ISSI International Teams Call

- Annual Call by International Space Science Institute (Bern-Beijing) to address specific self-defined problems in the Space and Earth Sciences (deadline usually around mid March)
- Proposal Evaluated by Science Commitee
- International Teams composed of about 8-15 scientists of different nationalities and expertise
- ISSI supports lodging and per-diem for all team members and travel only for team leader for 2 to 3 one-week meetings in 2 years

Characterization of the transition from supervolatiles-driven activity to water-driven activity in inbound Dynamically New Comets

ISSI International Team

F . La Forgia, D. Bockelee-Morvan, D. Bodewits, B. Gundlach, Y. Kim, S. Lorek, R. Marschall, A. Migliorini, S. Opitom, A. Pommerol, S. Protopapa, C. Tubiana, J.-B. Vincent, A. Guilbert-Lepoutre & M. Fulle

Motivation

- *Comet Interceptor* mission will encounter a DNC (first time in the inner Solar System) at about 1 AU but it will choose the target to get there in time when it will be at about 10 AU
- At large heliocentric distances cometary activity is driven by supervolatiles sublimation (+amorphous-crystalline transition phase?) while at perihelion it is driven by water-ice sublimation.
- The target will be chosen and the spacecraft will depart before the comet will cross the water activity onset
- Need to characterzie this transition in order to
  - Forecast at best a comet activity behavior from the sole observations @ >10 AU
  - And therefore give constraints to choose the best target in terms of science & safety

The Team

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Additional Experts

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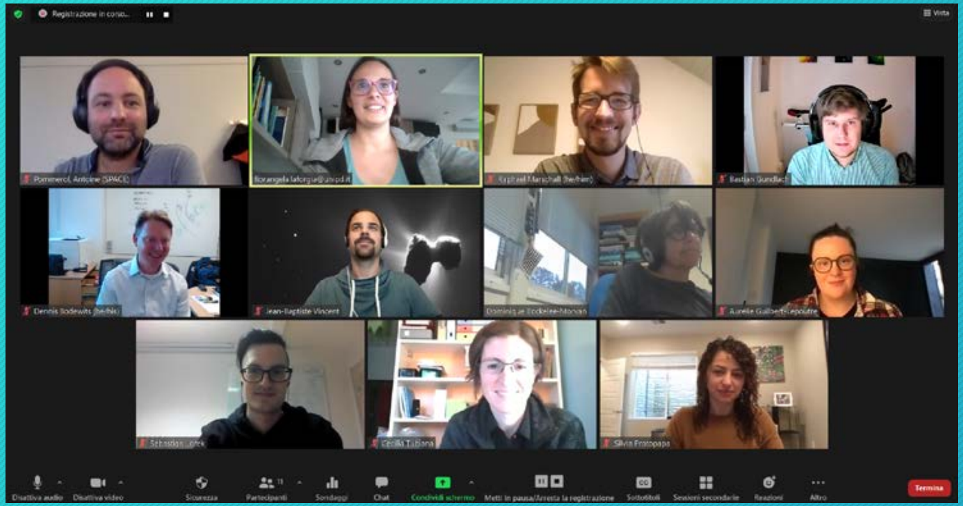
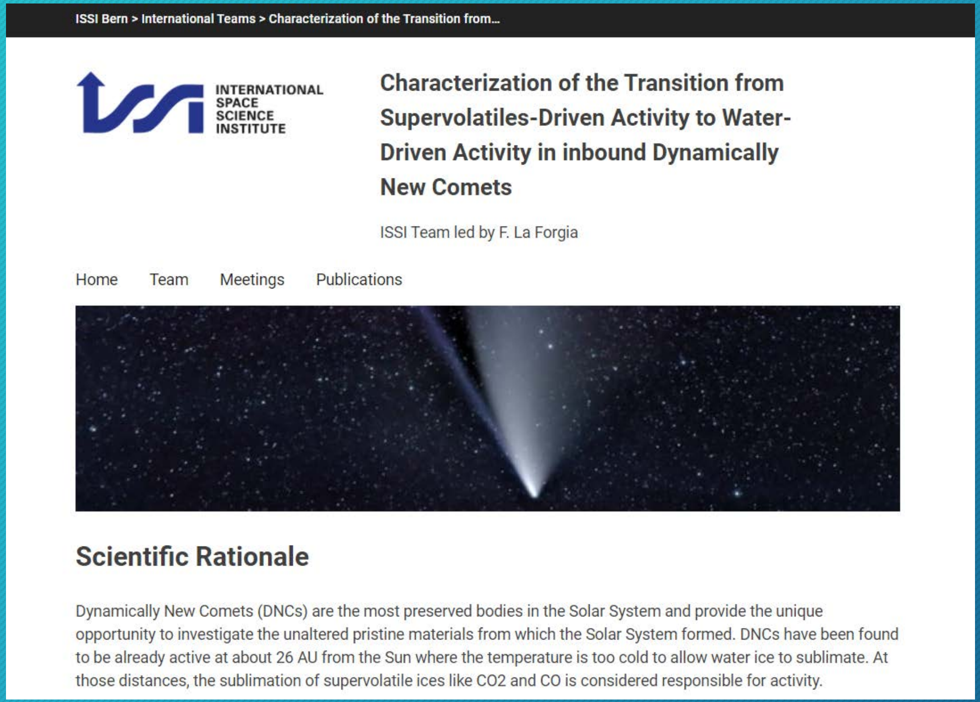
Aurelie-Guilbert Lepoutre	*CNRS*	FRANCE	aurelie.guilbert-lepoutre@univ-lyon1.fr

+ Marco Fulle (additional expert invited for first meeting)

- Adding Young Scientists (also supported by ISSI) https://teams.issibern.ch/newcomets/





- Kickoff Meeting 15 Nov 2021
- First in-person Meeting in Bern 7-11 March 2022
- Planning for the next steps..

The project: Goals

- Investigate and characterize the transition from the supervolatiles-driven activity observed at large heliocentric distances and the water-driven activity typically observed around perihelion.
- Build up robust observational methods and modeling constraining to improve our capability to anticipate the activity levels and patterns of inbound DNCs in view of the *Comet Interceptor* mission.

Key questions

- Are there any differencies/similarities within DNCs and returning comets?
  - in the observed gas/dust/icy grains/relative abundances/radial profiles, etc..
- What are the best observables for identifying and characterizing a DNC's activity early on?
- Is there any observational evidence specific at the transition points?
- The differences observed in the behavior of different comets at the transitions are due to specific physical properties?
  - Nucleus size/shape/spin, chemical composition, different evolution, different structure?
- What are the model parameters that mostly influence the predictions and which are the most sensitive to uncertainty
- Are there sublimation experiments that can further constrain models and/or observational strategies?

The first meeting: Agenda

- First in-person meeting in Bern 7-11 March 2022
- Quite full agenda, very interesting presentations by all team members
- A few merged session with Rosita's team (same week in Bern – 3 team members in common)
- Visit to IceLab Laboratory in Bern

ISSI Team

Characterization of the Transition from Supervolatiles-Driven Activity to Water-Driven Activity in inbound Dynamically New Comets

7-11 March 2022, First Meeting

Agenda v.5

Monday, 7th March

Morning Session – Motivation & Comet Interceptor mission

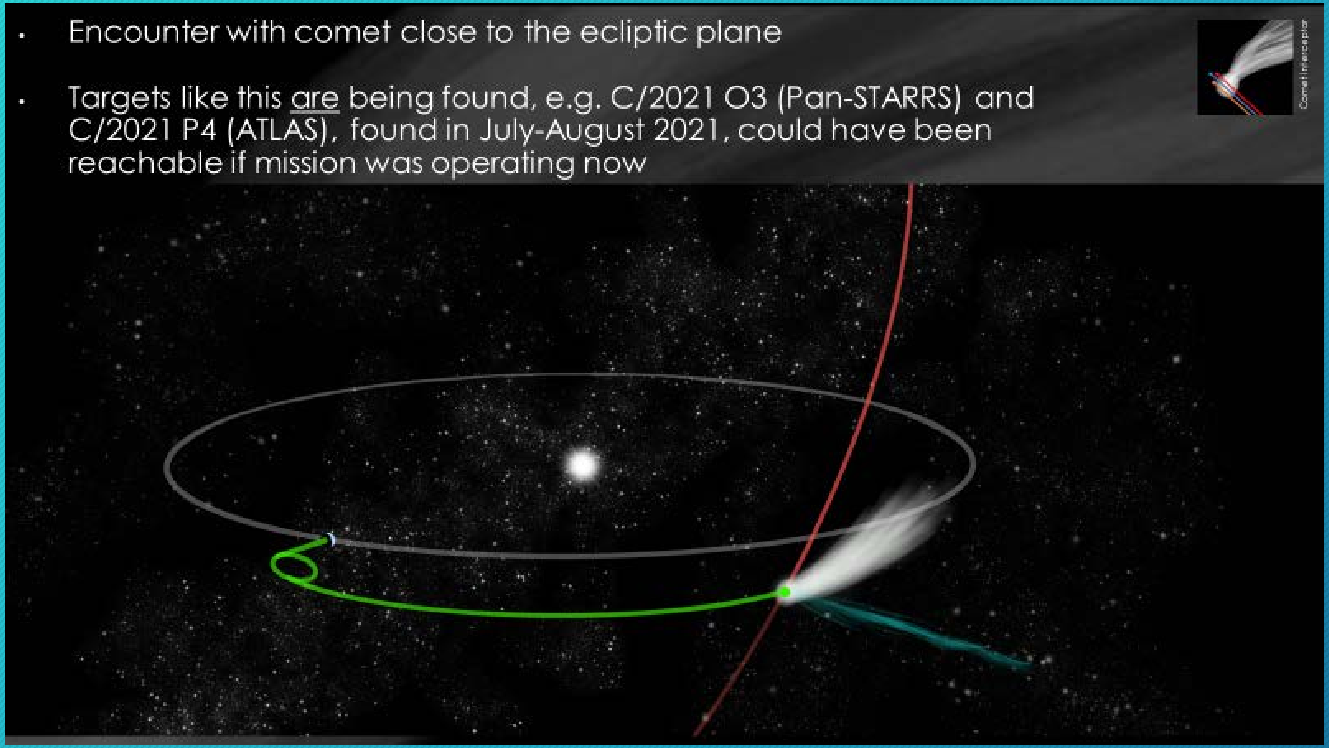
9:30	Mark Sargent *ISSI Science Program Manager*	Welcome, Introduction
9:45	Fiorangela La Forgia	Motivation & summary of the project
10:00	Cecilia Tubiana	Comet Interceptor science goals
10:30	Raphael Marschall	Dust Hazard Assessment Model
11:00	*coffee break*	
11:30	Aurelie Guilbert-Lepoutre	Gas Coma Modeling for Comet Interceptor
12:00	Antoine Pommerol	Colour Imager for Comet Interceptor
12:30	*Lunch break*	

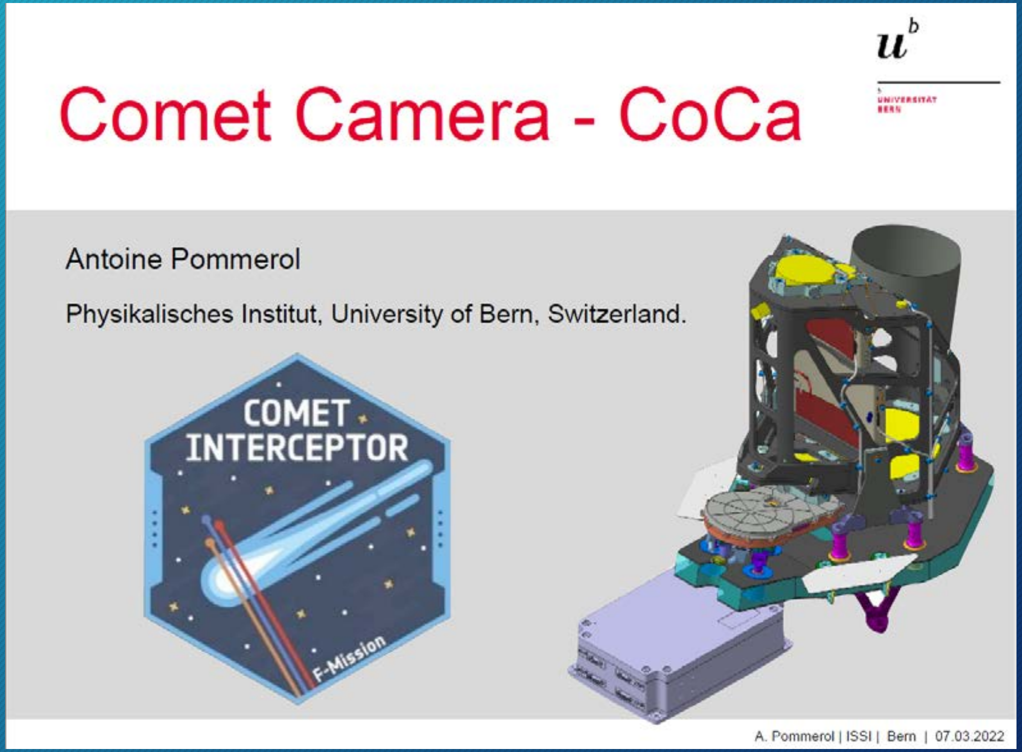
Afternoon Session – Observations (gas/dust)

14:30	Cyrielle Opitom	Observations of volatiles N2+ and CO+ in the optical
15:00	Cyrielle Opitom	Oxygen G/R ratio and Fe/Ni emissions observed at 2I/Borisov
	➔ *Merged Session with Rosita's Team*	
15:30	Alessandra Migliorini (remotely)	Comet discovery surveys: LSST status update
16:00	D. Bockelee-Morvan	New findings on distant activity of 29P
16:30	Aurelie Guilbert-Lepoutre	New results on Centaurs
17:00	*Welcome Drink ISSI?*	
17:30	*EOB*	

Motivation and Mission perspective

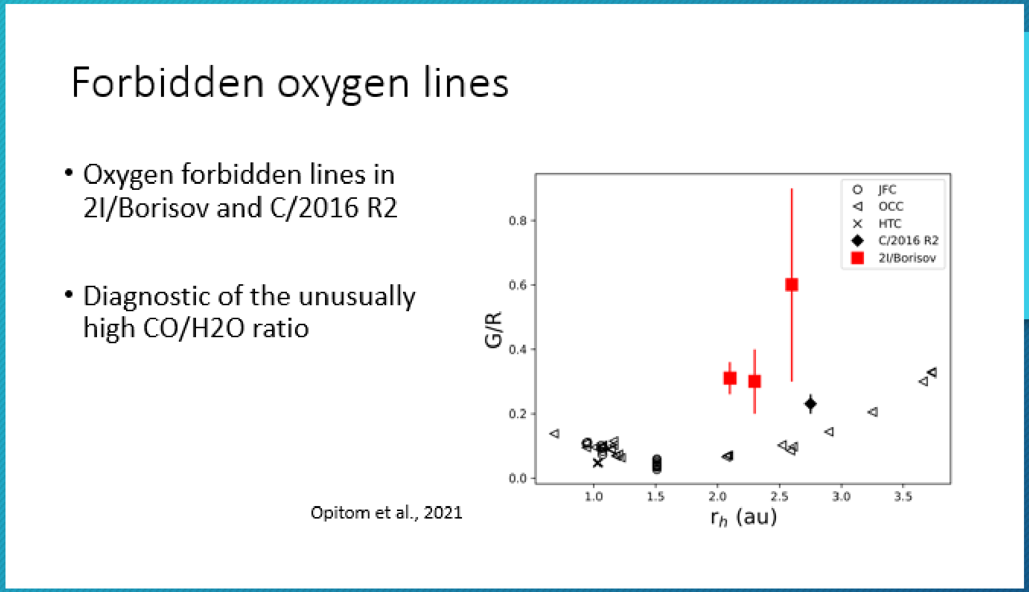
- Overview of CI (C. Tubiana)
- Overview of the Dust Hazard Engeneering Model used for CI and its funcionalities (R. Marschall)
- Overview of the Gas Coma Modeling used for CI (A. Guilbert-Lepoutre)
- Status of CoCa camera (A. Pommerol)

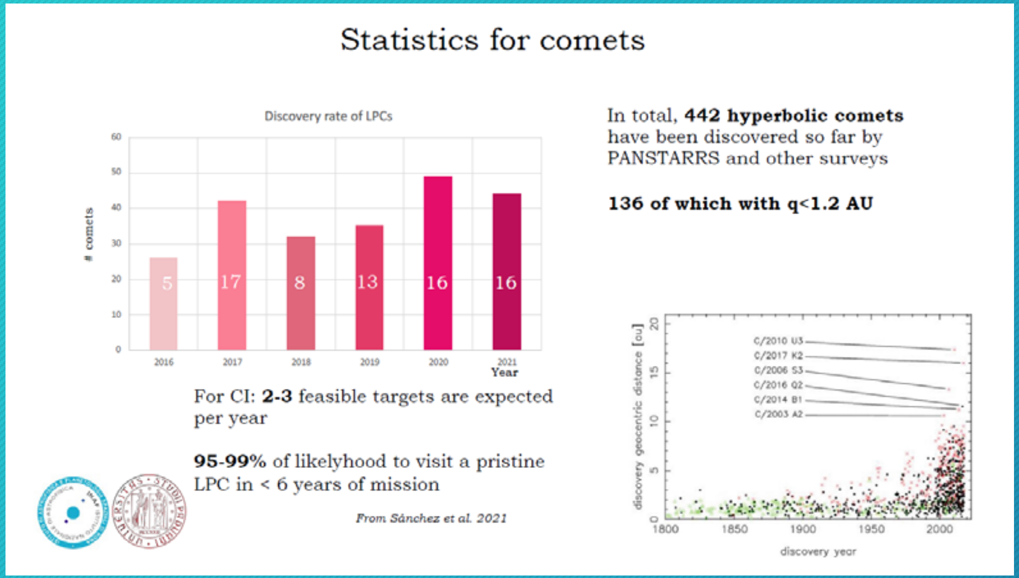


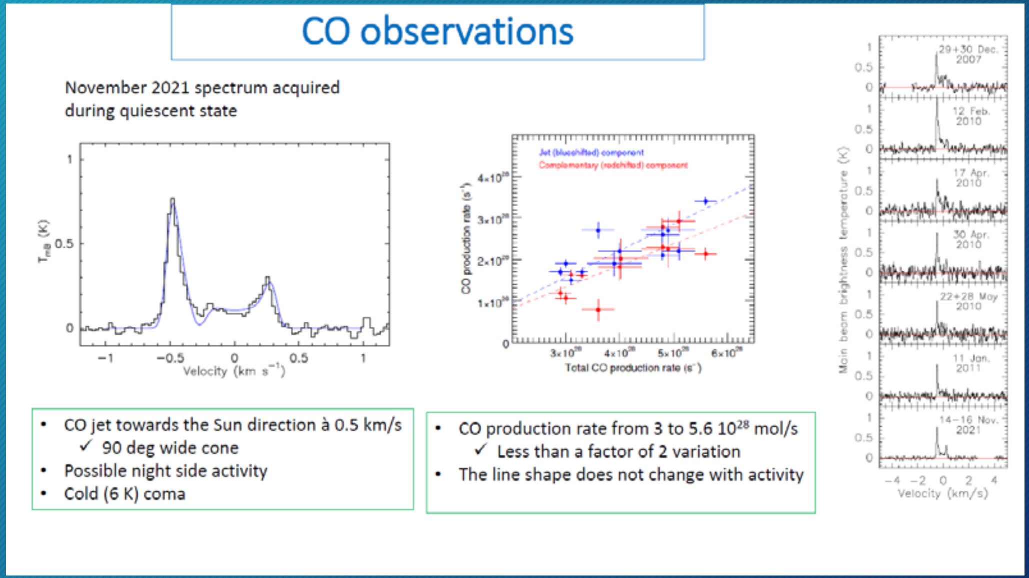


Ground based Observations

- Statistics of DNC discovery and LSST (A. Migliorini)
- Optical spectroscopy of DNC (C. Opitom)
- IR and sub-mm observations of 29P (D. Bockelee-Morvan)



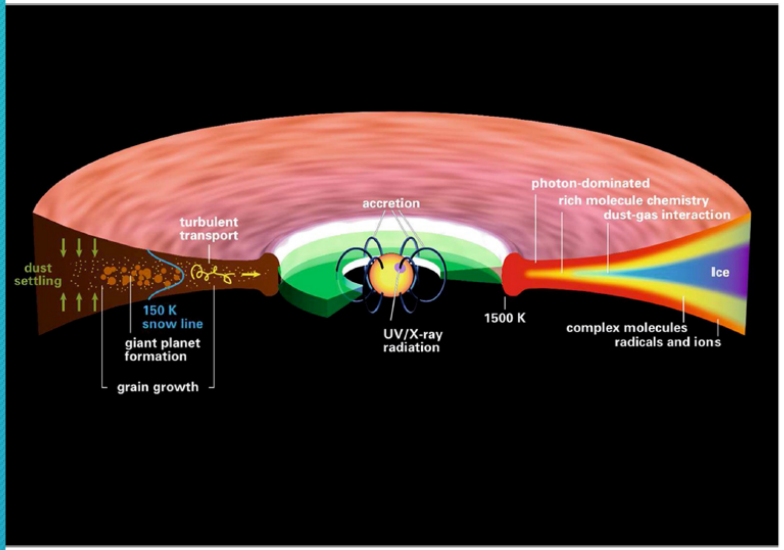




Comets formation and evolution

- Overview of comet formation models (S. Lorek)
- New results on collisional evolution of the Kuiper Belt (R. Marschall)

Formation location of comets



- formation in the cold midplane layer
- outside snowline
- presence of ices
- mixed-in material from inner disc

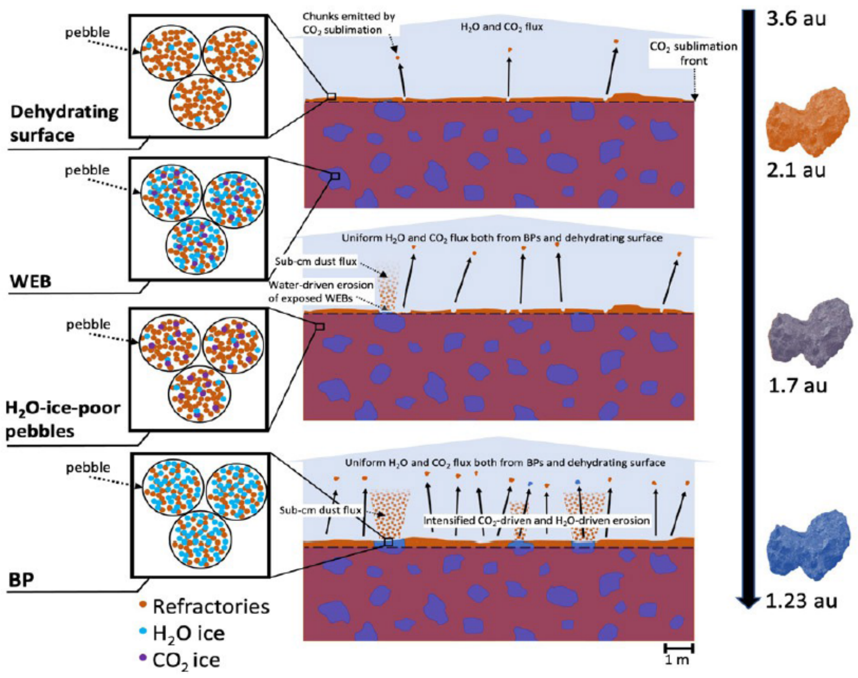
Henning & Semenov (2013)

Comets activity

- Models of comets internal structure and activity drivers (B. Gundlach)
- Morphological features as proxy of comets evolution by supervolatiles (J.-B. Vincent)
- WEB’s activity model (M. Fulle)

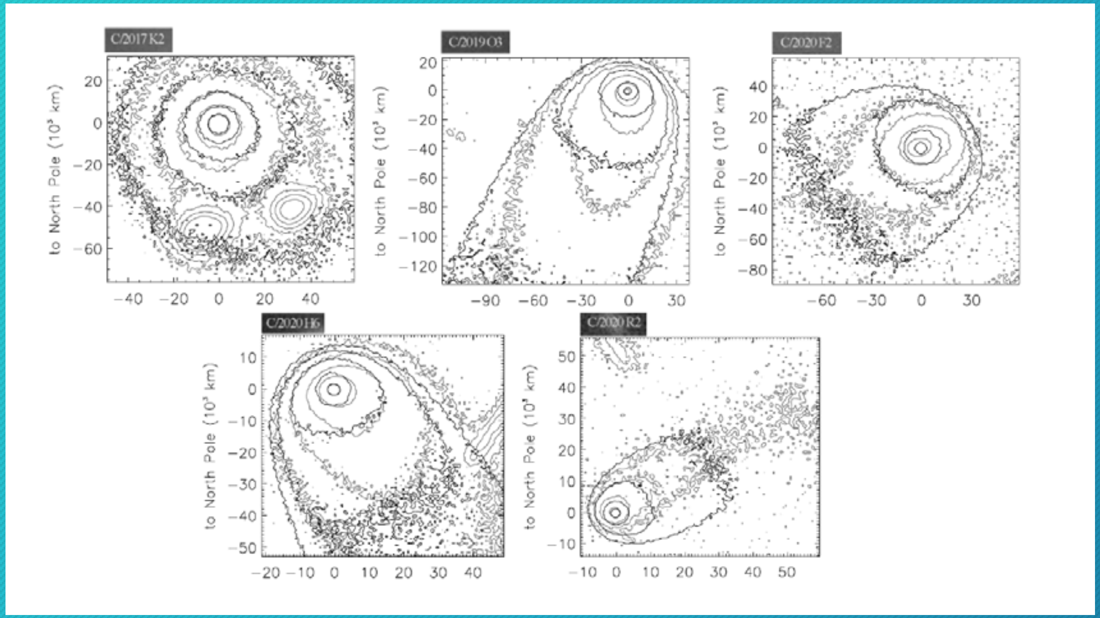
Meter-sized WEBs embedded in **pristine** water-poor matrix

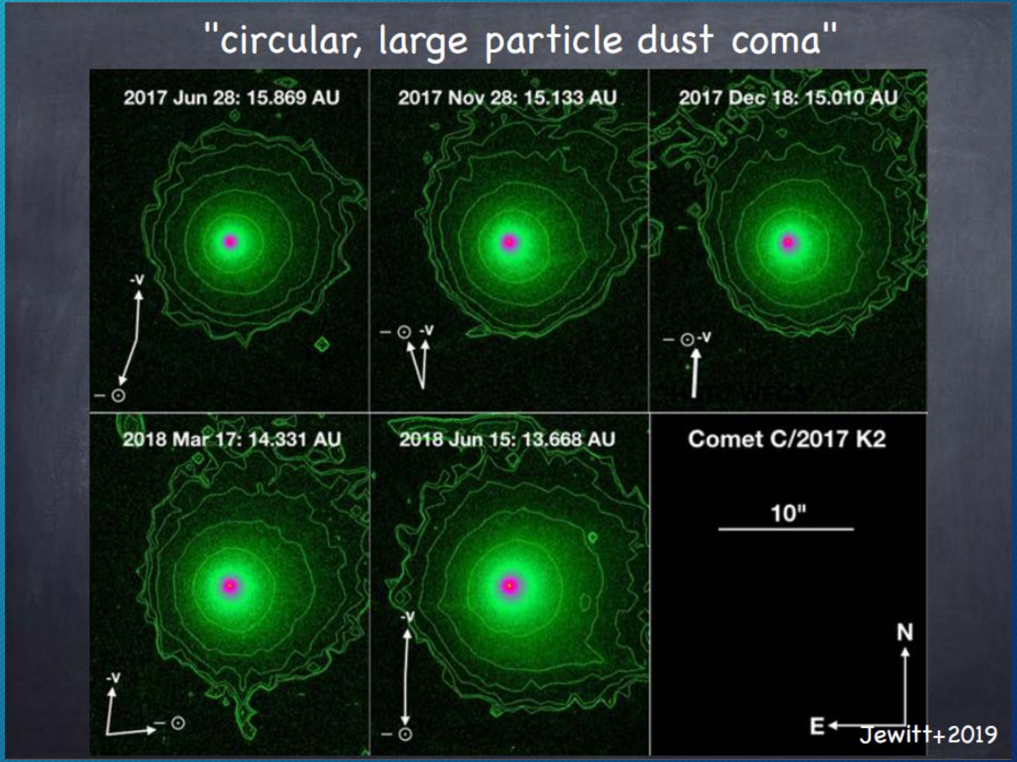
(Ciarniello et al. 2022, Nature Astr., **now** in press)



Ground based Observations 2

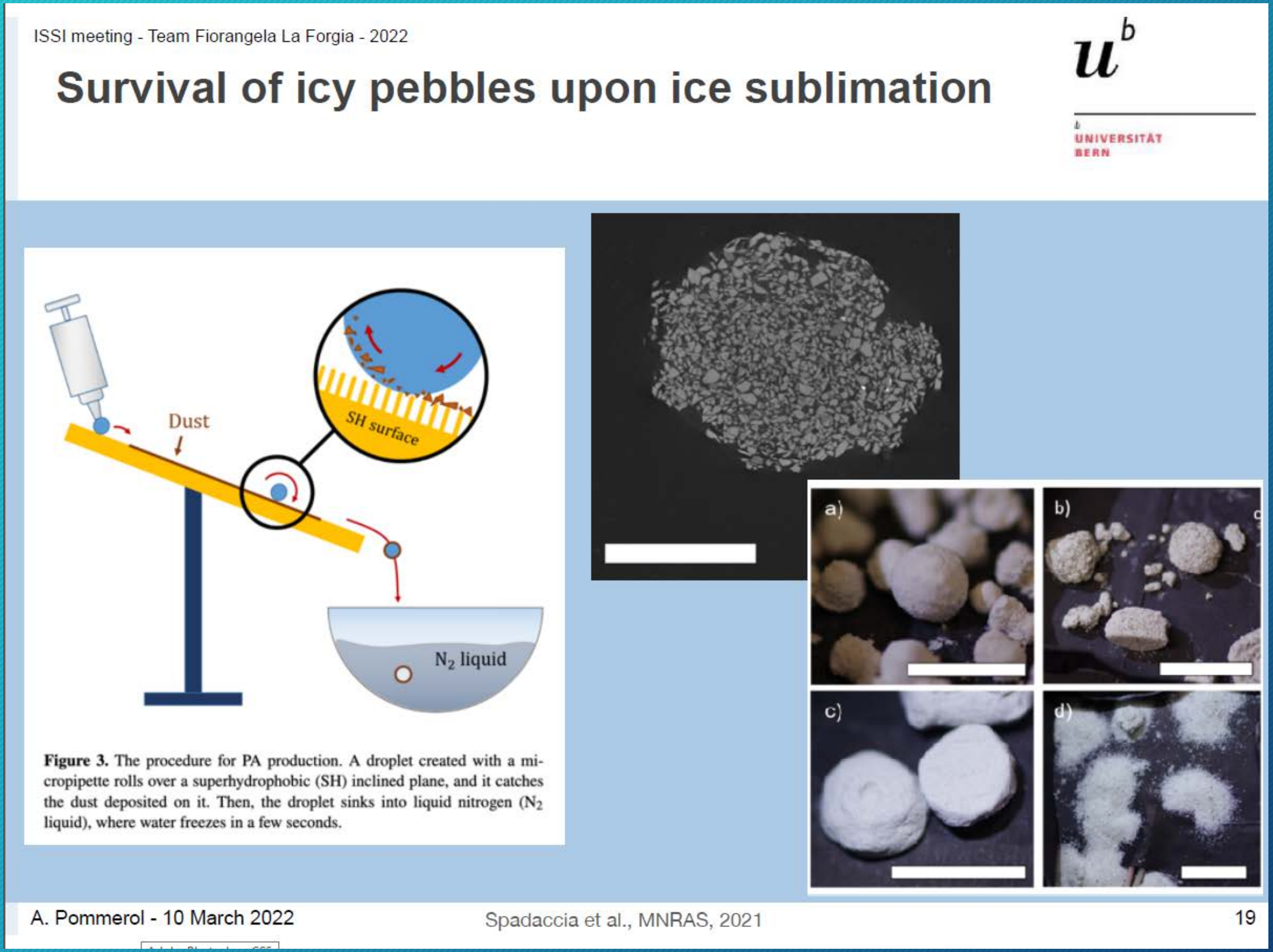
- Application of WEBs model to observations of distant comets (F. La Forgia)
- Dust coma observations C/2017 K2 (Y. Kim)
- Importance of seasonal variations on observations (R. Marshall)
- Observations and modeling of water ice in the coma of comet (S. Protopapa)
- CO bump as evidence of past activity? (D. Bodewits)





Laboratory Sublimation Experiments

- The IceLab project (A. Pommerol)



Wrap Up

- interstellar comets which behaves as SS comets
- LPC which show peculiar composition (C/2016R2, etc)
- CO/CO2 driven activities observed also in JFCs, Centaurs, etc..
- Very few data

- There is no corrent **observational** difference between LPC and DNC…
- Currently 443 hyperbolic comets are known, almost half of them discovered after 2005 (205)
- LSST will be able to discover LPC at a rate much higher than today
    - operating from mid-2024, 6 bands
- Eccentricity can not be retrieved with enough accuracy until after a few months of observations
- 39 DNCs have been actually "studied" (Leonard, Siding Spring, ISON, Garrad, etc..)
- Very few observed @ large r_h (C/2010 U3, C/2017 K2 ..)
- Many of them have q > 4-5 AU → distant LPC with q<4AU

- Comets formed (most probably) within streaming instabilities that brought to gravitational collapse (gentle process) in the protoplanetary disk
- Maybe they suffered by collisional evolution, but this seems to have somehow preserved their structure/composition (pebbles)
- Assuming they are formed by pebbles:
  - Thermal conductivity
  - Dust-to-ice ratio
  - Permeability/diffusivity
  - Tensile strengths

  → Follow T @ sunrise,
  Analyze "local" activity timescale → dust-to-gas
- Surface topographic features are possible representative of CO/CO2 activity
- Water poor/Water rich pebbles with analytical models are able to describe most of Rosetta data
- Within WEBs model differences among comets (gas mixing ratios, dust activity) might only be due to
  - A_p/A_r
  - R_N
  - Seasons → nucleus spin rate/spin status

First results

- Acnowledgement to ISSI Team in the paper in review (application of WEBs model to TNG observations, M. Fulle)
- Proposal submitted for observations at VLT of Oxygen ratio in distant comets (C. Opitom)
- Paper by Fulle

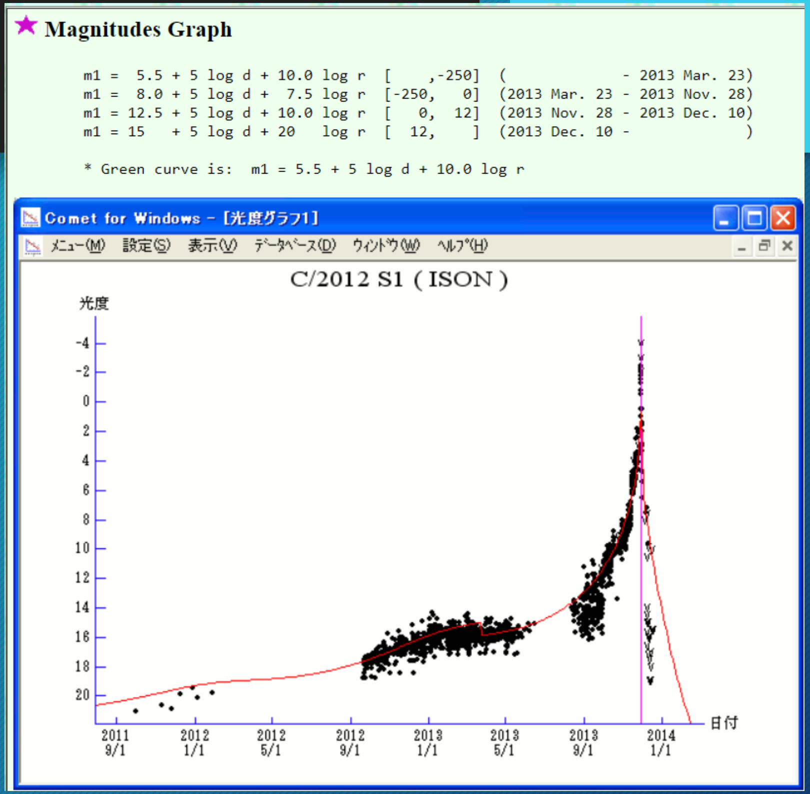
A possible selection criterion of the target of Comet Interceptor mission
https://ui.adsabs.harvard.edu/abs/2023AdSpR..71.4424F/abstract

Computation of the maximum size of the nucleus of a comet that will be under the activity level safety criterion for CI and detectability from ALMA and JWST

Ongoing work..

1. Review and merge available results on LPCs (with q<4 AU) observed @ large heliocentric (gas, dust, etc.) and experiments
   - different tecniques: photometry, low/high res spectroscopy, radio

2. Map how comets increase in brightness (r_h-dependencies)
   → Large databases (COBS, Yoshida?)
   → how to sample also faint comets?
   → look for observational correlations ($Af\rho$, volatile abundances etc.)
   → look for dynamical correlations (q, a , perihelion argument, etc.)?
   → give different weights to parameters using statistical analysis within models?



Ongoing work..

3. Check statistics of comet magnitudes expectations increases/decreases from 10 to 1 AU
   - Do they really are statistically more frequent comets that deceive the expectations among DNCs ?
   - From a dynamical point of view:
     → Is there a way we can form different populations of comets?
     → Is there a way in the structure of the nuclei to retain ices so that DNC "should" behave differently than LPCs?

4. Planning proposals for
   - ground-based reference check of CO, CO2 detection through IFU observations of OI lines
   - other proposals? Smaller telescopes?
   - Snapshots of large number of comets vs monitoring of single comets?
   - Low resolution / high resolution?
   - Radio/submm
     - magnitude-CO correlation → limiting magnitude estimate for radio observations