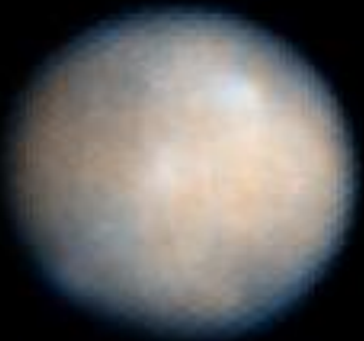
Asteroids

James Appleton

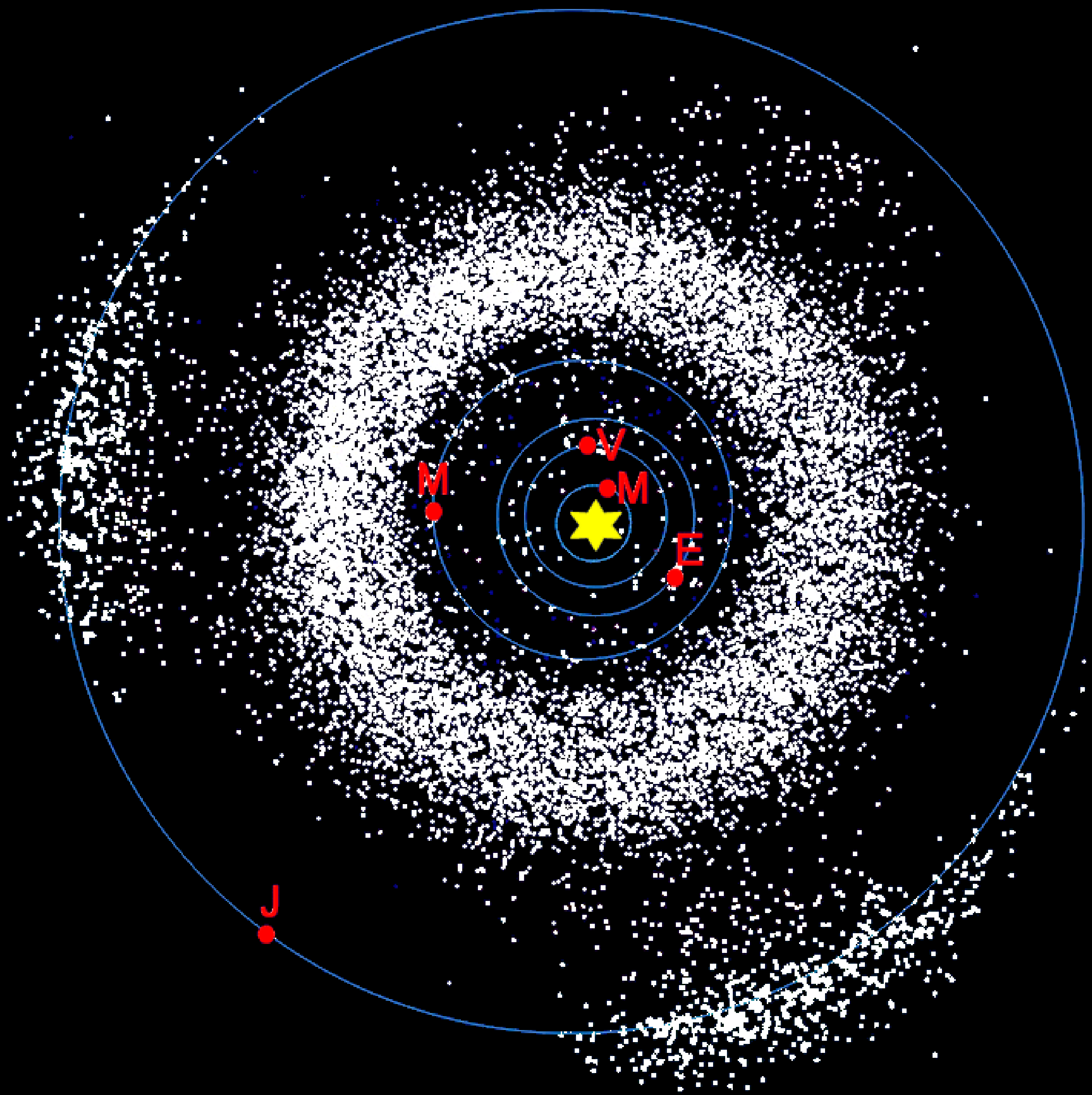
Size Of The Asteroids



(1) Ceres
975km diameter

Moon
3475km diameter

Orbital Distribution



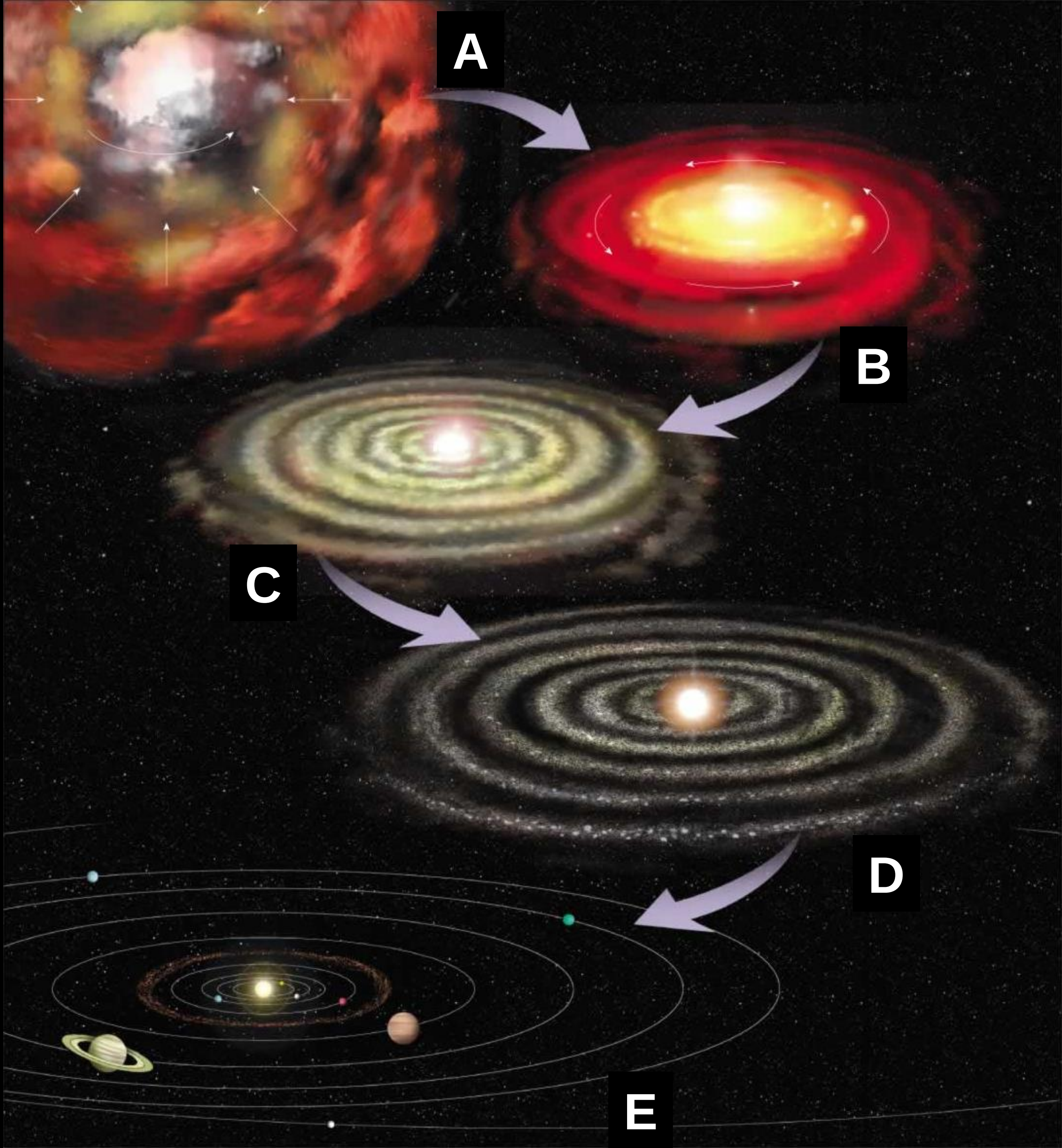
How Many Are There?

IAU tally of asteroids as of 06 March 2011

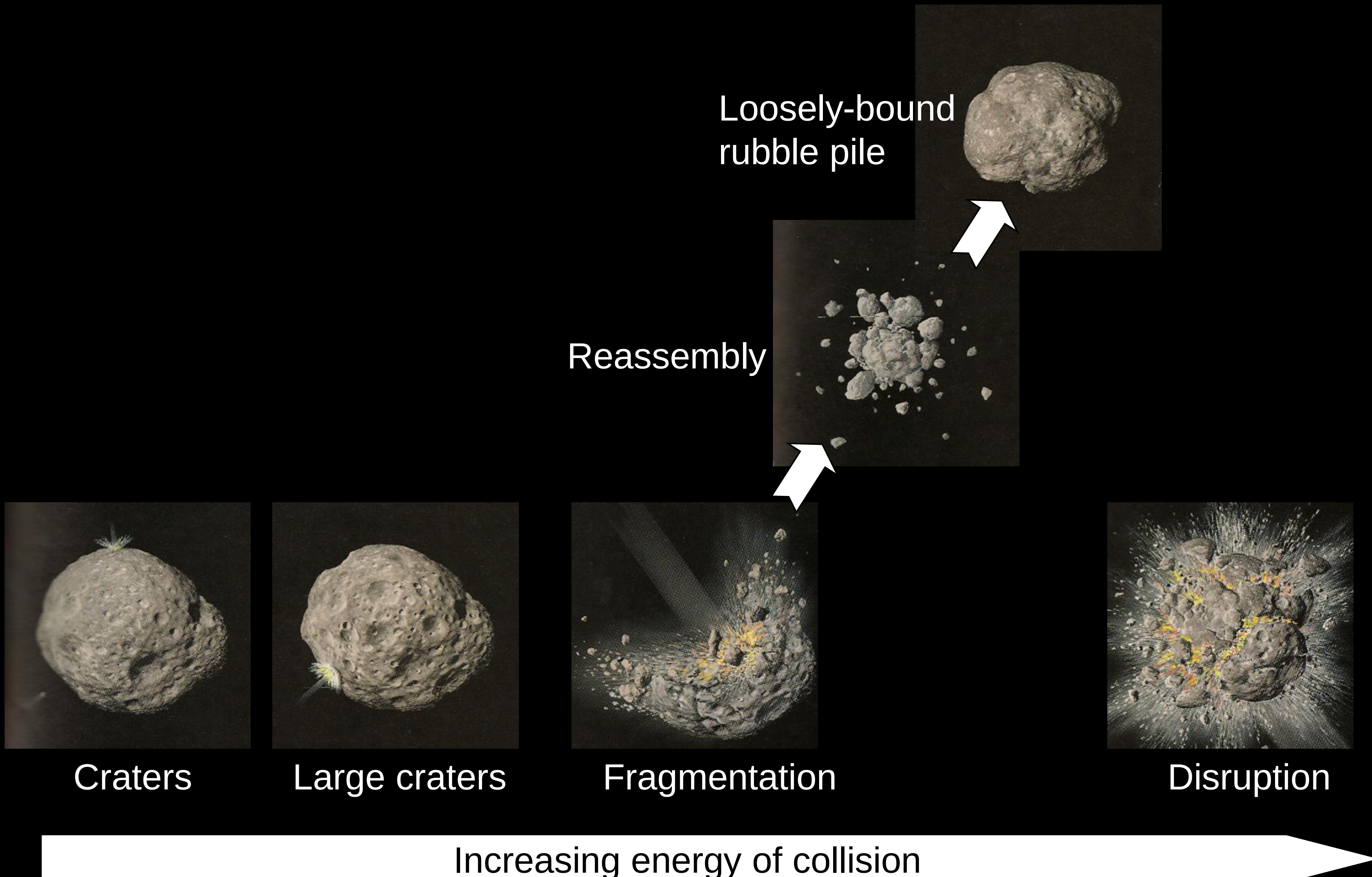
With known orbits	264,258
With orbits not established	281,823
Total	546,081

Minimum detectable size ~1km diameter

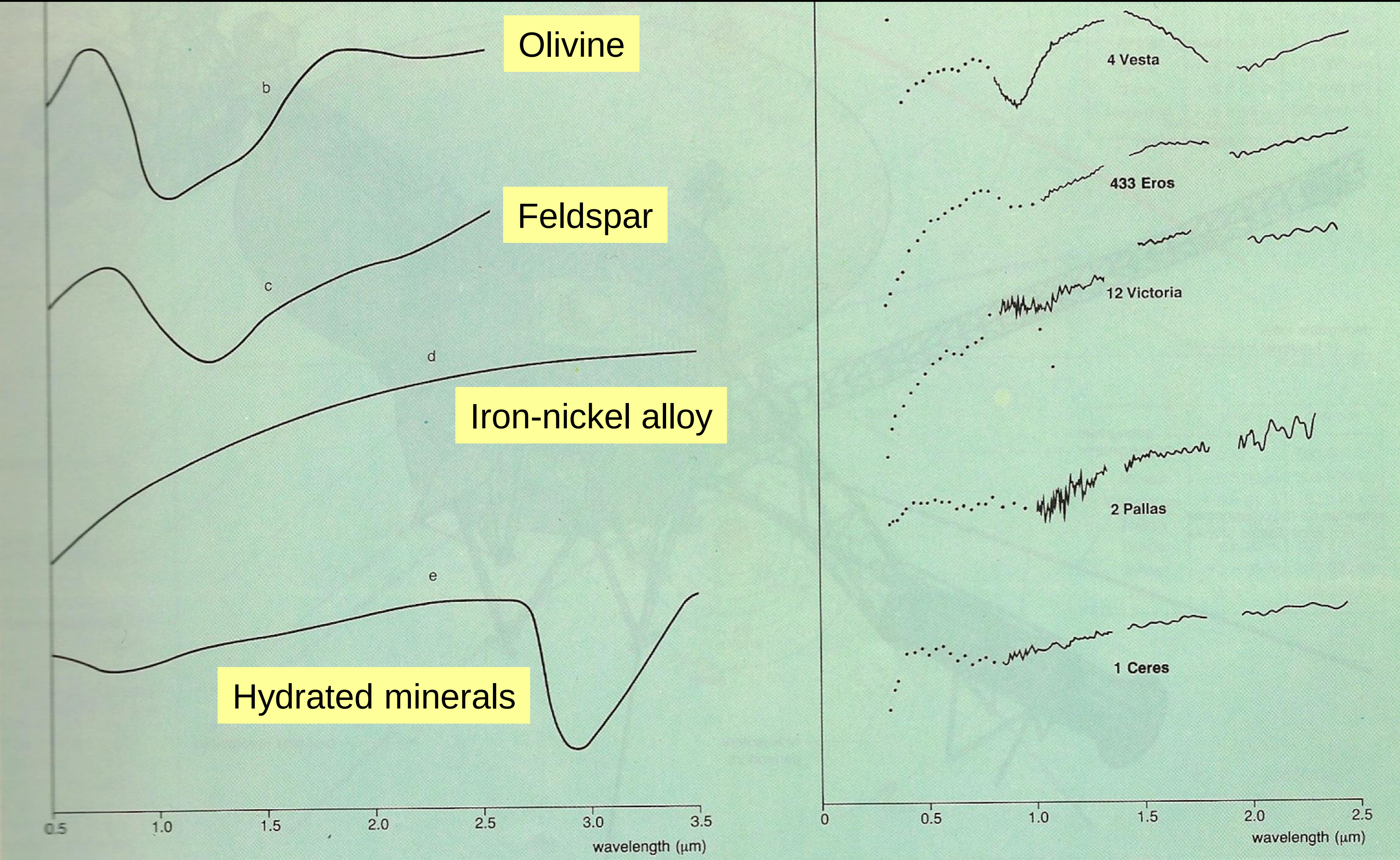
Formation Of The Solar System



Collisions


Loosely-bound
rubble pile
Reassembly
Craters
Large craters
Fragmentation
Disruption
Increasing energy of collision

IR Spectrophotometry



Taxonomy

Class	Characteristics
C (Carbonaceous)	Dark bodies: albedo as low as ~4%. Spectrally similar to carbonaceous chondrite meteors. Rich in hydrated silicates and carbon. Approx 75% abundance. Especially common in outer asteroid belt.
S (Stony)	Reddish hue. Albedo typically ~14%. Spectrally similar to stony-iron meteors. Contain silicates and sometimes metal. (Presence of metal can increase albedo significantly, e.g. 48% for (44) Nysa.) Approx 17% abundance. Most common in inner asteroid belt.
U (Unusual or unclassified)	?

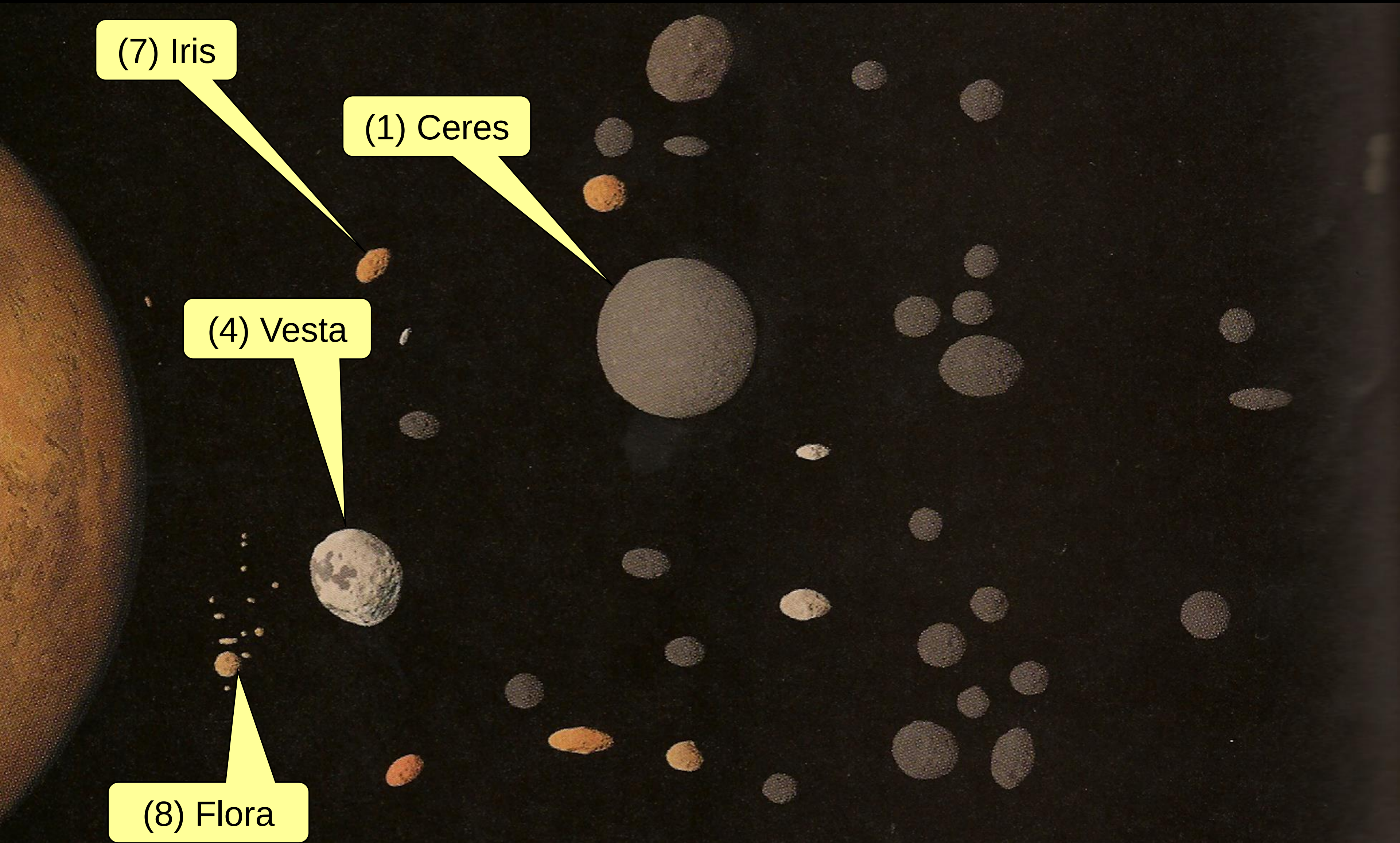
References: C R Chapman, The Nature Of Asteroids, *Scientific American*, **232**(1), 24-33, 1975 and E Bowell *et al*, Taxonomy of Asteroids, *Icarus*, 35, 313-345, 1978.

Taxonomy, 2

Class	Characteristics
C	Carbonaceous, as earlier schema
B	Subset of carbonaceous; brighter and neutral colour
G	Subset of carbonaceous; brighter and strong UV absorption
F	Subset of carbonaceous; flat spectra with no UV absorption
R	High albedo, very red hue
D	Very red hue, dark in IR band, very low albedo
S	Stony, as earlier schema
A	Subset of S class; strong absorption in UV and near 1.1 µm due to olivine
M	Linear spectrum and slightly reddish. Metallic.
P	Subset of M with low albedo
Q	Like S but with strong absorption. (1862) Apollo is exemplar.
E	Enstatite: linear, flat spectrum. Slightly reddish. (Pyroxene silicate mineral.)
V	Like S but with strong absorption due to olivine. (4) Vesta is exemplar.
T	Intermediate between S and D

Reference: D J Tholen, Asteroid Taxonomy From Cluster Analysis of Photometry. PhD thesis, University of Arizona, 1984.

Shapes, Colours, Albedos & Sizes



Minor Planet Centre

Asteroid Nomenclature Example

Provisional designation

1935 SO1

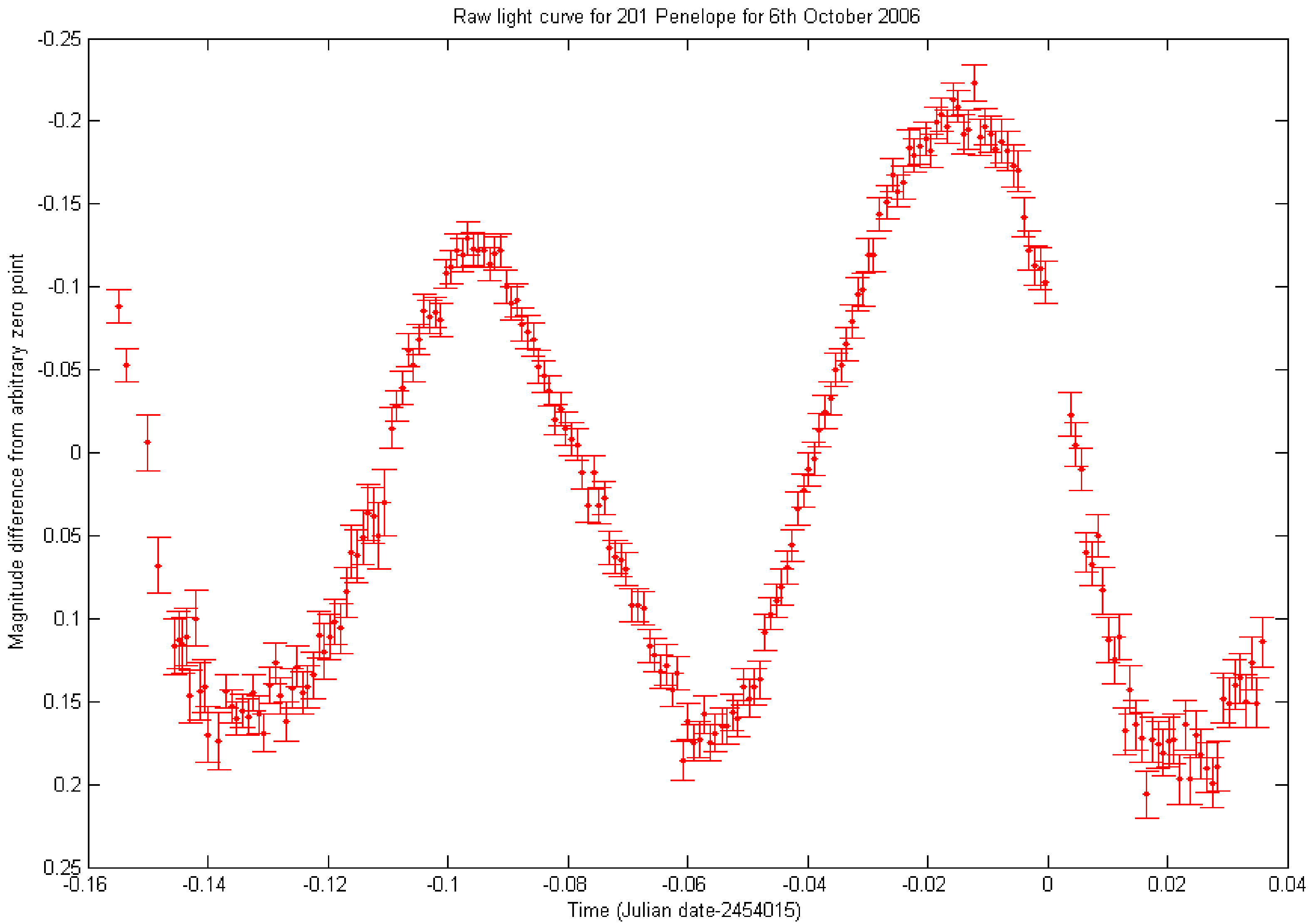
- 1935 — Year of discovery
- S — Half-month of discovery (defined as days 1-15, whatever the length of the month). A is 1^{st} half of Jan, B is 2^{nd} half Jan, C is 1^{st} half Feb, etc. “I” is not used.
- O1 — Order of discovery within half-month. Sequence is A, B, C,…Z, A1, B1, C1,… Z1, A2, B2,... “I” is not used.

Final designation

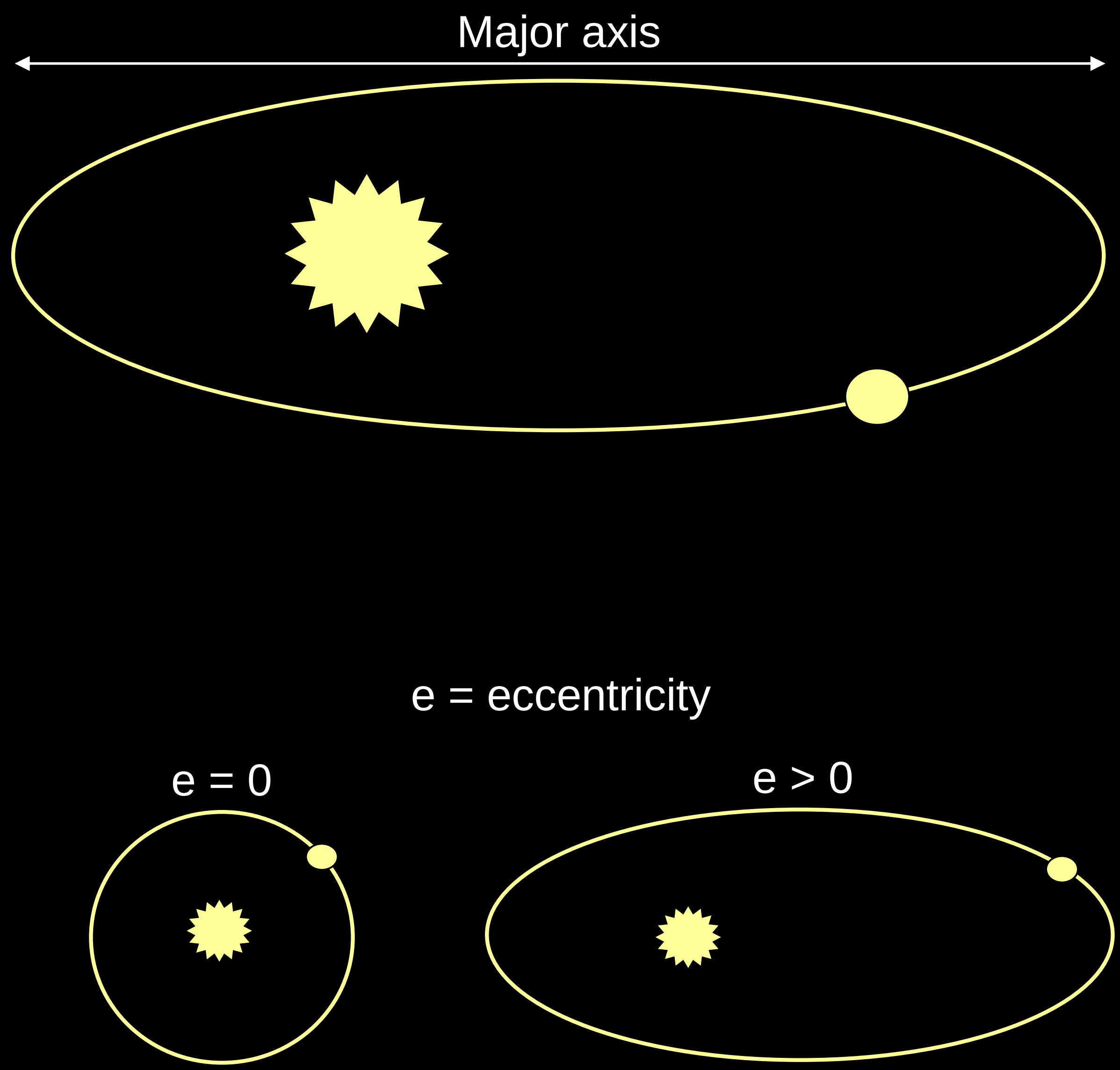
(2213) Meeus

- (2213) — Order of discovery
- Meeus — Name (optional)

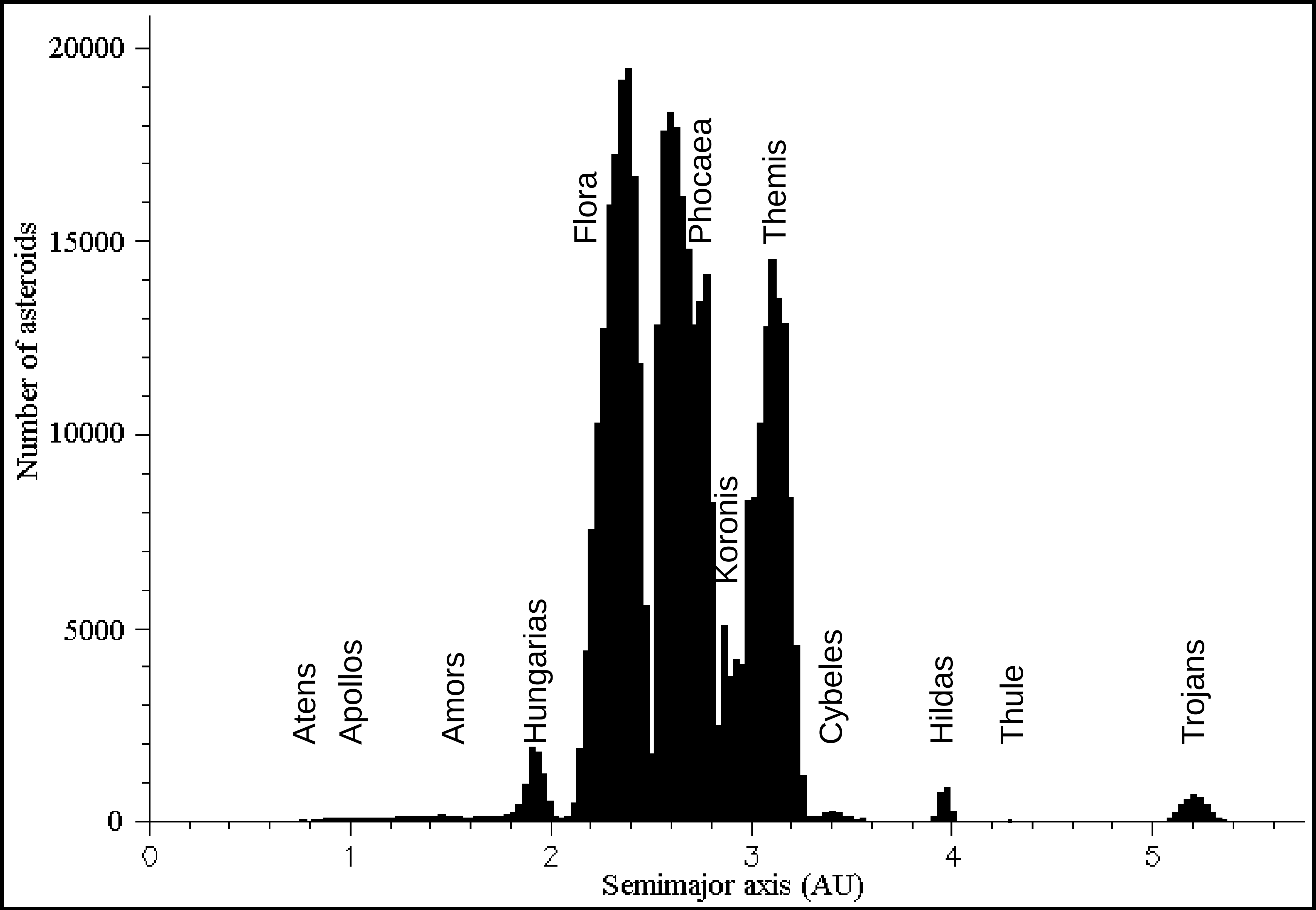
Asteroid Light Curve



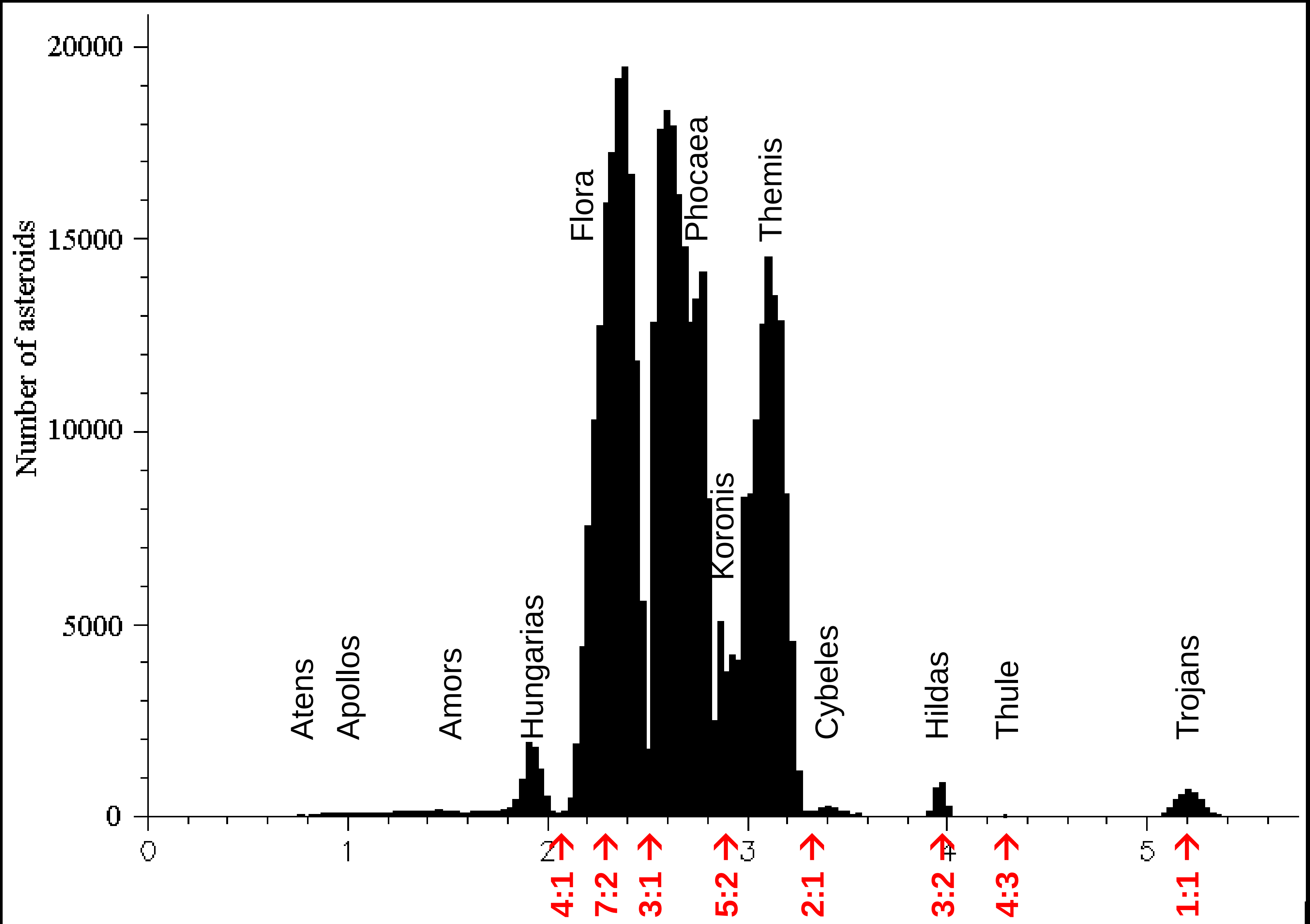
Keplerian Orbits



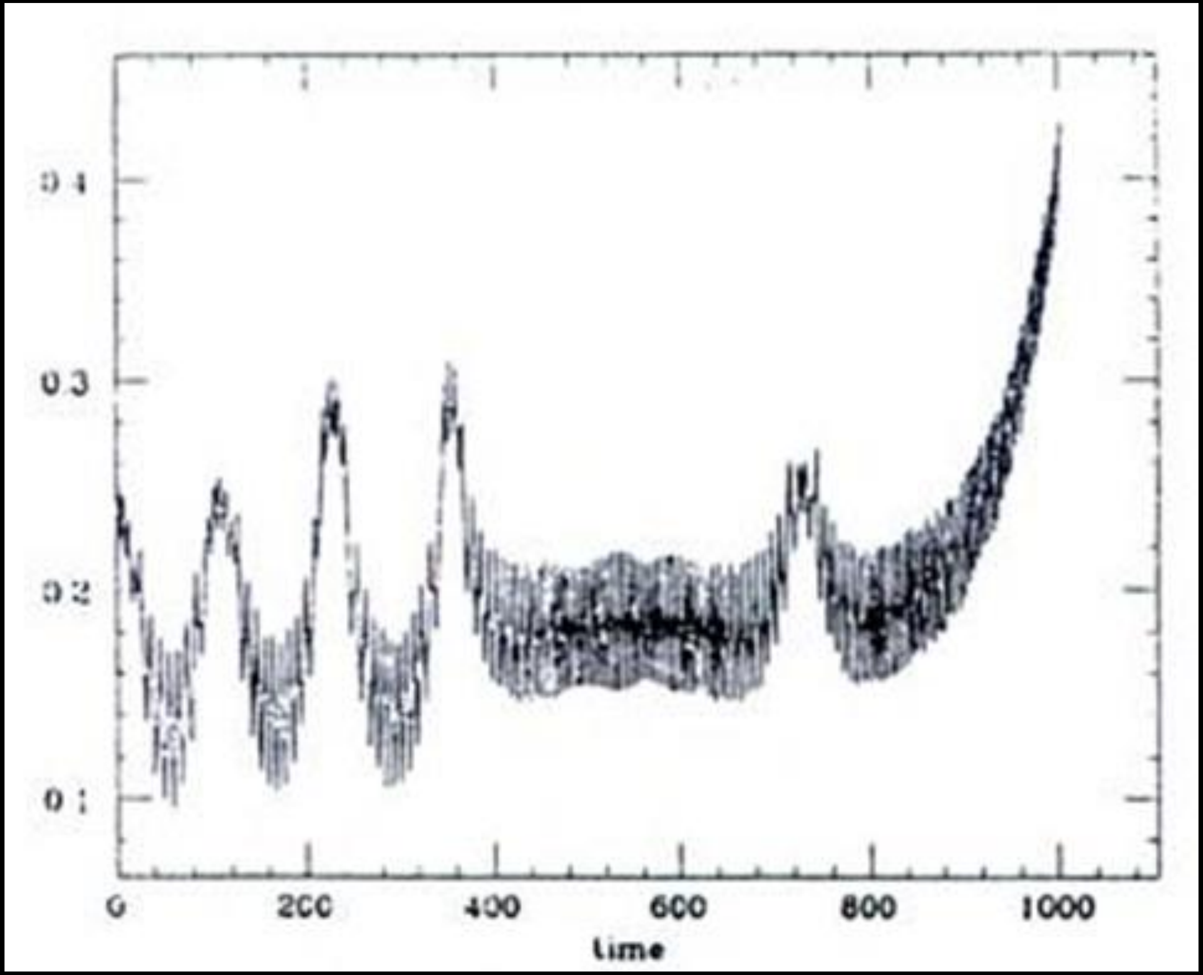
Distribution Of Semi-Major Axes



Kirkwood Gaps



Chaotic Change In Eccentricity



Eccentricity of fictitious asteroid in 3:1 resonance with Jupiter. (R Dvorak, New Results on the Motions of Asteroids in Resonances, pp. 145-152 in *Chaos, Resonance, and Collective Dynamical Phenomena in the Solar System*, Sylvio Ferraz-Mello (Ed), IAU Symposium 152, Kluwer Academic Publishers, 1992.)

Surprise Asteroid Makes Near-Miss of Earth

Monday, March 02, 2009
FOX NEWS

Wait! Did you hear that whooshing sound?

A small asteroid buzzed by Earth Monday, though only real astronomy geeks in the Pacific would have noticed.

The rock, estimated to be no more than 200 feet wide, zoomed past our planet at an altitude of 40,000 miles at 1:44 p.m. universal time — or 8:44 EST.

Dubbed 2009 DD45, it was discovered only on Friday by Australian astronomers.

Forty thousand miles may sound like a lot, but it's only about one-seventh of the way to the moon, and less than twice as far out as many telecommunications satellites.

Had 2009 DD45 hit the Earth, it would have exploded on or near the surface with the force of a large nuclear blast — not very reassuring when you consider humanity had only about three days' notice.

According to the Australian news Web site Crikey, the asteroid is likely to be drawn in by Earth's gravity, meaning it may return for many more near misses in the future.

IAU Definitions

- NEO = Near Earth Object
  - A Solar System object with perihelion distance <1.3AU

- PHO = Potentially Hazardous Object
  - An asteroid or comet having
    - (a) an orbit that comes within 7.5m km of that of the Earth, and
    - (b) a diameter of at least 150m

Awareness Of NEO Dangers

1980	Luis and Walter Alvarez publish paper explaining extinction of dinosaurs due to an asteroid strike
1980s	Gradual increase in awareness of the danger of an asteroid collision
1992	NASA report recommends establishing a “Spaceguard Survey” to discover all Earth-crossing asteroids
1994	Shoemaker-Levy collision with Jupiter further raises concern about as asteroid collision
1995	NASA report recommends programme to discover at least 90% of Earth-crossing asteroids by 2010
1998	NASA begins programme to discover 90% of all NEOs with diameter >1km by 2008

Some Spaceguard Observatories

Observatory	**Started**	**Telescopes**	**Location**
Spacewatch	1980	1 x 1.8m 1 x 0.9m	Kitt Peak, Arizona
LONEOS (Lincoln NEO Survey)	1993	1 x 0.6m	Flagstaff, Arizona
NEAT (NEA Tracking)	1995	1 x 1.0m 1 x 1.2m	Palomar, California
LINEAR (Lincoln NEA Research)	1996	2 x 1.0m 1 x 0.5m	Kitt Peak, Arizona
Catalina Sky Survey	1998	1 x 1.5m 1 x 0.7m 1 x 0.5m	Tucson, Arizona Siding Spring, NSW
UK Spaceguard Centre	2001	1 x 0.3m 1 x 0.6m	Knighton, Powys
Pan-STARRS (Panoramic Survey Telescope and Rapid Response System)	2012	4 x 1.8m Aperture synthesis	Mauna Kea, Hawaii

Near Earth Asteroids

Object	Close Approach Date	Miss Distance (million km)	Estimated Diameter	Relative Velocity (km/s)
2008 CA22	2011 Mar 09	29.6	200 m - 440 m	27.7
2008 DY22	2011 Mar 09	19.5	38 m - 86 m	11.3
2005 EA	2011 Mar 09	19.9	170 m - 390 m	25.9
2008 EY5	2011 Mar 10	13.4	260 m - 570 m	12.0
(23187) 2000 PN9	2011 Mar 10	17.5	1.6 km - 3.6 km	32.9
2010 JK1	2011 Mar 11	27.6	36 m - 79 m	4.7
2000 EB14	2011 Mar 11	19.3	62 m - 140 m	12.9
2005 EY169	2011 Mar 11	10.9	97 m - 220 m	12.4
2007 CT26	2011 Mar 12	27.1	57 m - 130 m	8.4
2005 ES70	2011 Mar 14	8.7	51 m - 110 m	12.0
2011 CD22	2011 Mar 14	23.5	91 m - 200 m	12.0
2001 FO127	2011 Mar 15	25.5	9.4 m - 21 m	8.9
(11885) Summanus	2011 Mar 17	15.2	510 m - 1.1 km	16.2

Titius-Bode Law

Modern formulation:

Where a is the semi-major axis in AU of each planet outwards from the Sun

$$a = 0.4 + n/10$$

$$\text{for } n = 0, 3, 6, 12, 24, 48, \ldots$$

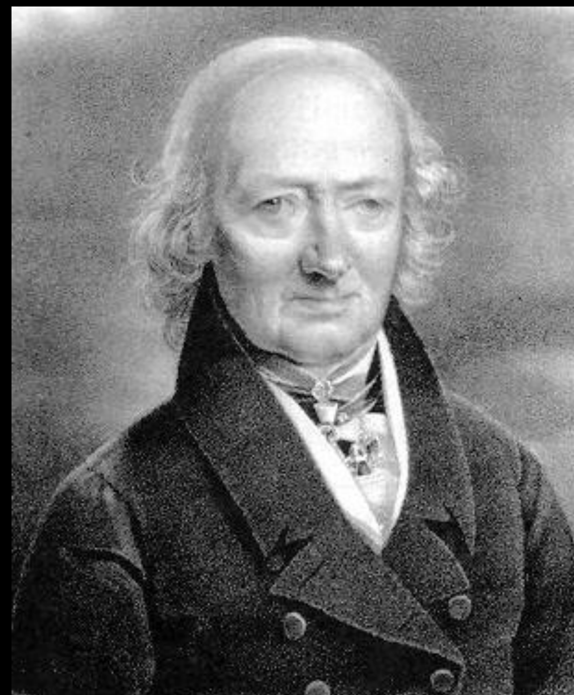
Planetary Orbits (pre-1781)

Planet	n	a (Titius-Bode)	a (modern, USNO)
Mercury	0	0.4	0.4
Venus	3	0.7	0.7
Earth	6	1.0	1.0
Mars	12	1.6	1.5
?	24	2.8	--
Jupiter	48	5.2	5.2
Saturn	96	10.0	9.6

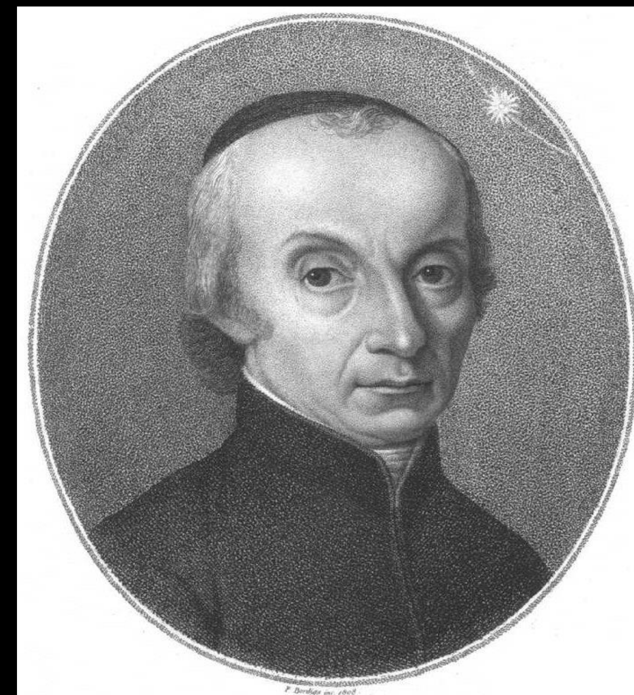
Planetary Orbits (1781 Onwards)

Planet	n	a (Titius-Bode)	a (modern, USNO)
Mercury	0	0.4	0.4
Venus	3	0.7	0.7
Earth	6	1.0	1.0
Mars	12	1.6	1.5
?	24	2.8	--
Jupiter	48	5.2	5.2
Saturn	96	10.0	9.6
Uranus (1781)	192	19.6	19.2

Johann Daniel Titius
(1729-1796)



Johann Elert Bode
(1747-1826)

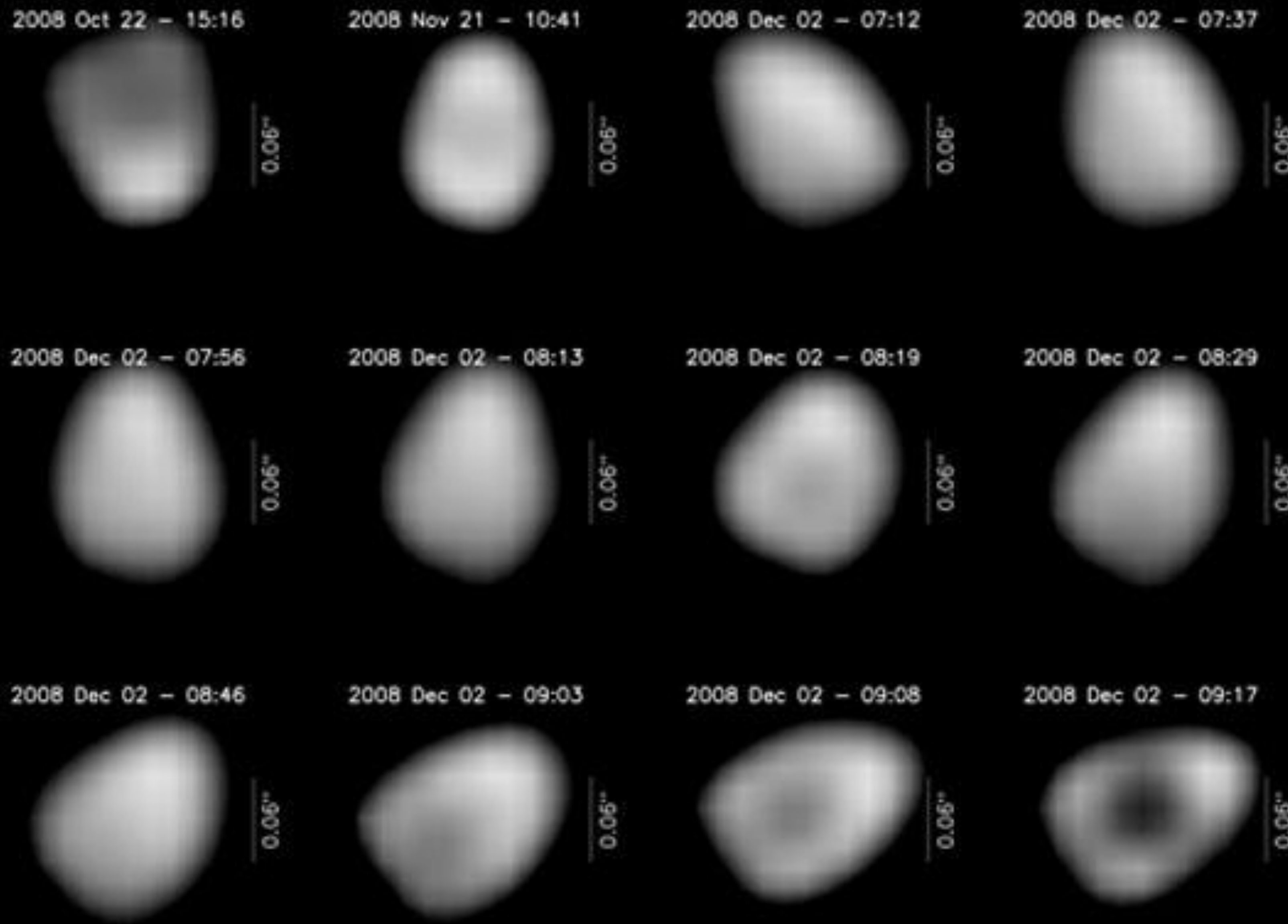


Giuseppe Piazzi
(1746-1826)

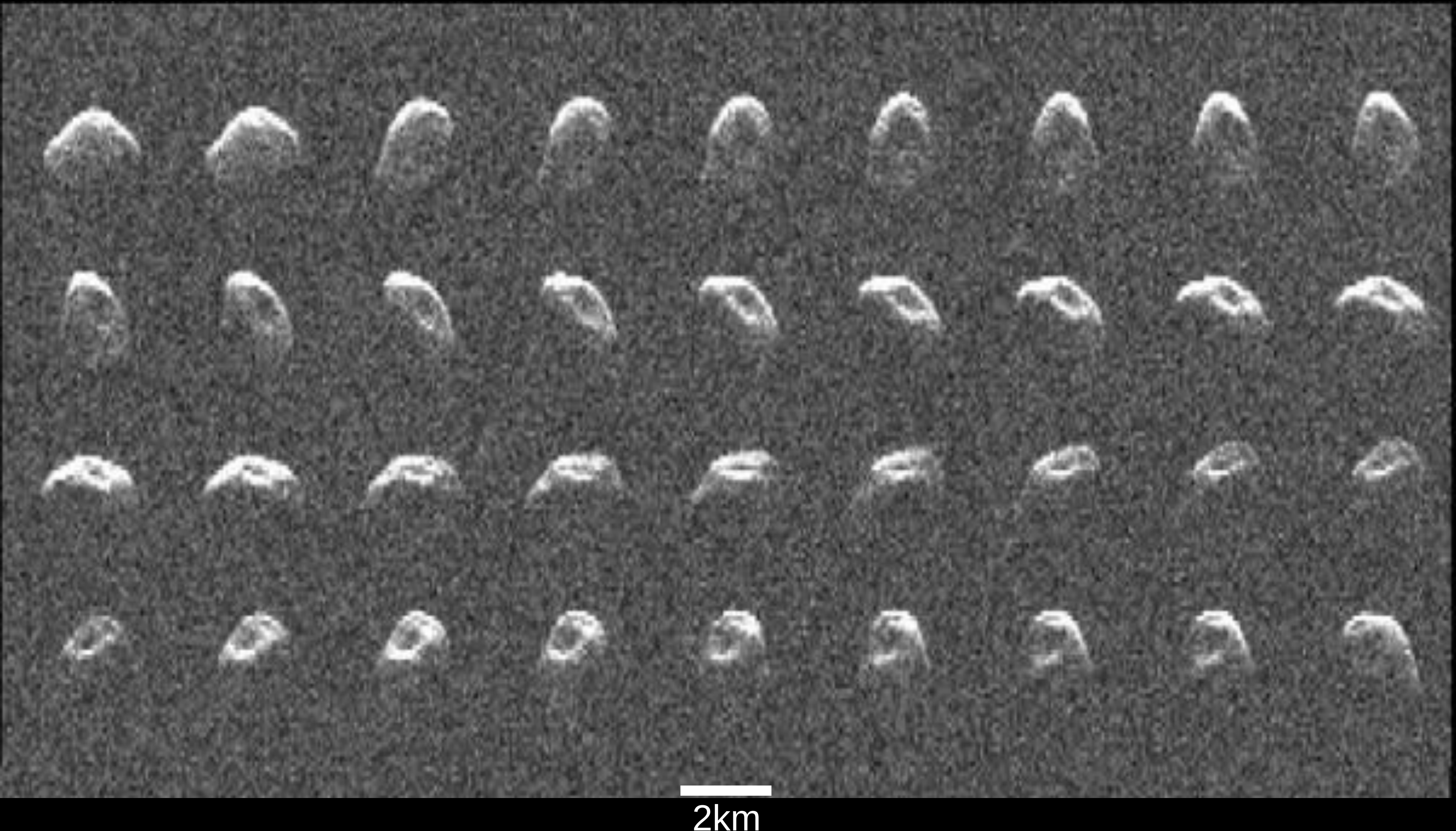
Early Discoveries

Asteroid	Discoverer	Date
(1) Ceres	Giuseppe Piazzi	01 Jan 1801
(2) Pallas	Heinrich Olbers	28 Mar 1802
(3) Juno	Karl Harding	01 Sep 1804
(4) Vesta	Heinrich Olbers	29 Mar 1807
	. . . . .	
(5) Adastrea	Karl Hencke	08 Dec 1845
(6) Hebe	Karl Hencke	01 Jul 1847

W M Keck Images of (21) Lutetia



Radar Images Of 2010 JL33



Galileo At (951) Gaspra

First image distance: 164,000 km.
Last image distance: 16,000 km.

Dimensions 18 x 10.5 x 9 km.
Colour exaggerated.

Galileo At (243) Ida

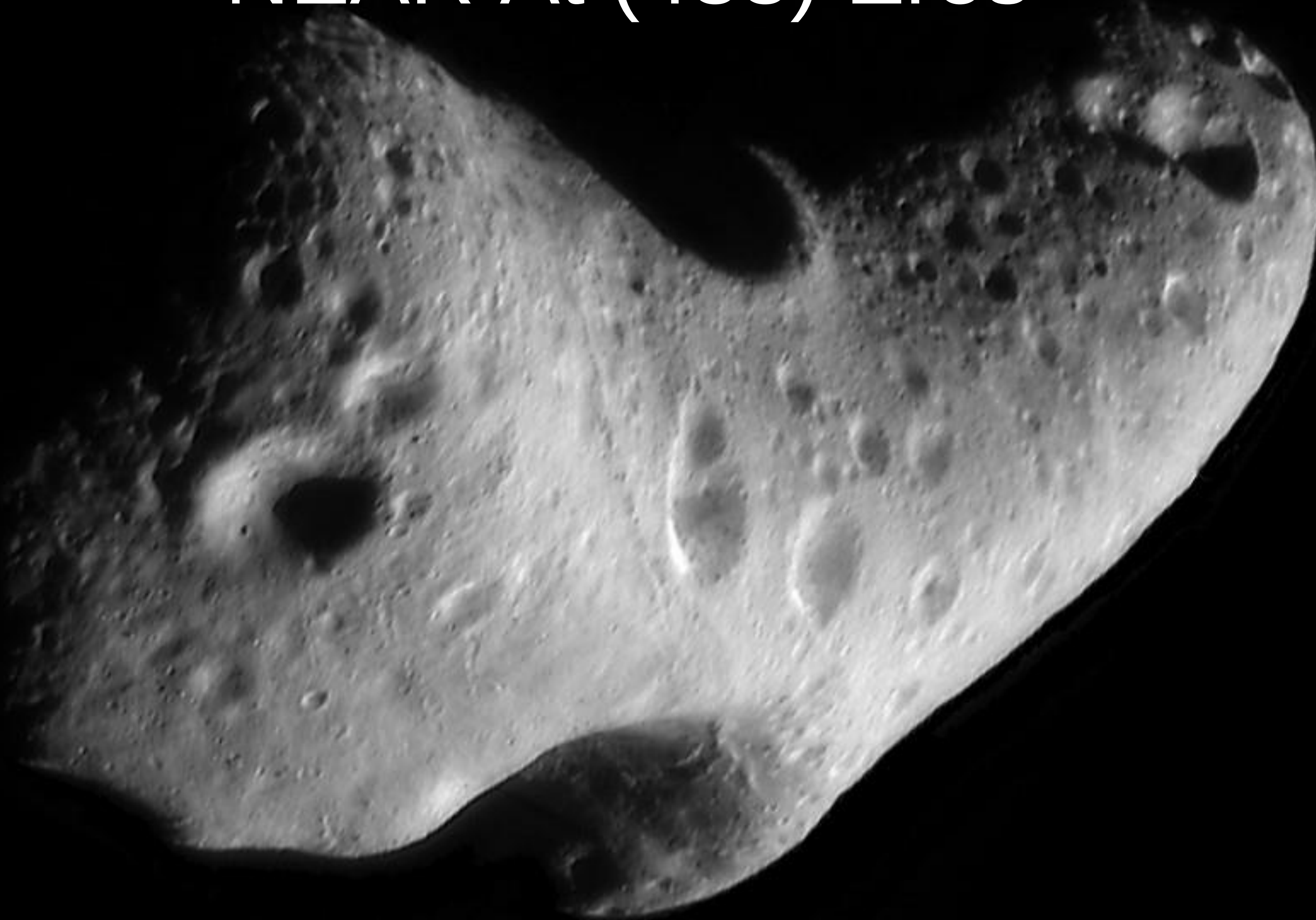
Distance 10,500 km

NEAR At (253) Mathilde

Distance: 2400 km

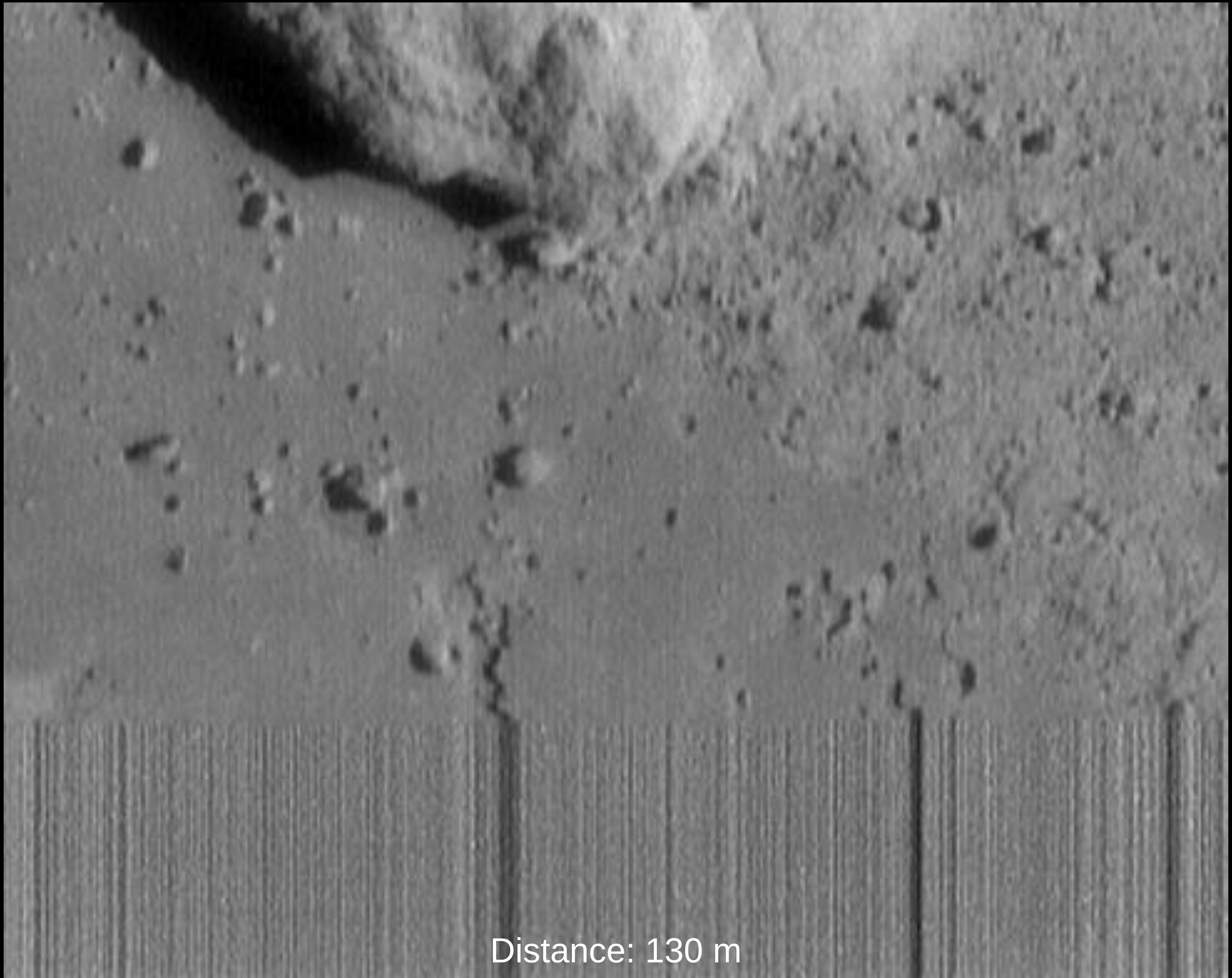
NEAR Approaching (433) Eros

NEAR At (433) Eros



Distance: 200 km

NEAR At (433) Eros



Hyabusa At (25143) Itokawa

Distance: ~10 km

Rosetta At (21) Lutetia

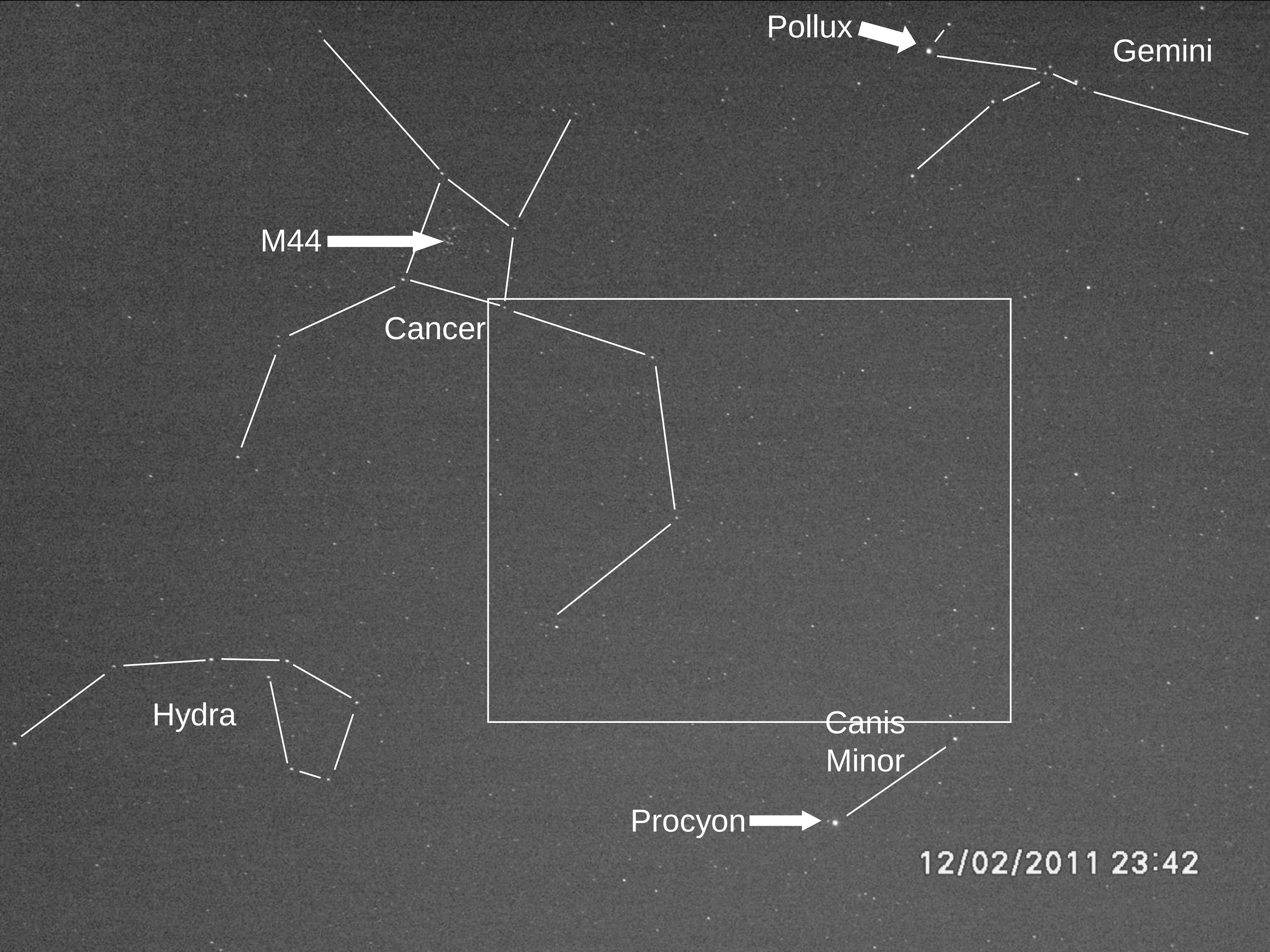
Distance: 3162 km

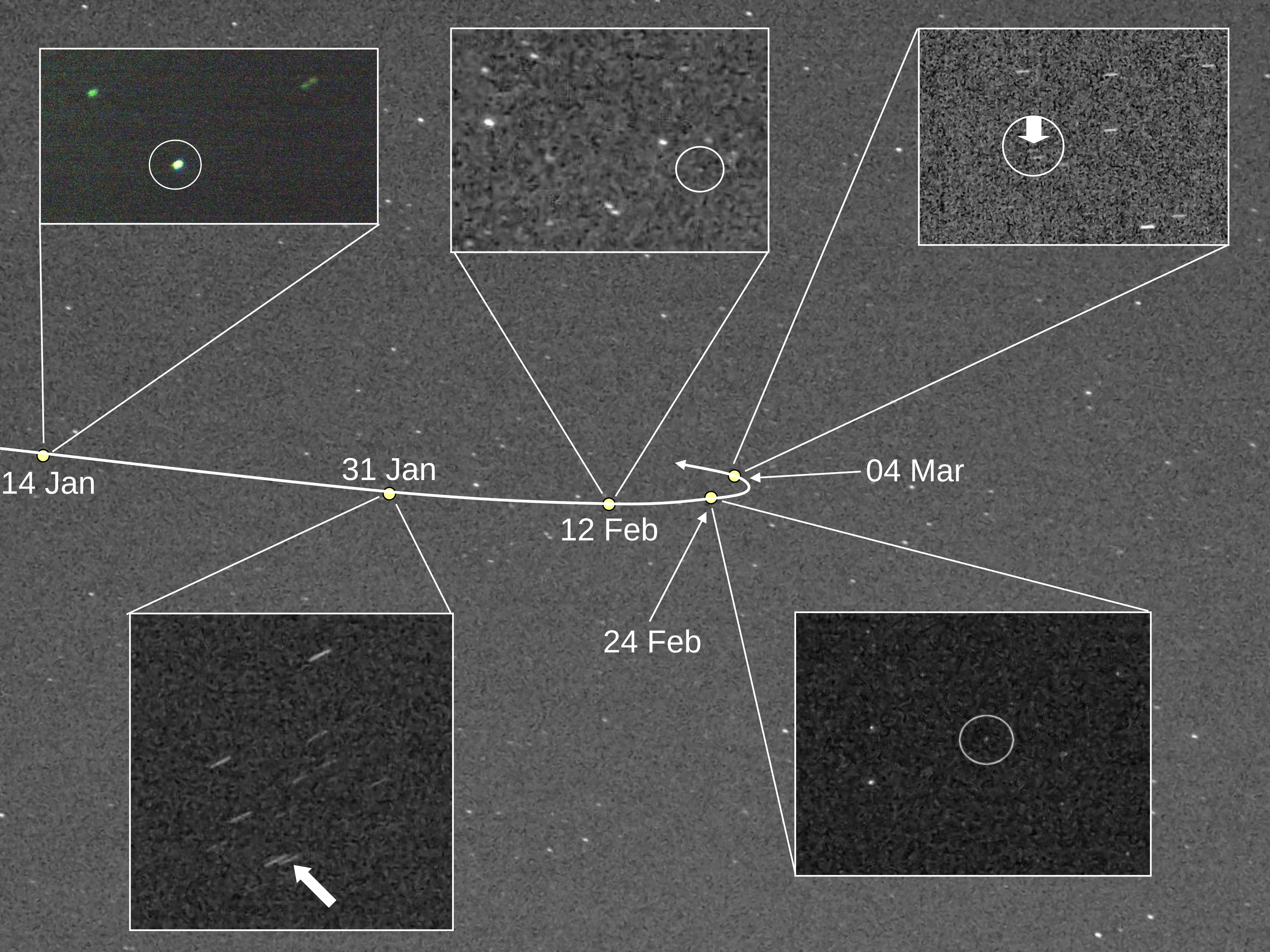
Asteroid Observing Project

Bright Asteroids 2011

Asteroid	Opposition	Opp Mag	Brighter than mag 9.5	Constellation
(7) Iris	2011 Jan 24	8.7	2010 Oct 12 - 2011 Mar 21	Cancer
(44) Nysa	2011 Feb 10	8.7	2011 Jan 13 - Mar 06	Leo
(3) Juno	2011 Mar 12	8.8	2011 Feb 01 - Apr 06	Leo / Virgo
(20) Massalia	2011 Mar 14	8.8	2011 Feb 15 - Apr 04	Leo / Virgo
(4) Vesta	2011 Aug 05	5.6	Always	Sagittarius / Capricornus / Aquarius
(192) Nausikaa	2011 Sep 02	8.3	2011 Aug 05 - Oct 08	Aquarius
(1) Ceres	2011 Sep 16	7.6	Always	Aquarius / Cetus
(1036) Ganymed	2011 Oct 29	8.3	2011 Sep 18 - Nov 13	Cassiopeia / Perseus / Andromeda / Triangulum
(29) Amphitrite	2011 Nov 05	8.7	2011 Sep 29 - Dec 13	Aries
(15) Eunomia	2011 Nov 29	7.9	2011 Aug 18 - 2012 Feb 12	Taurus / Perseus

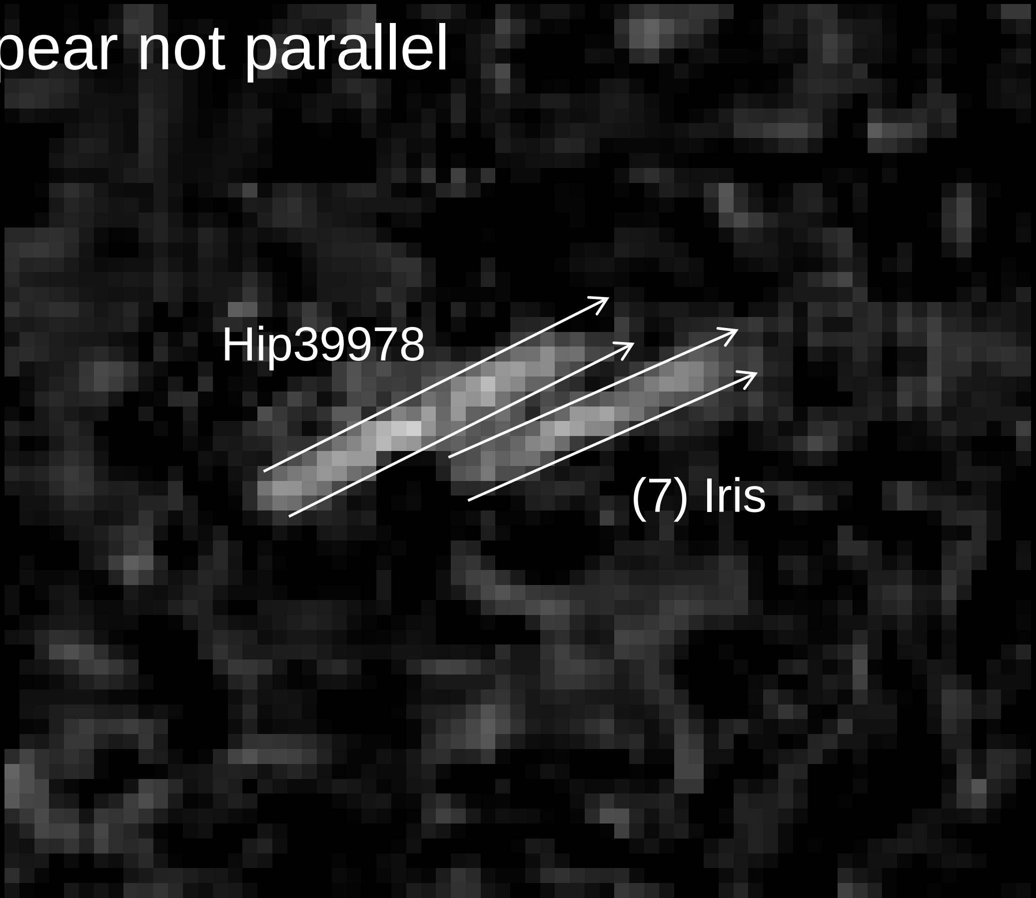
Star Field For (7) Iris


Pollux
Gemini
M44
Cancer
Hydra
Canis
Minor
Procyon
12/02/2011 23:42


14 Jan
31 Jan
12 Feb
24 Feb
04 Mar

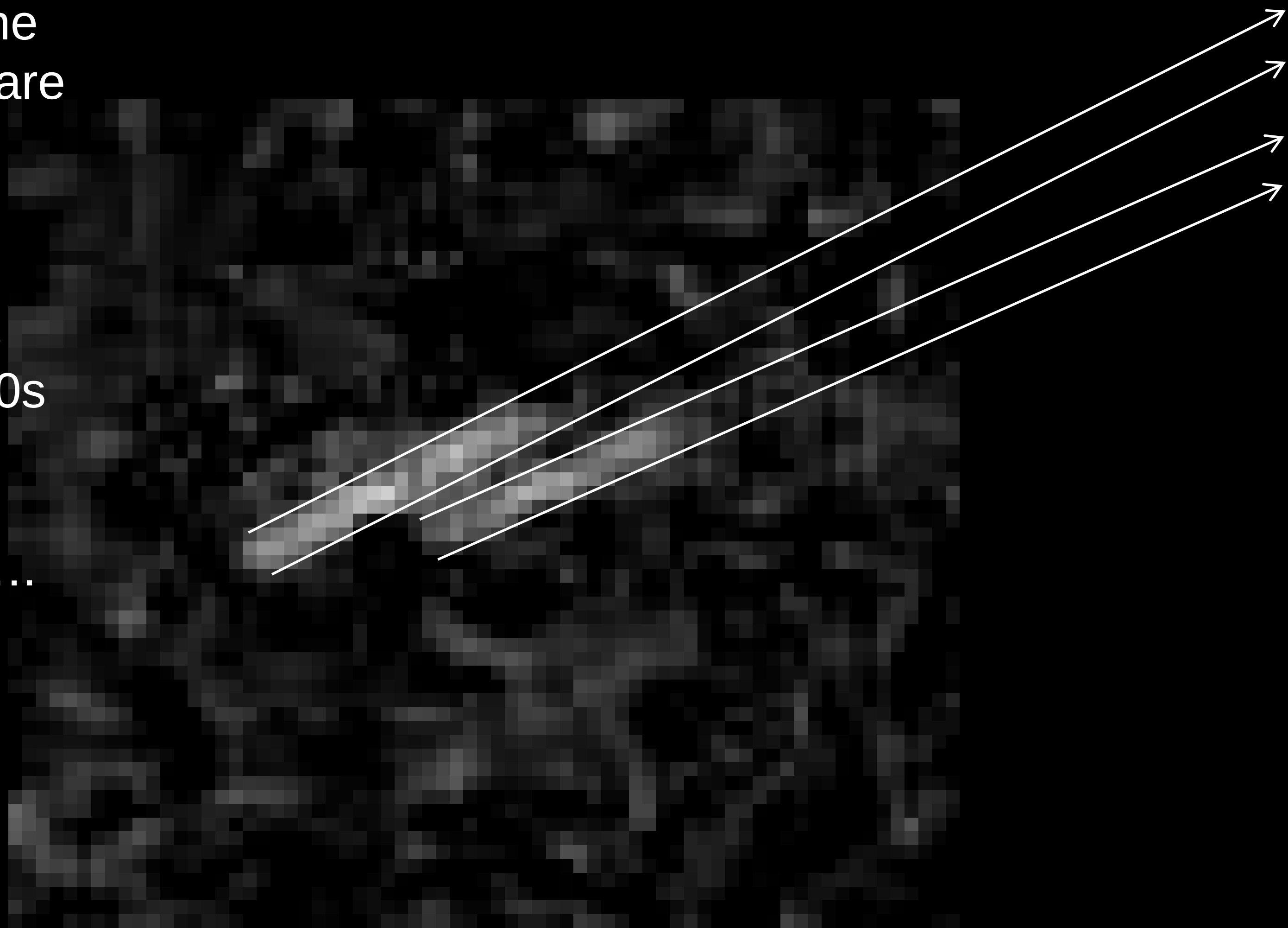
(7) Iris Motion, 31 Jan

- Image of 31 Jan under extreme magnification and contrast stretch
- Trails formalised by “best fit” arrows fitted by eye
- Trails appear not parallel

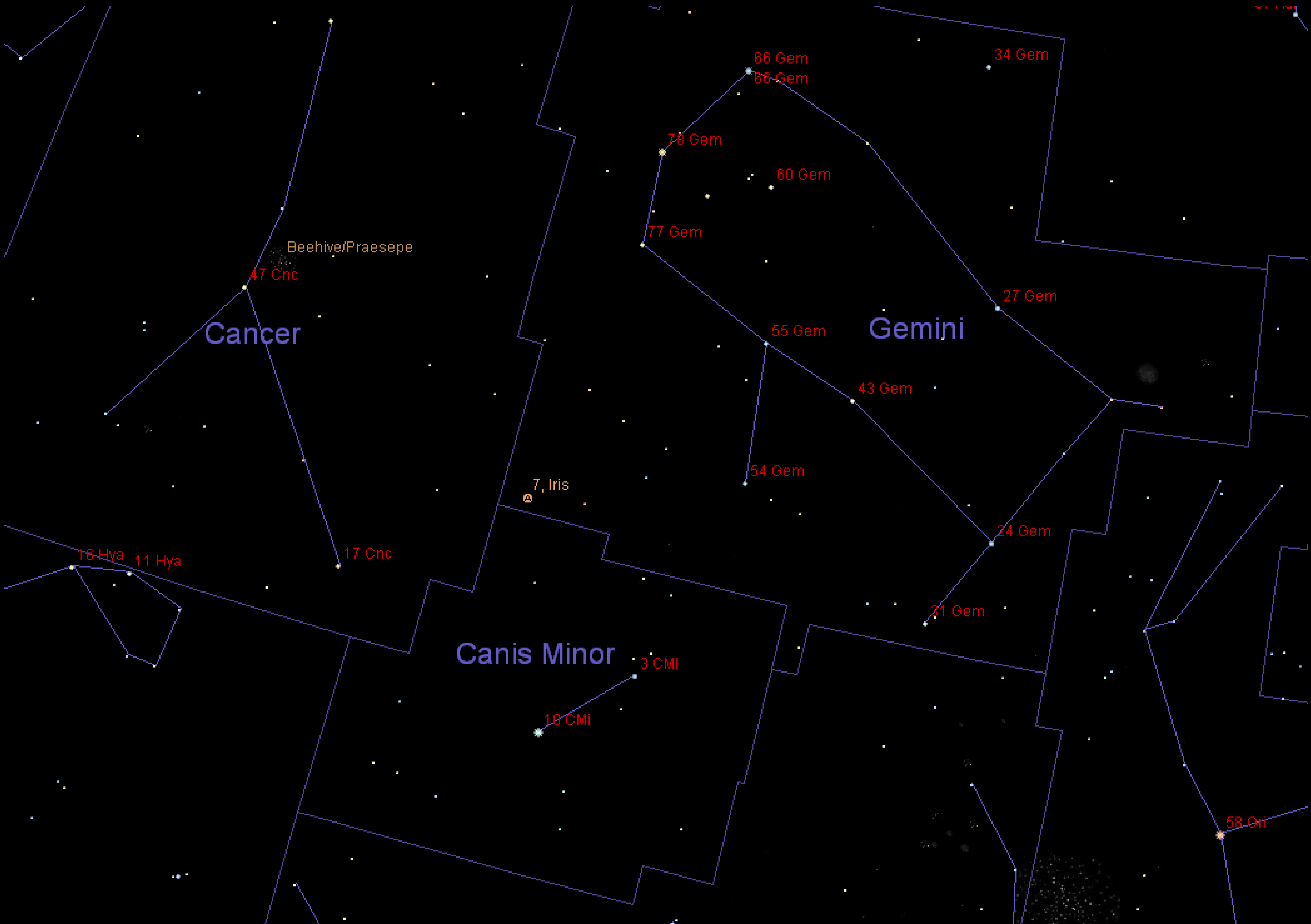


(7) Iris Motion, 31 Jan

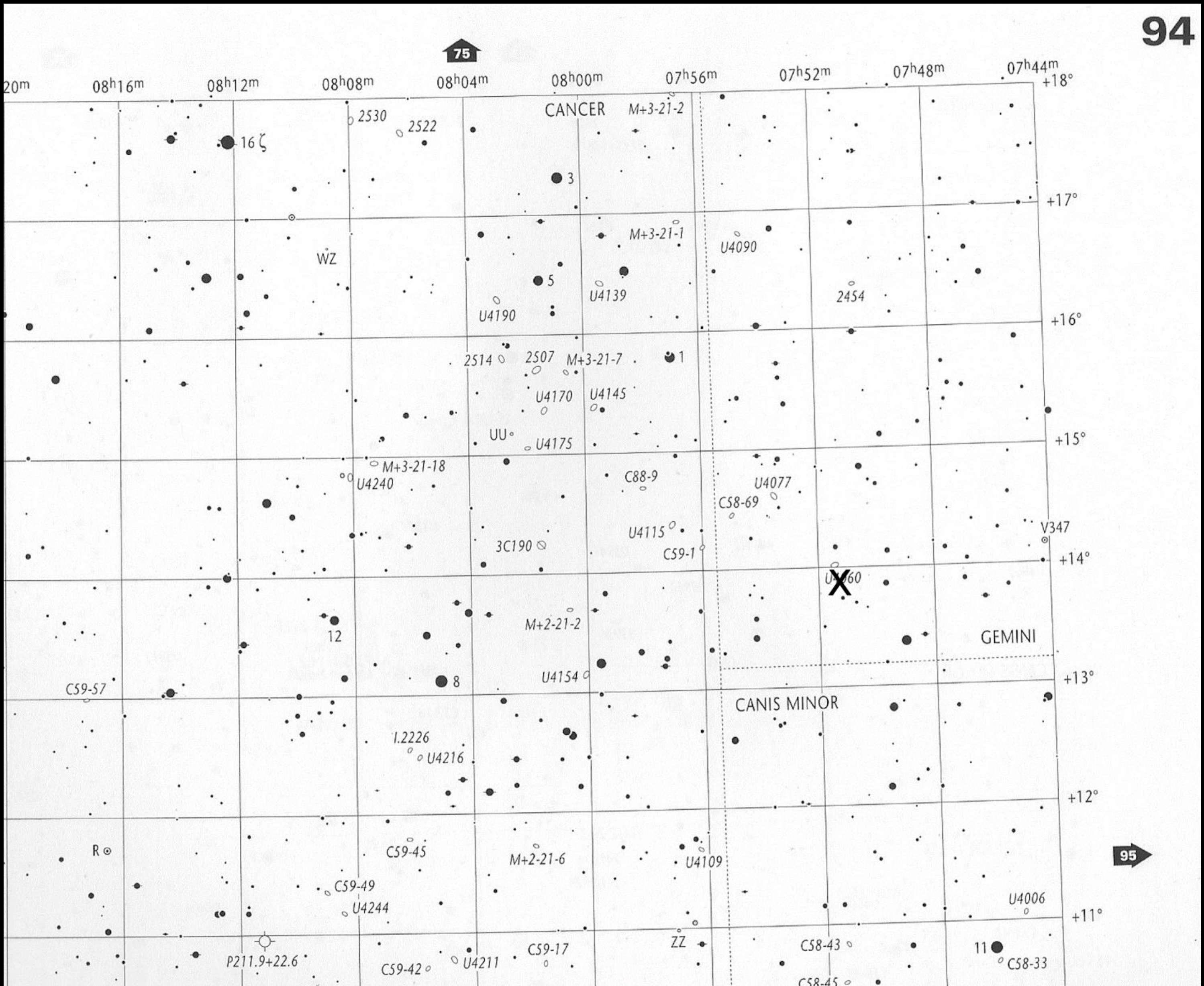
- Extending the motion arrows shows that the trails clearly are not parallel
- But the apparent motion of Iris during the 8.0s exposure is only 32 milli-arcseconds….



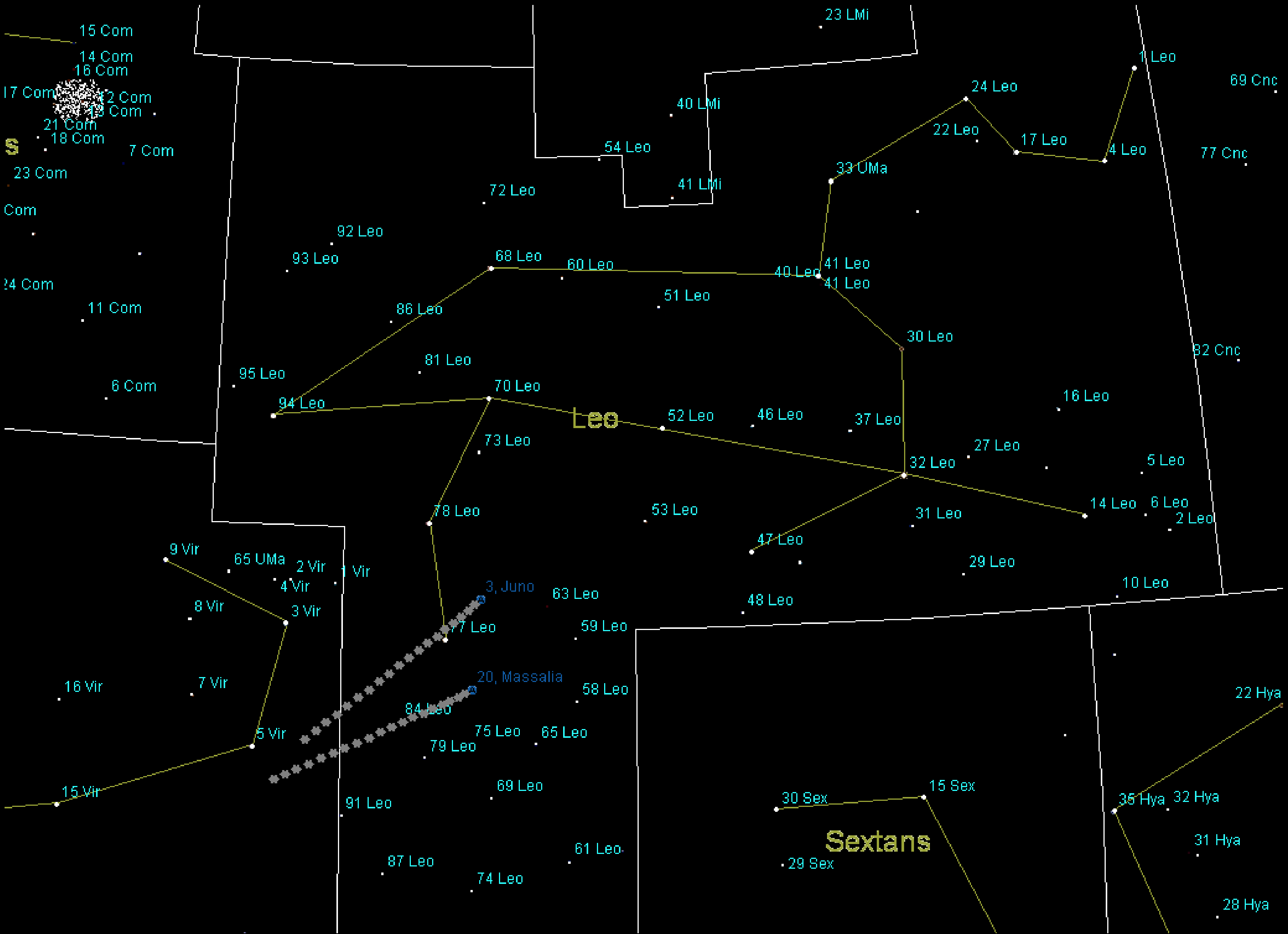
(7) Iris, 09 March 2011



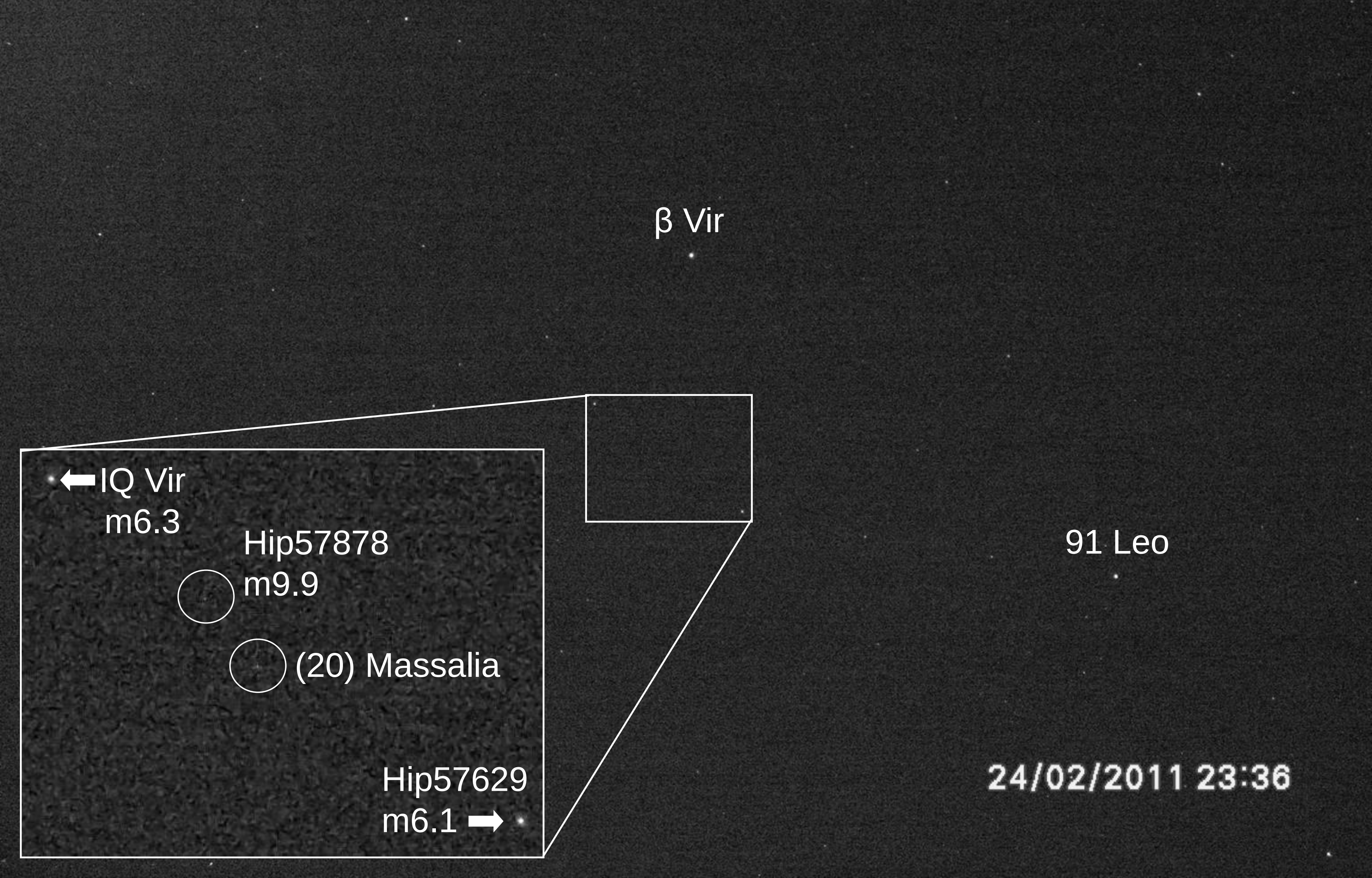
(7) Iris Finder Chart



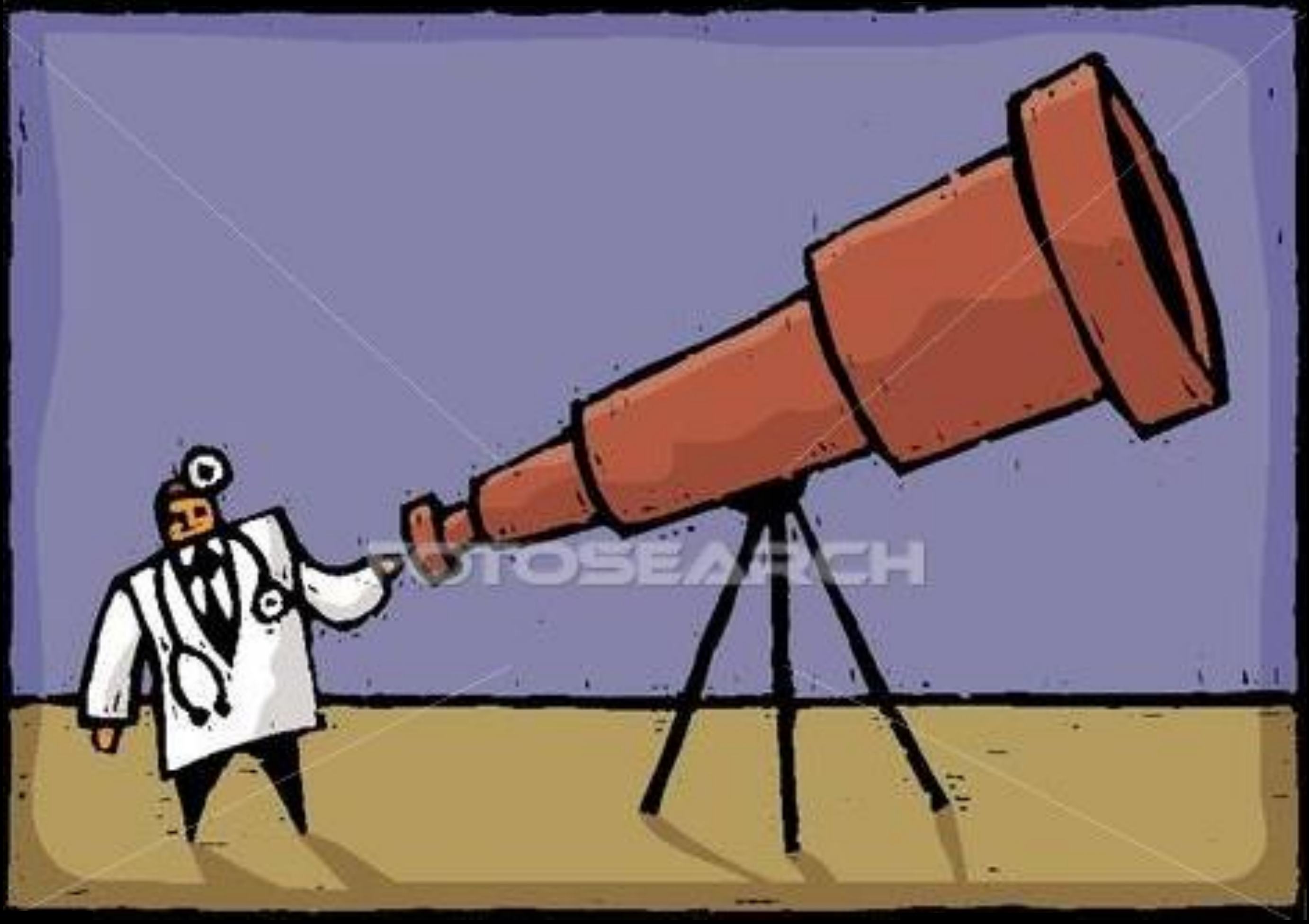
(3) Juno & (20) Massalia



(20) Massalia, 24 Feb 2011



Please Observe!



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