The September 1, 2007, Aurigid outburst

A remarkable shower of remarkable meteors

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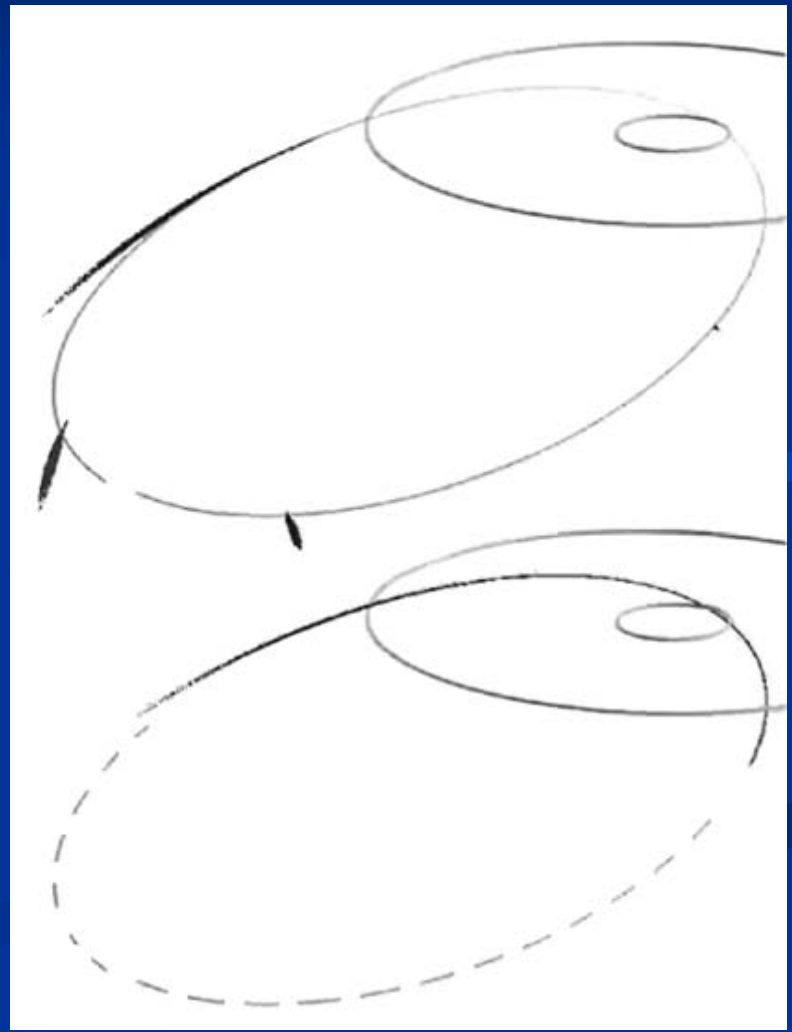
83 BC: A bit of history

- In Rome, Julius Ceasar (18 years old) is about to change his career...
  - In 83 BC, Ceasar and Cornelia Cinna is born a daughter Julia. His uncle Gaius Marius and father-in-law, consul Lucius Cinna, get embroiled in a conflict with former protegé Lucius Sulla, a general who becomes dictator in Nov. 82 BC (setting a precedent for later dictators). Ceasar loses his inheritance, his wife's dowry and his priesthood (*Flamen Dialis* - high priest of Jupiter). He refuses to divorce Cornelia and goes into hiding. Fortunately for Ceasar, his mother's family supported Sulla and saves his life. No longer a priest, Ceasar decides to pursue a military career. The rest is history ...

Coin honoring L. Sulla. 84 - 83 BC (with head of Venus).

83 BC: A comet

- 83 BC: In the sky is a faint comet that rounds the Sun and releases a cloud of dust particles…
  - First, the cloud moves along with the comet.
  - Then spreads into a trail when some particles make a wider orbit than others.
- The comet will not return until 1911.

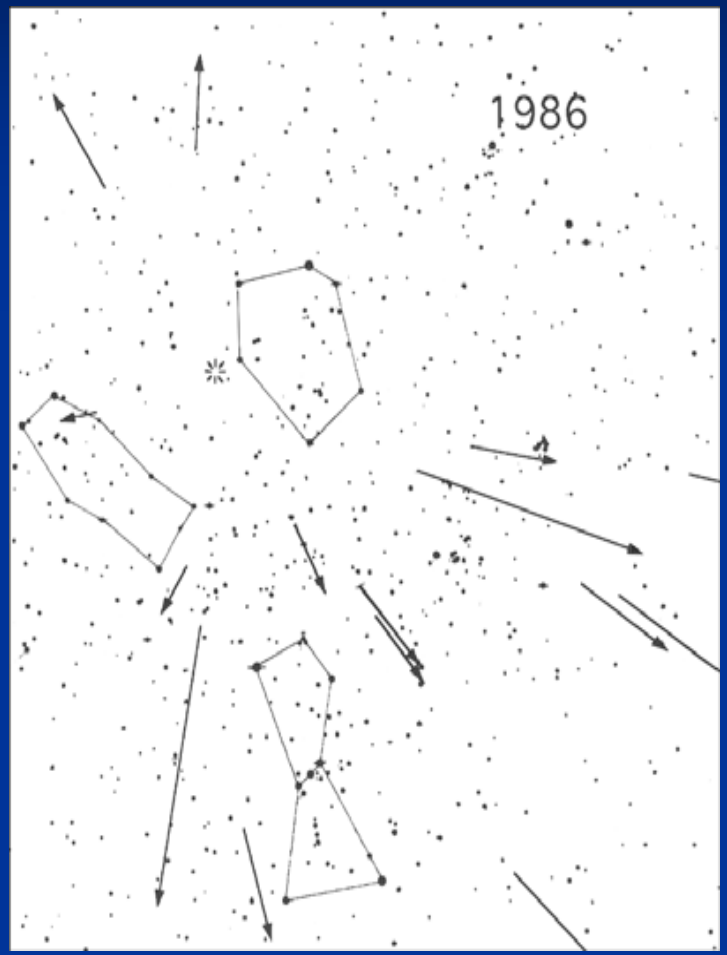


1911: The comet returns

- 1906: An earthquake destroys San Francisco.
- 1911: An aftershock damages *Lick Observatory*
  - One telescope is moved off its pier
  - A building has to be taken down
- 5 days later, post-doc *Carl Clarence Kiess* aims to find comet Encke, and discovers comet C/1911 N1 (Kiess)
  - Reached +7 magnitude with 0.5º tail

C/1911 N1 on Aug. 5, 1911

Following years: meteors!

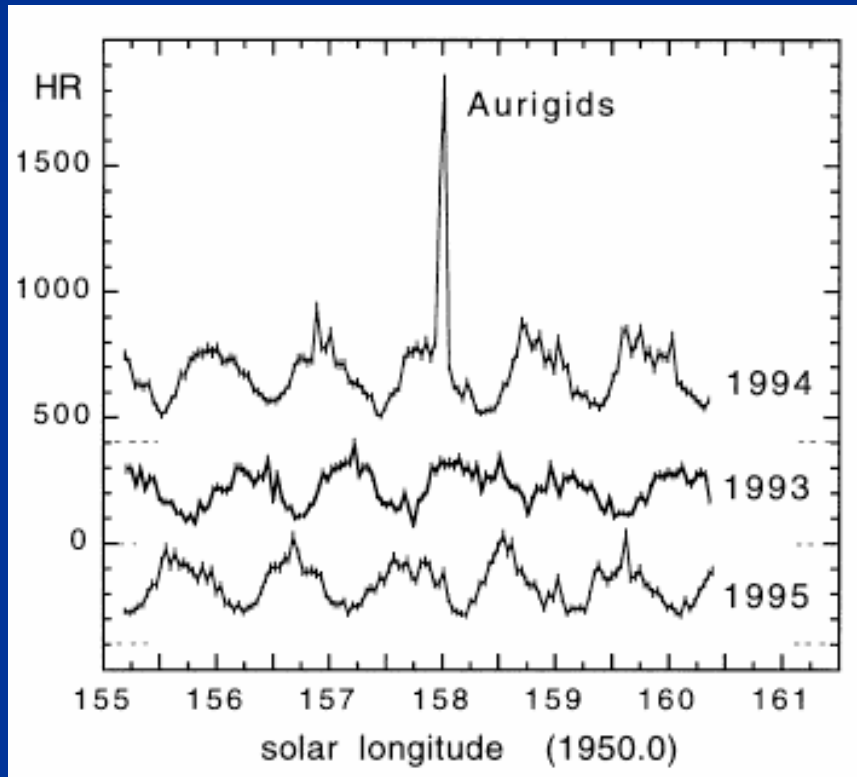


Drawing from plots by Istvan Tepliczky, M.M.E.T.H.

- In 1935, an outburst of Aurigids is observed at Potsdam and Prague.
- In 1986, another outburst is seen in Hungary.
  - Duration ~ 2 hours
  - Relatively bright meteors in narrow magnitude range
  - Tens of bright meteors
  - Radiate from the Kiess radiant

1994: Again!
No simple periodicity ?!

- Seen by Bob Lunsford and George Zay in southern California
  - Radiant close to horizon: grazing meteors
  - Many +1 and +0
- Confirmed by Radio MS (Ilkka Yrjola, Finland)
  - Rates very high in two 1-hour intervals

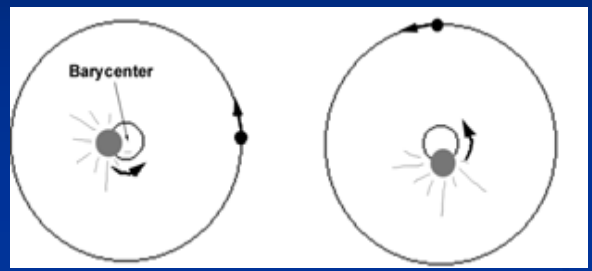


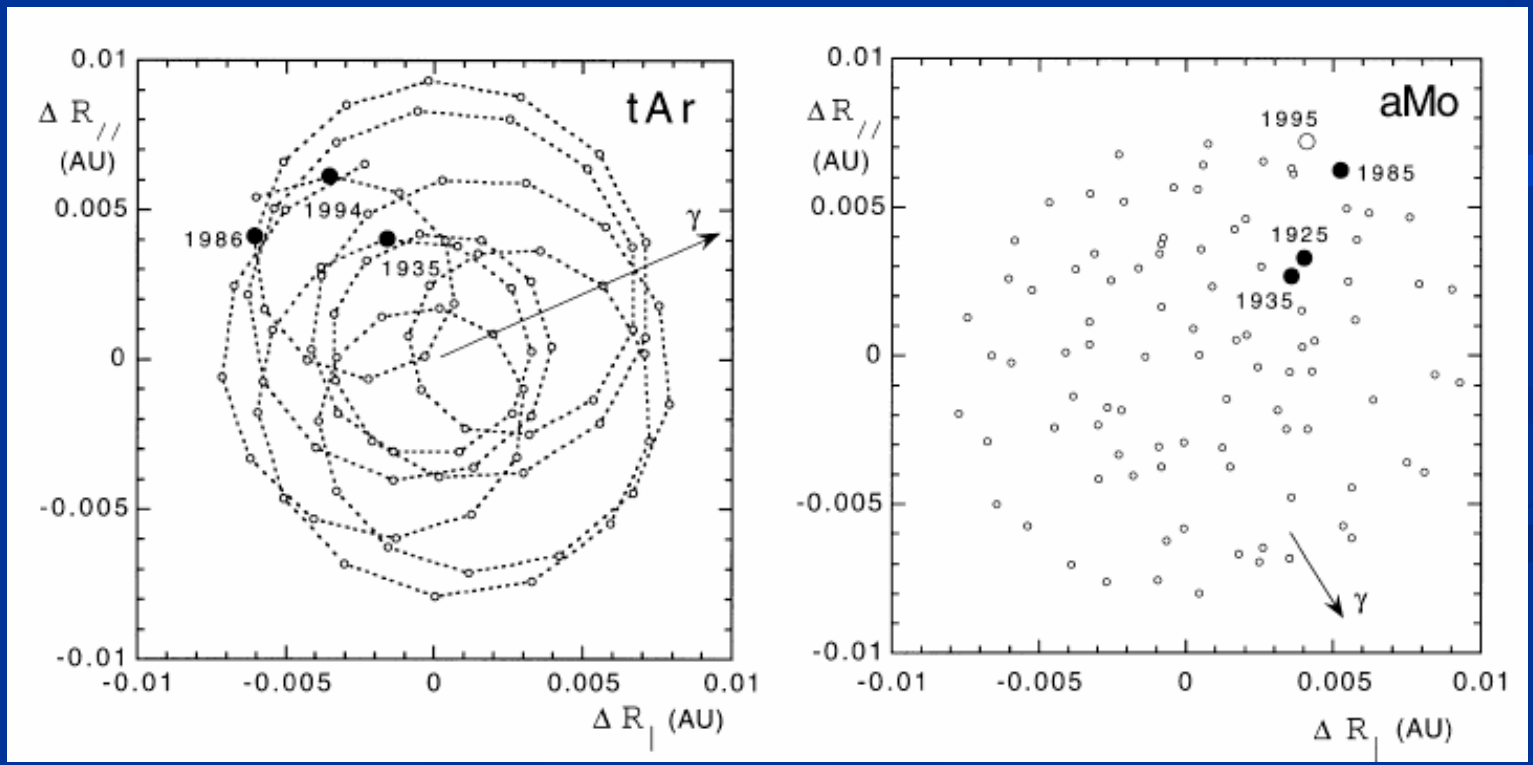
Radio MS detection by Ilkka Yrjola

A hypothesis is formulated

Jenniskens, 1995. JIMO 23, 84; Jenniskens, 1997. Astron. Astrophys. 317, 953

- Showers are caused by a dust trail moving in and out of Earth orbit.
- Trail motion is that of Sun's reflex motion.





Confirmation: correct prediction of 1995 Nov 22: alpha-Monocerotids

Jenniskens et al., 1997. ApJ 479, 441

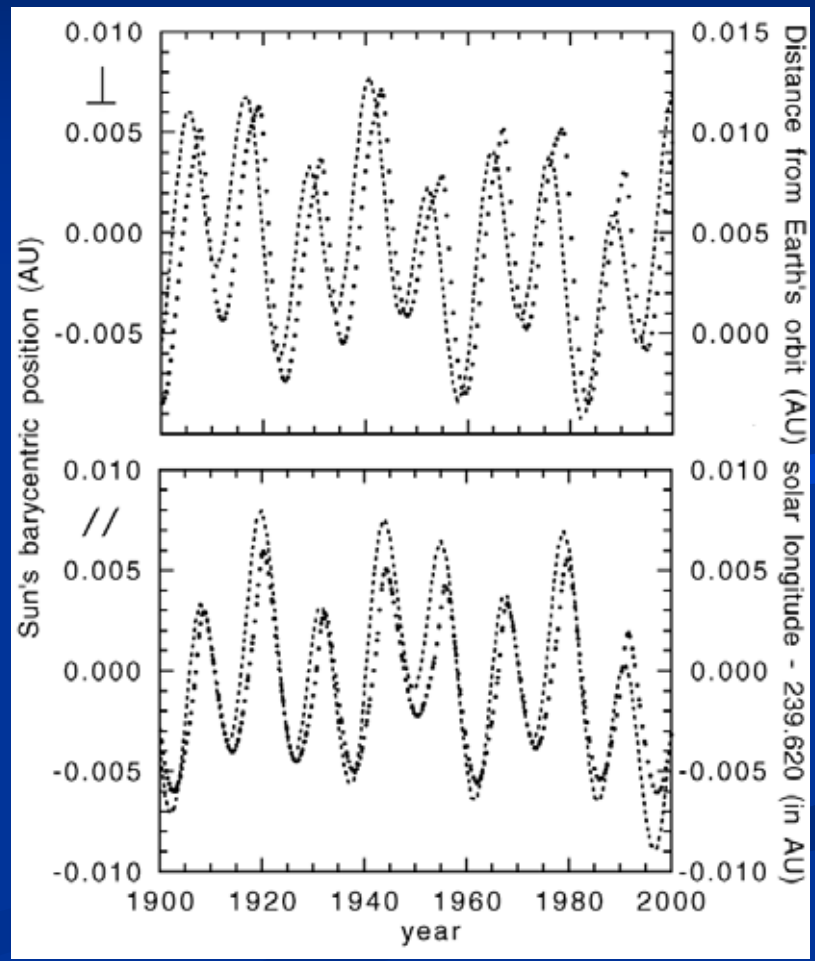
Compilation of video images by Sirko Molau

- Observed in coordinated campaign (Dutch Meteor Society + S.O.M.Y.C.E.)
- Proven that meteoroids move in long-period (longer than 10-year) orbits
  - RESULT: > 149 years
  - Alpha-Monocerotids were seen in 1925, 1935, and 1985 because trail wandered in Earth's path

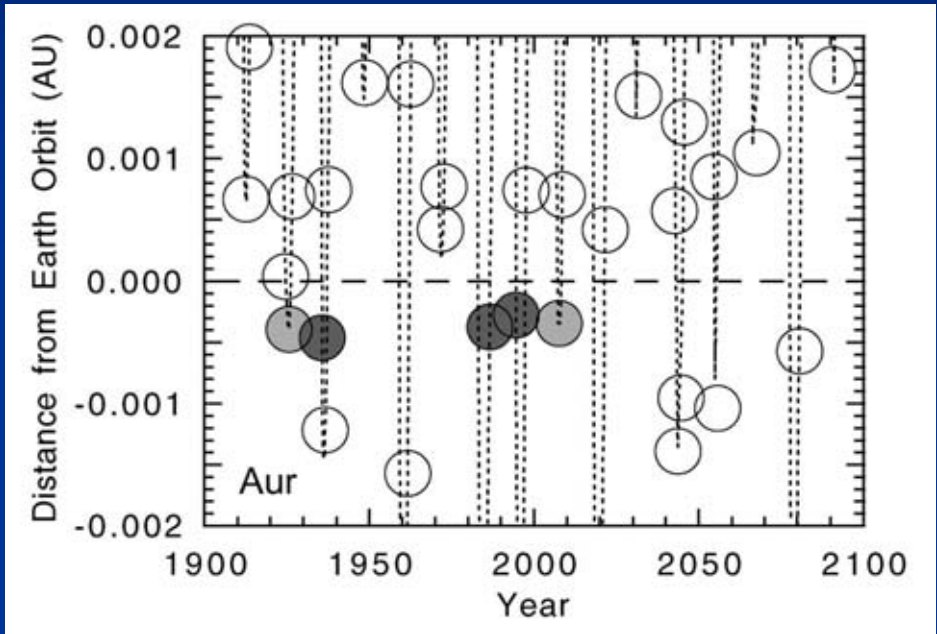
Calculations confirm

Lyytinen and Jenniskens, 2003. Icarus 162, 443

- Long-period comet dust trail moves roughly with Sun's reflex motion.
- It does not (much) depend on orbital period of comet: perturbations on inward leg
- Make predictions for future outbursts: AURIGIDS!



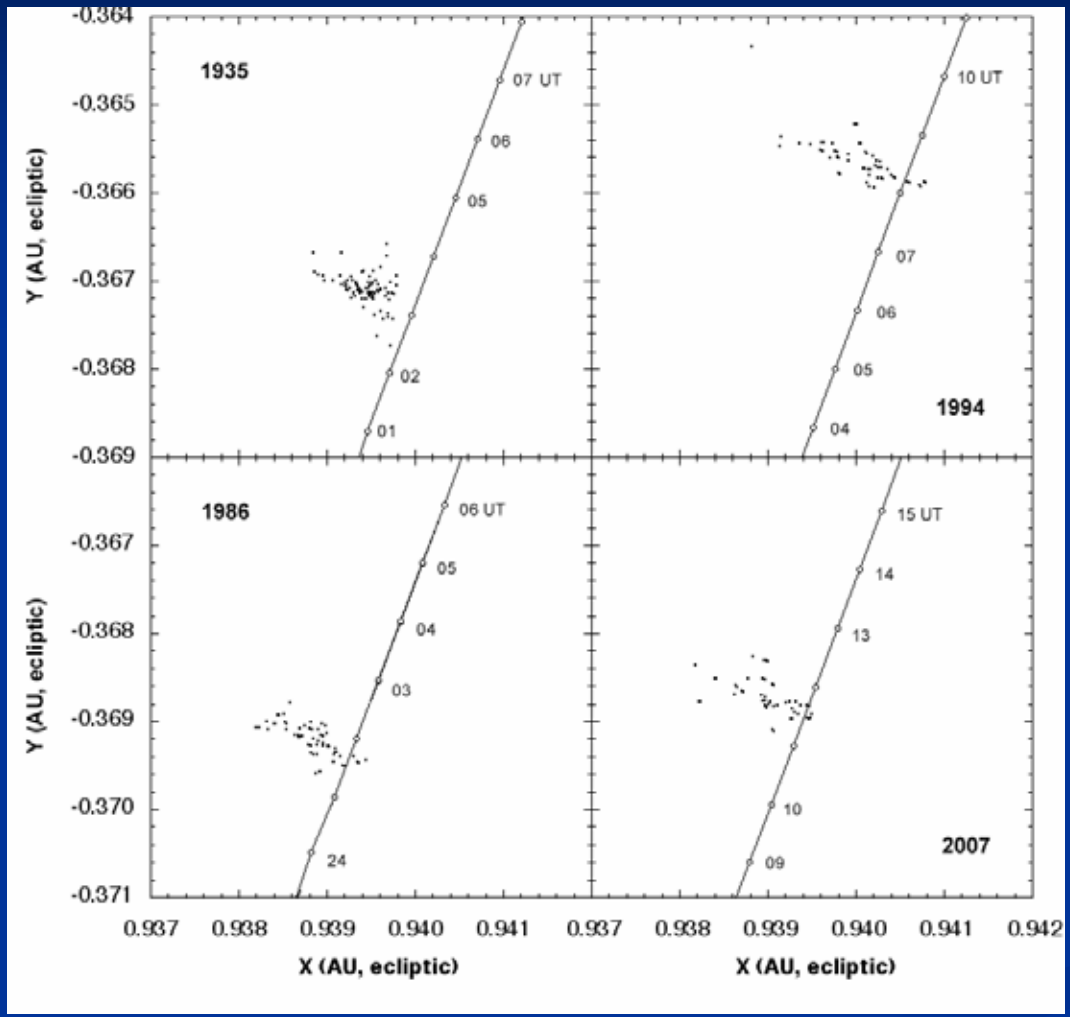
One more Aurigid outburst in our lifetime!



Lyytinen and Jenniskens, 2003. Icarus 162, 443

- In most years, the trail is not in Earth's path on Sept. 1
- It is in 1925, 1935, 1986, 1994, **and 2007**
- Not again after that for a long time.
- No other known long-period comet has such well defined dust trail crossing!

2007: A new dust trail model

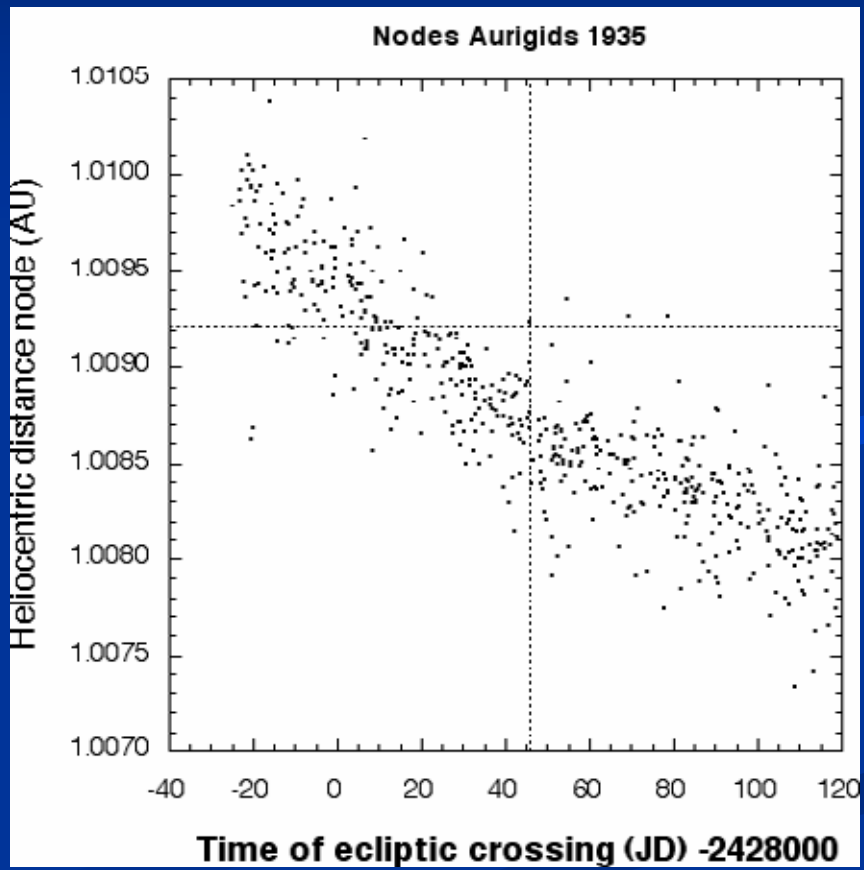


- Vaubaillon model (Crifo ejection model):
  - Particles spread rapidly, much dilluted
  - Trail moves rapidly in 1994, not so much in 2007
  - +/- 1 week around Sept 1: trail at same position as in 1935, 1994, and 1986

Jenniskens and Vaubaillon, 2007. JIMO

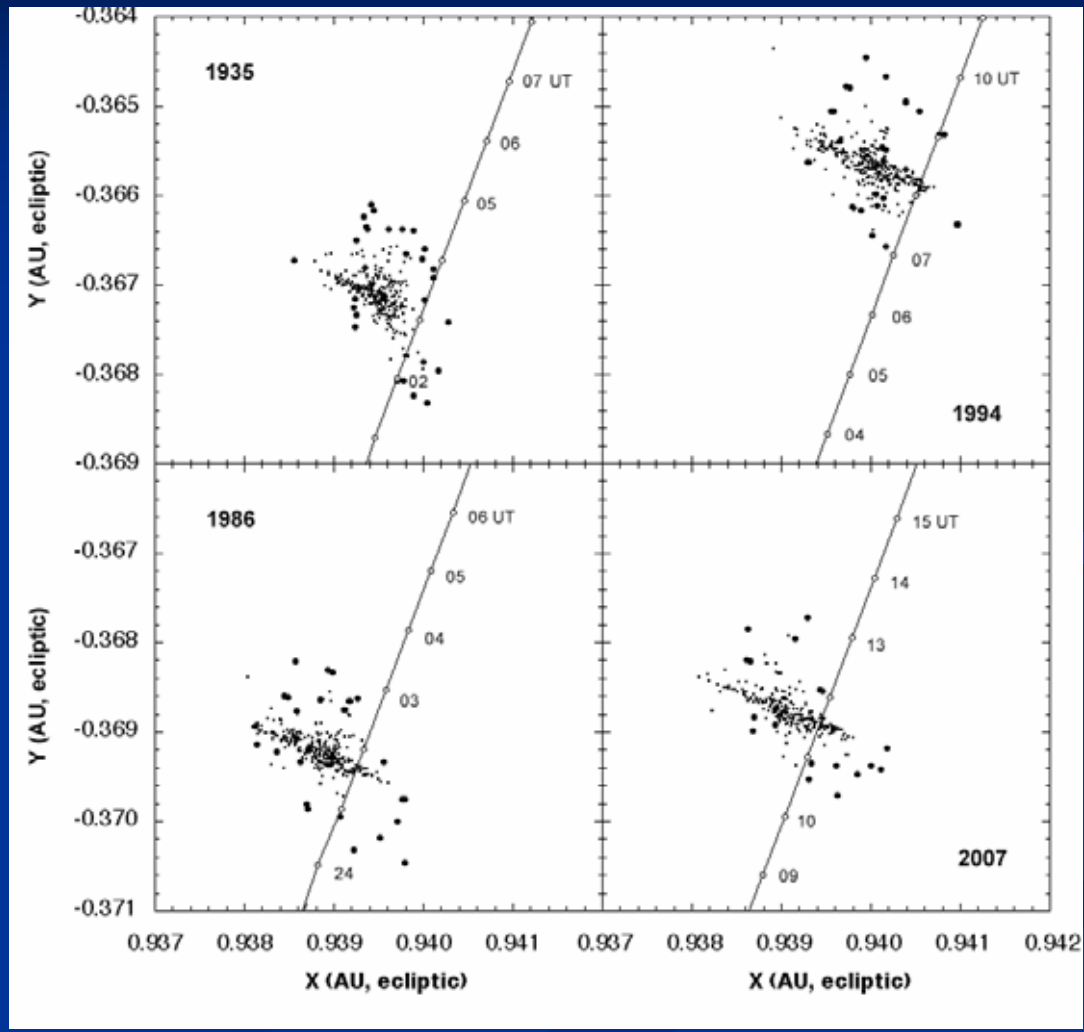
Correct for motion of trail

- Trail section ±2 months from passing node on Sept. 1
- Motion is gradual
- No clumping or gaps
- Correct for motion, then add all particles together



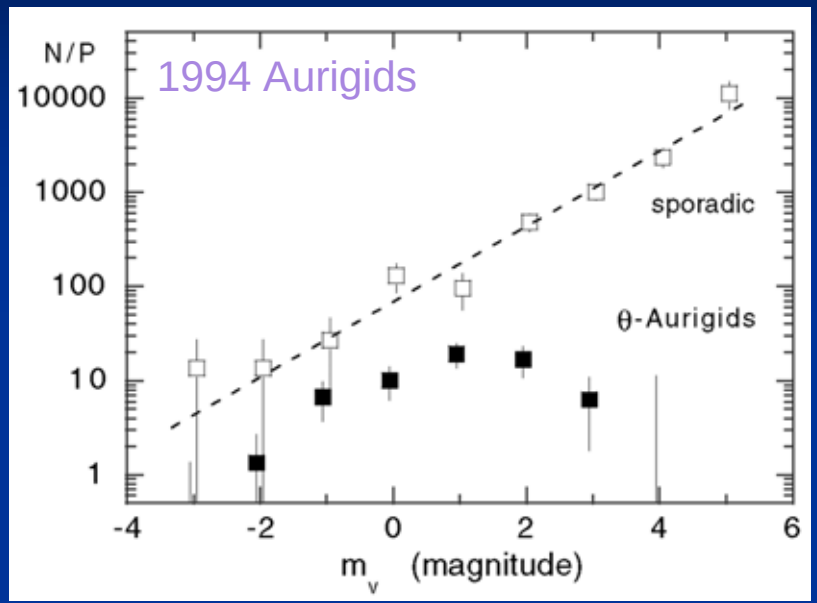
Result shows trail cross section

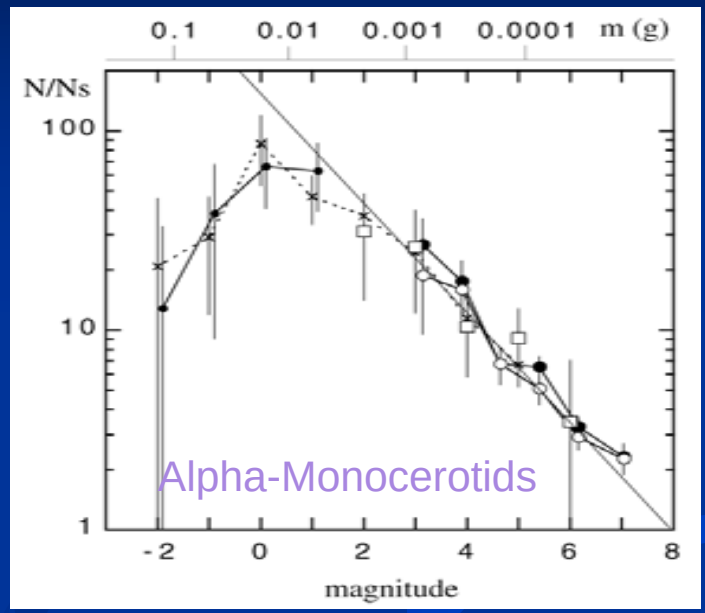
- Same position as in prior years
- Peak at 11:36 UT 2007 Sept. 1
  - California, Hawaii
- FWHM ~ 25 min
- About same activity as in prior years (peak ZHR ~ 200 /hr)



Jenniskens and Vaubaillon, 2007. EOS (submitted)

What to expect: meteor brightness





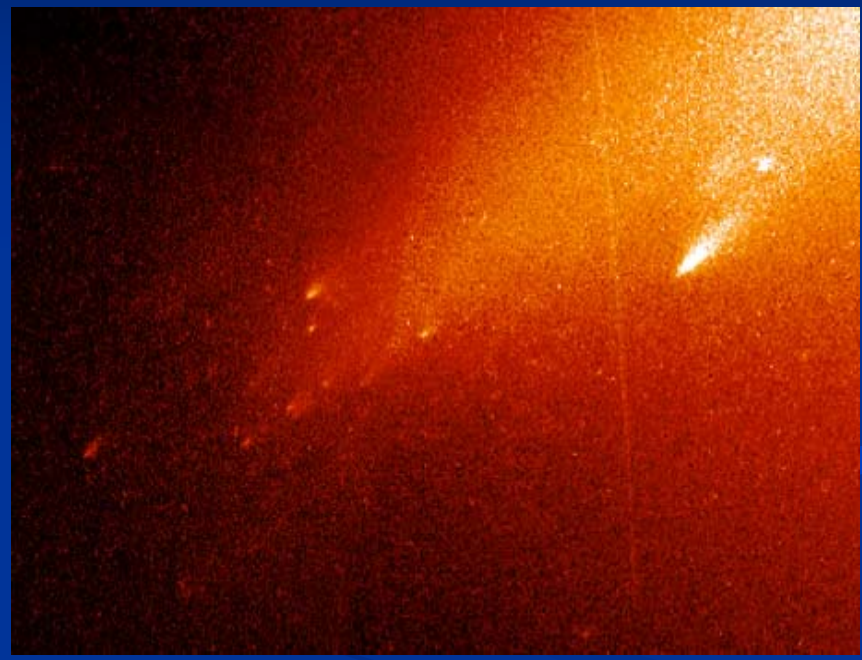
- Meteor magnitudes in narrow range
- Many bright meteors (gladly so: the Moon is four days past full on September 1)
  - Low mass distribution index
  - Upper mass cut-off

Long-period comets

Comet McNaught

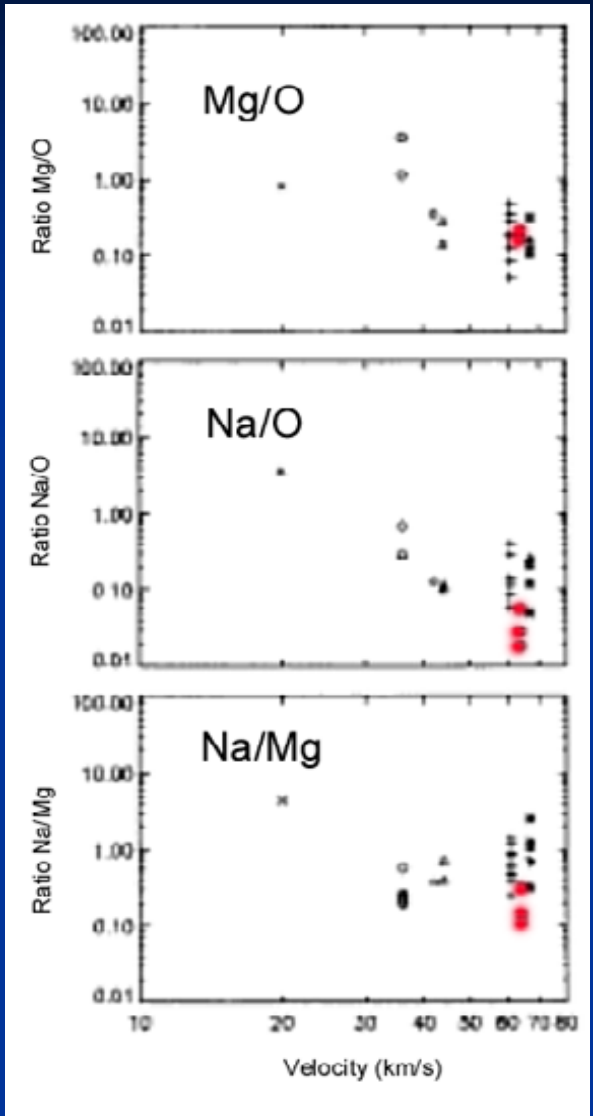
They can still have a pristine crust

- They can be very big (Hale-Bopp!) and create big impact craters
- Most don’t survive more than a few orbits: they break or fade
- Can still have a crust from 4.5 billion years worth of cosmic ray bombardment in the Oort cloud



C/2000 WM1 (LINEAR) / NASA-Hubble

α-Monocerotids: peculiar meteoroids



From: Stork et al., 1998. MPS 33, A151.

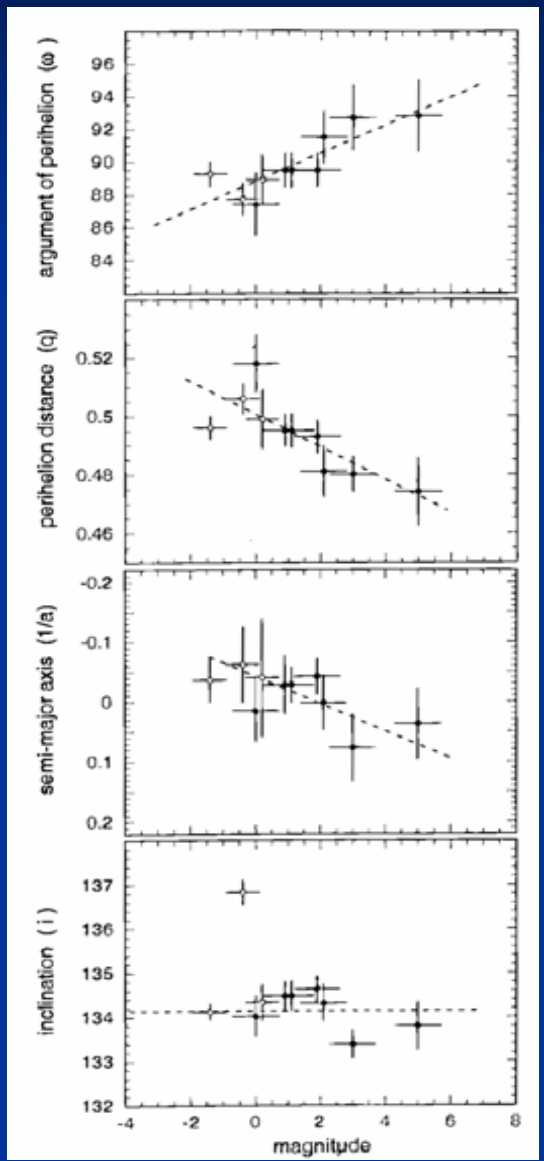
- Lack of sodium
- Penetrated 5 km deeper in Earth's atmosphere than other meteors of similar speed
- Smooth light curves

Pristine crust!

Jenniskens et al. 1997. ApJ

Imaging[a]	Time (1995 Nov 22)	H_b (km)	H_e (km)	m_V (mag)
				Annual
PH	3:57:41	97.5	84.1	−0.9
				Outburst
PH	1:41:21	110.8	81.3	−1.4
	1:33:41	97.1	85.2	−0.4
	1:37:54	97.0	85.0	+0.2
TV	1:41:51	116.9	99.2	+0
	1:45:53	101.3	89.6	+1
	1:29:40	103.1	95.7	+1
	1:25:10	123.6	94.8	+2
	1:37:39	112.4	89.1	+2
	1:21:33	114.0	88.9	+3
TV	1:31:14	...	97.0	+5

mass-dependence of orbital elements



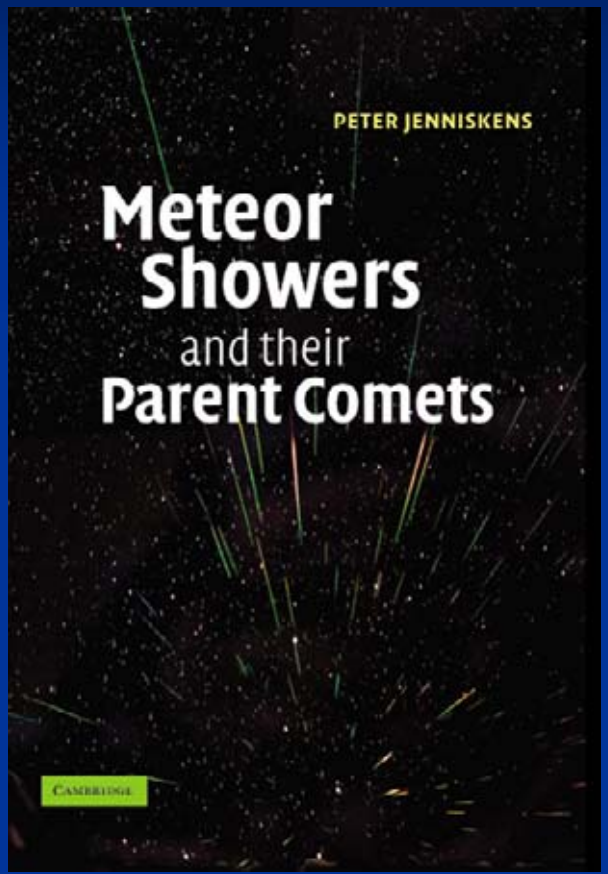
- Decrease of perihelion distance with meteor magnitude
  - Different magnitudes could sample dust ejected from different heliocentric distances
- We want to find out where the dust is located and when and how it was ejected

Jenniskens et al., 1997. ApJ 479, 441

Sept 1, 2007: A bit of history

- In late August 2007, you traveled to California, where the shower was best seen.
  - You chose the Bay Area near San Francisco for the best chance of clear weather
  - The SETI Institute helped with your logistical needs
- You had the best multi-station scientific results by coordinating your observations with others
  - Meeting Aug 30 at SETI

For more information:



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Welcome to California!

San Francisco…
Yosemite…
Redwood trees...
Sea Elephants…
Disneyland…
Hollywood...
Oh, yeah: and the most unusual shower ever...