# Building a unique science scenario to support cross-mission science with SPICE:


## SIDING SPRING COMET ENCOUNTER WITH MARS

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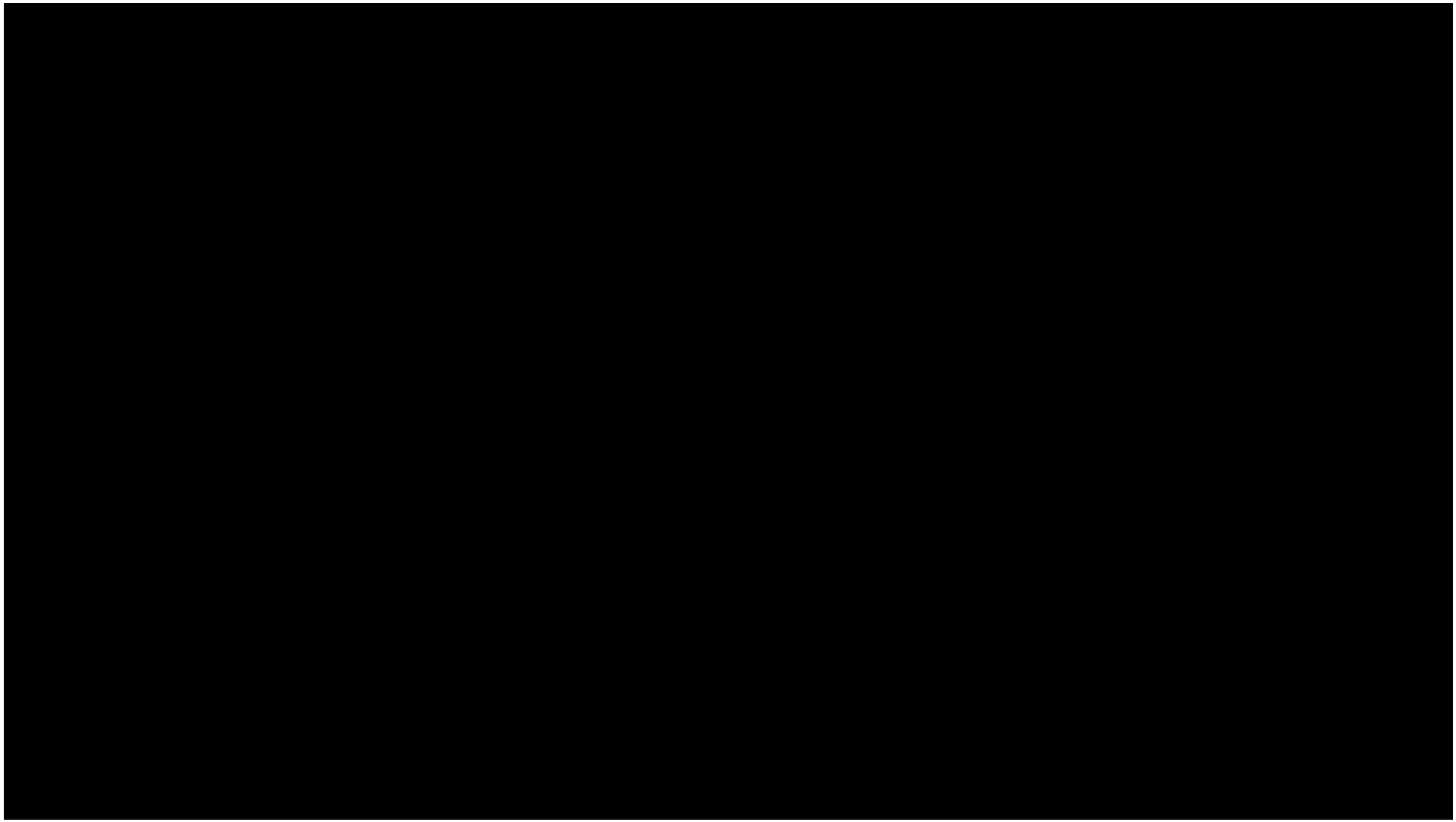
# Comet Siding Spring flyby



# Comet Siding Spring flyby

- On October 19th 2014, Mars experienced a close encounter with Comet C/2013 A1 (Siding Spring)
- The closest approach with comet Siding Spring took place at a distance of ~138,000 km from the center of Mars, on 19 October 2014 at 18:28 UT (Solar longitude Ls 217, Martian Year 32).
- It flew by Mars at a relative velocity of ~56 km/s, moving from South to North (retrograde orbit, 129 degrees inclination). That is a third of the Earth-Moon distance.
- The gaseous coma washed over Mars and Mars passed directly through the cometary debris stream. As a close encounter of this type is predicted only once in 100,000 years, this is likely the only opportunity for measurements associated with planetary/cometary encounters.
- This unique event allows us to investigate the response of the Mars' upper atmosphere to such a rare encounter, as this may have implications for overall atmospheric evolution.

- **The rest of the talks of this session and its continuation on the poster session are about the science results.**

- In this talk I focus on explaining why and how the video that we have just seen can be good for science.

# Motivation

- The Comet Mars flyby: a very interesting geometrical event.
- Science Analysis is complex due to different interactions between Mars and the comet:
  - Solar wind
  - Coma
  - Dust tail
- Those interactions vary rapidly in space and time.
- Multi-spacecraft analyses are performed.

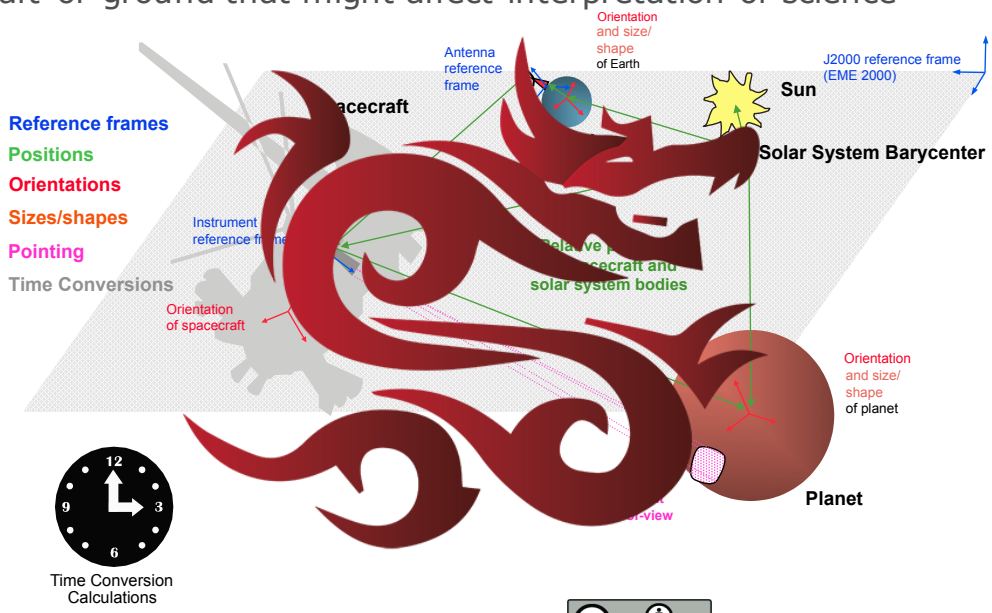
- All these circumstances result in a complex geometry for which to having a global picture is challenging and usually requires lots of resources.
- There is a need, amongst others, to have a realistic visualization tool.

# HOW? Do it with SPICE!

- SPICE is an information system that uses *ancillary data* to provide Solar System geometry information to scientists and engineers for planetary missions in order to plan and analyze scientific observations from space-born instruments. SPICE was originally developed and maintained by the Navigation and Ancillary Information Facility (NAIF) team of the Jet Propulsion Laboratory (NASA). SPICE for ESA is provided by the ESA SPICE Service (a.k.a me).
- "Ancillary data" are those that help scientists and engineers determine:
  - where the spacecraft was located
  - how the spacecraft and its instruments were oriented (pointed)
  - what was the location, size, shape and orientation of the target being observed
  - what events were occurring on the spacecraft or ground that might affect interpretation of science observations

- SPICE provides users a large suite of SW used to read SPICE ancillary data files to compute observation geometry.
- The ancillary data (kernels) comes from: The S/C, MOC/SGS, S/C manufacturer and Instrument teams, Science Organizations.

- **See Talk "SPICE for ESA Missions" MT6 session tomorrow at 9:00h**



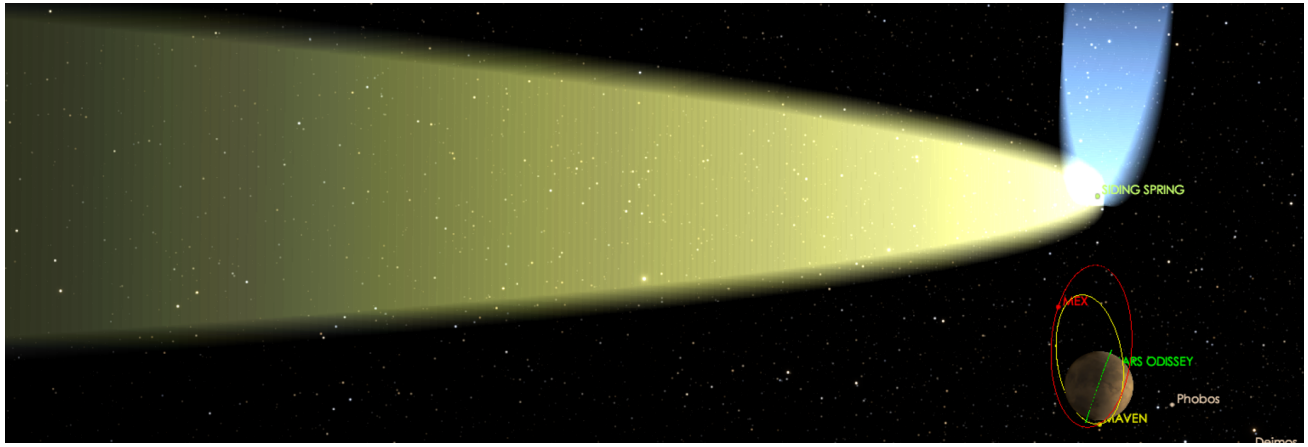
# HOW REALLY? COSMOGRAPHIA

- In Space missions design, planning, operations and data analysis the ability to visualize and interpret the geometry of a given mission in an easy an comprehensive manner is key.
- **SPICE-enhanced Cosmographia**[1] is a downloadable tool used to help visualize and analyze astrodynamics and science aspects of a mission in a 3D scenario (it is a spin-off of the well known Celestia tool)
- It can depict such things as:
  - spacecraft trajectory and orientation
  - target body ephemeris and size, shape and orientation
  - reference frames (coordinate systems)
  - vectors and angles
  - ranges
  - instrument view cones and footprints
  - … and more.
- The SPICE-enhanced Cosmographia distributed by NAIF makes use of SPICE kernels.
- The Configuration for ESA Missions is maintained by the ESA SPICE Service and is available for download
- Everything you need is to install Cosmographia, and download the configuration files and SPICE kernels for the mission you want to use.
- In addition Cosmographia (and WebGeocalc) allows us to exploit SPICE data and a subset of its functions without the need to "properly" learn SPICE.

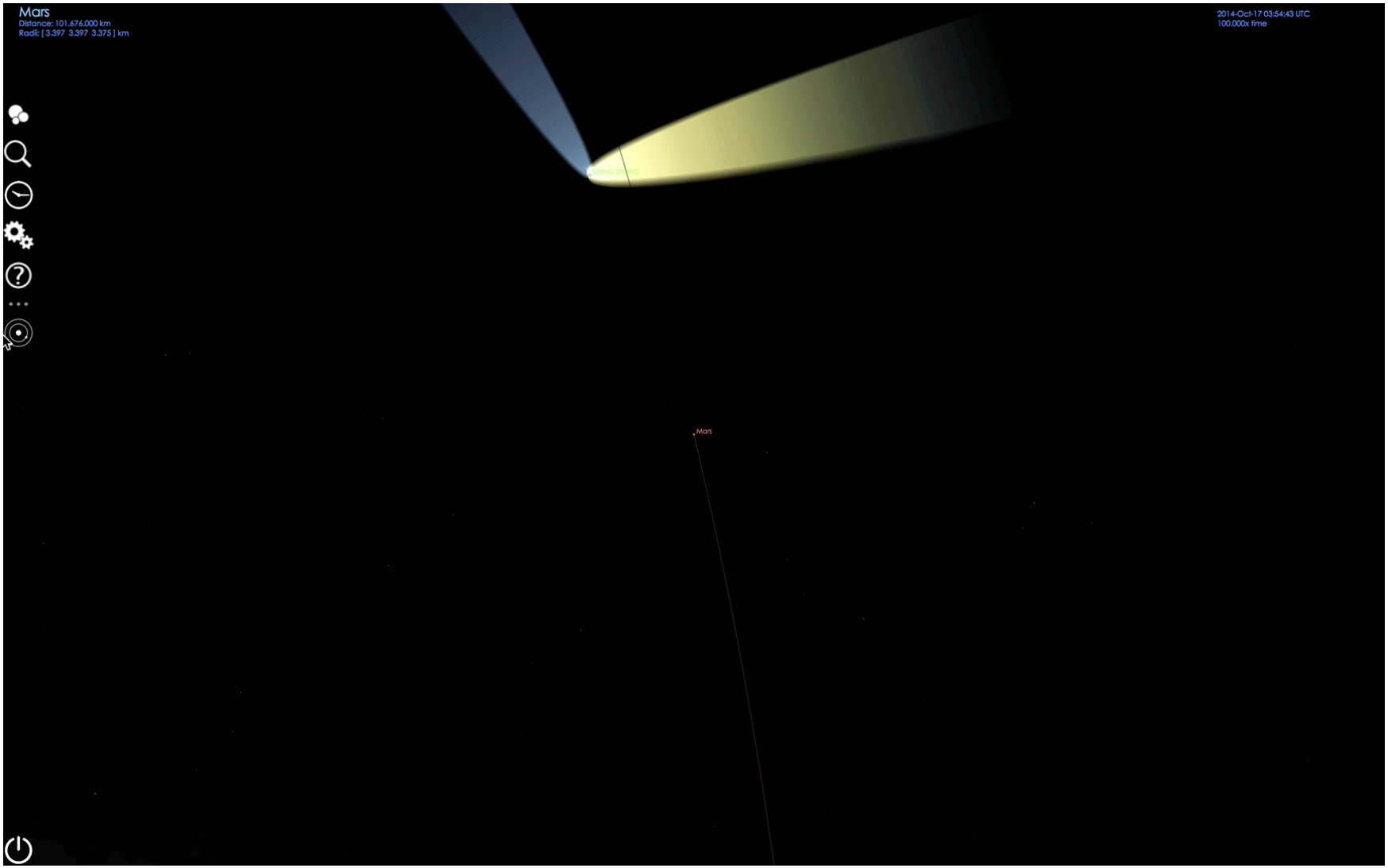
[1] *It is important to stress the "SPICE-enhanced" part. Please do so when you reference the tool.*

# Three S/C and a Comet at once

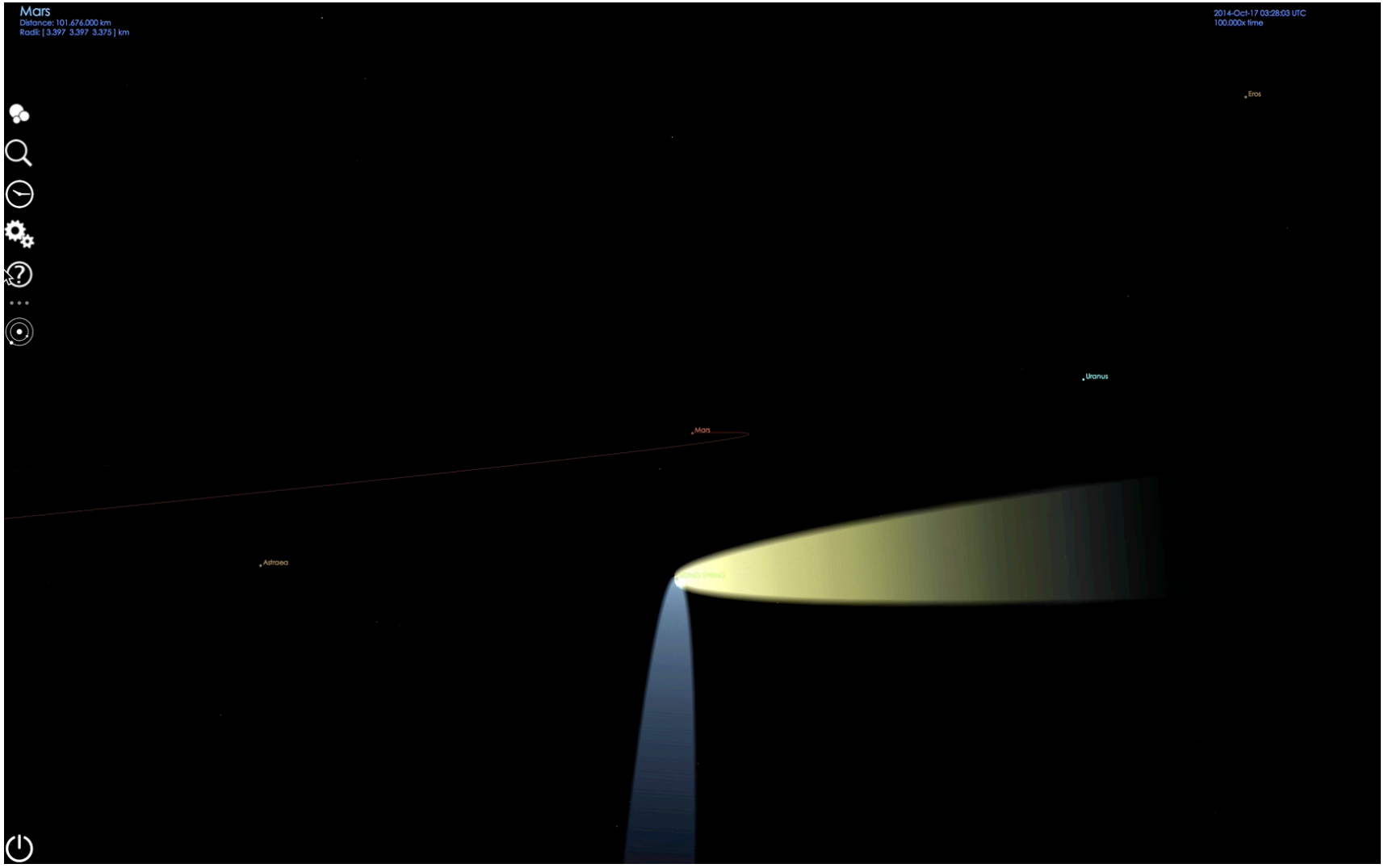
- My task was to prepare a SPICE Kernel dataset and the Cosmographia configuration for such scenario.
- This scenario contains the appropriate SPICE datasets of Mars Express, MAVEN and Mars Odyssey and comet Siding Spring. In addition the following modeling has been done:
  - Siding Spring-specific dynamic reference frames for data analysis:
    - SIDING SPRING Body-Centered Solar Equatorial,
    - SIDING SPRING Dust Coma (Z: SS-Sun vel vector, X: SS-Sun pos vector),
    - SIDING SPRING Ion Tail (X: SS-Sun vel vector, Z: SS-Sun pos vector),
    - SIDING SPRING Mars Direction (Z:SS-Mars vector)
  - Coma influence spheres:
    - Inner Coma with a radii of 15000 km
    - Outer Coma with a radii of 1000000 km



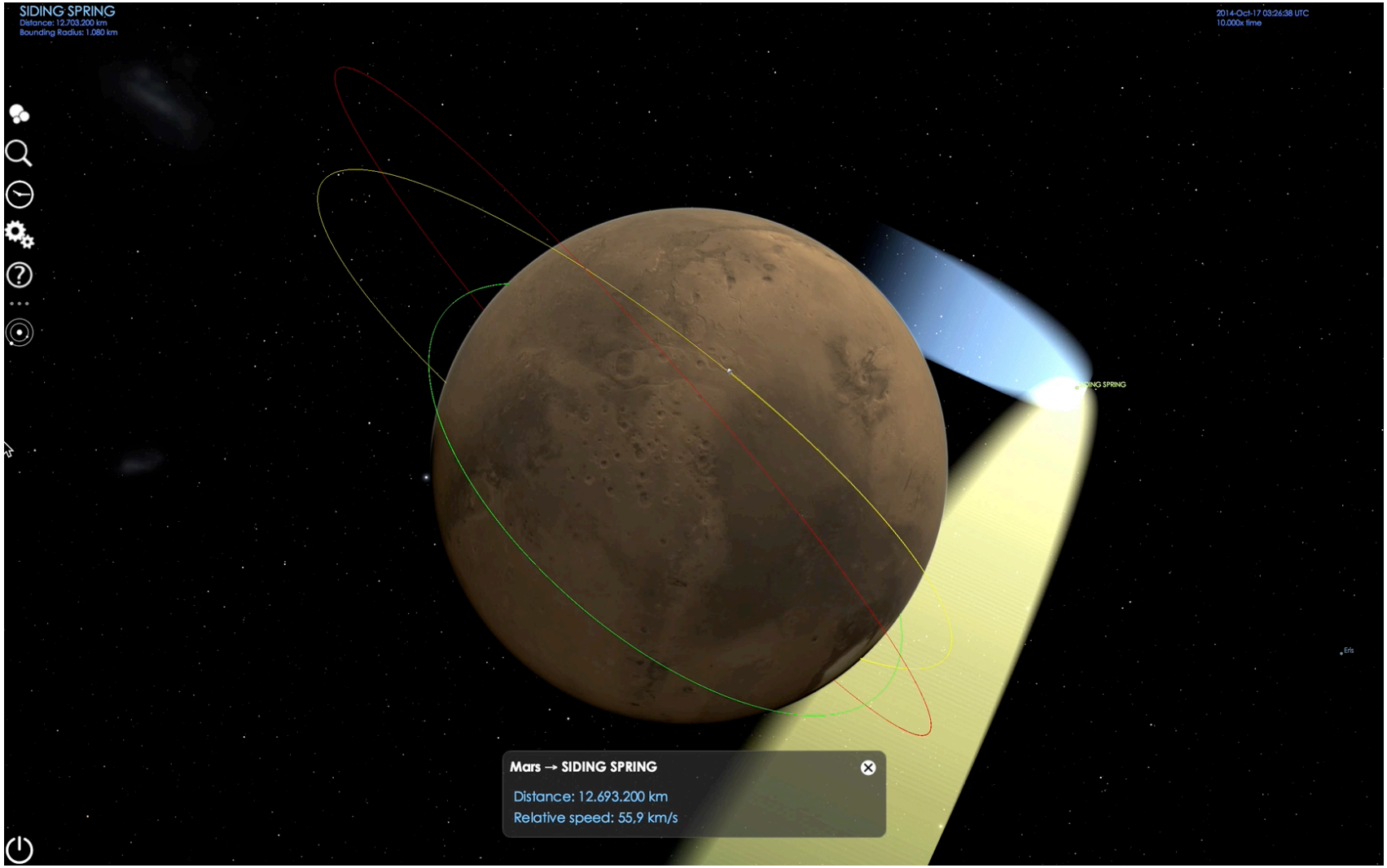
# Some Examples – Normal to Ecliptic



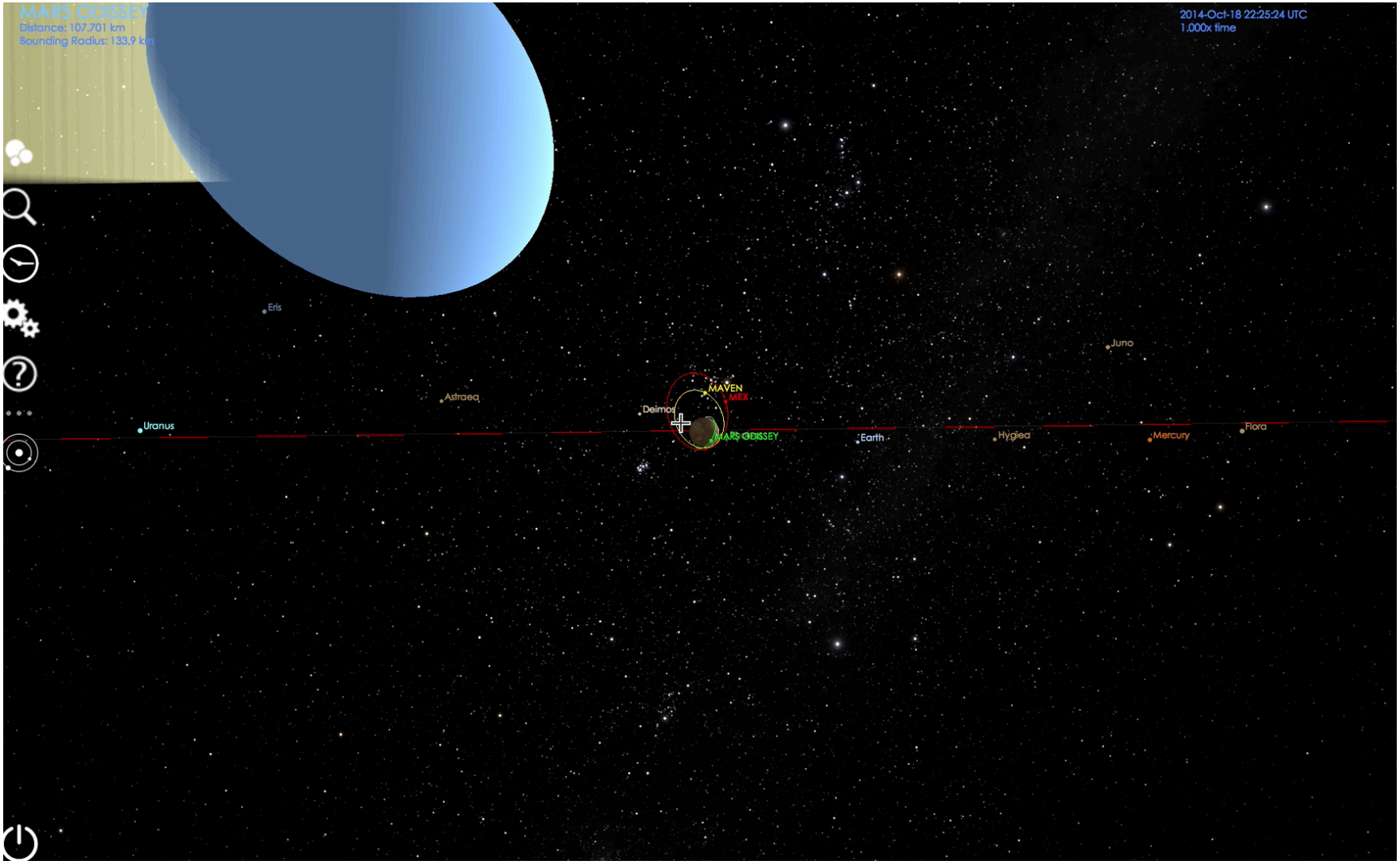
# Some Examples - Crossing the Ecliptic



# Some Examples – Global Scenario



# Some Examples – Coma Influence Spheres



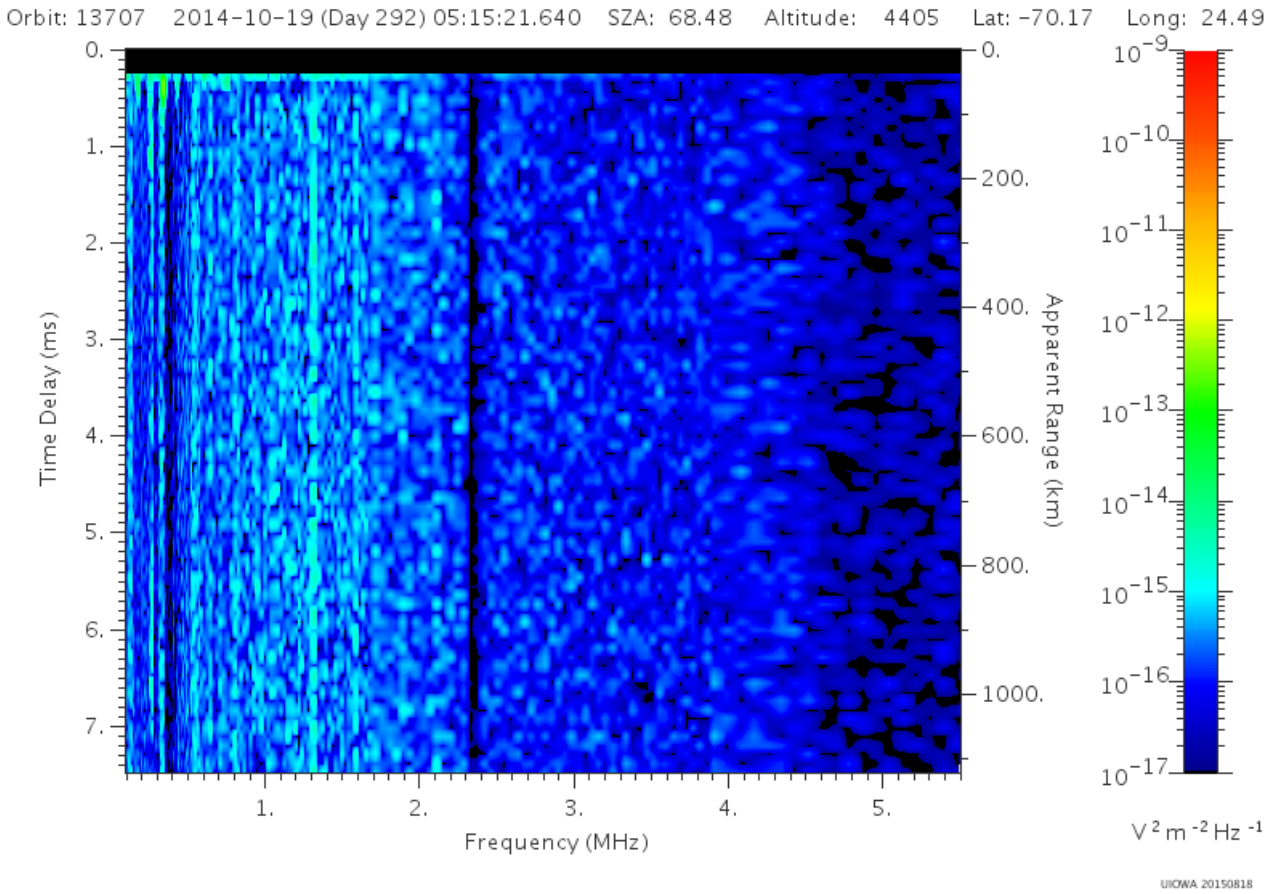
# Mars Express Observations

- Mars Express Fourier Spectrometer (PFS) and the MARSIS performed dedicated observations to Siding Spring during the comet closest-approach coordinated by the MEX SGS at ESAC.
- Note that even though I work door-to-door with the MEX SGS I did not drop them an e-mail to check **when did the observations took place**, instead, **I took a quick-look with Cosmographia**, I could also have done a Target-in-FoV search with the Geometry Finder API or even with WegGeocalc.
- Here's were the dedicated pointing for MEX took place:
  - **2014-Oct-18 12:00:00 - 2014-Oct-18 12:30:00** (PFS)
  - **2014-Oct-18 19:30:00 - 2014-Oct-18 20:00:00** (OMEGA, PFS)
  - **2014-Oct-19 05:10:00 - 2014-Oct-19 05:40:00** (MARSIS, OMEGA)
  - **2014-Oct-19 15:30:00 - 2014-Oct-19 16:10:00** (OMEGA)
  - **2014-Oct-19 19:15:00 - 2014-Oct-19 19:30:00** (*SCAN*, MARSIS)
  - **2014-Oct-20 03:25:00 - 2014-Oct-20 03:55:00** (OMEGA)

- One can use the PSA UI to look for the MARSIS and PFS data during that period, I did so and I found some data! (See Talk **EPSC2017-574 The Planetary Science Archive (PSA): Exploration and discovery of scientific datasets from ESA's planetary missions, C. Vallat et al.**)

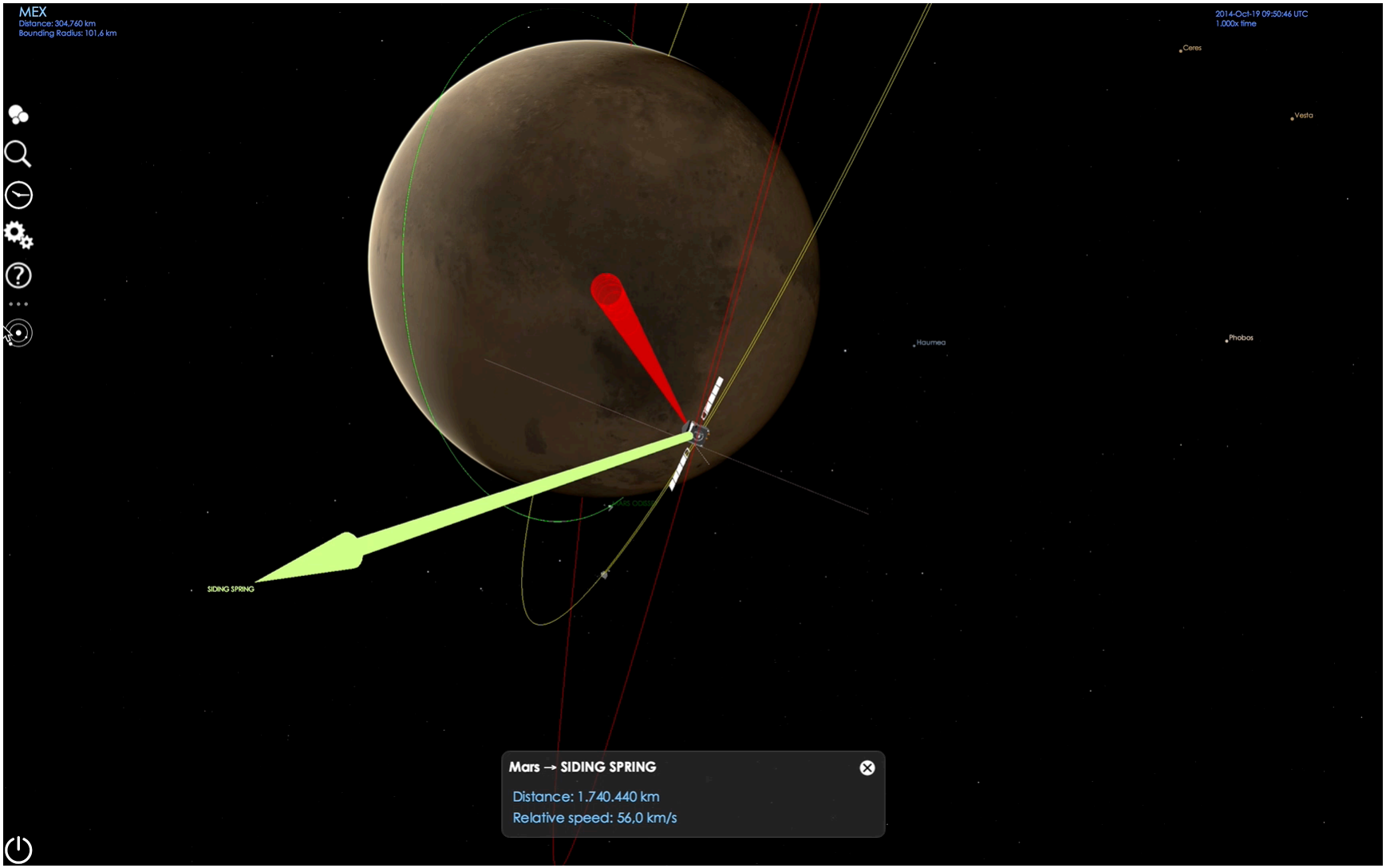
- Unfortunately there was no such thing as nice pictures of the Comet, which for me, not being very much of a scientist, is a bit frustrating, we rather have something like this:

# Mars Express Observations



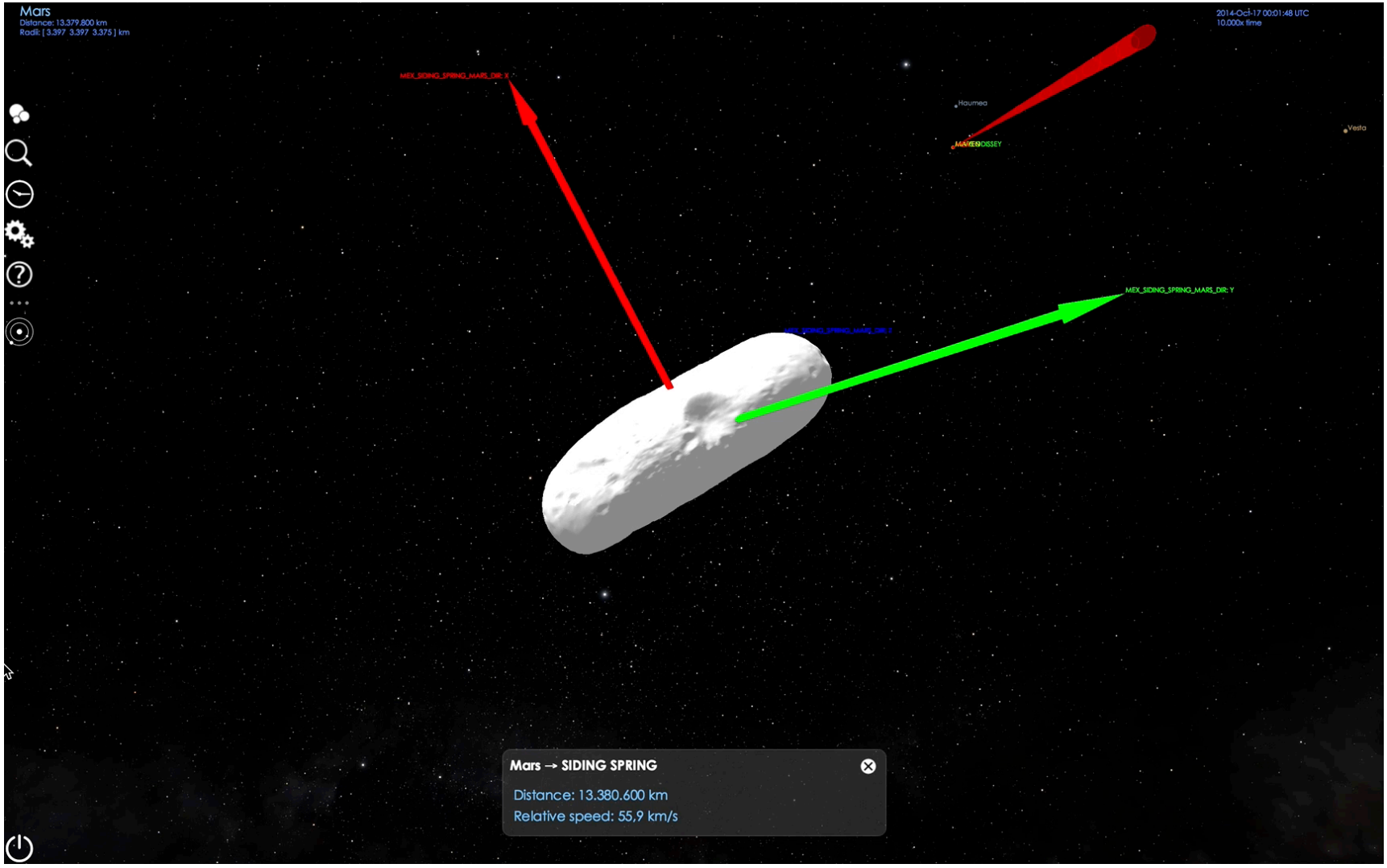

- Apparently not the most up to date comet ephemeris were used, something which could had been spotted whilst building such a scenario for the sience operations planning.

# Some Examples - PFS Observations



# Some Examples – PFS FoV

# Some Examples – Comet View



# Wrapping up

- My task is to facilitate scientist the task of building up a scenario for this given study providing also a configuration of already existing SPICE based tools. The same applies for the rest of ESA Planetary Missions and are already available.
- Building such scenarios is something that can improve the studies and collaborations in between missions which are studying the same body. The canonical example would be ExoMars 2016 and Mars Express .
- Such scenarios can be helpful not only for data analysis but also for planning the observations

- This afternoon I will be available at the follow up Poster Session with my laptop to give you demos of Cosmographia if you wish.
- Follow up **"SPICE for ESA Missions" MT6 session tomorrow at 9:00h**