Historic Great comets

1600 -2010

Great comets – Ancient observations / theories

Have inspired civilizations over millenia

Ancient Greeks

-Thought that comets were atmospheric objects
- (Aristotle 3rd cent BC)

-Ancient Romans

-Believed comets were celestial in nature(Seneca 1st AD)

-Europe – maintained Aristotelian view of cosmos into
- Medieval times

-Tycho Brahe/ Kepler – proved comets are in orbit around Sun

Wood-cut from German Pamphlet (Great comet of 1556)

What is a Historic Great Comet ?

3 main properties for great comet :

(a) Closeness to the Earth

(1861 Great comet : 0.82 au from Sun / 0.13 au from Earth)

- visible for many hours in dark sky / large developed dust tail

(b) Closeness to the Sun

(Kreutz sungrazers : over 0.8au from Earth / 0.05au from Sun)

- extremely conspicuous in close perihelion passage

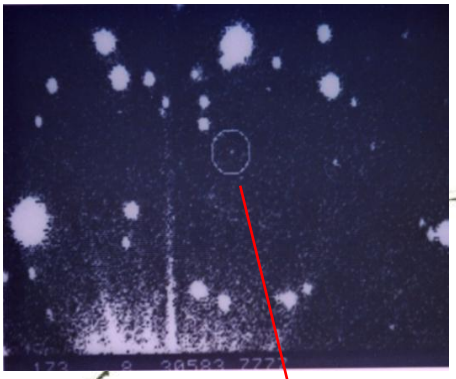
(c) Very large and active

(Great comet of 1811 / Hale Bopp)

- quite rare for historic great comets

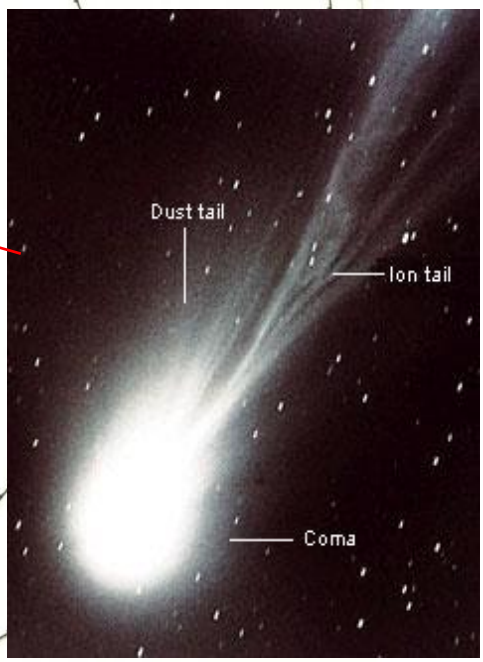
- naked eye visibility for over 100 days (260 days for 1811 comet)

Types of comet orbits – Short Period



Comet Halley recovery image (Oct 1982)
5.1m Palomar telescope / CCD camera
Magn +24.2 (bright star at bottom Magn+21)
Comet 11Au from Sun

The entire orbit of Halley's Comet among the planets.



Comet Halley showing
Developing coma/gas
& ion tails

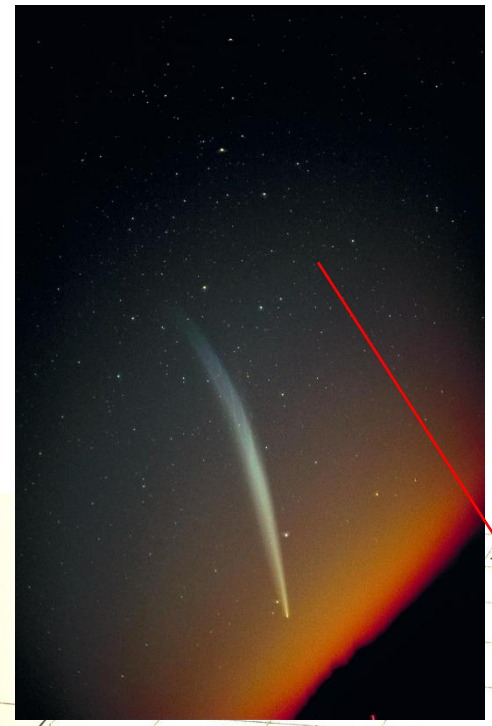
Comet Period < 200 years

Types of Comet Orbit – Long Period

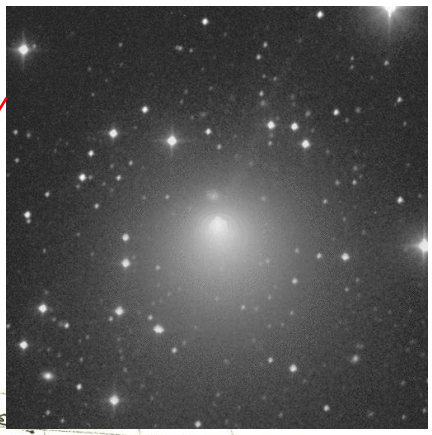
Period > 200 years –

Returning comets (eg Hale Bopp) – 4300 year period

Fresh (dynamically new) Oort comet – 100,000 year period



Comet Ikeya – Seki close to sun
(long period comet)



Comet Encke
(short period comet)

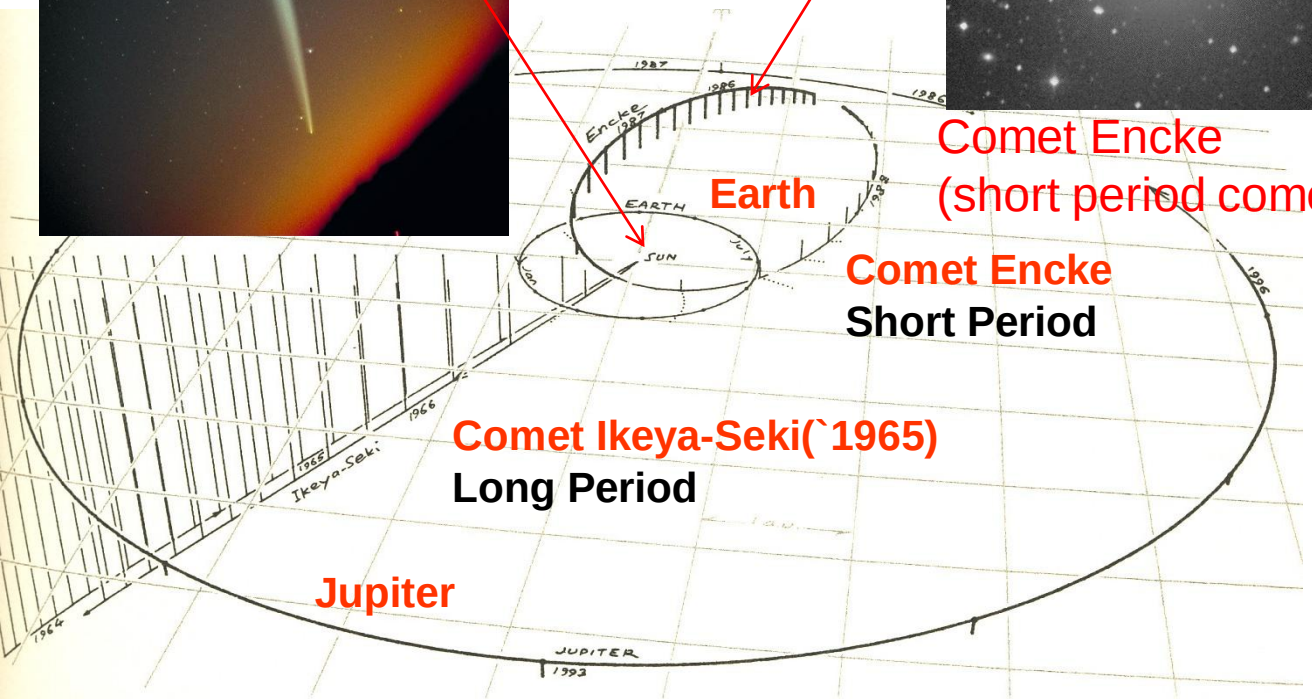


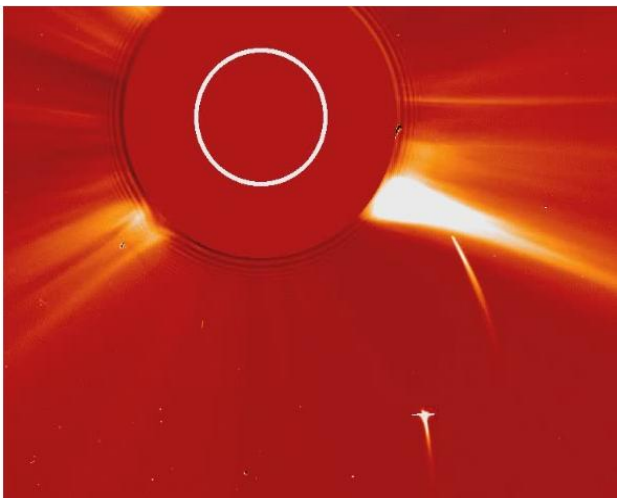
Diagram of the orbits of Comet Ikeya-Seki (long-period comet) and Comet Encke (short-period comet).

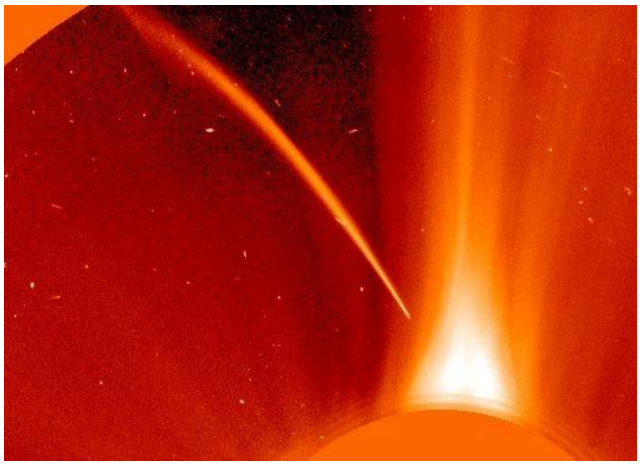
Sungrazer Comets

Close perihelion passage to Sun (within few thousand km)

Influence of Sun – Evaporation of comet ices/ tidal fragmentation

Examples of Sungrazing comets(SOHO) :





SOHO images

Kreutz sungrazing comets :

--Fragments of one giant comet – great comets of 1843/1882/1965 (75 mile diameter nucleus- fragmented 10,000 year ago)

--plunge into sun / disintegrate during perihelion passage

---usually are high inclination comets – perihelion < 2AU

Gravitational perturbations – reduce perihelion to low level

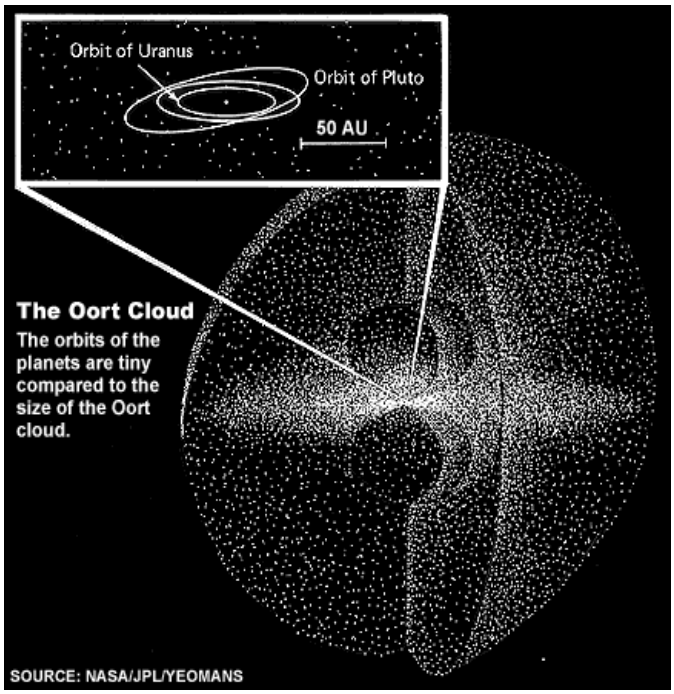
--- future great comet – likely to be Kreutz Sungrazer

----- Great comet of 1680 –sungrazer – Newton verified Kepler`s equations of orbital motion

The Origin of Comets - Oort Cloud

Immense spherical cloud surrounding solar system

Comets within Oort cloud –weakly held by Sun- perturbed by nearby stars
(solar influence out to about 2 light years)



Oort Cloud –40xMass of Earth

Source of periodic comets

Average distance – 44,000AU from sun

Discovered by Jan Oort(1950)

Comets in Oort cloud :

-Icy balls of H_2O / CH_4 / NH_3

- & rock /dust

Oort Cloud formation :

Formed 4.5 billion years ago from icy/rocky debris (planetesimals)

Planetesimals ejected into large orbit by gravitational interaction with Jupiter

Ejected debris either escaped from solar system / populated Oort cloud

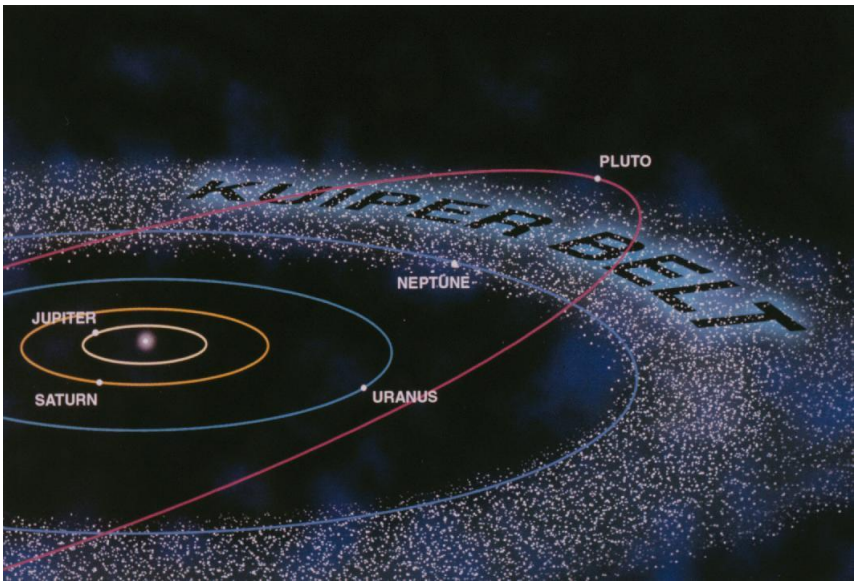
Comets from Oort Cloud:

Gravitational interaction between comet & passing star or molecular cloud

Causes comet to fall into solar system on long period elliptical orbit

The Origin of Comets – Kuiper Belt

Resevoir of dormant icy comets just beyond Neptune (30- 1000AU) dist)



Orbital features:

Orbital direction same As planets

Slightly inclined orbits

Source of short period comets

1110 Kuiper belt objects known (10-50km) – millions more smaller than 100m

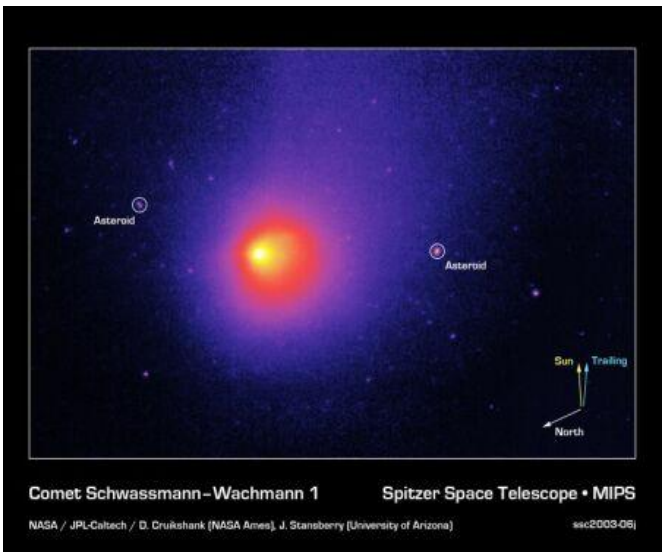
Kuiper belt object characteristics

icy pristine objects – mainly water / methane

Gravitational interaction with Neptune / Uranus –

- (i) eject Kuiper belt object into Oort Cloud / Interstellar space

(ii) send object into inner solar system as short period comet (unstable orbit)



Kuiper Belt objects:

Show Presence of coma

-Chiron (170km diameter)

-20x size of Halley comet nucleus

-Potential spectacular comet

-

Comet Structure – the Nucleus

Irregular shaped body – about 10 to 20 km in size

Nucleus composition – ices{H2 O,CO2,NH3} / stony & metallic solids surrounded by dark crust - dirty snowball

Dormant in outer solar system

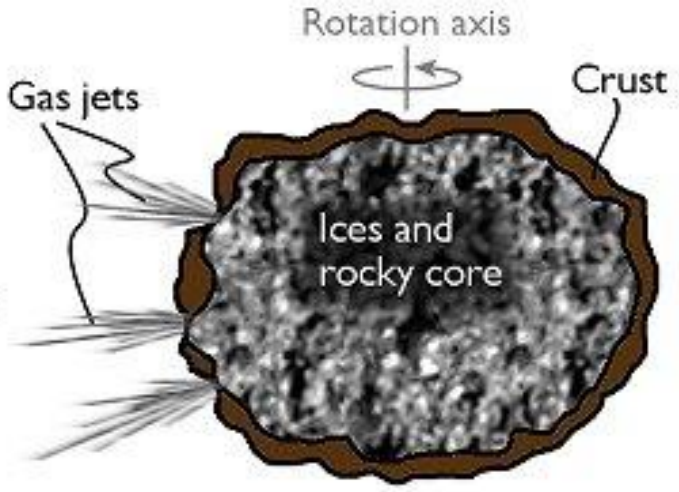
Close to Perihelion :

(1) Gases evaporate in jets

Venting through crust

(2) Material in jets form coma

and comet tails



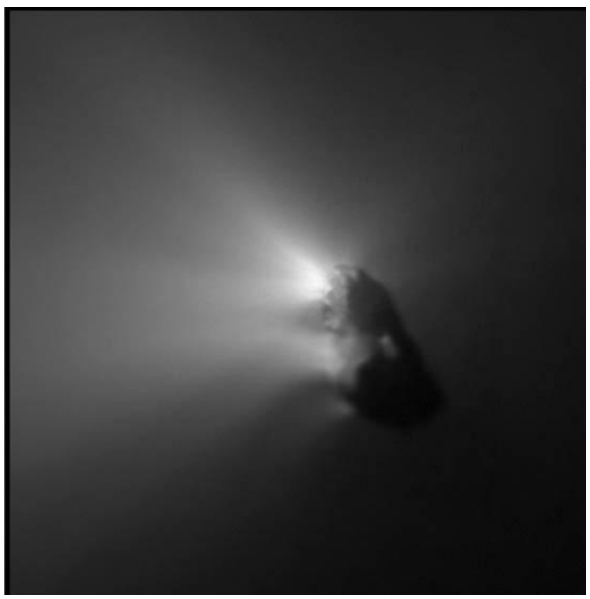


Image of Halley`s Comet
(Giotto Probe 1986)

Surface of Comet nucleus :

Dark material (albedo of 4%)

Dust / complex organic molecules

Temperature of outer layers of 330K

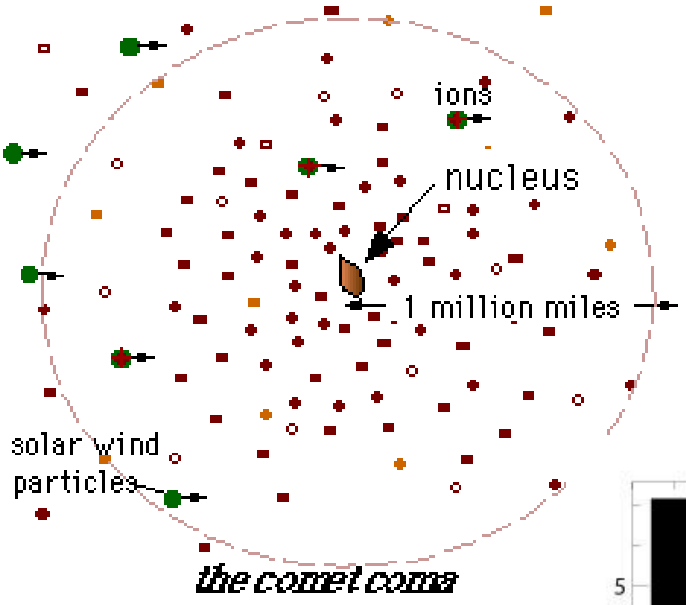
Gas jets generate

Non-gravitational forces
(influence on comet orbital period)

Complex rotation of nucleus – rotation / spin axes and precession

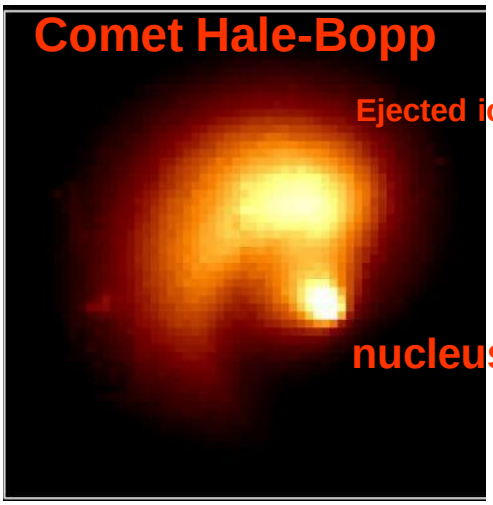
Comet Structure – the Coma

Cometary ice evaporation – formation of atmosphere around nucleus(coma)



Coma characteristics :

- **Very low density**
- **Millions of miles in extent**
- **Neutral Coma particles excited by solar wind and ionized .**

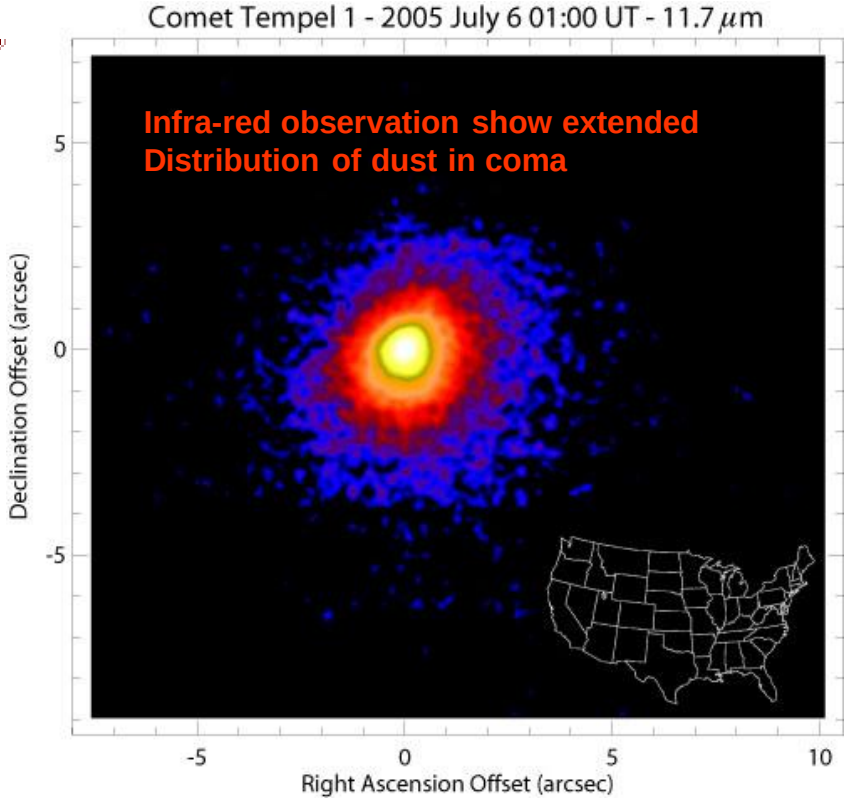


Hubble image showing :

Ejection of icy crust from nucleus due to evaporation/ comet rotation

Distribution of ice particles around Nucleus in coma

Cloud of material in coma is 3.5x Fainter than nucleus



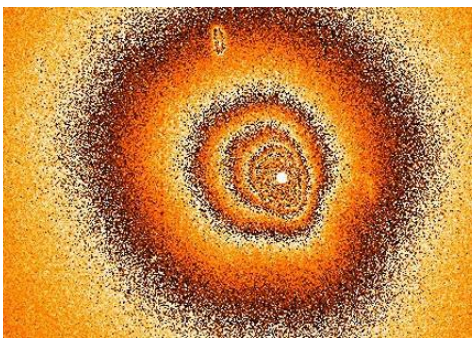


Image of Central part of Hale Bopp nucleus :

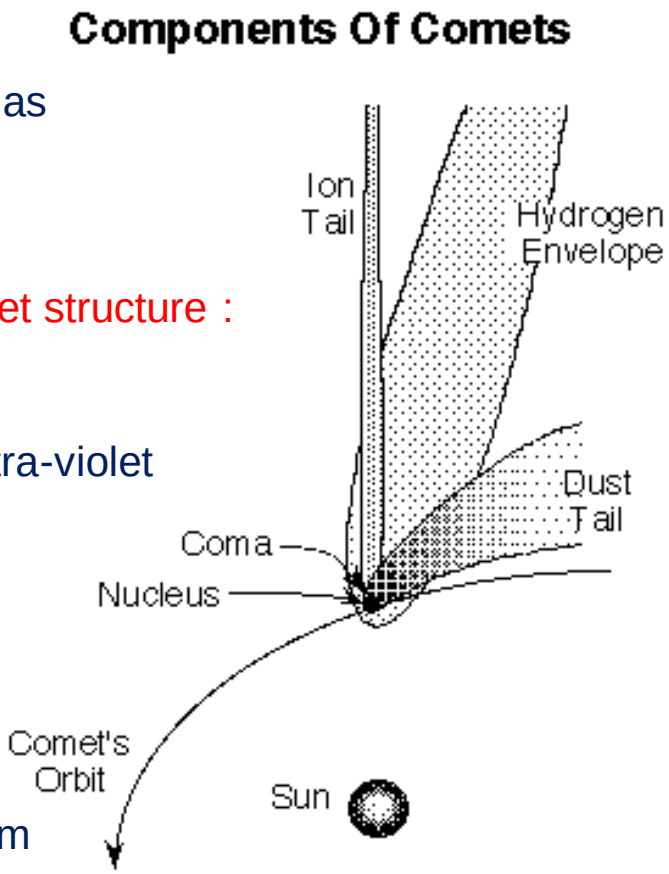
Distribution of molecules / dust

Fan / Jet structures in coma

ESO observatory

Comet Structure – Gas / Ion Tails

Dust / ion tails Comet tails form as Comet approaches the Sun



There are 3 features in the comet structure :

Hydrogen Envelope
-Hydrogen molecules absorb ultra-violet Light and form large envelope (invisible from Earth)

Ion Tail (Type I)

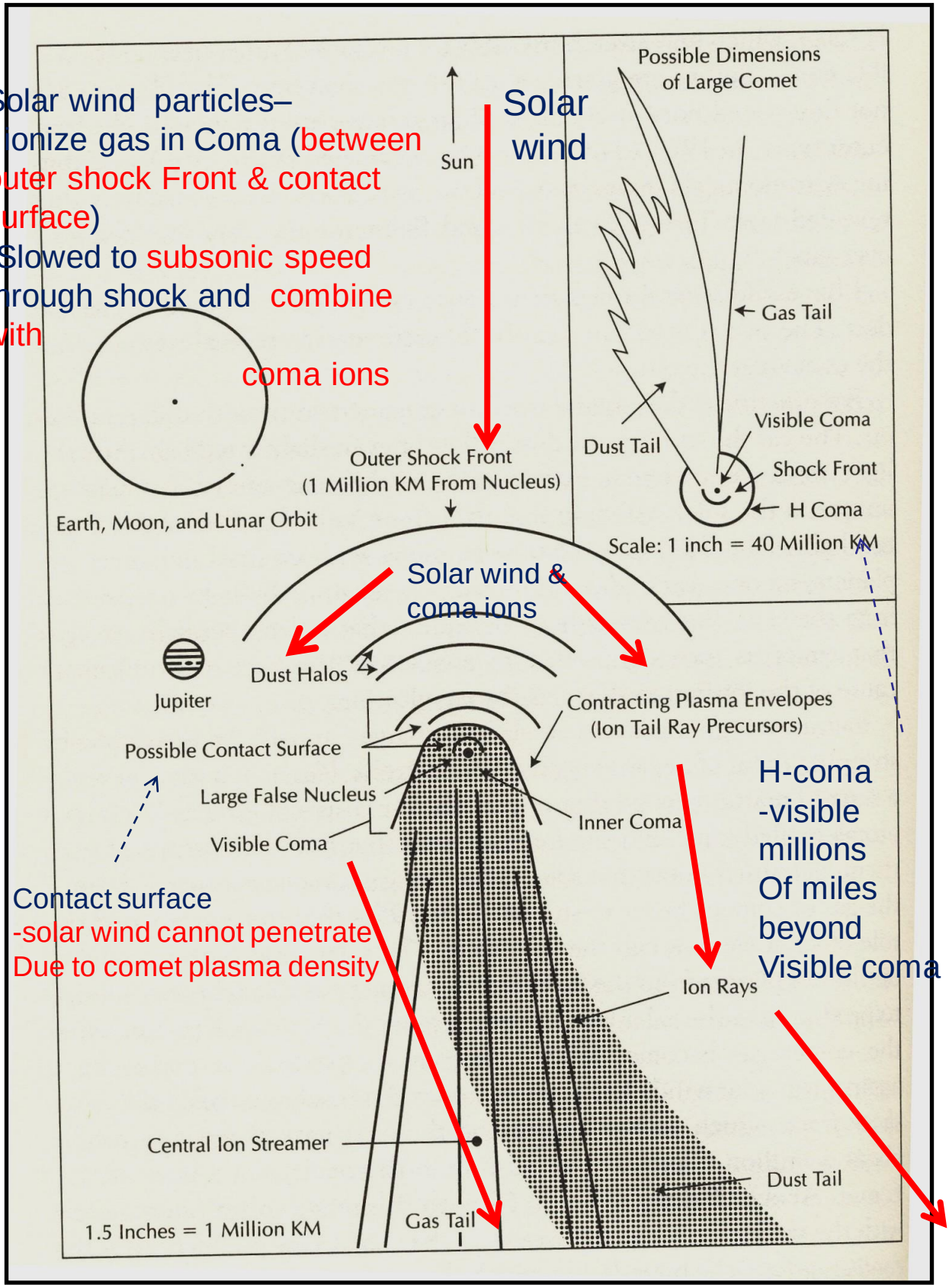
Low mass ions released from coma are accelerated away from Nucleus – directly away from Sun
Strongly affected by solar wind-

Dust Tail (Type II)
The dust particles are left behind Along the comet`s orbit and form a curved tail
-(carbon- rich /
-Silicate material) –

-(Mabe over 10 million
-Miles in length)

Comet P1 McNaught

Comet Structure : H Coma / Shock Fronts



Halley`s Comet through the Ages – 1404BC – 1682AD

Perihelion distance – 0.6AU)

Halley`s comet (Bayeux Tapestry) 1066AD`

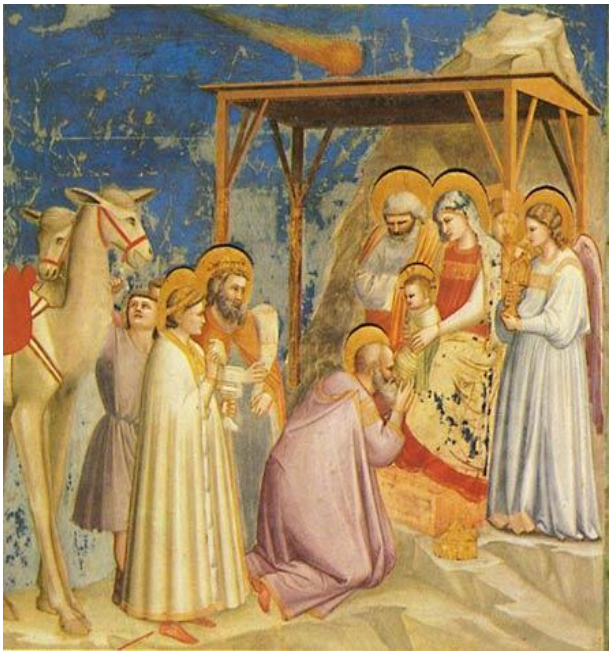
One of the most impressive returns of Halley` comet
-Passed only 0.1au from Earth after Perihelion (magn-4)
-Tail spanning over 90deg (visible all night)

Halley`s comet (Adoration of Magi) – Giotto fresco

1301 (Giotto`s Christmas star)

pre-perihelion encounter
(comet only 0.18au from Earth)
Comet Magn+2 (tail 50-70deg)

-Giotto painted Nativity scene
-In Arena Chapel(Padua) in 1306
(realistic comet)

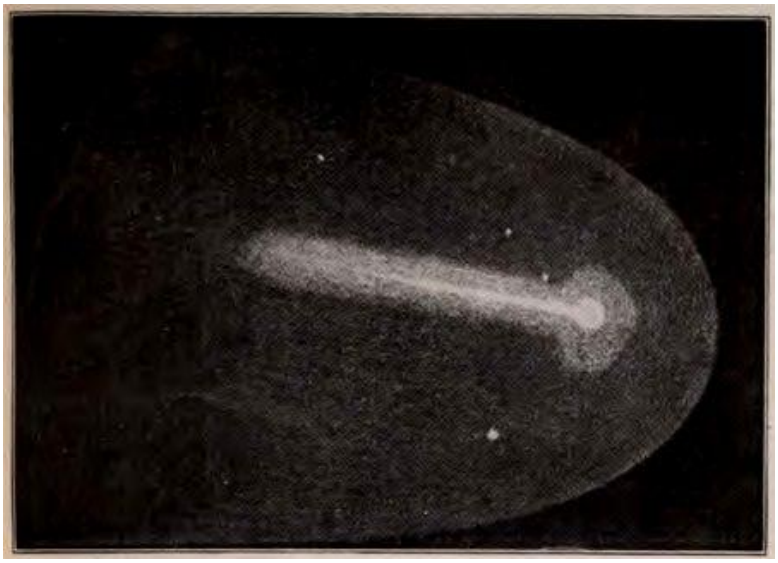


Halley`s Comet through the Ages
1680AD – 1836AD

1682 Return – seen by Halley and Newton (Magn 0-1) 30deg tail

1759 – first predicted return – only 0.122au from Earth
(seen by Messier – best seen in southern hemisphere)

1835 – seen and sketched by Sir John Herschel (southern hemisphere)
fairly close (0.19au) to Earth before perihelion (Nov 1835)



After Perihelion – outburst of comet
1.5AU from Sun

-Brightened by 2 to 3 magnitudes

-- enormous halo(million miles in 3 weeks)

-Likened to transparent gauze

Halley`s Comet through the Ages
1910AD

Close approach (0.15au)
& bright (magn -1.5)

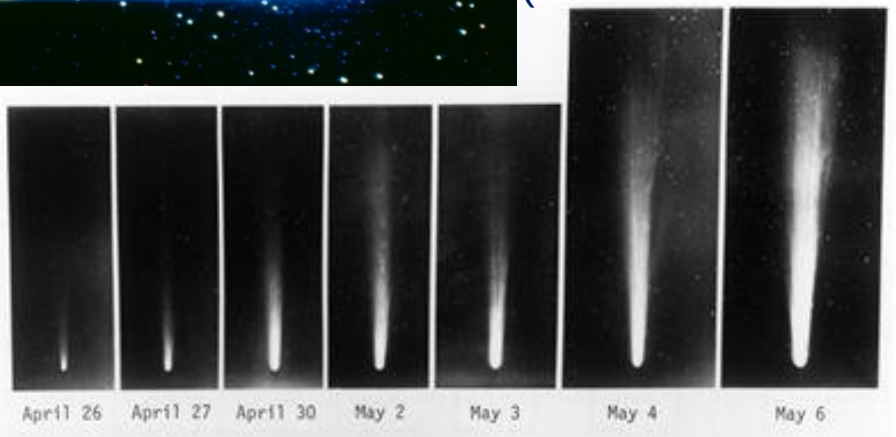
Earth passed through gas tail
& leading edge of dust tail
missed by 240,000 miles

Last seen by Barnard on
May 23 1911 at 5 au from Sun

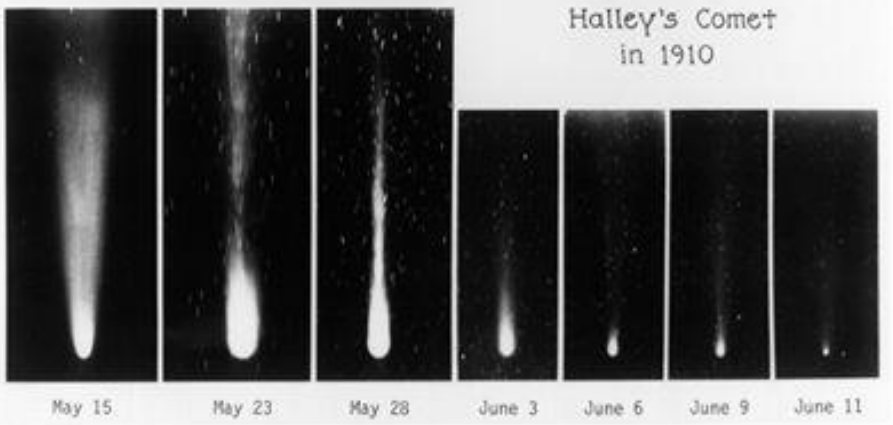
Spectroscopic analysis of tail
- Discovery of cyanogen

Disconnection events seen in tail –effect of Solar wind

Digitized / colourized image from 1910
(Kitt Peak Observatory)



Sequence of
Images from 1910
Showing
Comet Halley
(Apr1910-Jun1910)



Halley`s Comet through the Ages

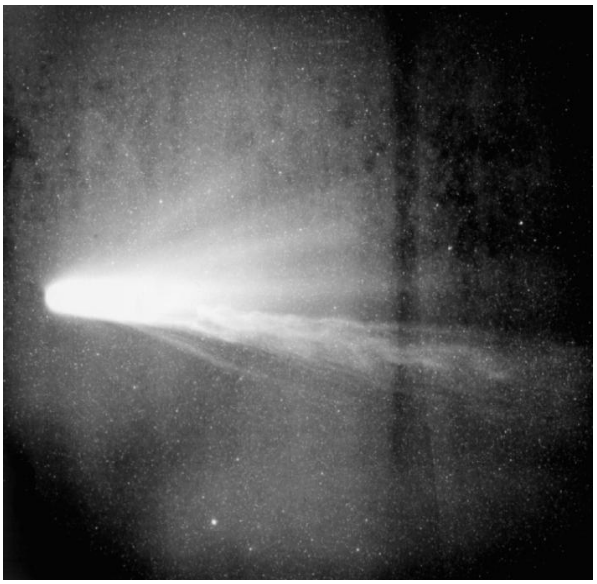
1986AD

Halley`s comet(1986)

Halley`s comet nucleus (imaged by Giotto)

5 spacecraft sent to investigate Halley`s comet :

Giotto (Jul 85) / Vega 1&2(Mar 86- USSR) / Sagikake &Suisei(Japan)



Ion Tail Detachment event (Apr 1986 (Cerro Toledo Observatory)

Halley Comet Events

CCD Recovery image(Mag24)
(Oct16 1982 – 11 AU from Earth)

Fist visual sighting (Mag19.6)
(Jan 23 1985 – 4.3AU from Earth)

First Naked Eye sighting
(Nov 8 1985) – 0.9AU from Earth

Perihelion – Feb 9th 1986

Giotto Flyby - Mar 14 1986

Closest Approach to Earth
(Apr 1986)- 0.4AU (dust tail 30-50deg)

Final naked eye sighting
(May 29 1986 – 1.7AU from Earth)

Great Comets (16th – 19th Century)

(a) 1577

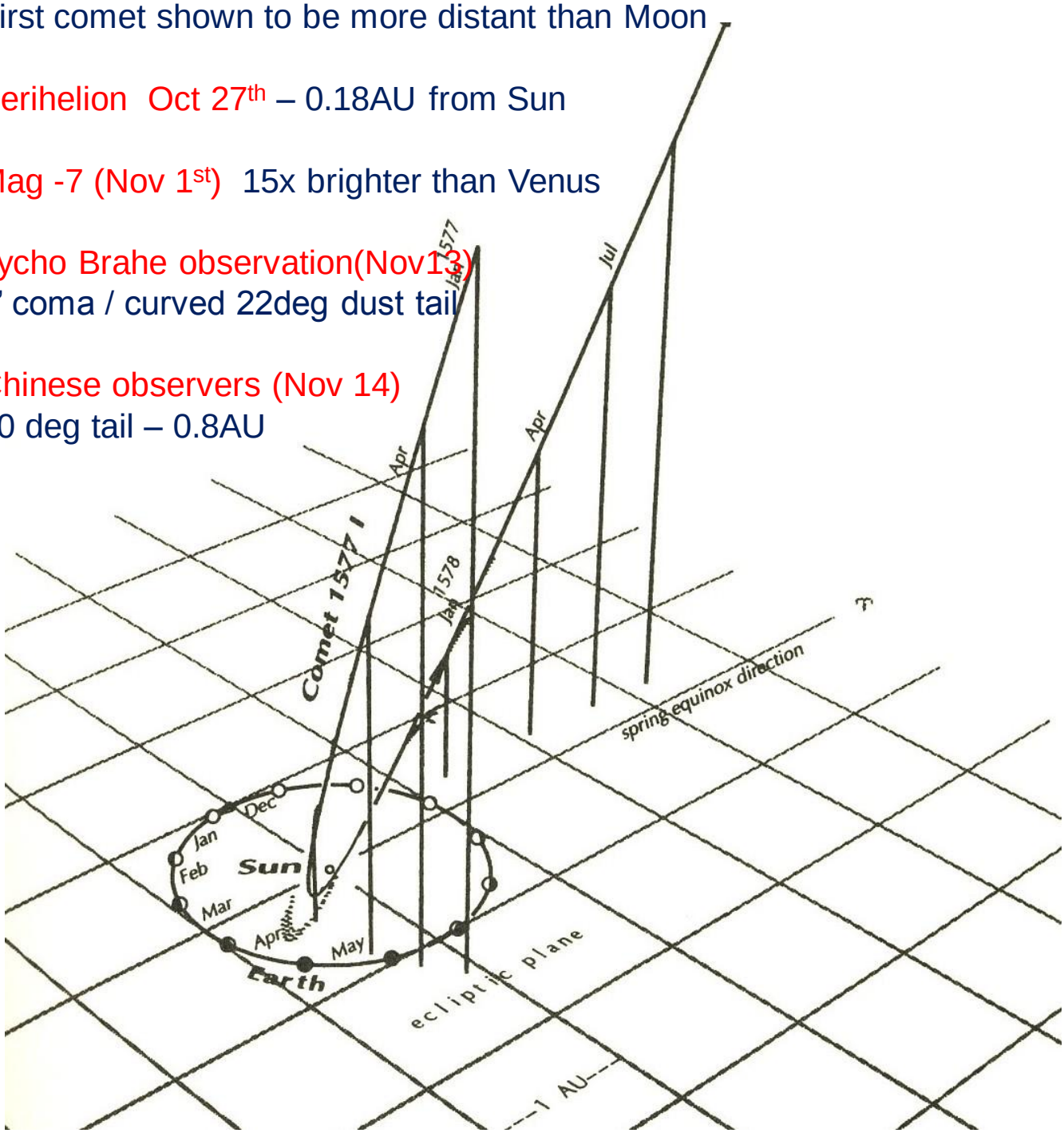
First comet shown to be more distant than Moon

Perihelion Oct 27th – 0.18AU from Sun

Mag -7 (Nov 1st) 15x brighter than Venus

Tycho Brahe observation(Nov13)
8' coma / curved 22deg dust tail

Chinese observers (Nov 14)
50 deg tail – 0.8AU



Most famous observer - Elizabeth I

Great Comets (16th – 19th Century)

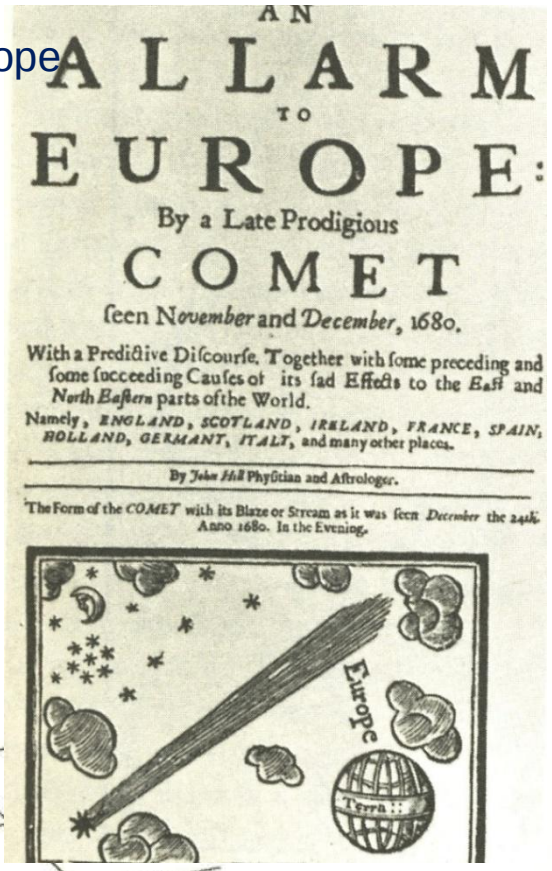
(b) 1680

First great comet discovered with telescope

Perihelion : only (Earth-Moon) distance from Photosphere

Famous observers:
Flamsteed (Dec20) – Greenwich
(tail halfway across sky – like sabre)

Issac Newton (Feb 18th 1681)
(2.2 au from Earth)


AN
ALLARM
TO
EUROPE:
By a Late Prodigious
COMET
ſeen *November* and *December*, 1680.

With a Predictive Diſcourſe, Together with ſome preceding and ſome ſucceeding Cauſes of its ſad Effects to the *Eaſt* and *North Eaſtern* parts of the World.

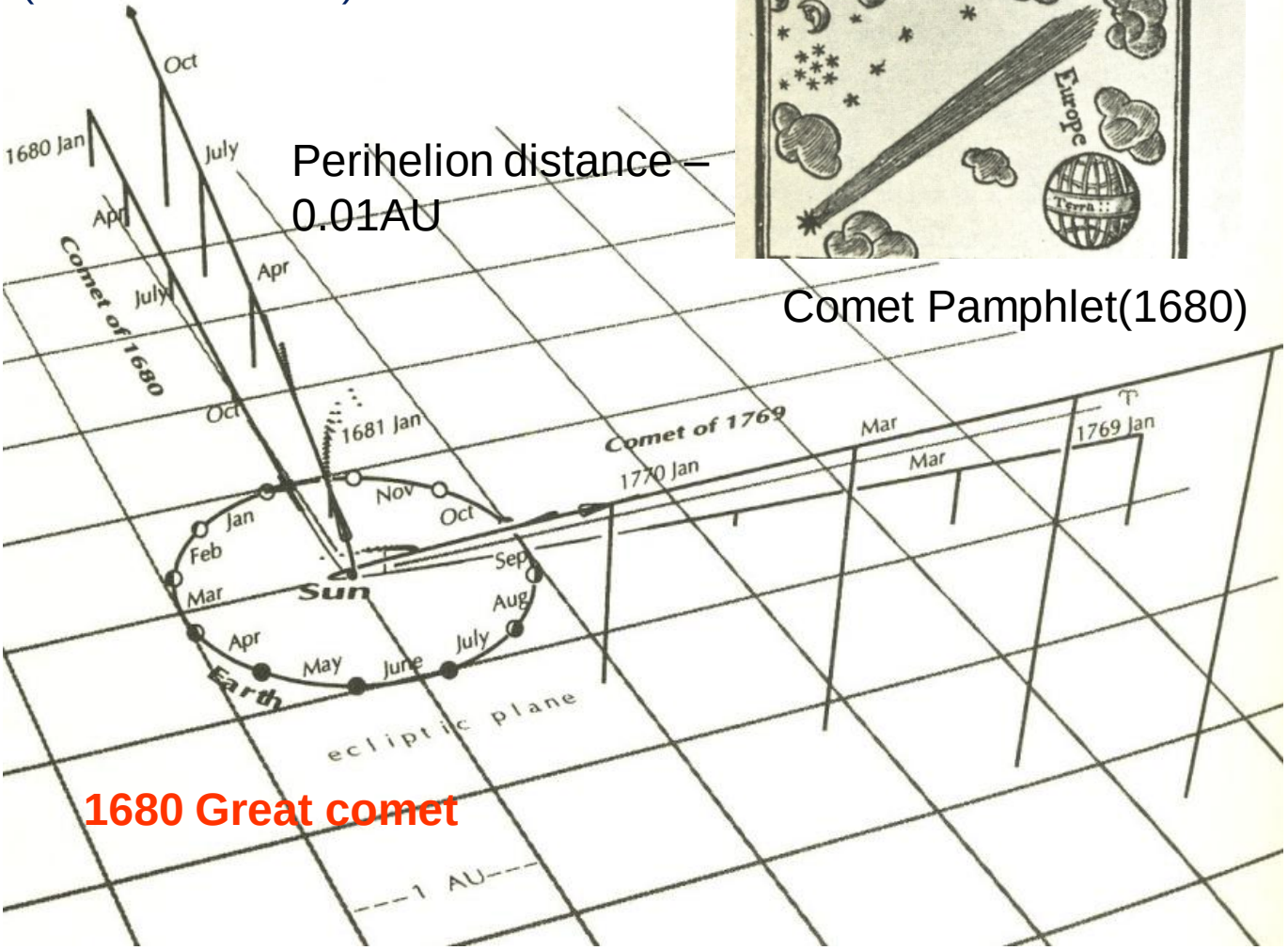
Namely, *ENGLAND*, *SCOTLAND*, *IRELAND*, *FRANCE*, *SPAIN*, *HOLLAND*, *GERMANY*, *ITALY*, and many other places.

By *John Hill* Phyſician and Aſtrologer.

The Form of the *COMET* with its Blaze or Stream as it was ſeen *December* the 24th. Anno 1680. In the Evening.

Comet Pamphlet(1680)

Perihelion distance – 0.01AU



1680 Great comet

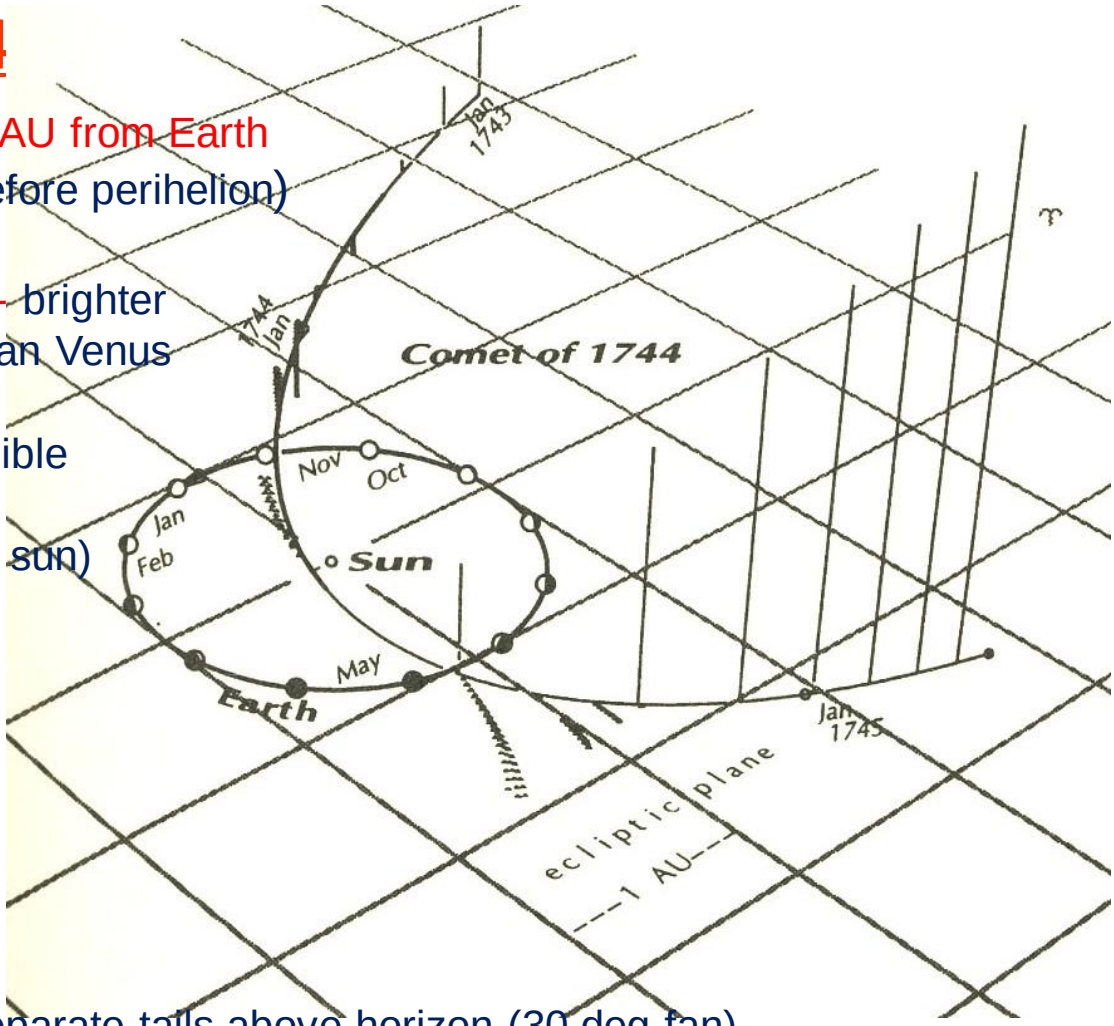
Great Comets (16th – 19th Century)

(c) 1744

Spotted at 1AU from Earth
(3months before perihelion)

Feb 1 1744- brighter
than Venus

Feb 28 – visible
In daylight
(12deg from sun)



Mar 6 – 5 separate tails above horizon (30 deg fan)
(comet head 20 deg
below horizon)

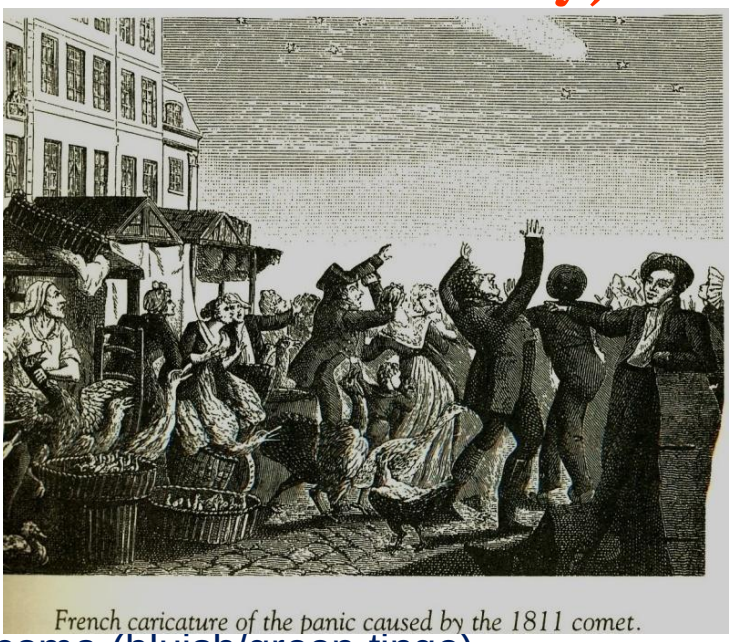
Mar 18 – tail 90deg
Across sky

5 months of naked
Eye visibility

Greatest intrinsic
Brightness of any
sungrazer

Great Comets (16th – 19th Century)

(c) 1811



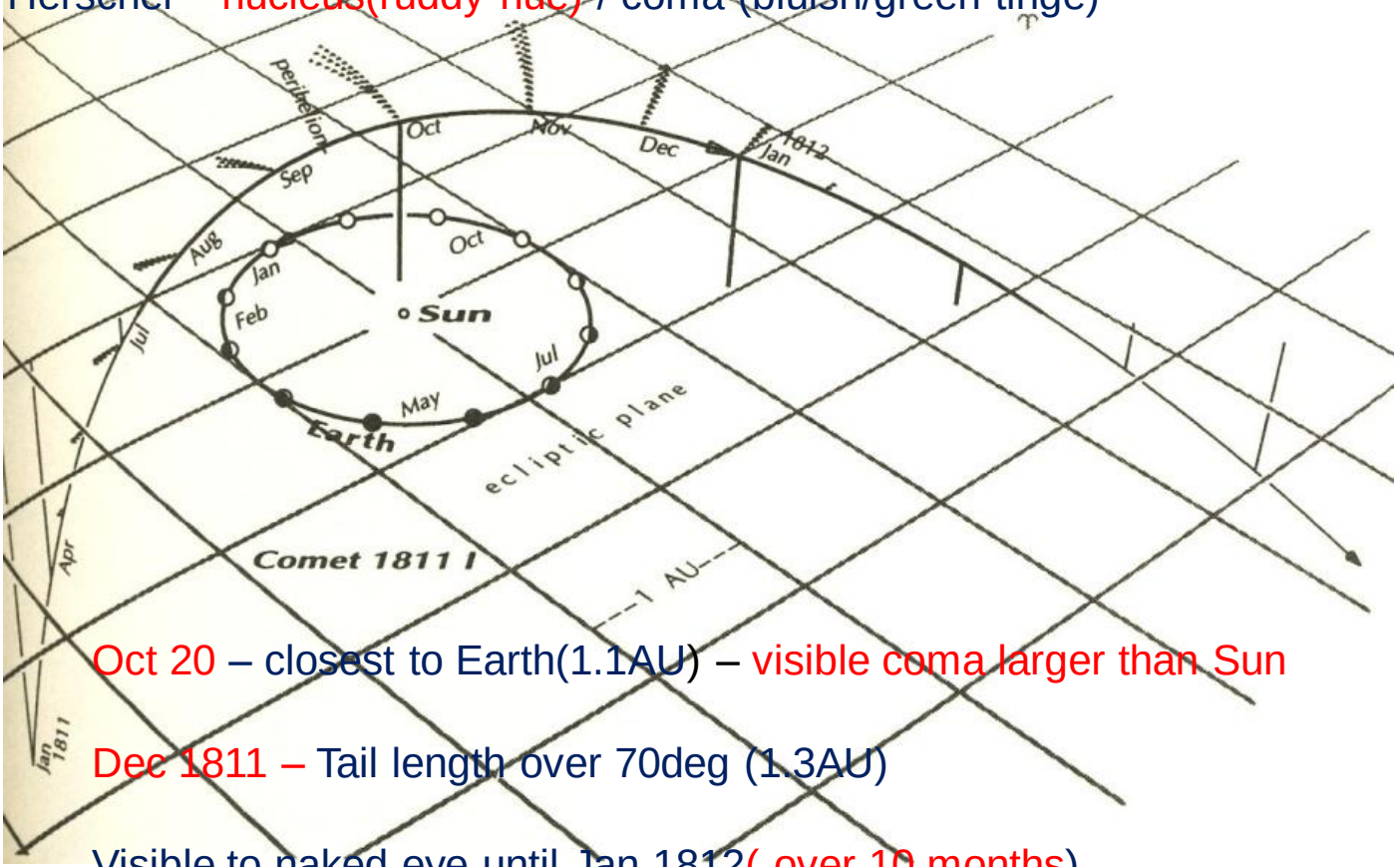
French caricature of the panic caused by the 1811 comet.

Found on Mar 25 1811

Huge / bright comet
(visible to naked eye longer than
Any comet in over 500 years)

Perihelion distance of 1.04 AU

Oct 16 – circumpolar object
(gas tail 24deg)
Herschel – nucleus(ruddy hue) / coma (bluish/green tinge)



Oct 20 – closest to Earth(1.1AU) – visible coma larger than Sun

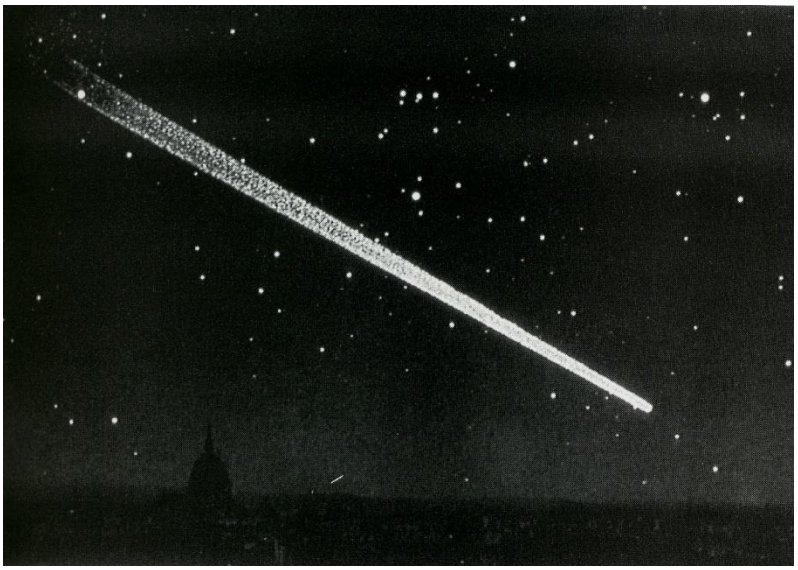
Dec 1811 – Tail length over 70deg (1.3AU)

Visible to naked eye until Jan 1812(over 10 months)

Seen in telescopes over 3.3AU from Earth

Great Comets (16th – 19th Century)

(d) 1843



The Great March comet
(Kreutz sungrazer)

Spotted 1 deg from edge of sun
(broad daylight) –perihelion

Reported at Magn -7 and spotted
by Thousands of people

Tail of up to 90deg (Mar 4)
(190 million miles long)

Apparent nucleus of 12” and comaOf 45”

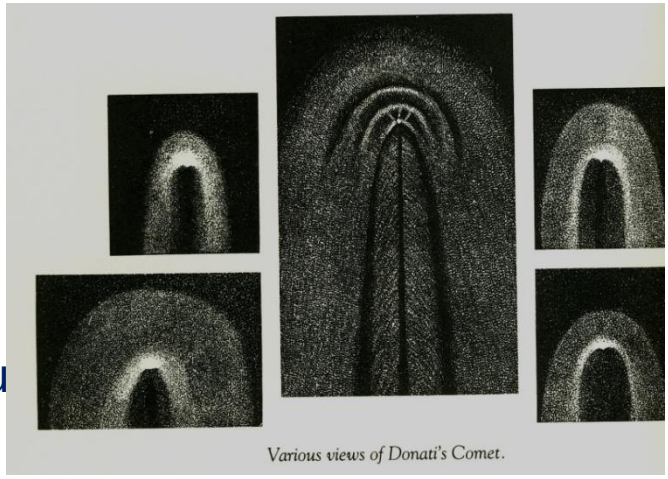
Mar 18th – comet seen far enough north to be seen in Europe (tail over 45deg)

Perehelion distance :
0.006AU

Tail of over 64 deg (Mar 21)
Comet faded in April (over 2AU
From Earth

Orbit of Great Comet of 1843.

Great Comets (16th – 19th Century) 1858


Various views of Donati's Comet.

Donati`s Comet –
First visual sighting on Sept 6th

Perihelion reached on Sept 30th (0.58au)

Interesting structure in nucleu (false nucleus)

Comet head brighter than Arcturus (magn -1) and tail over 35 deg – Oct 5

Broad dust tail –
Like a curved scimitar

2 delicate rays
- Twin components of gas tail


Donati's Comet on October 5, 1858.


Donati's Comet on October 9, 1858.

Comet closest to Earth – Oct 10 (0.5au away/dust Tail 60deg)- tail length 0.5au

Last telescopic view (Mar1859) - Magn 10

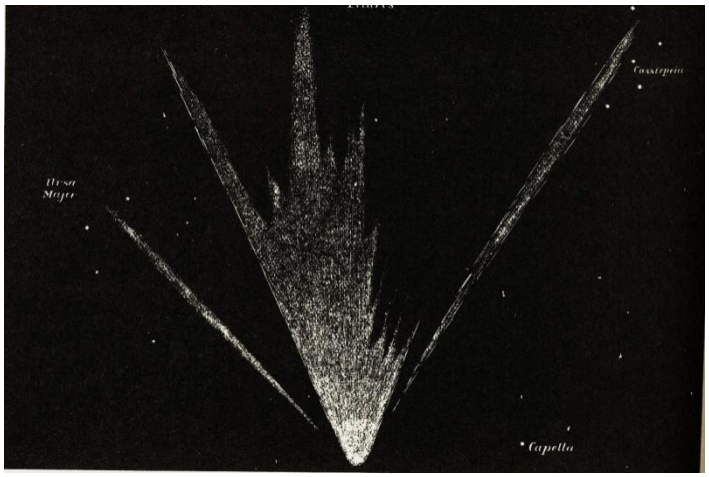
Orbit of the great comet of 1858 (Donati's).

Donati`s Comet

Donati`s comet as seen from Paris (1858)

Great Comets (16th – 19th Century)

(d) 1861



Closest great comet (0.13au)

Broadest / longest fan tail
(80deg fan & 50deg tails)

Highly inclined orbit (86 deg)

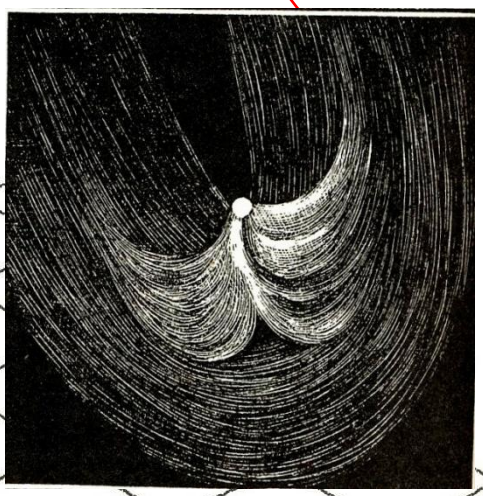
Earth passed through tail
(0.34 au in length)

12 jets observed from
Central nucleus

Last seen :
Visually (Aug 1861)

Telescope(May 1862)
Distance of Jupiter

Structure seen in
nucleus after Perihelion
(Jul 1861)



Orbit of the great comet of 1861.

Great Comets (16th – 19th Century)

(d) 1882

he Great Comet of 1882, photographed by Sir David Gill.

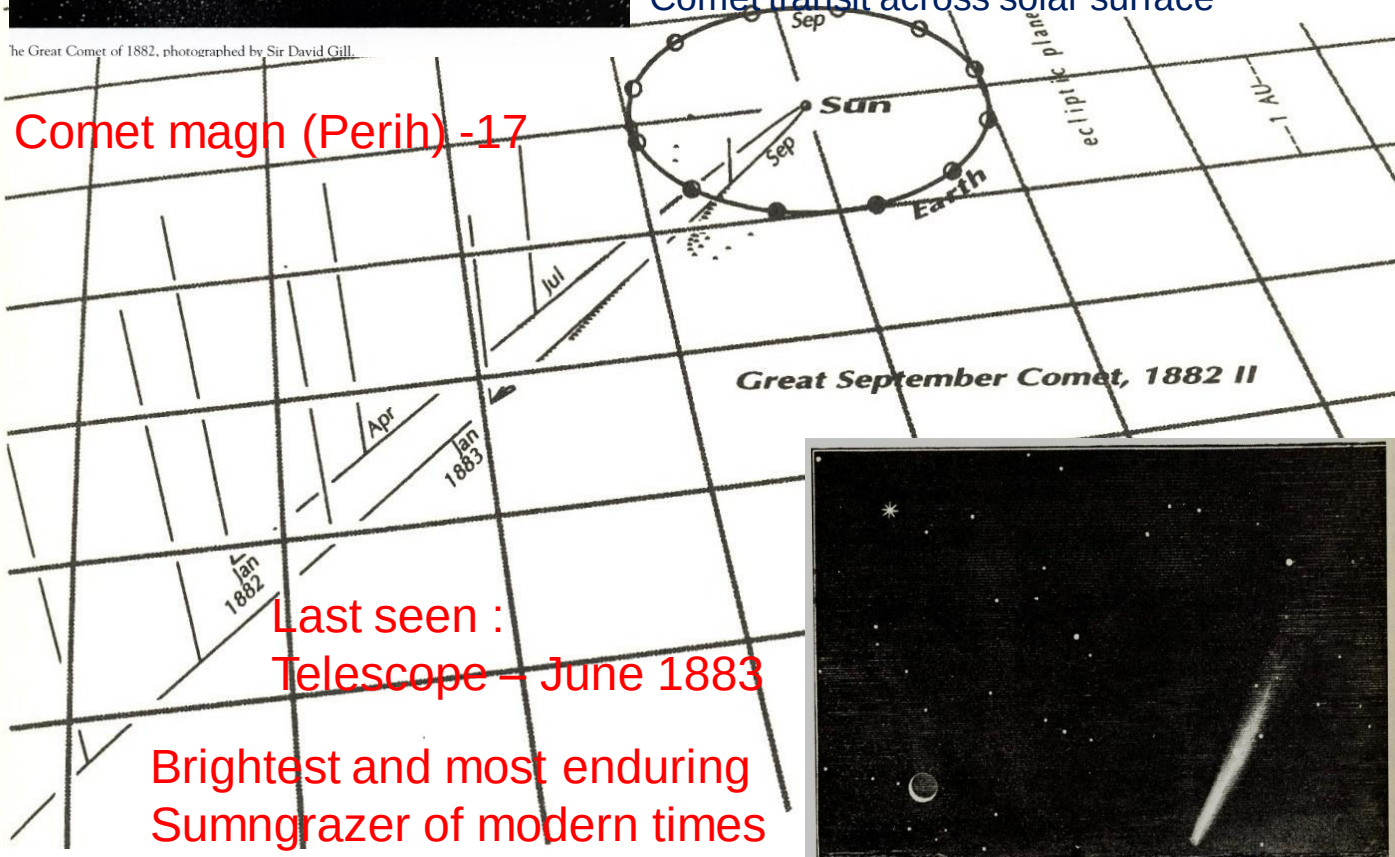
Brightest comet in over 700 years
Near Sun

Bright as Venus (Sept 5 1882)

12deg from Sun(Sept 14)
seen in daylight

Perihelion – Sept 17 – only 464,000km
From solar surface –seen next to Sun`s Limb

Comet transit across solar surface



Comet magn (Perih) -17

Last seen :
Telescope – June 1883

Brightest and most enduring
Sumngrazer of modern times

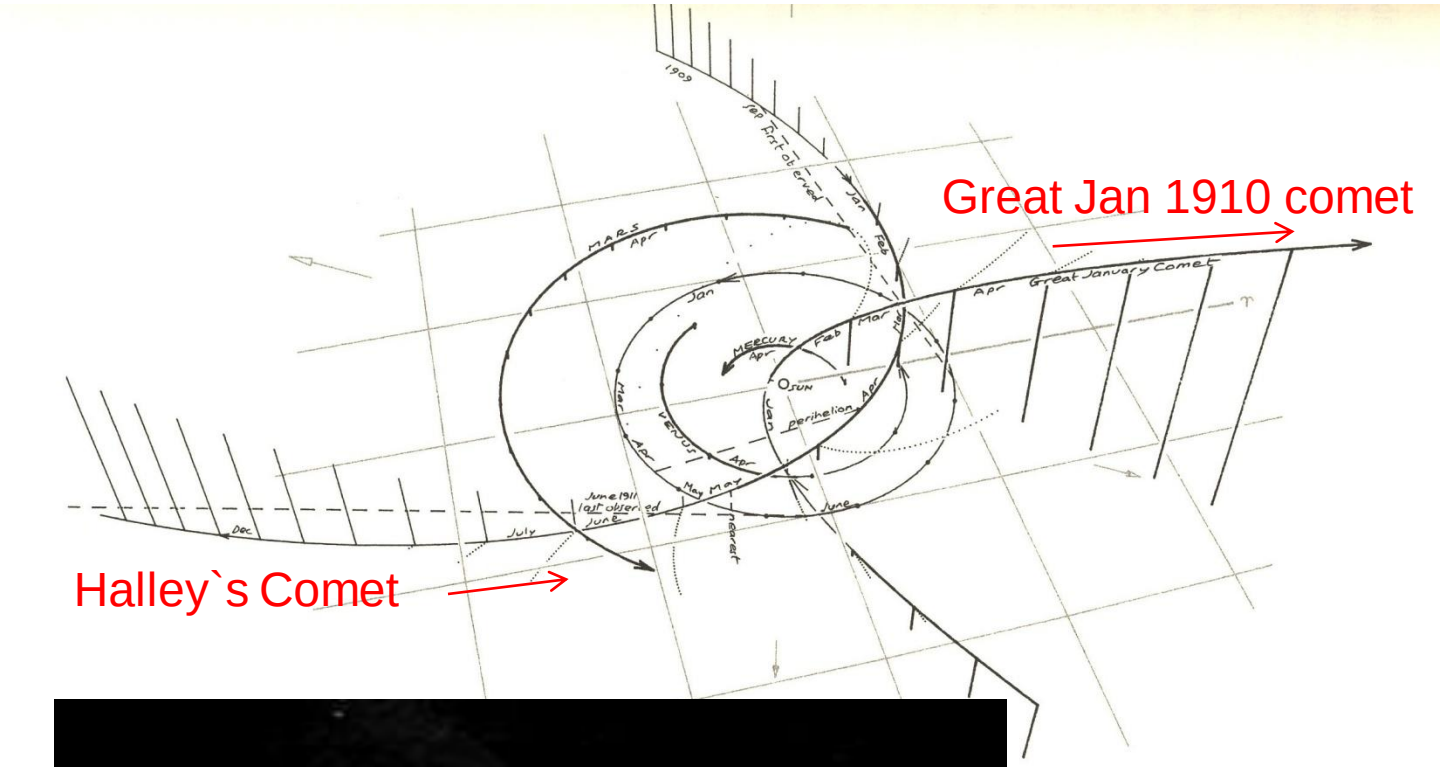
The Great September Comet of 1882 and the Moon.

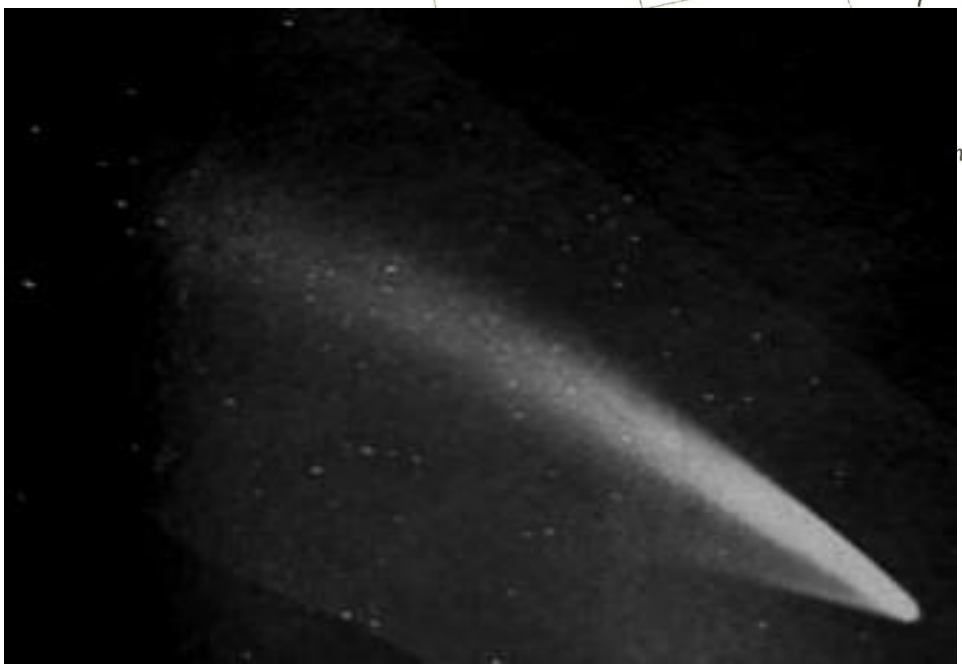
Comet features :
Strange tail structure (above photo)

Split nuclei – day after perihelion
- Like a string of beads - 4 separate nuclei seen until Feb 1883- & tails

Great Comets (20th century– 2010)

(a) 1910





...net in 1910.

First seen – Jan 13 1910 (South Africa)

Rival to Halley`s comet

Perihelion dist – 0.18 au - curved tail over 50 deg

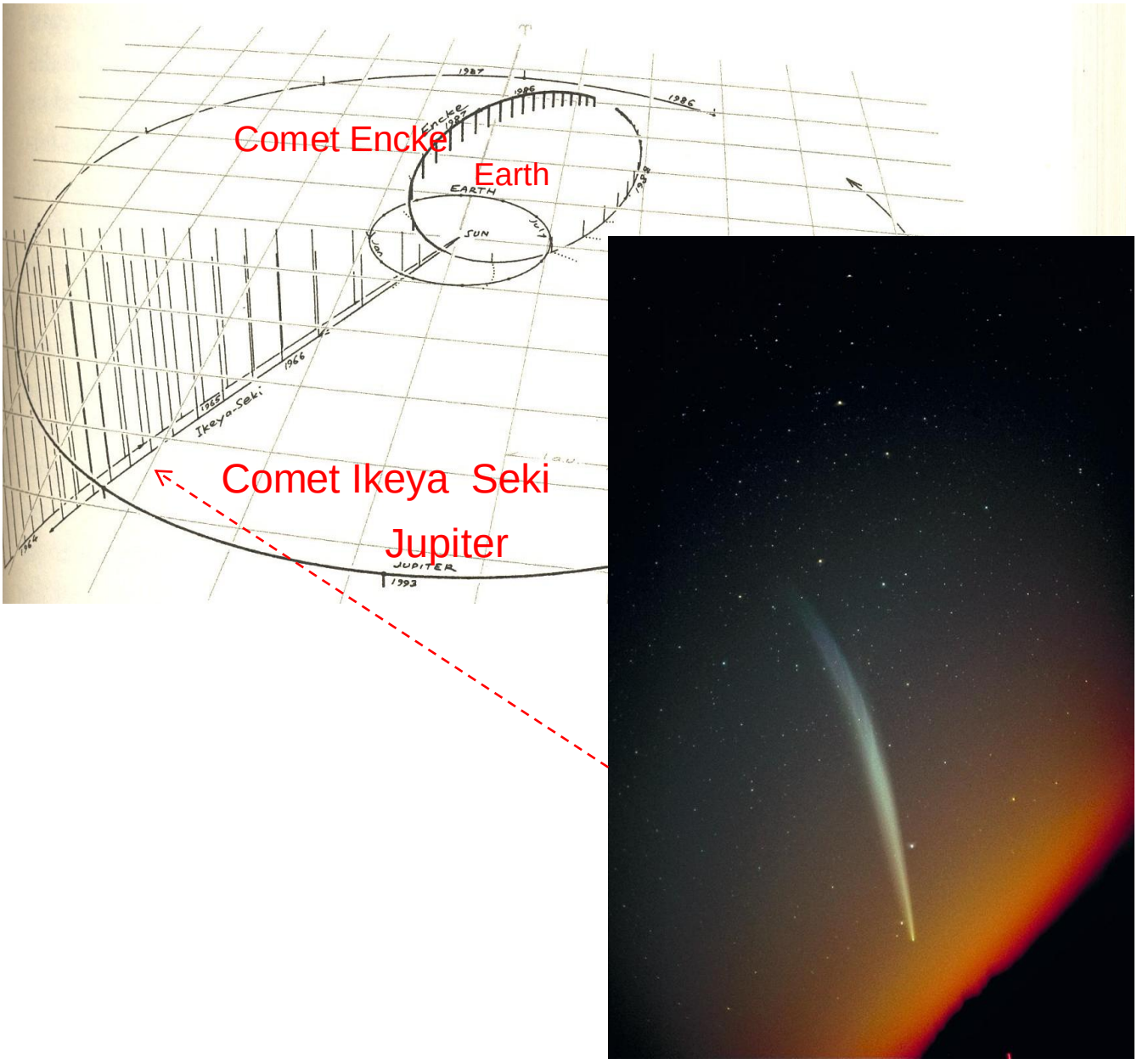
Great Comets (20th century– 2010)

(c) Oct 1965 (Ikeya- Seki)

Greatest Kreuz sungrazer since 1882
(perihelion distance from Sun only 0.0008au ---Oct 21

Intense nucleus – magn -10 – split into 3 parts 30 min before Perihelion

Tail maximum length – over 60 deg (1.3 au)



Kitt Peak Observatory – Oct 29 1965

Great Comets (20th century– 2010)

(d) 1976 (West)

Orbital period – 558,000 years

Perihelion on Feb 26th (0.2au)

Observed in daylight after perihelion

Best visibility – Mar 4th – closest to Earth

Gas / dust tails (30 deg) easily visible

Nucleus fragmentation(March) caused :

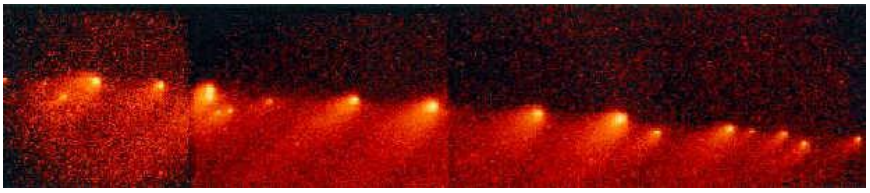
Dust tail structure

Unexpected brightness of comet

Last visual observation – Aug 25th (magn 11)

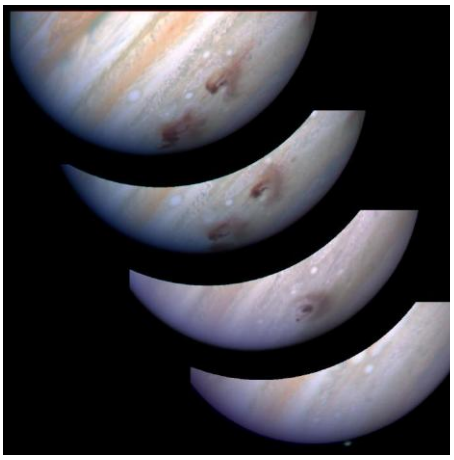
Great Comets (20th century– 2010)

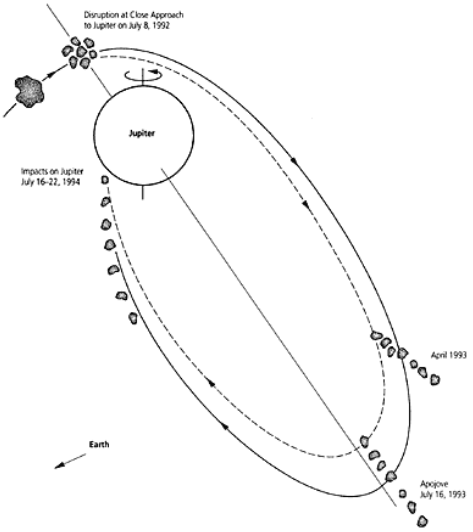
(e) 1993 (Shoemaker-Levy 9 (SL9))



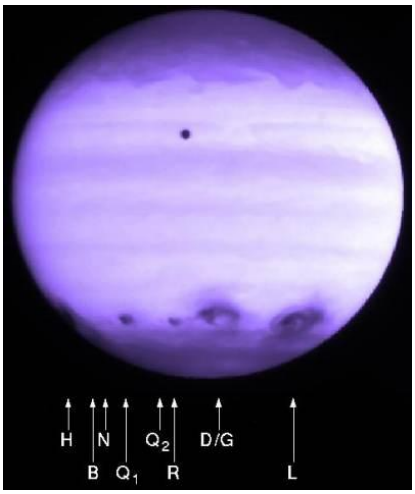
21 fragments from comet (HST image)

Impact sites (HST)





UV image of impact sites(HST)



Comet captured by Jupiter – fragmentation (Jul 1992) at perihelion

Discovered by Shoemaker/ Levy – Mar 1993 - predicted collisions

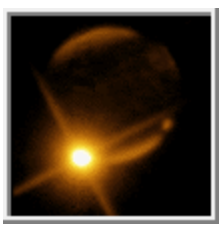
SL9 fragments – 100m to 1 km in size (original nucleus 5 km across)

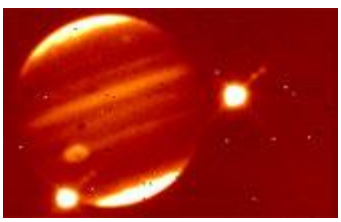
Simultaneous spacecraft observations : Hubble / ROSAT/Galileo/Ulysses/Voyager2

21 impact sites observed – Jul 1994 – typically 12000km across (fragment G)

Energy released on collision – 6million tons of TNT(600x world`s nuclear arsenal)

Long term effects – visible scars for many months – global atmospheric changes





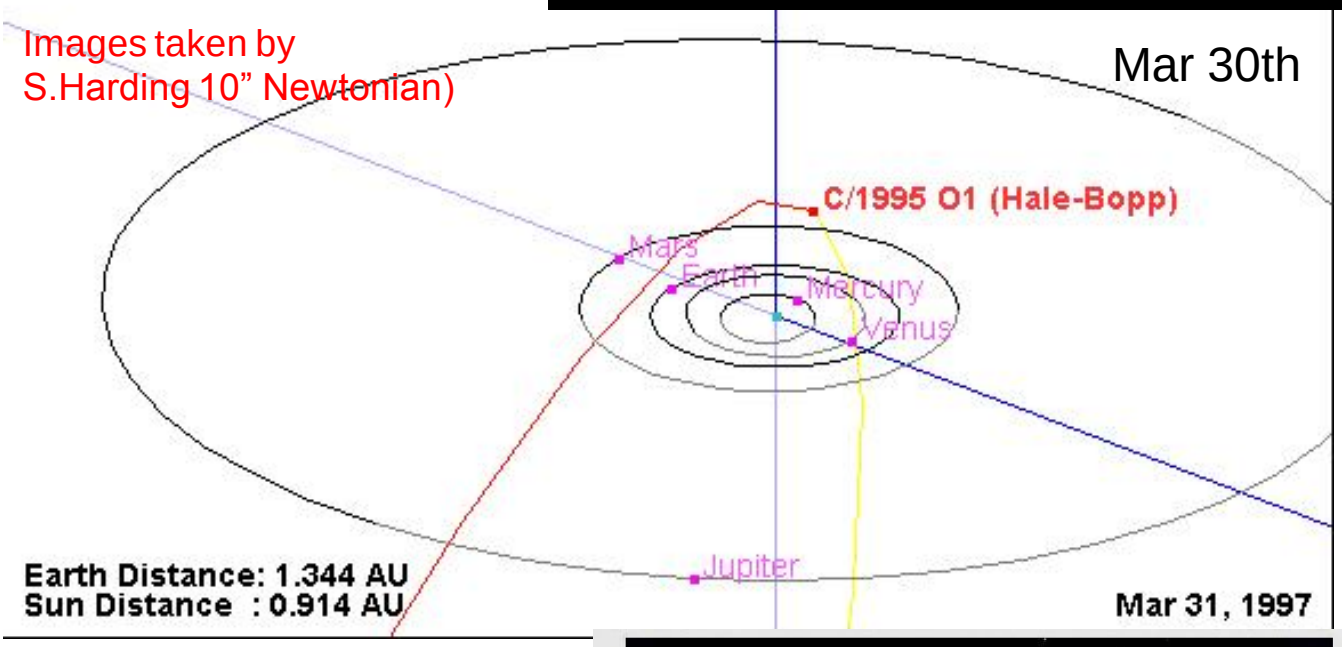
Great Comets (20th century– 2010)

(e) 1997 (Hale Bopp)

Feb 15th

C/1995 O1 (Hale-Bopp)

Images taken by
S.Harding 10" Newtonian)



Comet of 20th Century :

Discovered Jul 23rd 1995 (7au)

Perihelion Apr 1st 1997 (0.914au)

- Almost as bright as Sirius

Dust tail of 40-45 deg

Still active in 2007 (25.7au)

Hale Bopp images (1)

Hale Bopp seen close to the North American Nebula (NGC7000)

March 4th 1997 (T & D Hallas)

165mm f/4 lens – 10min exposure

Hale Bopp images(2)

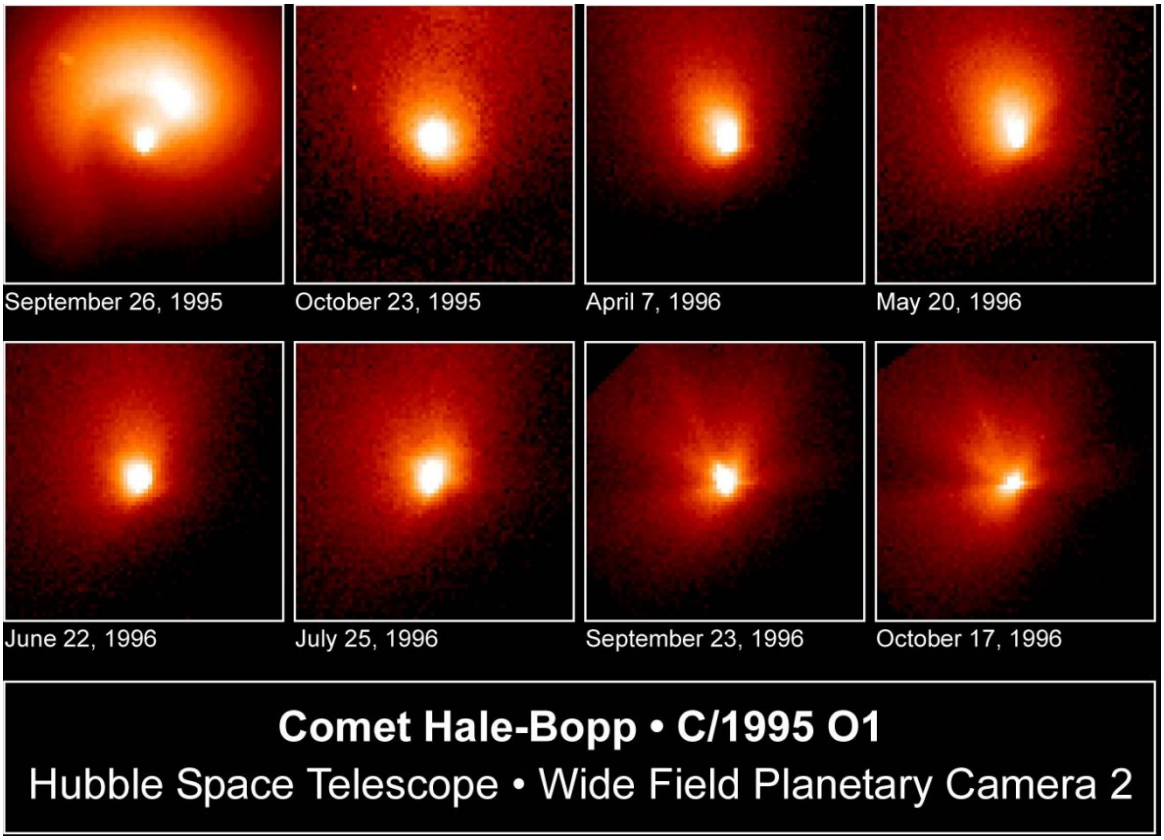
Hale Bopp seen close to Double Cluster
(open cluster M34 near comet`s head)

L.Tan 165mm lens 16min exp April 4th 1997

Great Comets (20th century– 2010)

(e) 1997 (Hale Bopp)

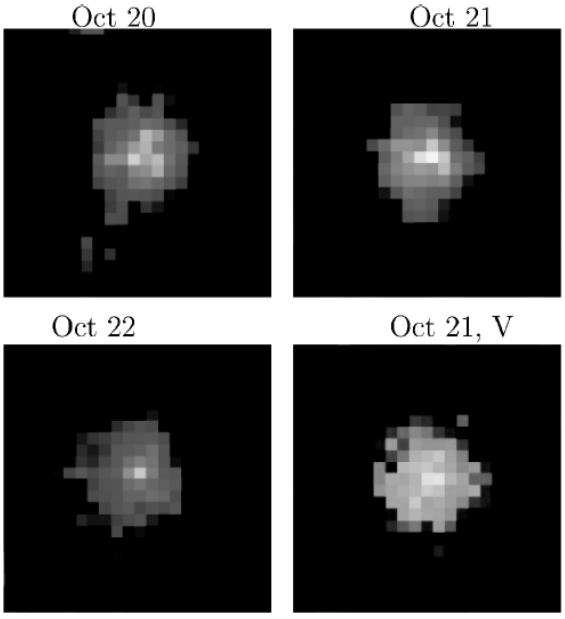
Beyond orbit of Jupiter



Images of the nucleus of Hale Bopp :

Outburst of dust beyond the orbit of Jupiter

1996 images show multiple jets connected with active nucleus vents



Images of Hale Bopp taken on Oct 20-21 2007 :

Diffuse coma of 180,000 km

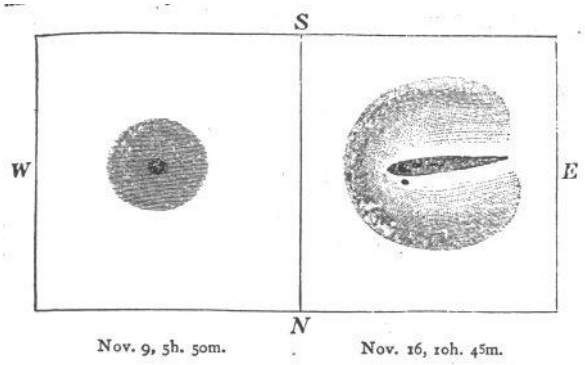
Magn +20 at distance of over 25AU

Comet activity detected (sublimation of CO)
(most distant activity detected in any comet)

(2.3m ANU telescope – Siding Spring)

Great Comets (20th century– 2010)

(g) 2007 (Comet Holmes)



Images of comet Holmes in 1892

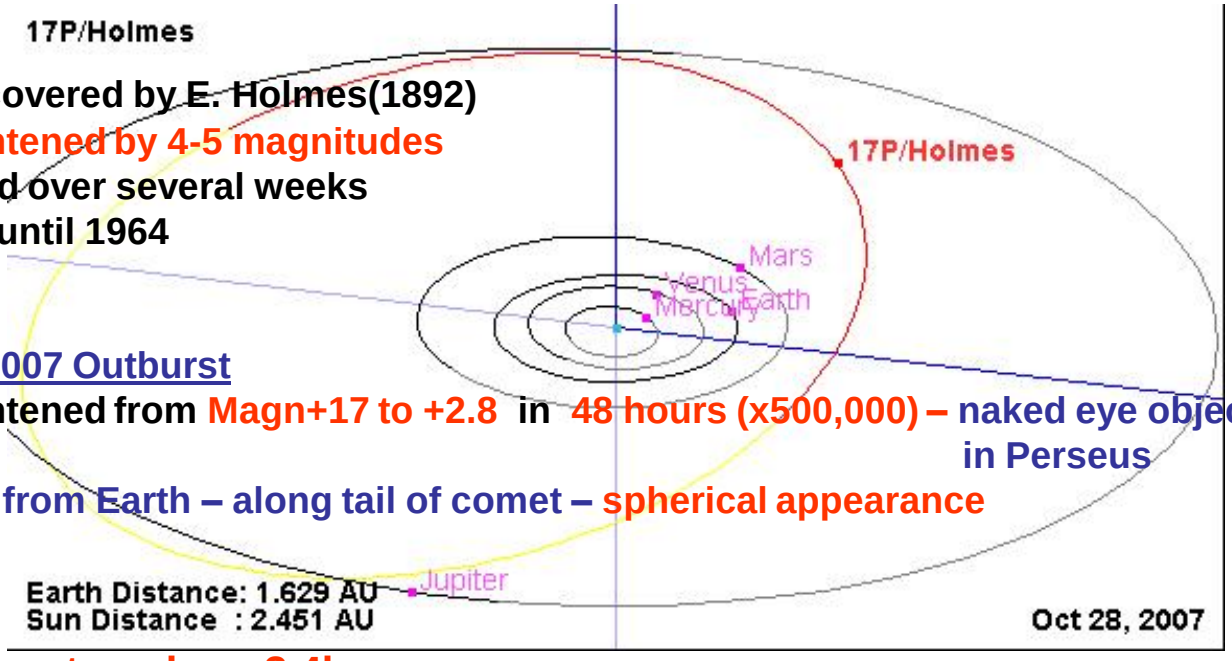
17P/Holmes

Discovered by E. Holmes(1892)

-Brightened by 4-5 magnitudes

-Faded over several weeks

-Lost until 1964

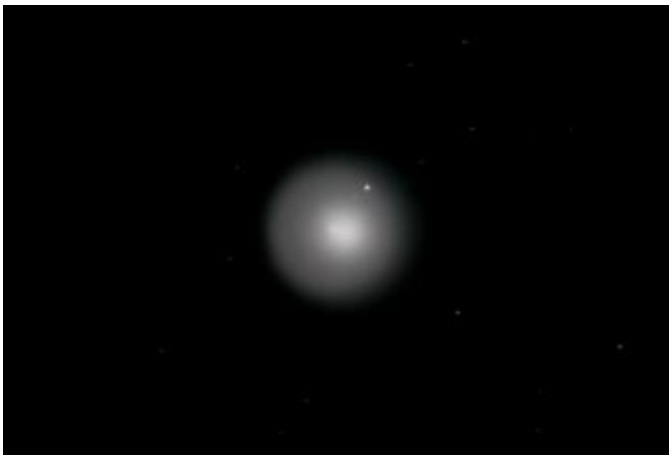


-Oct 2007 Outburst

-Brightened from Magn+17 to +2.8 in 48 hours (x500,000) – naked eye object in Perseus

-View from Earth – along tail of comet – spherical appearance

Comet nucleus 3.4km



(28/10/07)

(30/10/07) S.Harding images(8"SCT)

Great Comets (20th century– 2010)

(f) 2007 (Comet Holmes)

Oct 2007- coma diameter of 13arc min (1million km at 2AU)

02/11/07 (8" SCT 60 sec)

06/11/07 (8" SCT 2 min)

Coma diameter –
x0.7 diameter of Sun

Outburst
– maybe caused by sudden Venting of gas through Nucleus

Comet fade to magn +5 / Expanded to 2 deg (Feb2008)

wide field image(300mm lens) 12/11/07

(S.Harding images)

19 nov-07(10" SN)

28-nov-07(widefield 300mm lens)

(1)Spacecraft Missions to Comets

Giotto

First close-up images of a comet nucleus(March 1986)

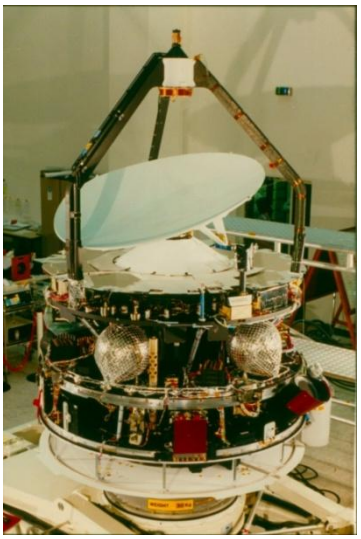
Key objectives:

-Determine composition of ices & Dust in Comet`s coma

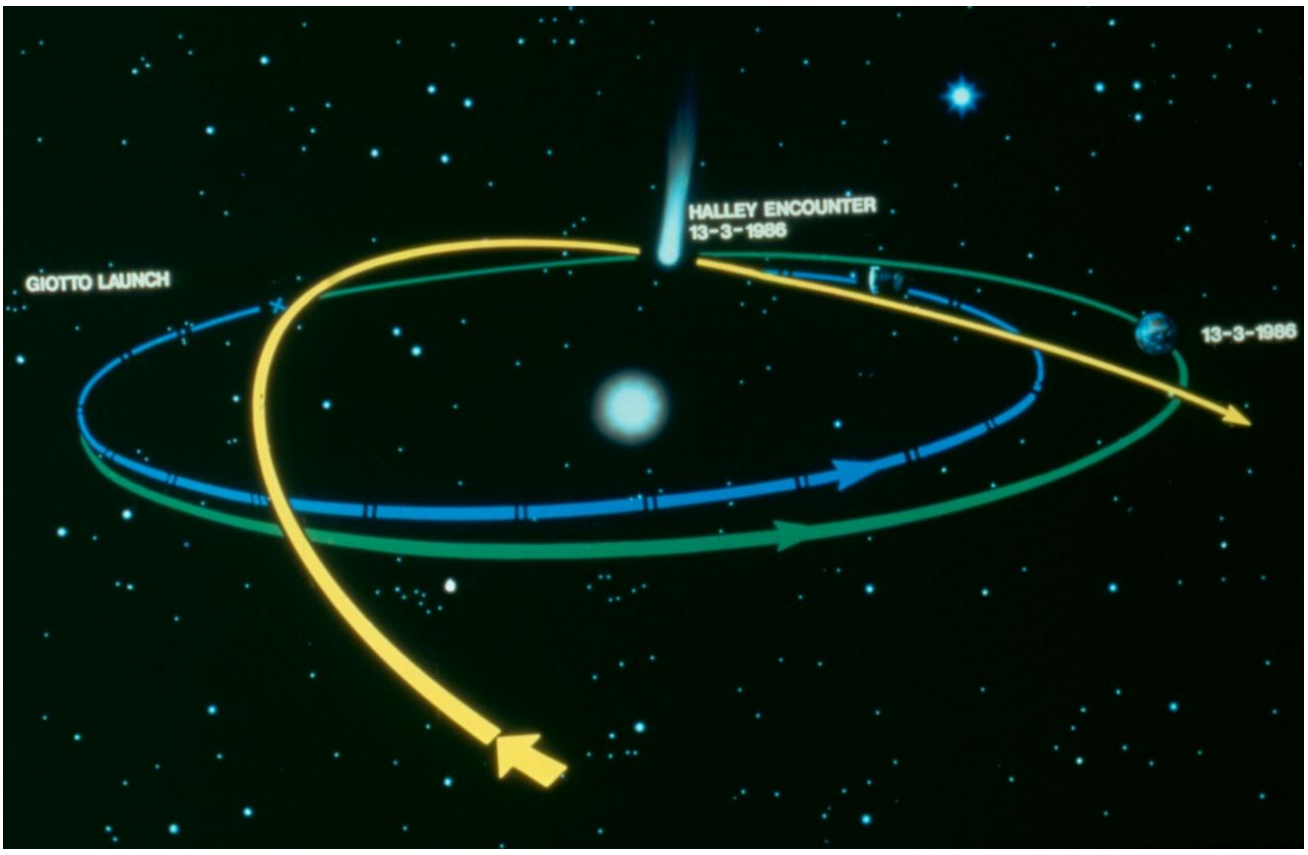
-Measure comet`s gas production -Rate

-Measure amount of dust around -Comet & size/mass distribution

- investigate interaction of comet -With solar wind particles

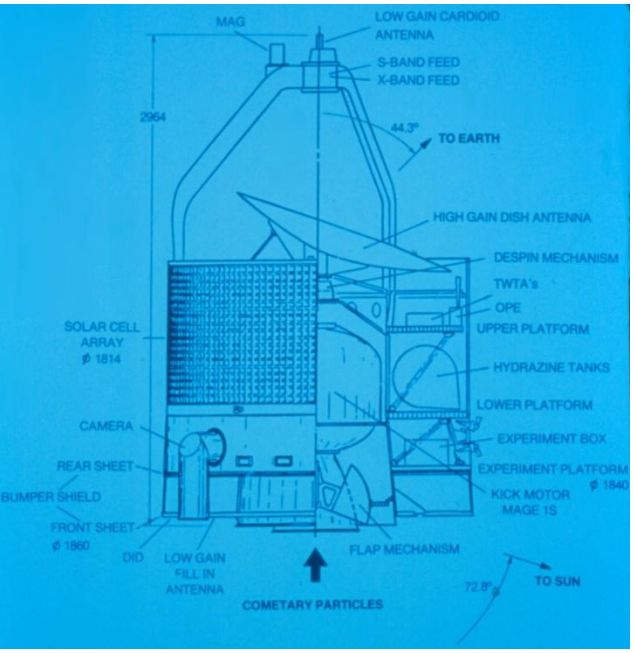


Launch 02/09/85 (Ariane 1)



First deep space mission using the Earth for gravitational assist

(1) Spacecraft Missions to Comets



Giotto Probe instruments:

Narrow angle multicolor camera – nucleus

3 mass spectrometers- gas/ dust composition

Plasma experiments –solar wind /charged particles

Energetic particle analyzer – electrons/protons/ alpha particles

Magnetometer – changes in magnetic field

Optical probe- brightness of nucleus

Radio science experiment solar wind environment

Giotto Events

March 13 1986 – **Halley crosses bow shock of solar wind (solar particles slowed to subsonic speed in coma)**

12,000 dust particle impacts occurred 2hours before closest approach

Images transmitted up to 1372km from nucleus (sharp increase in dust particles – Giotto passes through jet from nucleus)

7.6 sec before closest approach – comet sent spining by impact with large (1 gm) dust particle

Giotto passed within 596km of nucleus

(1) Spacecraft Missions to Comets

Giotto Results

Results showed :

Nucleus – dark elongated body(15x10km) – **3 bright jets** – v dark

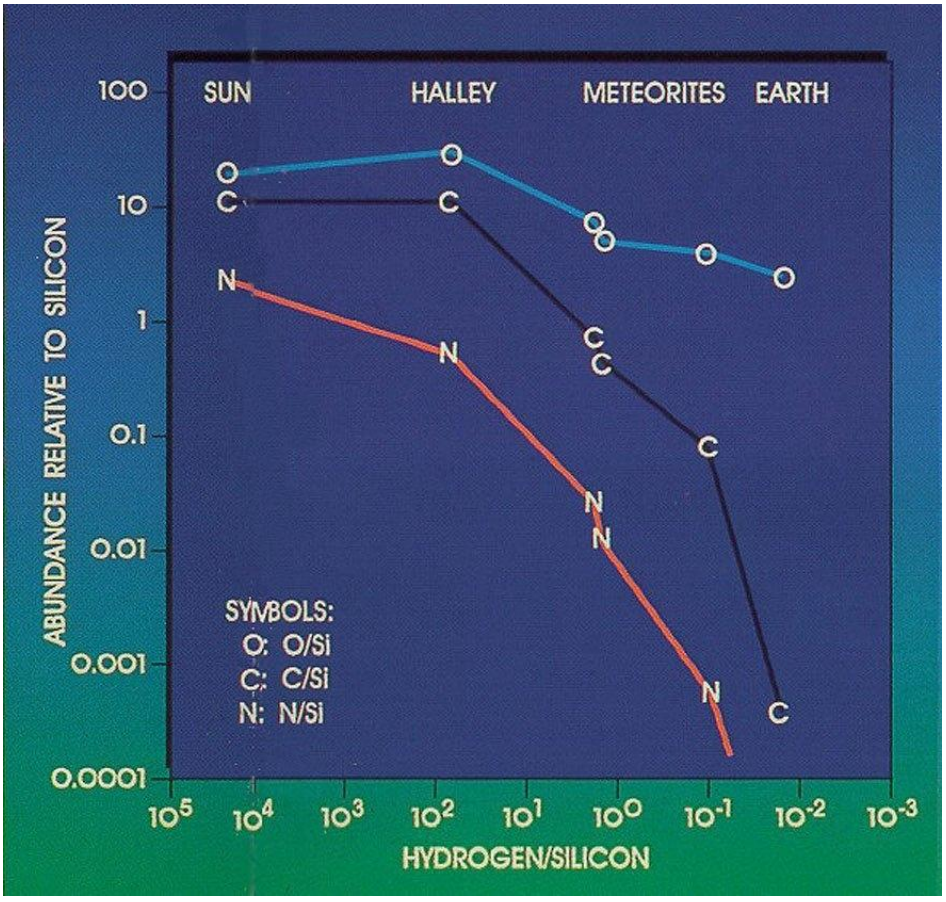
Jets – ejection rate of 3 tonnes/sec – **strange wobbling rotation of comet**

Dust grains – like smoke – particle mass about 40mg

Comet – formed 4.5 million yrs ago – **ices condensing onto interstellar dust grains**

Material ejected by comet (by vol) : **80% H_20 , 10% CO , 2.5% CO_2 + traces of NH_3 / CH_4**

Abundances of elements relative to Silicon :



Dust particles :
contain CHON
Or
Na, Mg, Si ,Fe,Ca

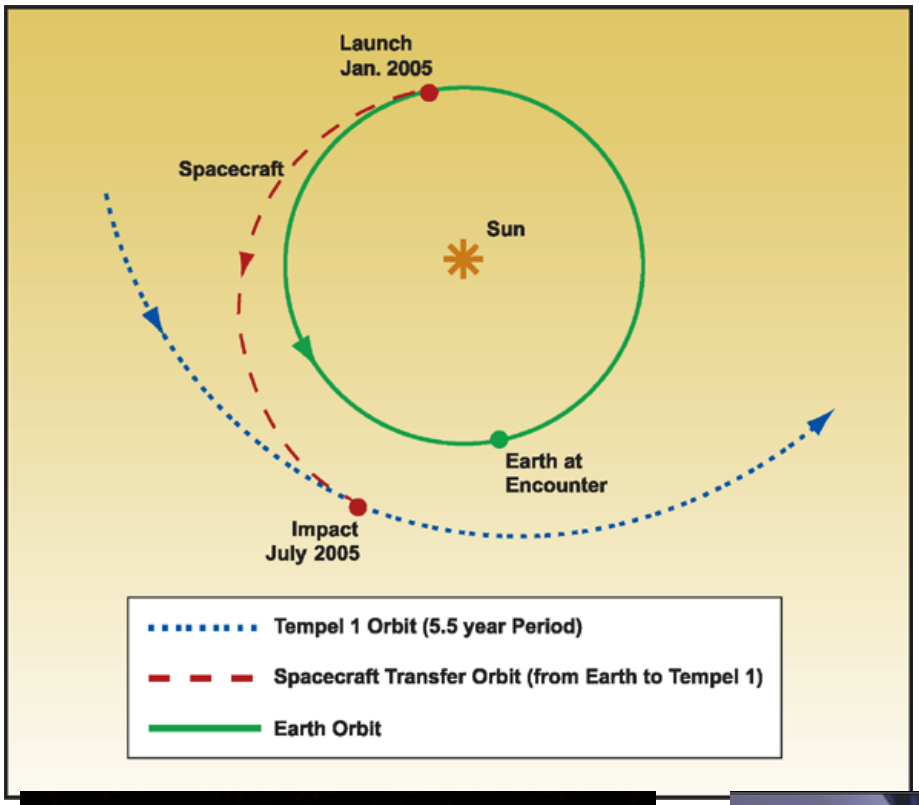
All light elements
In comet (except N):

Same abundance
As in Sun –

Comet material
Is pristine and
Unprocessed

(2) Spacecraft Missions to Comets
Deep Impact Mission(2005)

Deep Impact Mission to Comet Tempel 1 – impactor sent to comet



Crater on comet :

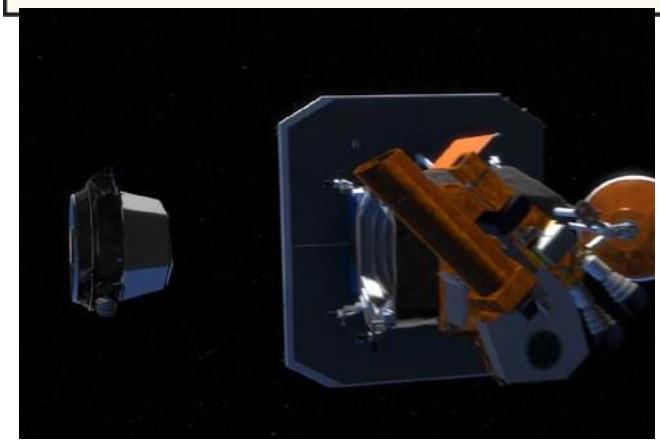
About size of stadium

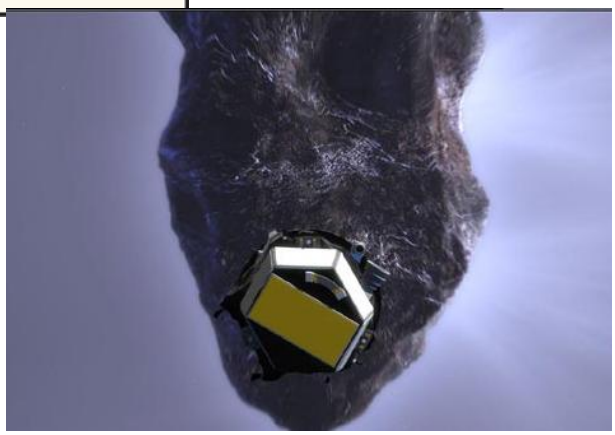
Ice/ dust ejected & Observed from Spacecraft & Earth

Comet Tempel1:

Discovered in 1867

Orbital period 5.5 yrs



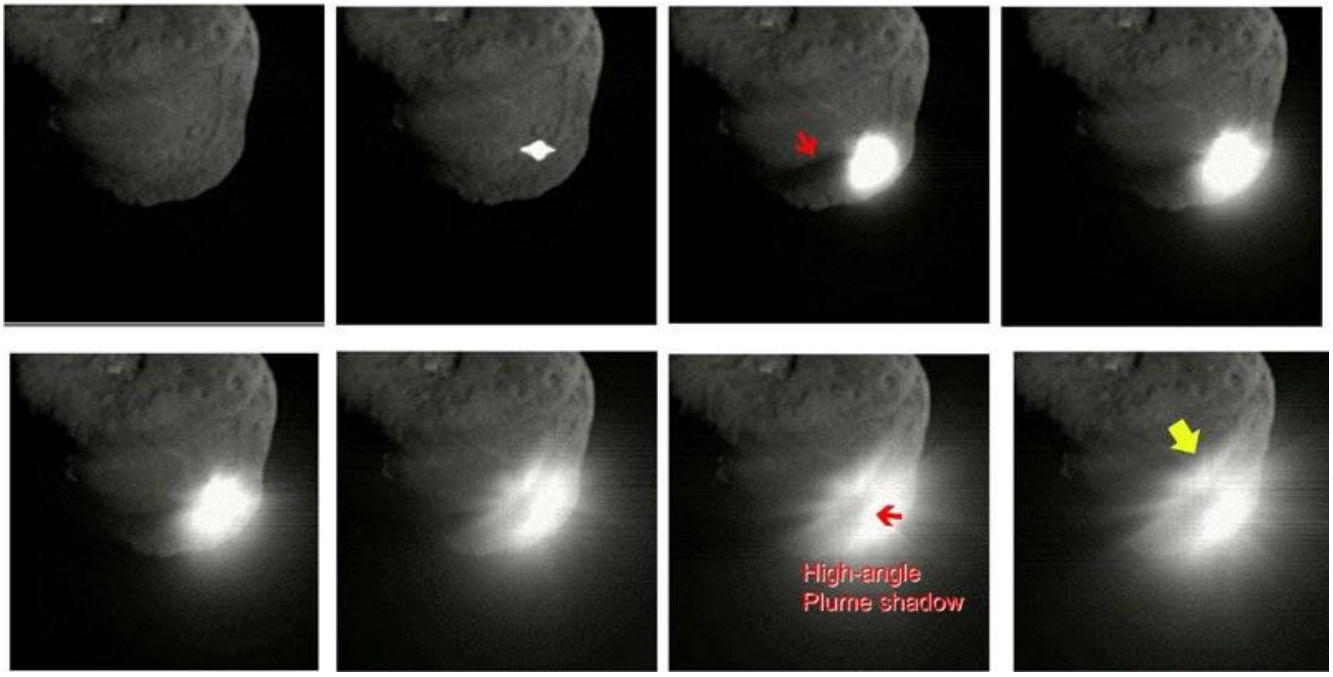


Release of impactor from Deep Impactor Spacecraft

Flyby spacecraft - 500km from comet :
observation of Impact / ejected material from crater

Structure / composition of crater interior

(2) Spacecraft Missions to Comets
Deep Impact Mission (2005)



Deep Impact results showed for comet Tempel 1 showed :

a small amount of water ice on surface of comet

An abundance of organic material in comet`s interior

The comet is a geologically active body – surface changing over time

(3) Spacecraft Mission to Comets
Stardust (2004) – Mission to Comet Wild2

Stardust mission Goal :

To return both particle samples from Comet Wild 2 and from interstellar dust.

Sample Return Mission :

Samples were returned to Earth for analysis:

Wild2 / Stardust

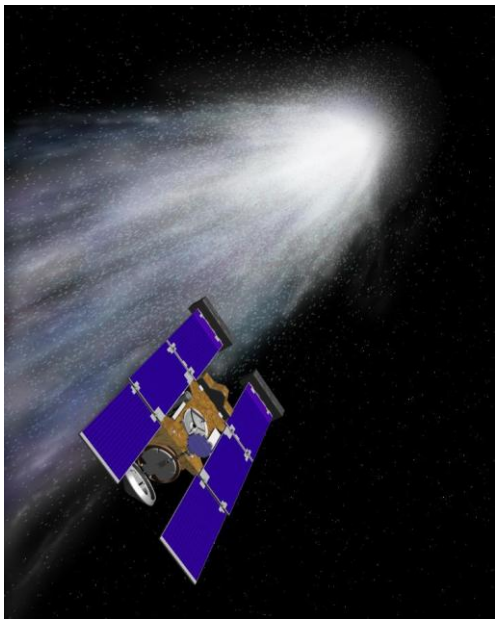


Image of Nucleus of Wild2

Interstellar dust / comet material captured in aerogel

Aerogel returned to Earth in Sample Return Capsule

Analysis of aerogel results :

Primitive organic matter found in aerogel – similar to material in early solar system

Polycyclic Aromatic Hydrocarbons(PAH) –found in sample – molecules common in interstellar space

Comet material may even contain pre-solar system interstellar dust grains

Visual / Photographic Observation of Comets

Steps to observe / image potentially bright comets :

(a) The orbit of the comet is usually known with great accuracy
– RA/Dec positions published on web sites
-Expected apperent magnitude

-(b) Wide field instrument can be used to scan region of
-Sky (eg binoculars)
-Bright comet will appear as diffuse object (few arc min in size)
-Beware of bright Deep sky object

-(c) Larger instrument will show structure of nucleus /coma
-Motion of comet apparent in field of view over short period
-
-(d) Astrophotography of comets

-Large bright comets – DSLR camera / 300mm lens
-(exposures up to 1-2min possibly to image faint tail structures)

-Fainter comets – prime focus imaging –DSLR/CCD camera
- shorter exposures (<1min) to avoid motion comet relative
-To background stars