Transient phenomena and variations in comets, asteroids, centaurs and trans-Neptunian objects

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Planetary Science Institute

"The Eventful Universe", Tucson AZ, March 19, 2010

Focus of talk

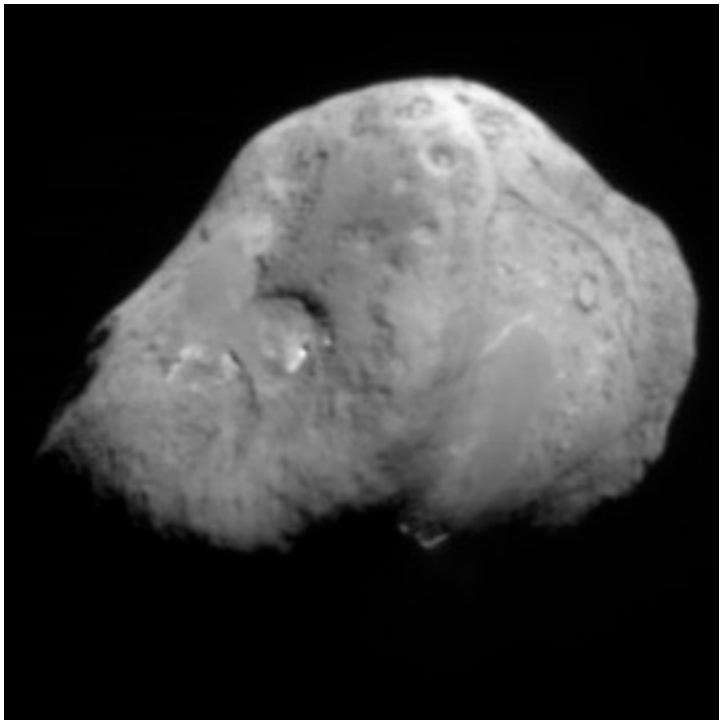
- **Restricted to *physical transient* phenomena**
- **Variations: mostly lightcurves**

Some Reminders

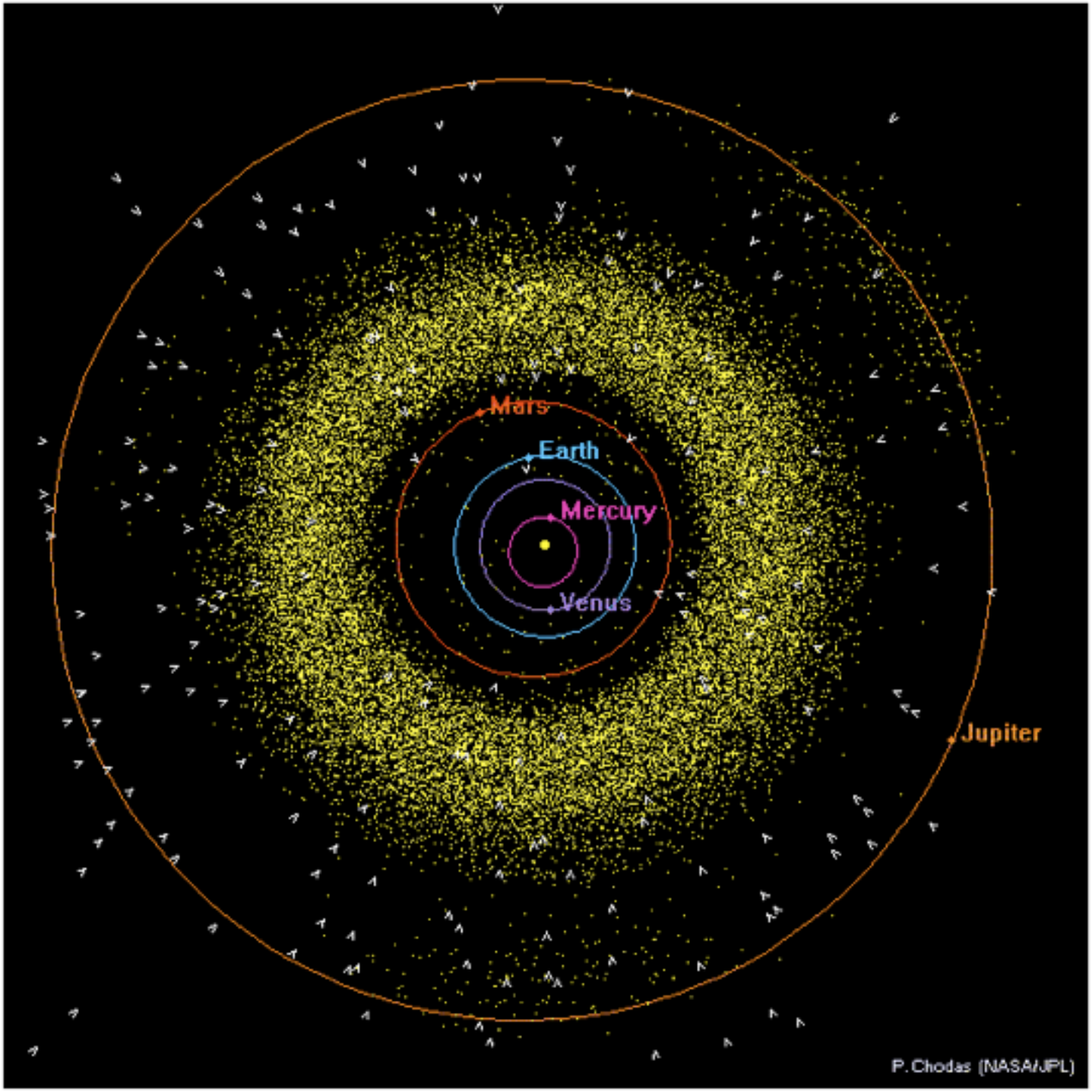
- **Small solar system objects are different: they move wsrpt to stars, the Sun, and the Earth.**
- **Visible only due to reflected light or scattered light and fluorescence (comets)**

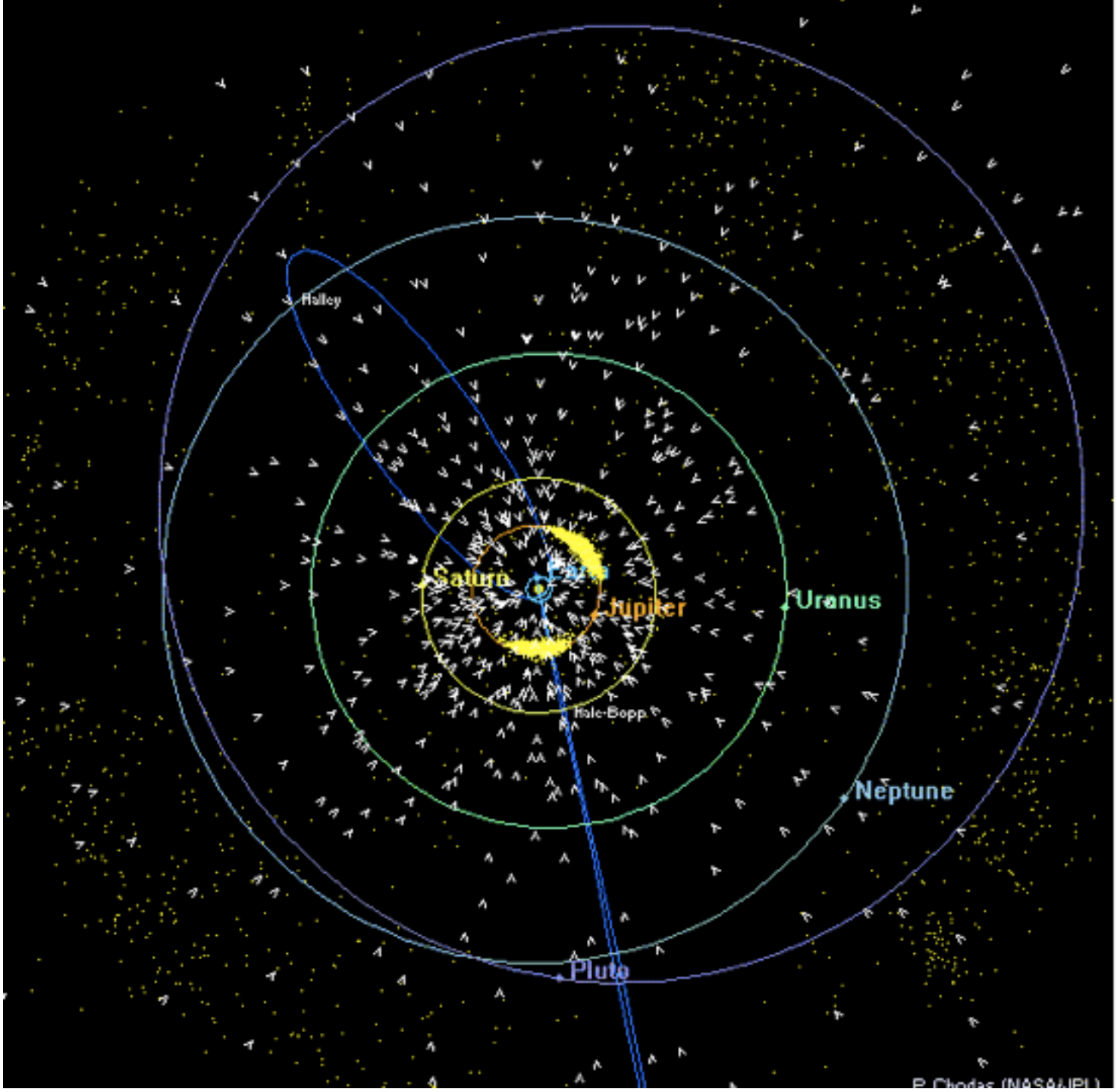
Some Definitions

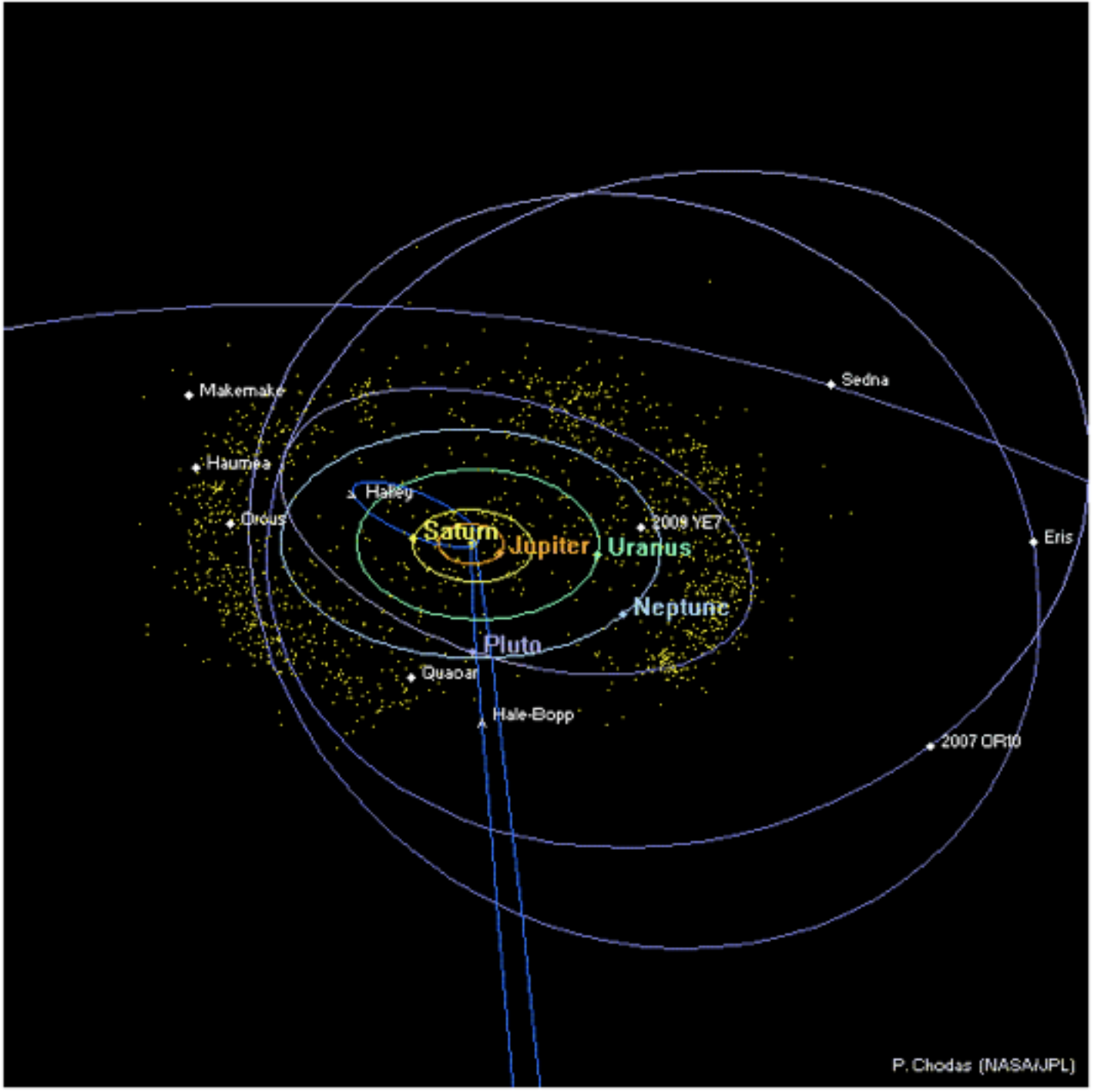
- **Comets: objects with elliptical (periodic) or hyperbolic orbits around the sun. Need to show activity somewhere in their orbit**
- **Asteroids: objects in the solar system that do not show activity. These objects are further distinguished dynamically:**



- **Near-Earth objects (might contain dead comets) in Earth-crossing orbits (perihelia < 1.3 AU)**
- **Main belt asteroids (between Mars and Jupiter)**
- **Trojans around Jupiter, Neptune, and Mars (at respective Lagrange points)**
- **Centaurs, transient orbits with semi-major axis between 5.5 and 30.1 AU. Some show cometary activity**
- **Trans-Neptunian Objects: larger semi-major axis than Neptune**


Mars
Earth
Mercury
Venus
Jupiter
P. Chodas (NASA/JPL)

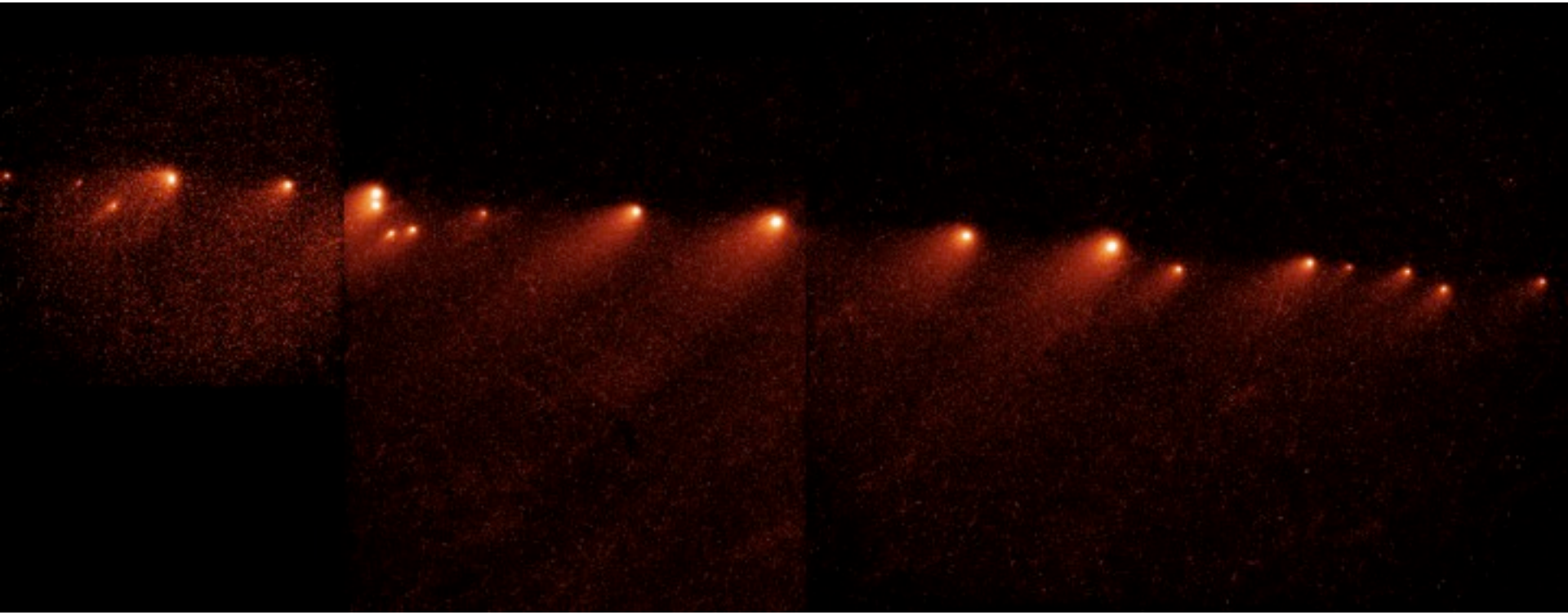

Halley
Saturn
Jupiter
Uranus
Hale-Bopp
Neptune
Pluto
P.Chodas (NASA/JPL)

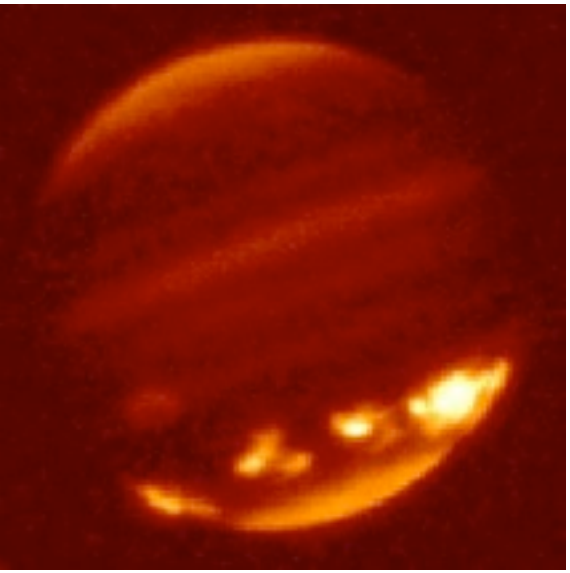

Sedna
Makemake
Haumea
Orcus
Halley
Saturn
Jupiter
Uranus
2009 YE7
Eris
Neptune
Pluto
Quaoar
Hale-Bopp
2007 OR10
P. Chodas (NASA/JPL)

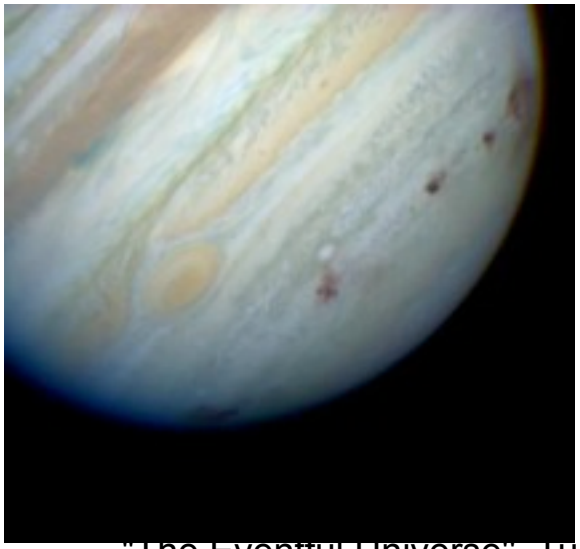
Calm and boring solar system?

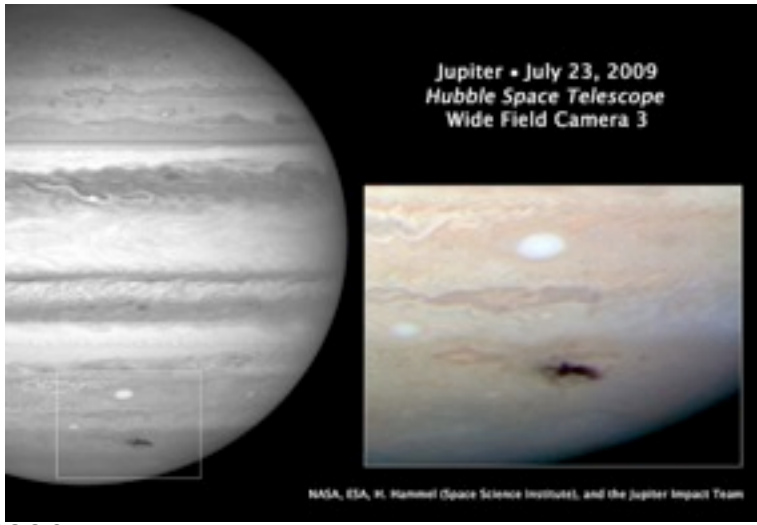
- **Solar system is dynamically pretty stable**
- **But there is still a lot going on!**

- **Example: Comet Shoemaker-Levy 9's impact into Jupiter in 1994. Once in a life-time event? 15 years later another impact into Jupiter!**









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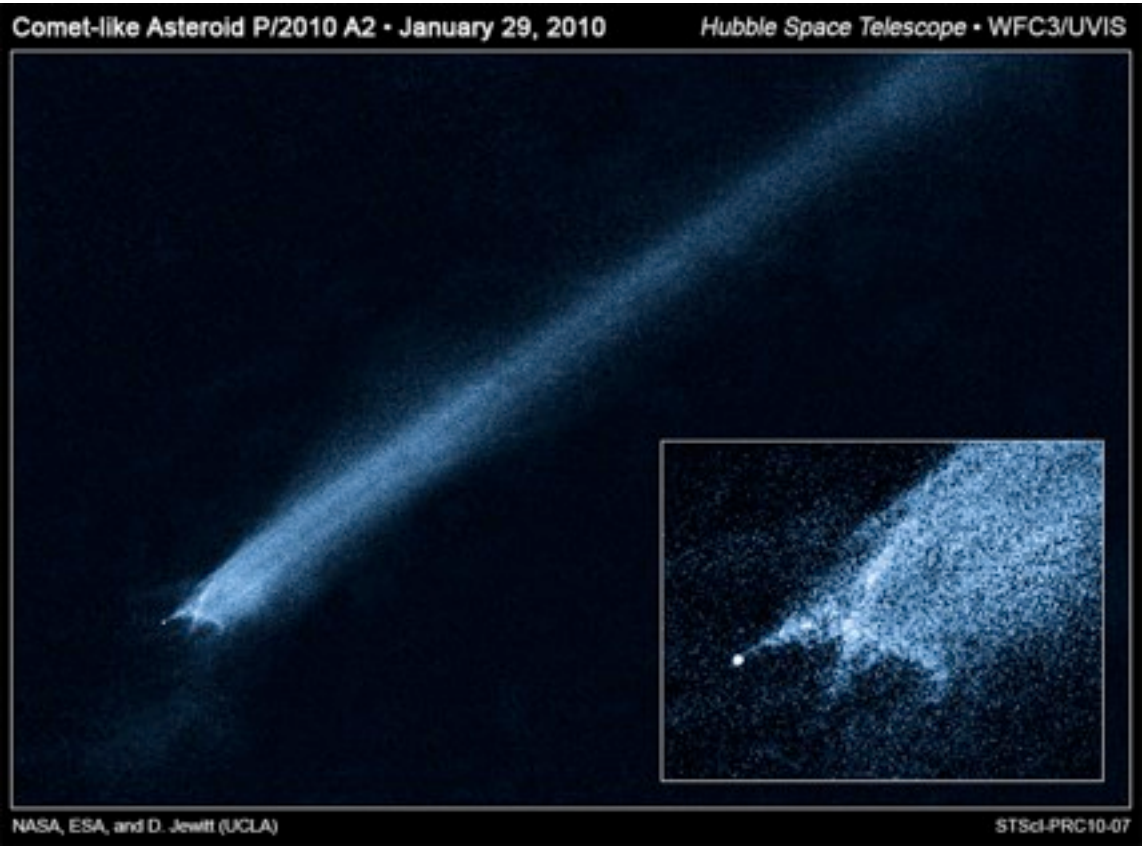
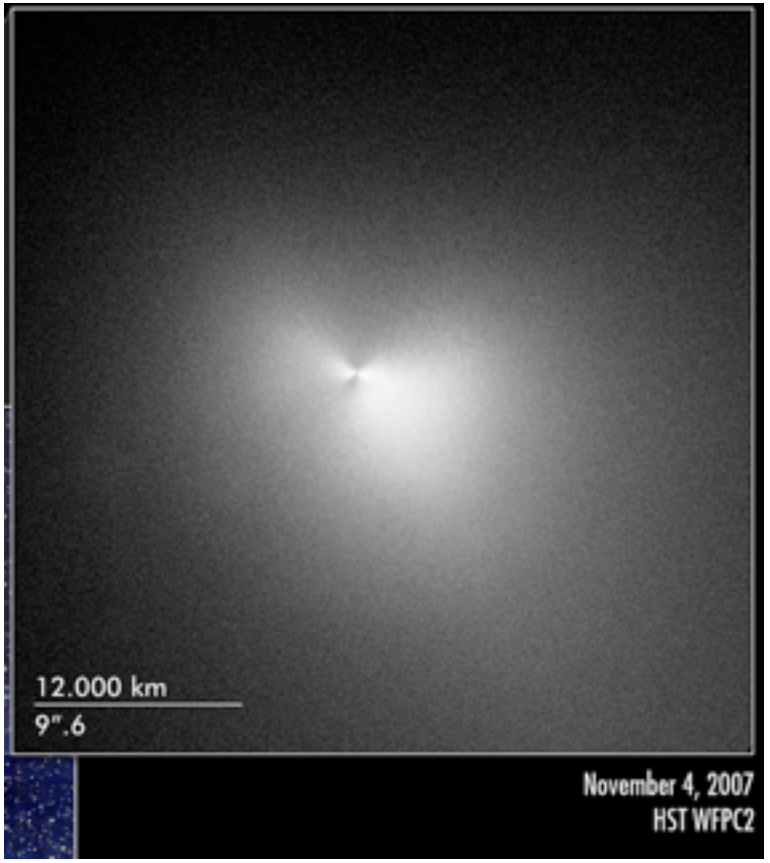
What happened here?

- **P/2010 A2 discovered by LINEAR Jan 6, 2010**
- **Small object about 150m in diameter in the main belt.**
- **Comet-like appearance but HST follow-up shows a very unusual pattern in the dust.**





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Possible explanations

- **It is a main-belt comet (it has a comet designation) --> does not look like any coma or tail we have seen in comets.**
- **It is an asteroid collision --> need detailed modeling of the dust pattern to confirm this**
- **It is an asteroid/(dead) comet break-up: spin-up due to YORP or jets past the break-up limit --> dust pattern should be very different from collision.**

More transient phenomena

- **Unexpected outburst in comets (**far from the sun e.g. Halley at 14 AU outbound), (immense increase in brightness in a short time, e.g. Holmes at about 2.5 AU, from mag 17 to about 3)
- **Turn-on points for comets and centaurs (brightening in magnitude, exhibiting non-stellar appearance)**
- **Catastrophic disintegration of comets (e.g. C/ 1999 S4 LINEAR)**
- **Intermittent activity in centaurs**
- **Intermittent activity in main-belt comets**

Why do we care?

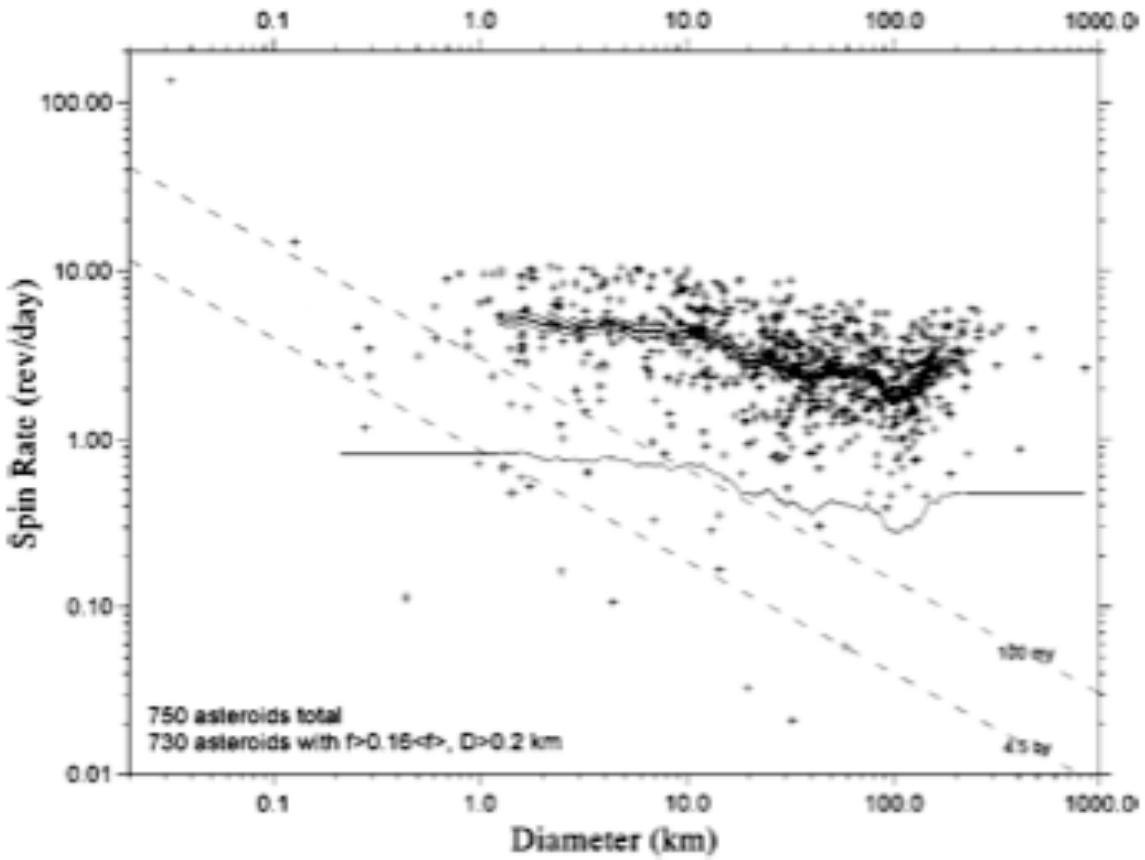
- **Interior structure**
- **Impact dynamics**
- **Evolution of small solar-system bodies**
- **Detailed understanding of solar system formation**
- **Death of comets/asteroids**
- **Frequency of transient phenomena**

Observations

- **Often serendipitous**
- **Dependent on limiting magnitude**
- **Unpredictable frequency**
- **Recognizable?**

Variations

- **Mostly rotation period**
- **Could also be due to albedo or color variations**
- **Why? Spin state is a basic parameter (often needed to explain other observations in comets)**
- **Distribution of spin states or rotation periods among and between the different solar system objects. --> Inference for internal structure, evolution of the objects.**
- **For comets: NPA paradox**
- **For comets: spin-up due to jet action (has been observed)**
- **For small asteroids spin-up due to YORP effect (has been observed)**



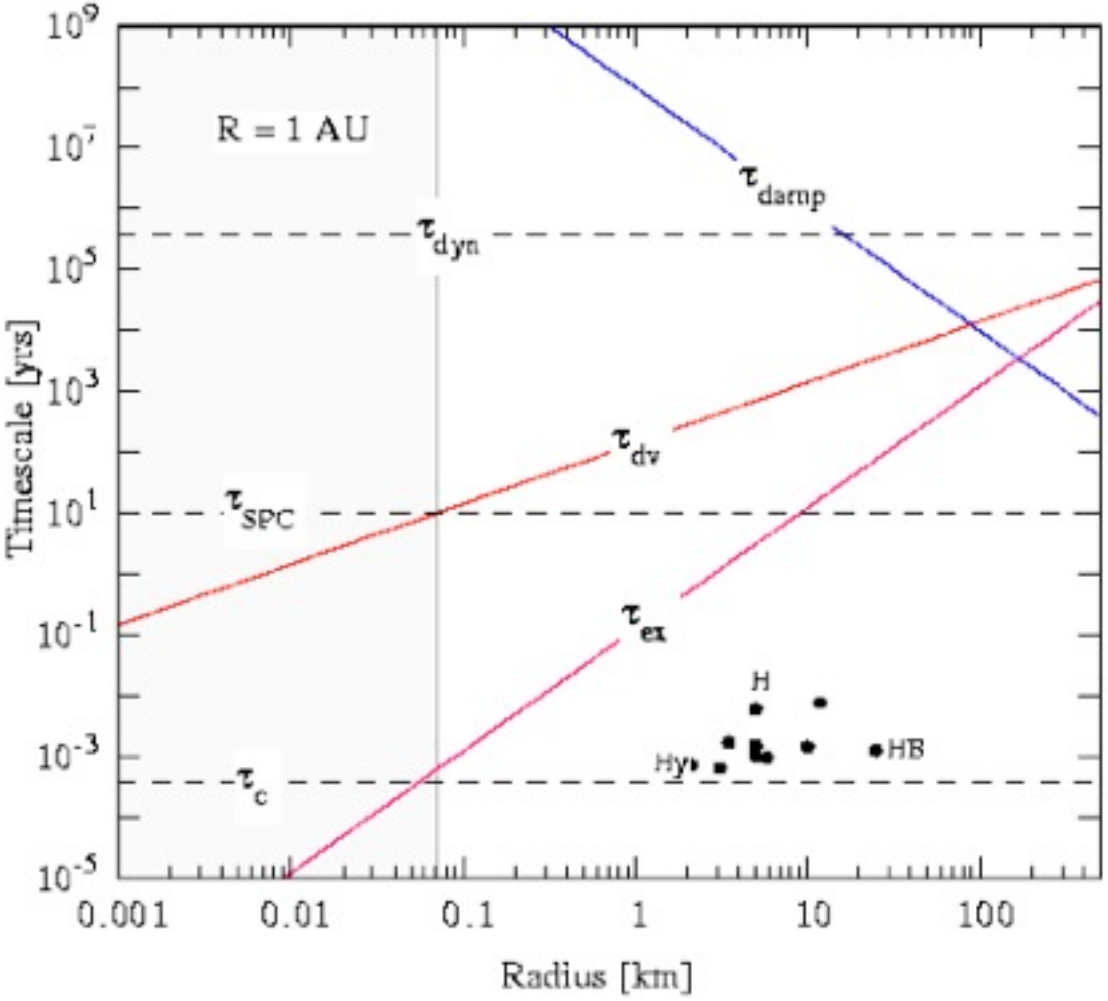
From Pravec and Harris 2000 (Icarus, 12-20)

Spin states of other objects

- **Periods of only about 25 comets known. Why? Comets are very faint (4% albedo) when far from the sun when inactive**
- **Need a lot more to populate the diagram as for asteroids.**
- **Spin states for TNOs even sparser. Only known for large TNOs. (Interesting object Haumea, fast rotator, cigar shaped).**

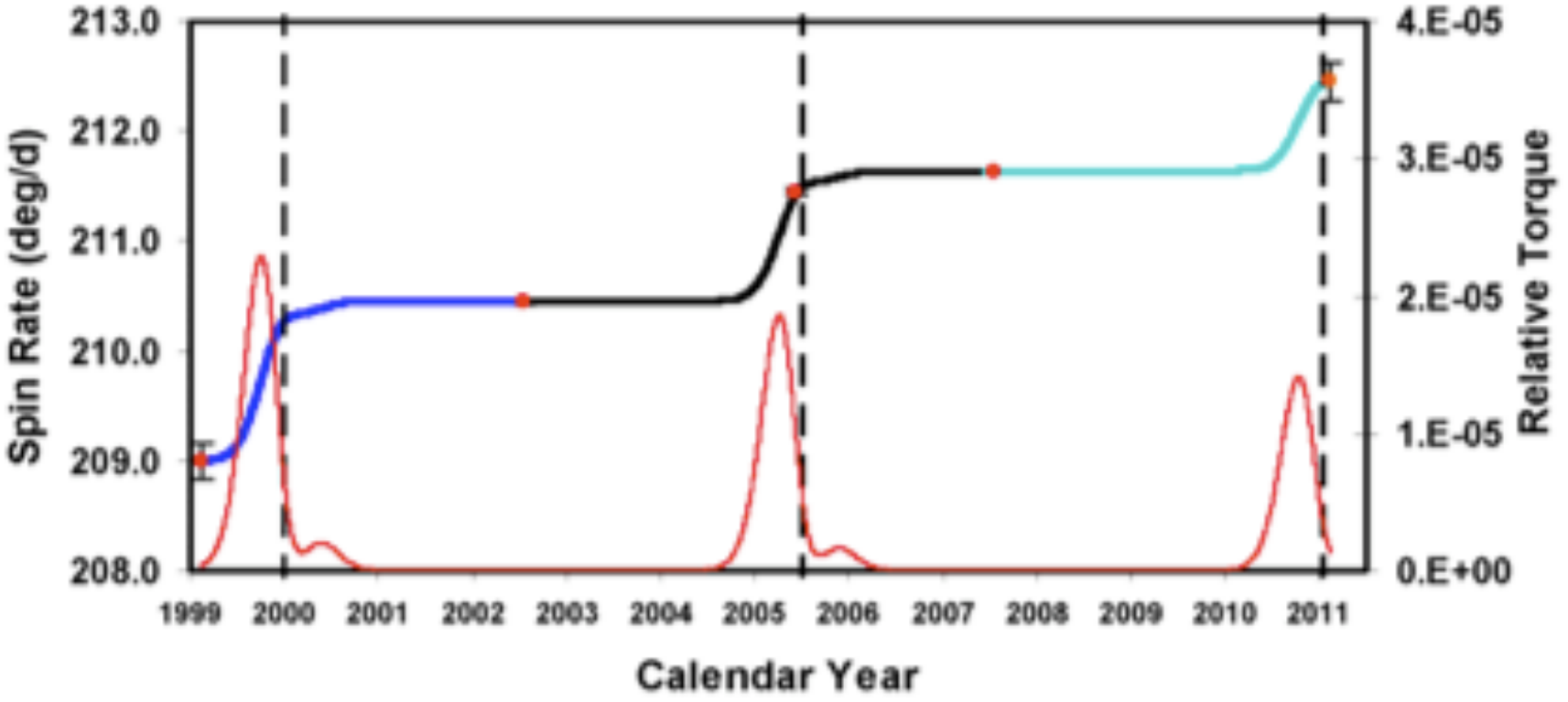
How are spin states acquired?

- **The old fashioned way: lightcurves covering several cycle of the entire rotation period at several different geometries ---> Laborious, time & telescope intensive.**
- **Some new methods: AO ---> less time intensive but needs large telescopes and objects.**



From Jewitt 1997 (EMP 79, 35-53)

Example: Spin Acceleration of Comet 9P/ Tempel 1



Observations needed

- **Surveys to get initial determinations of a rough rotation period. How easy and feasible is this?**
- **Surveys feasible for detailed studies like for comet Tempel 1?**
- **A lot of observations covering the entire rotation period over a long period of time. Combination of lightcurves over time need to take geometry into account.**