Small bodies of the solar system

Lecture by Klaus Jockers, Göttingen, winter term 2004/2005

Comets5

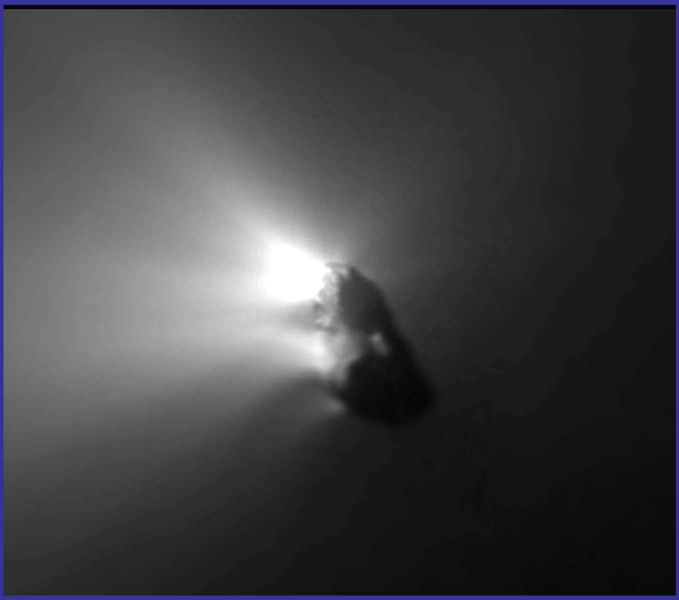
Photographs of cometary nuclei

- 1P/Halley
- 19P/Borrelly
- 81P/Wild 2
- 2P/Encke (ground-based study)

H.U.Keller, in W.F.Huebner (Ed.) “Physics and Chemistry of Comets”, Springer, Heidelberg, 1990, pp 13-68

The Giotto probe approaches comet Halley on March 13, 1986

"Best" image of the nucleus of comet Halley as obtained with the Halley Multicolor Camera



Comet 1P/Halley:
Very famous intermediate-period comet
(P = 76 years, q=0.587 AU, aphelion at about Neptune's orbit)

First images of a nucleus, taken by MPI of Aeronomy. Because of high relative speed a very short time interval was covered. Soviet images were very poor, rotation rate and direction could not be determined unambiguously. Rotation state of nucleus complicated (tumbling)

Nucleus albedo ≈ 4%.

Comet 19P/Borrelly:

- Discovered 1904 and observed in next four apparitions.
- 1936 perturbed by Jupiter into unfavorable orbit.
- 1972 again perturbed and observable again.
- Presently P = 6.9 years, q = 1.36 AU
- Rotation period 25 ± 0.5 hr
- Sept. 22.4925 2001 visited by spacecraft Deep Space 1
- Encounter distance 2171 km, encounter speed 16.5 km s^{-1}
- Encounter shortly after perihelion

The following description is based on the paper:
Soderblom L.A. and al. Imaging Borrelly, Icarus 167 (2004), 4-14

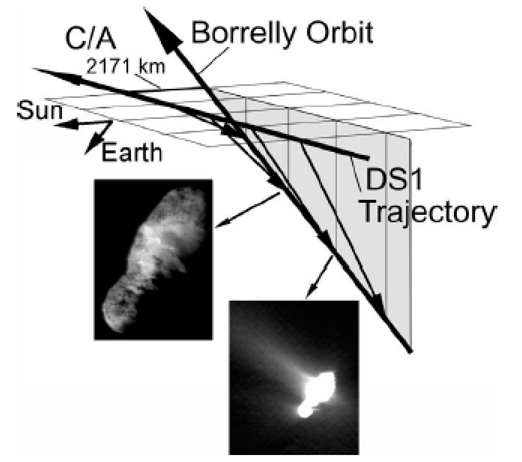


Fig. 1. DS1-Borrelly encounter geometry. The DS1 trajectory was nearly in the plane of the ecliptic (horizontal plane). Borrelly was imaged as rose in its inclined orbit from ecliptic south toward the spacecraft. Two images are shown in schematic position: the best image of the nucleus (CCD_NEAR_1, upper) and the best of the dust jets (CCD_MID_5_2, lower).

Wide dynamic range of images

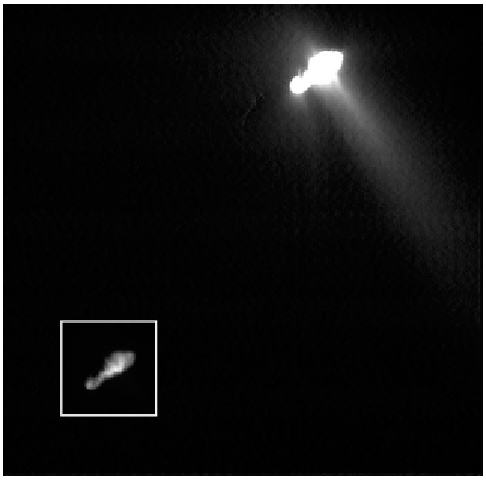


Fig. 5. VISCCD image after radiometric corrections and coherent noise suppression (same image as in Fig. 2). Small inset is stretched to show the nucleus demonstrating the large dynamic range in the images.

Deblurring

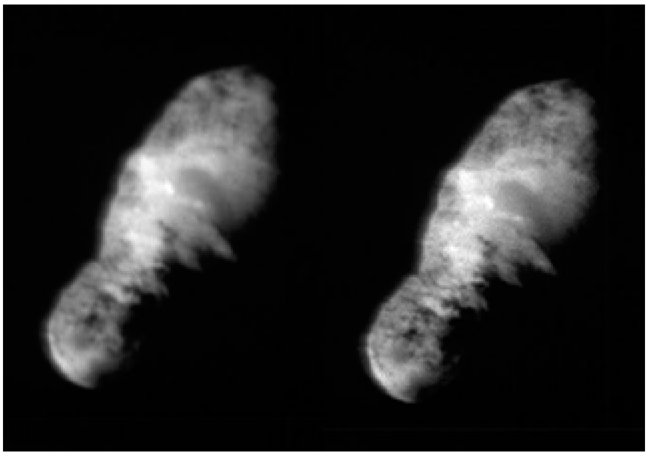
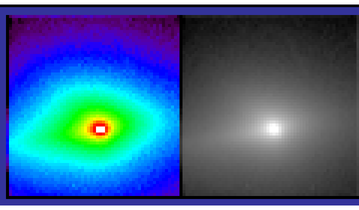
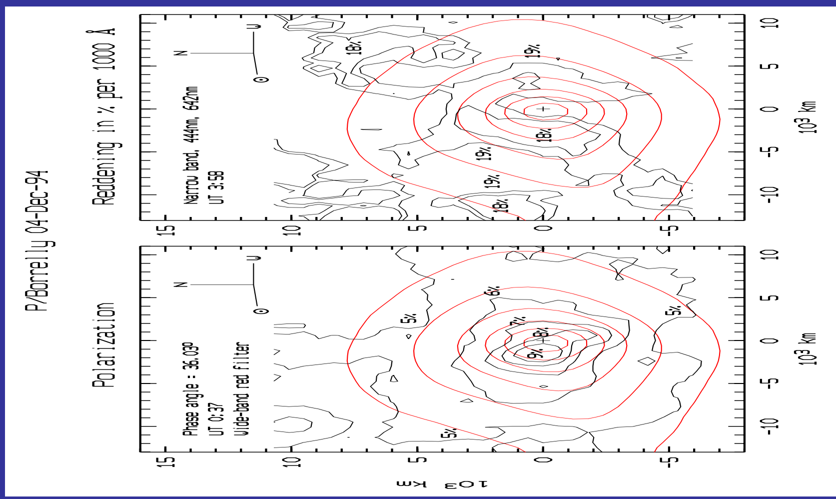


Fig. 6. Deblurring applied to remove a small degree of image-motion blur in the highest-resolution image (CCD_NEAR_1).

Comet 19P/Borrelly observed from Calar Alto observatory with the 1.26m telescope in 1994 (own work)
← to Sun



Sunward Fan



← to Sun

Nucleus being viewed end-on light curve minimum

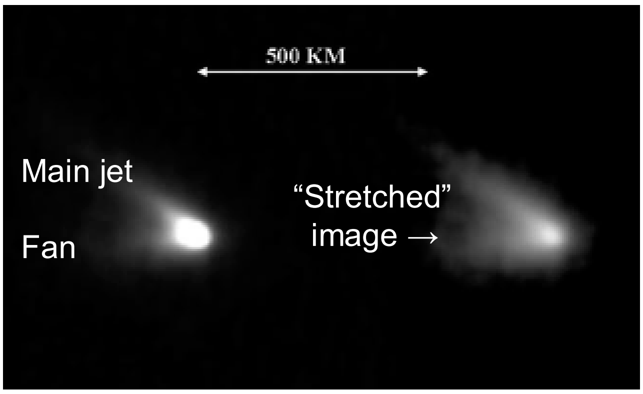
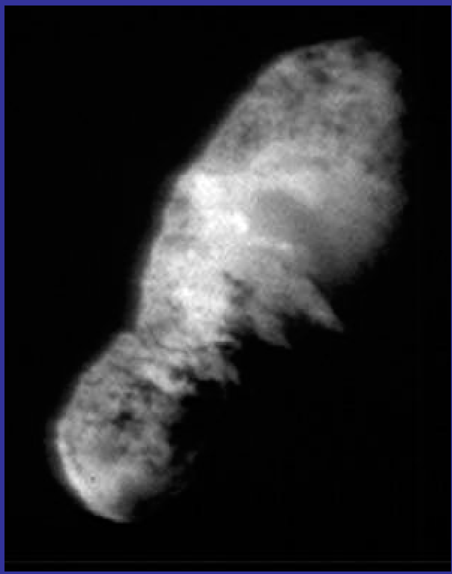
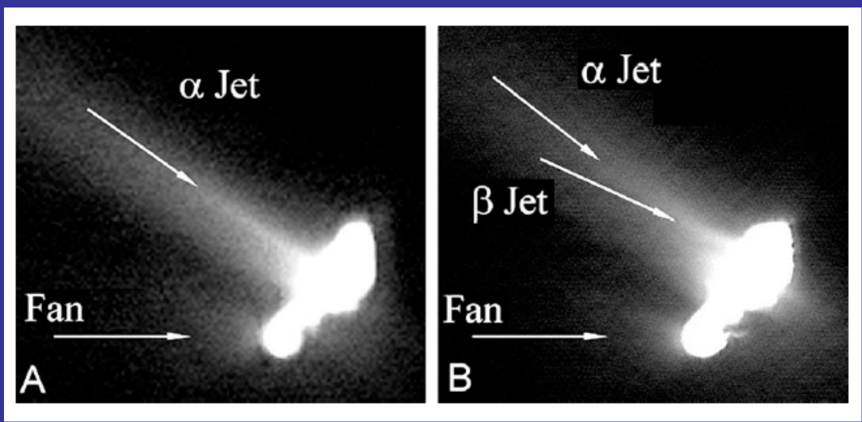


Fig. 7. Composite image from final approach image set acquired 10.4 hr before encounter at a range of 0.62 million km. The image on the right has had a log stretch applied. The fan jet is sun-pointed (Sun to left); the main jet is canted ~ 35° clockwise from the sun line. These two jets remained fixed in orientation for at least a full rotation period.



bottom part points to observer



Two high-resolution images (173 and 63m/pixel) showing details in the near-nucleus coma and dust jet features

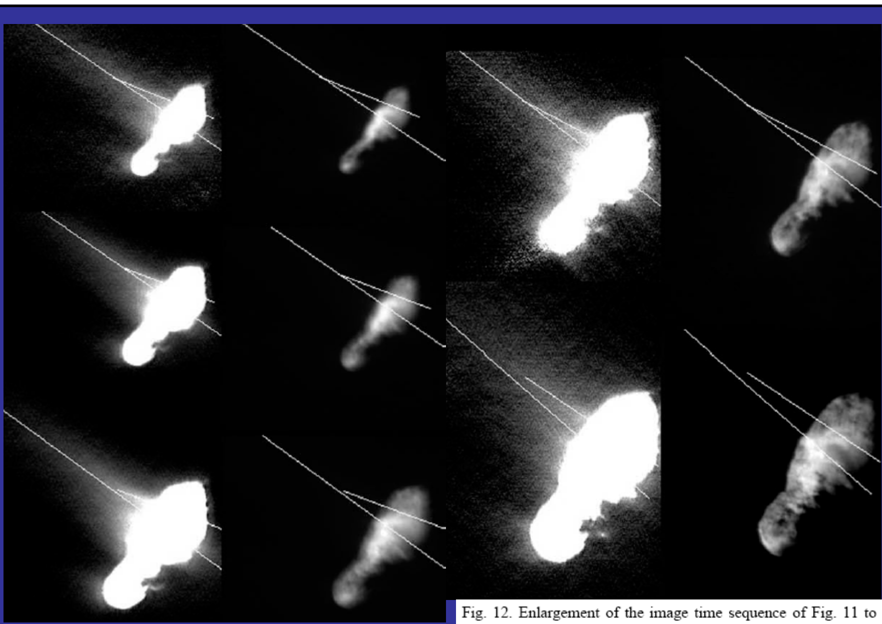


Fig. 12. Enlargement of the image time sequence of Fig. 11 to show the traces of both the α and β jets (β-jet traces are shorter and above the α traces). The panel on the right shows the same image set and traces but has been stretched to show the nucleus detail and the suggestion of source regions.

α-jet was fixed in direction
the change in direction of the β-jet was negligible

Conclusions about jets:

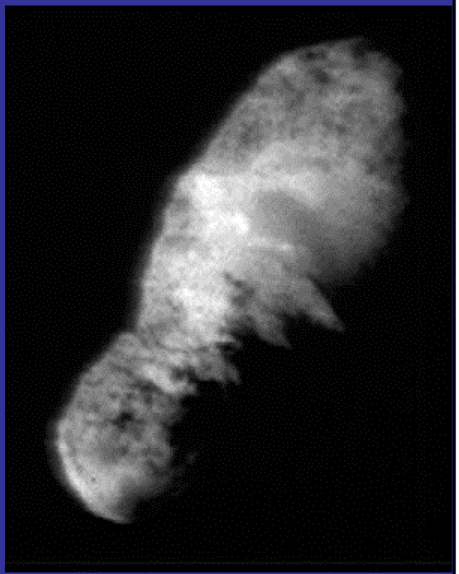
α-jet RA = 218º ± 2º DEC = -12º ± 2º, fixed in inertial space
β-jet RA = 237º ± 4º DEC = 10º ± 4º.

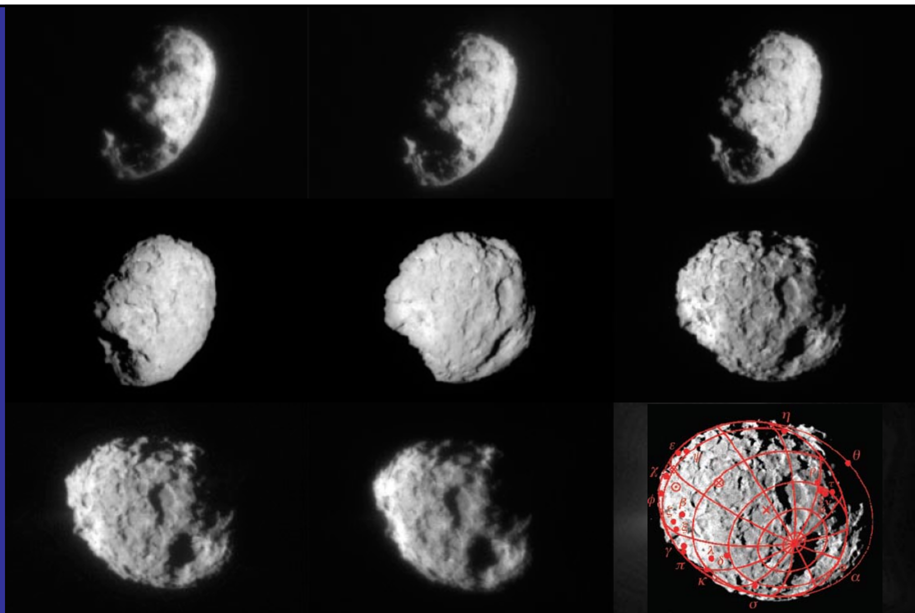
Fan always pointing to the Sun, moving across nuclear surface and changing strength depending on where it leaves nuclear surface.

Conclusions about nucleus:

Two terrain types: slightly brighter smooth rolling planes and darker, rougher mottled terrain that appears inactive. Craters?

Average normal albedo 0.03±0.01





Comet 81P/Wild 2

Stardust at comet Wild 2, Science 304, 1760-1780

Shape and size:
oblate ellipsoid in contrast to previous two comets
1.65 x 2.00 x 2.75 km ± 0.05 km

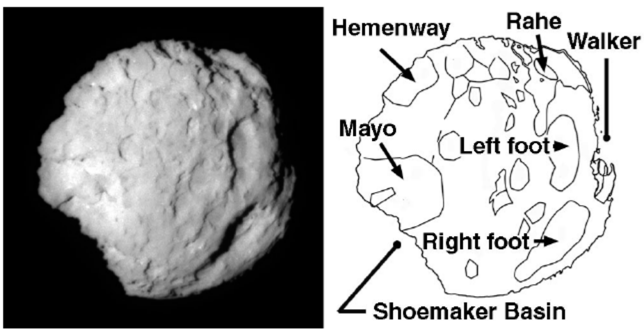
Axis of rotation RA = 110º and DEC = -13º.
Observed phase angle range from -72º to 103º.
Albedo = 0.03±0.015.

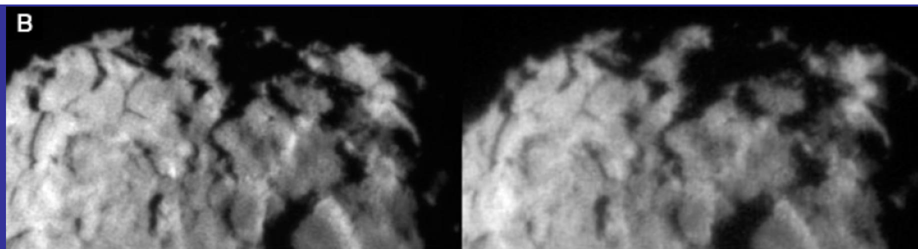
Surface depressions:
Craters:
Pit halo and flat floor craters (with nearly vertical crater rim, flat floors inert, i.e. no outgassing). No signs of rised rims or concentric ejecta aprons, nevertheless believed to be of impact origin.
Other depressions: < 0.5 km, noncircular, may be related to sublimation.

Mesas:
Mesas on Borrelly may be locations of outgassing, i.e. size of mesas may diminish with time. If so, Borrelly's surface is at an earlier stage of ablation evolution.

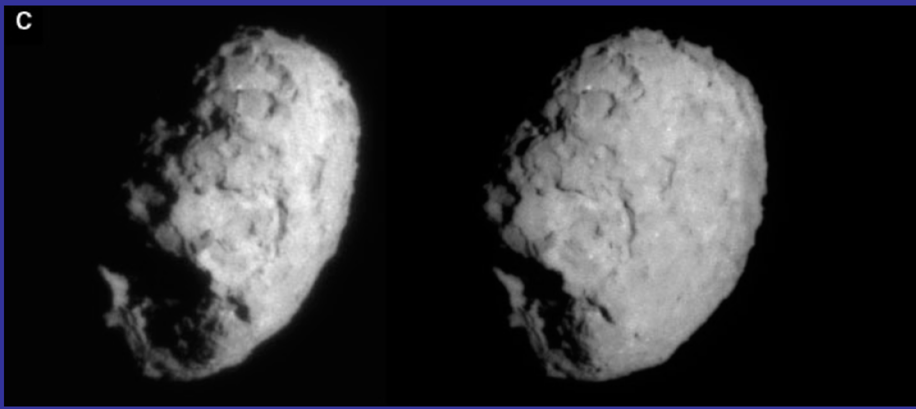
Lineaments are rare. Evidence for down-slope mass movement.
Pinnacles not anticipated landforms on small bodies. Erosional remnants?

Fig. 2. The closest short-exposure image taken at 11.4° phase angle, the angle between the camera, comet, and the Sun. In the camera-centric directions used in this paper, north is at the top, perpendicular to the ecliptic, and east is to the right. The listed names are those used by the Stardust team to identify features. Basin does not imply an impact origin.





Pit-halo crater Rahe, just to the right of centre



Stereo pair taken just before closest approach:
From top to bottom along terminator:
Craters Hemenway (with its bright spot), Mayo and Shoemaker
Mesa and pinnacle in crater Shoemaker (?)

Stereo pair taken just after closest approach

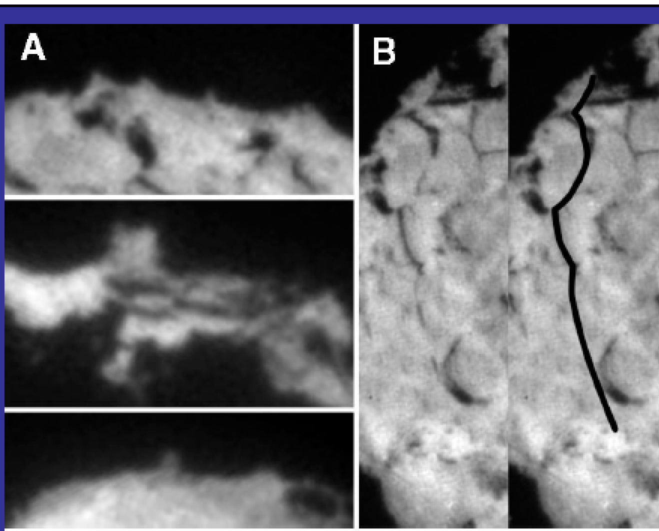


Fig. 6. (**A**) A variety of small pinnacles and mesas seen on the limb of Wild 2. (**B**) The location of a 2-km series of aligned scarps that are best seen in the stereoimages.

Fig. 5. A 10-cm-sized laboratory hypervelocity impact crater made as an analog of Wild 2's flat-floor craters. The crater was made with a 3.2-mm ceramic projectile impacting a porous target at 2 km s^{-1}.

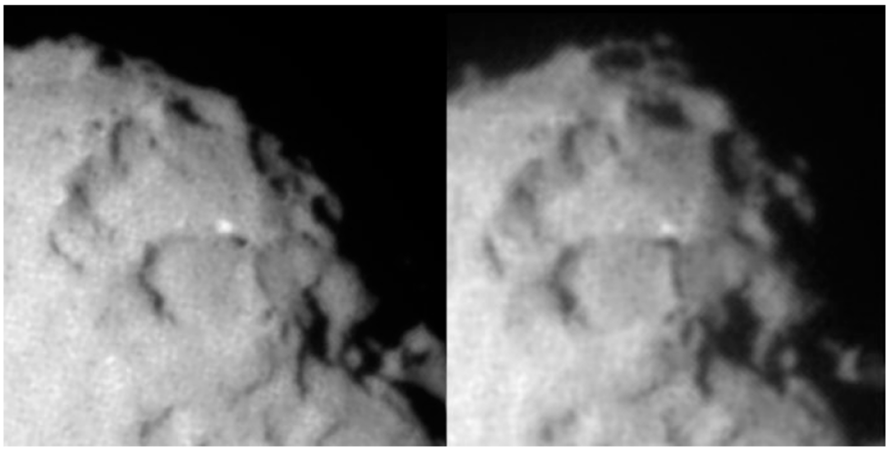
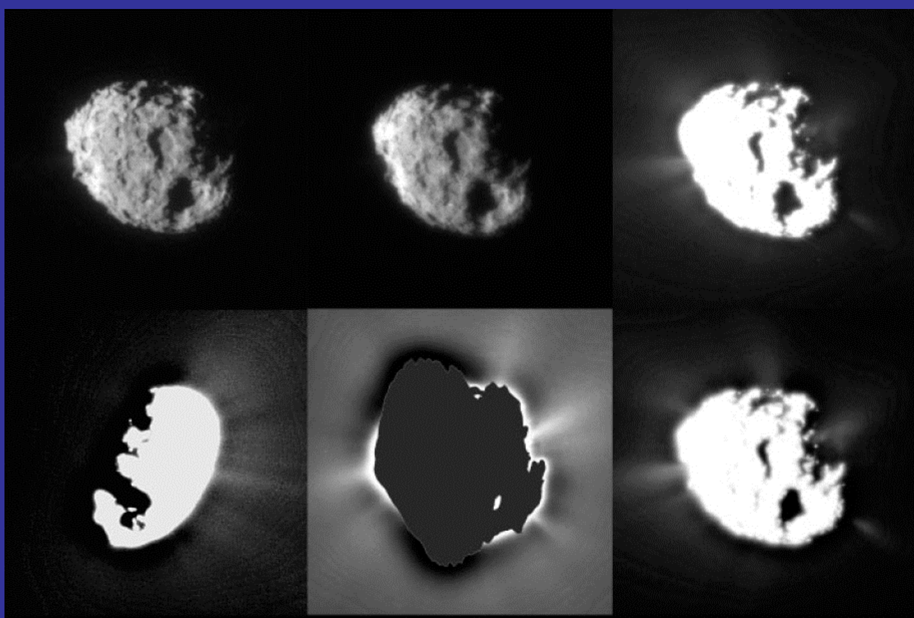
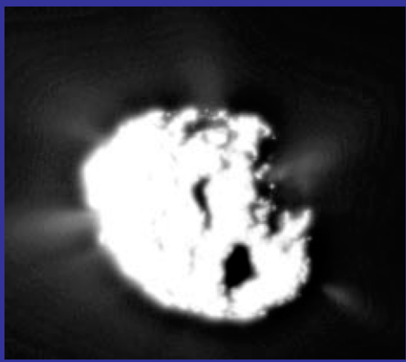
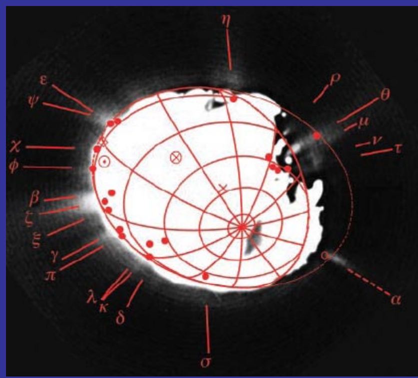


Fig. 7. A stereoview of the bright spot in the central region of Hemenway. A smaller spot barely detected in both images is seen just to the left of the central spot. The stereoimage also shows several remarkable upturned ridges.







The diamond is the intersection of the long-axis meridian with the equator, the circled dot is the subsolar point, and the circled cross is the subspacecraft point on the nucleus approximated by the fitted ellispoid. The ellipsoid center is marked by the X.

Comet 2P/Encke:

Short-periodic comet with the smallest known perihelion distance q = 0.33 AU and with a period of 3.28 years.
Comet Encke does not display a tail. Instead a so-called “fan” is observed, a broad feature visible at an angle to the Sun-comet line.
Comet 2P is probably the most evolved comet.

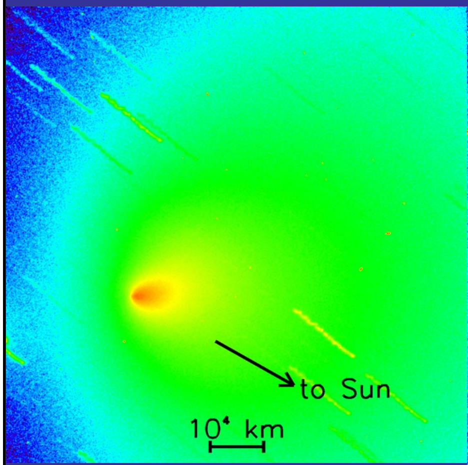
According to Sekanina (1988, Astron. J. 95, 911-924) comet Encke’s north rotation pole is located at right ascension 205º and declination 2º. Two vents on the nucleus surface were identified, one at latitude +55º (source I) and another one at latitude -75º (source II).

The comet was observed (own work) in 2003 before perihelion, when source I was active. As it turns out, the jet from the active region is visible in the light of the CN radical. The visible dust come is round with very slight extension in the direction of the fan.

Radio observations of the HCN molecule obtained simultaneously with the optical observations show a Doppler line profile consistent with ejection from the jet.
Note that HCN is a possible parent molecule of the CN radical.

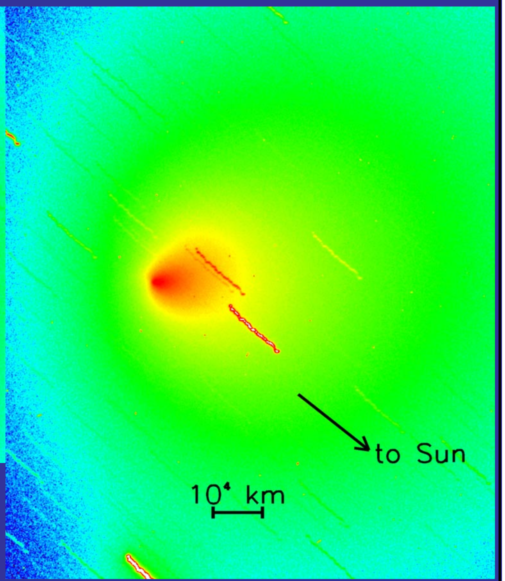
CN

18-11-2003

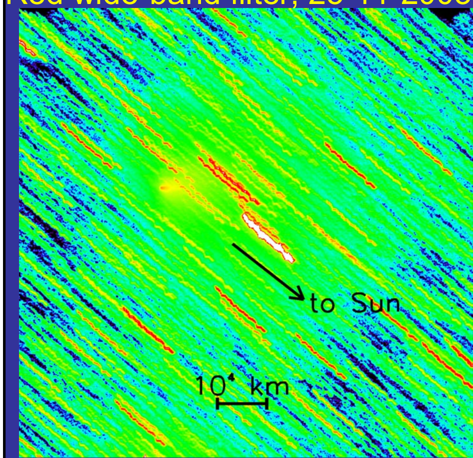


CN-coma not spherical.
Asymmetry not aligned with solar-antisolar direction.

25-11-2003

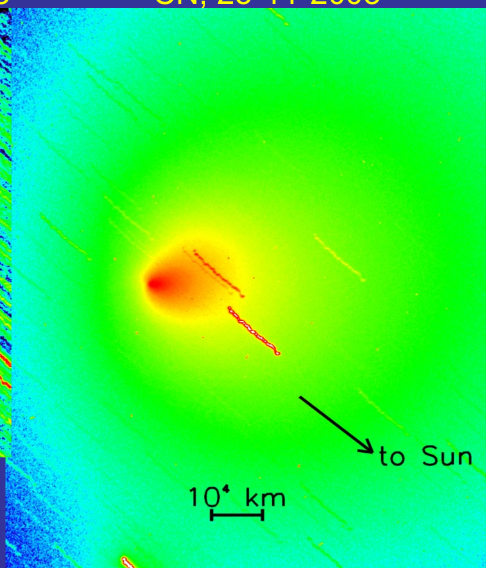


Red wide-band filter, 25-11-2003



Both images show the asymmetric coma. Is it gas or dust or both?

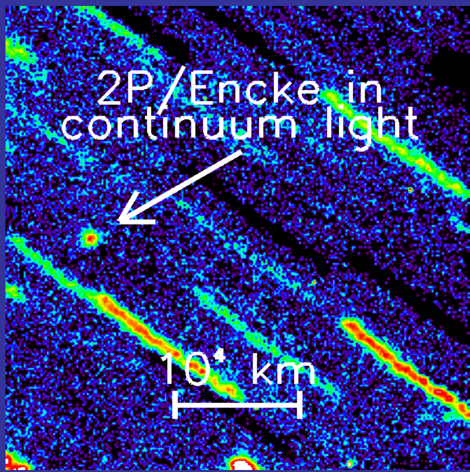
CN, 25-11-2003



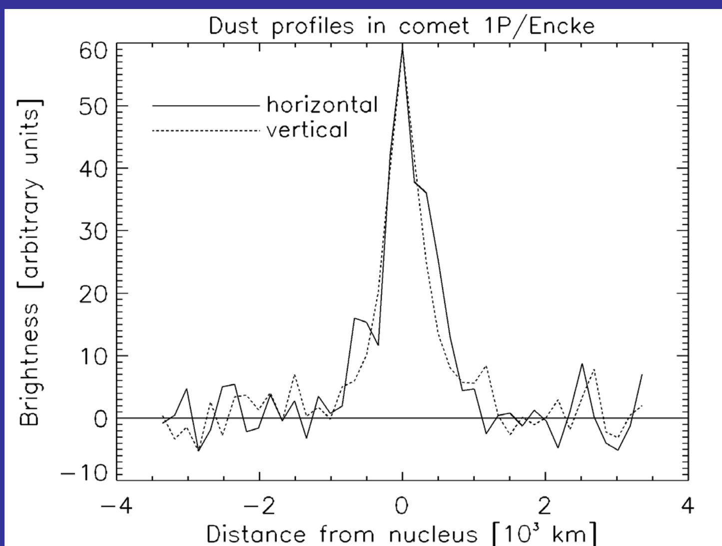
In order to derive a dust image in the visual wavelength range, images taken through different filters must be combined. →

We conclude:

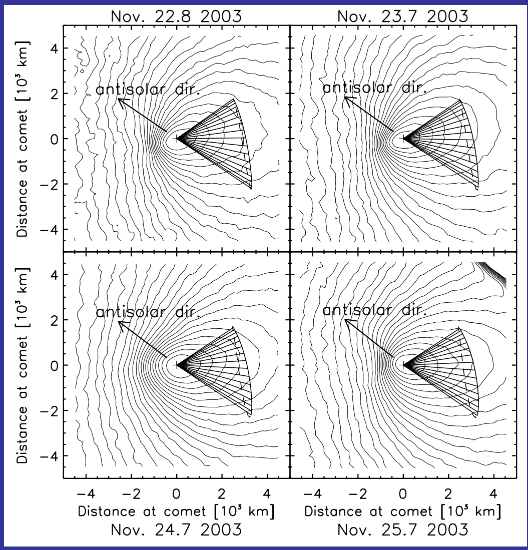
• The fan consists of molecules.
• The dust coma is round.
• The dust particles must be large.



Cross-sections through dust image of previous slide

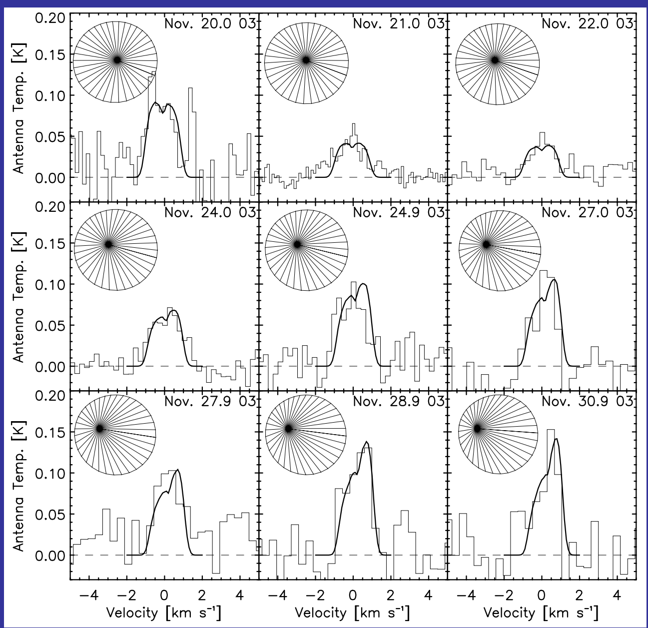


Isophotes of the CN emission with the emission cone of the active region superimposed.



The line profile of the HCN line (354.505 GHz and 265.886 GHz) fitted by a model of HCN emission from source I.

In the upper left corner of the panels we see the projection of the emission cone into the NS plane along the line of sight.



The outgassing from the nucleus of comet 2P/Encke is not isotropic but occurs from a limited active area.

The observed HCN line profiles can be explained by our Monte Carlo model of a ring-shaped active source, with the position of comet Encke's north pole at right ascension 205° and declination 2° (Sekanina 1988), and the ring-shaped activity at a latitude of 55° (source I of Sekanina 1988). Instead of a ring-shaped active region an active polar cap extending from the north pole to 55° latitude could possibly also explain the observations.

The observed radio lines of HCN reveal a gas expansion velocity of the coma equal to 1.2 km s^{-1}.

The location of the optical CN jet is consistent with pole and source position of Sekanina (1988, Astron. J. 95, 911-924)