Fast Radio Bursts
et
campagnes d'observation de FRB121102

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A. Shearer, E. O'Connor – NUI Galway
M. Dennefeld, IAP
V. Savchenko, ISDC
+ ….

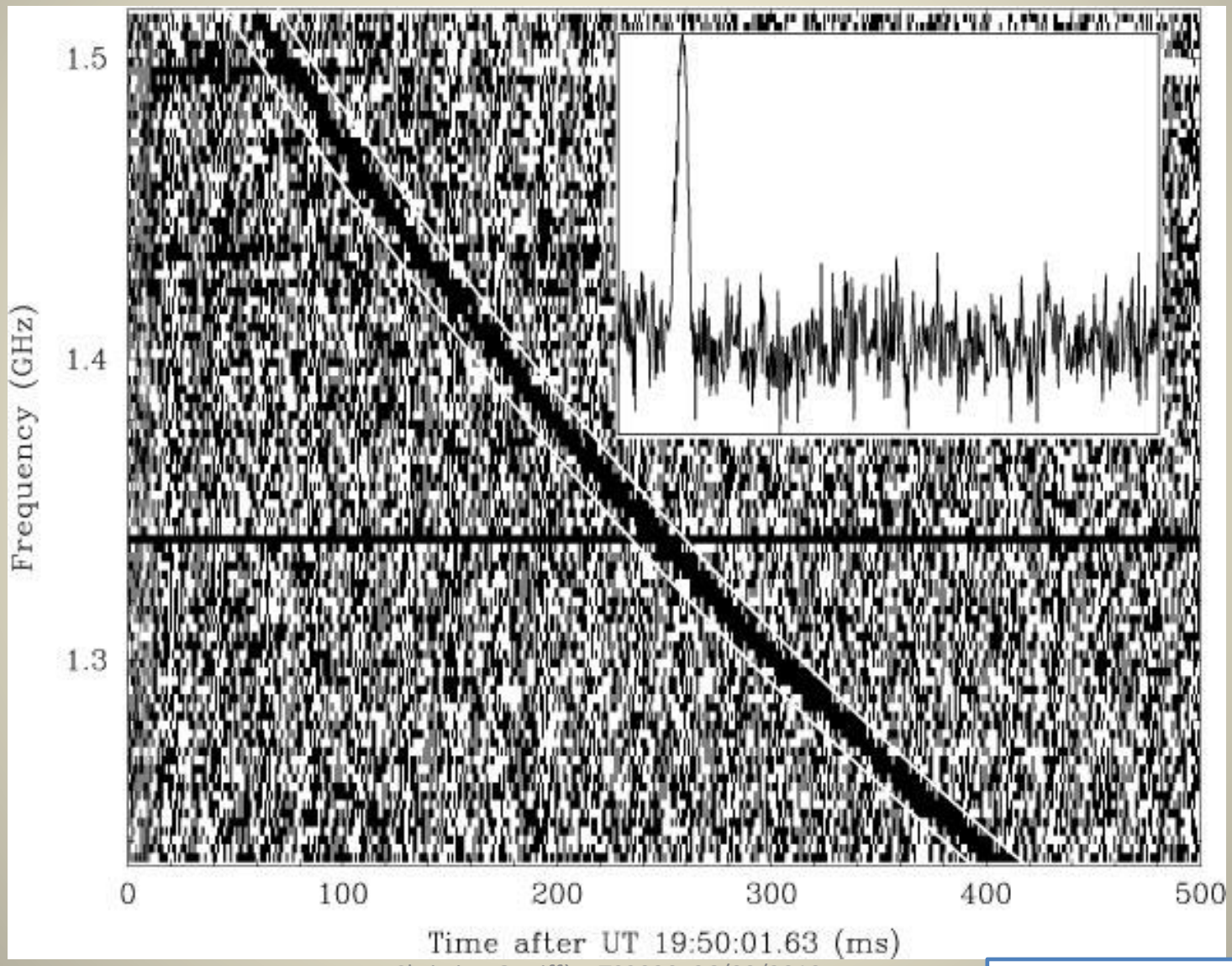
PNHE Programme national hautes énergies

PNCG Programme National de Cosmologie et Galaxies

Outline :

- ✓ “Very brief Introduction” to Fast Radio Bursts
- ✓ FRB121102, a special and unique target for years
- ✓ Search for a counterpart to FRB121102 , the INTEGRAL programme
- ✓ The host galaxies programme

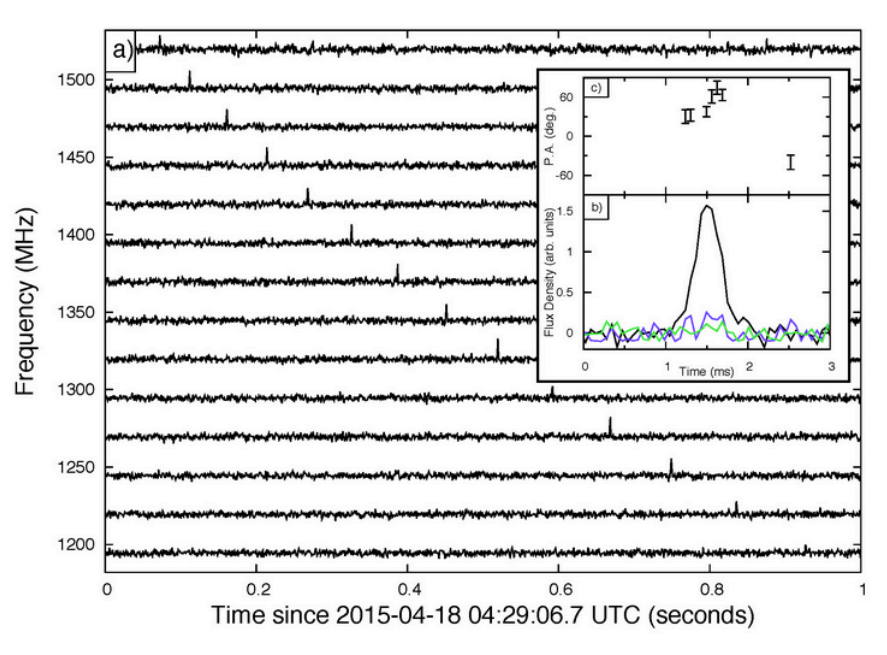
Fast Radio burst was discovered in 2007 by Duncan Lorimer during a Parkes LMC archive search – 2001 - programme forlooking to fast/very fast variable objects :
Remarks : D. L. expert in radio pulsars science

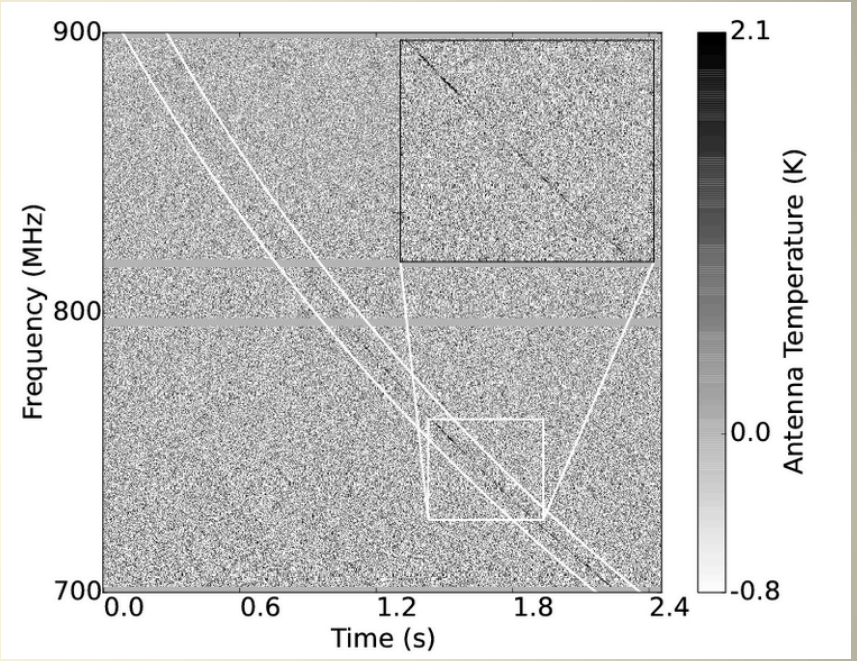


The « Lorimer » burst

Fast Radio Bursts:

- Discovered in 2007 (Lorimer burst)
- Bright, short radio pulses
- High dispersion measure (DM) -> Extragalactic origin
- Cataclysmic event ?

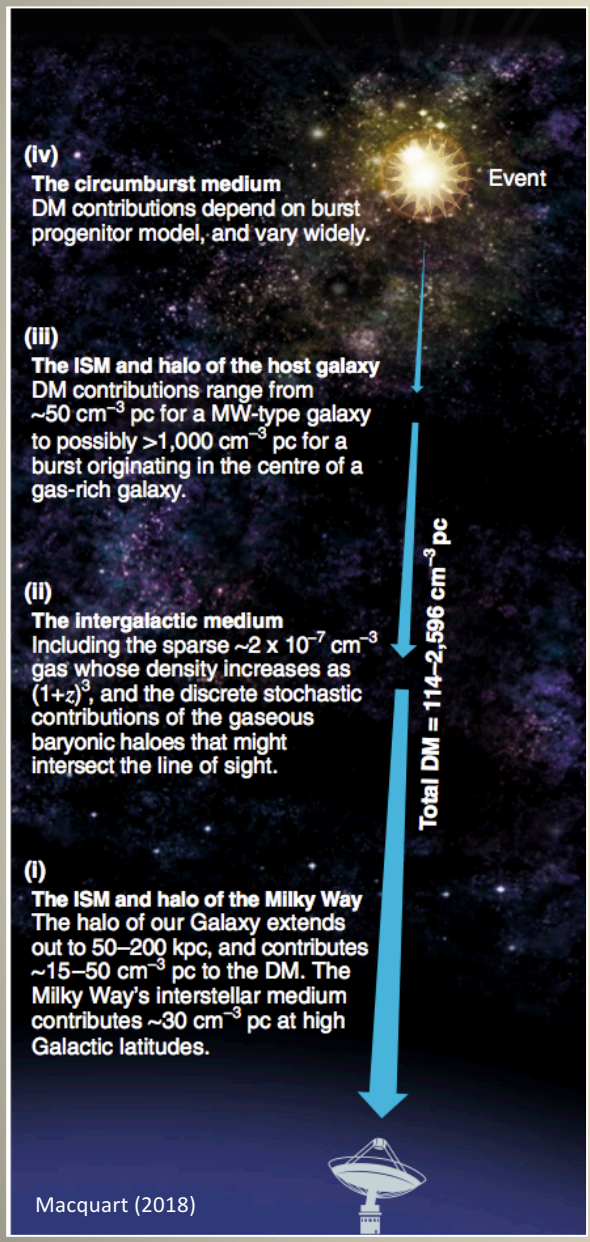




- Radiations propagating through an ionized medium disperse FRB pulses and delay the arrival time

$$\mathrm{DM} = \int_0^D n_\mathrm{e} dl$$

$$t_1 - t_2 = 4.16 \times 10^6 \ \mathrm{DM} \left[\frac{1}{\nu^2_{1,\mathrm{GHz}}} - \frac{1}{\nu^2_{2,\mathrm{GHz}}} \right] \mathrm{ms}$$



$$DM_{tot} = DM_{MW} + DM_{IGM} + DM_{HG} + DM_{circum}$$

- DM_{MW} ~ 30 cm^{-3} pc at Galactic latitudes |b| > 30deg

  (possible extra contribution of ~15-50 cm^{-3} pc from the Galactic Halo)

- DM_{HG} : ~ 50 cm^{-3} pc from the ISM of the host galaxy, possibly up to ~1000 cm^{-3} pc if occurring in dense gaseous regions from the inner parsecs of the host

- DM_{circum} : very hard to constrain (progenitor dependent)

DM_{tot} ~ 100 – 2500 cm^{-3} pc

→ DM_{IGM} is largely dominant
→ DM_{IGM} indicates distance (assuming homogeneous IGM distribution)
→ If known z, DM_{IGM} constrains IGM baryons

Major progress recently thanks to new wide field networks/telescopes


Effelsberg telescope

Without forgetting other very active facilities

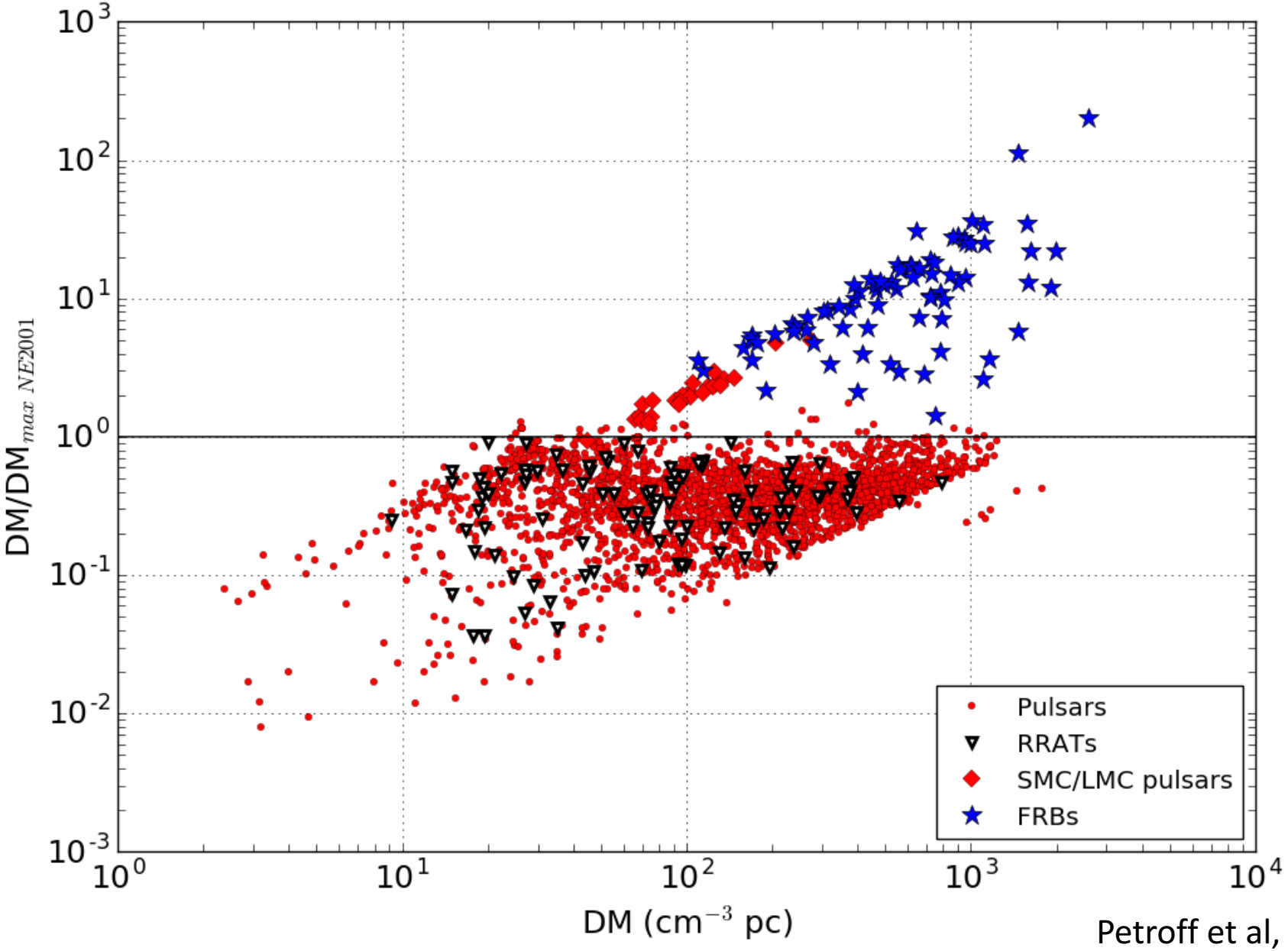

Arecibo telescope


FAST


GBT


NRT : Nançay Radio Telescope

J.-P. Letourneur, CRDP Orléans



Petroff et al, 2019

FRB Catalogue

90 FRBs on 2019, Sept, 25th

This catalogue contains up to date information for the published population of Fast Radio Bursts (FRBs). This site is maintained by the FRBCAT team and is updated as new sources are published or refined numbers become available. Sources can now be added to the FRBCAT automatically via the VOEvent Network, details of this process are given in Petroff et al., 2017. FRBs confirmed via publication, received with a high importance score (>0.95) over the VOEvent Network, or with a high confidence value defined explicitly in an Astronomer's Telegram are given 'Verified' status and are shown on the default homepage; to see all events (including unverified candidates received via the VOEvent Network or ATel system) toggle the "Verified events/All events" button below. As refined and peer-reviewed confirmation of FRB detections are received they will be moved to the Verified category.

Information for each burst is divided into two categories: observed parameters from the available data, and derived parameters produced using a model. Cosmological values are obtained using the Cosmology Calculator (Wright, 2006). The observed parameters are sometimes either lower or upper limits, due to the limitations of the data acquisition systems. Where multiple fits or measurements of a burst have been made each one is provided as a separate sub-entry for the FRB.

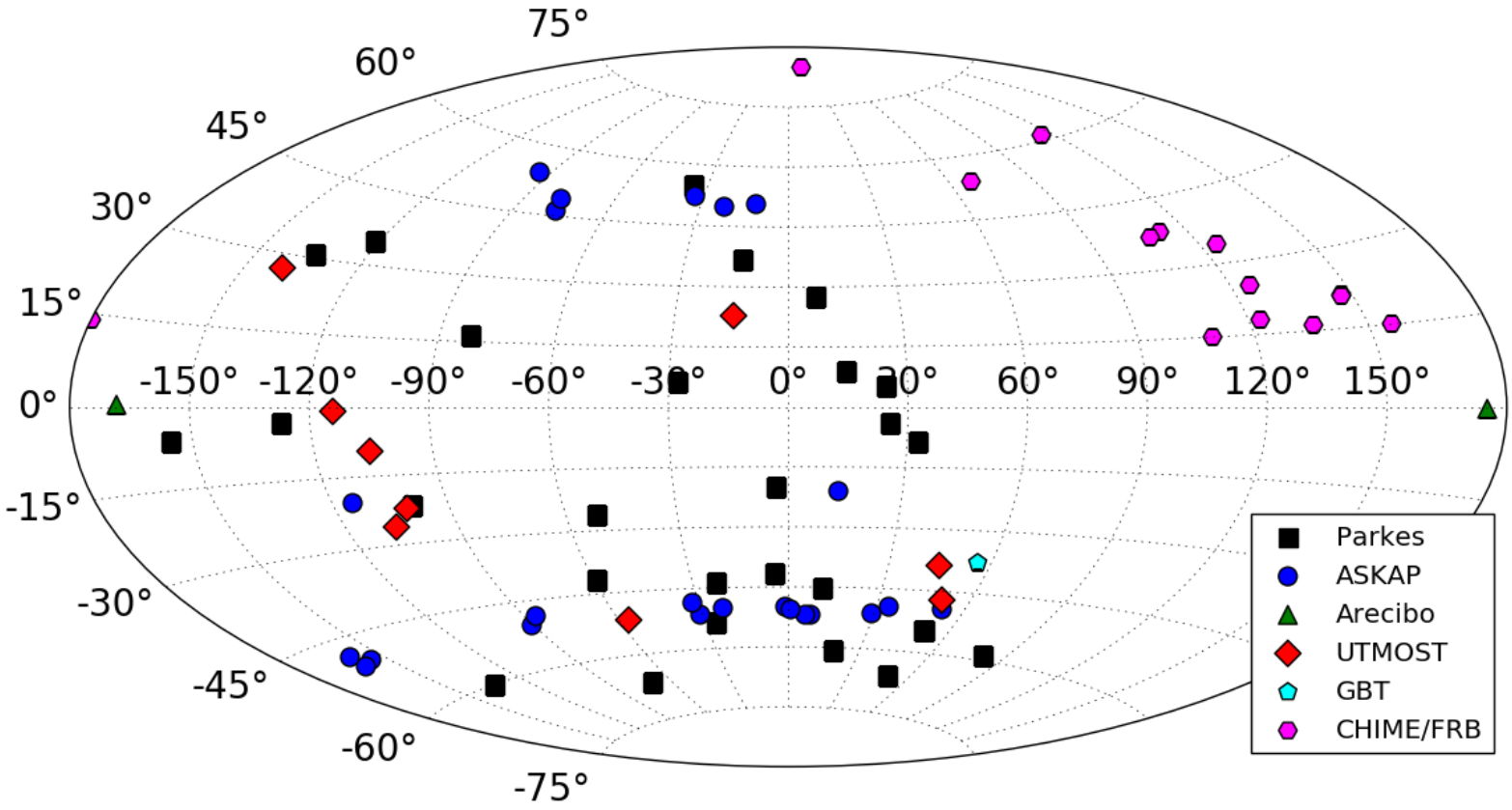
You may use the data presented in this catalogue for publications; however, we ask that you cite the paper (Petroff et al., 2016) and provide the url (http://www.frbcat.org). Any issues relating to the use of the catalogue should be addressed to FRBCAT team (primary contact: Emily Petroff).

The most recent version of the catalogue database and previous versions are available in CSV format on Zenodo at the DOI: http://www.frbcat.org/frbcat.csv

Visible columns | Verified events | Export to CSV | Search | Clear

	FRB	UTC	Telescope	RAJ	DECJ	gl	gb	DM	Width	S/N
+	FRB190523	2019/05/23 06:05:55.815	DSA-10	13:48:15.6	+72:28:11	117.03	44	760.8±0.6	0.42	11.5
+	FRB190222.J...	2019/02/22 18:46:01.367	CHIME/FRB	20:52	69:50	104.9	15.9	460.6±0.1	2.97	0
+	FRB190209.J...	2019/02/09 08:20:20.977	CHIME/FRB	09:37	77:40	134.2	34.8	424.6±0.6	3.7	0
+	FRB190116.J...	2019/01/16 13:07:33.833	CHIME/FRB	12:49	27:09	210.5	89.5	444±0.6	4	0
+	FRB181228	2018/12/28 13:48:50.100	UTMOST	06:09:23.64	-45:58:02.4	253.3915	-26.0633	354.2±0.9	1.24	12
+	FRB181128.J...	2018/11/28	CHIME/FRB	04:56	63:23	146.6				

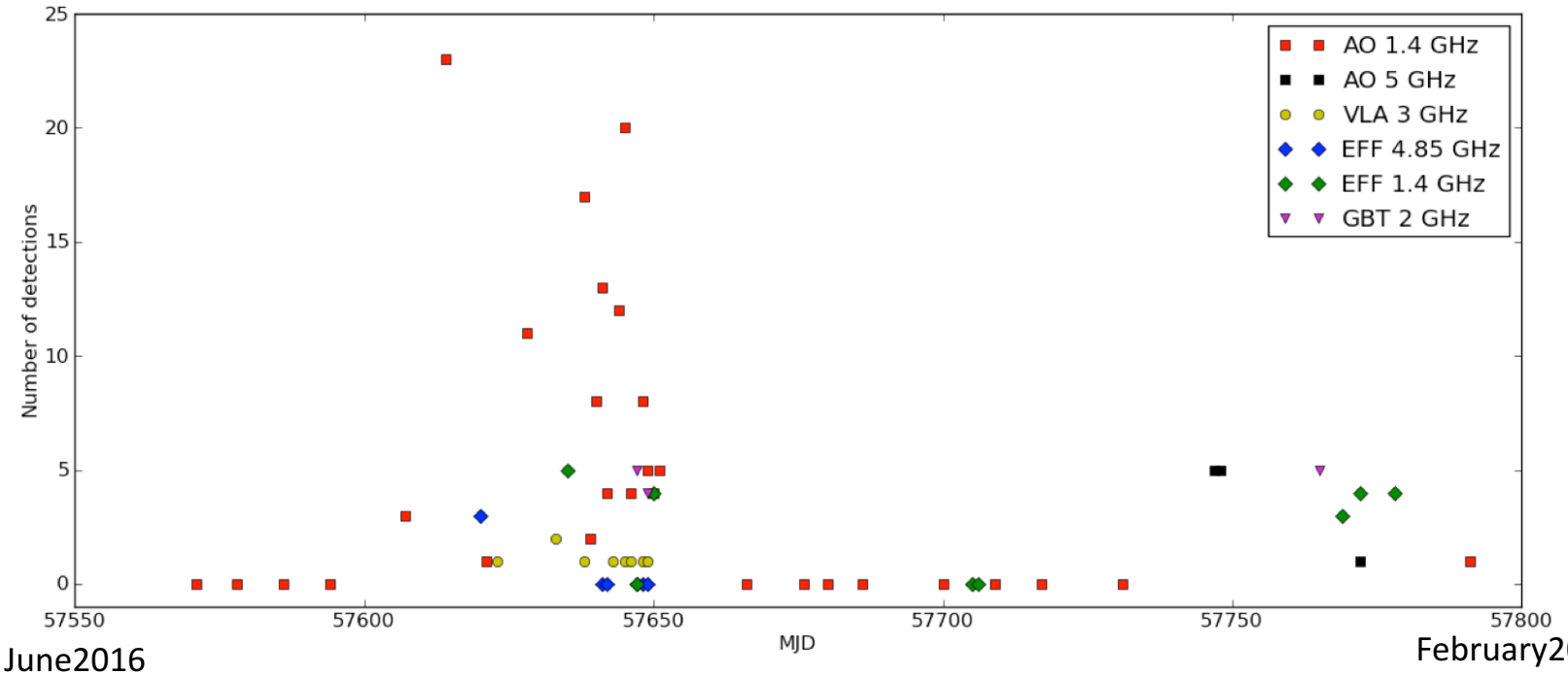
http://www.frbcat.org (Petroff et al, 2016)



2 class of FRB's : repeating and not repeating (often referred as cataclysmic event)

Petroff et al, 2019

FRB121102, the first repeating FRB



June2016

February2017

(Spitler, private com.)

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)

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)
- Extreme environment : "An extreme magneto-ionic environment associated with fast radio burst source FRB121102.', Michilli et al, *Nature*, January 11th, 2018 : Polarization (nearly 100%) → emission close to a massive black hole or within a very powerful nebula
- …

Several arguments to search for a counterpart/afterglow of FRB's in lambda ≠ radio

- Important to look for afterglow
- Several models predict extended gamma-ray emission (Murase et al, 2017)
- Search for the host galaxy when possible (precision of the localization)
- A possible afterglow detected by Swift/BAT from FRB131104 (Delaunay et al, 2016)

The 2017 Campaign

Two orbits allocated late September 2017, multi-lamda campaign organized

Several facilities involved
BUT….

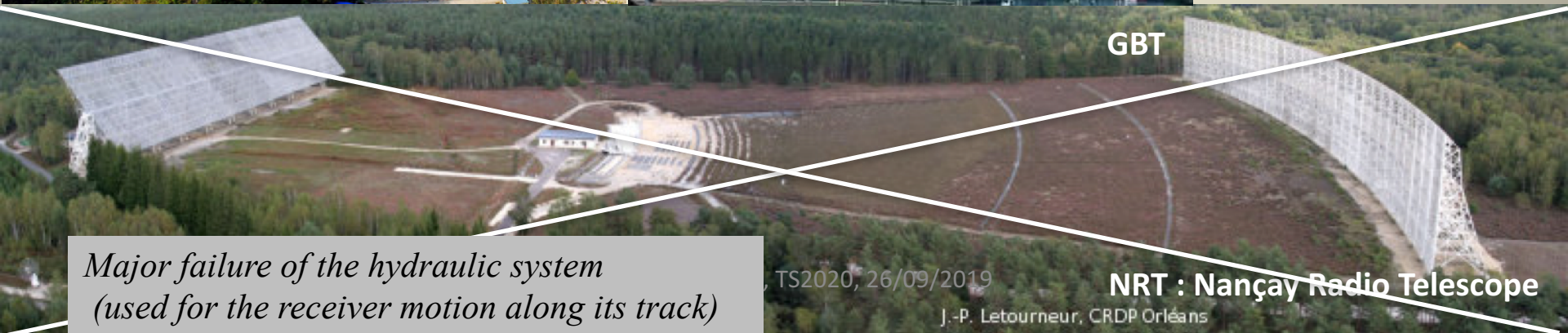

Effelsberg telescope


OHP

Hurricane Maria


FAST

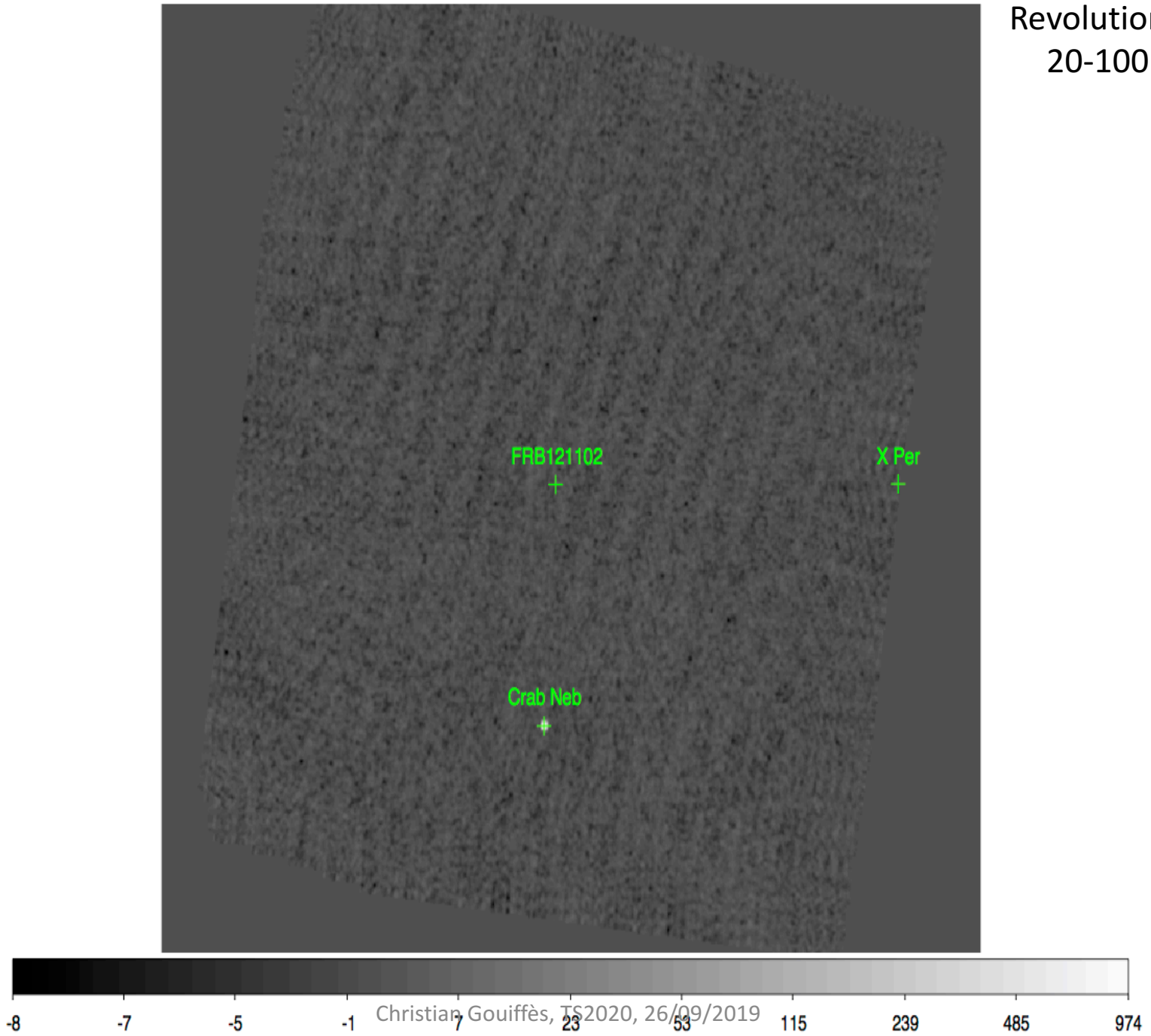

Arecibo telescope

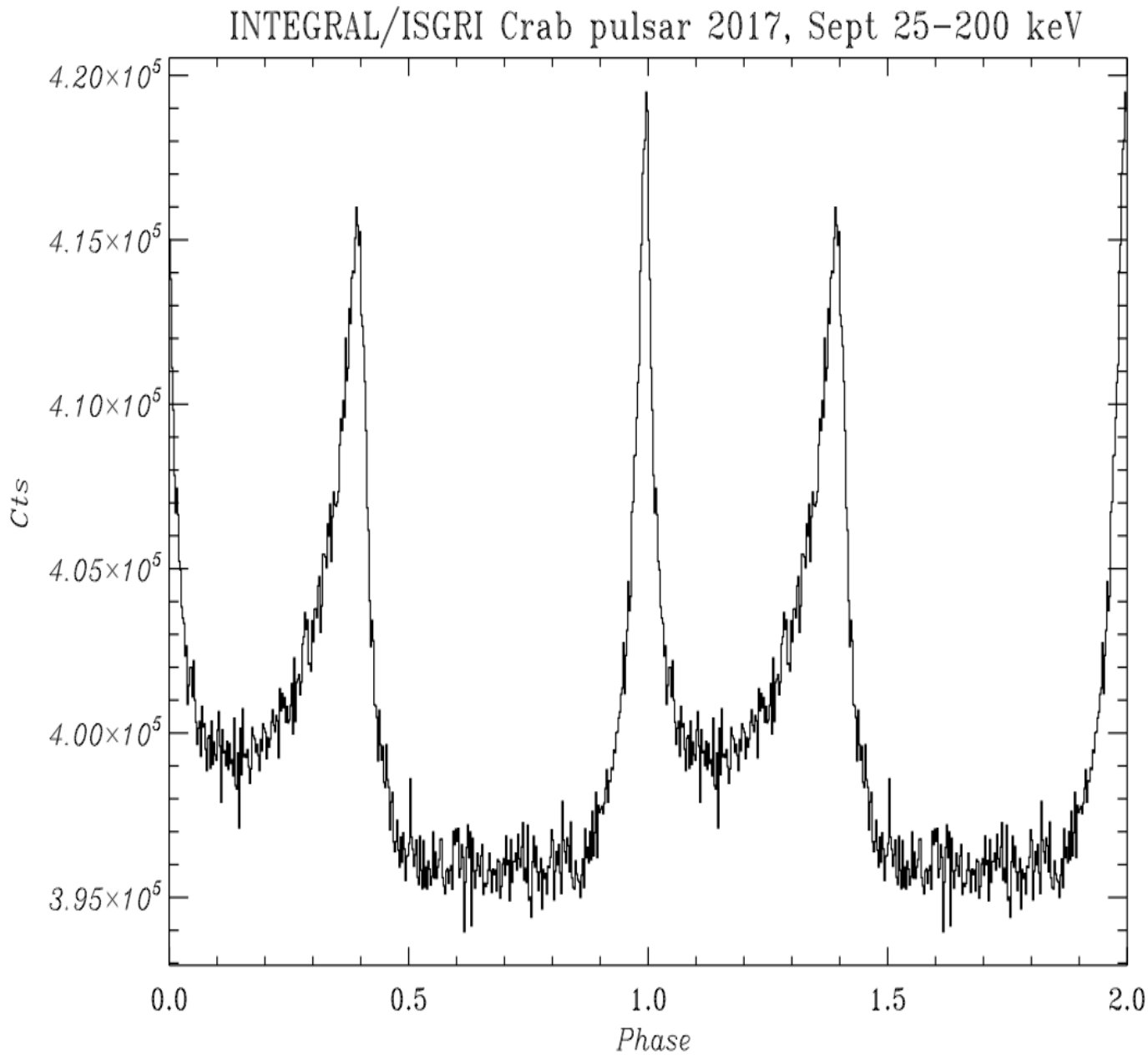

GBT

Major failure of the hydraulic system
(used for the receiver motion along its track)

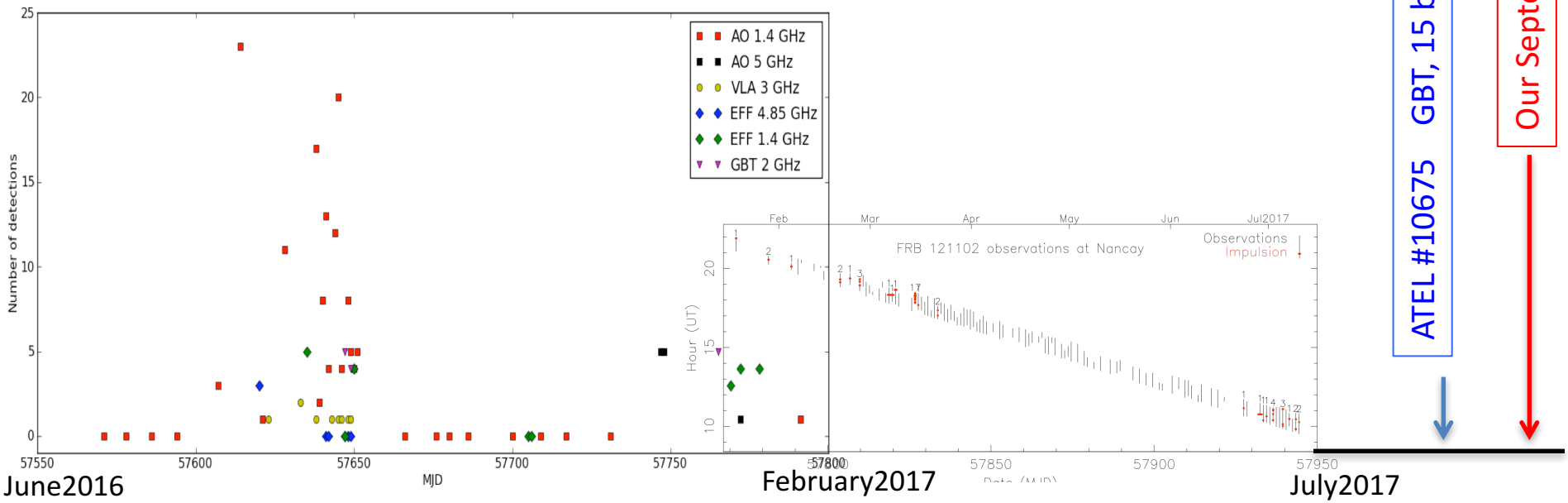
NRT : Nançay Radio Telescope

Revolution 1867
20-100 keV



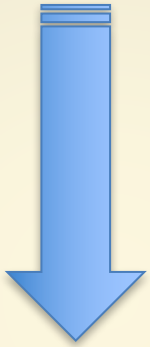

INTEGRAL/ISGRI Crab pulsar 2017, Sept 25-200 keV
4.20×10^5
4.15×10^5
4.10×10^5
4.05×10^5
4.00×10^5
3.95×10^5
Cts
0.0
0.5
1.0
1.5
2.0
Phase

No burst detected → periods of quiescence of the source ?

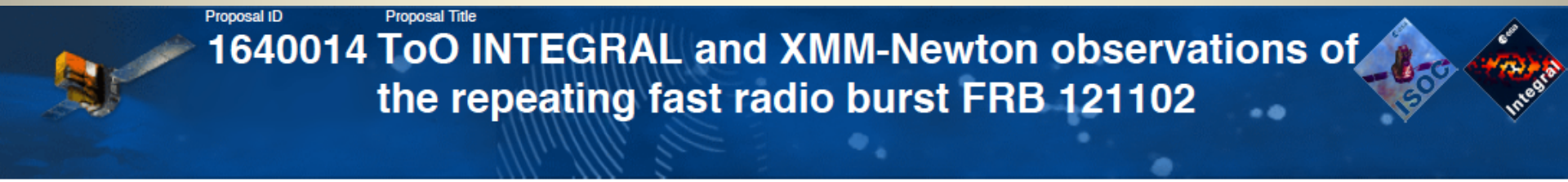


Change of strategy

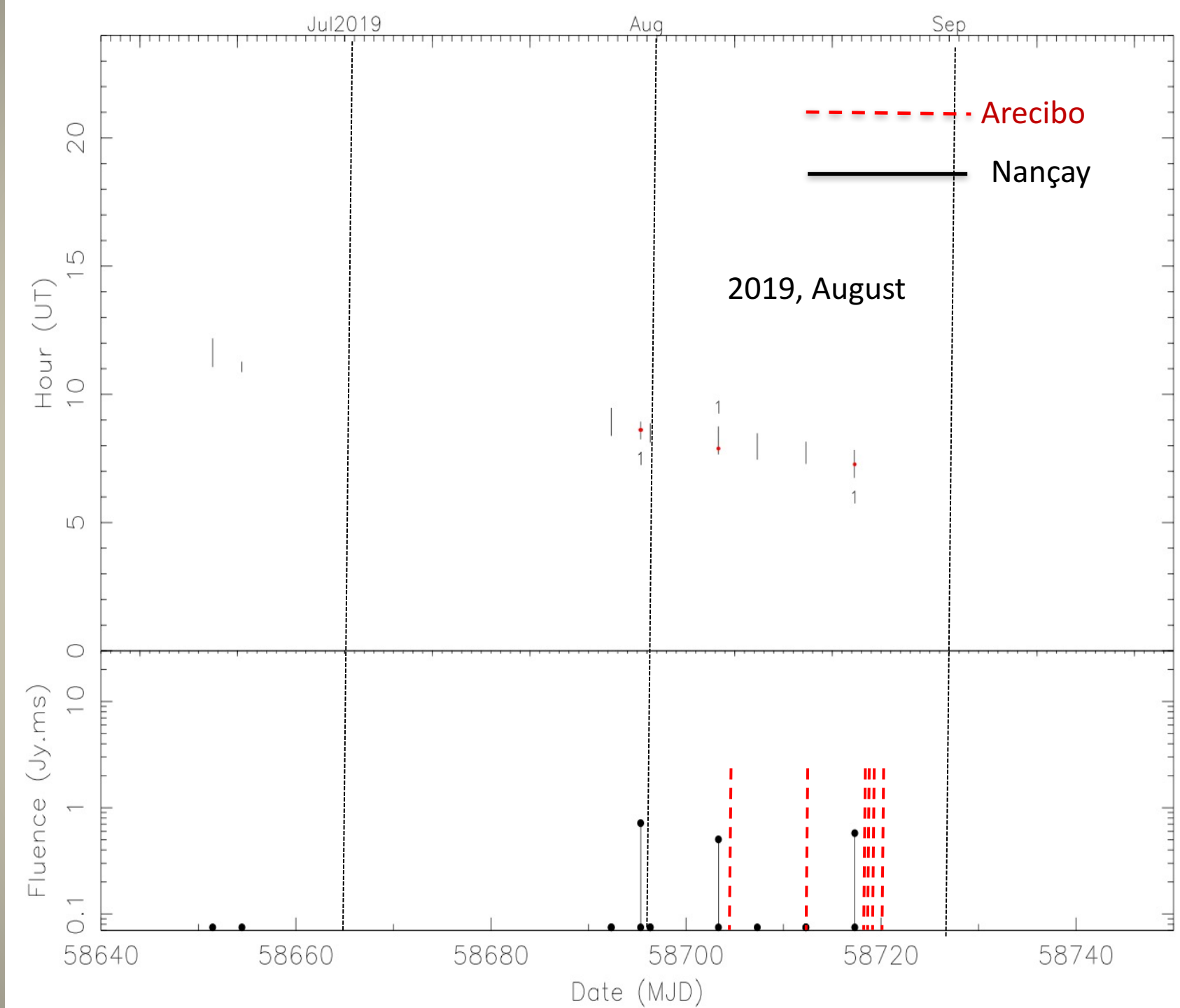
Daily monitoring of FRB121102 with the Nançay Radio Telescope



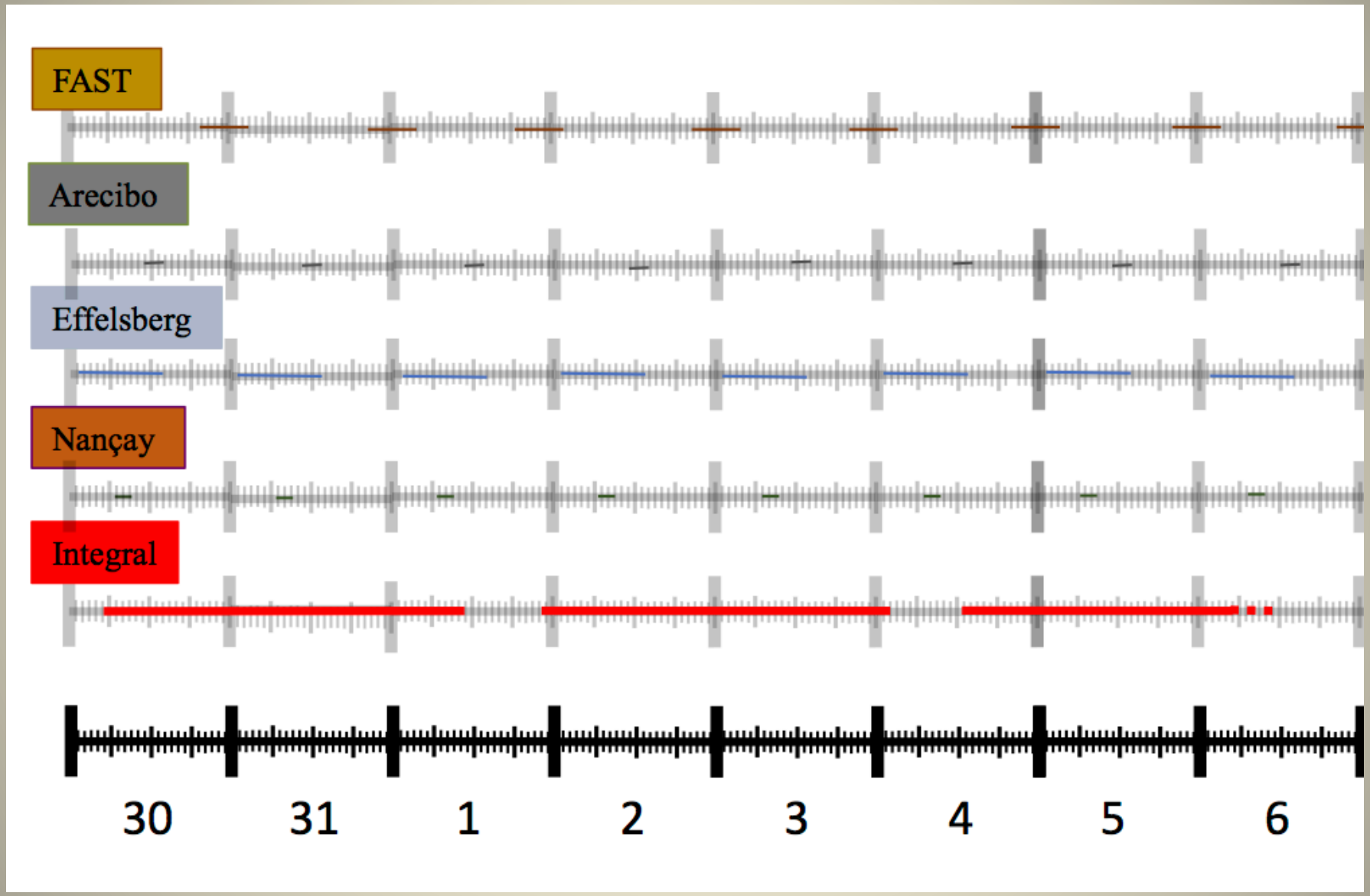
ToO programme

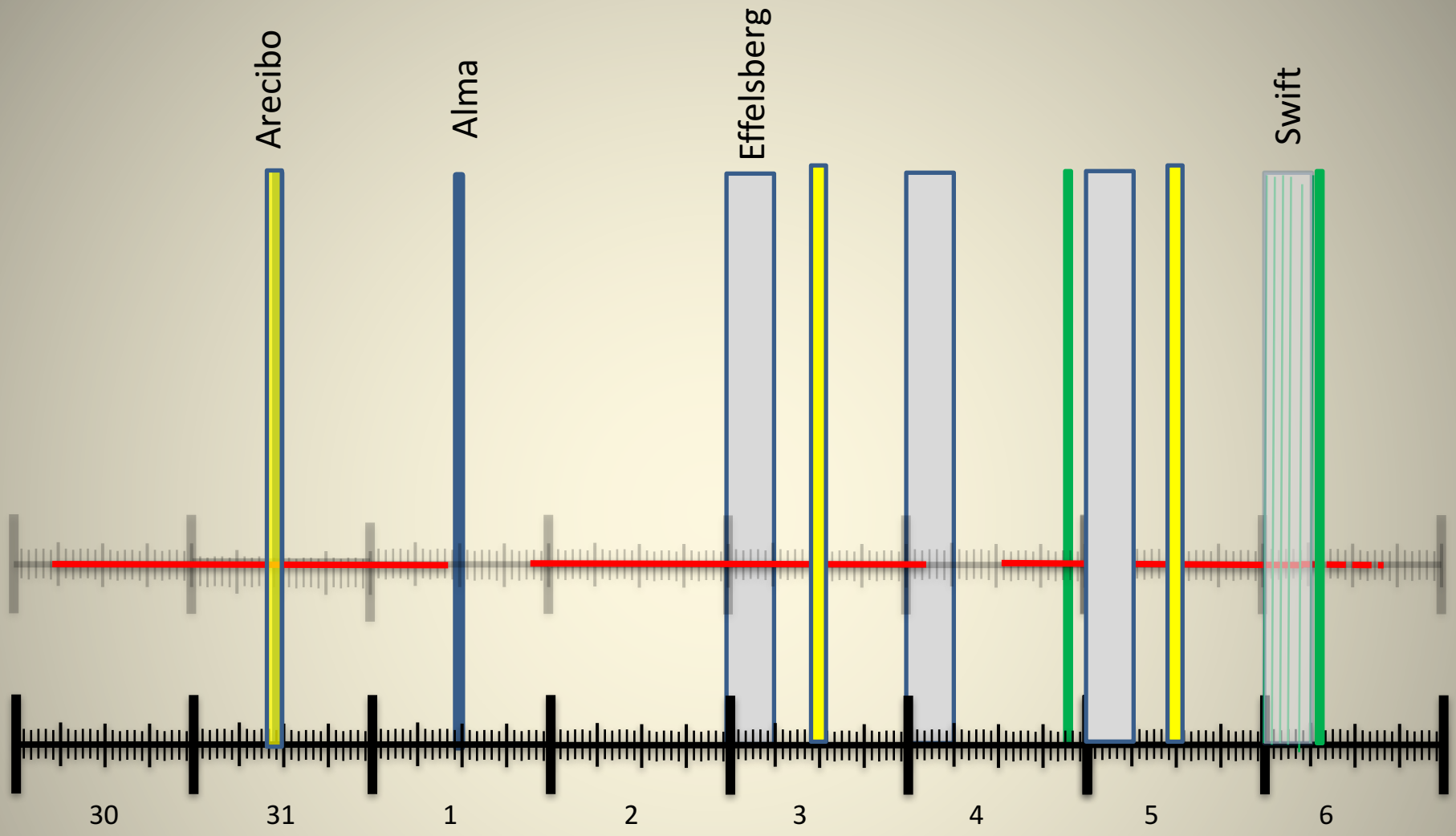


Criteria : Trigger the INTEGRAL ToO (+others) when radio bursts detected in at least in 2 over 3 one hour long successive observations with NRT (Nançay Radio Telescope) (+supporting observations with Arecibo and Effelsberg)


Jul2019
Aug
Sep
Arecibo
Nançay
2019, August
Hour (UT)
0
5
10
15
20
Fluence (Jy.ms)
0.1
1
10
58640
58660
58680
58700
58720
58740
Date (MJD)

INTEGRAL + friends triggered





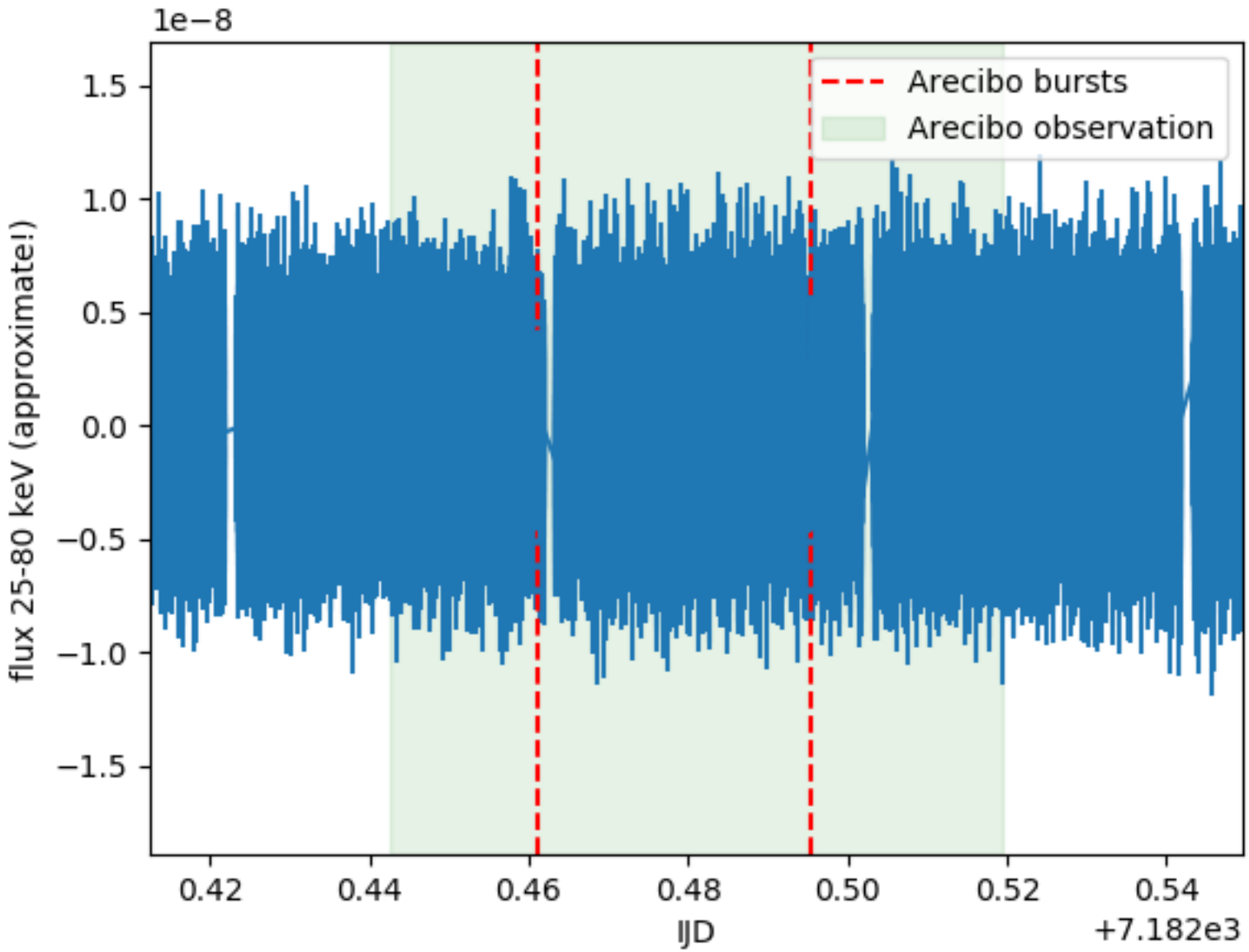
2019, September

+ many bursts detected by FAST during this period

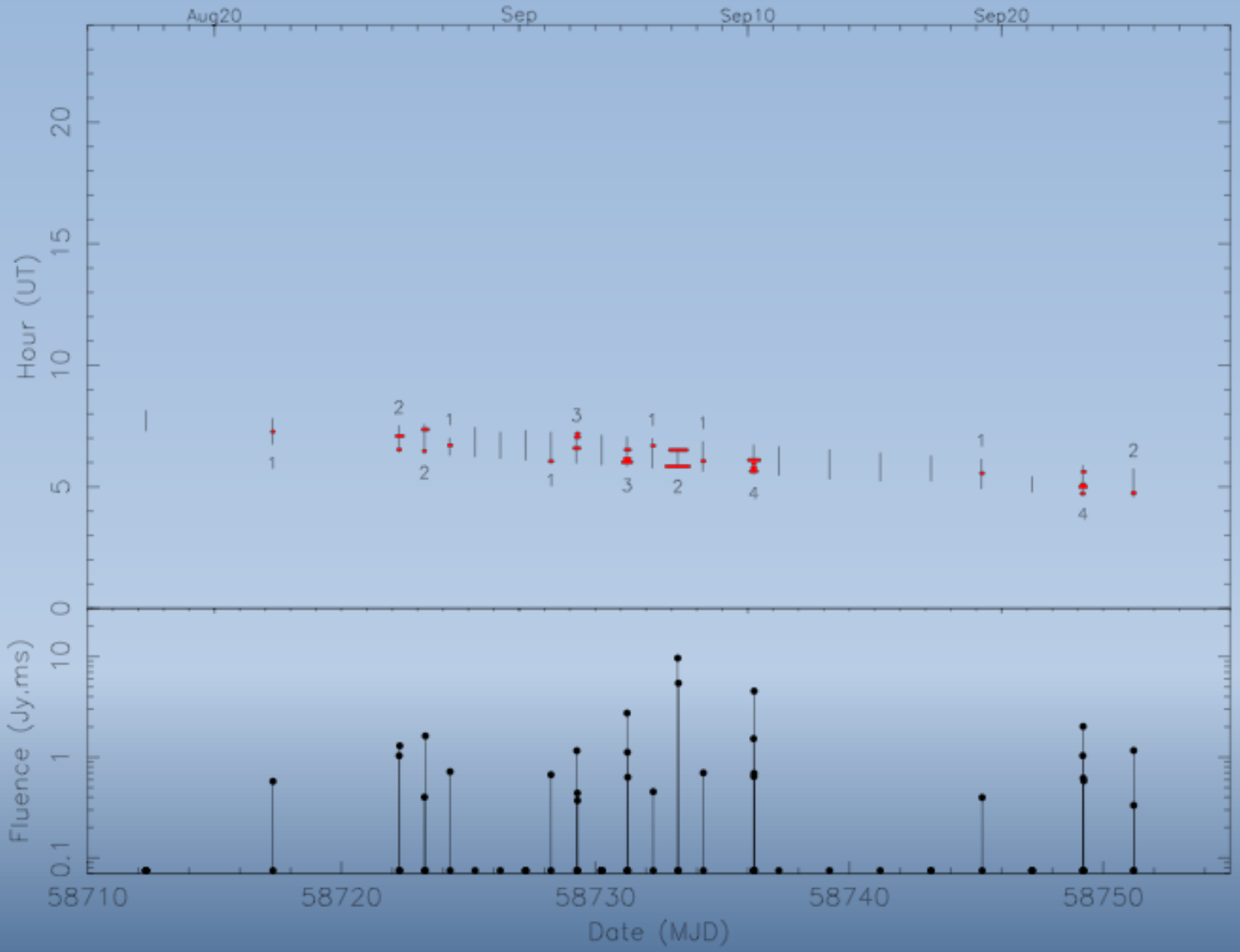
+ Nenuphar
+ SRT
+ GTC/Hypercam
+ Magic

Analysis in progress

INTEGRAL/ISGRI/preliminary



Nançay NRT detections of FRB121102



INTEGRAL and radio joint programme of FRB121102 during a renewed activity

ATel #13073; *Christian Gouiffes (CEA Saclay), Laura Spitler (MPIfR), Ismael Cognard (CNRS OrlÃ©ans), Anaelle Maury (CEA Saclay), Jason Hessels (University of Amsterdam), Andrew Seymour (Obs. Arecibo), DI Li (NAOC), Philippe Laurent (CEA Saclay), Emeric Le Floc'h (CEA Saclay), Eoin O'Connor (NUI Galway), StÃ©phane Corbel (CEA Saclay), Mary Cruces (MPIfR), Michel Dennefeld (IAP), Diego GÃ¶tz (CEA Saclay), Lei Qian (NAOC), Volodymyr Savchenko (ISDC Geneva), Andy Shearer (NUI Galway), Jerome Rodriguez (CEA Saclay), Philippe Zarka (Observatoire de Paris)*
*on **3 Sep 2019; 19:28 UT***
Credential Certification: Jerome Rodriguez (jrodriguez@cea.fr)

Subjects: Radio, X-ray, Gamma Ray, Transient, Fast Radio Burst

Referred to by ATel #: 13098

Tweet

Here we report on a renewed activity of the repeating fast radio burst FRB121102. During an on-going programme involving the INTEGRAL satellite in hard X-rays, the Arecibo, Effelsberg, and the Nançay radio telescopes, several radio bursts were detected in the last days. Previous activity of the source has also been reported using the FAST telescope (ATel #13064).

Our last observation on September, 3rd indicates that FRB121102 is still active and our monitoring of the source will continue in the coming days according to the following schedules :

- INTEGRAL observations will continue till 2019, September 6 05:00 UTC (revolution 2132 and 2133, see detailed scheduling information at https://www.cosmos.esa.int/web/integral/schedule-information)

- Nançay will observe on:

04.09.2019 05h59 -> 06h59 UT

05.09.2019 05h55 -> 06h55 UT

06.09.2019 05h51 -> 06h51 UT

- Effelsberg will observe on:

4.9 from 0:15 to 7:00 UTC

FAST Detects Multiple Bursts in L-band from FRB 121102

ATel #13064; *Di Li (NAOC), Xinxin Zhang (NAOC), Lei Qian (NAOC), Weiwei Zhu (NAOC), Ran Duan (NAOC), Dan Werthimer (Berkeley), Vishal Gajjar (Berkeley), Yan Zhu (NAOC), Jeff Cobb (Berkeley), Youling Yue (NAOC), Chengjin Jin (NAOC), Bing Zhang (UNLV), Christian Gouiffes (CEA), Shen Wang (NAOC), Laura Spitler (MPIfR), Mary Cruces (MPIfR), Jason Hessels (University of Amsterdam), Andrew Seymour (Arecibo), Eric Korpela (Berkeley), Jingtao Luo, HengQian Gan (NAOC), Peng Jiang (NAOC), Hui Li (NAOC), Qi Li (NAOC), HongFei Liu (NAOC), Chenchen Miao (NAOC), Chenhui Niu (NAOC), GaoFeng Pan (NAOC), Zhichen Pan (NAOC), Bo Peng (NAOC), JingHai Sun (NAOC), Ningyu Tang (NAOC), QiMing Wang (NAOC), Pei Wang (NAOC), Xin Pei (XAO), Jun Yan (NAOC), Rui Yao(NAOC), DongJun Yu (NAOC), Mao Yuan (NAOC), Haiyan Zhang (NAOC), Lei Zhang (NAOC), ShuXin Zhang (NAOC), and and FAST Collaboration (NAOC)*
*on **2 Sep 2019; 01:32 UT***
Credential Certification: Di Li (dili@nao.cas.cn)

Subjects: Radio, Fast Radio Burst

Referred to by ATel #: 13073, 13075, 13090, 13098

Tweet

Tracking observations of FRB 121102 were carried out with the newly commissioned Five-hundred-meter Aperture Spherical radio Telescope (FAST). We used the FAST L-band Array of 19-beams (FLAN), which has a FWHM of ~2.95' for individual beams and a ~26' footprint. The source was placed in the central beam, while all 19 beams were recorded. The bursts were firstly identified by the FRB backend on August 29th (UT), whichÂ performs real time signal processing of 19-beams data and automatic candidate selection/triggering. The subsequent single pulse search using multiple pipelines have turned up many tens of pulses with significant SNR in observations carried out so far, on the 29th, 30th, and 31st (UT). While careful cross-check are being carried out, the majority of these detections are expected to be credible. FAST has been targeting FRB 121102 since April of this year. In addition to the regular on-going FRB follow-up programs, the current observations was also motivated by timely and valuable alerts from our colleagues in the INTEGRAL team, Arecibo team, Max-Plank Institute for Radio Astronomy, Berkeley, and Cornell University. Given the significance of this source and its now apparent active state, FAST is executing more observations under the auspice of engineering testing time and multiple approved PI-led programs, which targeted FRB 121102. We encourage more ToO observations with other facilities.

FAST pulsar survey results

MeerKAT detections of FRB 121102 at L-band

ATel #13098; *Manisha Caleb (University of Manchester), Benjamin Stappers (University of Manchester), Ewan Barr (MPIfR), Mechiel Christiaan Bezuidenhout (University of Manchester), Laura Driessen (University of Manchester), Fabian Jankowski (University of Manchester), Michael Kramer (MPIfR), Mateusz Malenta (University of Manchester), Vincent Morello (University of Manchester), Kaustubh Rajwade (University of Manchester), Sotiris Sanidas (University of Manchester), Weiwei Chen (MPIfR), Jason Wu (MPIfR), Sarah Buchner (SARAO), Rob Fender (University of Oxford), Lauren Rhodes (University of Oxford), Maciej Serylak (SARAO), Lee Townsend (UCT), Patrick Woudt (UCT), Julio Andrianjafy (University of Mauritius/DARA), Nalini Heeralall-Issur (University of Mauritius), Divya Hurwanth (University of Mauritius/DARA)*
*on **11 Sep 2019; 13:24 UT***
Credential Certification: Manisha Caleb (manishacaleb@gmail.com)

Subjects: Radio, Transient, Fast Radio Burst

Tweet

The MeerKAT telescope carried out observations of the FRB 121102 on 10 September 2019 at 03:00 UT, motivated by the source's recent activity as reported by various facilities (ATels #13064, #13073, #13090). MeerKAT performed the observations centred on 1284 MHz in the range of about 900-1670 MHz, as part of a Director's Discretionary Time Proposal. 384 coherent beams centred on the location of the burst were formed using the Max Planck Institute for Radio Astronomy beam former. Using the MeerTRAP real-time single pulse detection pipeline and backend, in our preliminary analysis we identified 12 repeat bursts in 3 hours of observing time. Further data analysis is ongoing. An example pulse can be seen in the link below. FRB 121102 is still active and we encourage multifrequency observations.

The MeerKAT telescope is operated by the South African Radio Astronomy Observatory (SARAO), which is a facility of the National Research Foundation, an agency of the Department of Science and Innovation. MeerTRAP acknowledges funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 694745). We would like to thank the Director, the operators and SARAO for scheduling these observations.

MeerKAT FRB 121102

中国科学院 CHINESE ACADEMY OF SCIENCES

FAST Detects Multiple Bursts from Fast Radio Burst 121102

Sep 09, 2019

Five-hundred-meter Aperture Spherical Radio Telescope (FAST), the world largest single dish radio telescope, began commissioning on 25th September, 2016. In February 2019, it announced call for proposal publicly to Chinese astronomers. More than 133 proposals from 21 institutions including the University of Hong Kong were received. Granted proposals started to arrange observations on 18th April, 2019.

In its recent tracking observation of the Fast Radio Burst (FRB) FRB121102 using FAST L-band 19-beam receiver (with FWHM of ~2.95' for individual beam), FAST detected multiple bursts.

The bursts were firstly identified by the FAST FRB backend on August 29th (UT), which performs real time signal processing of 19-beam data and automatic candidate selection/triggering. The subsequent single pulse search using multiple pipelines have turned up many tens of pulses with significant SNR in observations carried out so far, from 29th August to 3rd September (UT).

The total number of bursts detected from FRB121102 this time is known to be the highest by far. Careful cross-check and further processing are being carried out.

FAST FRB backend was developed by researchers from the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC), and the collaborators from UC Berkeley, Beijing Normal University and Xinjiang Astronomical Observatory of the Chinese Academy of Sciences. It passed technical review and final project review in November 2018 and was rated as excellent NAOC project.

The FAST FRB backend system has high-efficiency real-time pulse capture capability, and can observe in parallel with most observation tasks. It will play an important role in the discovery of new FRBs, improving the position accuracy and capturing the high-resolution absorption lines generated by FRB in real time.

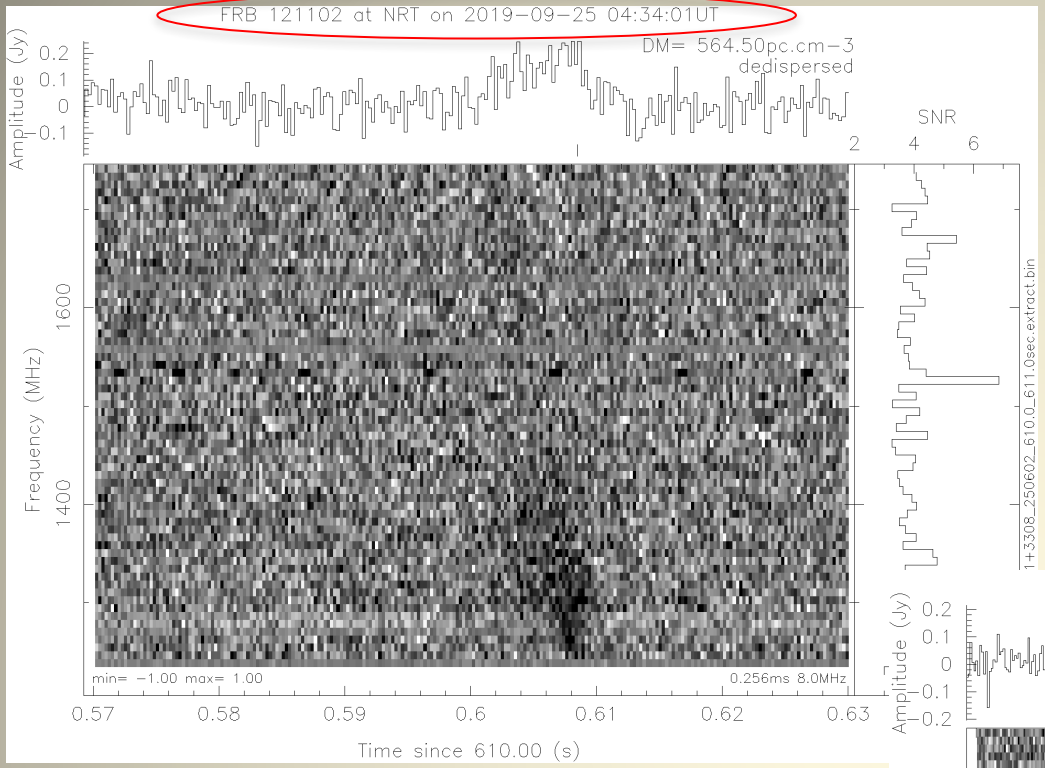
FRB are the brightest burst in radio band currently known in the universe, but there is no reasonable explanation for their origin. The repeated bursts detection of FAST will promote the research on understanding the origin and physical mechanism of FRB.

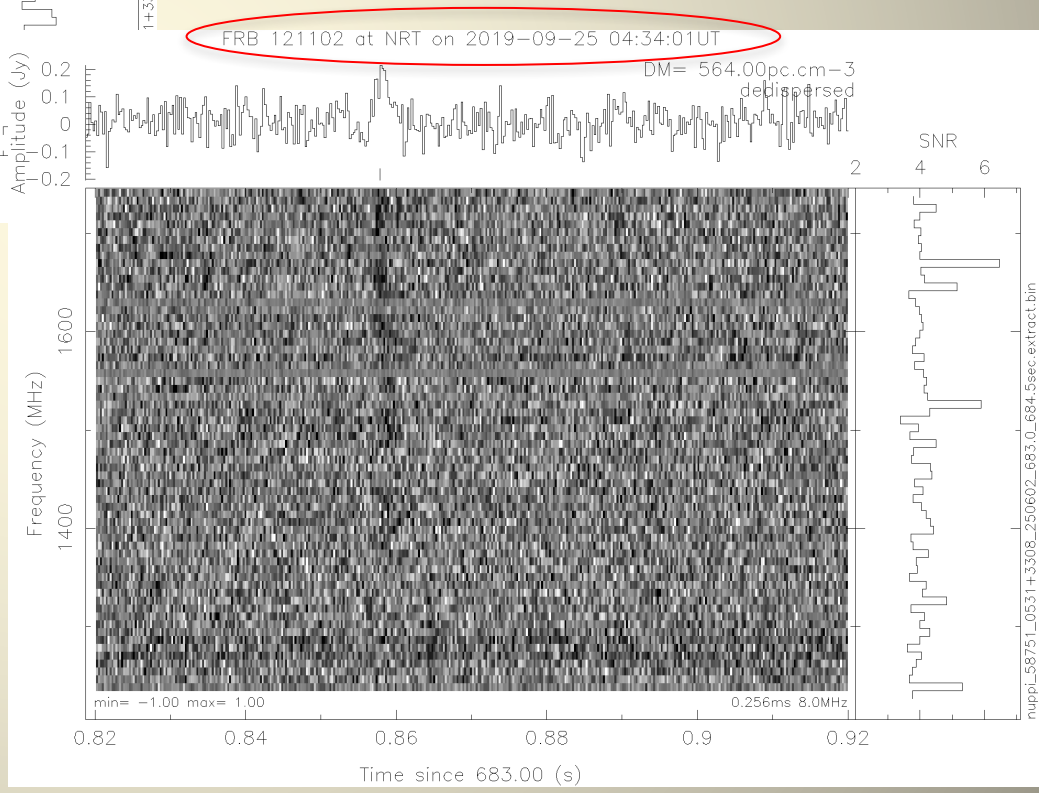
FAST has been targeting FRB 121102 since April 2019, and is executing more observations under the auspice of engineering testing time and multiple approved PI-led programs. In addition to the regular on-going FRB follow-up programs, the current observation was also motivated by timely and valuable alerts from the colleagues in the INTEGRAL team, Arecibo team, Max-Plank Institute for Radio Astronomy, Berkeley, and Cornell University.

Address: http://english.cas.cn/

Communication OK

FAST has been targeting FRB 121102 since April 2019, and is executing more observations under the auspice of engineering testing time and multiple approved PI-led programs. In addition to the regular on-going FRB follow-up programs, the current observation was also motivated by timely and valuable alerts from the colleagues in the INTEGRAL team, Arecibo team, Max-Plank Institute for Radio Astronomy, Berkeley, and Cornell University.





The « Cognard » bursts

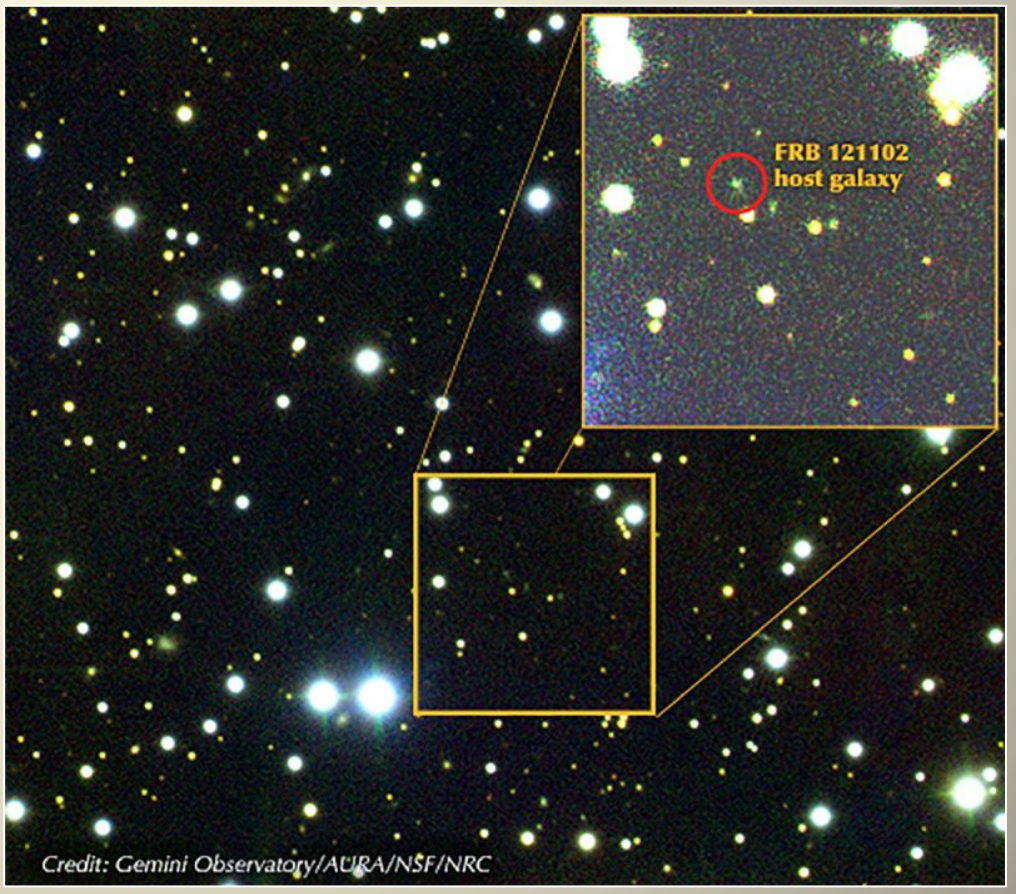
FRB121102 : a Fast Radio Burst with repeating pulses (Chatterjee+17)

→ Localization at sub-arcsec with the VLA

Host identification, redshift :

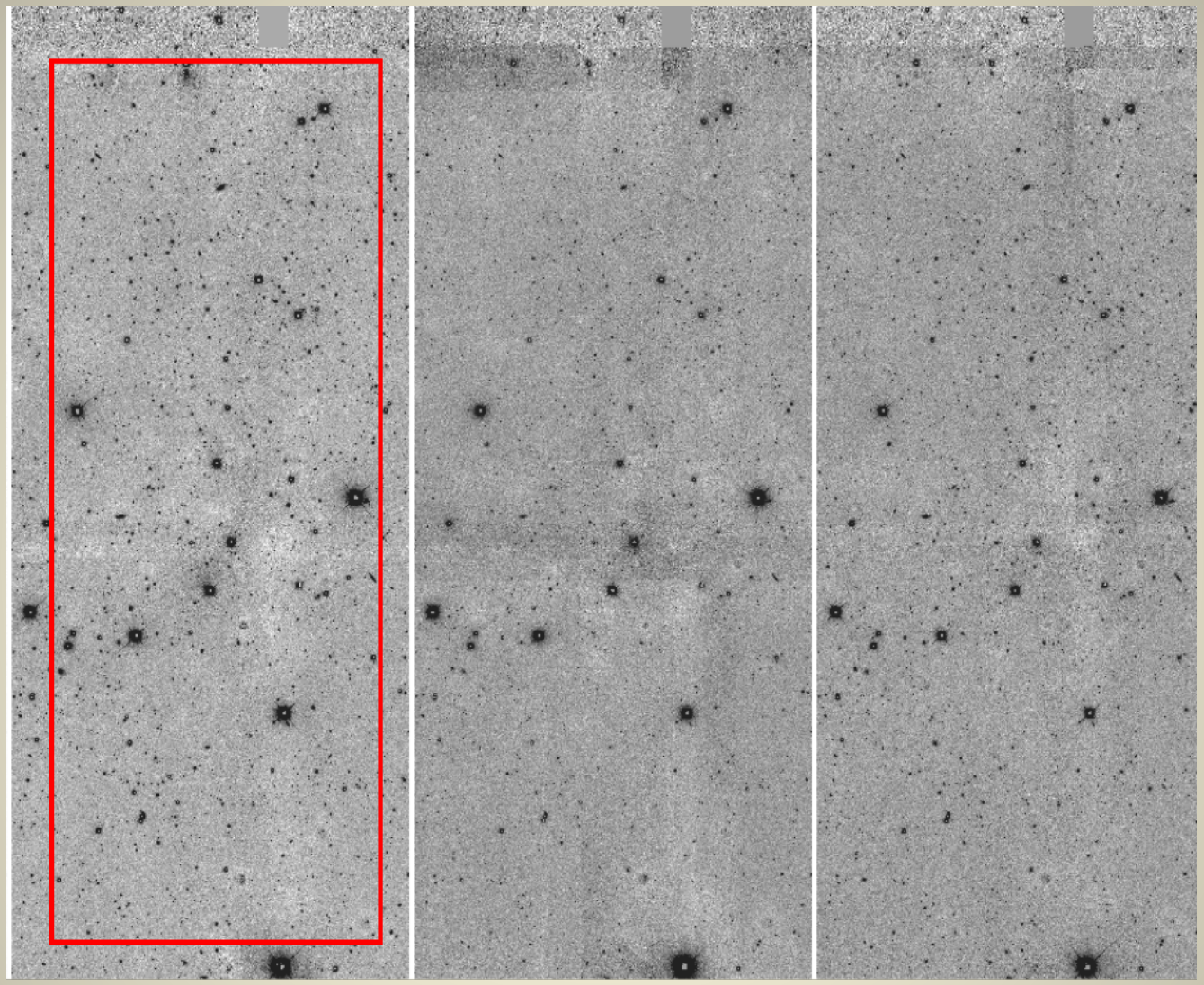
- z=0.2 (consistent with DM)
- Log (M*/Msun) = 8.2
- Star-forming (Main Seq.)
- No AGN (from BPT)
- + a persistent radio source (origin unknown)

Similarities with the hosts of Long GRBs and SLSNe



Refs: Tendulkar+, Chatterjee+, Bassa+, Spitler+

FRB180814.J0422+73, second repeater, CHIME/FRB, DM=190 cm^{-3} pc



The field of FRB180814.J0422+73 as observed by our team in February 2019. These frames were taken at the CFHT with the Infrared Wircam camera: images in the J, H and K band (from left to right). The 99% error box (20'x8') of the CHIME detection is indicated in red.

(Dennefeld, Le Floc'h, Gouiffès, Cuillandre et al, unpublished work)

Some thoughts

- ✓ NRT extremely useful for regular monitoring (caution to believe SKA will solve everything, as E-ELT)
- ✓ Good communication : programme lead by no-radioastronmers might have help
- ✓ Interaction with FAST encouraging (future collaborations, SVOM context, etc)
- ✓ Trigger extragalactic programmes and proposals (→ AO INSU 2020 PNHE+PNCG ☺)
- ✓ Need better localisation of FRB's for follow-up
- ✓ Host galaxies studies at the beginning, many things to be done
- ✓ Better communication to the « better localisation of FRB's for follow-up »
- ✓ New ToO INTEGRAL campaign in 2020 (3 orbits)

- ✓ Can we take advantage of GRB's studies/history to improve strategies, etc