The INTEGRAL satellite and the Fast Radio Bursts :

the case of the repeating FRB 121102

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A very brief history of the Fast Radio Burst FRB121102

- ✓ Discovery at Arecibo /PALFA survey, 2012 November 2 (Spitzer et al, 2014)
- ✓ Follow-up Arecibo 10 new bursts detected —> **FRB121102 is a repeating burst** (Spitler et al, 2016)
- ✓ Follow-up: Arecibo, Effelsberg, Green Bank telescope, Lowell telescope, VLA
  ➔ 6 more bursts (Scholz et al, 2016)

N=17 bursts

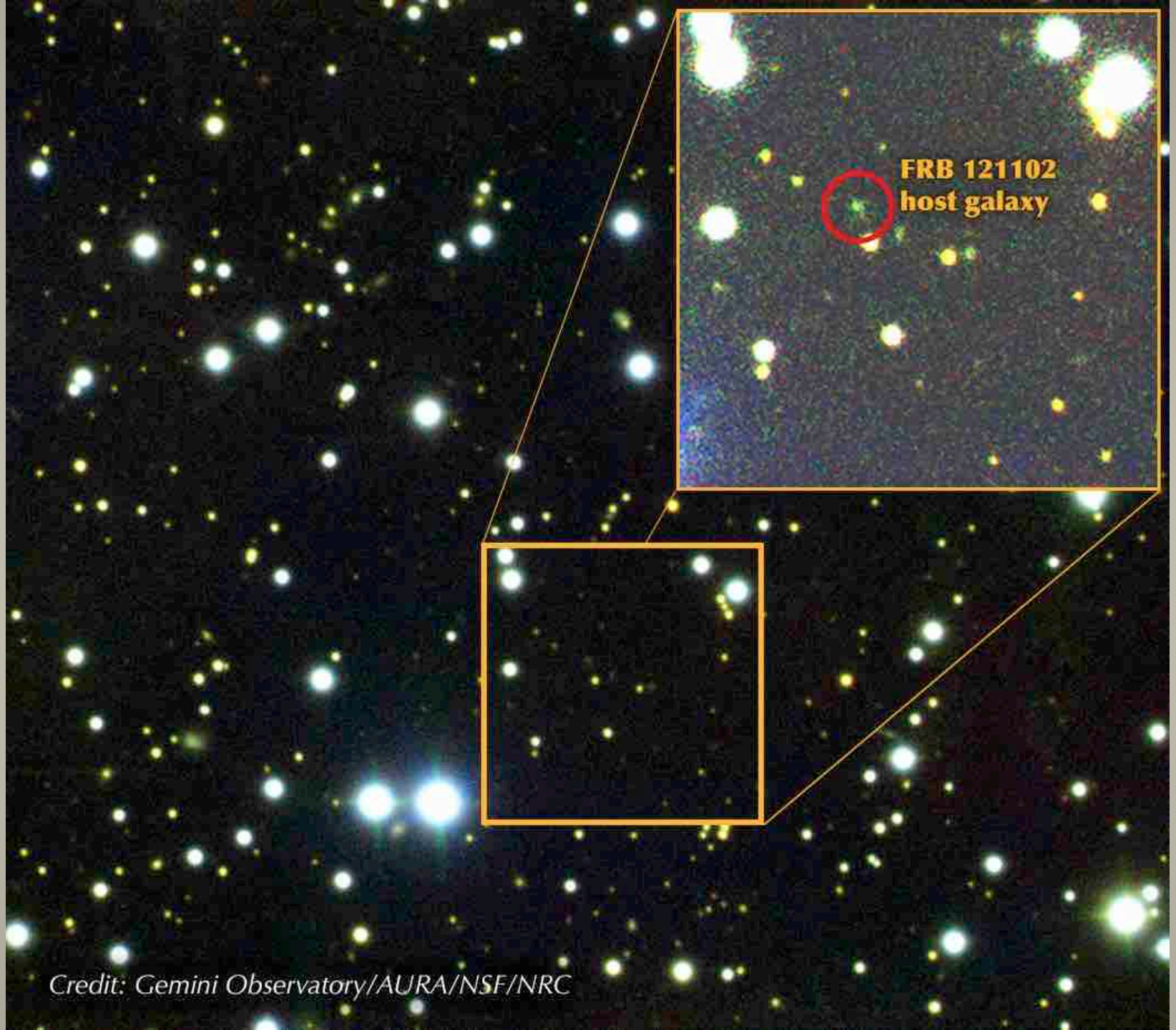
- ✓ VLA follow up: 83h distributed over 6 months ➔ 9 bursts detected in 2016
  + Optical identification of the host galaxy (Chatterjee et al, 2017)
  - accurate localization <100 mas
  - persistent radio and optical counterpart

N=26 bursts

✓ European VLBI networks + 305m-Arecibo telescope : detects both the bursts (4) and persistent radio emission at millisecond angular scale, persistent radio source less than 0.7 pc (Marcote at al, 2017)

N=30 bursts

✓ Gemini + GMOS Optical observation : low-metalicity dwarf galaxy at z=0.192, Persitent radio source offset by 200 mas from the galaxy's center
No optical signatures for AGN activity (Tendulkar et al, 2017)



Credit: Gemini Observatory/AURA/NSF/NRC

Many theoretical models proposed for FRB121102

- Collapses of supra-massive neutron star into black hole (Falcke et al, 2014, Zhang et al, 2014)
- Magnetar pulse-wind interactions (Lyubarsky, 2014)
- Charged black hole binary mergers (Zhang et al, 2016)
- Giant pulse emissions from pulsars (Cordes et al, 2016)
- Giant flares from magnetars (Katz at al, 2014, Kulkarni et al, 2014, Pen et al, 2015)
- Unipolar inductor model (Wang et al, 2016)
- Double neutron stars mergers (Totani et al, 2013)
- Encontering of many asteroids with a highly magnetised pulsar (Dai et al, 2016)
- Radio emissions from pulsar companions (Mottez et al, 2014)
- Magnetic energy release in magnetar magnetosphere (Katz J.I, 2016)
- …

Search for a counterpart/afterglow of FRB's in lambda ≠ radio

- Important to look for afterglow : see B. Zhang's talk on Tuesday for GW but same arguments remain valid for FRB's

- Several models predict extended gamma-ray emission (Murase et al, 2017)

- Search for the host galaxy when possible (precision of the localisation)

- A possible afterglow detected by Swift/BAT from FRB131104 (Delaunay et al, 2016)

HTRA : High Time Resolution Astrophysics
(Andy Shearer, CG)

Effort to promote sub-second Astrophysics in science and instrumentation (mainly in optical)

- magnetars, pulsars and neutron stars
- black hole binary systems
- white dwarf binary systems
- gamma ray bursts and supernovae
- normal stars - stellar oscillations
- solar system objects through transits and occultations
  - Planets and satellites
  - Kuiper belt objects

- Fast radio bursts

Shearer et al, 2010 , White paper on HTRA

INTEGRAL and FRB's : Search for a counterpart

- ✓ Right time to do it : hot topic, scientific interests, Integral still in operation
- ✓ New facilities : LOFAR, NICER, FAST, …
- ✓ Expertise in optical/radio/high energy (scientific and instrumentation)
- ✓ Oportunity for a large collaboration involving different communities
- ✓ Good exercise/experience for the SVOM mission (preparation of coordinated observational campaign)
- ✓ First step toward a SVOM/FAST/NAOC Observatory joint program ?
- ✓ ....

In the following, we will focus on FRB121102

A few words on the INTEGRAL mission

INTEGRAL (International Gamma-ray Astrophysics Laboratory)

- Launched 17th October 2002

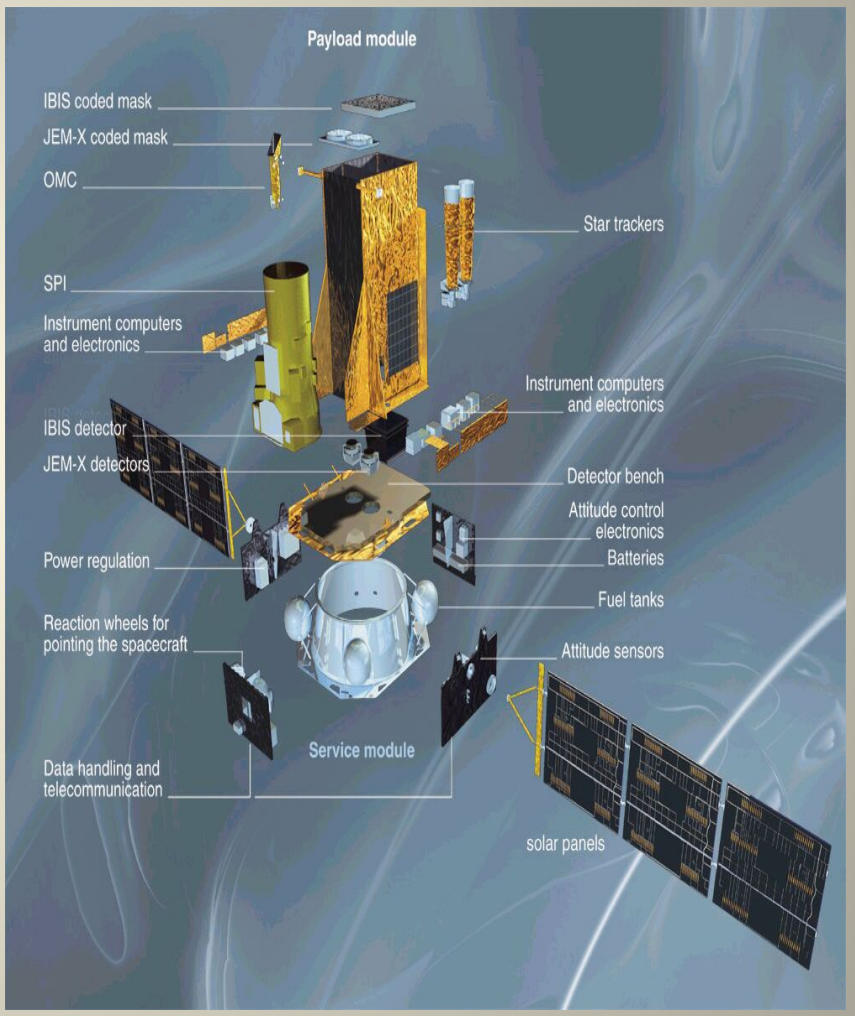
- Operational lifetime: 10+ years
  (at least December 2018)

- 4 Science Instruments:

  - SPI (Spectrometer on Integral)
  - IBIS (Imager onboard Integral Satellite)
  - JEM-X (Joint European X-ray Monitor)
  - OMC (Optical Monitoring Camera)

- Scientific Cases:

  - AGN & Black Holes
  - X-ray Binaries
  - Neutron Stars
  - Gamma-ray Bursts
  - Galactic Centre & Nucleosynthesis



INTEGRAL Scientific payload

Satellite
4.1 tons
5 m height
3.7 m diameter
16 m solar pannels

OMC (optical)

JEM-X

IBIS
15 keV – 10 MeV
12′ FWHM imaging
<1′ source location
19°x19° FOV

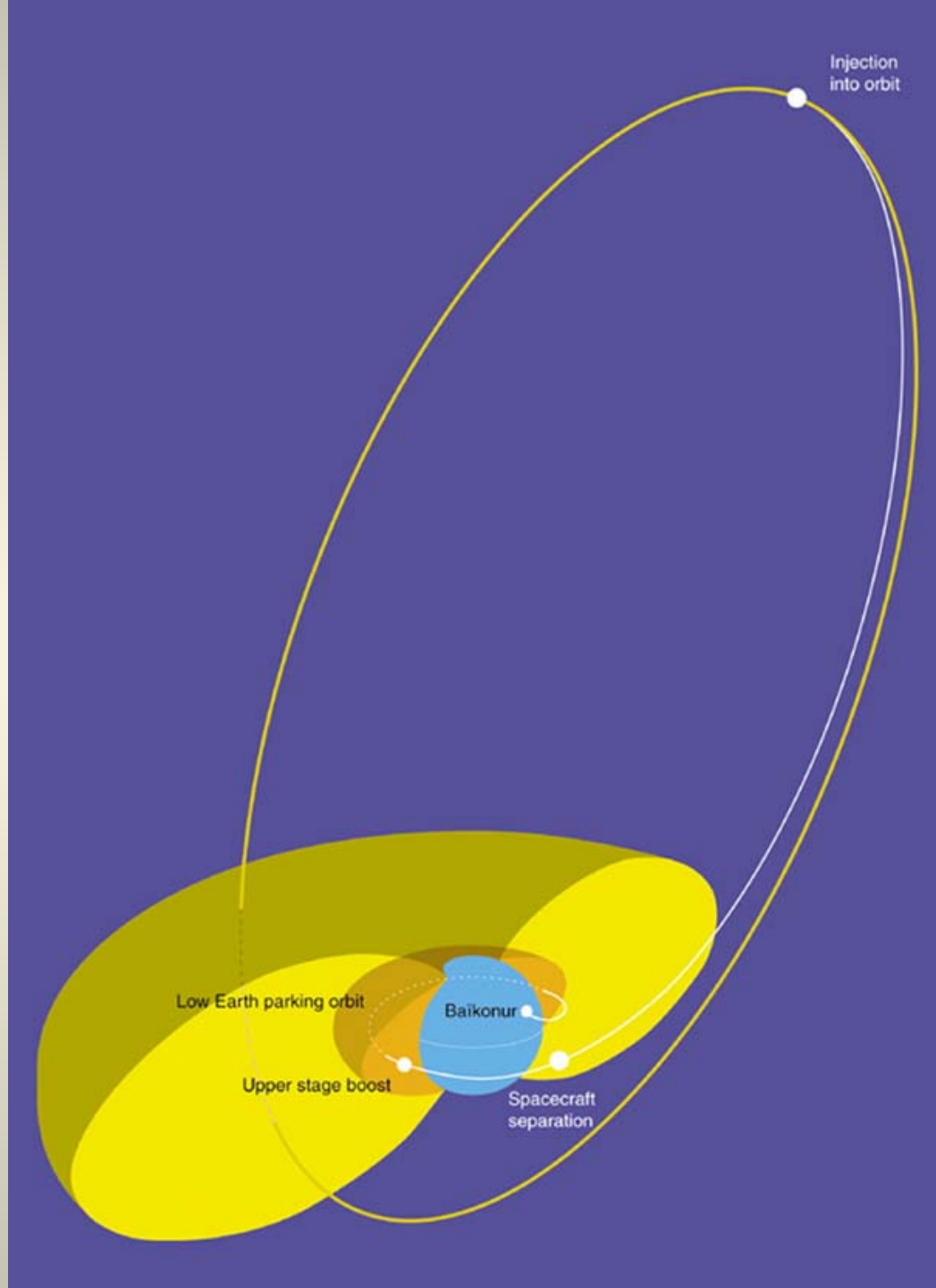
ISDC

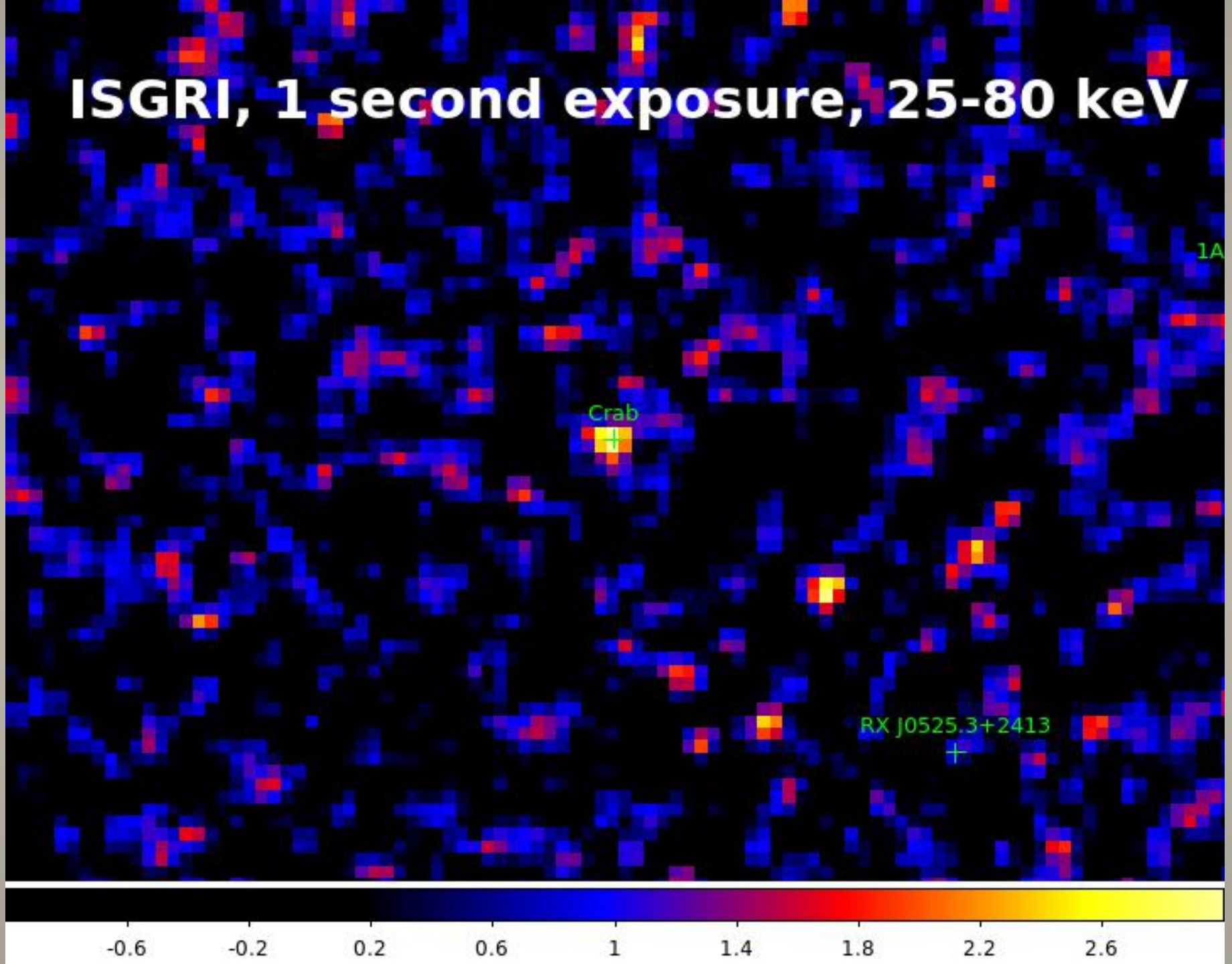
Spectrometer for Integral
20 keV – 8 MeV
2 keV FWHM
26° Ø FOV

Highly elliptical orbit

<u>from launch to early 2015:</u>
inclinaison 56 degrés
périgée 9000km , apogée 150000km
72 heures (90% utile)

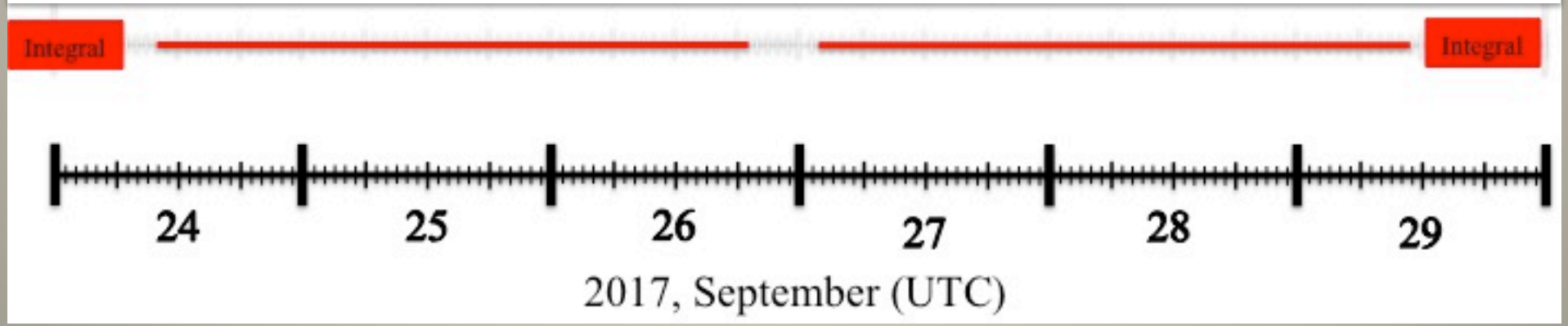
<u>Since 2015</u> :
64-hour duration, i.e., 3 revolutions in 8 days
(orbit modified to assure a safe disposal of the satellite in early 2029)




ISGRI, 1 second exposure, 25-80 keV
1A
Crab
RX J0525.3+2413
-0.6
-0.2
0.2
0.6
1
1.4
1.8
2.2
2.6

A exploratory program but proposal accepted

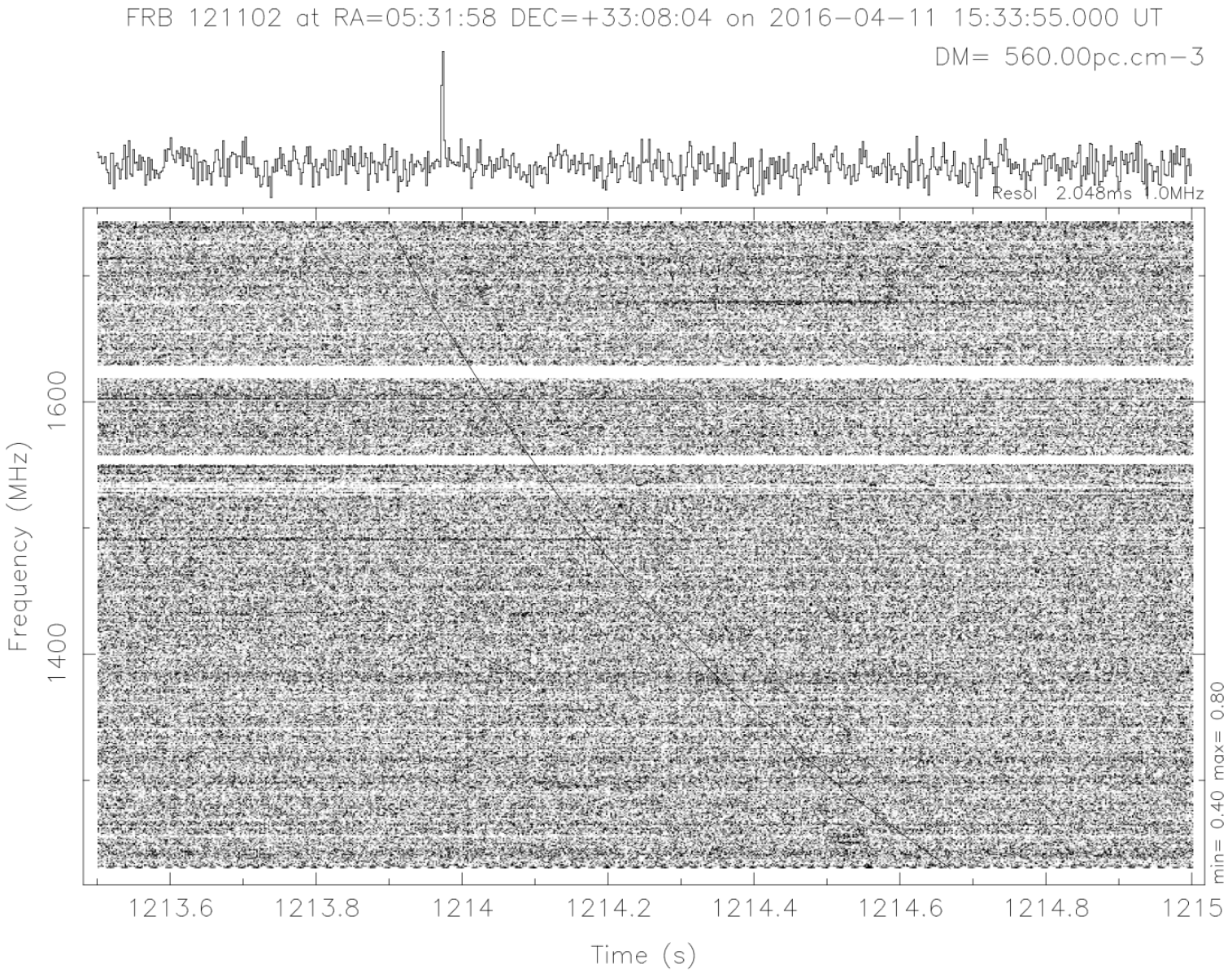
INTEGRAL observation of FRB 121102
2017, September 24-29



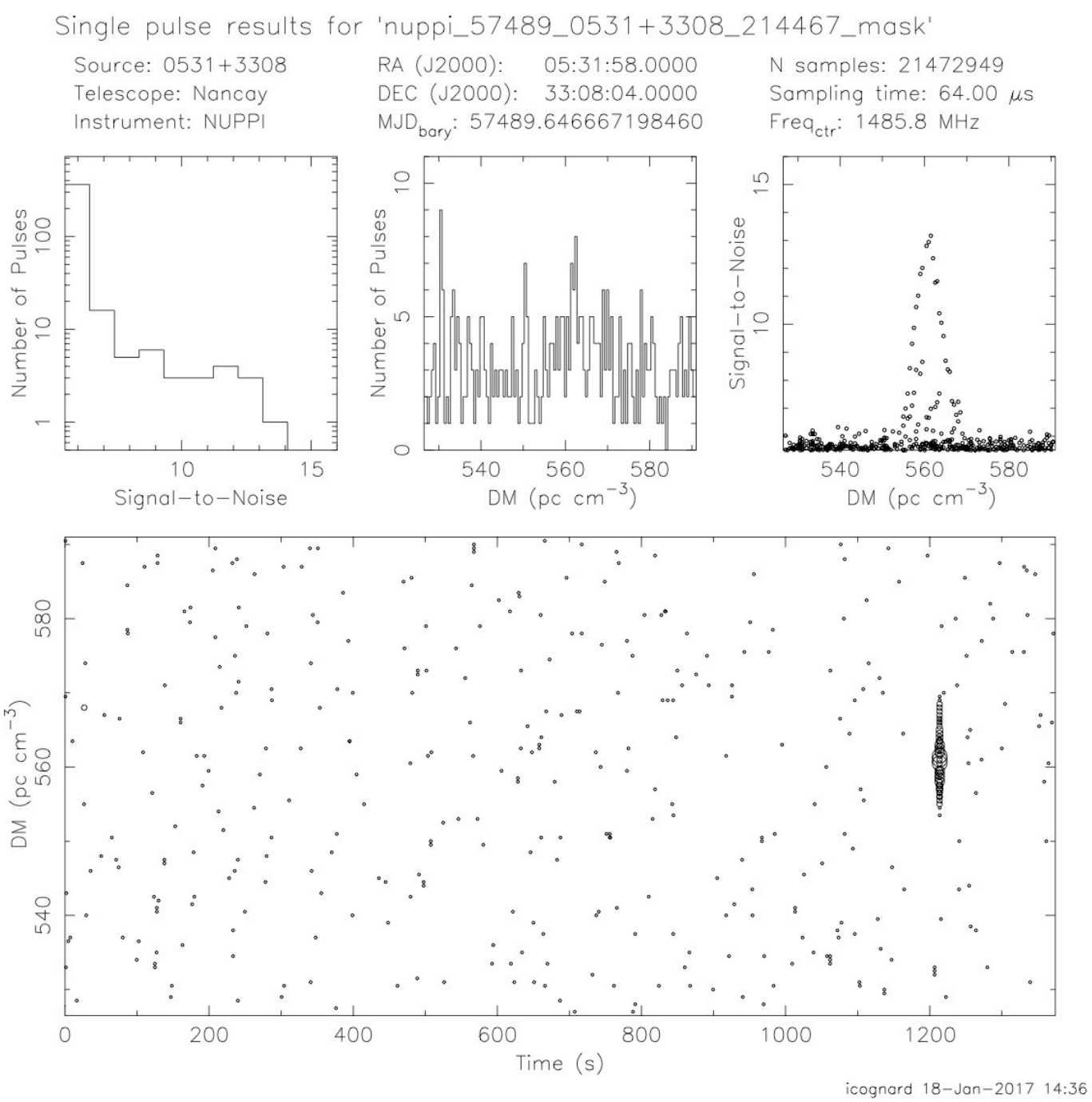
FRB = Fast Radio Burst

NRT : Nançay Radio Telescope, France

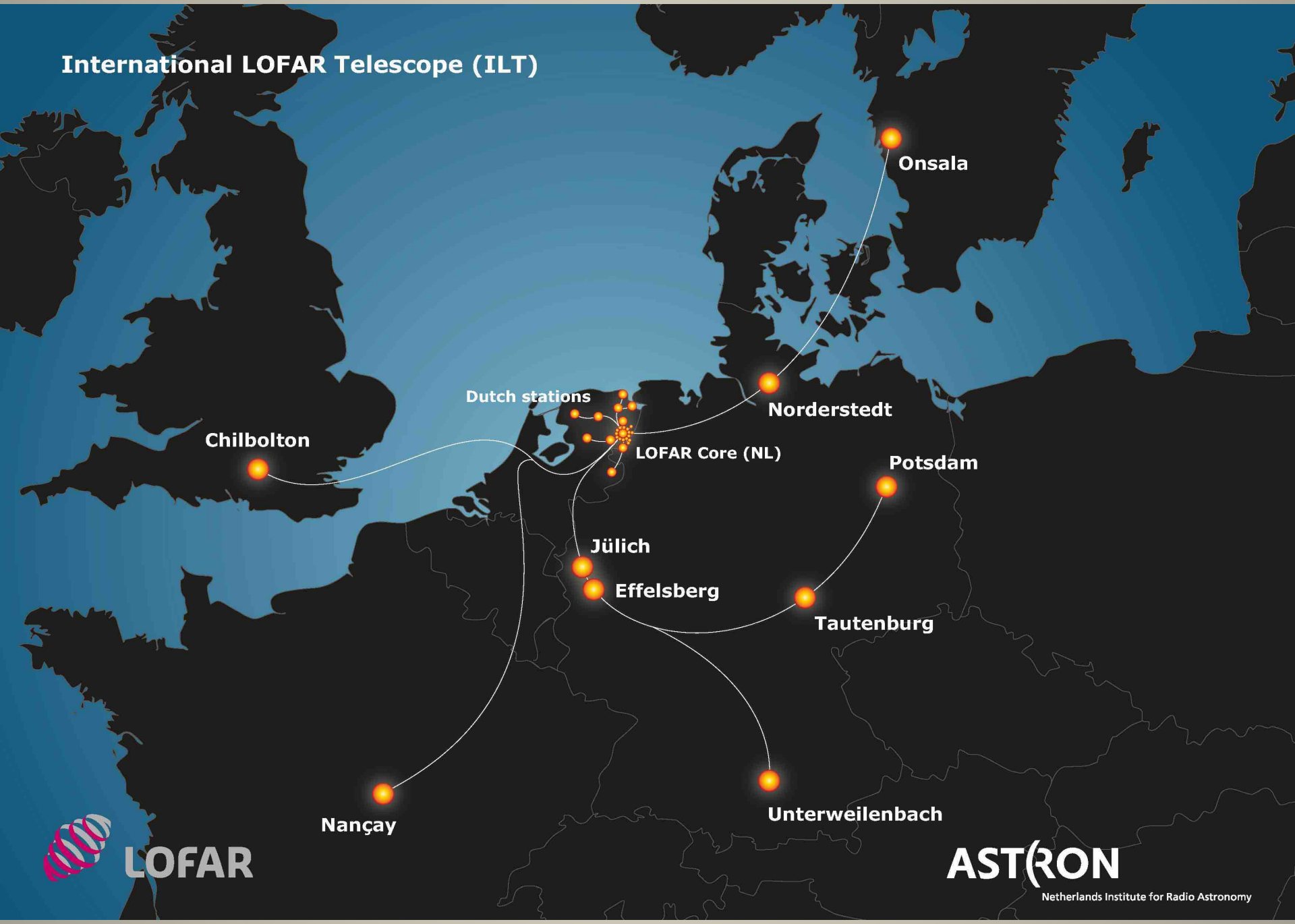
- Adjustable plane mirror (200 m x 40 m)
- spherical mirror (300 m x 35 m)
- Frequencies : 1,060 to 3,500 GHz



I. Cognard, private com.



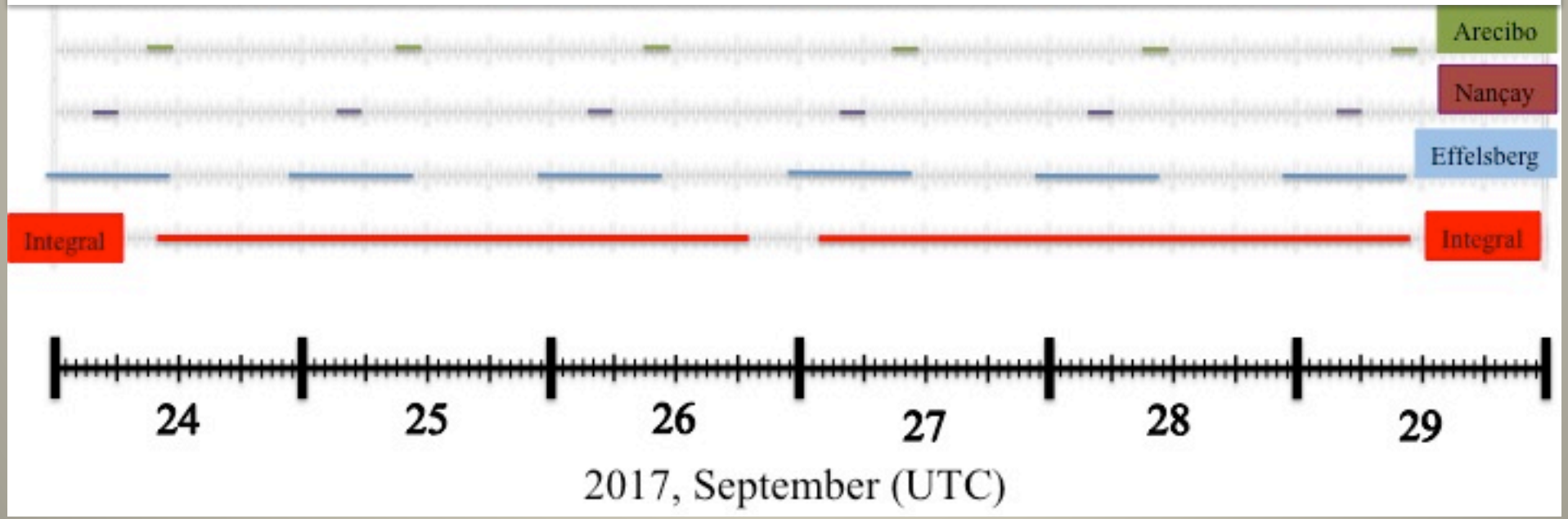
I. Cognard, private com.


International LOFAR Telescope (ILT)
Onsala
Dutch stations
Norderstedt
Chilbolton
LOFAR Core (NL)
Potsdam
Jülich
Effelsberg
Tautenburg
Nançay
Unterweilenbach
LOFAR
ASTRON
Netherlands Institute for Radio Astronomy

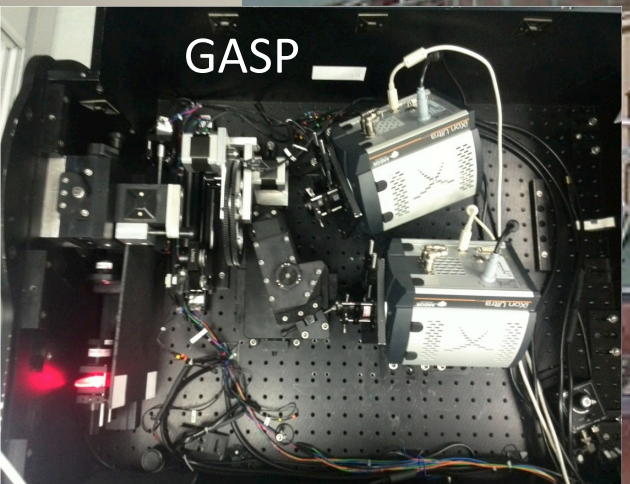

Effelsberg telescope , Germany

Arecibo telescope

INTEGRAL observation of FRB 121102
In Fall 2017 + radio friends

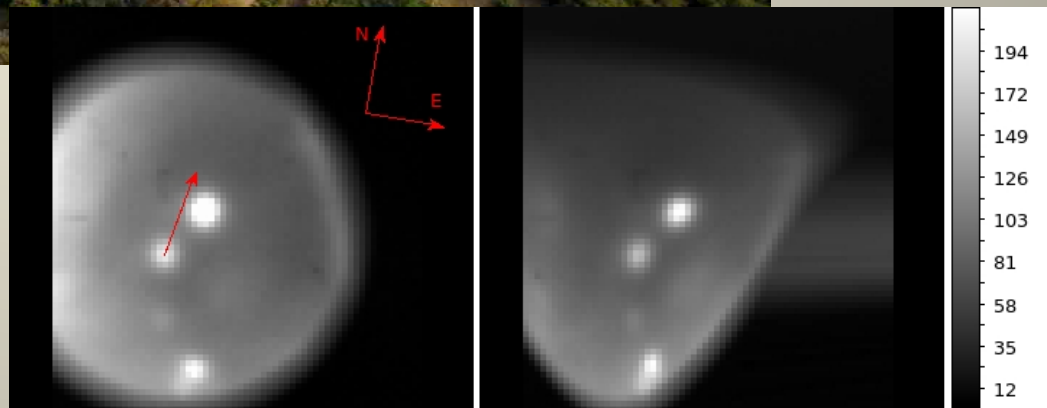


T193cm
Observatoire de Haute Provence (OHP), France

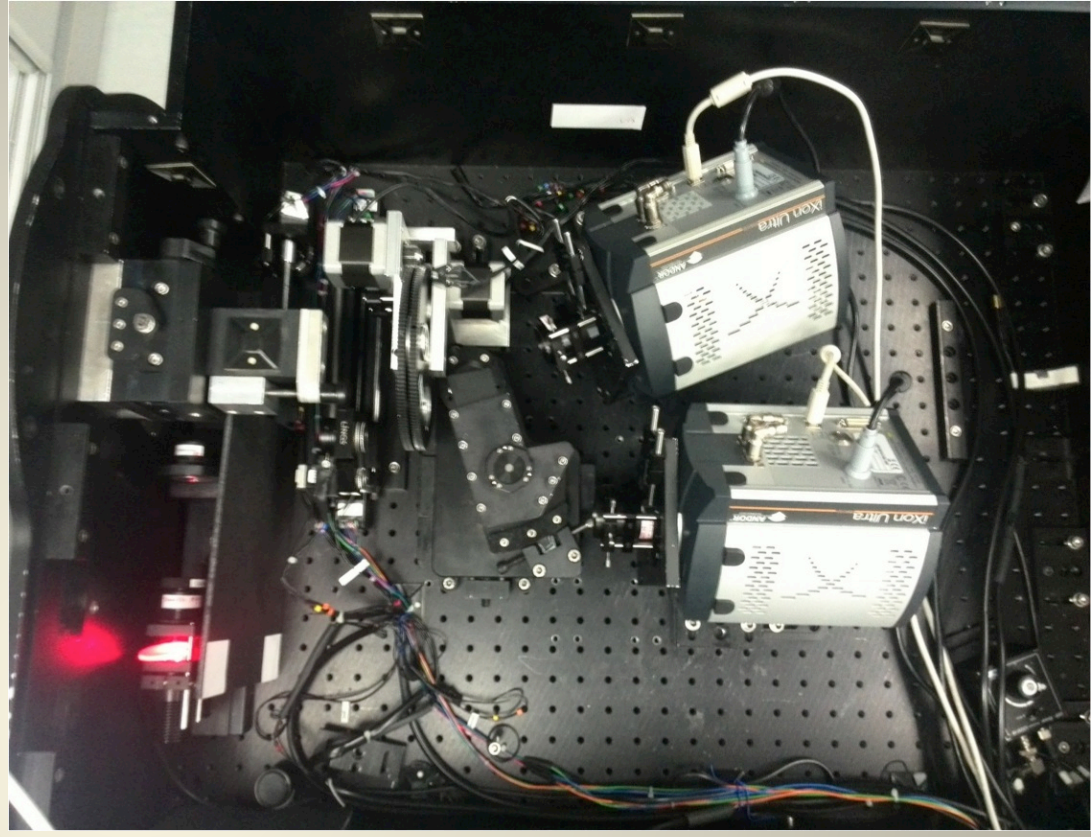


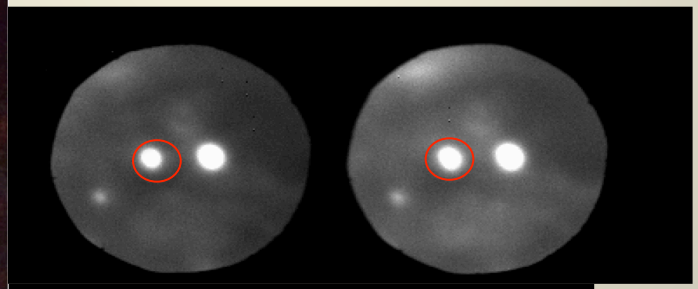
GASP = Galway Astronomical Stokes Polarimeter (GASP)
high-speed (sub-msec) , full Stokes, astronomical imaging polarimeter
Studies of extremely rapid stochastic (~ms) variations in objects such as optical pulsars, RRATs, magnetic cataclysmic variables and brown dwarfs.

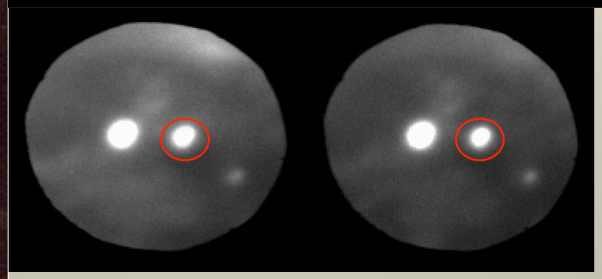

T120cm
Observatoire de Haute Provence (OHP), France



Palomar+GASP, 2012





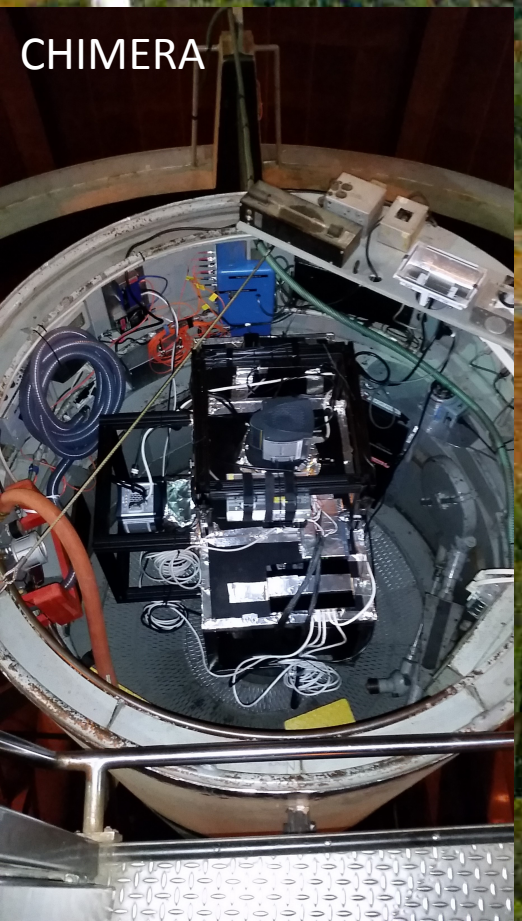


GASP at WHT

CHIMERA : Caltech HIgh-speed Multi-color camERA

Palomar 200 ’’ Telescope

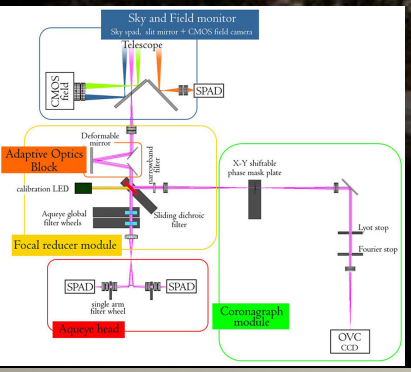
PI : Gregg Hallinan (Caltech)



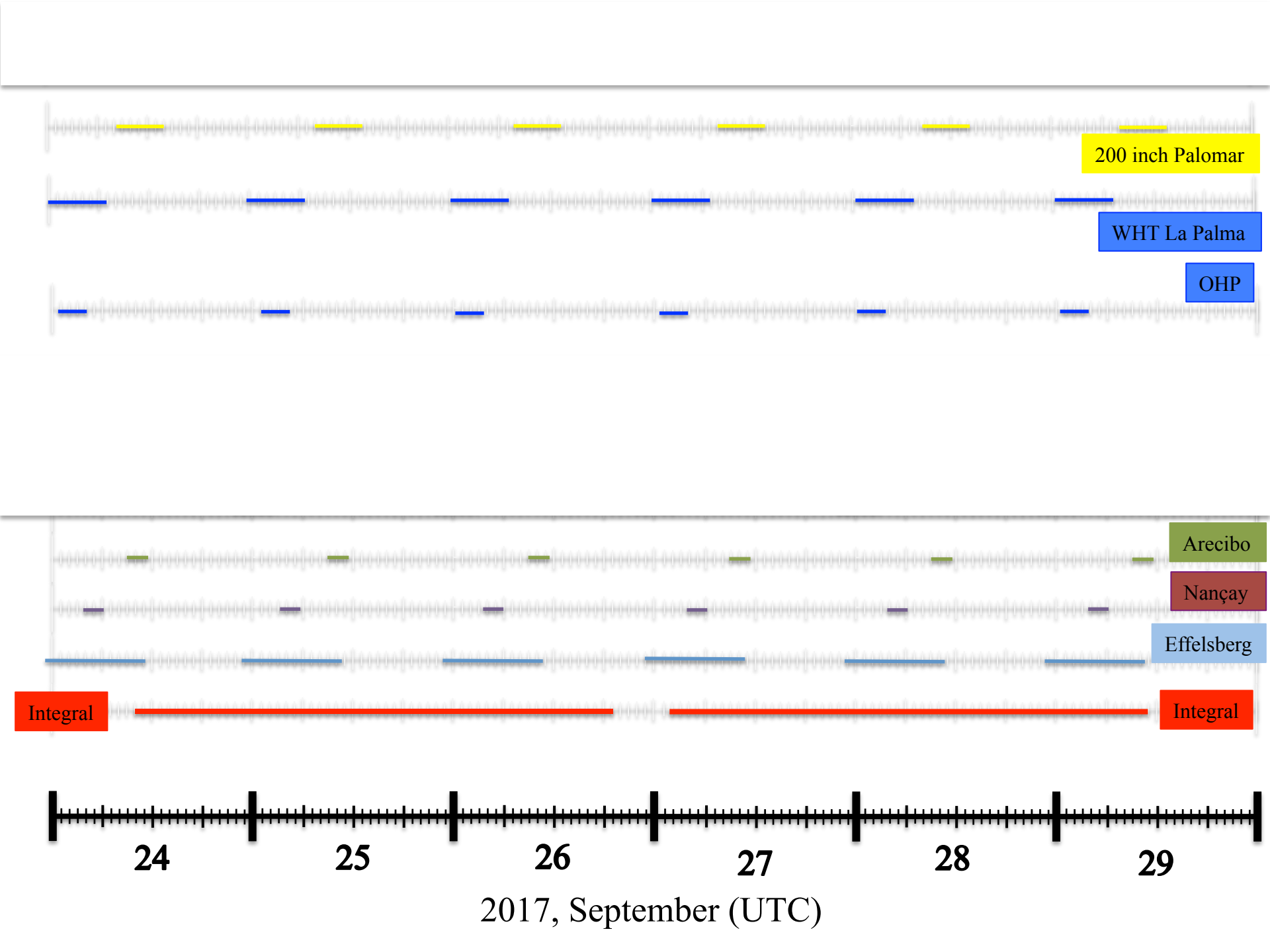
CHIMERA

Parameters	Blue Camera	Red Camera
Pixel Scale	0.28"/pix	0.28"/pix
Field of View (FOV)	5' x 5'	5' x 5'
Filters	Sloan g' and u'	Sloan r', i' and z'
Detector Noise	~6e- using the conventional amplifier (at 1 MHz readout rate) < 1e- effective read noise using the EM amplifier with EM gain applied	~6e- using the conventional amplifier (at 1 MHz readout rate) < 1e- effective read noise using the EM amplifier with EM gain applied
Frame Rate	8.7 frames/sec 1kx1k 17.4 frames/sec binned 2x2 up to 1000 frames/sec windowed	8.7 frames/sec 1kx1k 17.4 frames/sec binned 2x2 up to 1000 frames/sec windowed

Asiago + Aqueye



L.C.


200 inch Palomar
WHT La Palma
OHP
Arecibo
Nançay
Effelsberg
Integral
Integral
24
25
26
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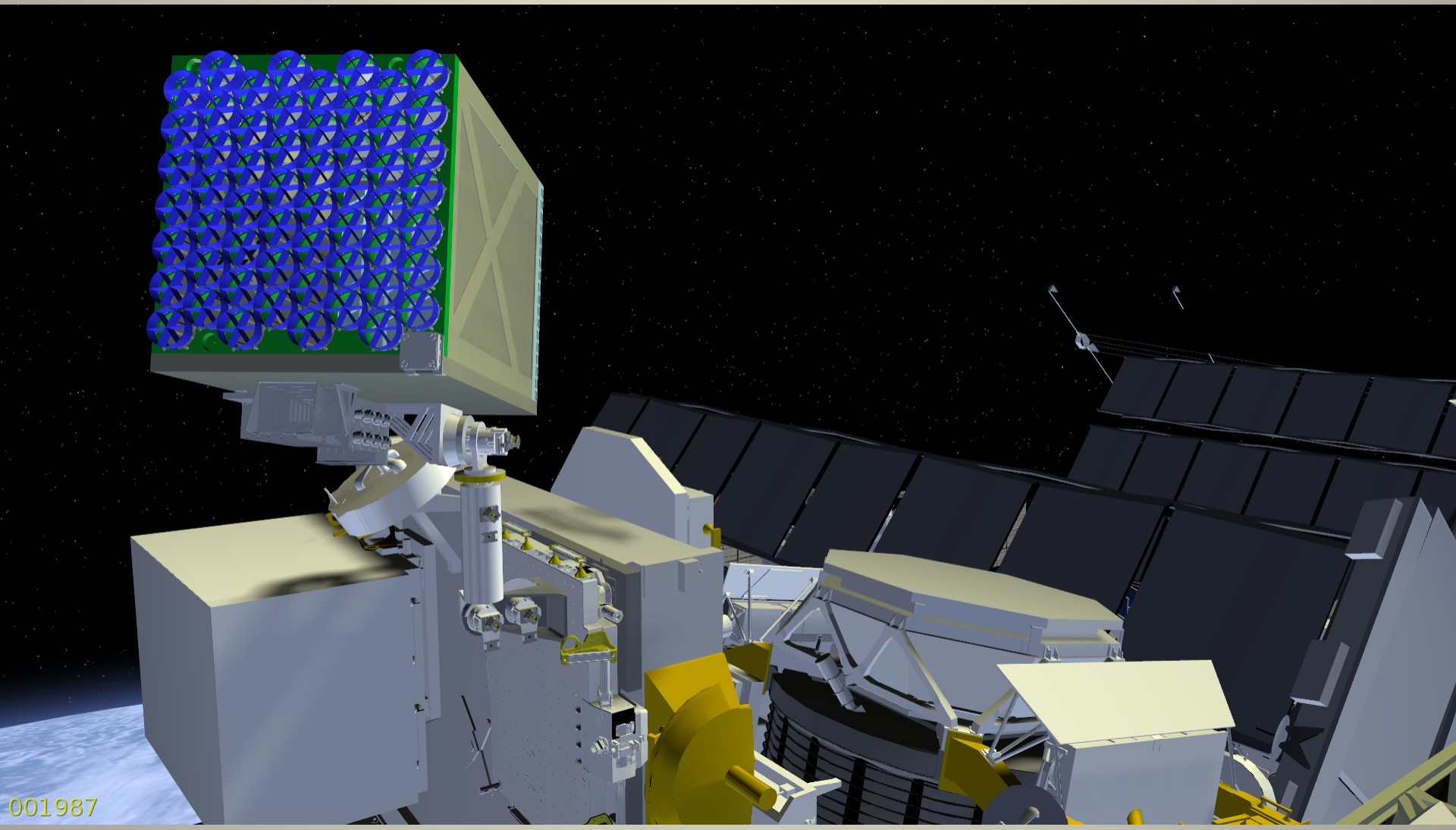
2017, September (UTC)

NICER: Neutron star Interior Composition ExploreR Mission

NASA mission of opportunity, on ISS,

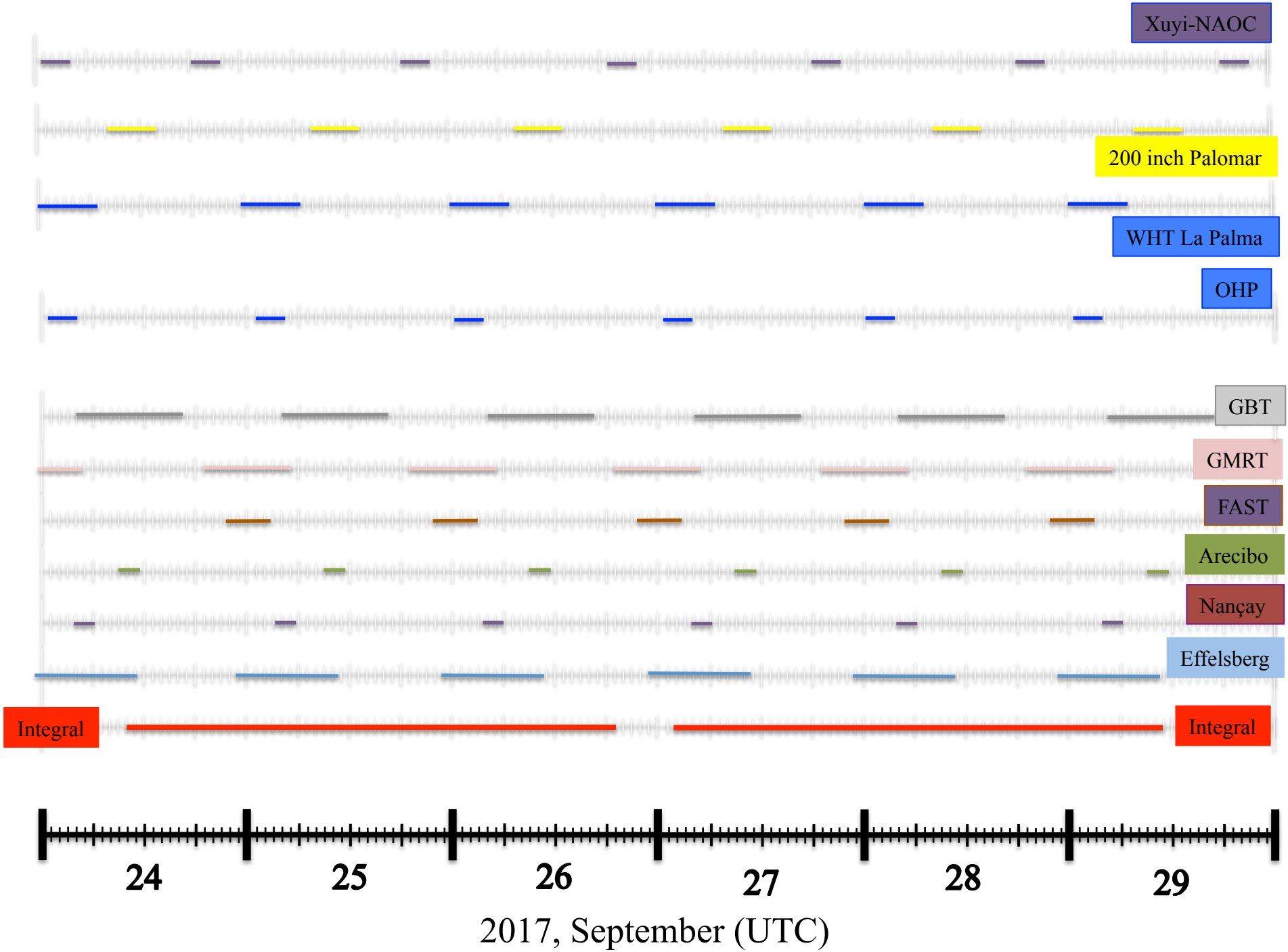
Expected launch (SpaceX-11) : 14 May, 2017



56 soft X-rays telescopes (0.2-12 keV), exquisite time resolution

+ in Radio: FAST, encouraging contact.

+ in Optical : Xuyi Station, PMO (see Dong's talk on Monday)


Xuyi-NAOC
200 inch Palomar
WHT La Palma
OHP
GBT
GMRT
FAST
Arecibo
Nançay
Effelsberg
Integral
Integral
24
25
26
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2017, September (UTC)

FRB's and SVOM

- ✓ In 2020+ more FRBs detected : on-going program, new instrumentations
- ✓ In 2020+ SKA will start operation
- ✓ In 2020+ new facilities in optical as LSST and wide field survey machines

- ➢ Many similarities with GRB's studies
- ➢ Appropriate muti-lamda instruments for FRB's follow-up
- ➢ Good link/relation with FRB (radio) community required : should start today
- ➢ Repeating FRB's : great potential
- ➢ For repeating FRB's clustering of the events (might be a key point for follow-up : 10-20 min for FRB121102
- ➢ Strategies should be carefully studied: ToO ? Etc
- ➢ INTEGRAL feedback might be useful

Conclusion/Thoughts

- ✓ An (very) exploratory program but :

"…FRB's is today at the front-line of several fields, from cosmology to physics of compact objects, from theory to multiwavelength observations. Putting together specialists with different expertise, this Integral proposal aims to contribute to their study and participate to this new field that in some respect shows similarities with the birth of the GRB's saga. "

- ✓ For more info on the INTEGRAL campaign, please contact me

- ✓ For results, please come to **the *3nd SVOM scientific workshop in 2018***