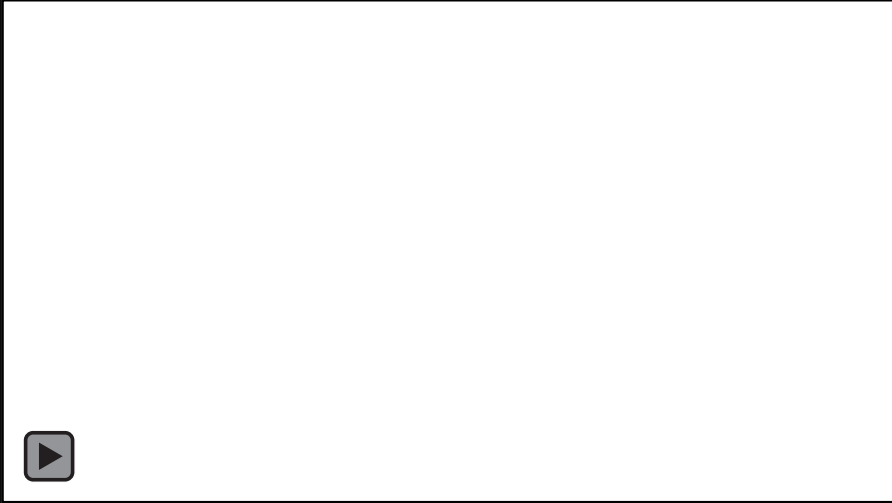
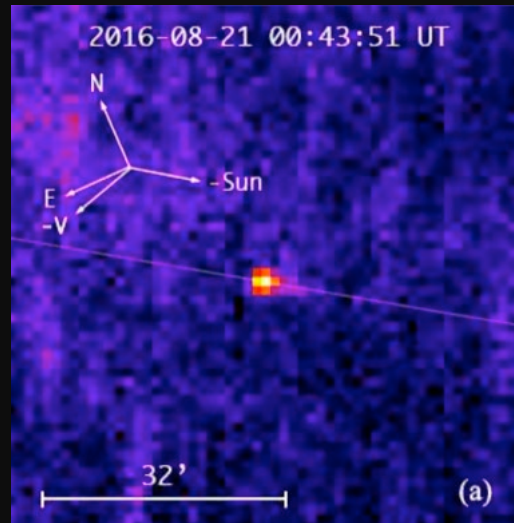


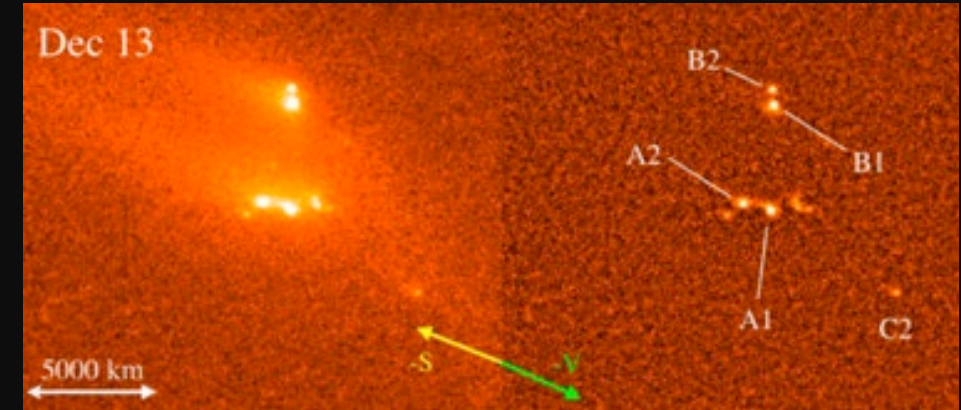
Discussion: What is an Active Asteroid?



300163/288P ESA/NASA HST, Agarwal et al. 2017



3200 Phaethon, Hui & Li, 2016



P/2013 R3, Jewitt et al. 2014

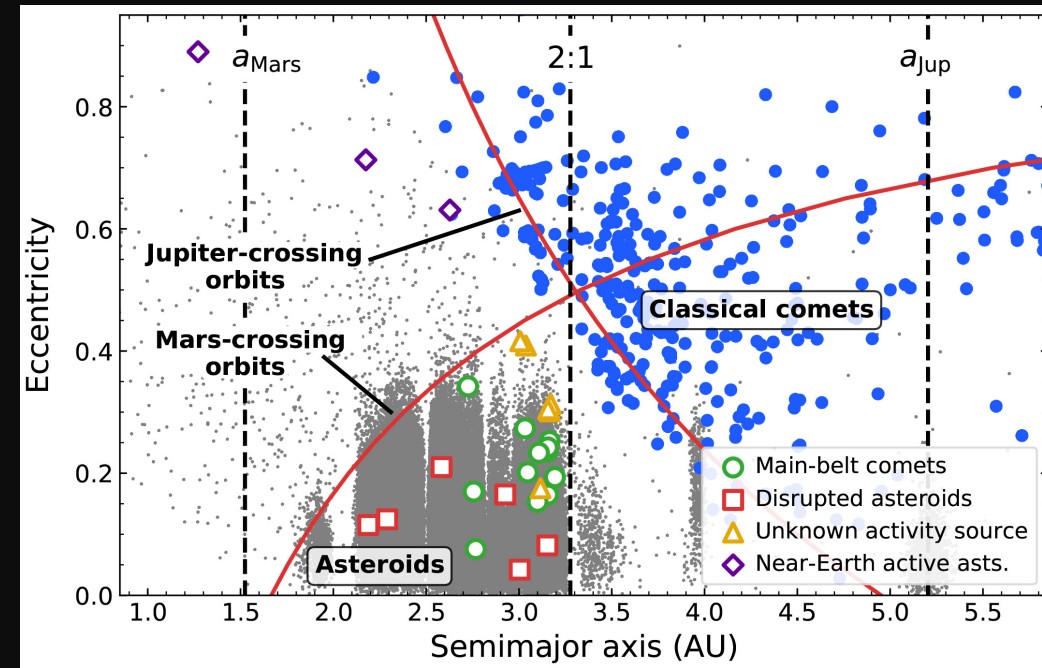
Gerbs (James) Bauer (UMD)

Jessica Sunshine (UMD), Henry Hsieh (PSI), Tim Swindle (LPI, UofA)

Some Active Asteroid Milestones

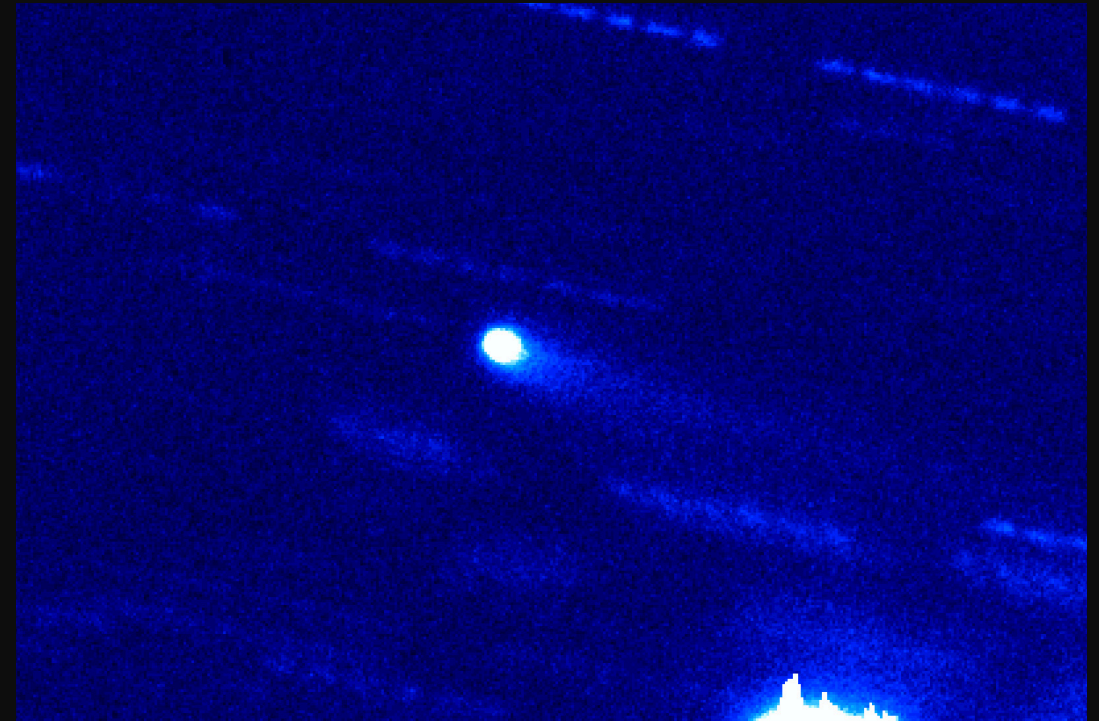
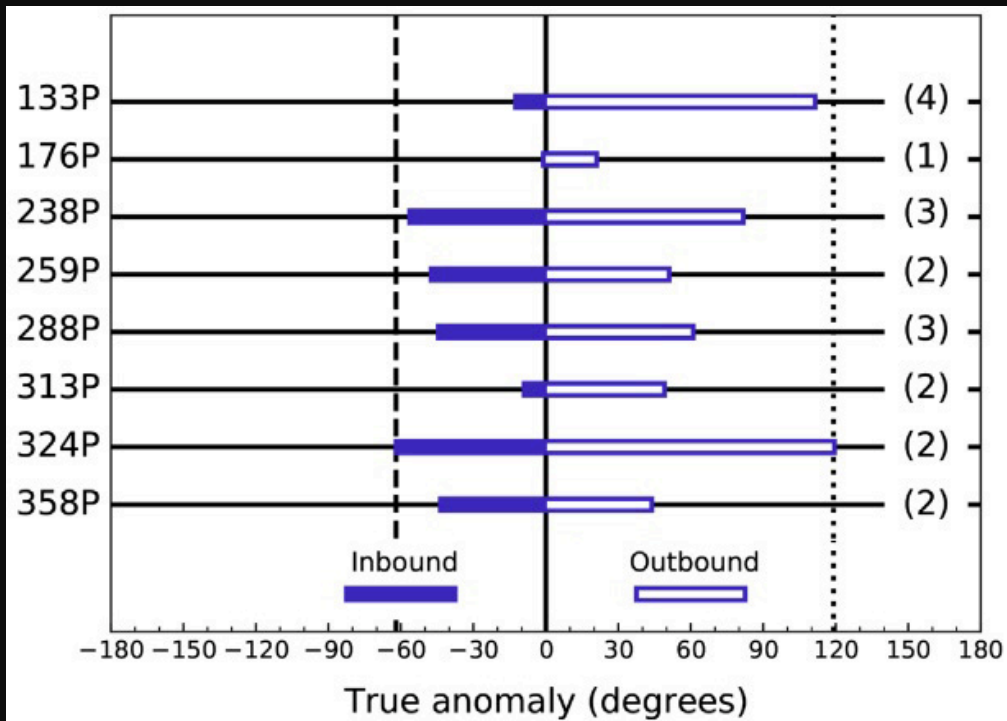
- July 1996: 133P/ Elst-Pizzaro discovered, active?
- 1999/2000 133P activity recurrent
- 176P/ LINEAR – Now a class of objects
- P/2010 A2 – A Disrupting/Impacted asteroid?
- Schiela – an impacted active asteroid
- P/2012 F5 & P/2013 R3 – Disrupting
- Bennu?

Multiple possible drivers for activity



Active Asteroids – Sublimation (Main-Belt Comets)

- Repeated periodic dust production near perihelion
→ Suggests sublimation, but not detected yet (probably very weak)
→ Maybe water, *but probably not other volatiles*



Hsieh & Jewitt (2006); Hsieh et al. (2008, 2018)

Reminder - Cometary Volatiles: Far More than Water

- Highly volatile compounds (mass spec)
 - Formation temperatures $<30\text{K}$
 - CO_2 , CO , CH_4 , complex hydrocarbons, glycine, N_2 , O_2 , Ar, K, Xe

Altwegg+16

→ THE COMETARY ZOO: GASES DETECTED BY ROSETTA

THE LONG CARBON CHAINS

Methane
Ethane
Propane
Butane
Pentane
Hexane
Heptane

THE AROMATIC RING COMPOUNDS

Benzene
Toluene
Xylene
Benzoic acid
Naphthalene

THE KING OF THE ZOO

Glycine (amino acid)

THE "MANURE SMELL" MOLECULES

Ammonia
Methylamine
Ethylamine

THE "POISONOUS" MOLECULES

Acetylene
Hydrogen cyanide
Acetonitrile
Formaldehyde

THE ALCOHOLS

Methanol
Ethanol
Propanol
Butanol
Pentanol

THE VOLATILES

Nitrogen
Oxygen
Hydrogen peroxide
Carbon monoxide
Carbon dioxide

THE "SMELLY" MOLECULES

Hydrogensulphide
Carbonylsulphide
Sulphur monoxide
Sulphur dioxide
Carbon disulphide

THE "SMELLY AND COLOURFUL" MOLECULES

Sulphur
Disulphur
Trisulphur
Tetrasulphur
Methanethiol
Ethanethiol
Thioformaldehyde

THE TREASURES WITH A HARD CRUST

Sodium
Potassium
Silicon
Magnesium

THE "SALTY" BEASTS

Hydrogen fluoride
Hydrogen chloride
Hydrogen bromide
Phosphorus
Chloromethane

THE BEAUTIFUL AND SOLITARY

Argon
Krypton
Xenon

THE "EXOTIC" MOLECULES

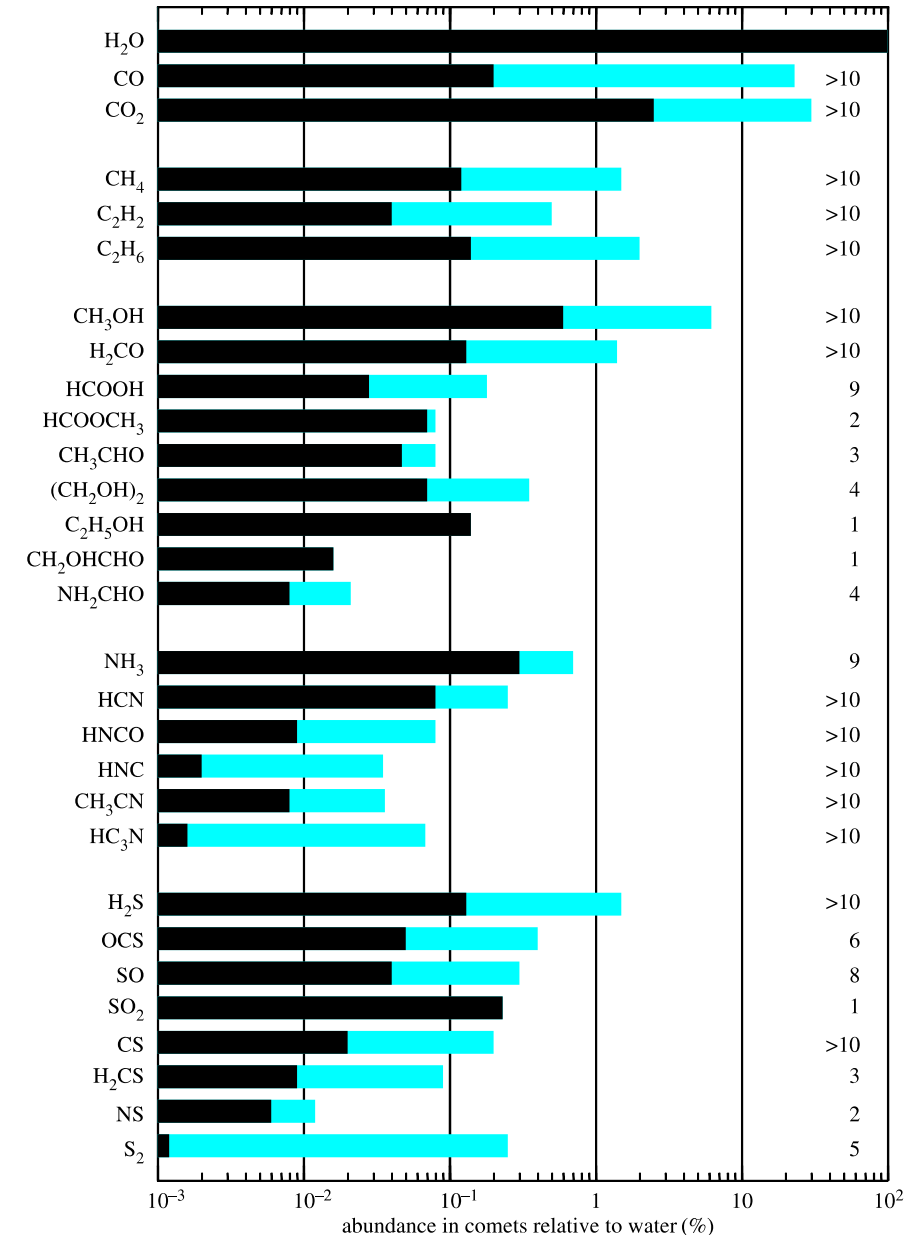
Formic acid
Acetic acid
Acetaldehyde
Ethylenglycol
Propylenglycol
Butanamide

THE MOLECULE IN DISGUISE

Cyanogen

• IR Remote Sensing

Bockelée-Morvan & Biver+17



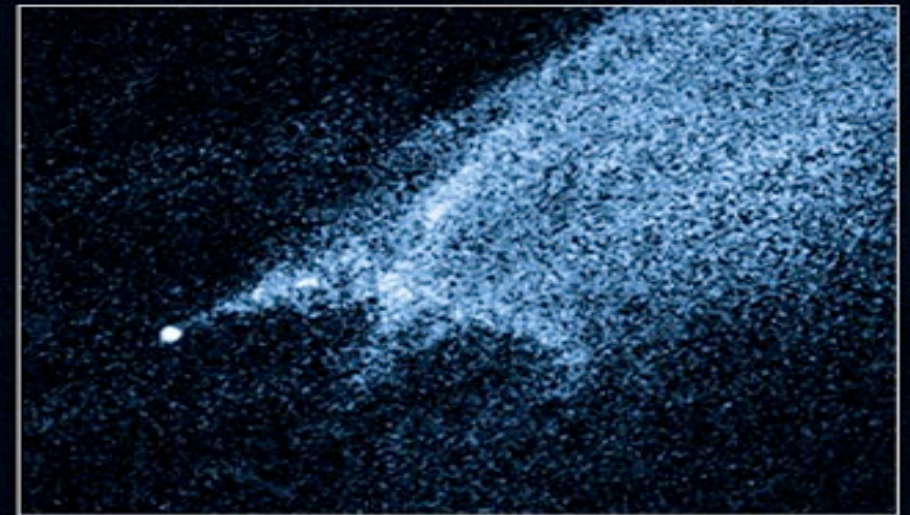
Active Asteroids – Impacts

Comet-like Asteroid P/2010 A2 • January 29, 2010

Hubble Space Telescope • WFC3/UVIS



Fine Dust under
Radiation Pressure



Active Asteroids – Rotational Disruption

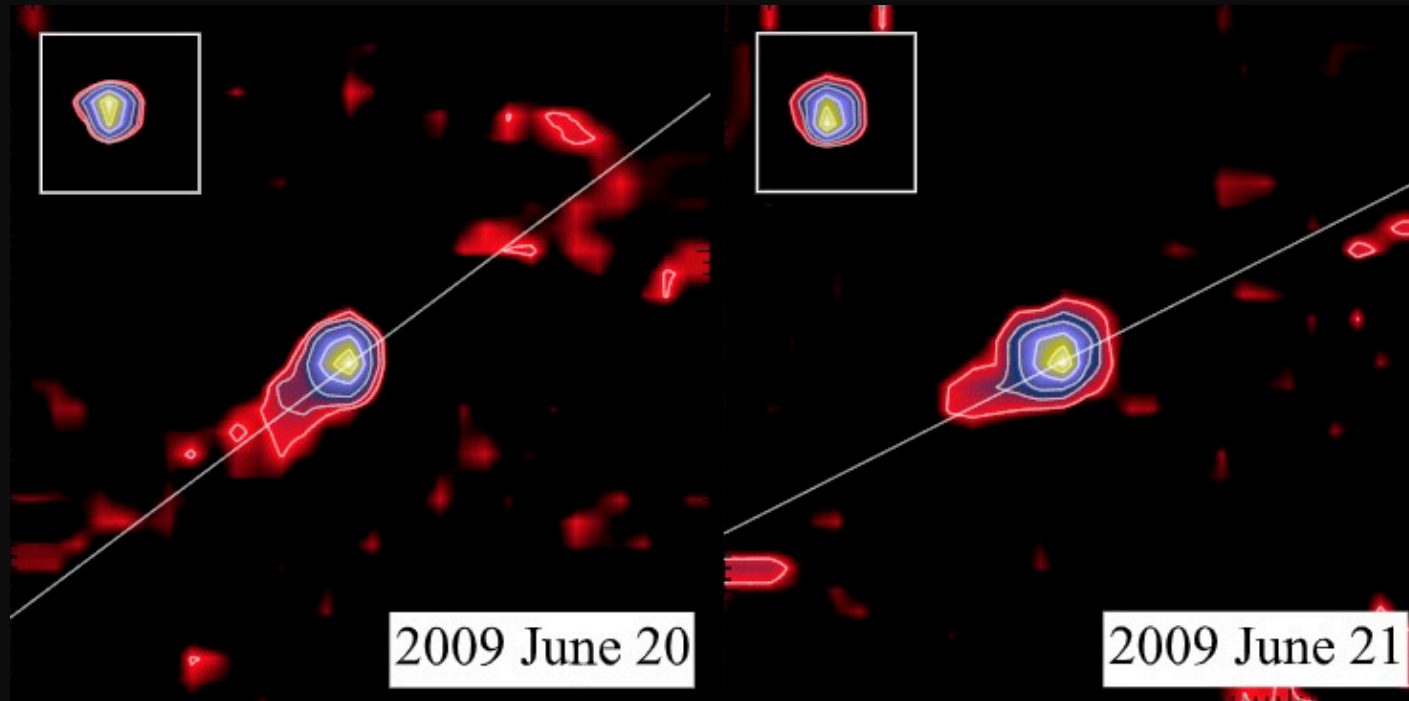
- e.g., (62412) 2000 SY178
 - Activity discovered by Sheppard & Trujillo (2015)
 - $P_{\text{rot}} = 3.33 \text{ hr}$
- Also P/2012 F5 and (6478) Gault



Gault

Active Asteroids – Thermal Fracturing

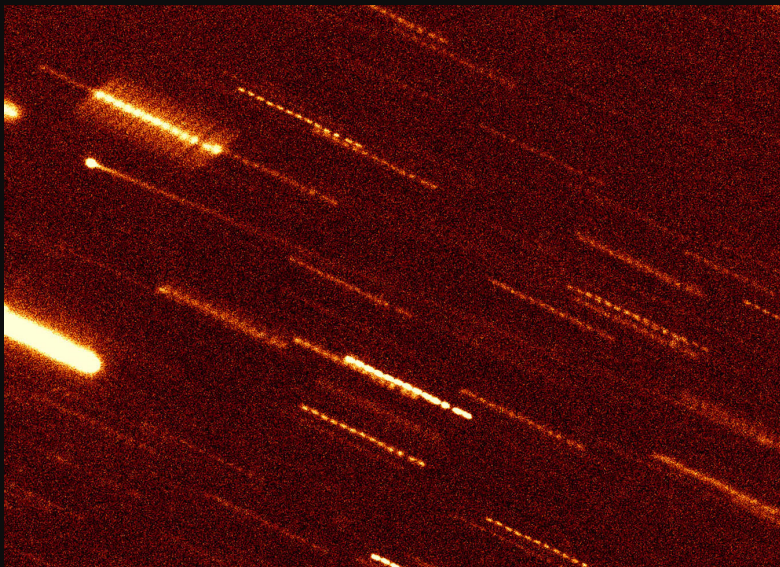
- Thermal fracturing/dessication for NEOs at high temperatures
- e.g., Phaethon ($q = 0.14$ au; $T \sim 1000\text{K}$)



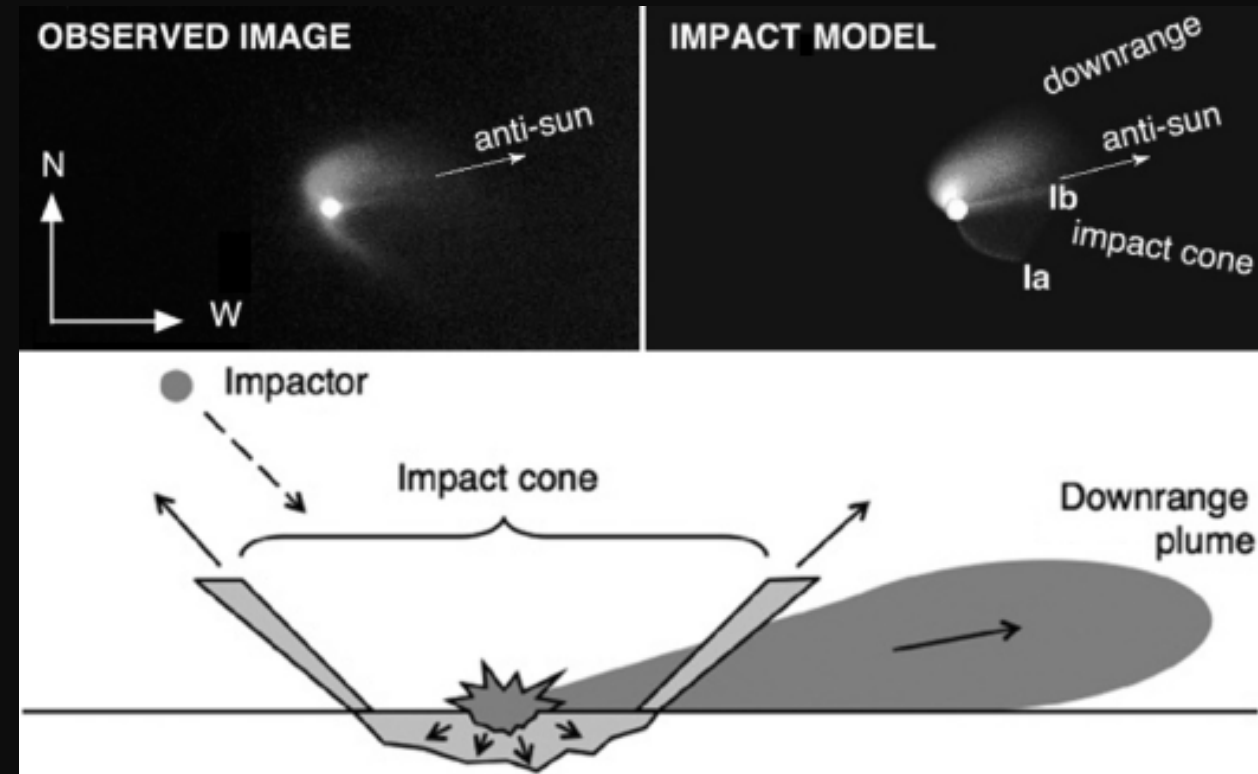
Jewitt et al. (2013)

Active Asteroids – Combinations of Mechanisms

- Multiple mechanisms could operate simultaneously
- e.g., Elst-Pizarro could be impact + rotation + sublimation
 - Impact as initial trigger
 - Recurrent activity = sublimation
 - $P_{\text{rot}} = 3.47 \text{ hr}$



- Asteroids (mainbelt) with extended sources
- Some dust from impact collisions
 - 596 Scheila plume Dec 2010 (Larson+10)



Active Asteroid Bennu?



- **Smaller-scale mass-shedding**
- **Not detectable from ground-based observatories**
- **Alternatively, Comet P/1999 RQ36 (LINEAR)?**

Some Active Asteroid Question Topics

Science Taxonomy:

- What do we consider “active” or “activity”?
- What are the dynamical boundaries?
- Sub-classes (MBCs, RAMBOs, ABCs, DAs, IAs, ANEAs/APHAs, SGAAs, etc.)?
- Where do they separate from “comets” (non-phenomenologically)?

Practical:

- What is the Hazard component?
- Should the ANEAs be included in NHATs?
- Are these a resource?
- If we include AAs in NHATs, do we include Comets (like P/2009 WX51 Catalina)?
- AA Bennu? P/1999 RQ36 (LINEAR)?