Microphysics of dust in distant comets

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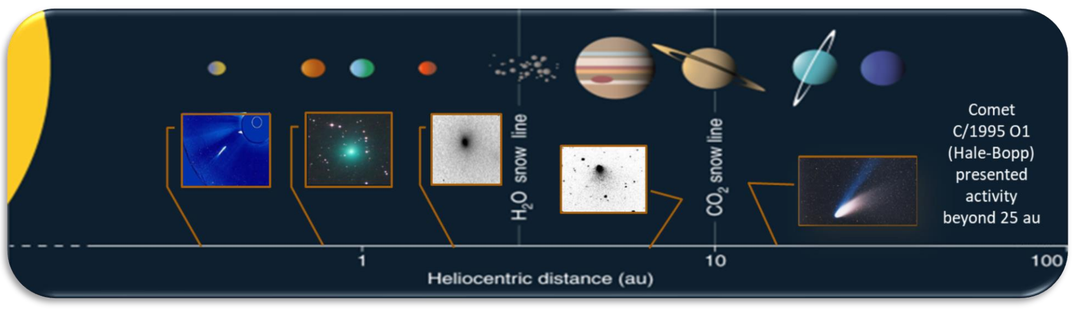
THE ACTIVITY OF COMETS OVER A WIDE RANGE OF HELIOCENTRIC DISTANCES



- The physical nature of comets is known mainly from the investigations of bright comets observed close to the Earth and the Sun (~1–2 au).

The physical mechanism:

(i) sublimation of water ice;

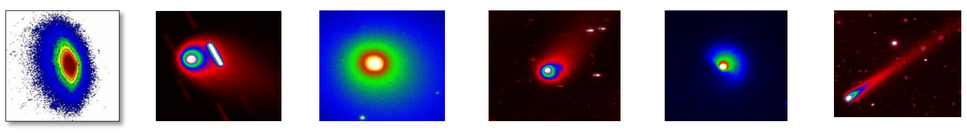
- Observations at large heliocentric distances (more than 5 au) are scarce and much more difficult.

The physical mechanisms:

(i) the sublimation of more volatile admixtures like CO and/or CO_2;
(ii) the transition phase between amorphous and crystalline water ice (Prialnik 1992);
(iii) the annealing of amorphous water ice (Meech et al. 2009).
(iv) the meteoroids bombarding the surfaces and other mechanisms (Ivanova et al., 2015).

These observations are, nevertheless, very useful to obtain more information about the origin of comets as well as their relation with similar objects, such as Kuiper belt objects and Centaurs.

THE MAIN PURPOSE OF THE OBSERVATION



Objects:

- Comets demonstrate high-level activity at large heliocentric distances (q>4 au, beyond sublimation water ice zone), with bright coma and dust tail.

Purpose of the study:

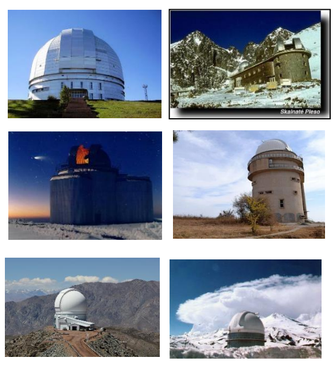
- Search for emission of gases responsible for the formation of asymmetric coma and long tail;
- Analysis of spectral energy distribution in different parts of the tail to study the physical properties of the dust particles forming the observed tails;
- Analysis of the polarimetry and color map, dustproductivity, and morphological features;
- Model interpretation of dust properties at large heliocentric distances.

Methods:

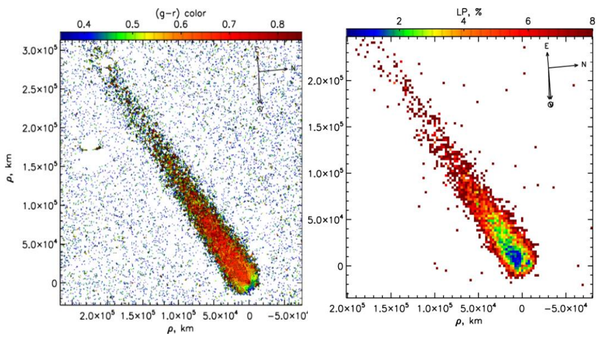
- Imaging photometry
- Imaging polarimetry
- Long-slit spectroscopy (3500-8500 Å)

Filters:

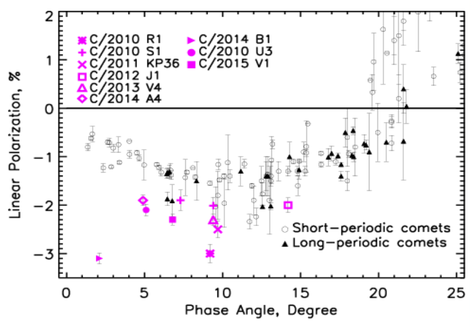
- Broad-band filters
- Cometary filters

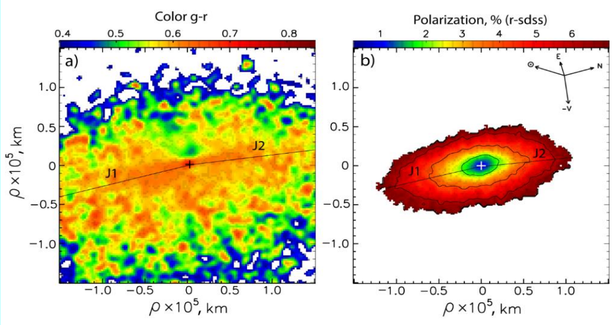


Color and Polarimetry maps

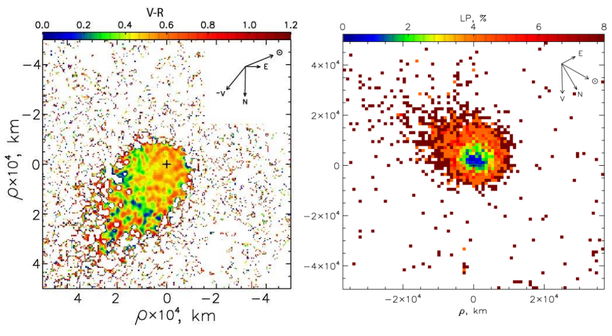


C/2014 A4 (SONEAR)





C/2014 B1 (Schwartz)

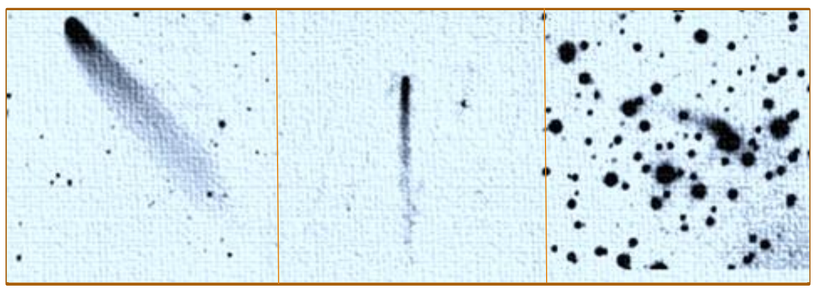


2I/Borisov C/2013 V4

- First detailed maps of the distribution of the linear polarization of selected distant comets were made.
- Polarization maps of these comets show spatial variations of polarization over the coma from about –2% up to 4% at phase angles α from 2° up to 14° which may be related to changes in the physical properties of the dust particles. Average values of the polarization are significantly higher (in absolute values) than the typical value of polarization (~ -1.5%) observed for the dust comas of most comets close to the Sun.

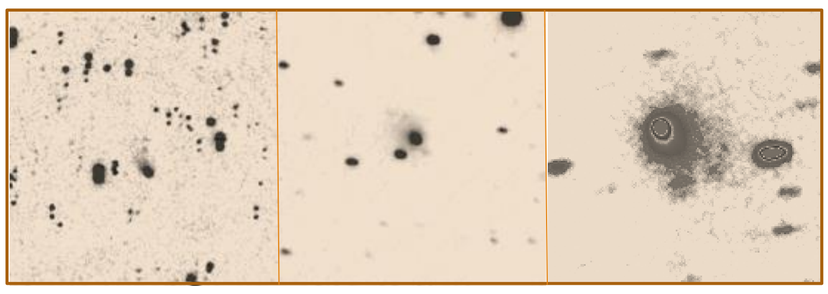
MORPHOLOGY OF DISTANT COMETS

The comets with dust tail

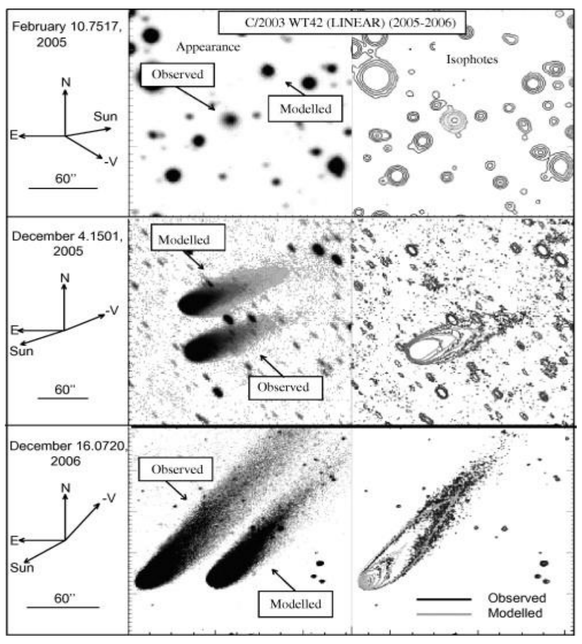


C/2003 WT42 (5.5 AU) C/2005 R4 (5.6 AU) C/2007 VO53 (6.2 AU)

The comets with asymmetric coma

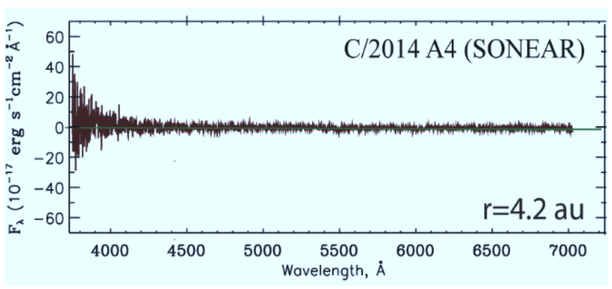


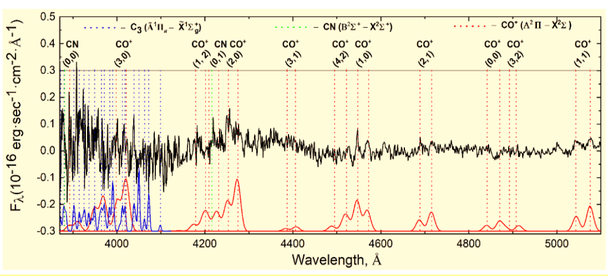
P/2008 CL94 (5.9 AU) C/2007 D1 (10.6 AU) C/2010 U3 (16.75 AU)



The tail of Comet C/2003 WT42 (LINEAR) was observed in 2005 and 2006. The modeling pointed out that the physical activity of the comet was mainly determined by these two active areas with outflows into wide cones (Korsun et al., 2010)

SPECTRA OF THE DISTANT COMETS



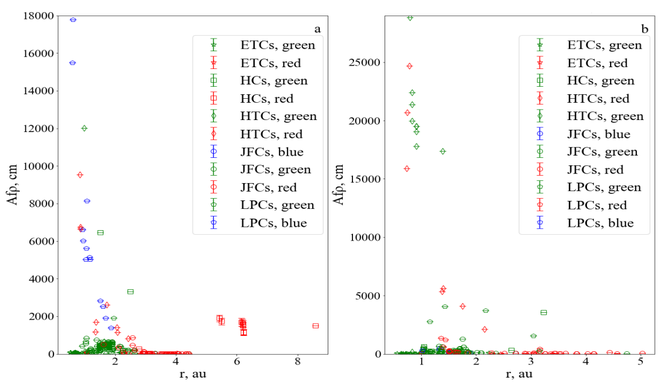


- In the spectra of most studied distant comets, only the continuum due to the scattering of sunlight by cometary dust is registered;
- In most cases, a reddening effect (increasing scattering efficiency with wavelength) was registered;
- For some comets, the efficiency of sunlight scattering by dust in the blue region of the spectrum was greater than in the red one.

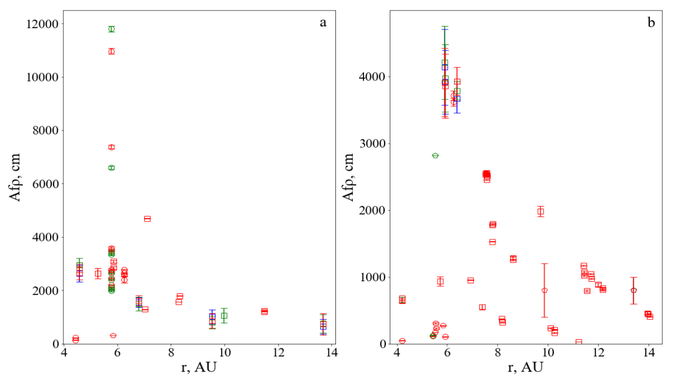
Only in the spectra of 4 distant comets emissions were registered:

29P/Schwassmann–Wachmann 1 :	CN, CO^+ and N_2^+ (r>6 au)
C/2002 VQ94 (LINEAR):	CN, C_3, CO^+ and N_2^+ (r>4 au)
C/2011 J1 (Catalina):	CN (r>3 au)
C/2011 KP36 (Spacewatch):	CO^+ (r>5 au)
C/2006 OF2 (Broughton):	CN, C_3, C_2 (r>4 au)

DUST PRODUCTIVITY OF THE DISTANT COMETS



Comets with q < 3 au. (a) and (b) contain pre- and post-perihelion observations, respectively (Voitko A. Afρ Data base).



Comets with q > 4 au. (a) and (b) contain pre- and post-perihelion observations, respectively (Voitko A. Afρ Data base).

- Decrease in Afρ with the aperture indicates either fading of the particles (decrease in albedo) or their fragmentation (decrease in scattering cross-section). One more evidence of fragmentation!
- Different Afρ in r and g filters indicate that the dominating size of the particles is in the submicron range. This is consistent with the polarization and color modeling results.
- For most distant comets, the dust productivity was found to be significantly greater than for short-period comets, including comets of the Jupiter family, which are observed at large heliocentric distances.

MODELING DUST ENVIRONMENT OF DISTANT COMETS

Material

- Halley-like dust
- Amorphous silicate (forsterite)
- Water ice (different porosities)
- Iron-rich pyroxene
- Olivine
- CO2 ice
- Amorphous carbon
- Pyrrhotite (FeS)
- Fe-rich olivine (Fayalite)
- Titan's tholin
- Tholin ice
- Cosmic organic refractory
- Mg-rich silicate

- The coma of some distant comets is dominated by submicron particles consisting of large amounts of ice and tolin-like organic matter or formed by particles of different sizes consisting of water ice, CO2 ice, and refractory material;
- Need fragmentation and dynamical sorting of particles to explain a larger number of icy particles at some distance from the nucleus (especially in the tail) than near the nucleus.
- Without ice it is difficult to explain the deep polarization minimum.
- Particles of high porosity are needed to reproduce the observed color and polarization.
- Thus, the modeling not only revealed the composition, structure, and size of the dust particles but also provided strong evidence of dust fragmentation.
- For some comets modelling of dust environment reproduced by Mg-rich silicate slightly contaminated with amorphous carbon

More results are presented in the articles on the page:
https://scholar.google.com/citations?user=EMxqwv0AAAAJ&hl=uk

Results were obtained and analyzed with co-authors:
V. Rosenbush, V. Afanasiev , I. Luk'yanyk, N. Kiselev, A. Moissev, L. Kolokolova, Yu. Skorov, E. Zubko, V. Kleshonok