Labex UnivEarthS

Université de Paris

Exploratory project 2021-2022

Toward an interdisciplinary approach of Fast Radio Bursts

AIM

APC

LUTH

l'Observatoire de Paris

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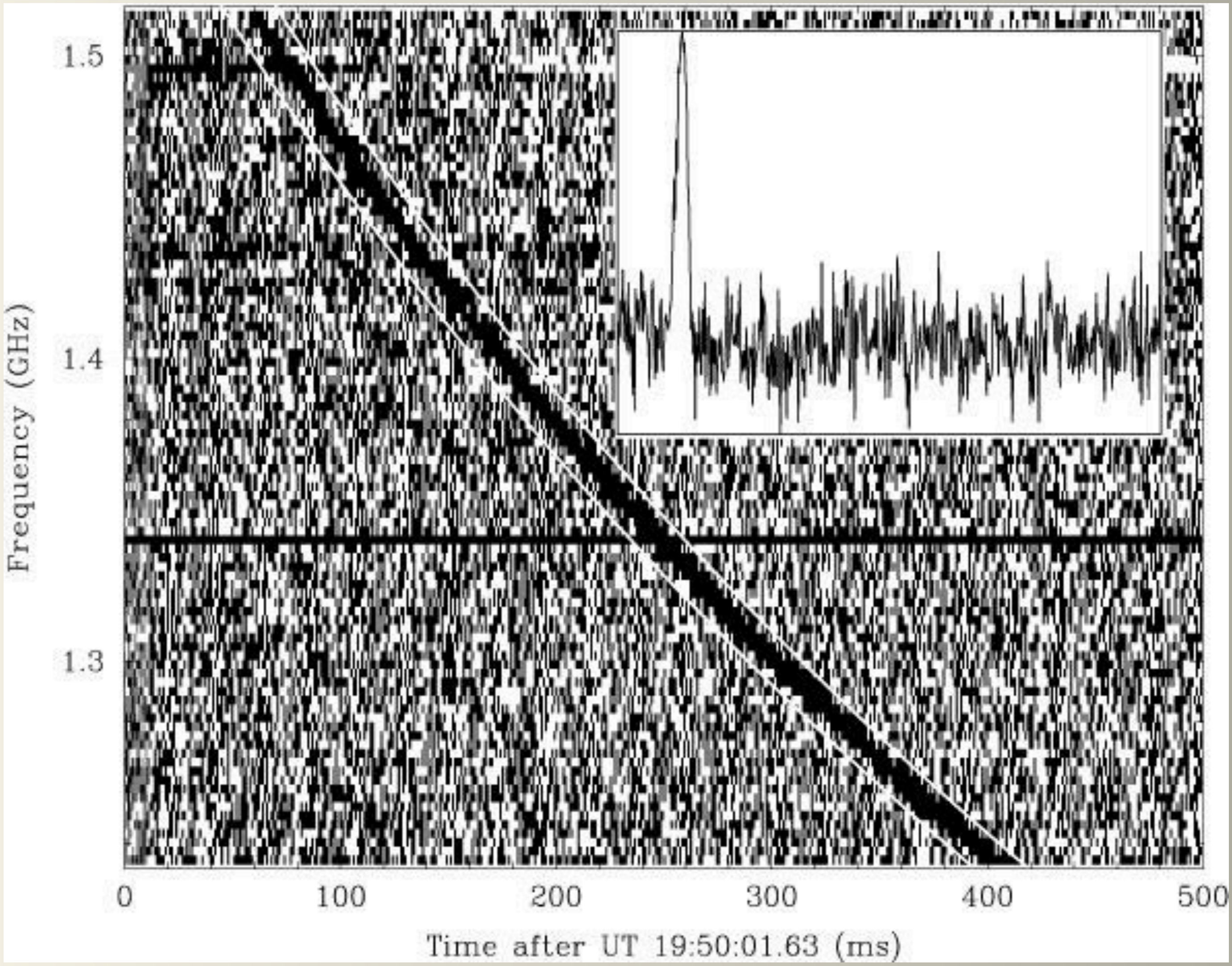
Outline :

- ✓ A short Introduction to Fast Radio Bursts + The INTEGRAL programme
- ✓ Our proposed exploratory project

Fast Radio burst was discovered in 2007 by Duncan Lorimer at Parkes during LMC archive searches – 2001 - programme for looking to fast/very fast variable objects

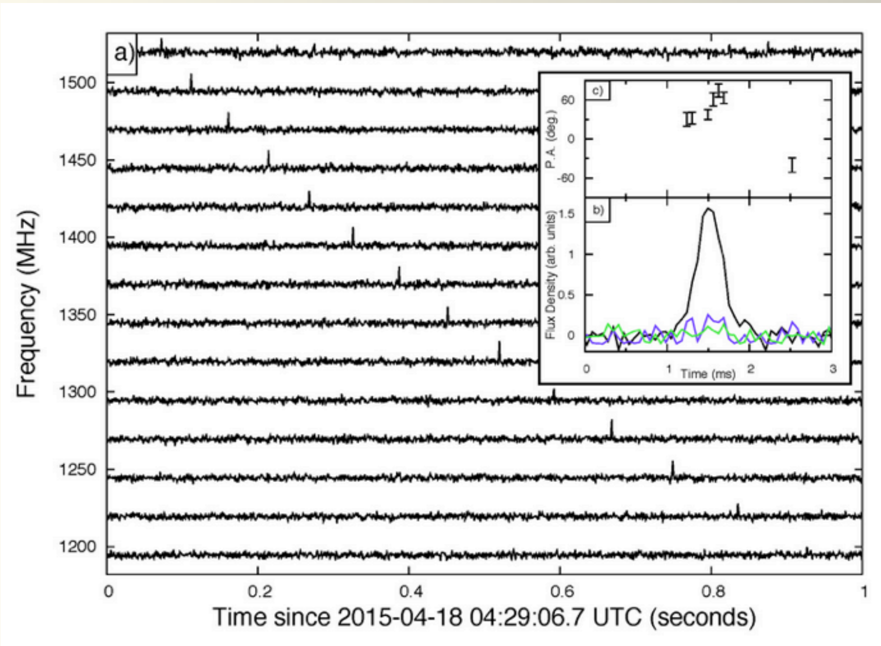
Remarks : D. L. expert in radio pulsars science

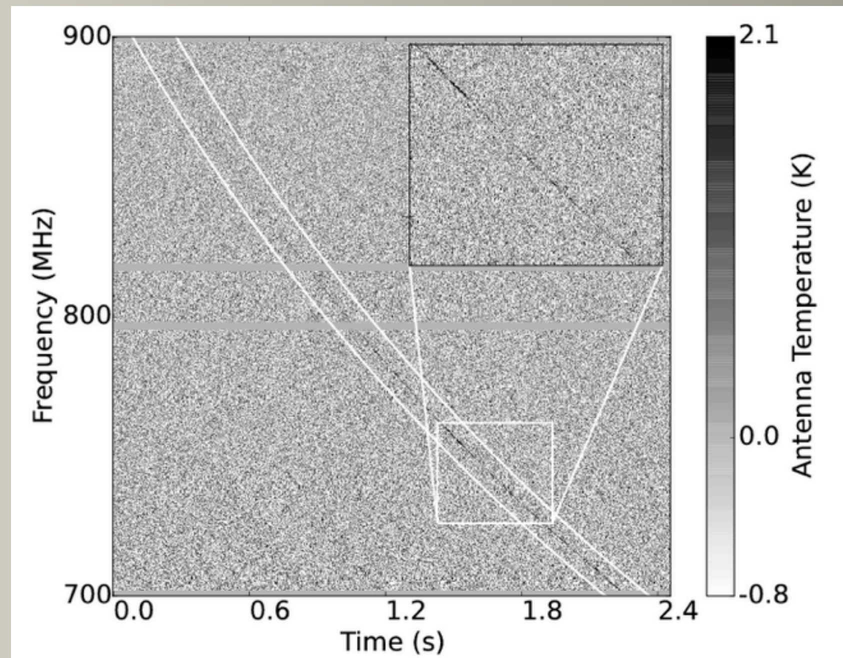


The « Lorimer » burst

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

$$\mathrm{DM} = \int_0^D n_e \, dl$$

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


Effelsberg telescope

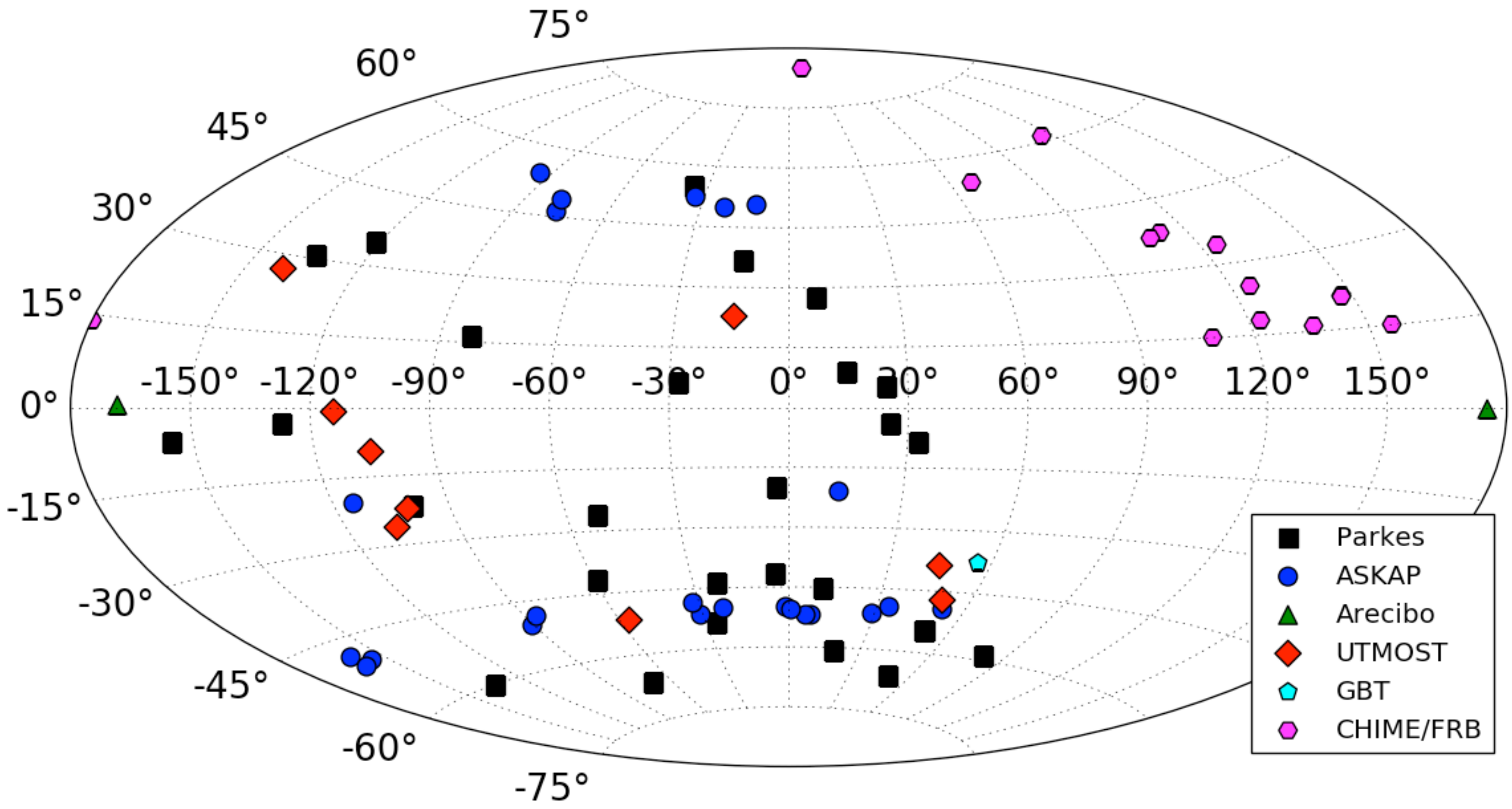

Arecibo telescope


FAST


GBT


NRT : Nançay Radio Telescope
J.-P. Letourneur, CRDP Orléans

Major progress recently thanks to new facilities



Two populations of FRB's : repeating and not repeating (often referred as cataclysmic event)

Petroff et al, 2019

FRBCAT

frbcat.org

FRB Catalogue

A complete catalogue of fast radio bursts (FRBs) is now maintained at the Transient Name Server (TNS). Please visit the TNS for the most up to date FRB population information. This catalogue contains the population of fast radio bursts (FRBs) published up to July 2020. This site is maintained by the FRBCAT team and is no longer actively updated. 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 the FRBCAT team (primary contact: Emily Petroff).

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

	FRB	UTC	Telescope	RAJ	DECJ	gl	gb	DM	Width	S/N
+	FRB20200125A	2020/01/25 12:15:19.600	GBT	14:36:31.580	+07:42:06.84	359.8	58.4	179.47±0.05	3.7	8.1
+	FRB20190614D	2019/06/14 01:13:02.010	VLA	04:20:18.13	+73:42:24.3	136.3	16.5	959.2±5	5	8.27
+	FRB191108	2019/11/08 19:48:50.471	Apertif	01:33:47	+31:51:30	133.3	-30.1	588.1±0.1	0.34	103
+	FRB190907.J...	2019/09/07 17:02:43.311	CHIME/FRB	08:09	+46:16	173.4	32.3	310.9±0.4	3	0
+	FRB190711	2019/07/11 01:53:40.861	ASKAP	21:57:40.68	-80:21:28.8	310.9078	-33.9023	593.1±0.4	6.5	23.8
+	FRB190611	2019/06/11 05:45:43.299	ASKAP	21:22:58.91	-79:23:51.3	312.9352	-33.2818	321.4±0.2	2	9.3
+	FRB190608	2019/06/08 22:48:12.883	ASKAP	22:16:04.75	-07:53:53.6	53.2088	-48.5296	338.7±0.5	6	16.1
+	FRB190604.J...	2019/06/06 05:34:23.574	CHIME/FRB	14:35	+53:17	93.8	57.6	552.7±0.2	1.2	0

Update: Sunday 15 Nov 2020, 118 FRBs

HOME Information FRBs Repeating FRBs Galactic Sources Transit Calculator CHIME Sign In

Last Updated: Fri, 06 Nov 2020 18:49:26 UTC

This data is provided to you by the CHIME/FRB collaboration. If you use this data, please use the following acknowledgement:

We acknowledge use of the CHIME/FRB Public Database, provided at https://www.chime-frb.ca/ by the CHIME/FRB Collaboration.

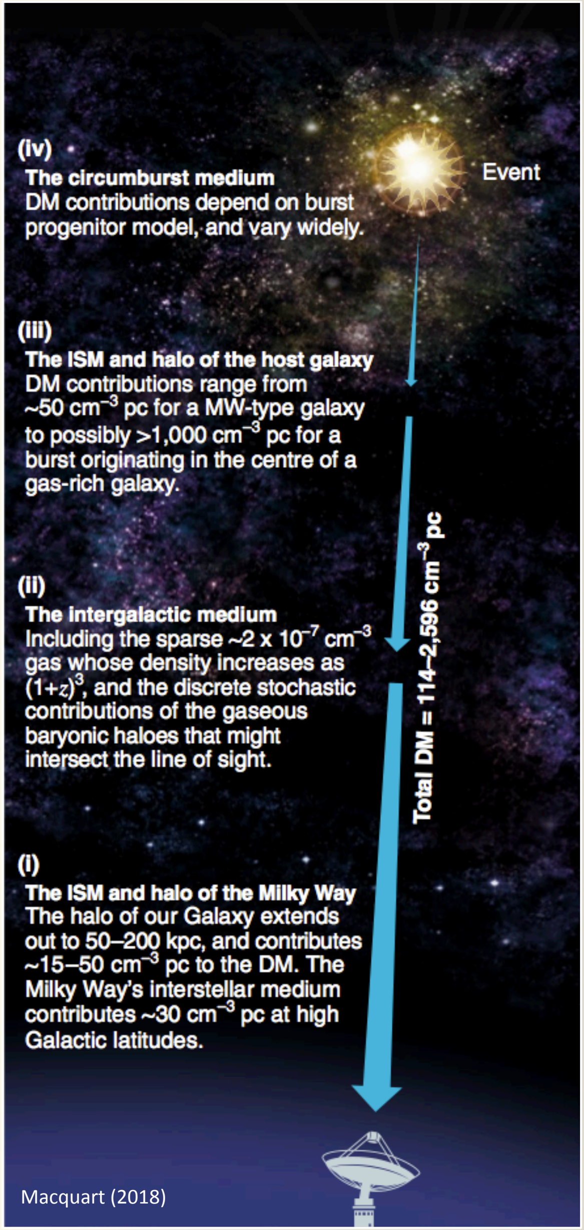
Repeating FRBs (Total: 18 sources)

Repeaters that have a burst in the past 10 days are highlighted in red

Per page 100 « ‹ 1 › » Download Repeaters Filter: Type to Search Clear

ID	Latest Event	DM (pc cm^{-3})	RA	Dec	Events	Arxiv Link	Host
180916.J0158+65	2020-09-19 09:45:15.585285	350.0 (2.9)	01:58	+65:44	56	1908.03507	spiral
190303.J1353+48	2020-09-09 22:30:03.587742	223.9 (3.5)	13:53	+48:15	16	2001.03595	
180814.J0422+73	2020-09-03 13:20:33.303715	189.4 (5.0)	04:22	+73:40	22	1901.04525	
190907.J08+46	2020-07-29 19:42:05.772016	309.1 (1.2)	08:09	+46:16	5	2001.03595	
190417.J1939+59	2020-07-26 07:21:42.417566	1378.0 (1.7)	19:39	+59:24	5	2001.03595	
190212.J18+81	2020-07-25 05:38:55.926594	302.3 (3.1)	18:24	+81:26	8	2001.03595	
181119.J12+65	2020-06-21 02:39:02.417397	367.0 (4.2)	12:42	+65:08	7	1908.03507	
190208.J1855+46	2020-05-13 11:24:33.224419	578.9 (2.8)	18:55	+46:58	6	2001.03595	
181030.J1054+73	2020-01-22 22:23:20.335682	103.5 (1.7)	10:54	+73:44	10	1908.03507	
190117.J2207+17	2019-12-23 00:07:07.130260	394.2 (1.2)	22:07	+17:23	6	2001.03595	

FRBs as potential cosmological probe



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

- 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)

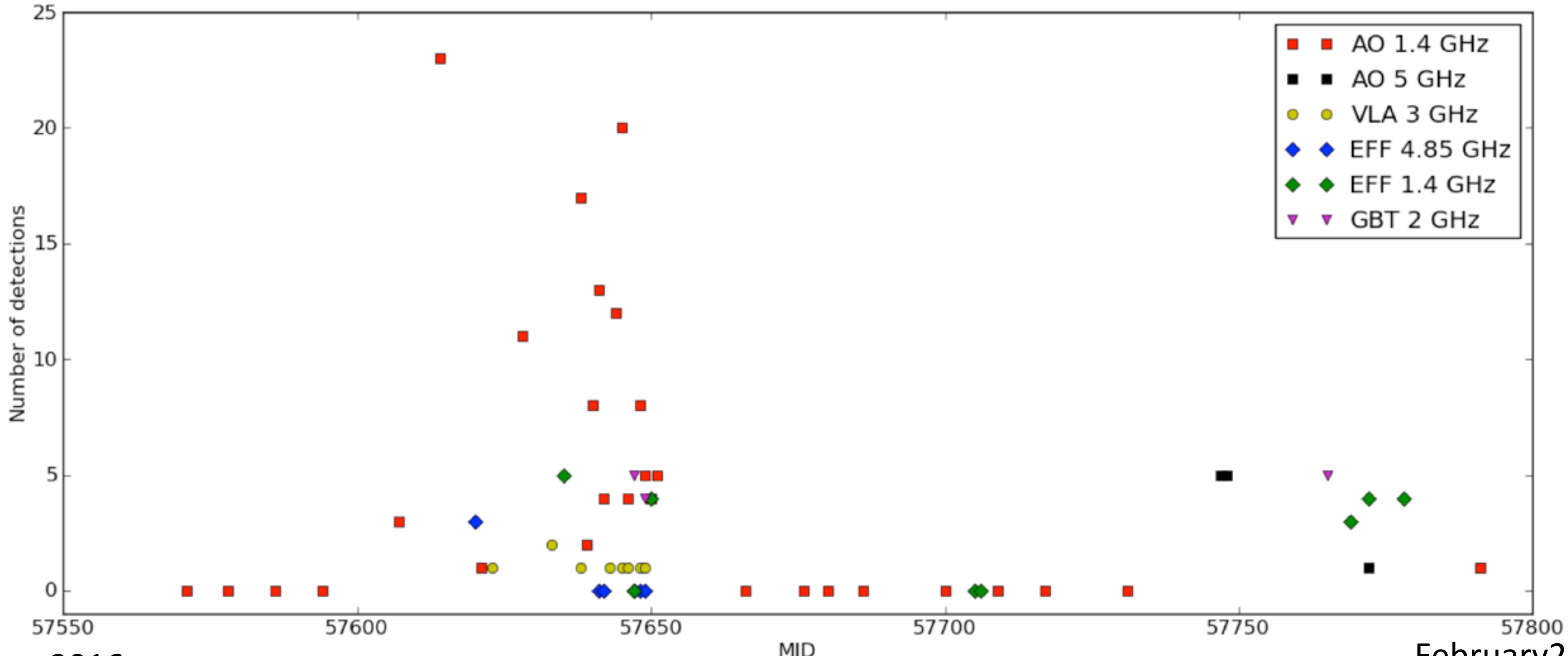
DM_{tot} ~ 100 – 2500 cm^{-3} pc

→ DM_{IGM} is largely dominant

→ DM_{IGM} indicates distance (assuming homogeneous IGM distribution)

→ If known z, DM_{IGM} constrains IGM baryons

FRB121102, the first repeating FRB



June2016

February2017

(Spitler, private com.)

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)

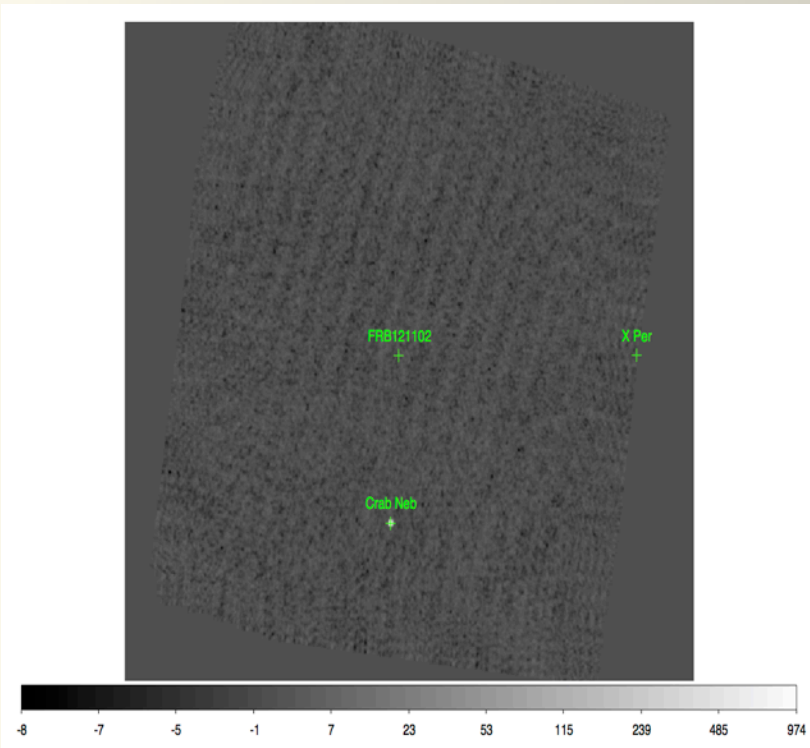
N=30 bursts

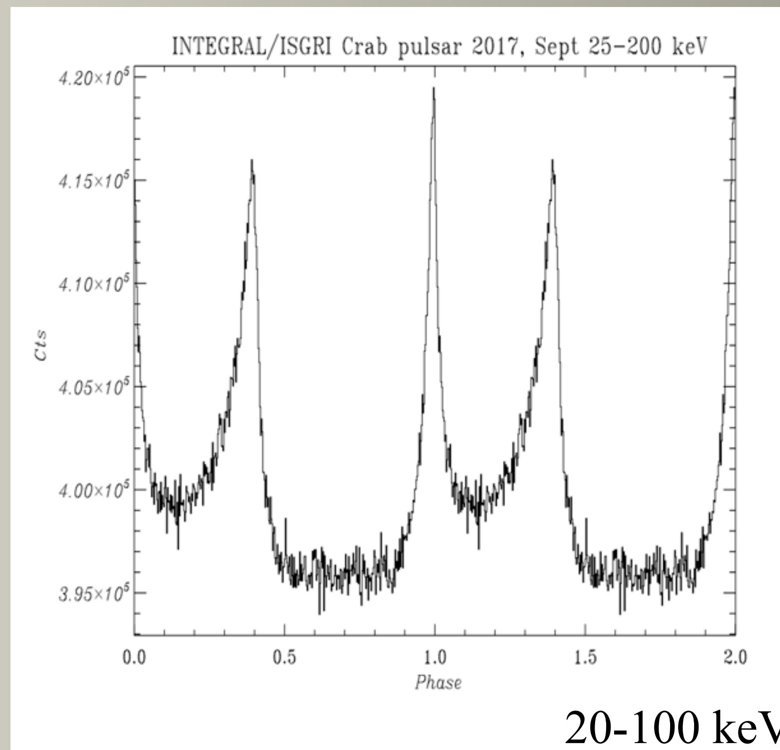
✓ Gemini + GMOS Optical observation : low-metalicity dwarf galaxy at z=0.192, Persitent radio source offset by 200 mas from the galaxy's center No optical signatures for AGN activity (Tendulkar et al, 2017)

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)
- Encountering 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
- …

INTEGRAL programme to look for counterpart
In coordination with NRT, Effelsberg, Arecibo, OHP, etc

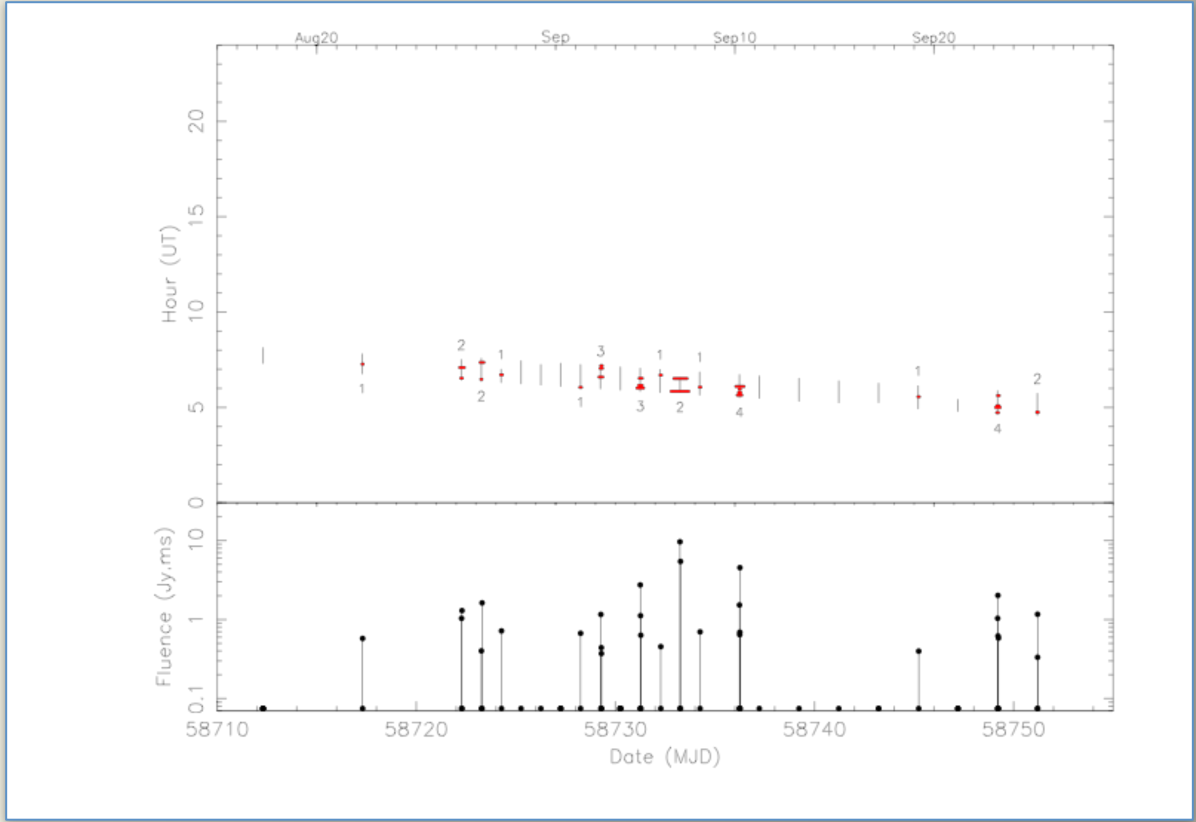




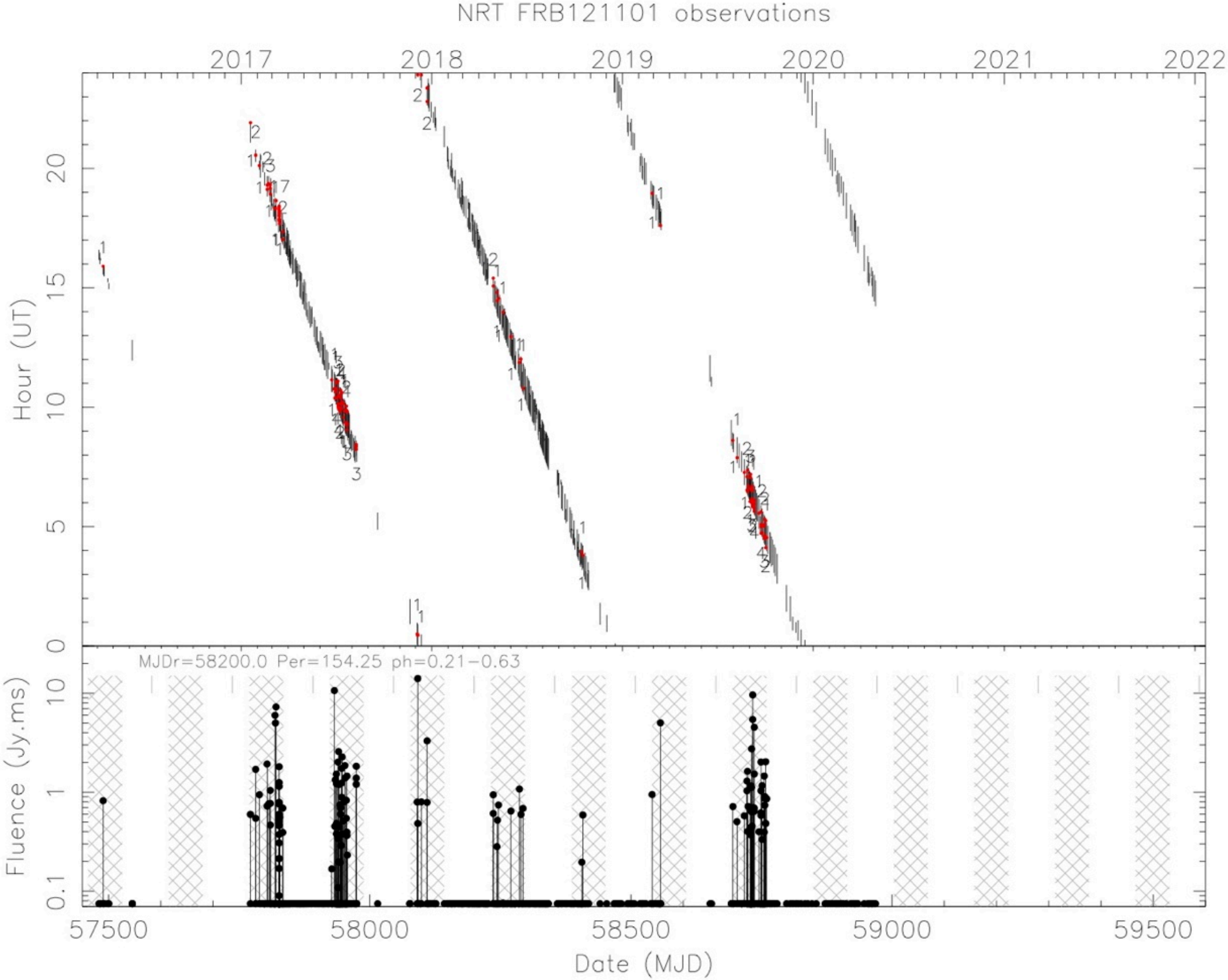
2017 : INTEGRAL ok but troubles with Arecibo and NRT, no burst detected

Daily monitoring of FRB121102 with the Nançay Radio Telescope

ToO programme in 2019 : strategy successful



NRT data indicate periodicity (160days), but complex behavior, mode data needed



Toward an interdisciplinary approach of Fast Radio Bursts

Researchers with complementary expertise

Position	Name / Surname	Laboratory	Grade / Employer	
WP leader	Christian Gouiffès	AIM	Researcher	HE
WP co-leader	Arache Djanatti-Ataï	APC	"	VHE
WP co-leader	Fabrice Mottez	LUTh/Obs. Paris	"	Th
WP member	Emeric Lefloc'h	AIM	"	Opt
WP member	Philippe Laurent	AIM	"	HE
WP member	Anne Lemière	APC	"	VHE
WP member	Jérôme Guilet	AIM	"	Th
WP member	Philippe Zarka	LESIA/obs. Paris	"	Radio
WP member	Ismael Cognard	LPCEE/Obs. Paris	"	Radio
WP member	Anaëlle Maury	AIM	"	mm
WP member	Guillaume Voisin	LUTh/Obs. Paris	"	Th
WP member	Michel Dennefeld	IAP	"	Opt
WP member	Benjamin Schneider	AIM	Ph-D	Opt
WP member	Julien Girard	AIM	Researcher	Radio
WP member	Diego Götz	AIM	"	HE

we identify three main topics :

How will we manage to articulate/organize the 3 main topics adressed in this project is the first step of this exploratory programme

- Observation :
  - ✓ INTEGRAL programmes (past, present and future)
  - ✓ Survey with NRT of short GRBs remnants
  - ✓ extension to VHE (HESS in particular), best strategies for future observations.
  - ✓ Optical, mm windows (high speed instrument i.e. mini-GASP @ OHP, NIKA2 in the mm range)

- Data analysis :
  - ✓ comparing and improving tools to study signals in the high time resolution mode
  - ✓ Benefit from experience on pulsars data analysis (in HE, VHE, Opt)

- Theory
  - ✓ How models can help/guide observations?
  - ✓ How the different approaches (radiation processes, formation of magnetars) can work together to explain the magnetar model?

Needless to say : Radio data are crucial at each step

Expected results

- ✓ To increase the interaction/links between observation, data analysis and theory.
- ✓ Confrontation between theories
- ✓ To discuss about the best possible future observing strategies : major coming facilities CTA, LSST, SKA, Lofar will emerge in a near future
- ✓ data analysis challenges in the “high” time domain in the high energy band in view of increasing FRBs
- ✓ From discussions and meetings : to provide opportunities to create new collaborations at the national and international levels (invitations of experts for short stays)
- ✓ Encouraging young researchers in the field (invitations, SF2A, etc)

Conclusion/final word :

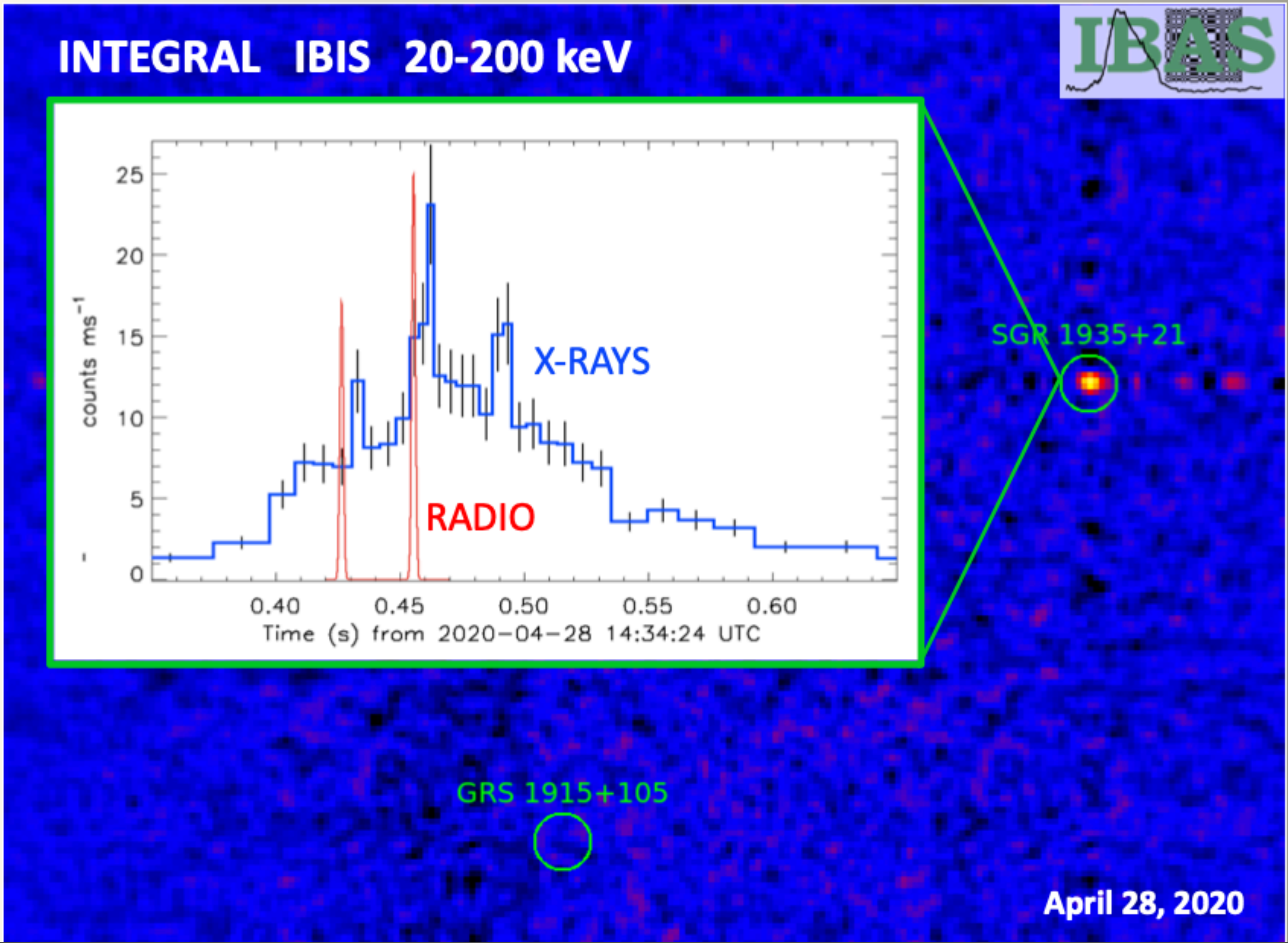
A few years ago we decided to explore the possibility to use the INTEGRAL satellite to contribute to the FRBs field with multi wavelength campains approaches (especially in the low gamma-ray range and optical).

Within this exploratory project and through an interdisciplinary approach, we would like to extend the coverage toward VHE and to join the effort to better understand the nature of these objects, this in synergy with theory and modelling.

THANK YOU

Extra slides

SGR1935+214


INTEGRAL IBIS 20-200 keV
IBAS
counts ms^{-1}
25
20
15
10
5
0
0.40
0.45
0.50
0.55
0.60
Time (s) from 2020-04-28 14:34:24 UTC
X-RAYS
RADIO
SGR 1935+21
GRS 1915+105
April 28, 2020

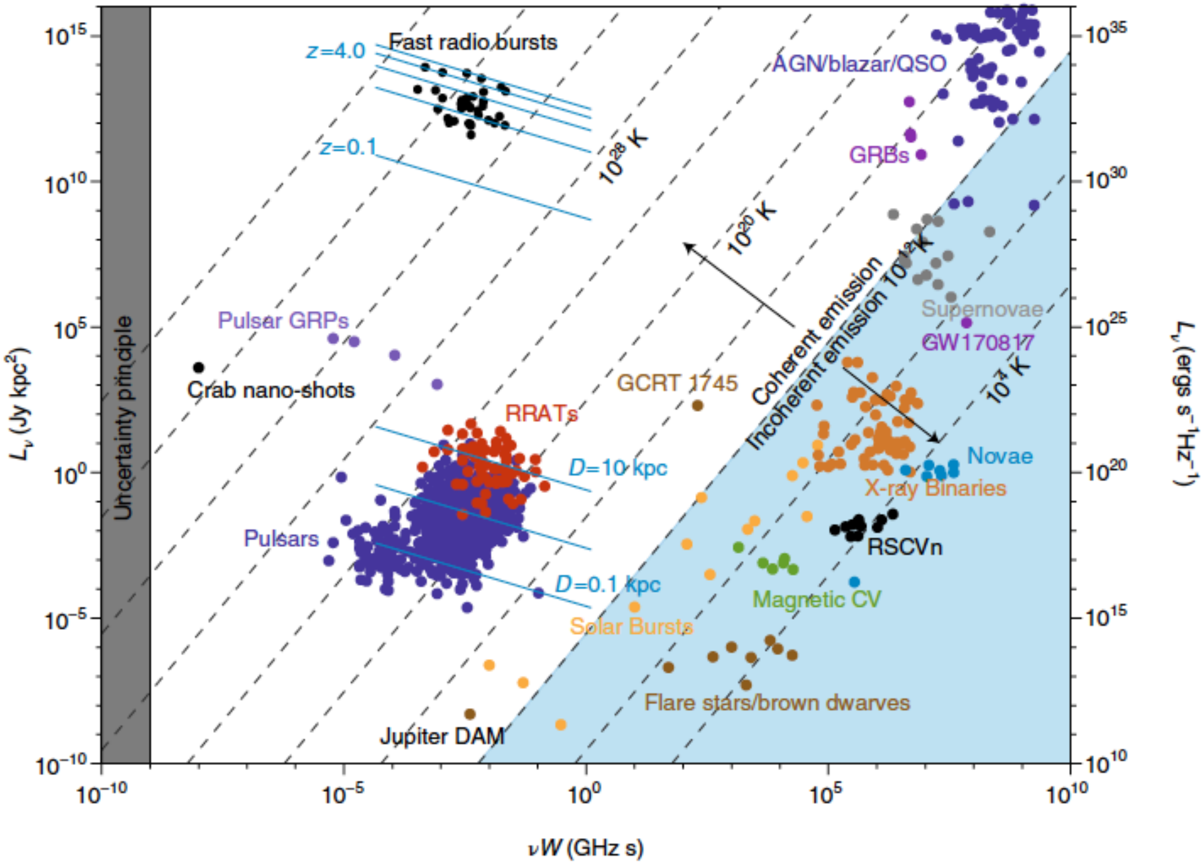
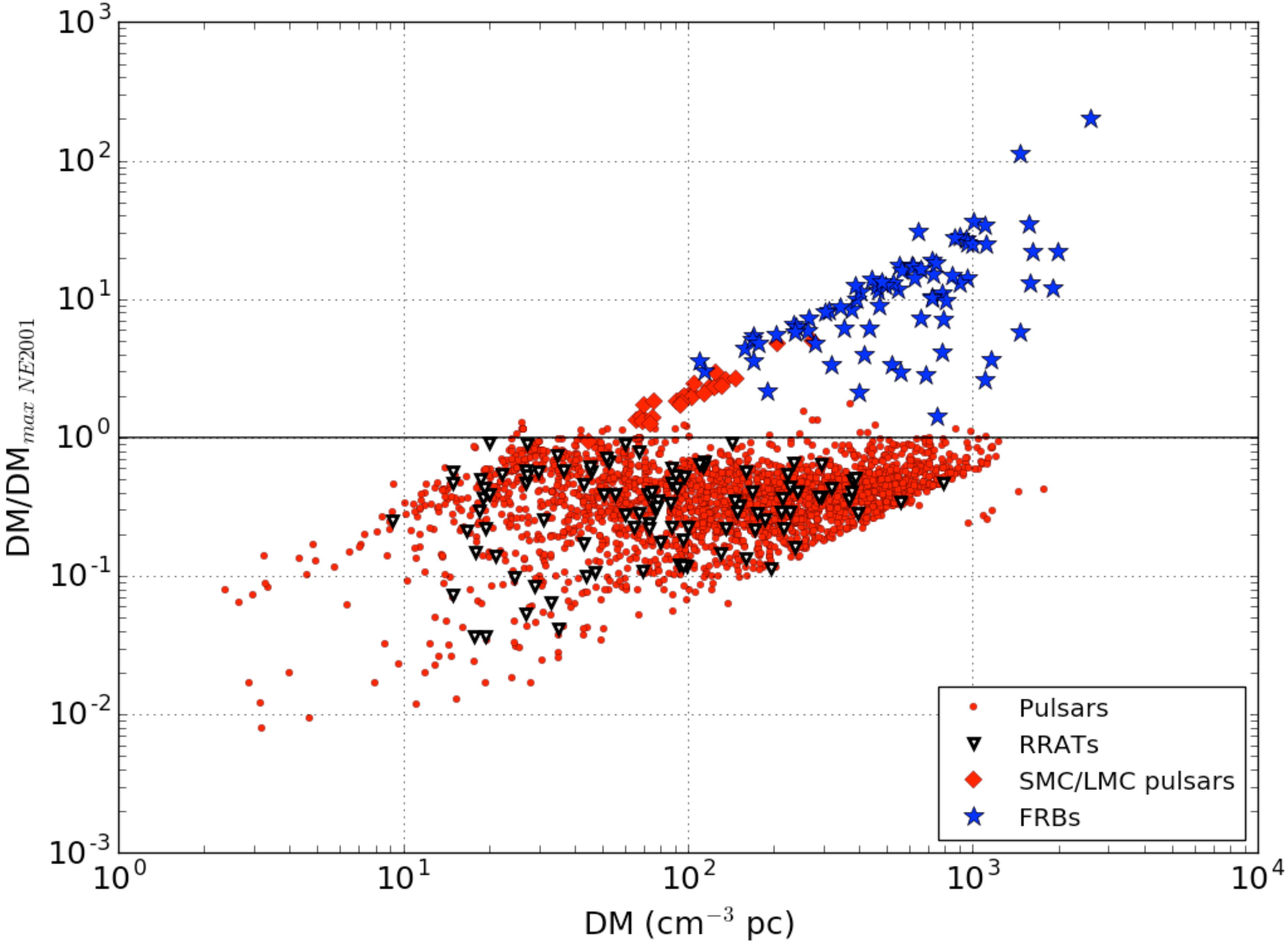
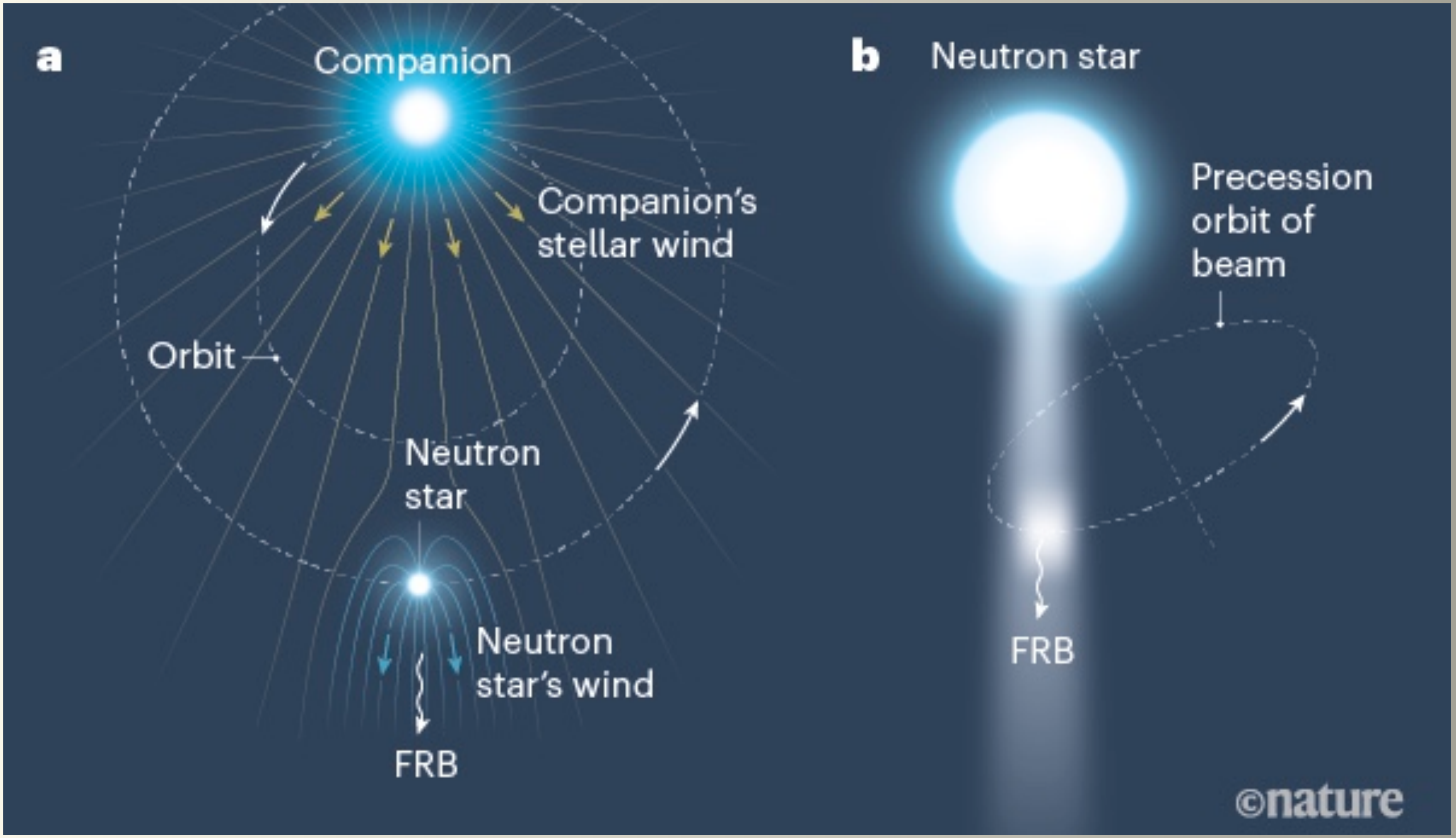


Fig. 1 | The transient parameter space showing radio luminosity, L_ν, on the vertical axis versus the product of observing frequency and timescale on the horizontal axis[95]. For illustrative purposes sensitivity curves for Galactic distances (0.1, 1 and 1 kpc) and various cosmological redshift values (0.1, 1, 2, 3 and 4) are shown that are appropriate for MeerKAT, or (to within the accuracy of the thickness of the lines) Parkes improved in gain by a factor of 3 (indicative of an upgrade involving a cooled PAF).

Keane, 2018



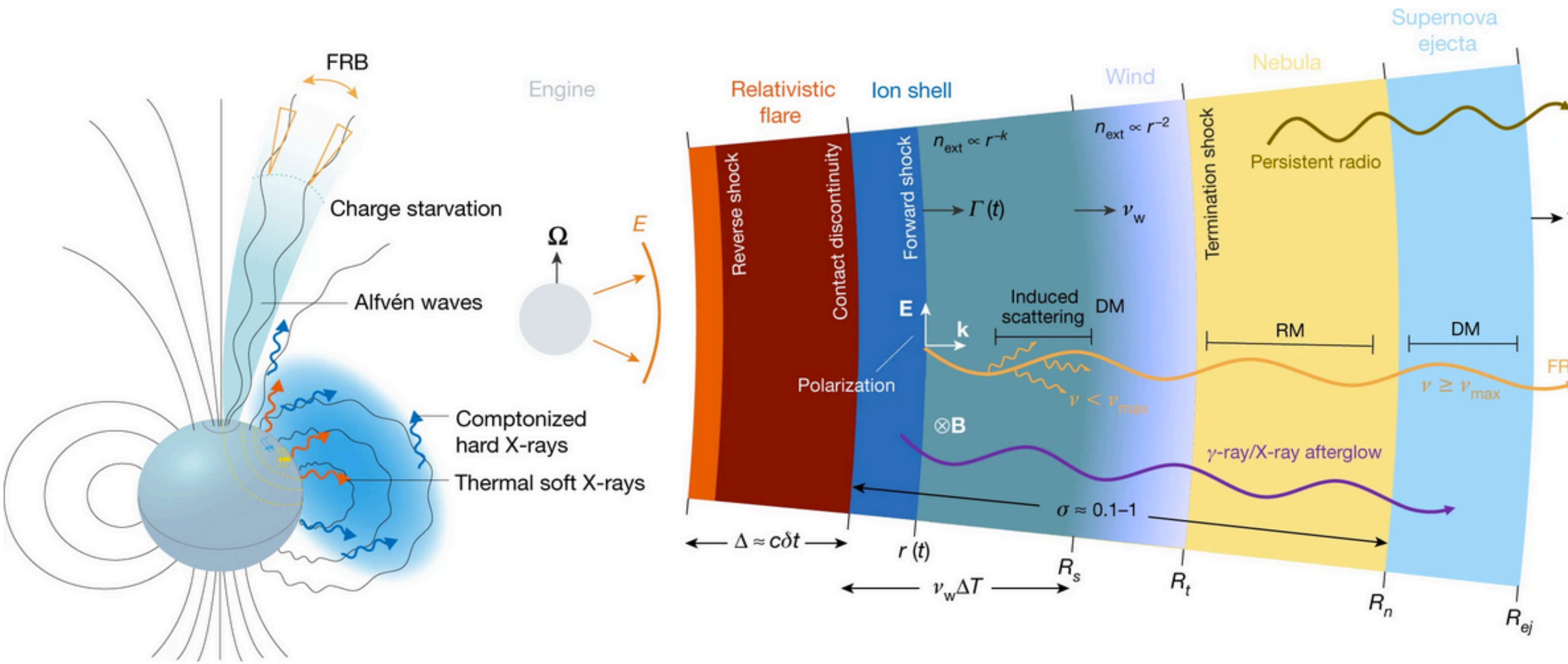
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
$DM/DM_{max\ NE2001}$
10^0
10^1
10^2
10^3
10^4
DM (cm^{-3} pc)
Pulsars
RRATs
SMC/LMC pulsars
FRBs



Two possible scenarios to explain the observed periodicity of a fast radio burst (FRB)

B. Zhang, News and Views, Nature, 2020

From: The physical mechanisms of fast radio bursts



a, Pulsar-like models that invoke the magnetosphere of a compact object[79]. **b**, GRB-like models that invoke relativistic shocks launched from a compact object[101]. Magnetars could be the common source for both models.