LISA Pathfinder launch & results

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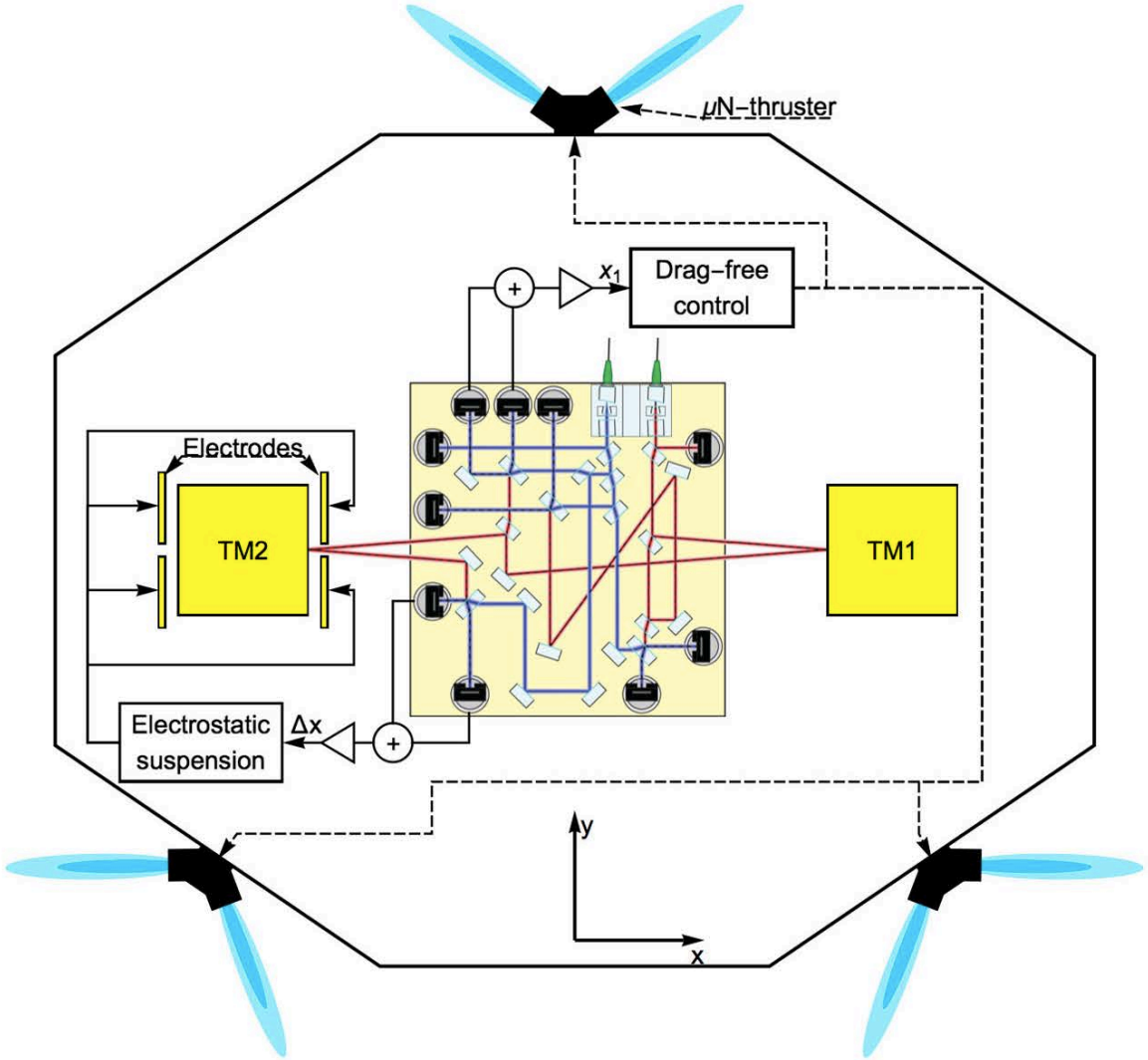
LISA Pathfinder spacecraft

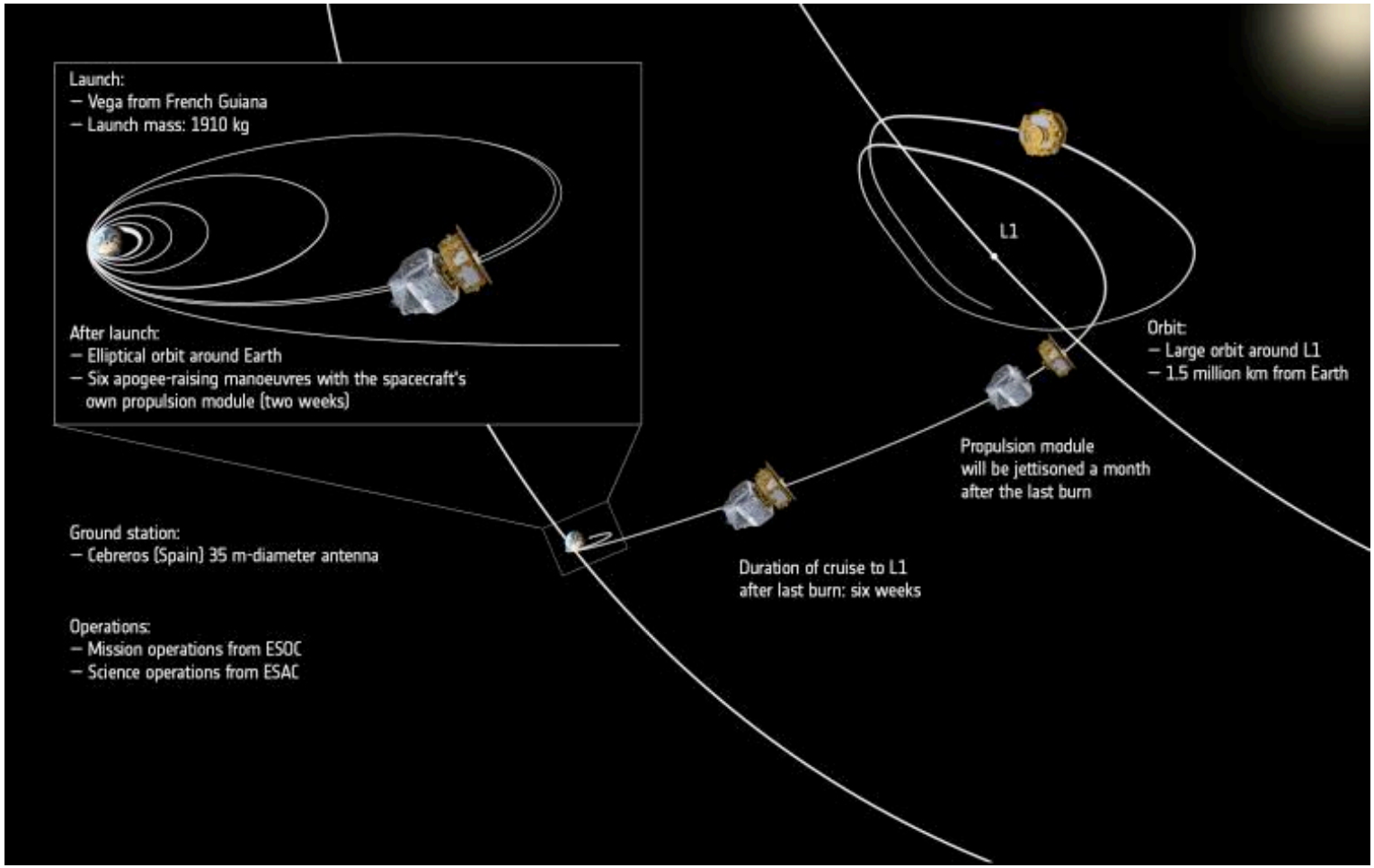
- ESA mission for technology testing of LISA the first interferometer for gravitational waves in space
- The aim of this experiment is to study residual acceleration noise between two truly free falling test masses in space (masses released in February)

LISA Pathfinder apparatus scheme



LISA-PF Orbit

Science operation mode: March 1st



Sub-Femto-*g* Free Fall for Space-Based Gravitational Wave Observatories: LISA Pathfinder Results

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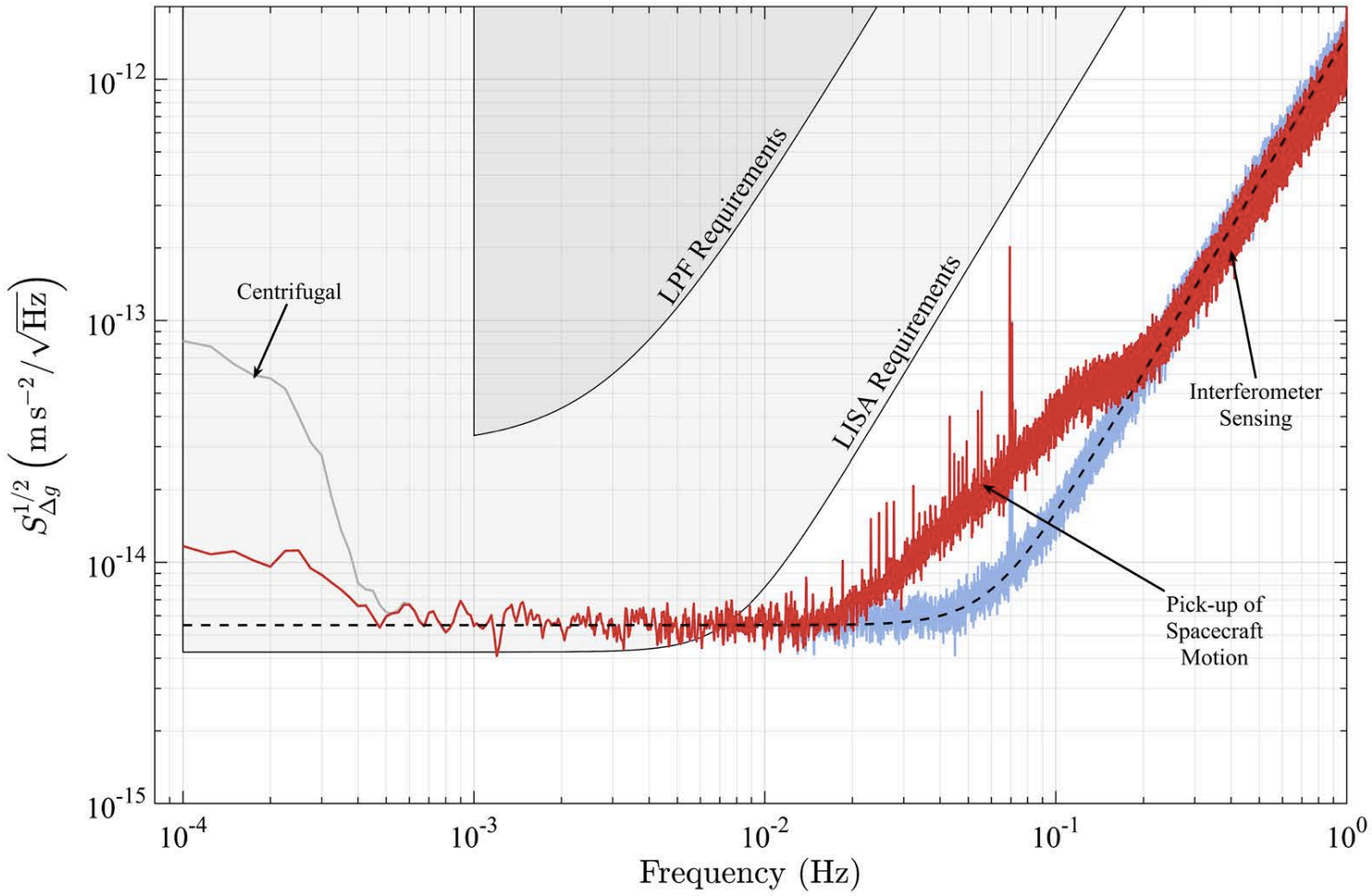
LISA-PF ASD



<0.1- 0.5 mHz 12 fm s^{-2} $Hz^{-1/2}$

0.7-20 mHz 5.2+/-0.01 fm s^{-2} $Hz^{-1/2}$

> 60 mHz (34.8+/-0.3) fm $Hz^{-1/2}$

LISA performance whith the LISA-PF acceleration noise

- Black hole merging with total mass 10^6 solar masses at redshift z=3 with S/N ratio of 5000 (several % of LISA expected performance)

- Heavy black hole merger with 10^7 solar masses total mass at redshift z=3 with
  S/N ratio of 1400 (2000 expected with LISA).

- EMRIs and coalescing compact binaries will present S/N ratio similar to LISA.

LISA-PF in Florence since 2003

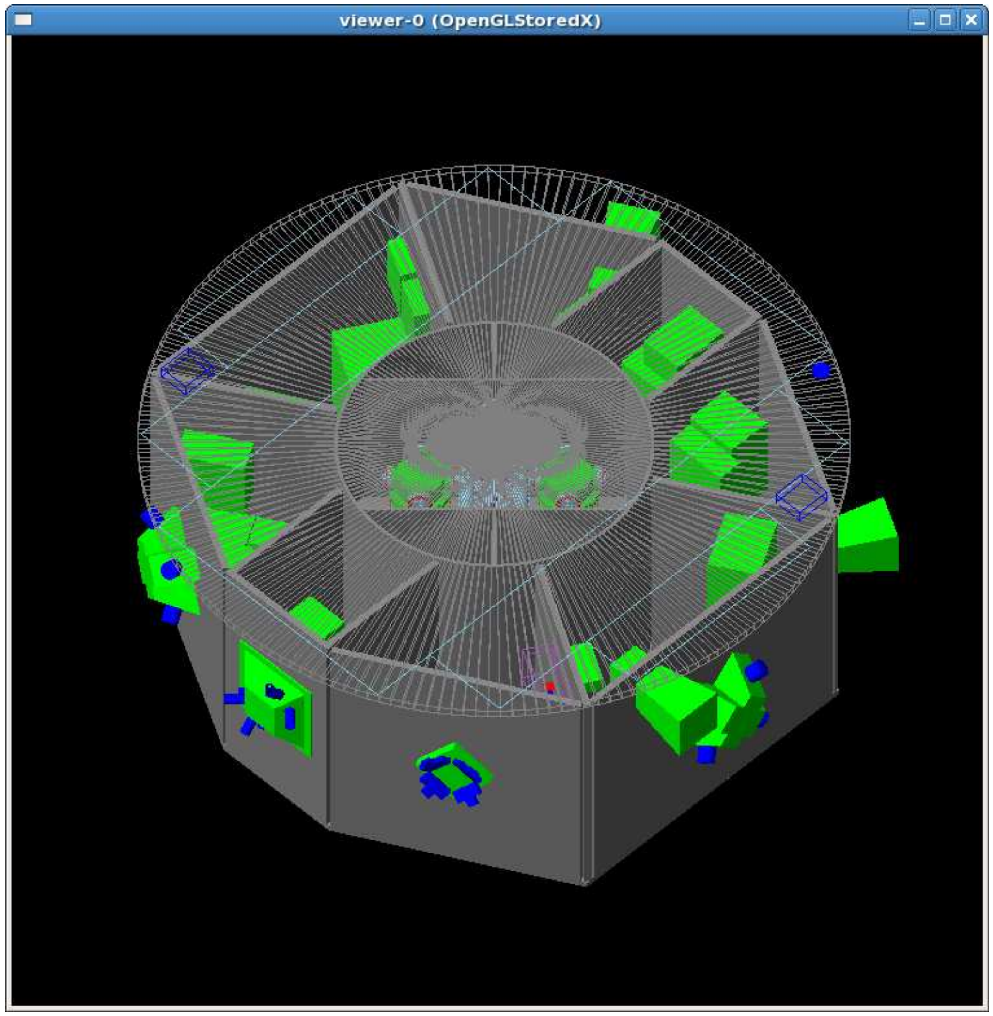
Catia Grimani
Ruggero Stanga
Noemi Finetti
Daniele Telloni (INAF - solar wind)
Monica Laurenza (INAF - SEPs)
G. Bagni, M. Barone, L. Marconi &
M. Fabi (Urbino)

2 main activities

(I) Two-degree-of-freedom pendulum
Florence - Rome - Naples

(II) Test-mass charging
Perugia for 4 years

Test-mass charging study with Fluka



FLUKA MC
Simulation

Wass et al., CQG, 22, 2005, S311-S317
CG et al., CQG, 32, 2015, 035001

Test-mass charging

Net and effective charging estimated with the **Fluka MC** Program

2x10^6 events in each run In order to limit the uncertainty on λ_{eff} <2%

$$\lambda_{NET} = \sum_{j=-\infty}^{+\infty} j\lambda_j$$

$$\lambda_{EFF} = \sum_{j=-\infty}^{+\infty} j^2\lambda_j$$

Ferrari et al., 2005-10 (Geneva:CERN)
Battistoni et al.,
AIP Conf. Proc. 896,
M. Albrow and R. Raja, 31-49

Where: j is the amplitude of the charge released by each event and λ_j is rate of occurrence of that event.

$$S_Q(\omega) = \frac{S}{\omega} = \frac{\sqrt{2e^2\lambda_{eff}}}{\omega}$$

$$S = \sqrt{2e^2\lambda_{eff}} \quad e\ s^{-1}\ Hz^{-1/2}$$

LISA
acceleration noise spectral density

$$S^{1/2}(\omega) = 0.8 \times 10^{-15} \frac{m}{s^2\sqrt{Hz}} \left(\frac{4mm}{gap}\right)\left(\frac{V_{dc}}{10mV}\right)\left(\frac{\lambda_{eff}}{300s^{-1}}\right)^{1/2}\left(\frac{0.1mHz}{f}\right)$$

TO BE UPDATED FOR LISA-PF

Required acceleration noise limit
for random charge:

$9.4 \cdot 10^{-16}$ ($m\ s^{-2}\ Hz^{-1/2}$)
[total: $3 \cdot 10^{-15}$]

($10^{-4} \div 10^{-1}$ Hz)

LISA-PF test-mass charging

Particle	λ_{net} (e^+/s)	λ_{eff} (e/s)	S (e $s^{-1}Hz^{-1/2}$)
p_{min}	14.1	168.9	18.4
p_{max}	32.5	295.5	24.3
He^3_{min}	0.22	0.92	1.4
He^3_{max}	1.9	5.6	3.4
He^4_{min}	0.81	1.9	2.0
He^4_{max}	3.8	10.7	4.6
$p_{11/2006}$	31.2	312.6	25.0
$p_{FD14/12/2006}$	19.4	213.1	20.6
$p_{27-day+;min}$	16.6	176.2	18.8
$p_{27-day-;min}$	10.9	173.7	18.6
$p_{27-day+;max}$	35.8	250.0	22.4
$p_{27-day-;max}$	27.1	239.7	21.9
$p_{2h\ min}$	11.5	176.6	18.8
$p_{2h\ max}$	30.0	231.1	21.5

@solar minimum

GEANT4:
24.9 e s^{-1} $Hz^{-1/2}$
Wass et al., 2005

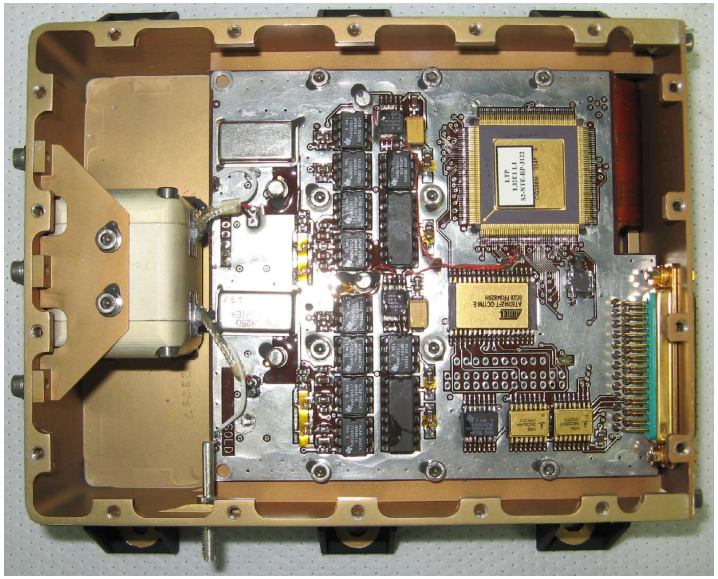
FLUKA:
25.0 e s^{-1} $Hz^{-1/2}$
(p_{max},He_{max})

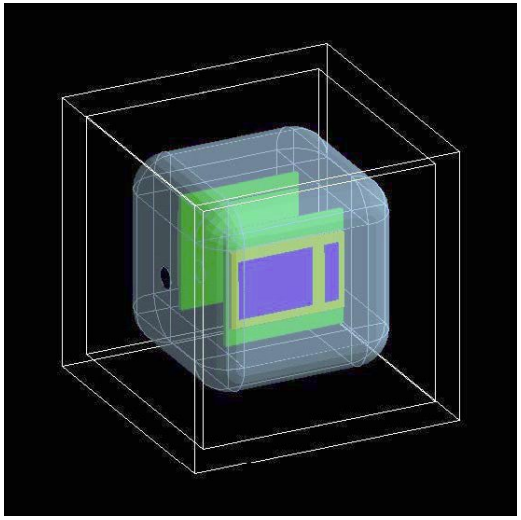
18.6 e s^{-1} $Hz^{-1/2}$
(p_{min},He_{min})

Real data (13 may 2016):
TM1: 24.5 e/s
TM2: 27 e/s

CG et al. CQG, 2015

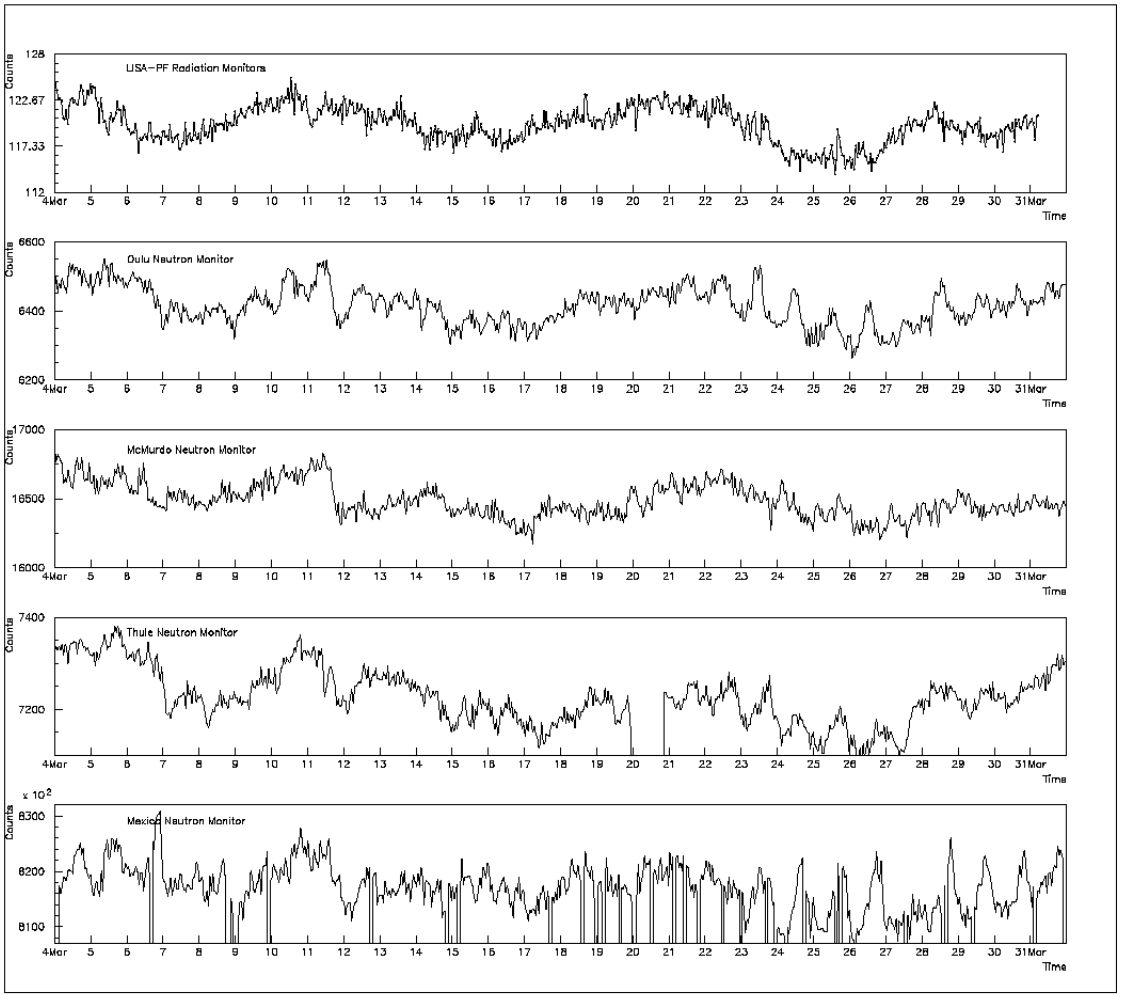
LISA-PF TEST masses and radiation monitors





2 silicon wafers
of 1.4 x 1.05 cm^2 area
placed 2 cm apart.

LISA-PF Radiation Monitor data
4 March – 31 March 2016



LISA-PF radiation monitor data

Oulu neutron monitors

McMurdo neutron monitors

Thule neutron monitors

Mexico neutron monitors

Figura 3: Same as figure 2 during the 2491 Bartels rotation.

About gravitational wave detection

- In November 2013 ESA selected the Gravitational Universe as one of its corner-stone science themes.
  LISA to be selected as the third large mission after JUICE (L. 2022), ATHENA (L. 2028) initially scheduled for launch in 2034 will go probably by 2029.
- On February 11th 2016 the discovery of gravitational waves was announced by the LIGO/Virgo collaboration.

LISA-PF mission extension

The mission duration, originally set to 6 months, was extended on June 21st to May 31st 2017

Future activity

- RADIATION MONITOR DATA ANALYSIS
- TEST-MASS CHARGING IN LISA

FTE 2017

- Catia Grimani 100%
- Ruggero Stanga 0%
- Noemi Finetti 50%
- Monica Laurenza 20%
- Daniele Telloni 40%
- **FTE: 2.1**

Recent publications:

Grimani C. et al., CQG, 32, 035001 (14 pp), 2015
Grimani C. et al., J. Phys. Conf. Ser., 610, 012025 (5 pp), 2015
Grimani C. et al., MG14 Proc. Electron test-mass charging aboard the future space interferometers. Published online March 2016
Robot.icra.it:8080/store/1165.pdf
Armano M. et al., Ph. Rev. Lett., 116, 231101, 2016