Rosetta-Philae RF link, from separation to hibernation

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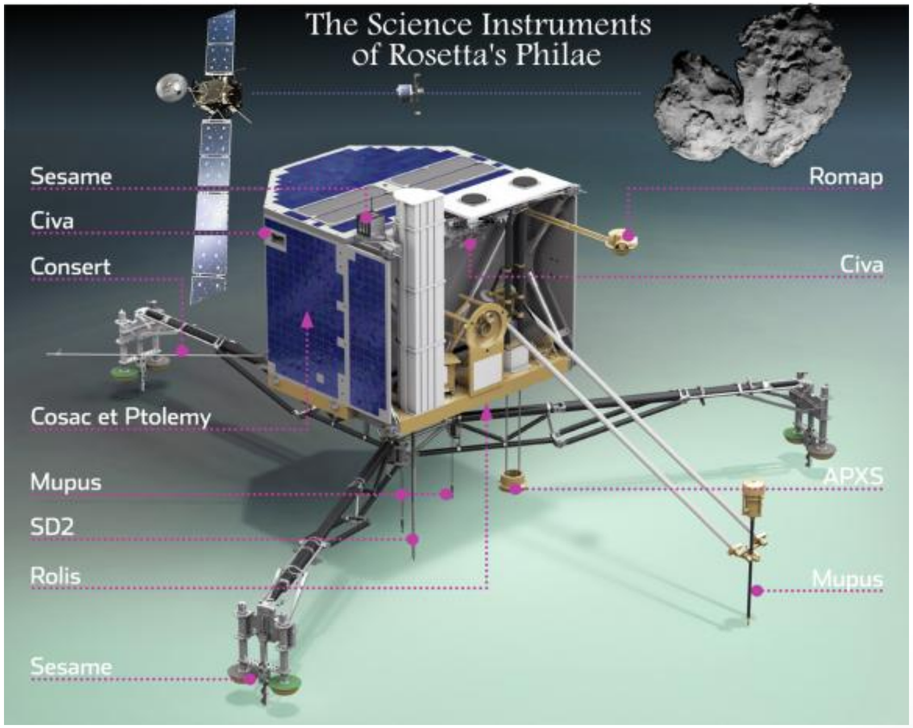
Topics

- Context
- Rosetta - Philae RF link overview
- RF Analysis
  - Separation and Descent
  - Landing
    - Rebounds
    - Stabilization
  - First Science Sequence
    - Interference analysis
- Conclusion

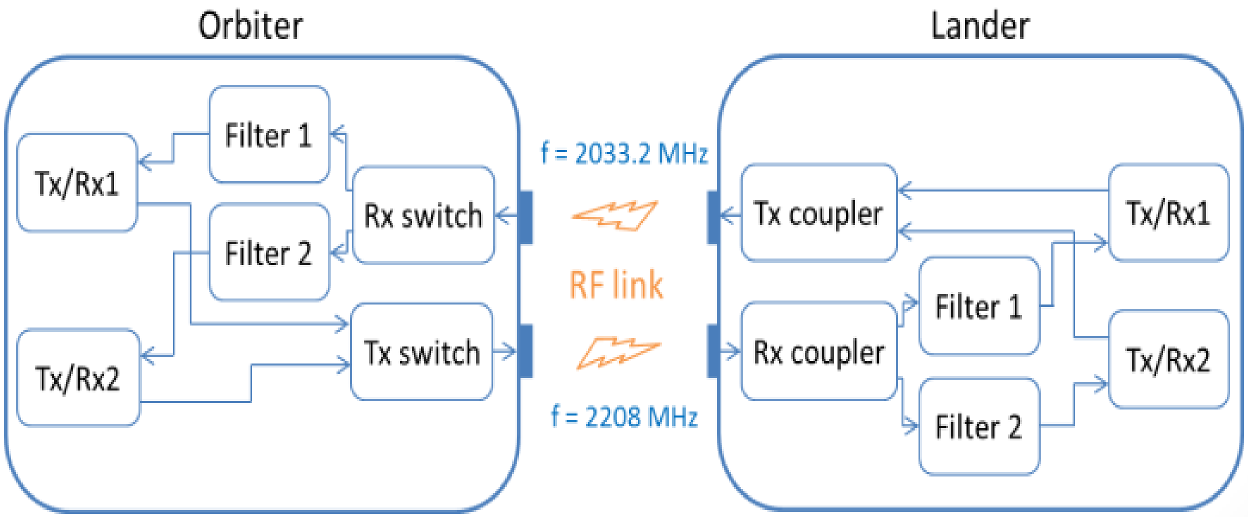
Context

- ROSETTA : ESA/CNES/DLR mission
- Spacecraft launched in March 2004 with the objective to reach the comet 67P/Churyumov-Gerasimenko 10 years later.
- Carrying Philae, 100 kg lander - equipped with 10 scientific instruments.



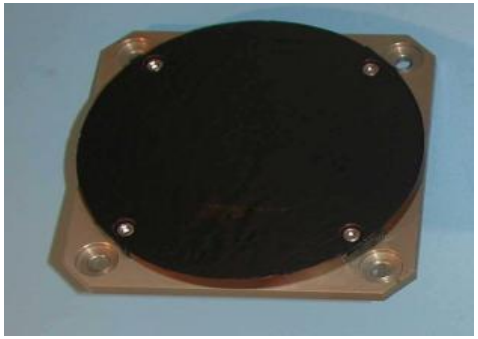
ISL RF link overview

- S band RF link
- Distances up to several hundreds of km
- Balanced TM and TC links at 16 kbits/s
- Full duplex link with Request To Send protocol (RTS)
- Filtered QPSK modulation with convolutional coding 7, ½
- Redundancy : 2 transceivers on both sides of the RF link



ISL RF link overview

- Same transceiver for ROSETTA and for the CNES micro satellites Myriades
- Conception based on COTS
- CNES highly involved in the design and qualification
- Manufactured by Syrlinks
- 1 dBi gain (@ 60°) patch antennas



Mass	950 g
Volume	160 mm x 120 mm x 40 mm
Power consumption (28 V power bus)	1.7 W Rx 6.5 W Rx/Tx at 20°C (1 W RF output power)
Temperature	Operational: -40°C to +50°C

RF Analysis

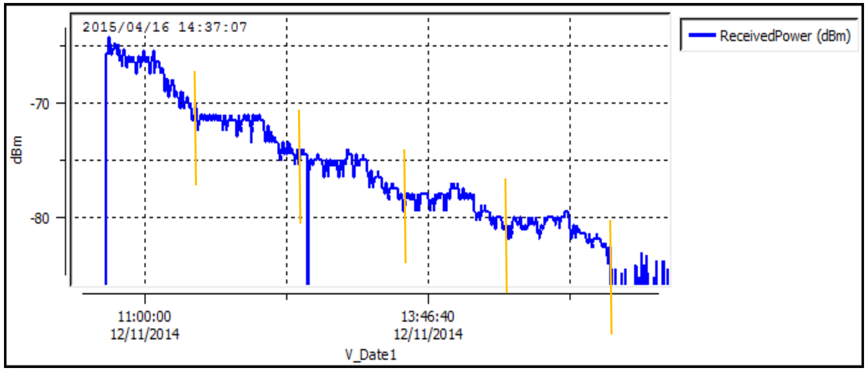
- The RF link telemetry provides monitoring parameters such as:
  - Temperatures
  - Currents
  - Received Signal Strength Indicator (RSSI)

- The RF analysis of the events is mainly based on these information sources

Separation and descent

- Nominal lander separation on November 12th, 2014 at 8h35 UTC.
- RF AOS programmed roughly 2 hours after separation.
- Link establishment within 5 min, as expected, stable during the 5 remaining hours of descent.

➡ Transmission of the CIVA (Comet Infrared and Visible Analyzer) and ROLIS (Rosetta Lander Imaging System) photographs taken before touchdown.



Low frequency oscillations noticeable on the RSSI (average duration 59 min)

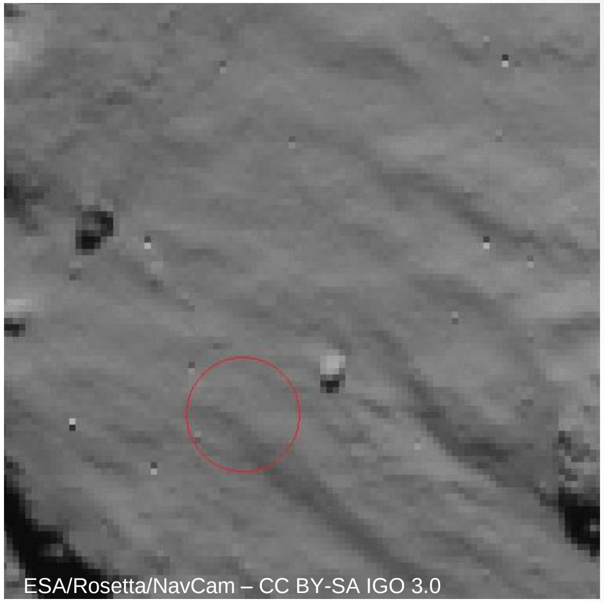
➡ Multipath effect on the orbiter structure

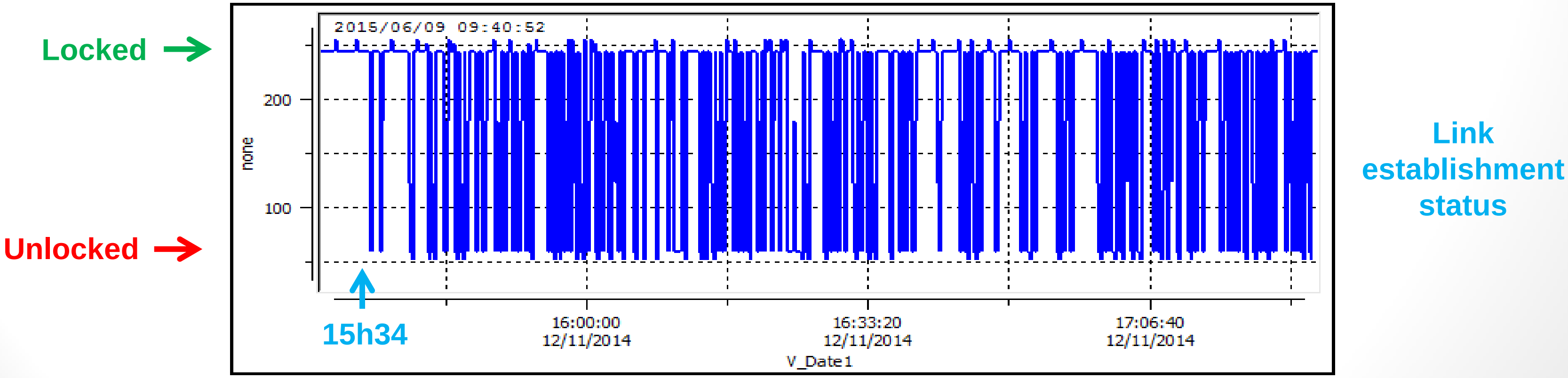
Landing

- **Touchdown** occurred at 15h34m10 UTC on Agilkia site with a precision of a few seconds.
- But multiple and regular interruptions in the received RF link telemetry.

➡ Failure of the anchoring system

Two rebounds before stabilization on the ground

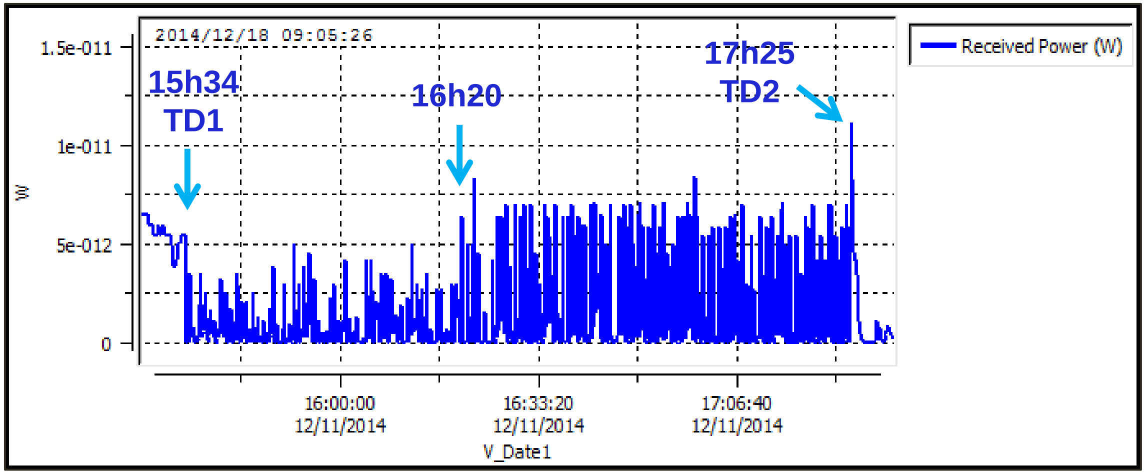




Landing - rebounds

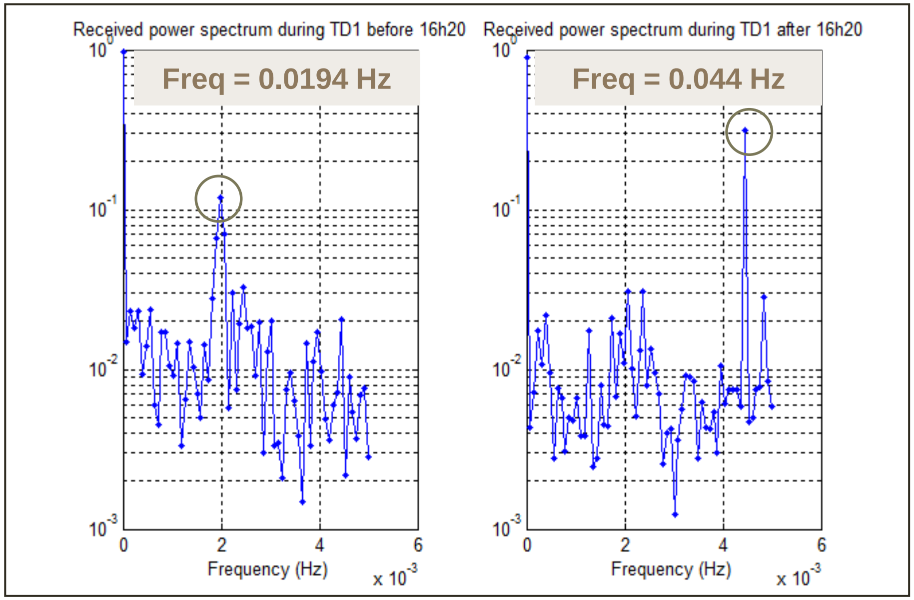
First rebound

- During 2 hours after touchdown (TD1)
  - Tumbling motion around the 3 axis but relatively stable position around Z-axis.
  - Multiple and periodic interruptions on the RF link.
  - Event at 16h20, leading to increased received power level (+3 dB)



Landing - rebounds

First rebound: signal frequency analysis



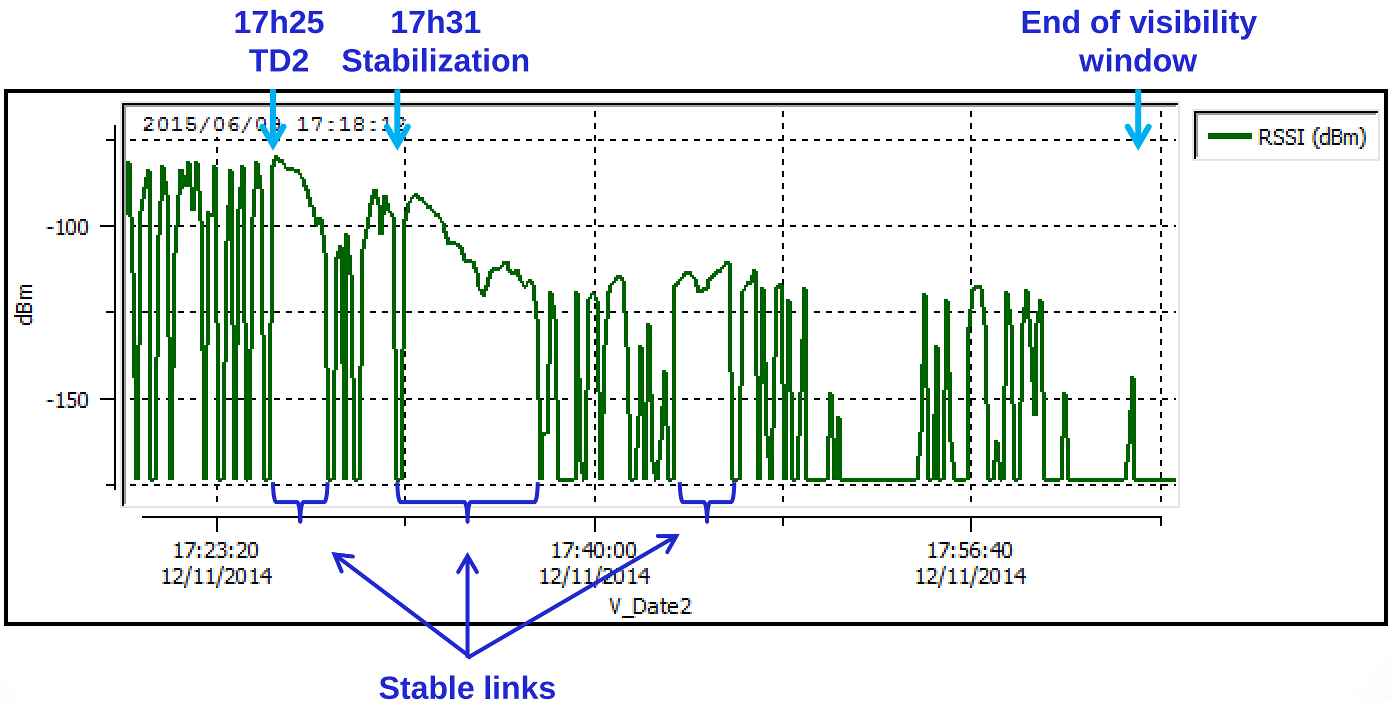
Timeline	RF analysis	ROMAP
Before 16h20	Frequency = 0,0194 Hz Period = 12.41 s (aliazing)	Lander spin at 13 s/rot
After 16:20	Frequency = 0,044 Hz Period = 22.7 s	Lander spin at 24 s/rot

- Analysis reveals a periodic phenomenon which frequency changes after 16h20
- The cross-comparison with ROMAP data allows concluding that the lander spin was lowered
- Explanation: at 16h20 the lander brushed the comet surface or a rock but did not stabilized on the ground

Landing - rebounds

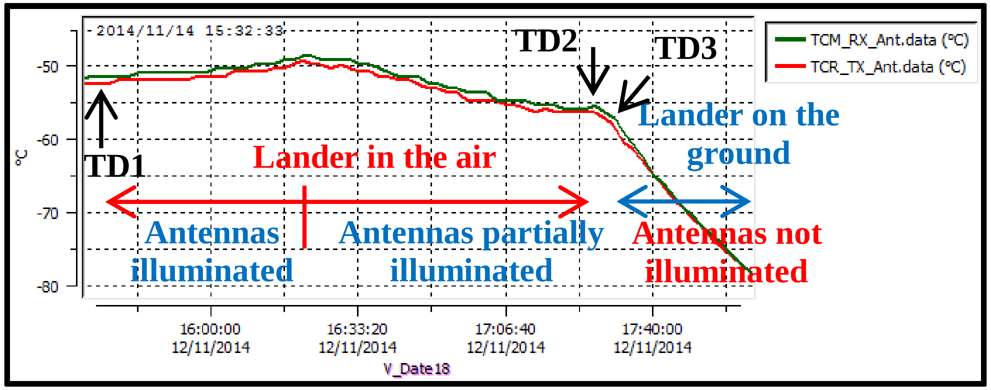
Second rebound and after

- Lasted less than 6 min
- **Stable links observed** before the end of visibility window
- Maximum received power lower than before TD2



Stabilization

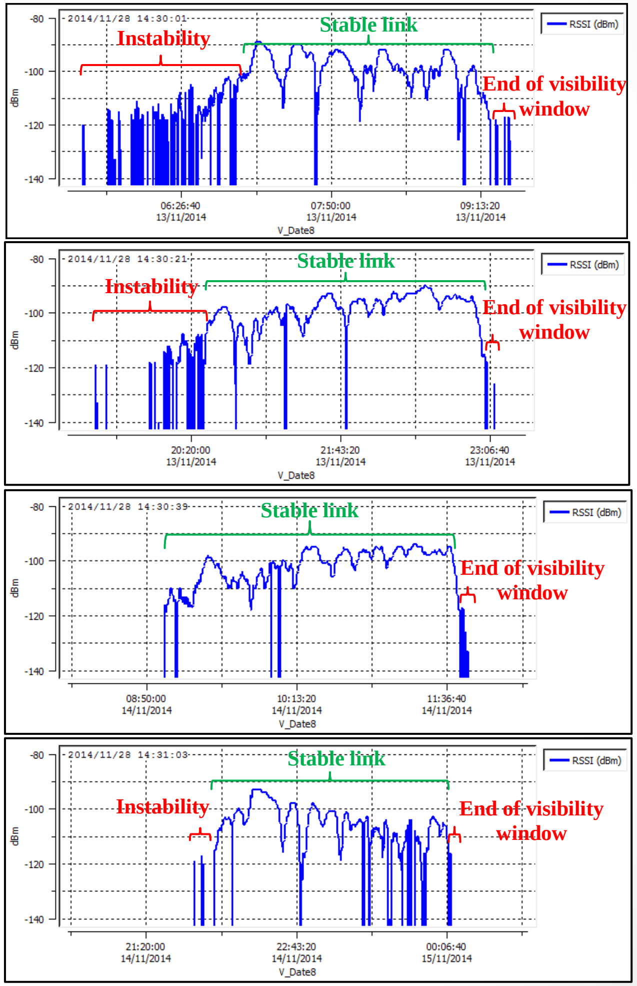
- **Final stabilization** on the comet at 17:31:17 UTC (only 30 min before the end of the RF visibility)
- Maximum measured level shows that a **high attenuation affects** the link compared to transmission at TD1.
  - Due to lander attitude on the ground and its surrounding environment.
- Analysis of the **Lander antennas temperature** :



- At the end of the RF visibility window, two crucial questions remained unanswered:
  - What are the final location and attitude of the lander?
  - When the RF link will be established again?

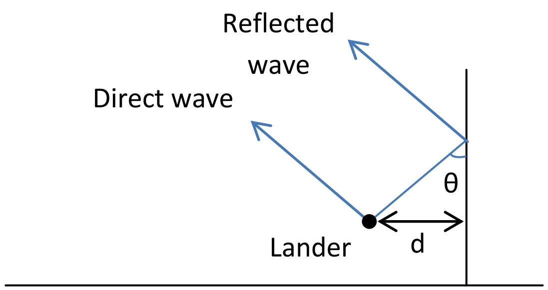
First Science Sequence

- Two science operations phases : **First Science Sequence (FSS)** - foreseen lifetime about 50 hours ; Long Term Science (LTS)
- **4 RF visibilities** during FSS with unstable and stable periods
- During the stable period, noticeable arches : **multipath interferences due to the surrounding relief.**
- Power variations also due to
  - Orbiter/lander antenna diagram variations
  - Increasing distance



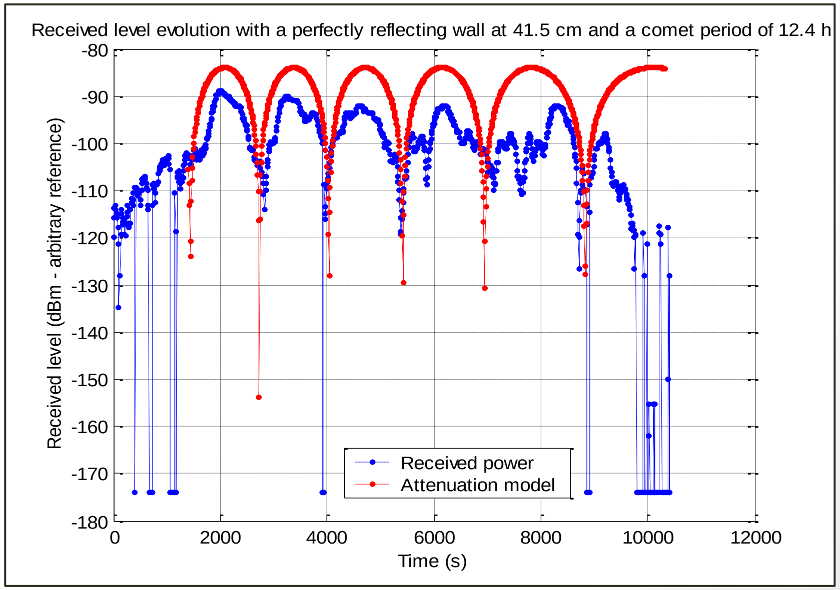
Interference analysis

- Simple modelling of the level profiles with arches due to multipath interferences.



- One direct wave
- One reflected wave with reflection angle **θ**,
- Distance **d** between the antennas and the reflecting surface

- **Customizing the distance to fit the model to the received signal**
- **Model improvements**
  - Nature of the relief
  - orbiter speed relatively to the comet
  - lander attitude.
- As visible on the figure, **complex interference phenomena** with multiple reflected signal combined with diffraction and possibly no direct signal.



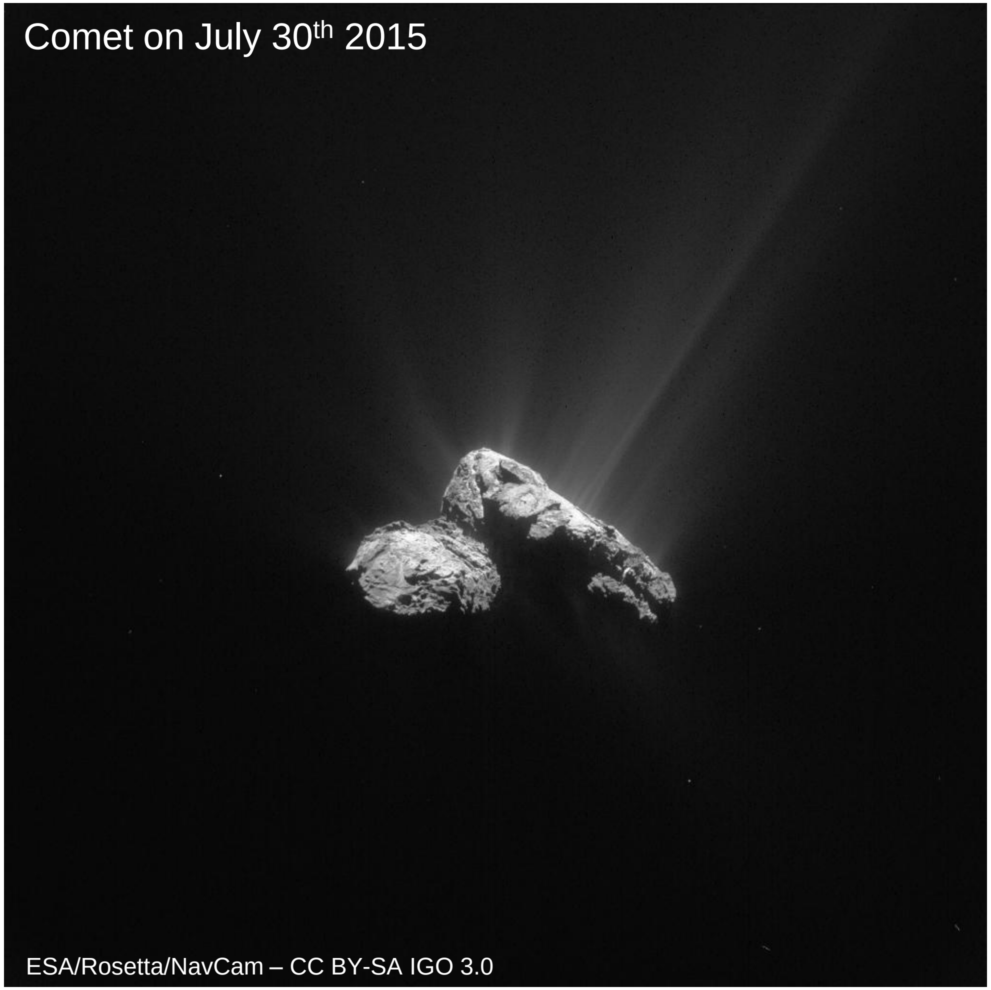
Conclusion

- The **ISL RF link analysis** of the first mission having landed a space science laboratory on a comet allowed **understanding the successive events** in the particular context of the **rebound landing** and the unknown final lander position.

- After stabilization, the **RF link could be established at each orbiter-lander visibility**. A propagation model derived from the power variations offers clues on the final lander attitude and position with regard to its environment.

- **The RF played its part at best** despite the unexpected conditions, from the separation with the orbiter to the final hibernation on 67P/Churyumov-Gerasimenko.

Questions



Thank you for your attention