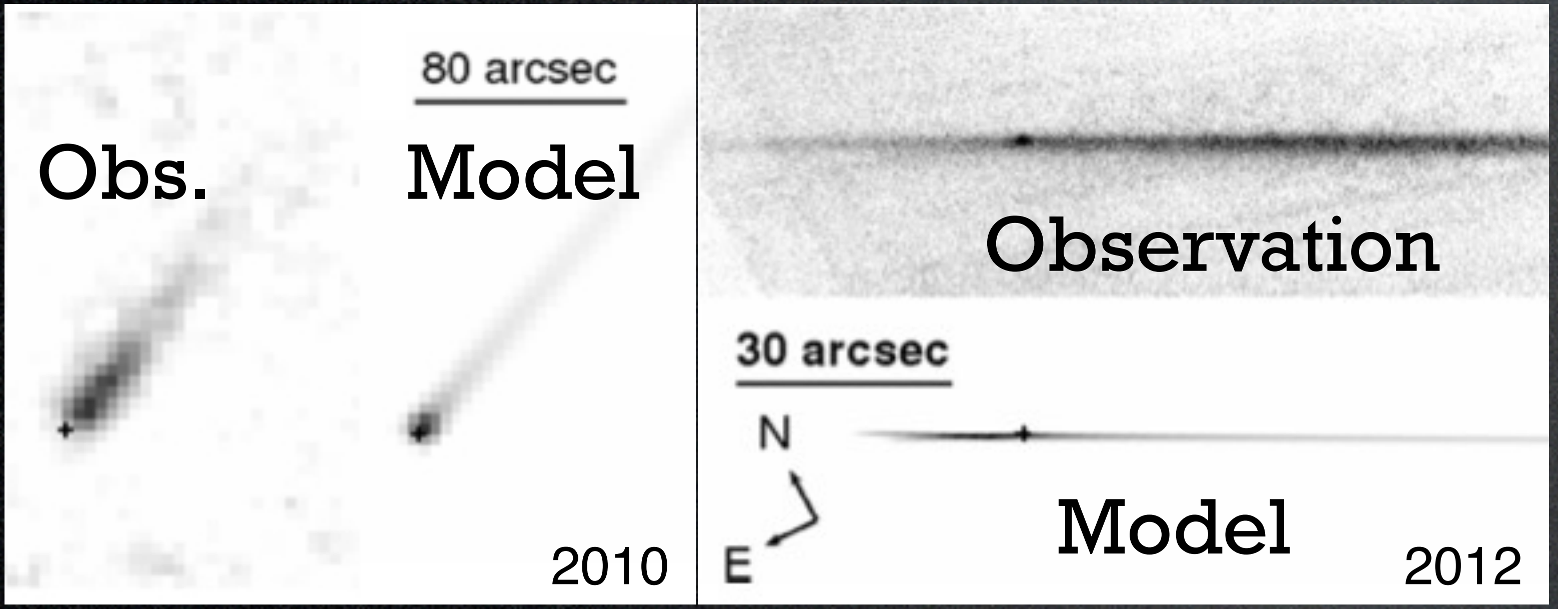
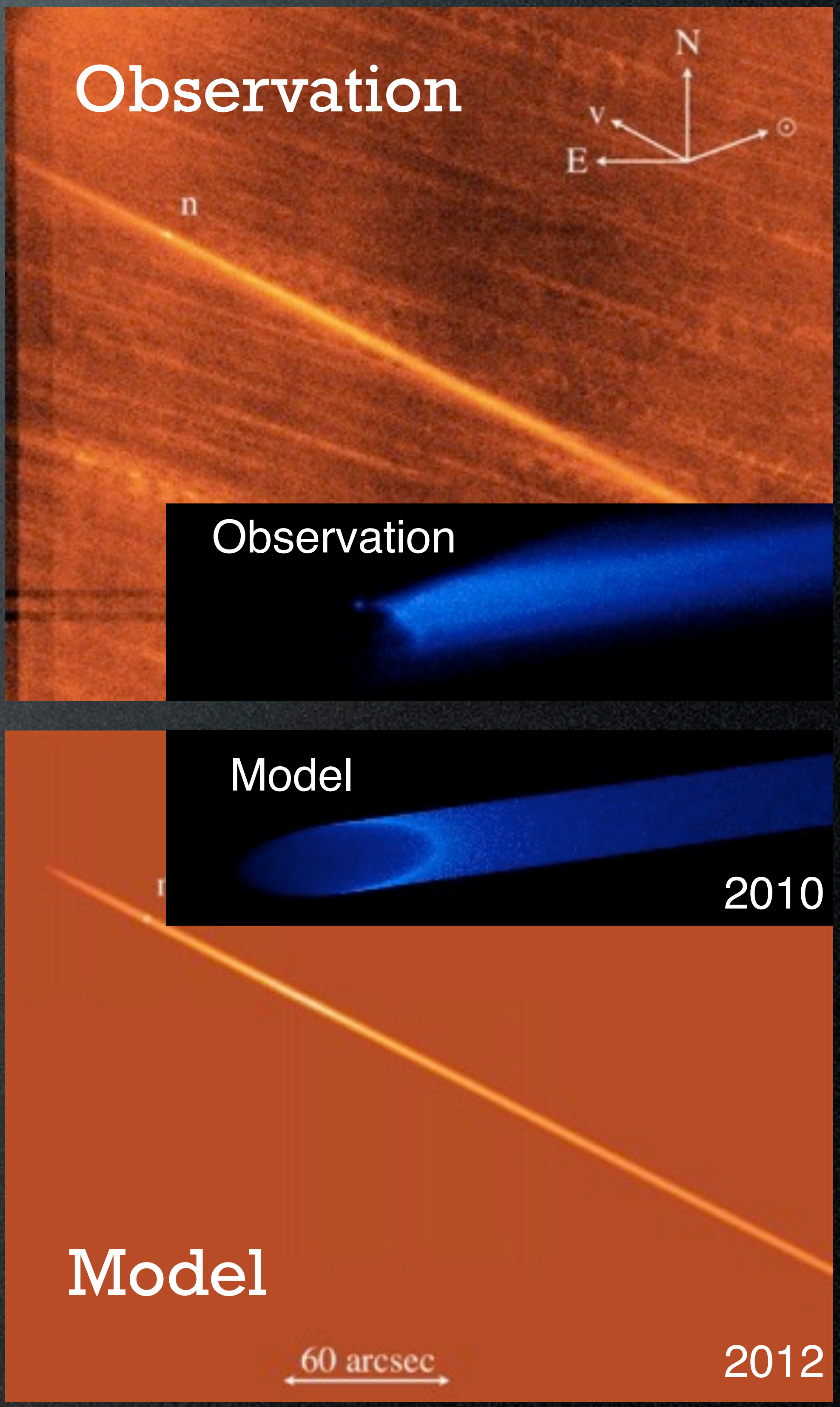


Agarwal+2013



Jewitt+2013



This study

- We revisited a mass ejection phenomenon occurred in active asteroid 354P/2010 A2.
- We conducted a dynamical dust modeling and light curve observations of the largest fragment to derive its rotation period.
- We aim to complement the modeling considering the time evolution, and clarify the ejection mechanism of 354P/2010 A2.

Observations

Gemini-N/
r' (3,000 sec)

HST/F606W

CFHT/R

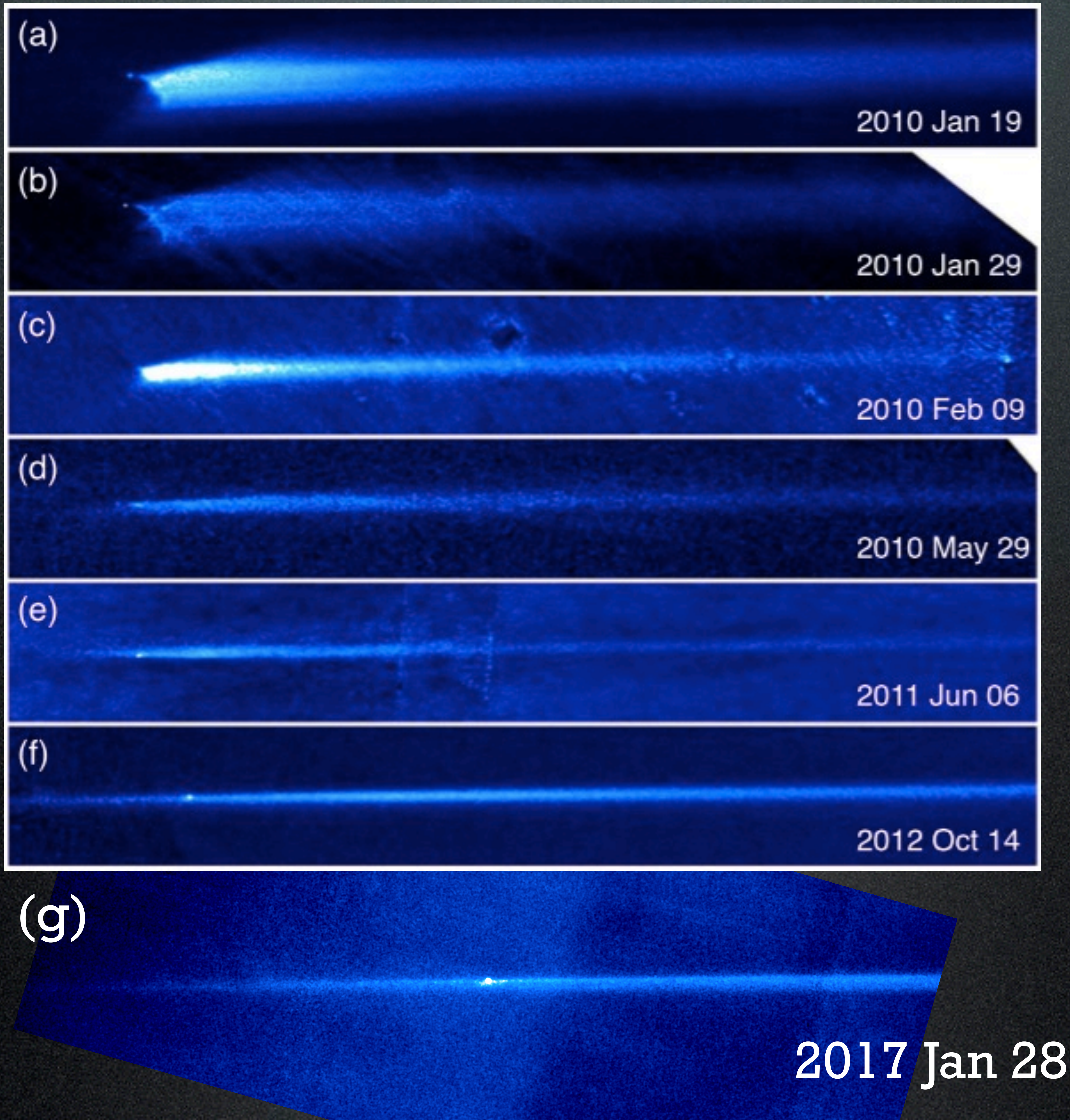
HST/F606W

Subaru/g'

Keck/B

Kim+2017a, 2017b

Observations



Gemini-N/
r' (3,000 sec)

HST/F606W

CFHT/R

HST/F606W

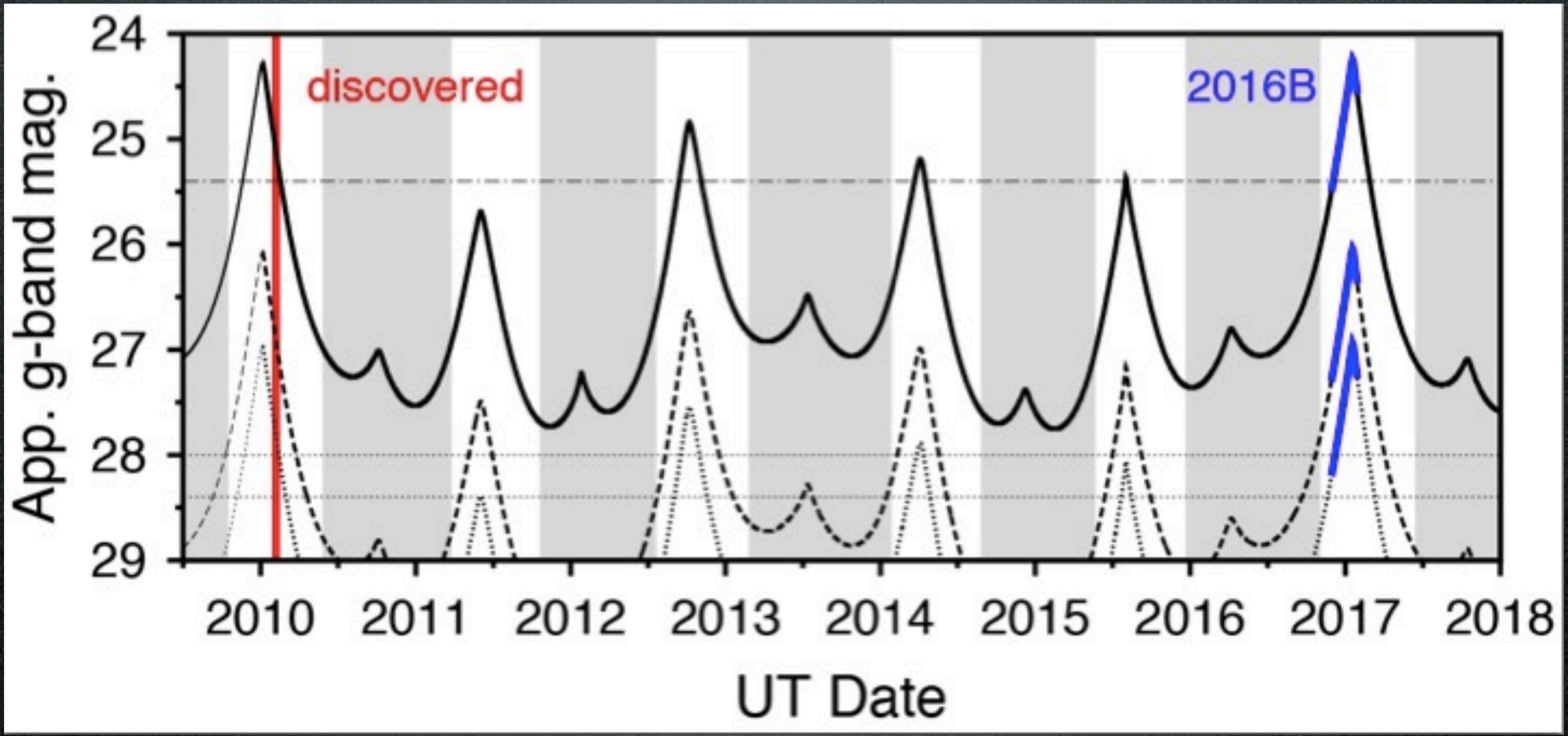
Subaru/g'

Keck/B

Gemini-N/
g' (15,000 sec)

Kim+2017a, 2017b

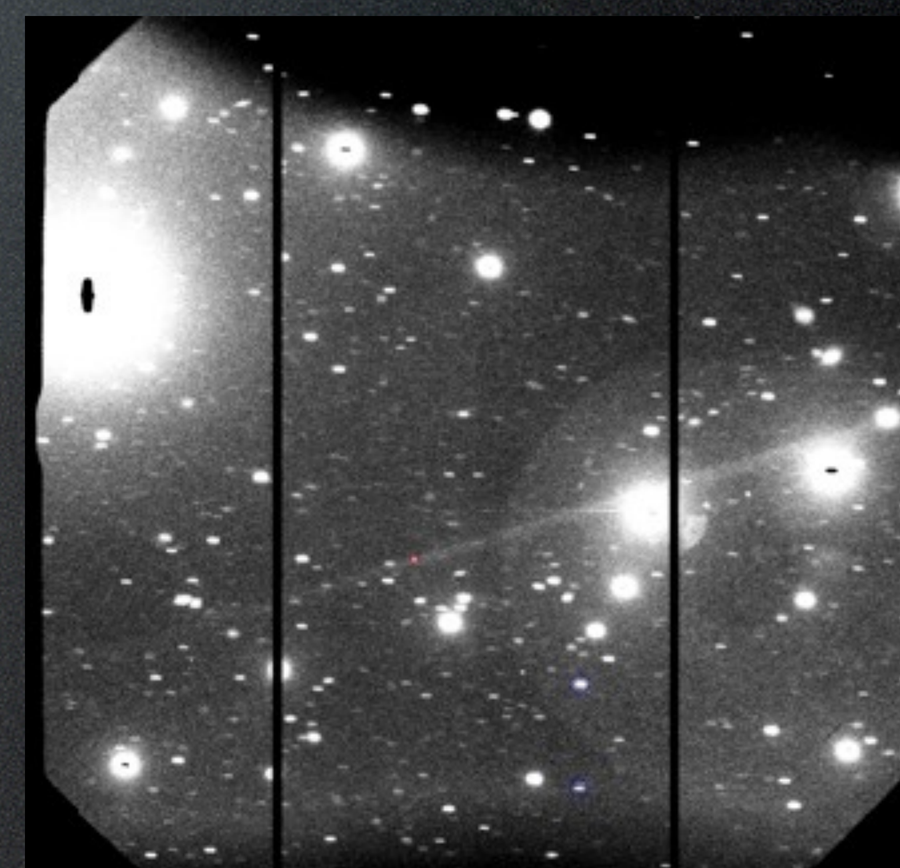
2017 Gemini Observations



K-GMT Science Program
PID: GN-2016B-Q-14 (PI: Y. Kim) 11 hour awarded

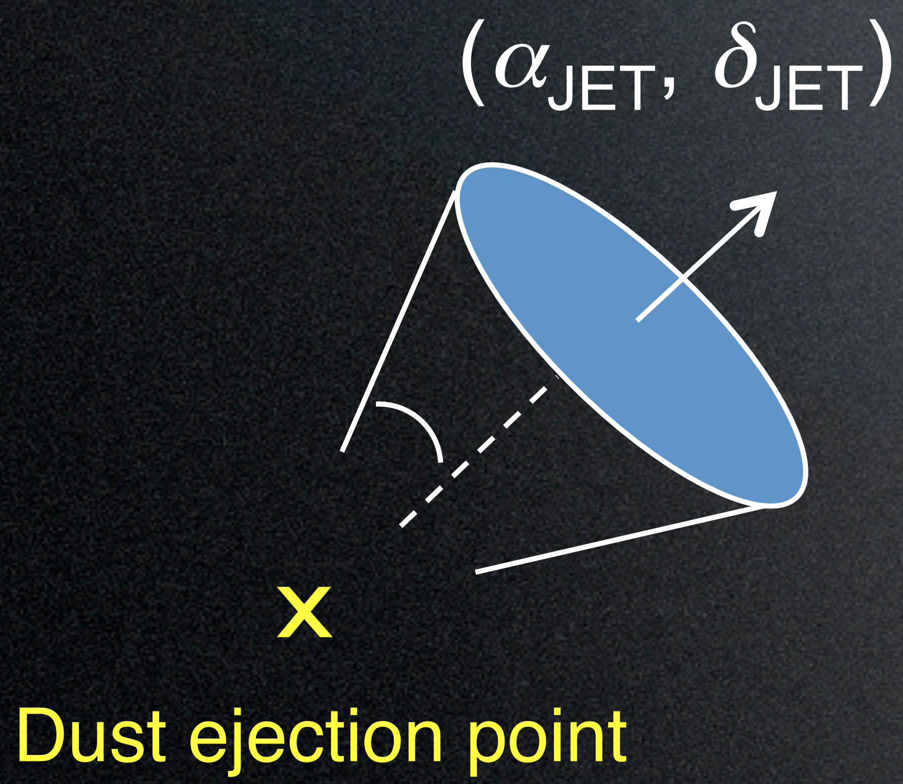
2017 Gemini Observations

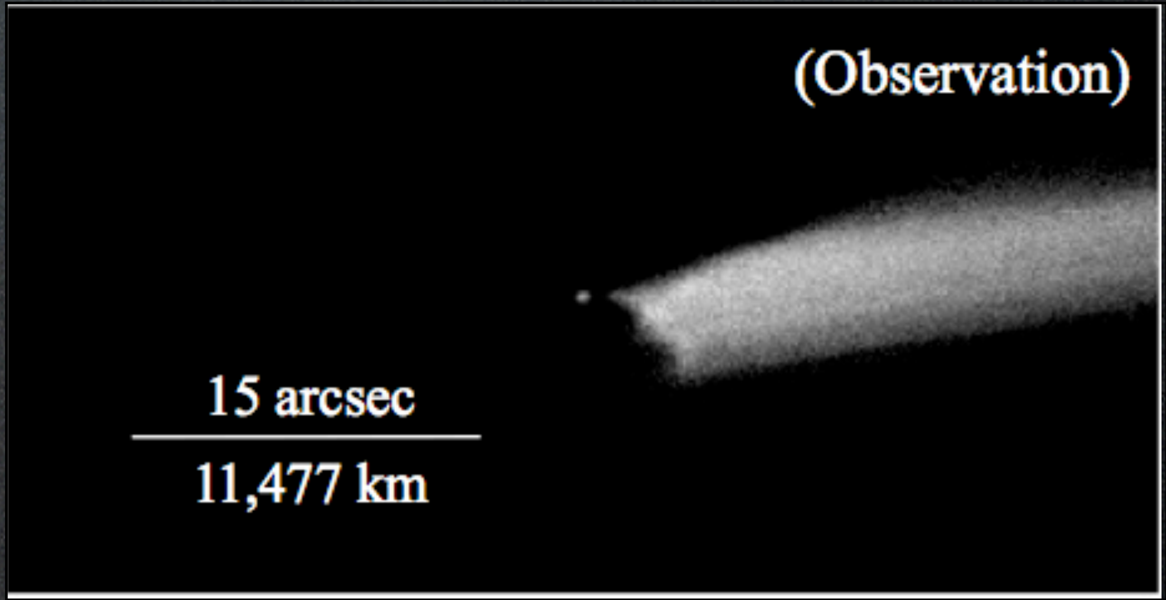
- Two successive nights on UT 2017 January 27-28
- Gemini/GMOS-N, g'-band imaging
- 5 min x 90 exposures, 7.5 hr of total effective exposure time



Anisotropic ejection model

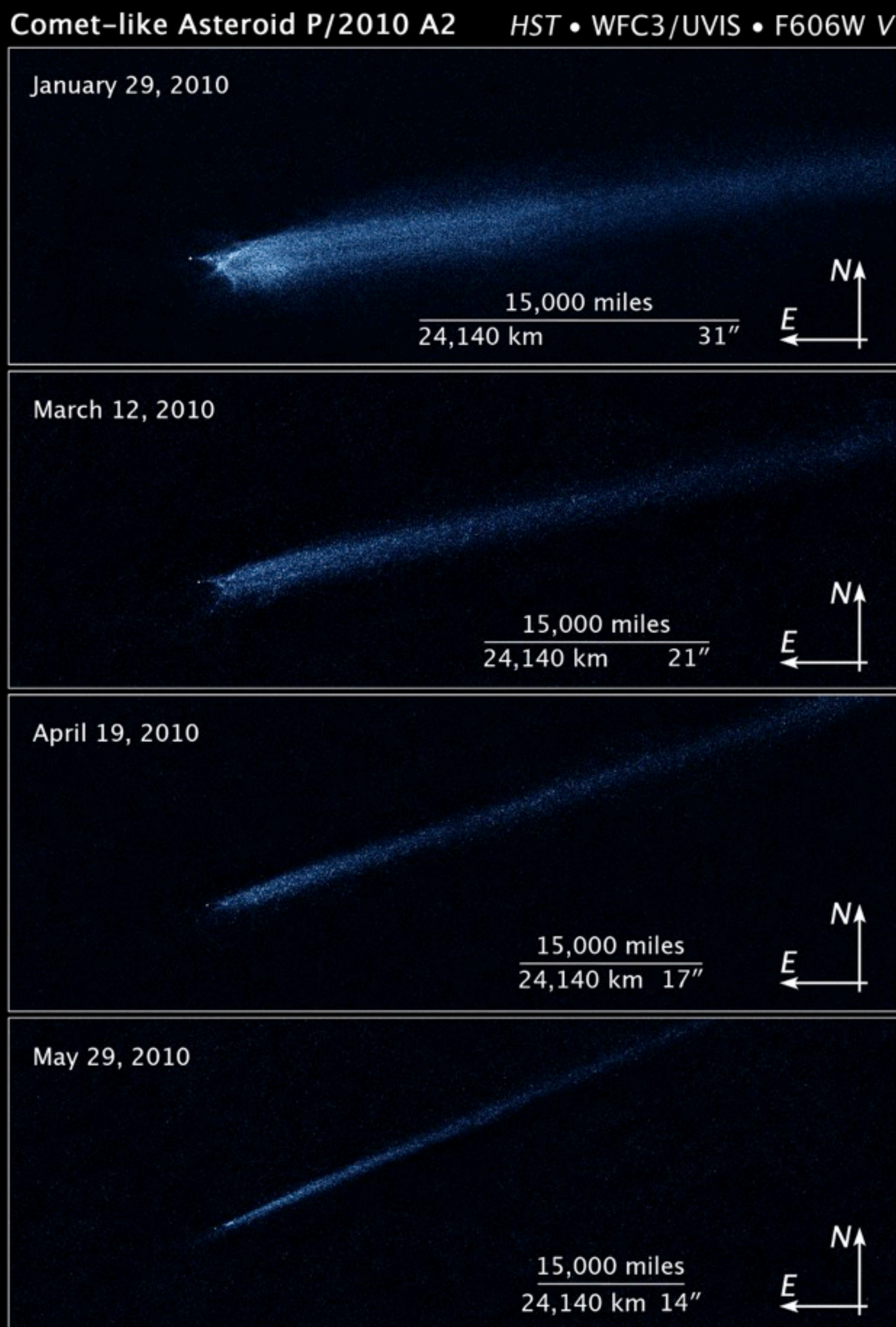
- *Anisotropic ejection within a solid cone-shaped jet*
- *Dust ejection point is a free parameter*
  (i.e., not fix on the largest fragment)



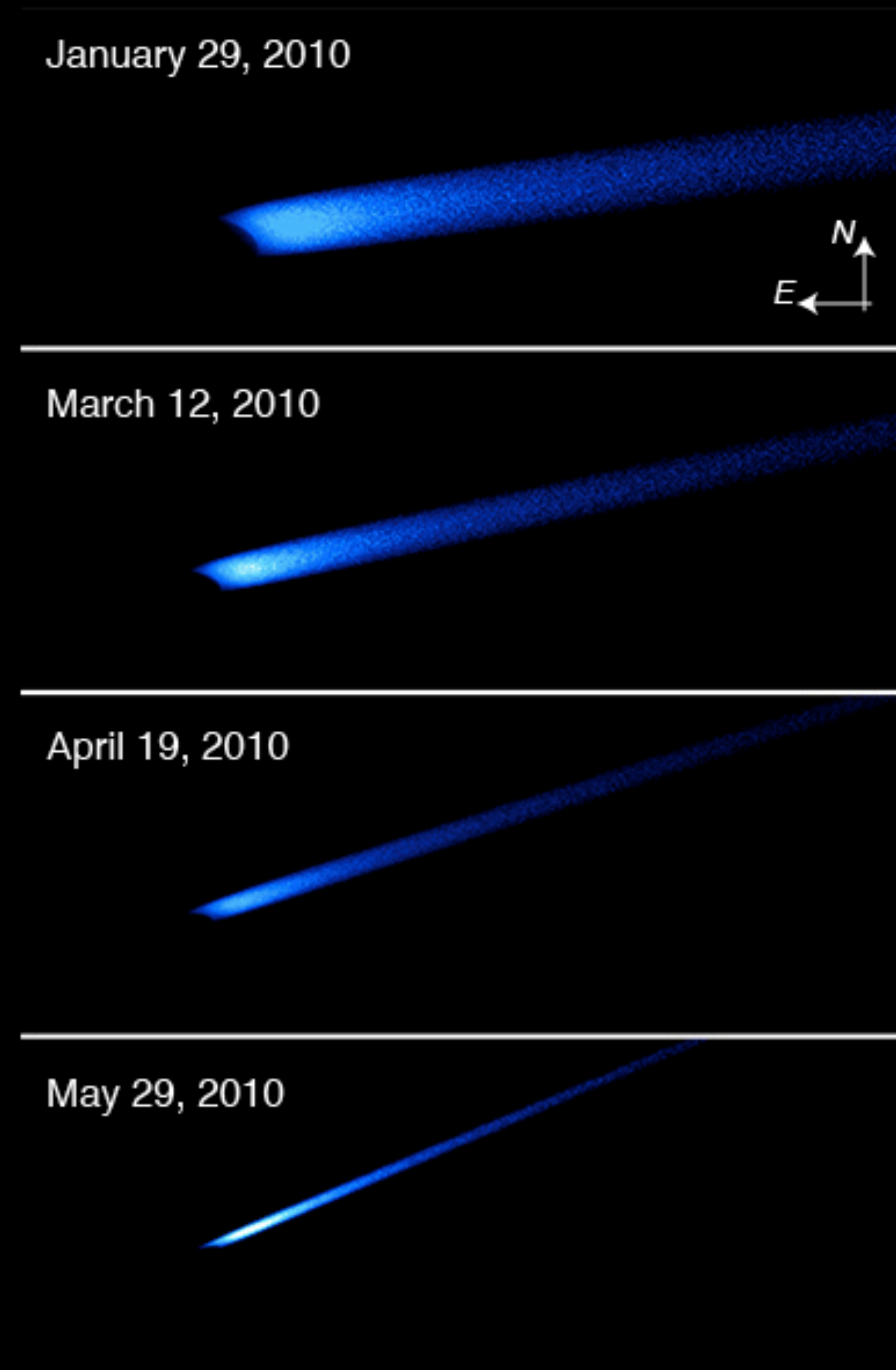


Parameter
u_1
q
β_{max}
β_{min}
V_0 (m s^{-1})
w (degree)
α_{jet} (degree)
δ_{jet} (degree)

Kim+2017a



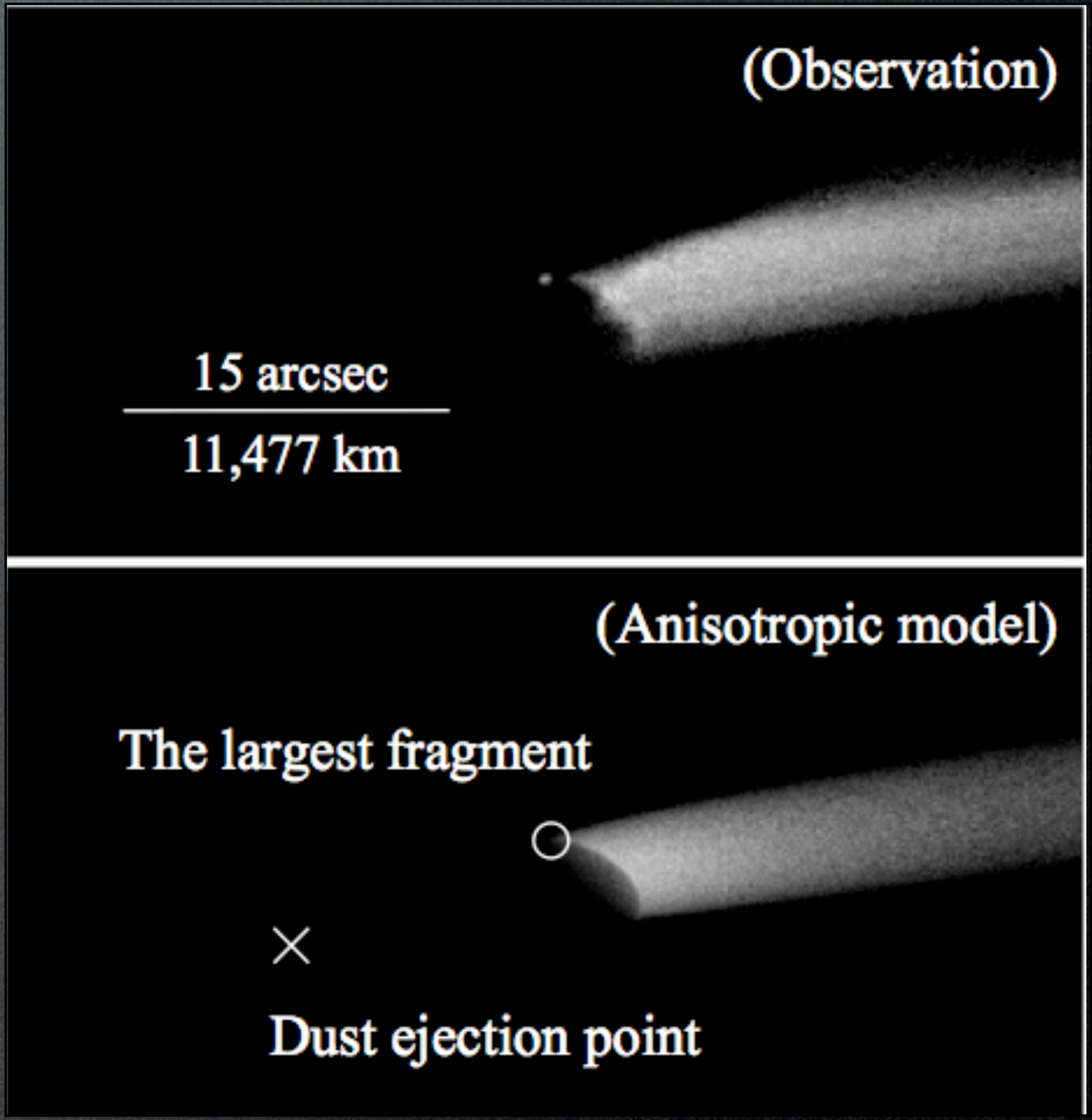
Jewitt+2010



Kim+2017

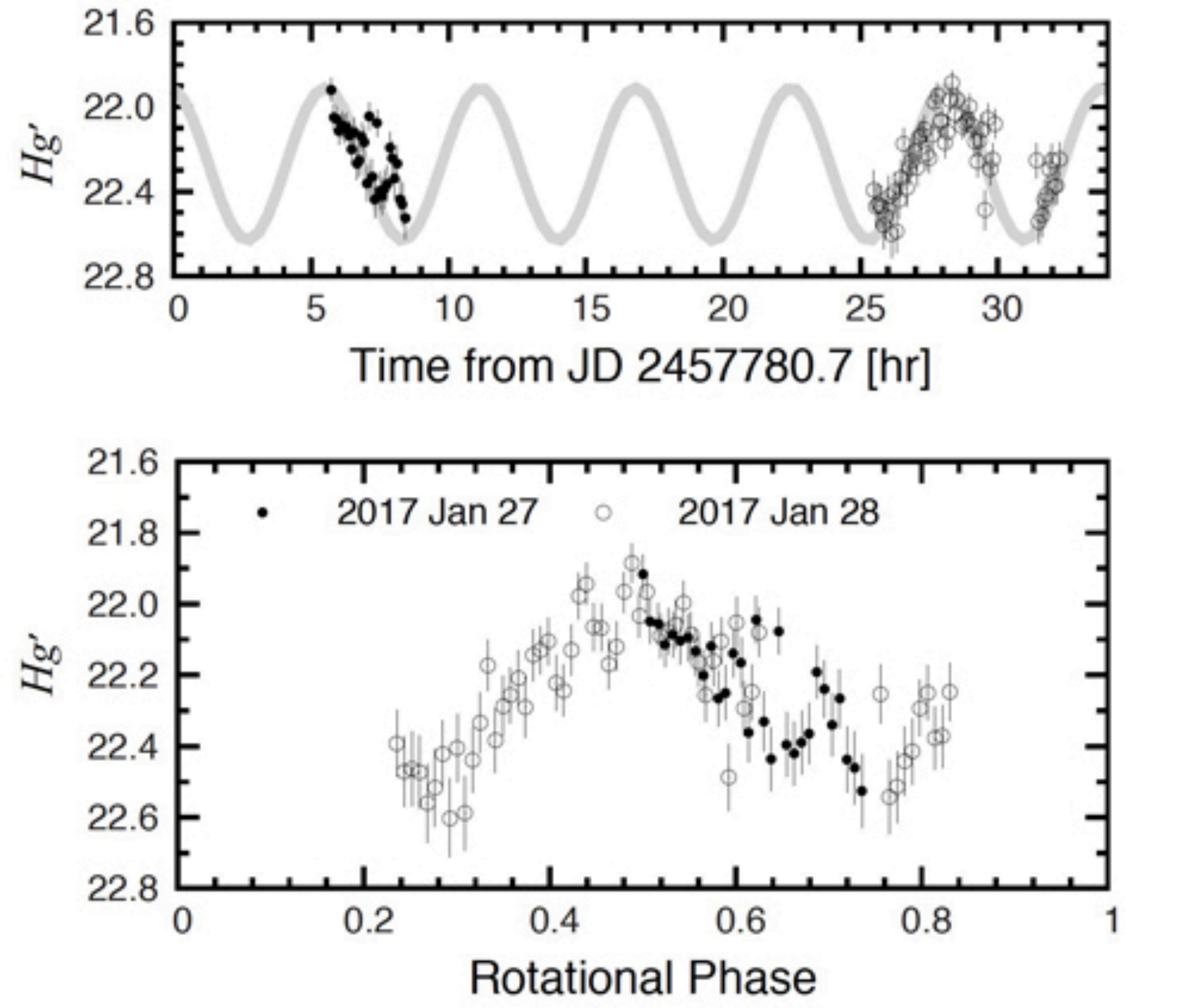
Result (1) Anisotropic ejection model

- No object had been detected at the dust ejection point (DEP) of our model in any observations.
- The ejecta momentum was not conserved on the DEP.
- The best-fit ejection speeds are ~0.3 m/s.
- The best-fit size distribution exponent (q = -2.5) is typical to impact fragments.



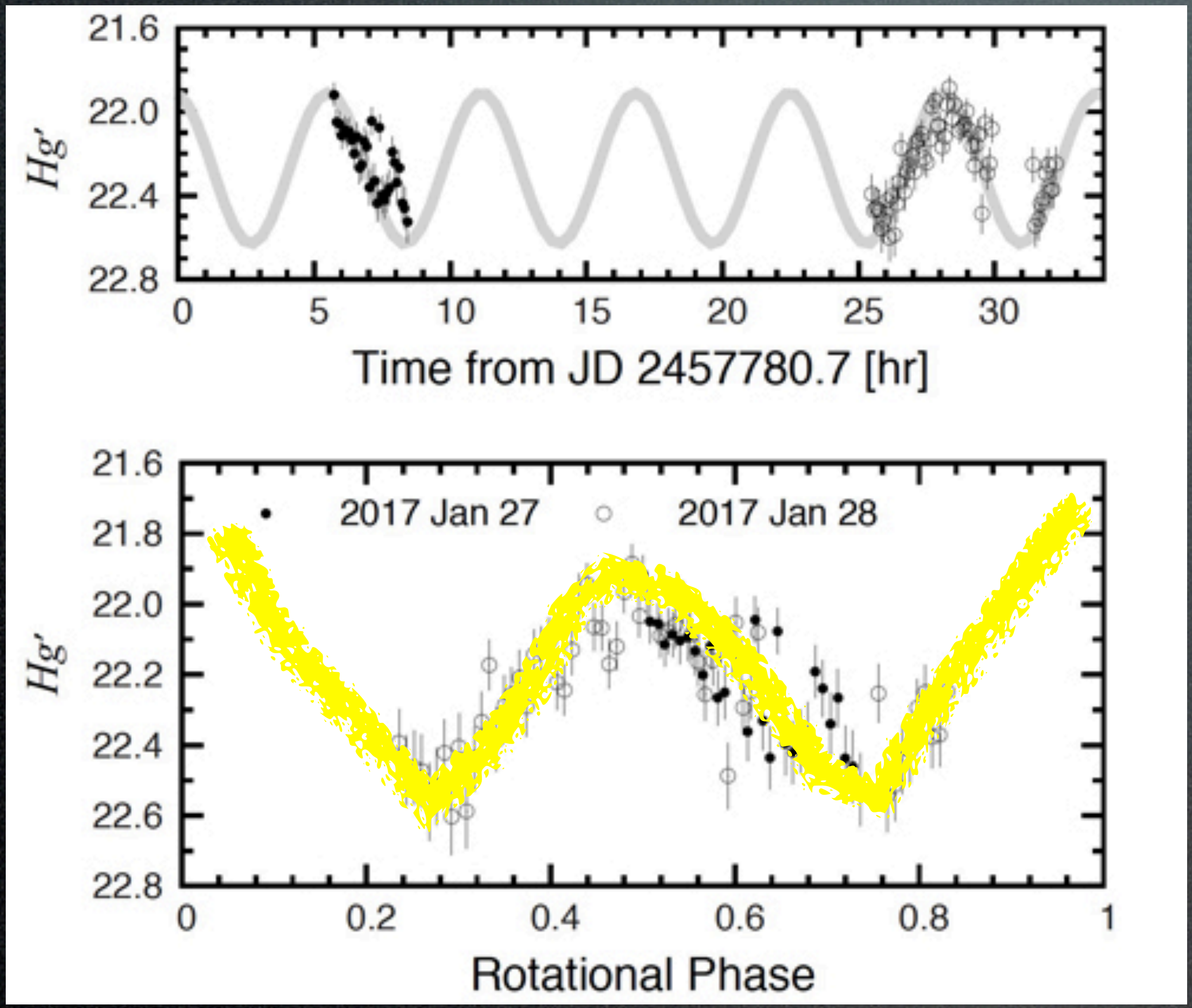
Kim+2017a

Result (2) Rotation, Shape, and Size of the Largest Fragment



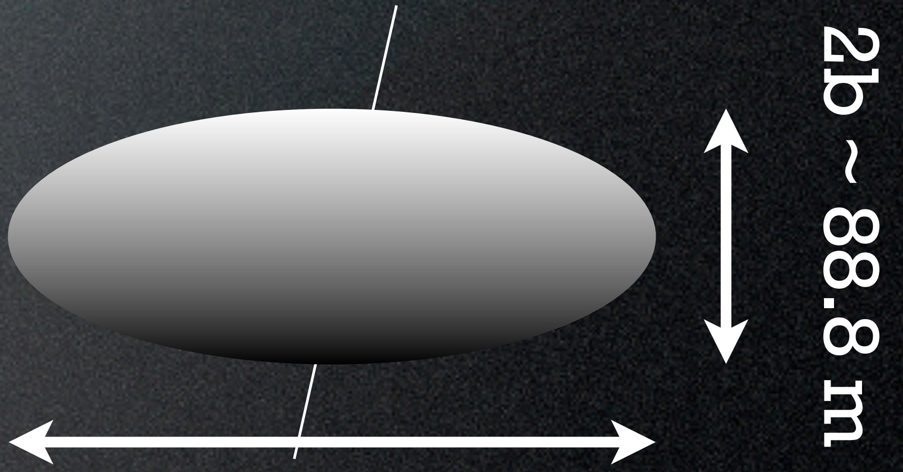
Kim+2017b

Result (2) Rotation, Shape, and Size of the Largest Fragment



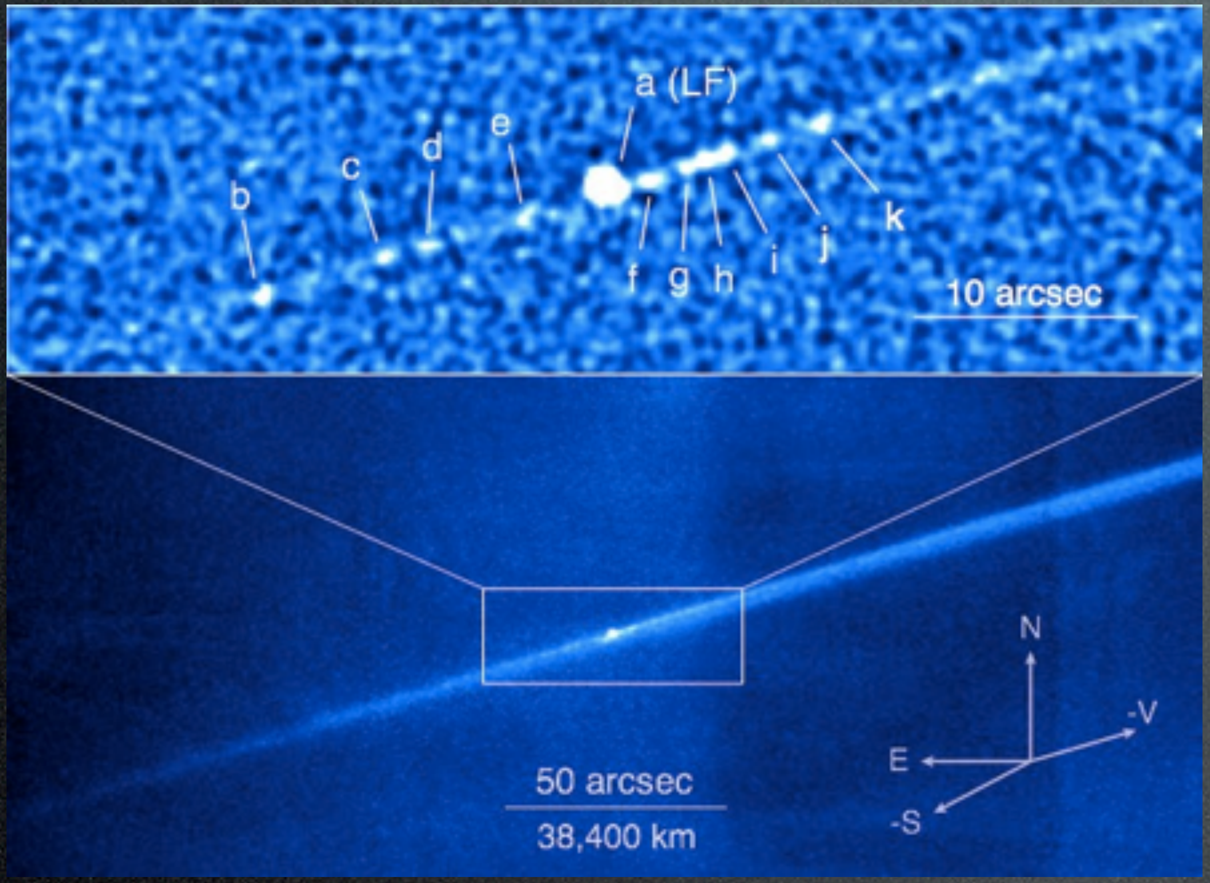
- Slow rotation (P_{rot} = 11.36 ± 0.02 hr)

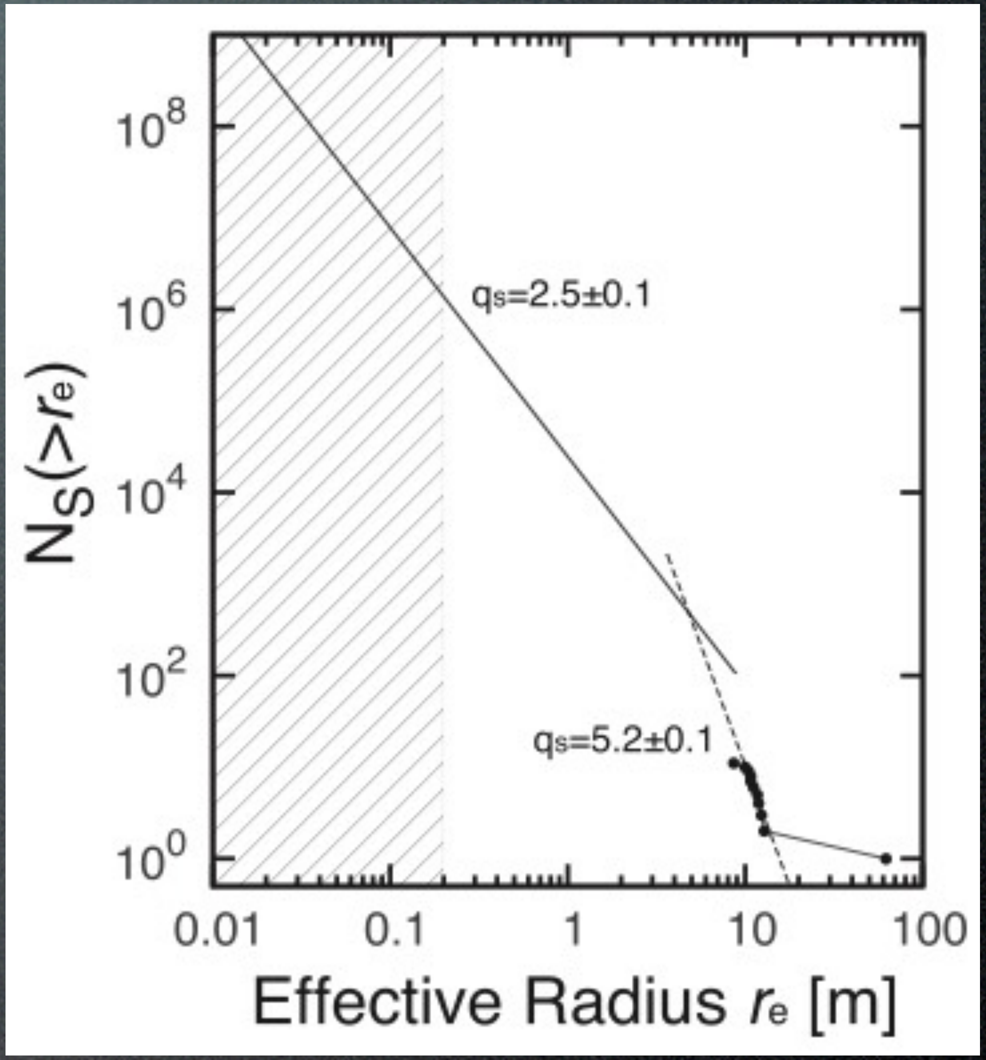
- Highly elongated object (a/b > 1.94)



Kim+2017b

Result (3) Size Distribution of the Fragments





The size distribution of the fragments is very steep

(q = -5.2)

Discussion (1) Ejection Mechanism

- We find that
  - absence of the central body at the DEP
  - non-conservation of momentum
  - slow rotation (11.36 hr)
- We conclude that 354P/2010 A2 is resulting from a catastrophic disruption.

Discussion (2) Comparison to Laboratory Experiments

We compared our results to the laboratory impact experiments.

Laboratory experiments:
Impacts on sub-kilometer sized, porous and low static strength asteroid enable a catastrophic disruption with a small specific energy of $Q^{*} \lesssim 350$ J/kg, resulting in low ejection velocities down to $\ll 1$ m/s.

Our results are consistent with those obtained through laboratory impact experiments.

Summary

- We performed observations and dust modeling analysis of 354P/2010 A2 to diagnose the mass loss mechanism.
- We conclude that 354P/2010 A2 is resulting from a catastrophic disruption.
- Our results are consistent with those obtained through laboratory impact experiments.

Concluding Remark

- We produced a detailed picture of the impacts in the Solar System,
- which have modified the primordial distribution of small bodies to create the present objects.
- Improving our understanding of evolutionary processes of small bodies,
- we ultimately aim to study early Solar System from small bodies.