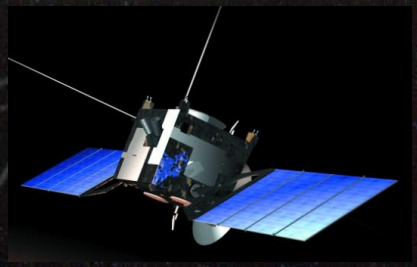
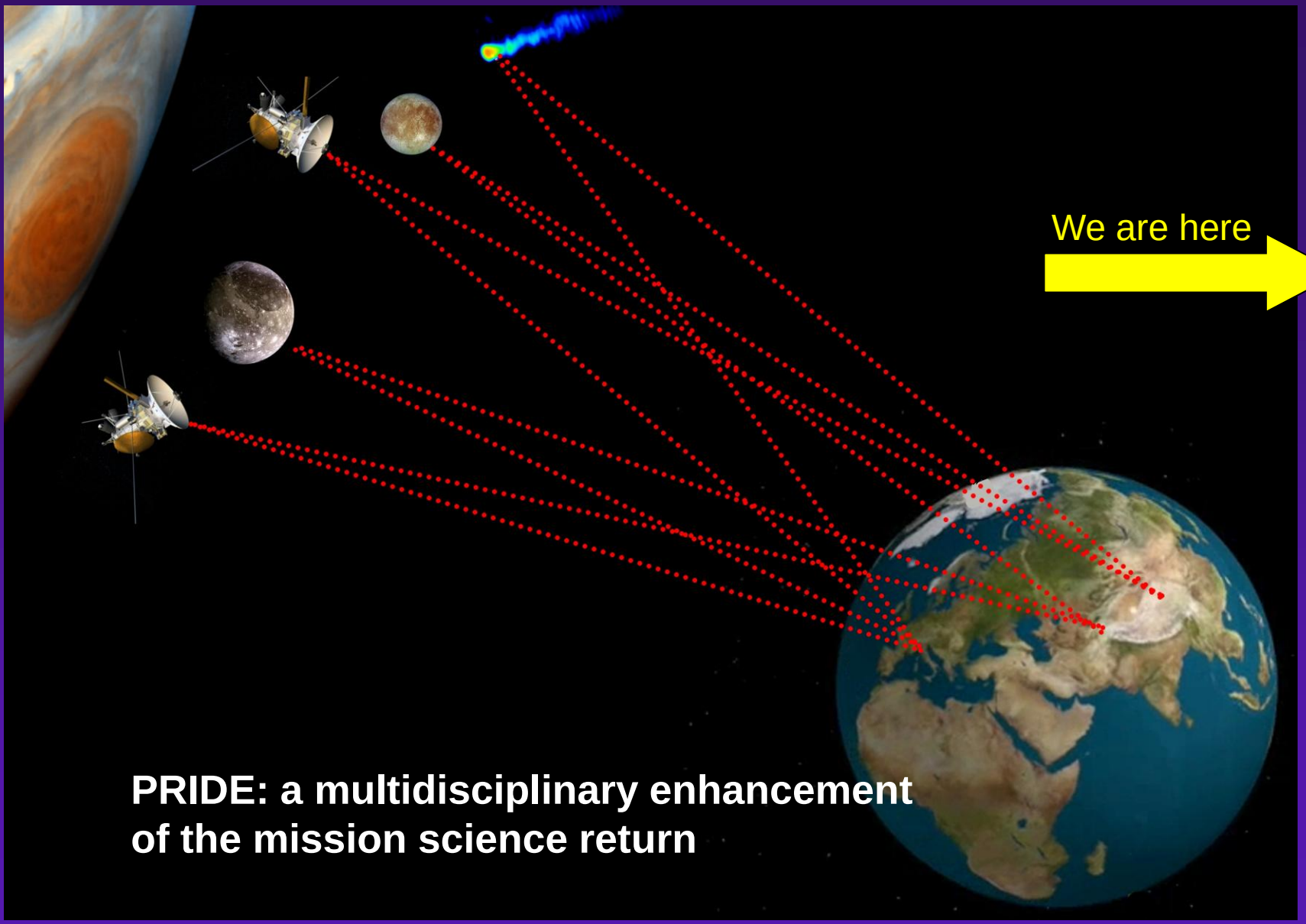


Planetary Radio Interferometry and Doppler Experiment (PRIDE) in the IVS context

L.I. Gurvits, S.V. Pogrebenko, G. Cimò
JIVE, Dwingeloo, The Netherlands

and *PRIDE collaboration*

Generic PRIDE configuration



PRIDE: a multidisciplinary enhancement of the mission science return

Spacecraft as a celestial radio source

- **Spacecraft tend to be radio loud… actually?**
  - *Transmitter power 1 W*
  - *Distance 5 AU (Jupiter)*
  - *On-board antenna gain 3 dB*
  - *Bandwidth 100 kHz*

Flux density ≈ 0.5 mJy

- **Operate at frequencies radio astronomers love (or hate):**

  UHF (400 and 800 MHz), S (2.3 GHz), X (8.4 GHz), Ka (32 GHz)

- **Estimates of state-vectors of spacecraft:**
  - *Need for "higher-than-standard" accuracy in special cases*
    - Geodynamics and planetology
    - Trajectory measurements in close vicinity of Solar System bodies (e.g. landings)
    - Fundamental physics
    - Space-borne astrometry missions (e.g. GAIA)

- **Need for "eavesdropping" (sometimes, in desperation…)**

S/C VLBI presentations at this meeting

- **S1-T12: How and why to do VLBI on GNSS S/C**
  John Dickey

- **S1-T13: Planning of an experiment for VLBI tracking of GNSS satellites**
  Vincenza Tornatore et al.

- **S2-T13: Zodiac extragalactic sources densification using phase-referencing technology**
  Guangli Wang

- **S5-T06: Lunar, Martian, and Jovian Geodesy and Science Mission Using VLBI and Astrometrical Technology**
  Takahiro Iwata et al.

- **S2-P11: Venus Express Spacecraft Observations with the Wettzell Radio Telescope – First Results**
  Alexander Neidhardt et al.

Huygens VLBI tracking: eavesdropping…

Cassini S/C

RCXO

RCXO
RUSO

10^5 km

Ch. B: 2097 MHz

TCXO

Huygens Data

Ch. A: 2040 MHz

TCXO
TUSO

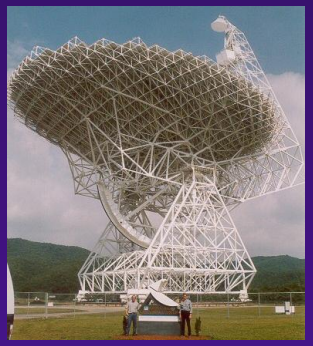
10^9 km

Huygens
Receivers

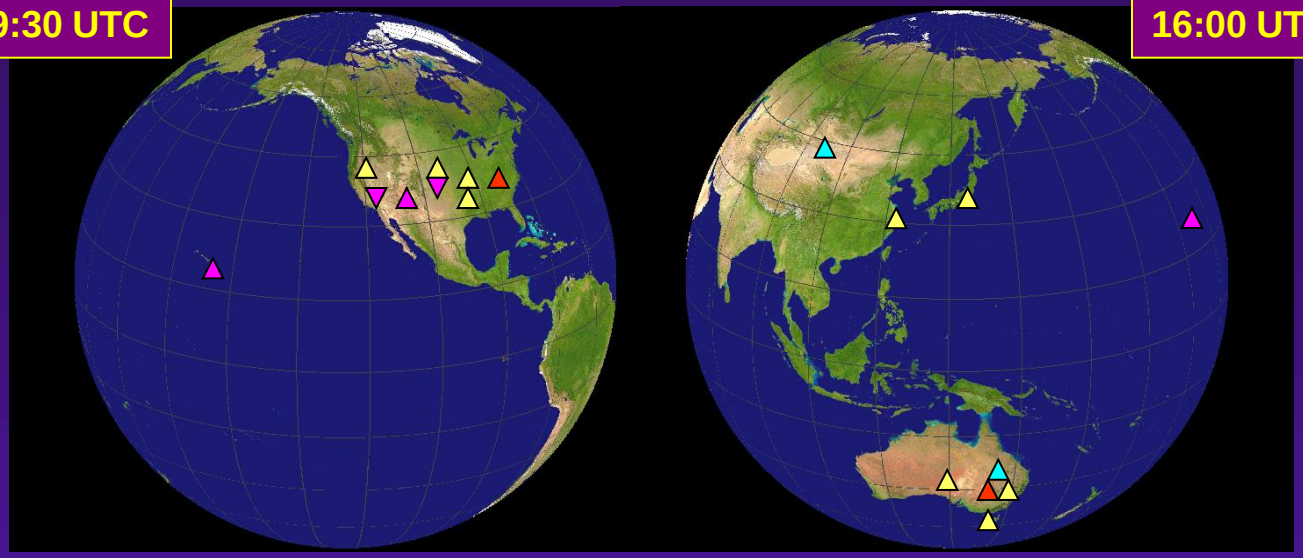
Huygens
Probe

"Channel C" – eavesdropping on Channel A carrier

VLBI tracking of Huygens, 14 January 2005



09:30 UTC



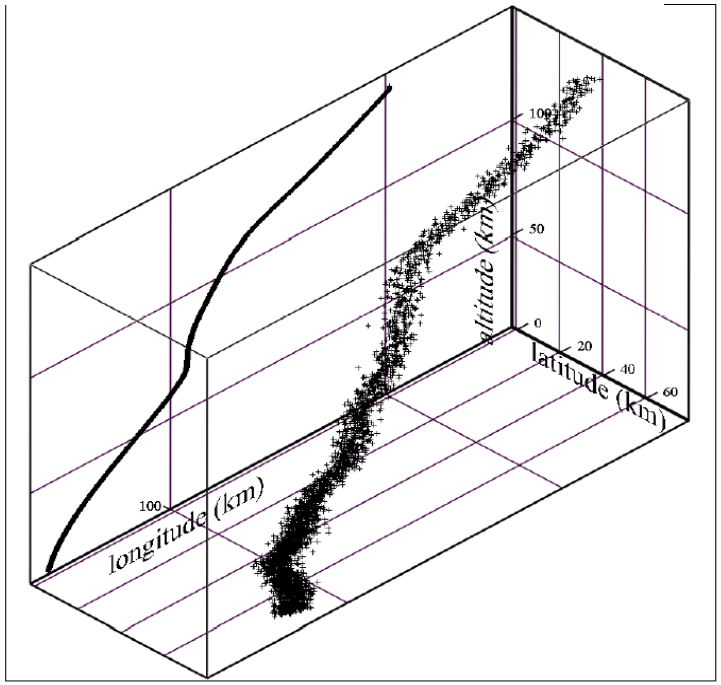
16:00 UTC

~20 radio photons per 25-m telescope per second…

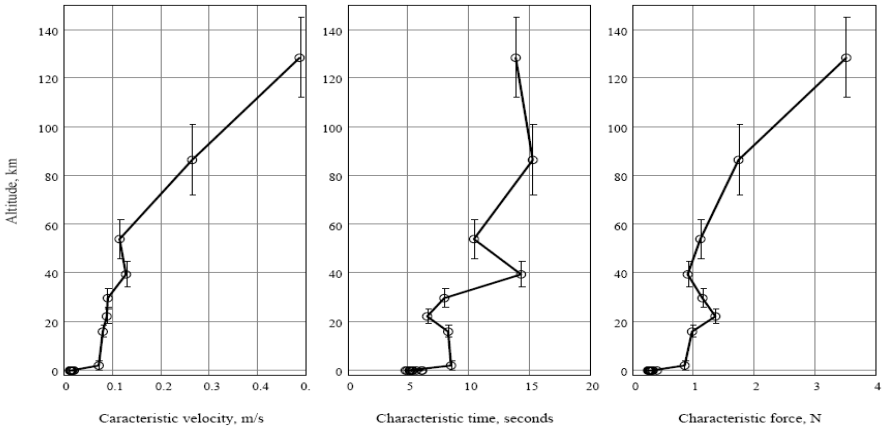
Huygens VLBI heritage: 20 photons/dish/s

- **Ad hoc use of the Huygens "uplink" carrier signal at 2040 MHz**
- **Utilised 17 Earth-based radio telescopes**
- **Non-optimal parameters of the experiment (not planned originally)**
- **Achieved 1 km accuracy of Probe's descent trajectory determination**
- **Assisted in achieving one of main science goals of the mission – vertical wind profile**

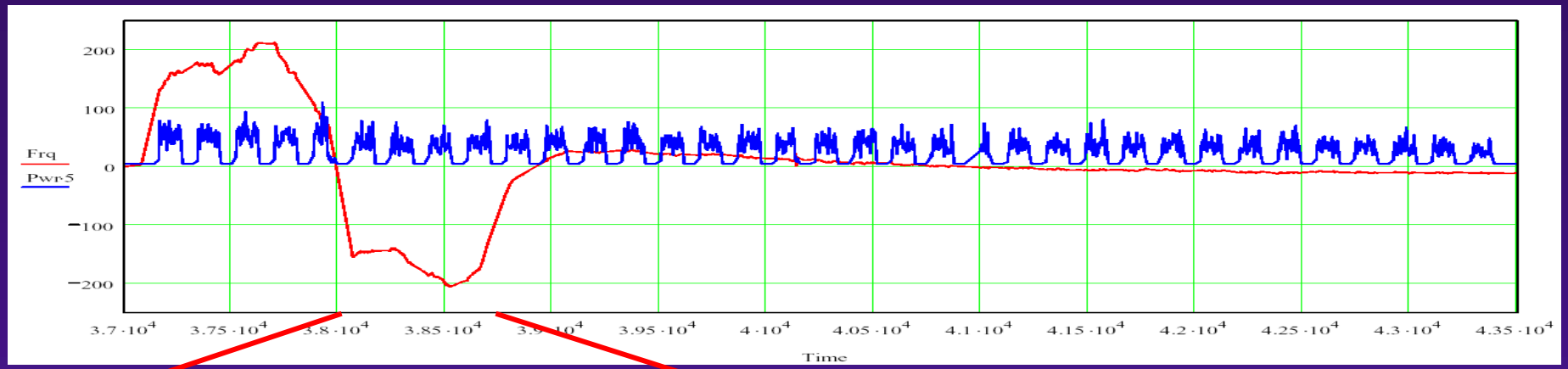
3D Huygens descent trajectory

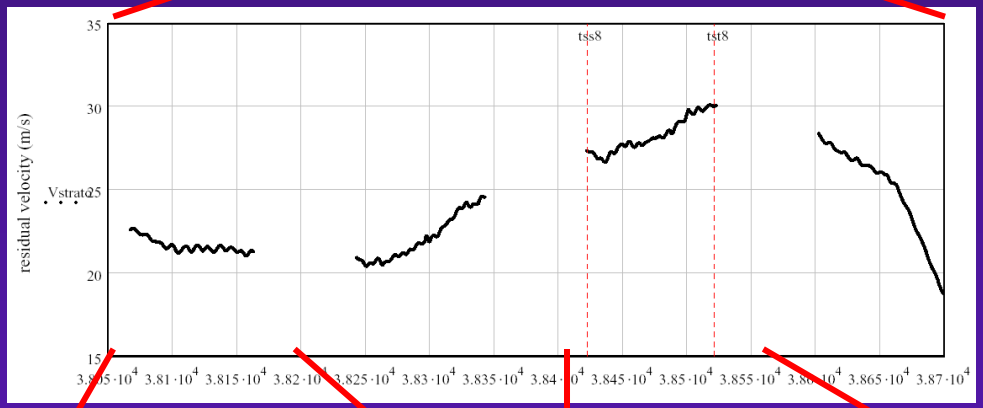


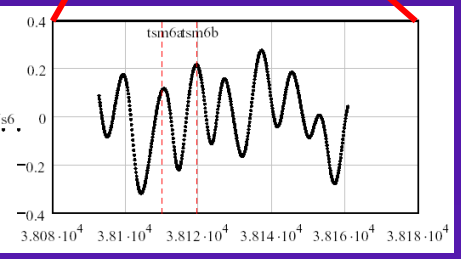
Titan atmosphere turbulence signature

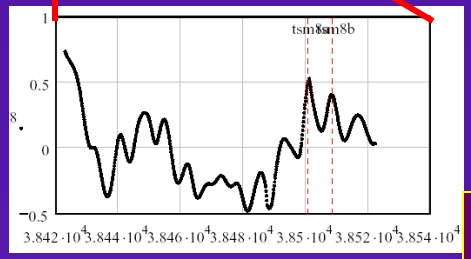


VLBI processing by-product: Doppler data (probe's motion)





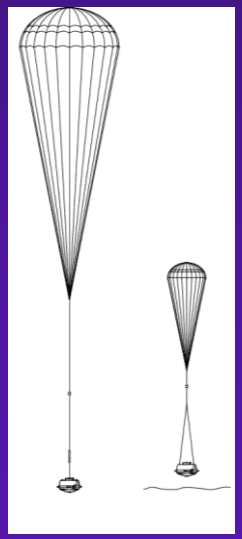


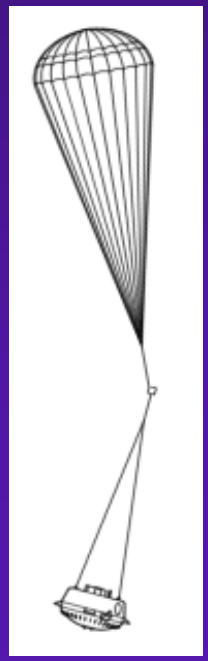


$T = 8 \div 10$ s

$\Delta V = 0.22$ m/s

$A \approx 0.6$ m

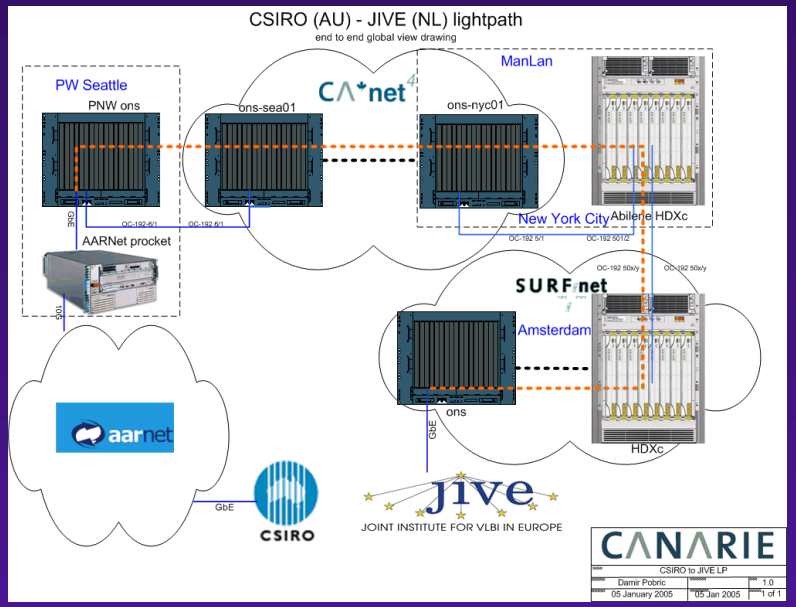


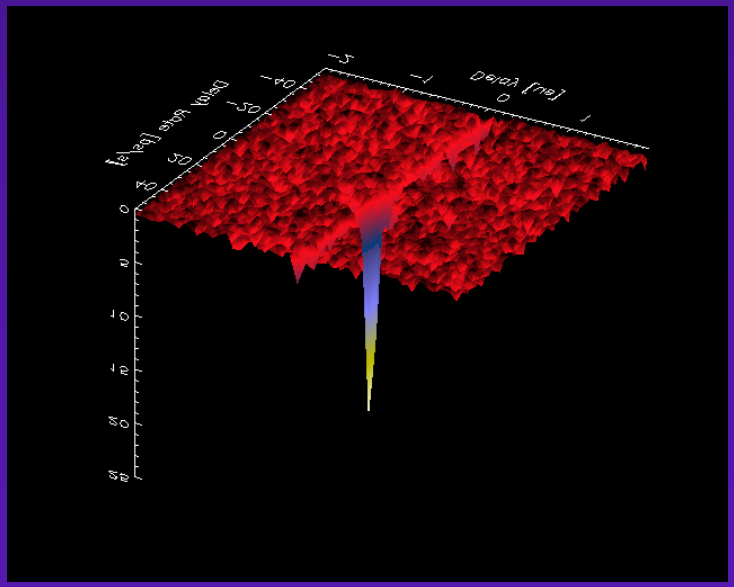


Data available for analysis!

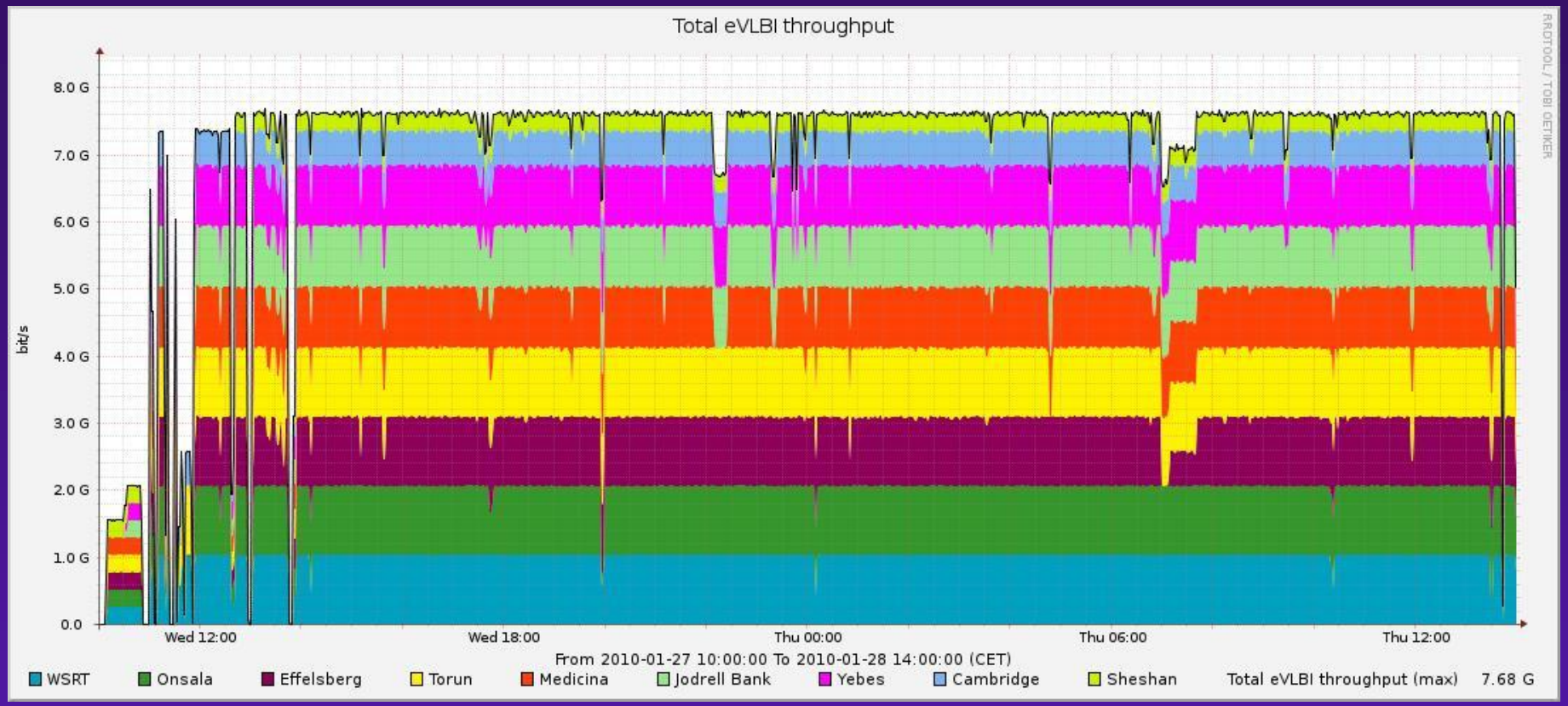
e-VLBI & "Night Flight": 14 – 15 January 2005

A.Tzioumis & C.Phillips, ATNF, acting in near-RT mode





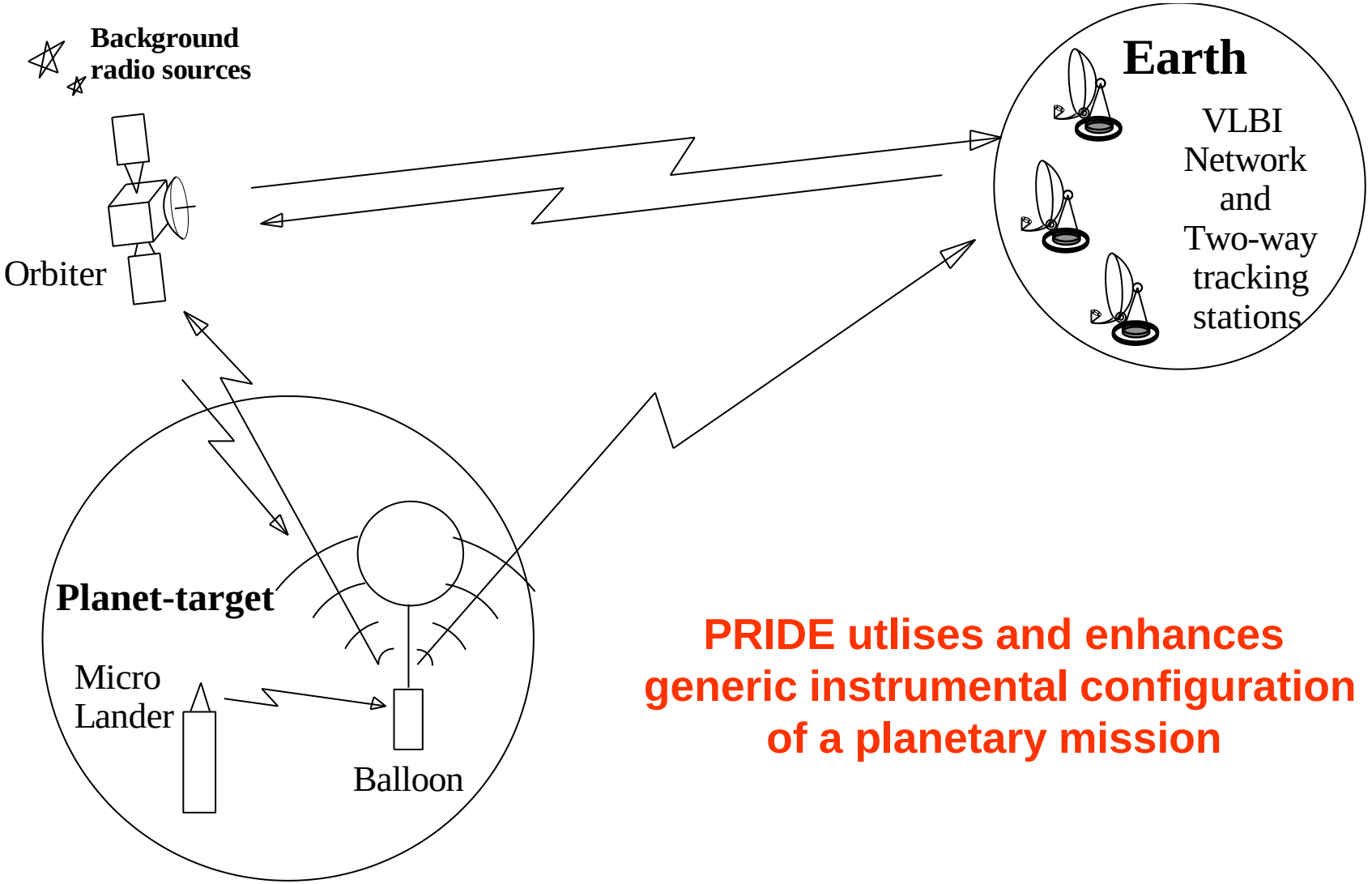
e-VLBI in action, Feb 2010



EC FP6 e-VLBI project EXPReS 2006-2009

Generic PRIDE configuration

Planetary Radio Interferometry and Doppler Experiment



PRIDE utlises and enhances generic instrumental configuration of a planetary mission

Science case for generic PRIDE

- **Direct characterisation of the orbiter (*and surface elements*?) signal by means of "VLBI tracking" and radial Doppler measurements**

- **VLBI estimates of the S/C state vector**
  - ***Tidal deformations, seismology and tectonics of planetary bodies***
  - ***Gravimetry***
  - ***Atmosphere dynamics and climatology (if there is an atmosphere…)***
  - ***Input to the fundamental physics***

- **Radio occultation observations (e.g. Jovian magneto-/iono-sphere)**
- **"Cruise" science plus mission diagnostics ("health check")**
- **High degree of synergy with in situ measurements**

- **Complementary to DeltaDOR measurements**

plus

- **Direct-to-Earth (DtE) delivery of critical data (e.g. via SKA)**

Planetary science missions – PRIDE customers

EJSM

ExoMars

BepiColombo

Phobos-Grunt

2010

2015

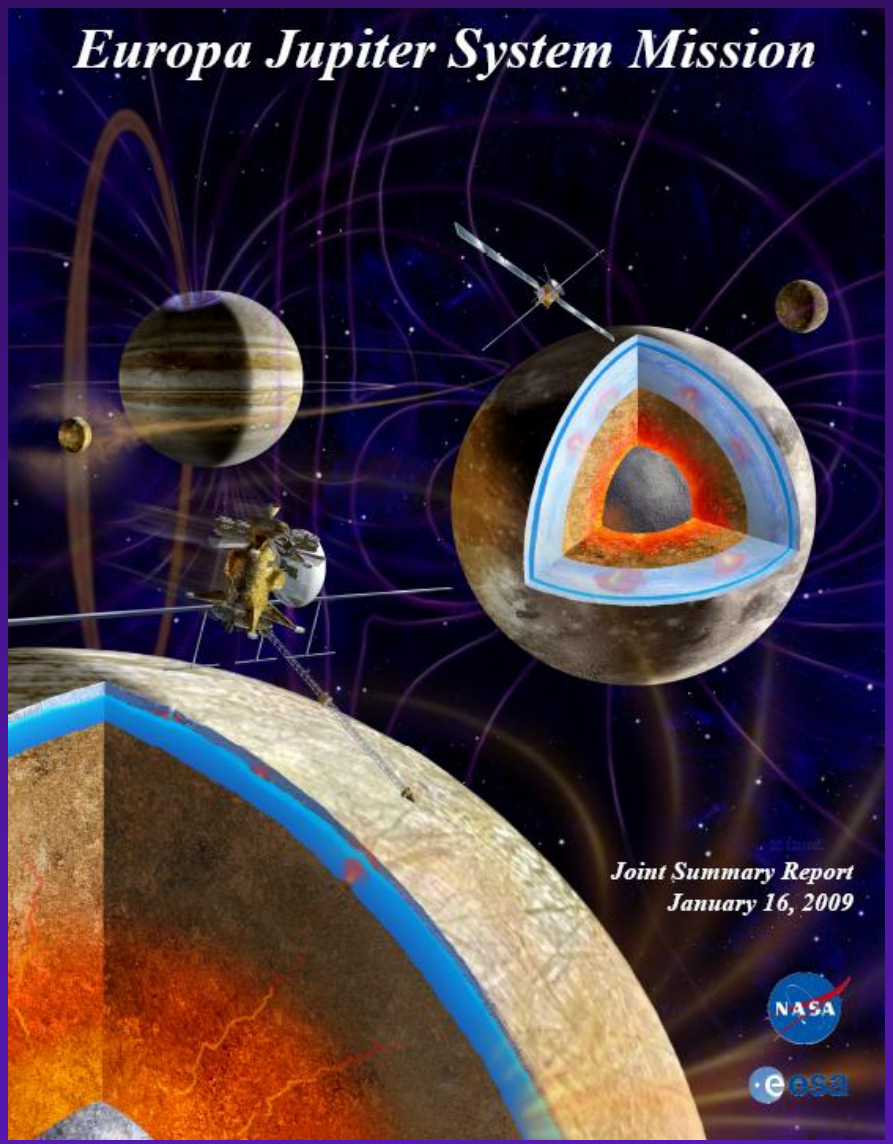
2020

2025

SKA era

- *Perfect match of timelines*
- *Potentially rewarding reciprocity*

ESA Cosmic Vision and NASA Flagship proposals



~4B projects, compete for launch in 2020-2022

PRIDE-EJSM vs Huygens VLBI tracking

Mission	Distance	Transmitter power/gain	Band	Time resolution	Delay noise	Positional accuracy (lateral)
	[AU]		*[GHz]*	*[s]*	*[ps]*	*[m]*
Huygens VLBI	8	3 W / 3 dBi	2.0 (S)	500	15	1000
PRIDE EJSM	5	10 W / 6 dBi	2.3 (S)	100	5	120
			8.4 (X)	10	3	70
			32 (Ka)	10	1	23

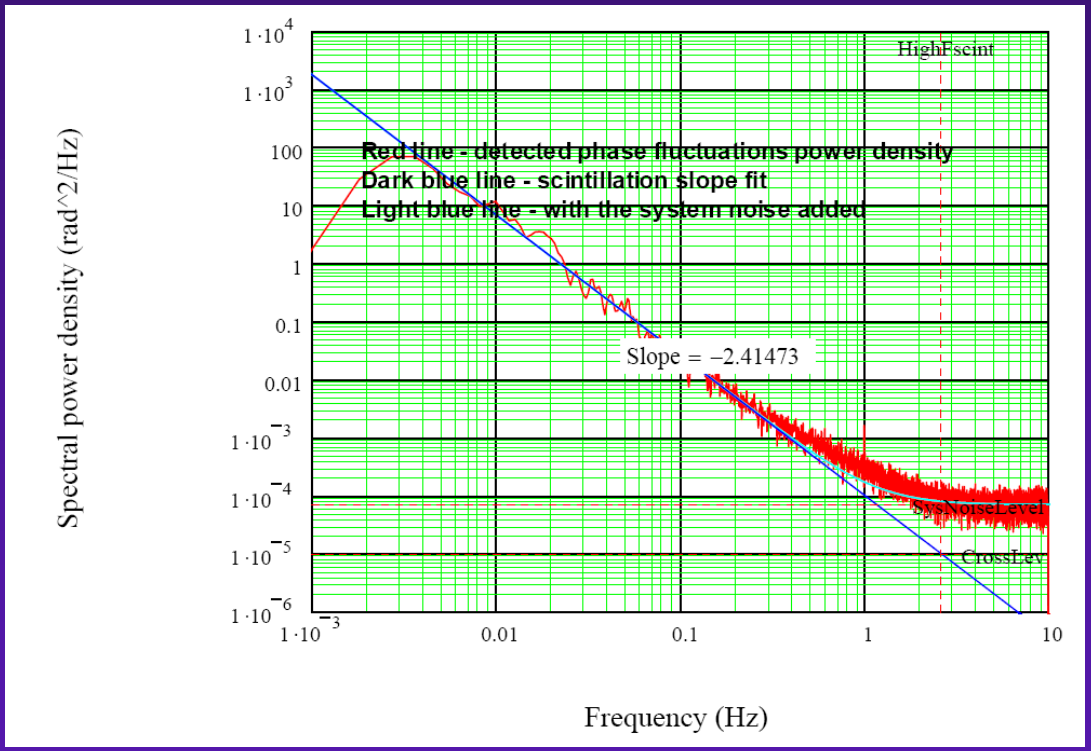
GPS accuracy anywhere in Solar System

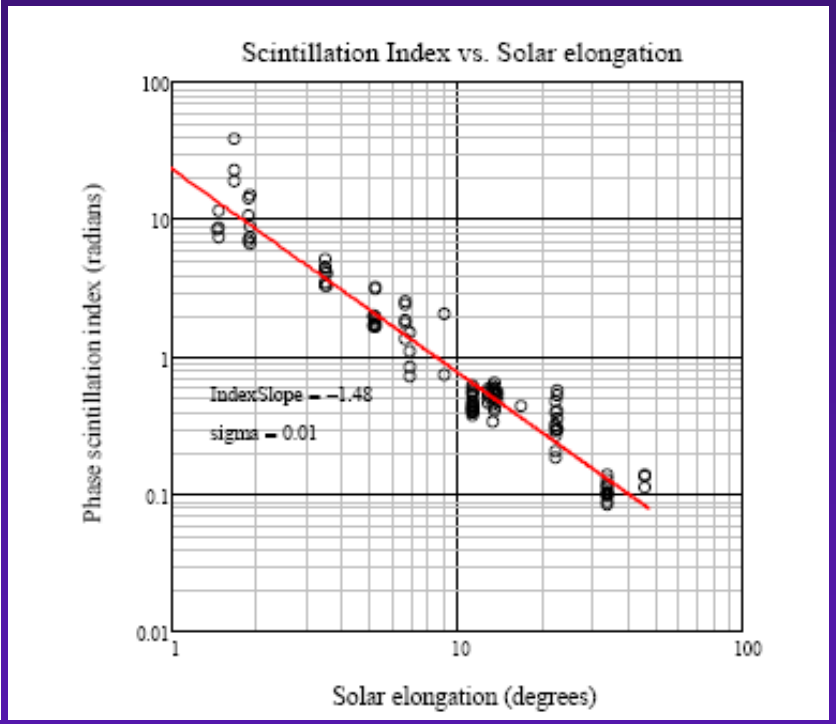
- Conservative estimate, today's technology
- Minimal special requirements for the on-board instrumentation
- In-beam "Orbiter-Probe" calibration can improve SNR further

PRIDE 2010: status and results (so far…)

ESA's Venus Express mission as a "training" target

Spectral power density of slow fluctuation phase turbulence below 10 Hz.





S2-P11, Neidhardt, Molera, Pogrebenko et al., this conference

Participating stations: Medicina, Metsahovi, Noto, Wettzell, Yebes

Toward S/C VLBI tracking in turbulent plasma

Allan variance of the stochastic part of the frequency detections on the Cebreros-VEX-Wettzell link