The Metis contribution in cometary science:
an initial assessment of the first three years of activities

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Summary of the activities

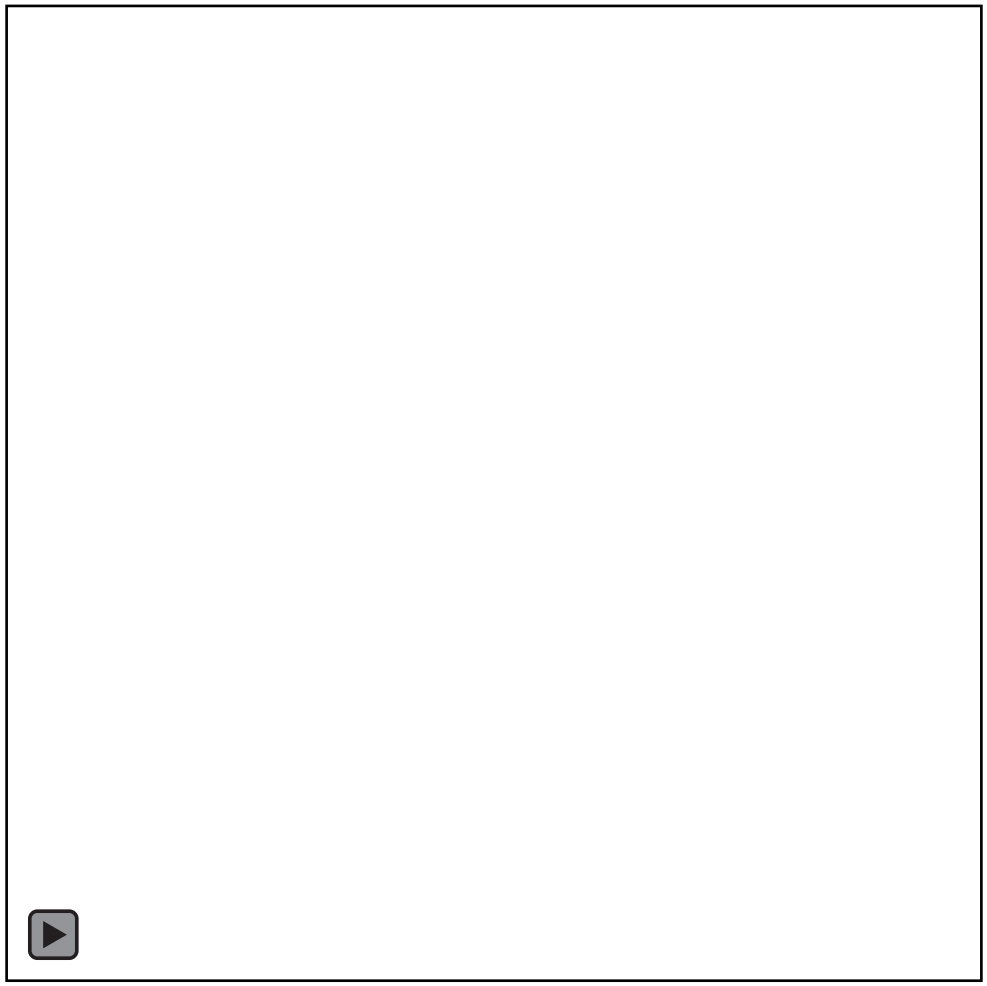
- Development of a tool able to foresee comet passages on the Metis FoV
  - Periodical check of new bodies on the IAU Minor Planet Center database for checking transits on the Metis FoV.

- Planning comets observations
  - Modeling of visible light curve based on available ground observations (typically amateur astronomers).
  - Modeling of UV light curved, based on literature or SOHO/SWAN observations.
  - Observation plan (… robust enough in order to avoid the failure if the comet changes the game).

Comet	Observation Outcome
C/2021 A1 (Leonard)	**Success**
96/P Machholz	**Success**
322P/SOHO	**Missed** (no observational window available)
2P/Encke	**Partially observed** (restricted observational window and low data volume)
321P/SOHO	**Partially observed** (At the limit of the Metis capabilities)
C/2020 P4-B	**Not observed** (because of probably out of Metis capability)

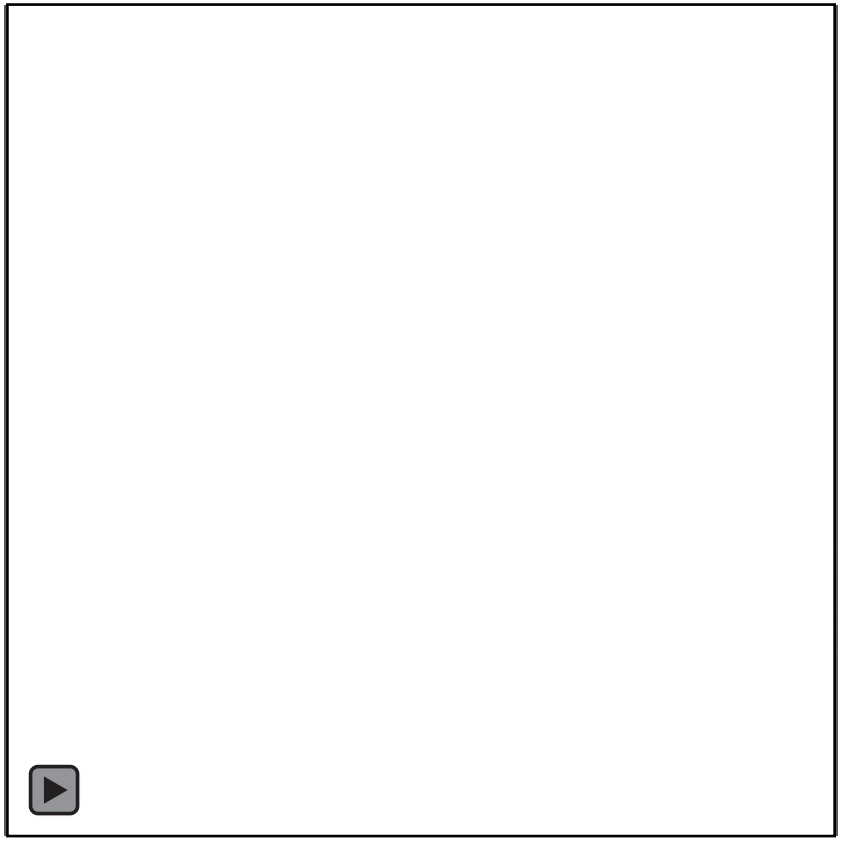
- Data analysis…
  - Participation (in representation of Metis) to the Comet Leonard HIS Group meeting (lead by Tim Stubbs, NASA/GSFC)

Example: 96P/Machholz

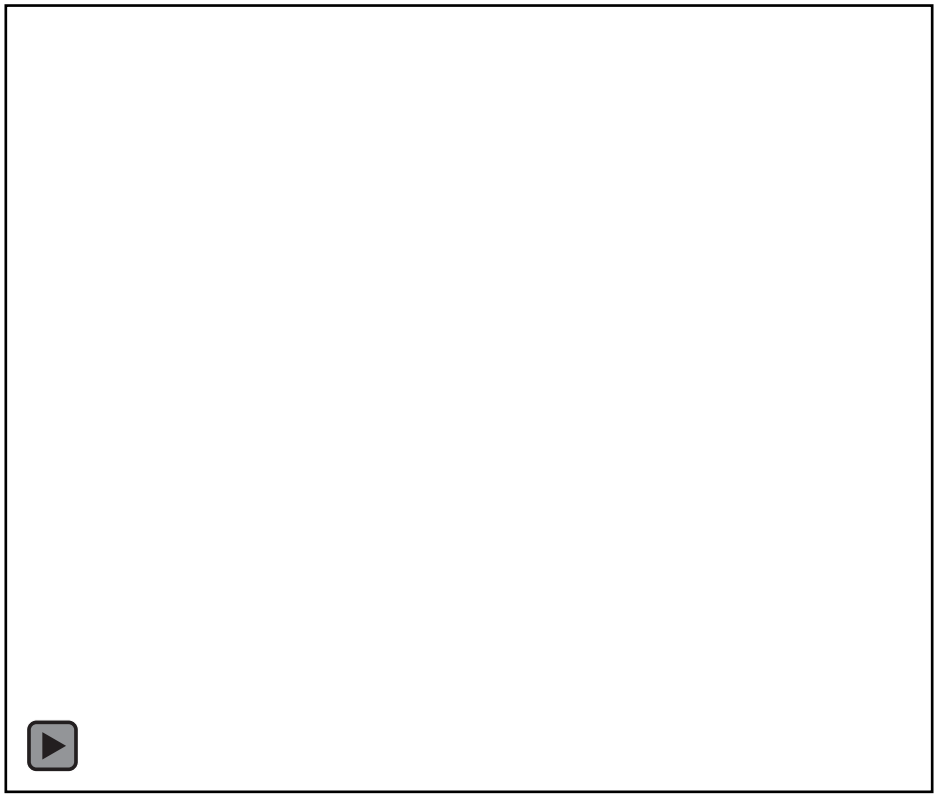


Example: 96P/Machholz

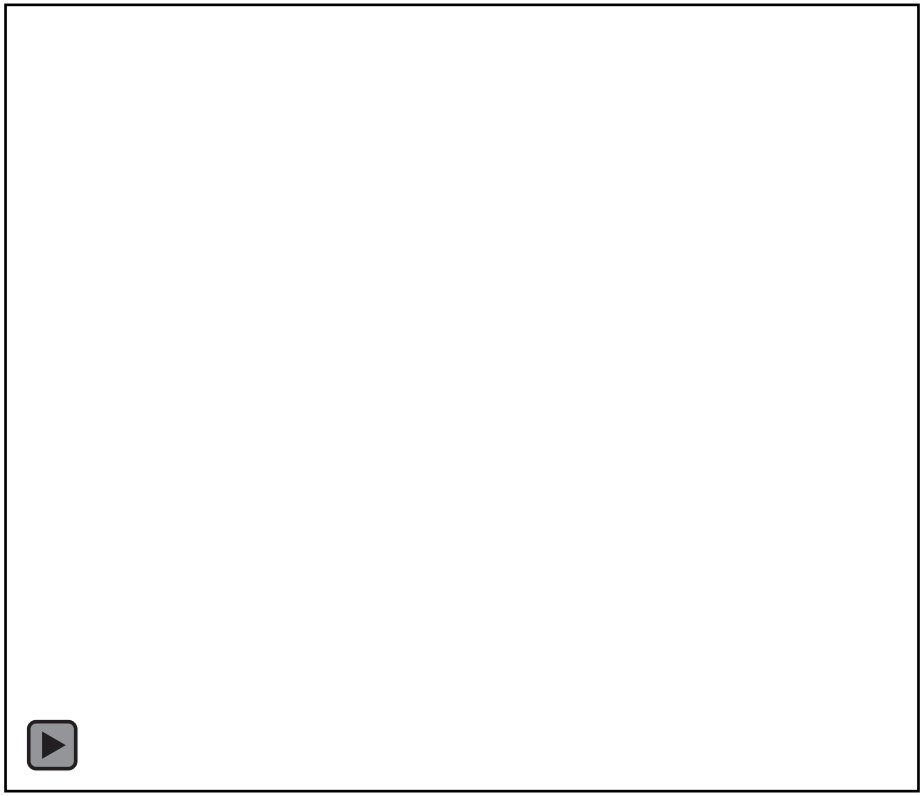
tB Visible observations



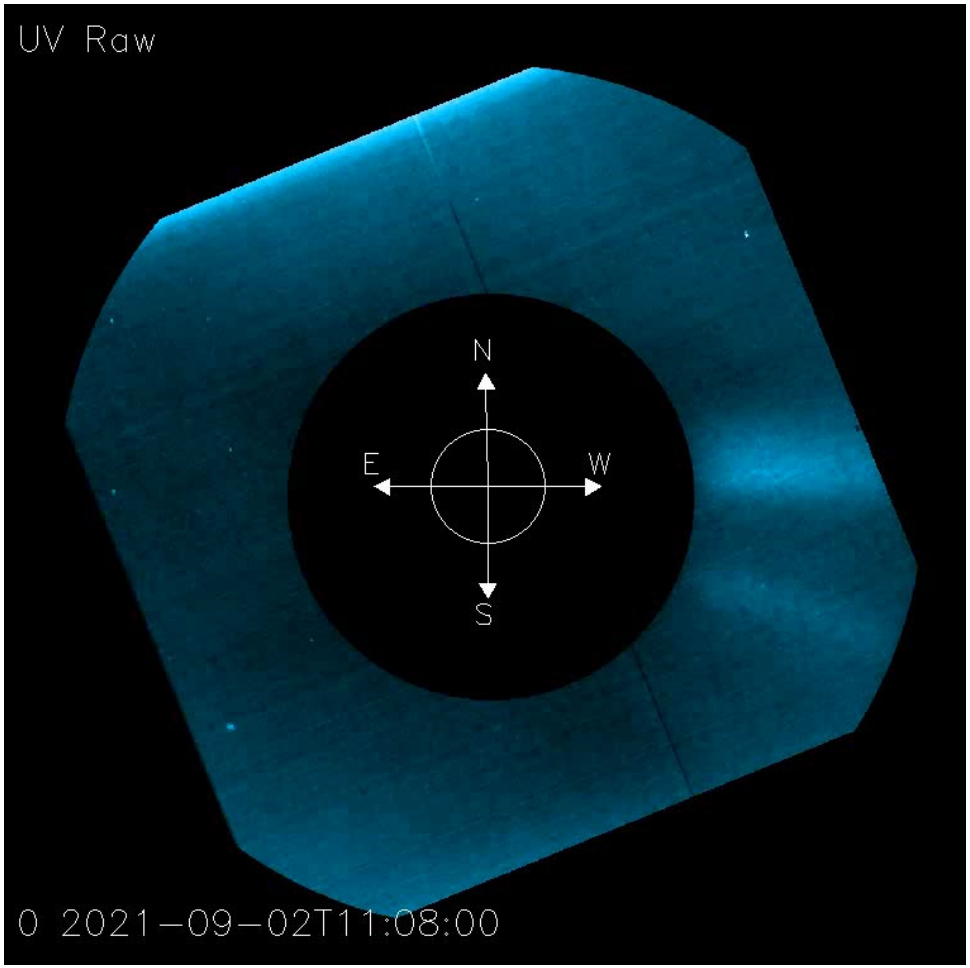
Example: C/2021 A1 Leonard

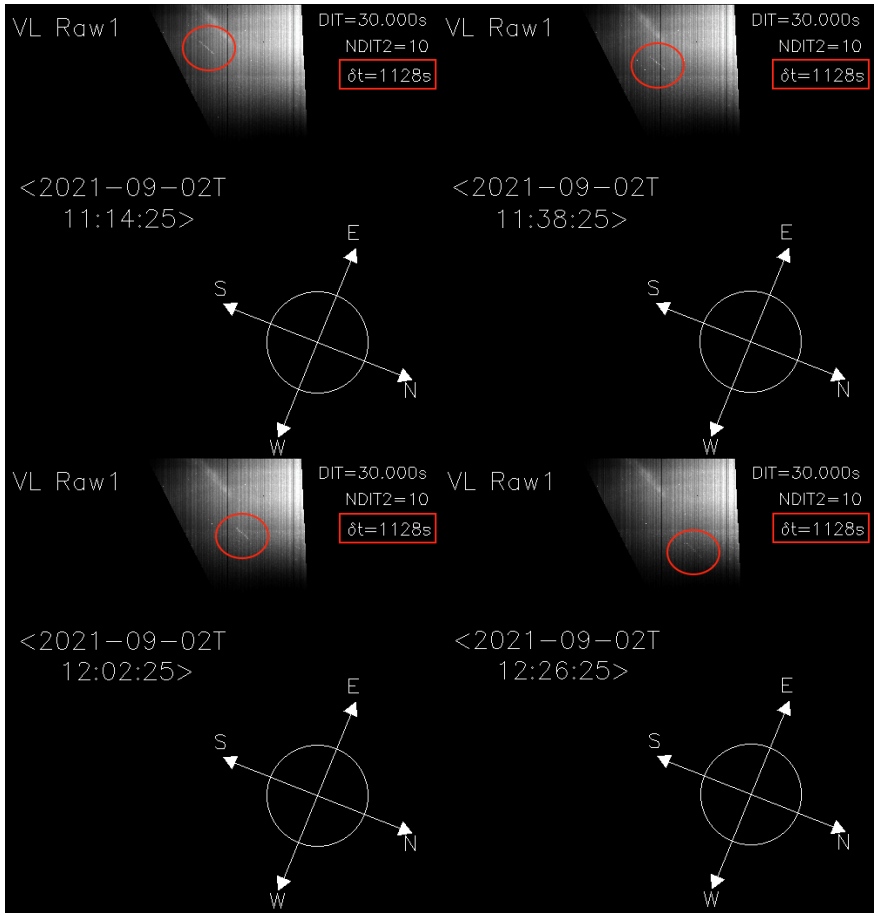


Example: C/2021 A1 Leonard

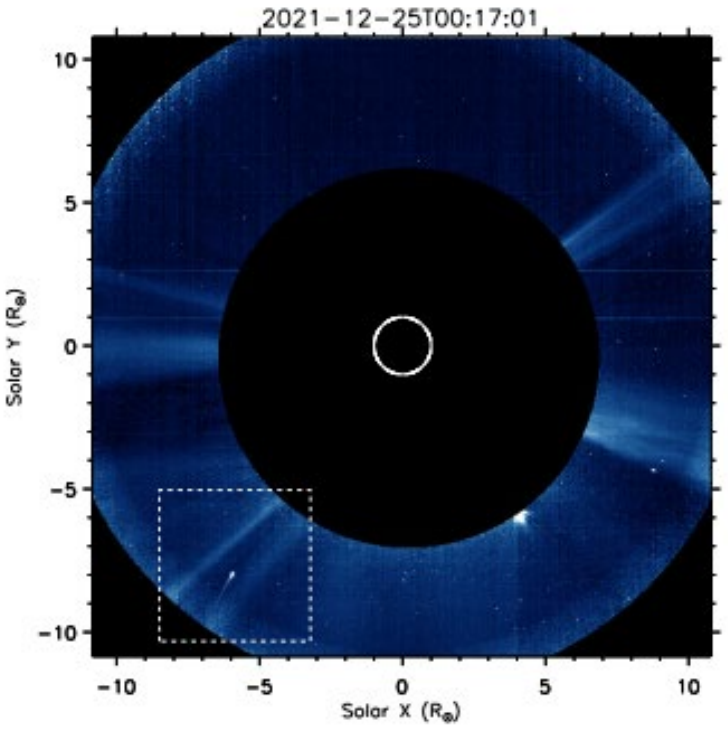


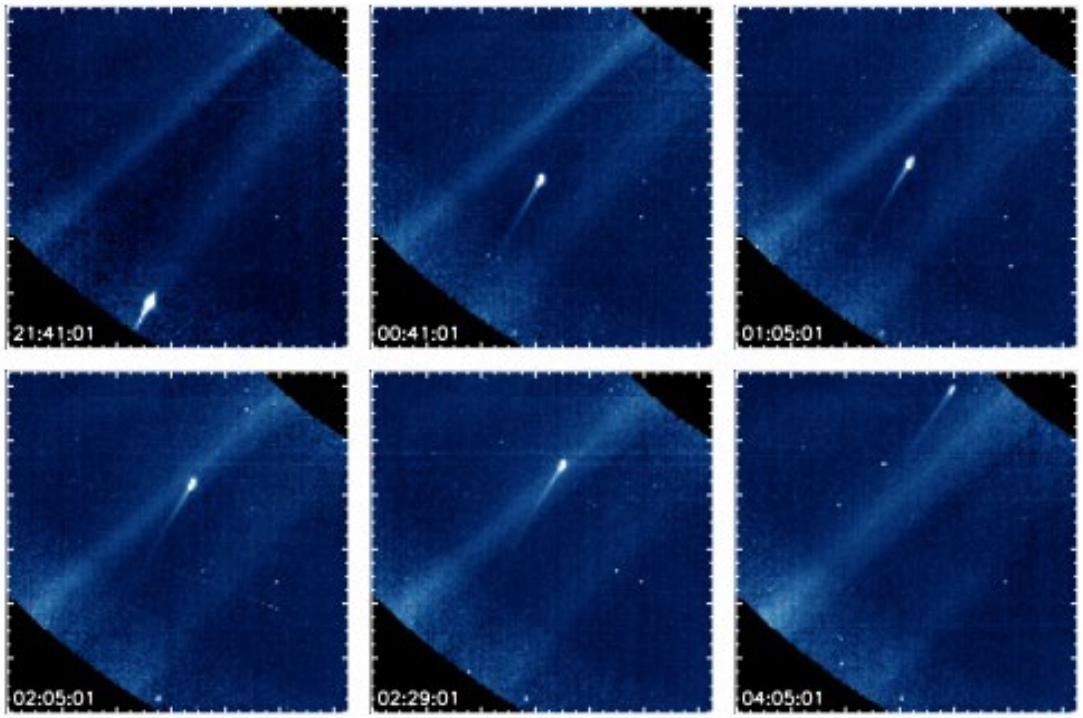
Serendipitous comets





Serendipitous comets



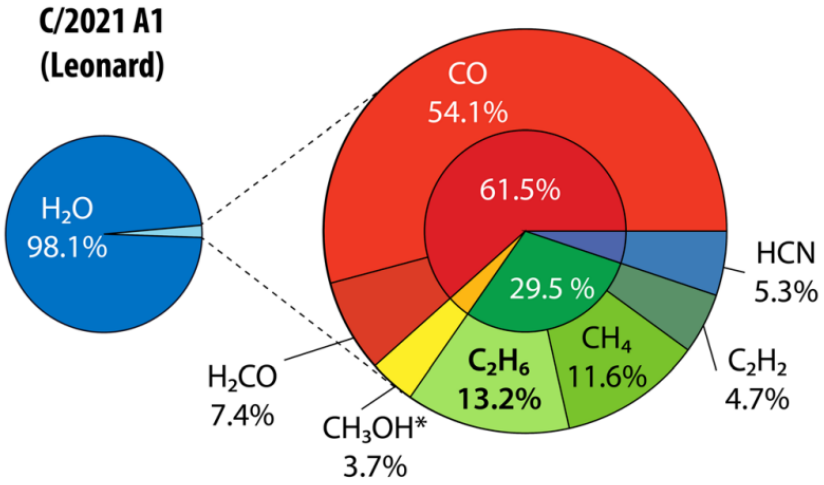


From A. BEMPORAD et al., Astronomy & Astrophysics 680 (2023)

Metis breakthroughs in cometary science

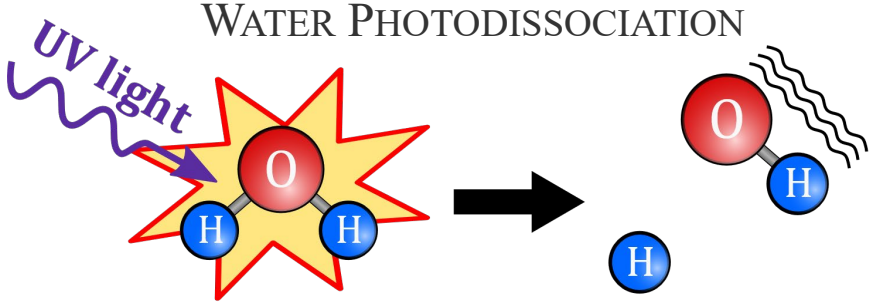
Observational context	Typically	Metis
UV Ly-α observations	• Ly-α ”full comet” integrated photometry (e.g. SOHO/SWAN) • UV spectrometer scanning	• Direct imaging with plate scale of $40.2\ ''/\mathrm{px}$
VIS observations	• Different spectral bands • Polarimetry • Light curve over time • Spectroscopy	• Polarimetry (tB, pB) • One spectral band, narrower than R band • Simultaneous with UV Ly-α imaging
Phase angle ϕ observations geometry	• Ground-based: $30° < \phi < 150°$ • Space-based coronagraph (e.g. LASCO…): $10° < \phi < 170°$	• $2° < \phi < 178°$ (… and probably better)

Outcomes from UV (H I Ly-α) observations

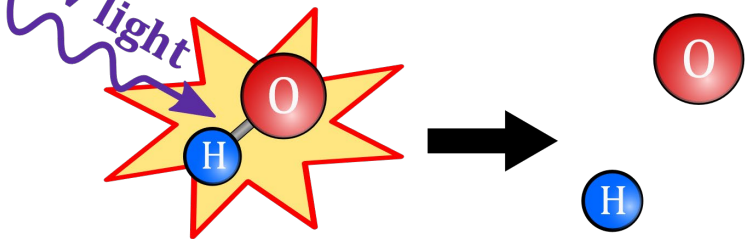


From FAGGI S. et al., The Planetary Science Journal (2023)

PROCESS 1:
WATER PHOTODISSOCIATION



PROCESS 2:
HYDROXYL PHOTODISSOCIATION

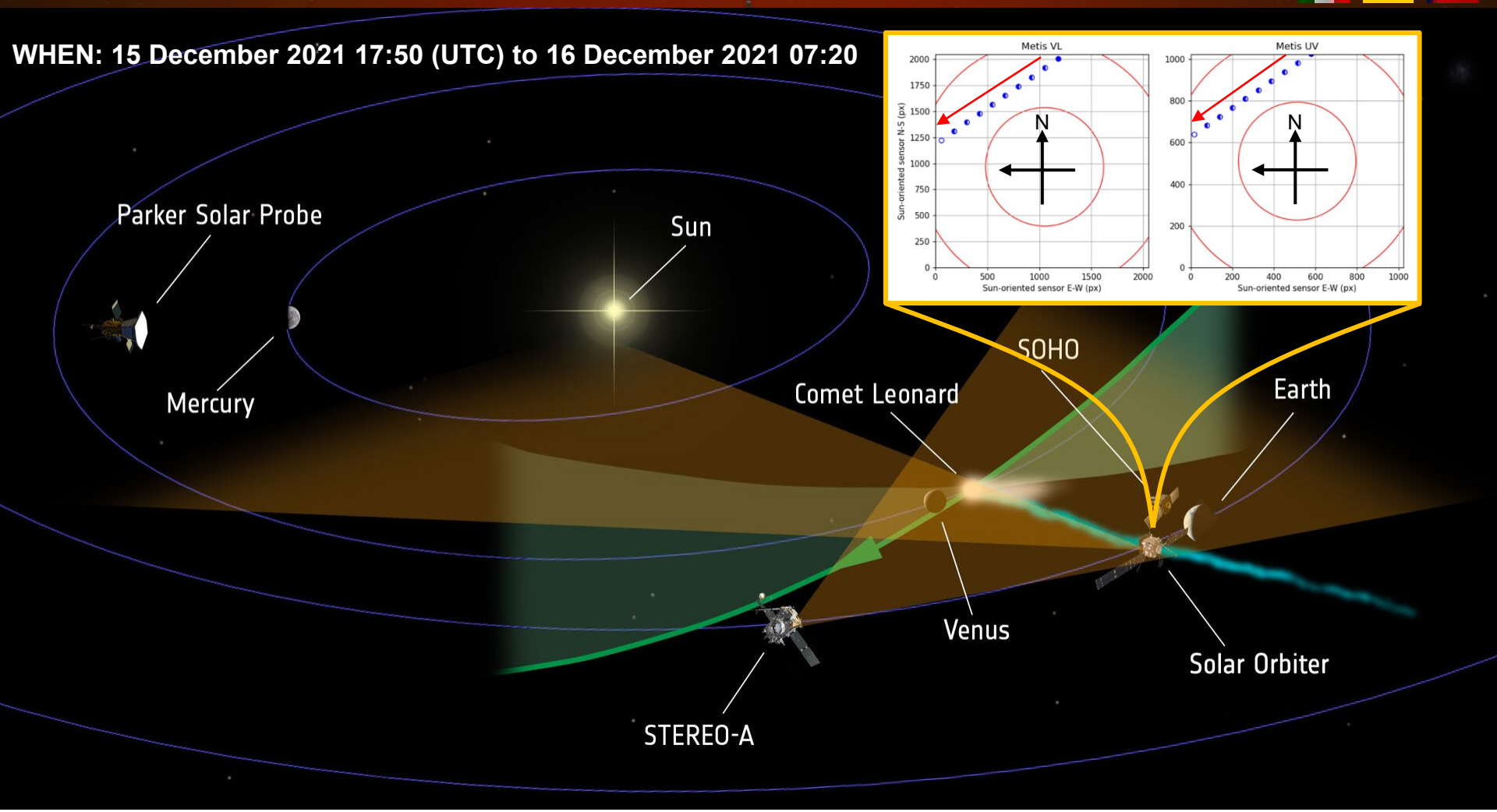


The Ly-α resonant scattering of the neutral H coma can be used to:

- estimate of the water outgassing rate.
- infer some properties of the local corona plasma when H atoms interact with solar wind (only for sun-grazing comets).

Example: C/2021 A1 Leonard Metis observations

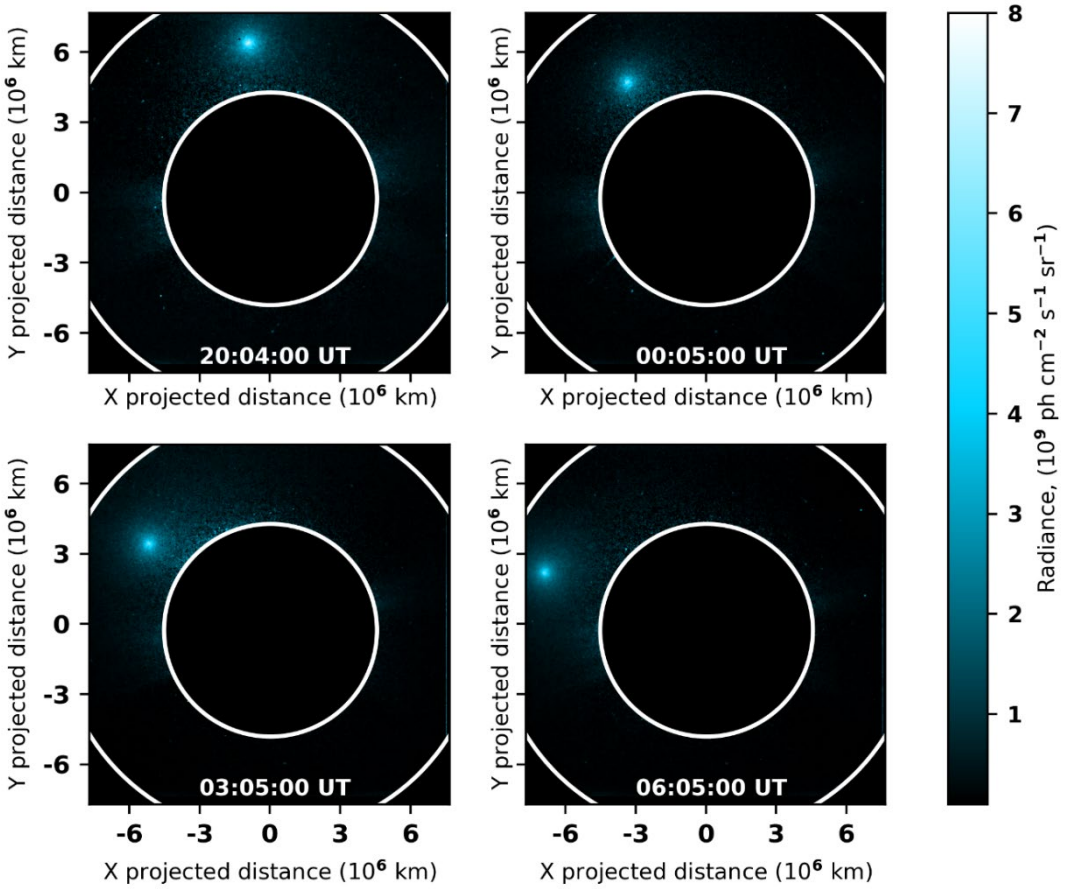
WHEN: 15 December 2021 17:50 (UTC) to 16 December 2021 07:20



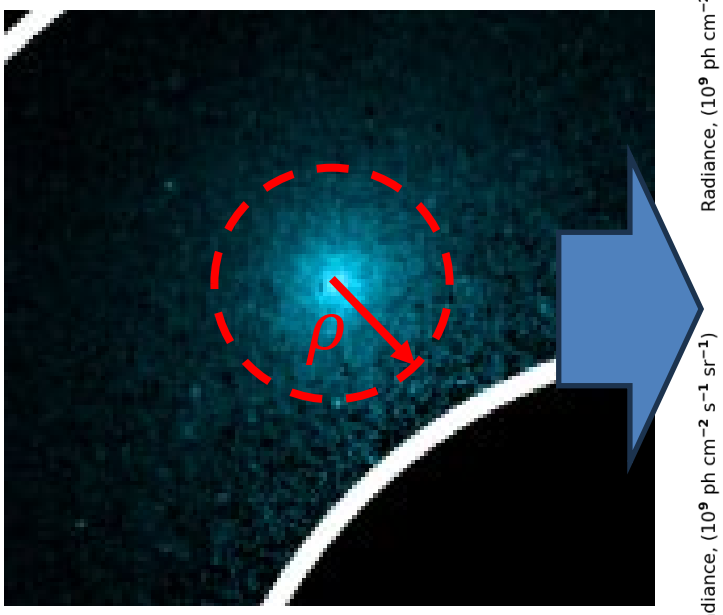
Example: C/2021 A1 Leonard UV observations

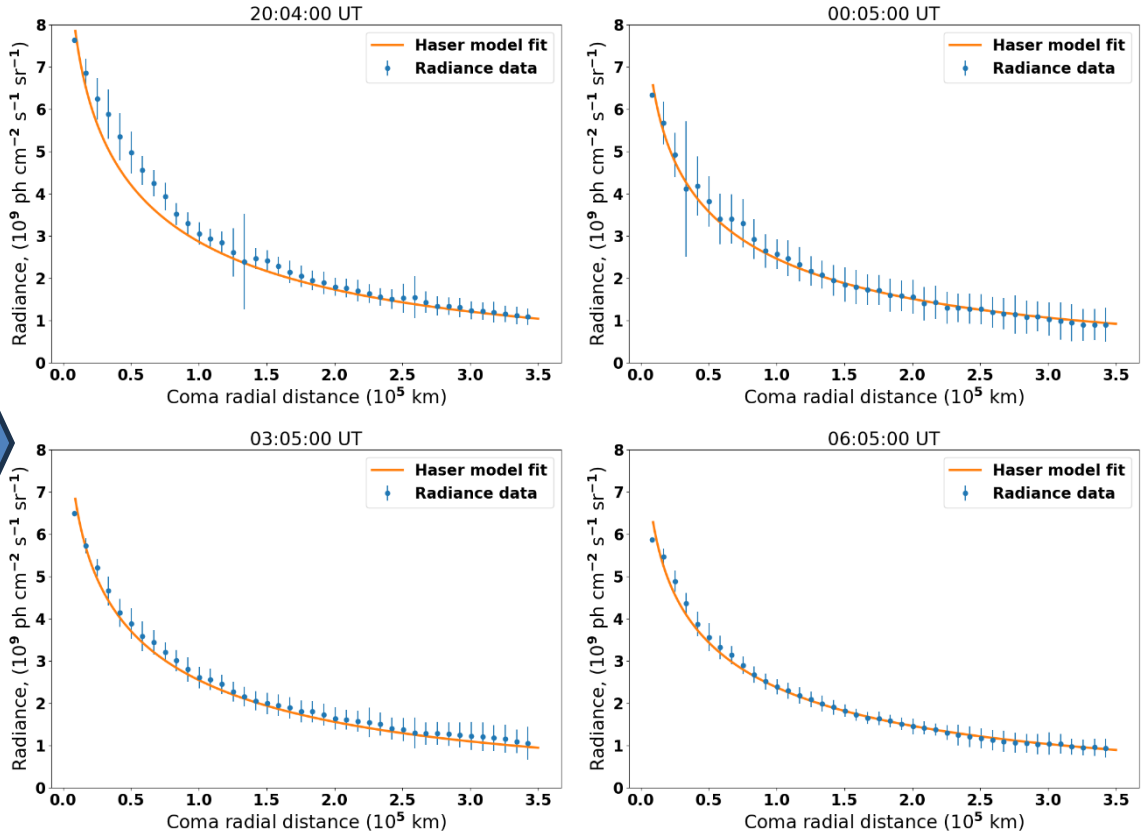
UV radiance given by the H coma fitted with a **Haser model**.

- ✓ Stationary model.
- ✓ Coma spherical symmetry.
- ✓ Model with **3** main populations of H atoms **speed**:
  - **20 km/s** coming from the first photodissociation process
  - **8 km/s** coming from the second photodissociation process
  - **< 4 km/s** coming from a thermalization of the high velocity atoms



Example: C/2021 A1 Leonard UV observations

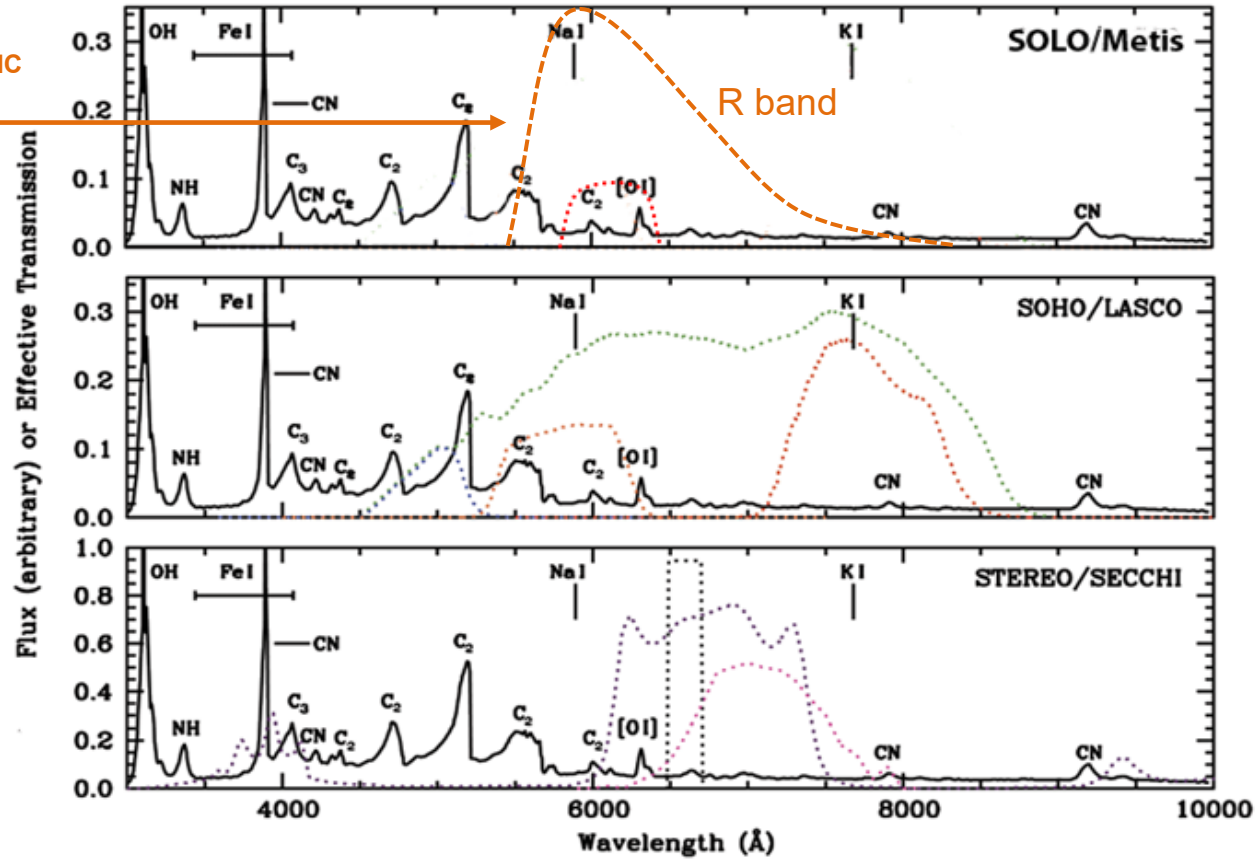




$$Q_{H_2O} \approx (1.80 \pm 0.27) \cdot 10^{29} \ \frac{\text{molecules}}{\text{s}}$$

Metis VIS bandpass vs other coronagraphs

STANDARD PHOTOMETRIC BAND FOR DUST STUDY



Visible Bandpasses comparison. SOLO/Metis, SOHO/LASCO, and STEREO/SECCHI bandpasses overlaid on a typical comet spectrum expressed in arbitrary units. (adapted from JONES 2018)
[Metis 580-640 nm LASCO C2 Orange filter 540-640 nm]

Coma dust analysis: the Afρ parameter

COMET NUCLEUS RADIAL DISTANCE

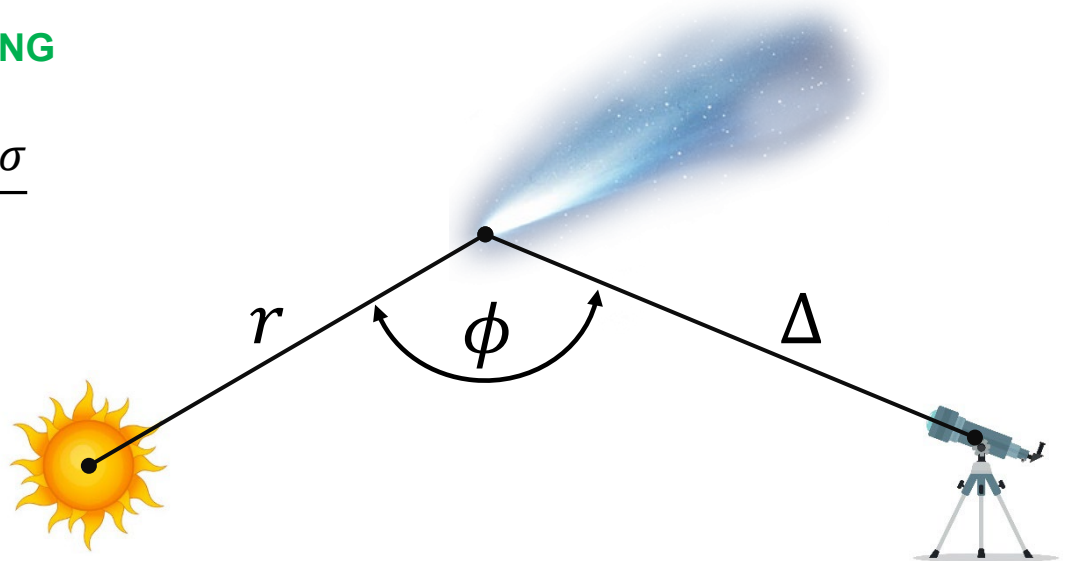
$$A f \rho = 4r^2 \frac{\Delta^2}{\rho} \frac{F_{\mathrm{Comet}}(\rho, \phi)}{F_{\mathrm{Sun}}}$$

COMA GRAINS AVERAGE ALBEDO

$$A = \frac{4\pi\Delta^2 \, F_{\mathrm{Comet}}(\phi)}{N(\rho)\sigma F_{\mathrm{Sun}}}$$

DUST FILLING FACTOR

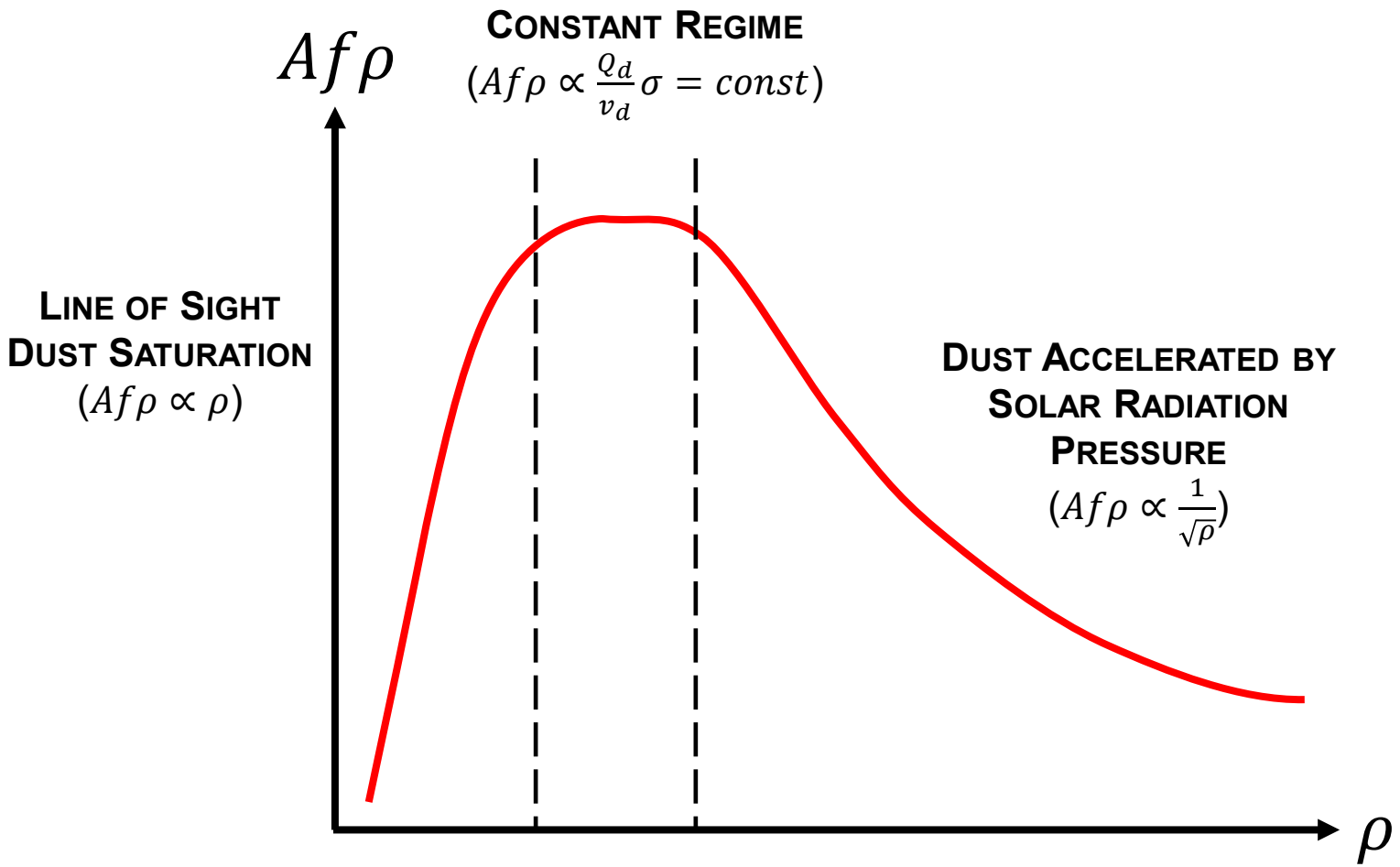
$$f = \frac{N(\rho)\sigma}{\pi\rho^2}$$



$N(\rho)$: dust grains within the radius ρ from the nucleus along the line of sight.

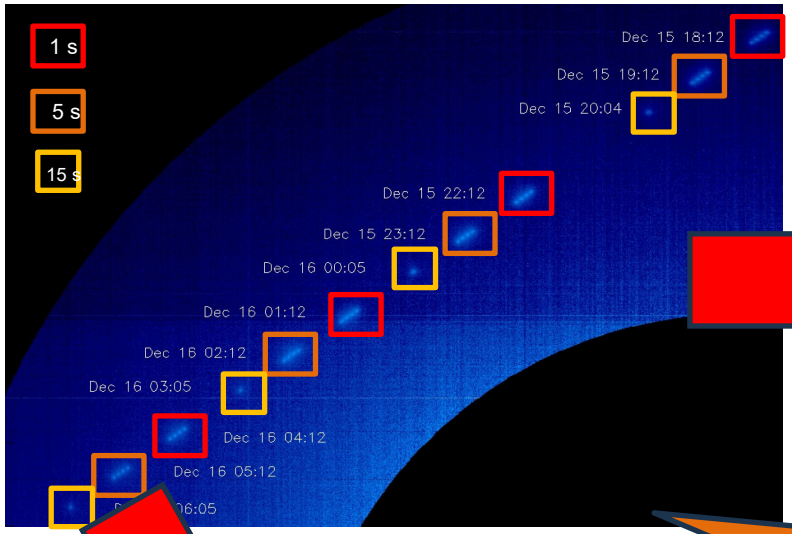
σ: average geometric section area of dust grains.

Coma dust analysis: the Afρ parameter



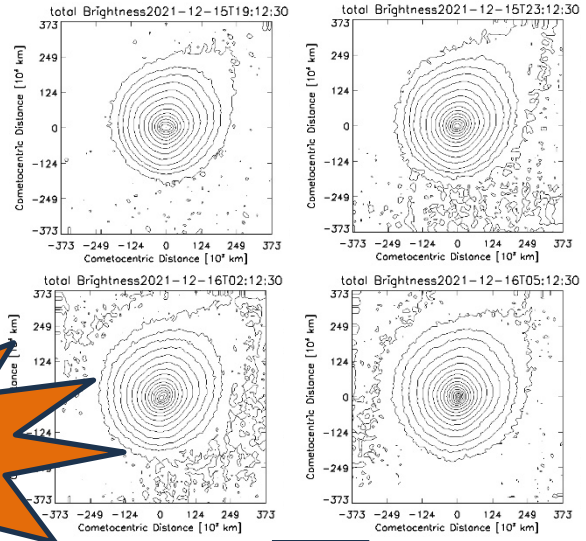
Example: C/2021 A1 Leonard dust study

VISIBLE DATASET



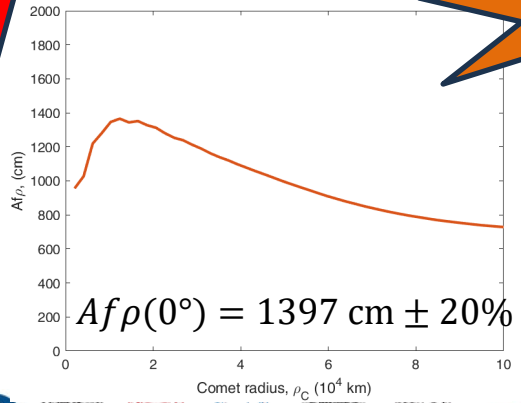
ISOPHOTE-BASE DUST COMA MODEL

Inferring on dust ejection velocity v_d of the grains and main dimensions σ (model provided by Marco Fulle, OATs)



PRELIMINARY RESULTS

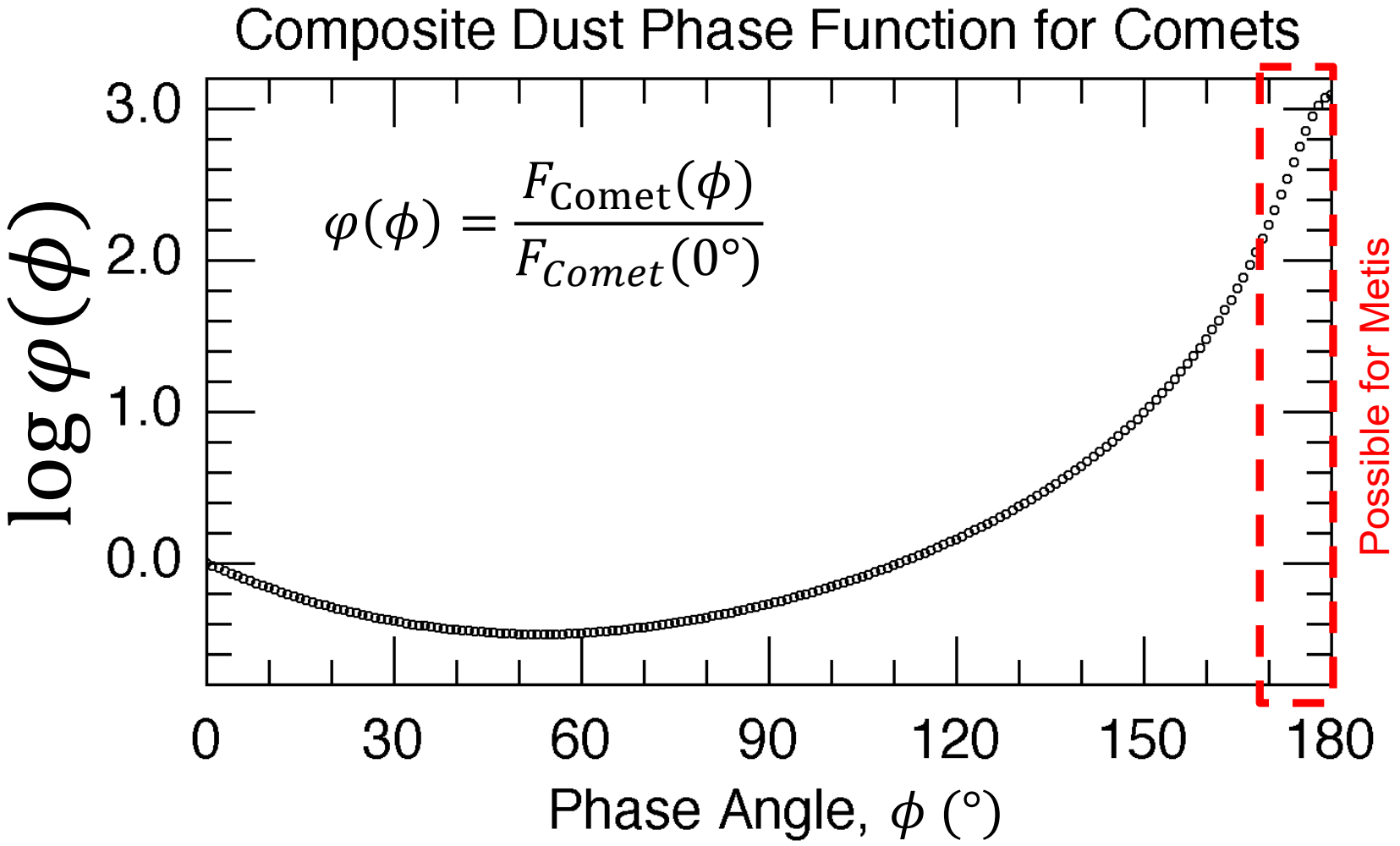
$Af\rho$ COMPUTATION



$$Af\rho(0°) = 1397 \text{ cm} \pm 20\%$$

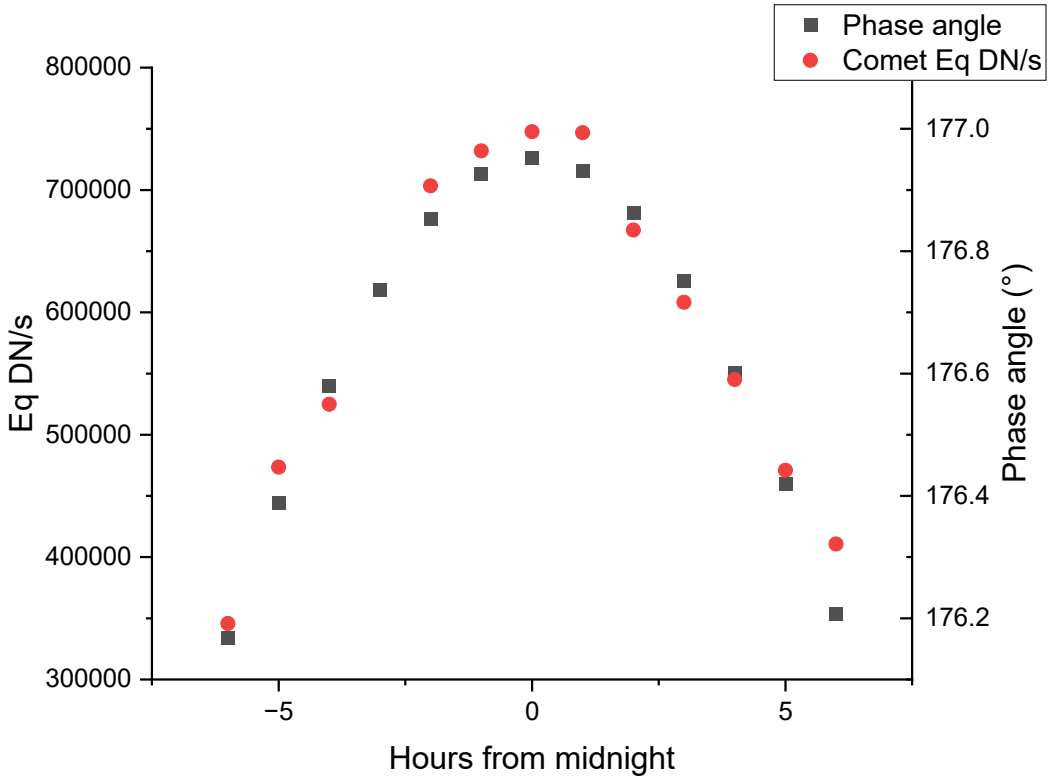
$$Q_d = 16500 \frac{\text{kg}}{\text{s}} \pm 25\%$$

Study of the comet dust phase function



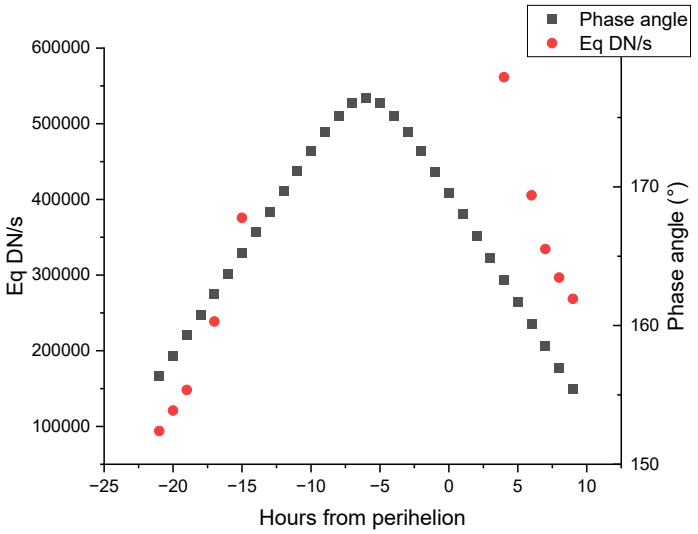
Study of the comet dust phase function

Leonard 15-16 December 2021



Multi-spacecraft observations needed

Machholz 30-31 January 2023



Summary and conclusions

Metis observations can be very useful for studying some main properties of comets:

- Water production rate (from UV images).
- Dust coma properties and dust production rate (from tB VIS observations).
- Comet phase function at high phase angles (from tB VIS observations).

Future work:

- Looking for new observation opportunities (i.e. 3200 Phaethon in 2025, Apollo active asteroid).
- Looking for serendipitous comets in Metis data.

Dreams (if God willing…):

- Follow-up of a great long-period comet (LPC) or a weakly hyperbolic comet (WHC) along its perihelium transit.
- Follow-up of a comet disaggregation process.