

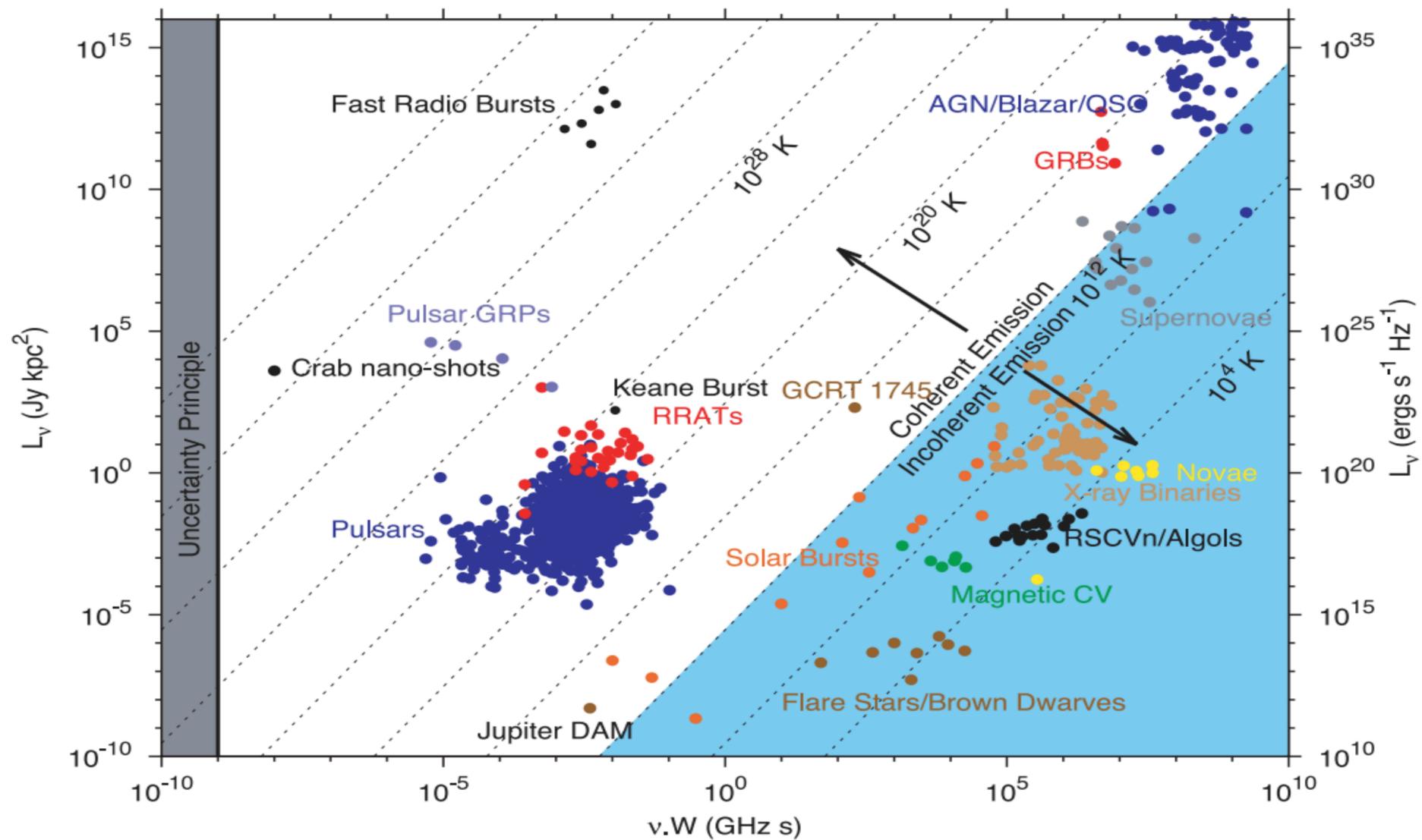
Fast and Slow(er) Radio Transients

the road from radio only to the full picture

Maura Pilia

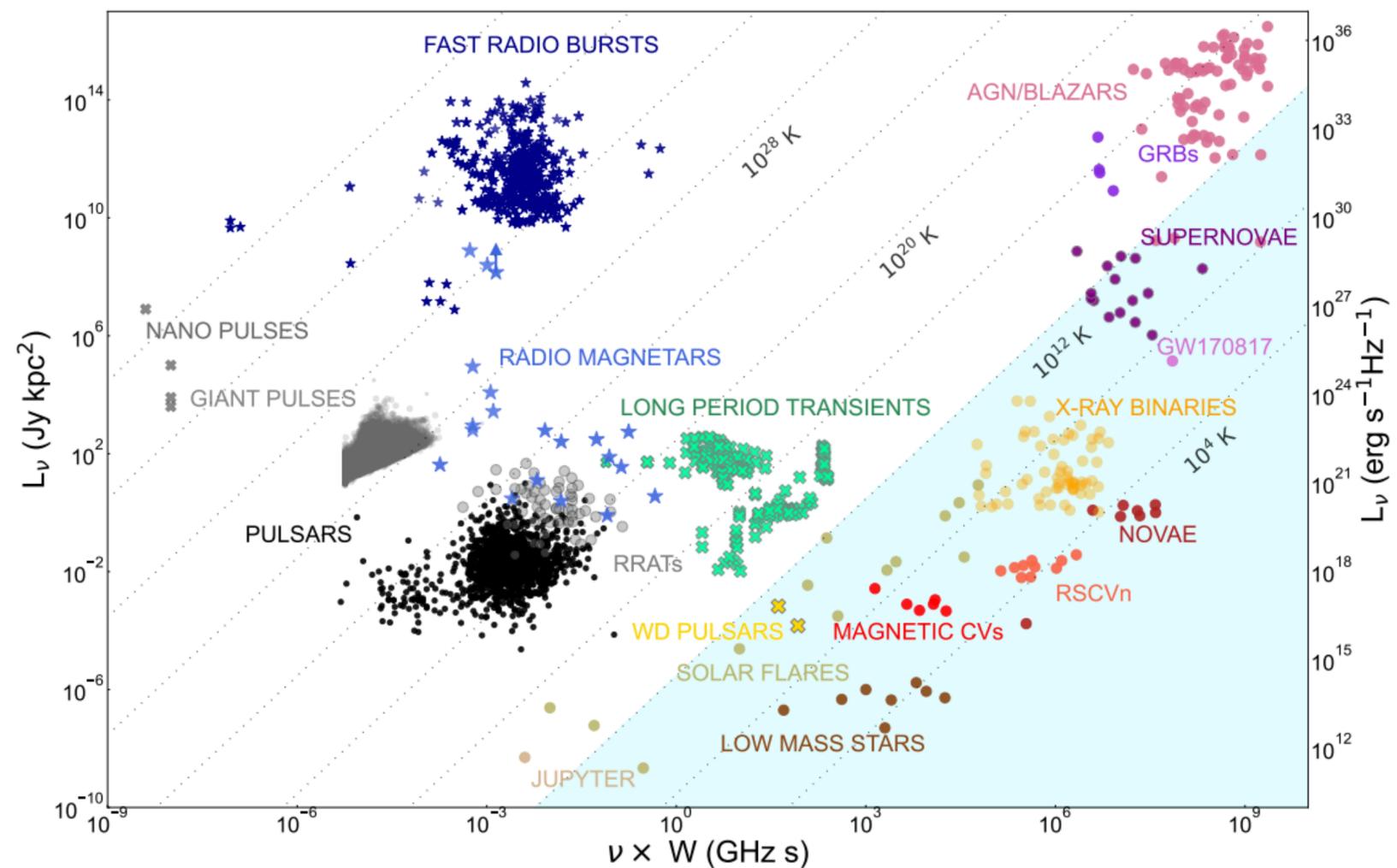
The transients phase-space

Pietka, Fender & Keane 2015



The transients phase-space

Rea, Hurley-Walker & Caleb 2026



How to look for transients?

PROF. SHRINIVAS KULKARNI



AWARDED A TOP HONOR:
Received the prestigious **Gold Medal** from the 200-year-old **Royal Astronomical Society** for transformative impact on astronomy.



www.astrophiles.in

MASTER OF THE CHANGING SKY



Kulkarni is a pioneer in time-domain astronomy, the study of fleeting cosmic events like exploding stars and novae.

BUILT REVOLUTIONARY SKY-SCANNERS



He led the creation of the Palomar Transient Factory (PTF) and Zwicky Transient Facility (ZTF), which have revolutionized how we observe the night sky.

LANDMARK COSMIC DISCOVERIES



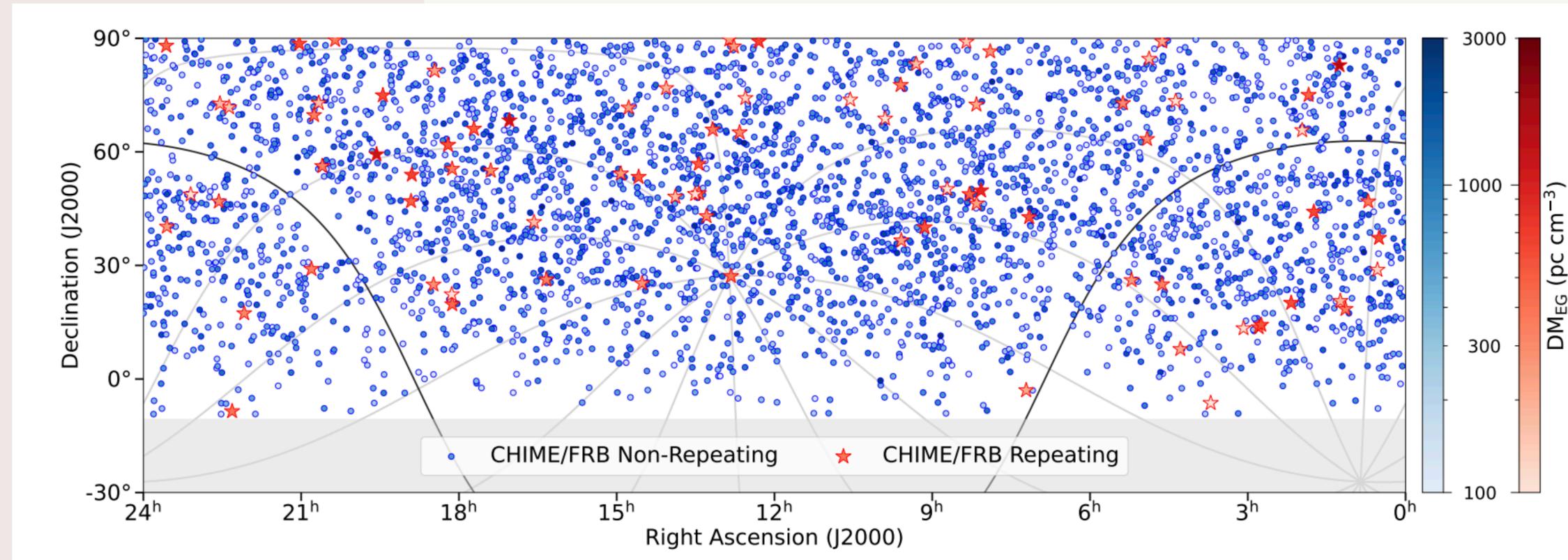
His achievements include discovering the first millisecond pulsar and proving that powerful gamma-ray bursts originate far outside our own galaxy.

Multi-messenger FRBs

Fast Radio Bursts

in pills

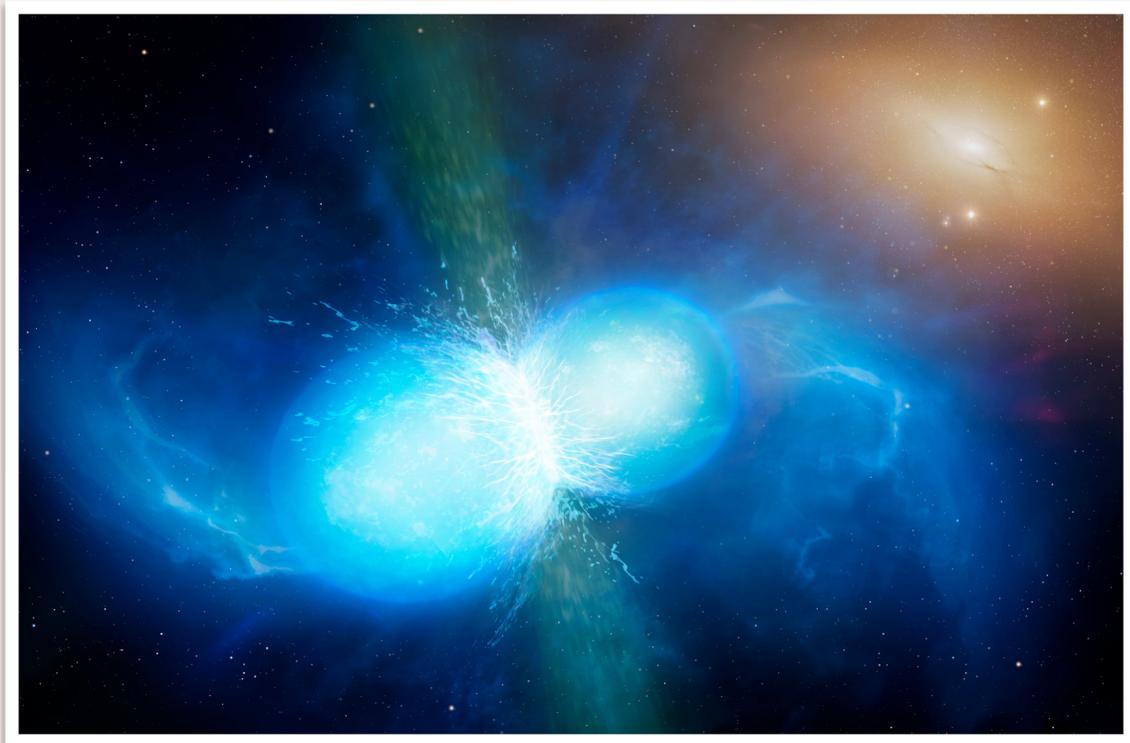
- ms-long events
- Energy $\sim 10^{36} - 10^{41}$ erg
- ~ 4500 known FRBs
- ~ 80 repeaters



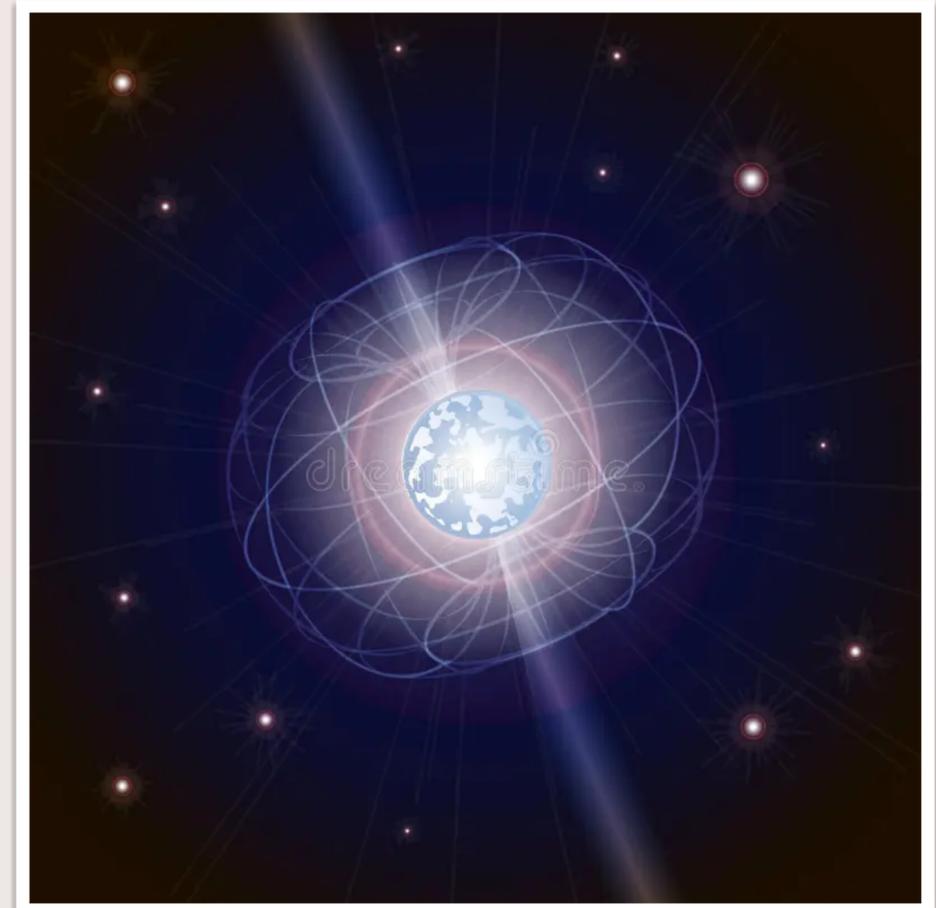
- One, two, more populations?

The CHIME/FRB Collaboration 2026

One-off FRBs



- BNS merger (Metzger, Berger & Margalit 2019)
- NS - BH merger? (Clarke et al. 2025)



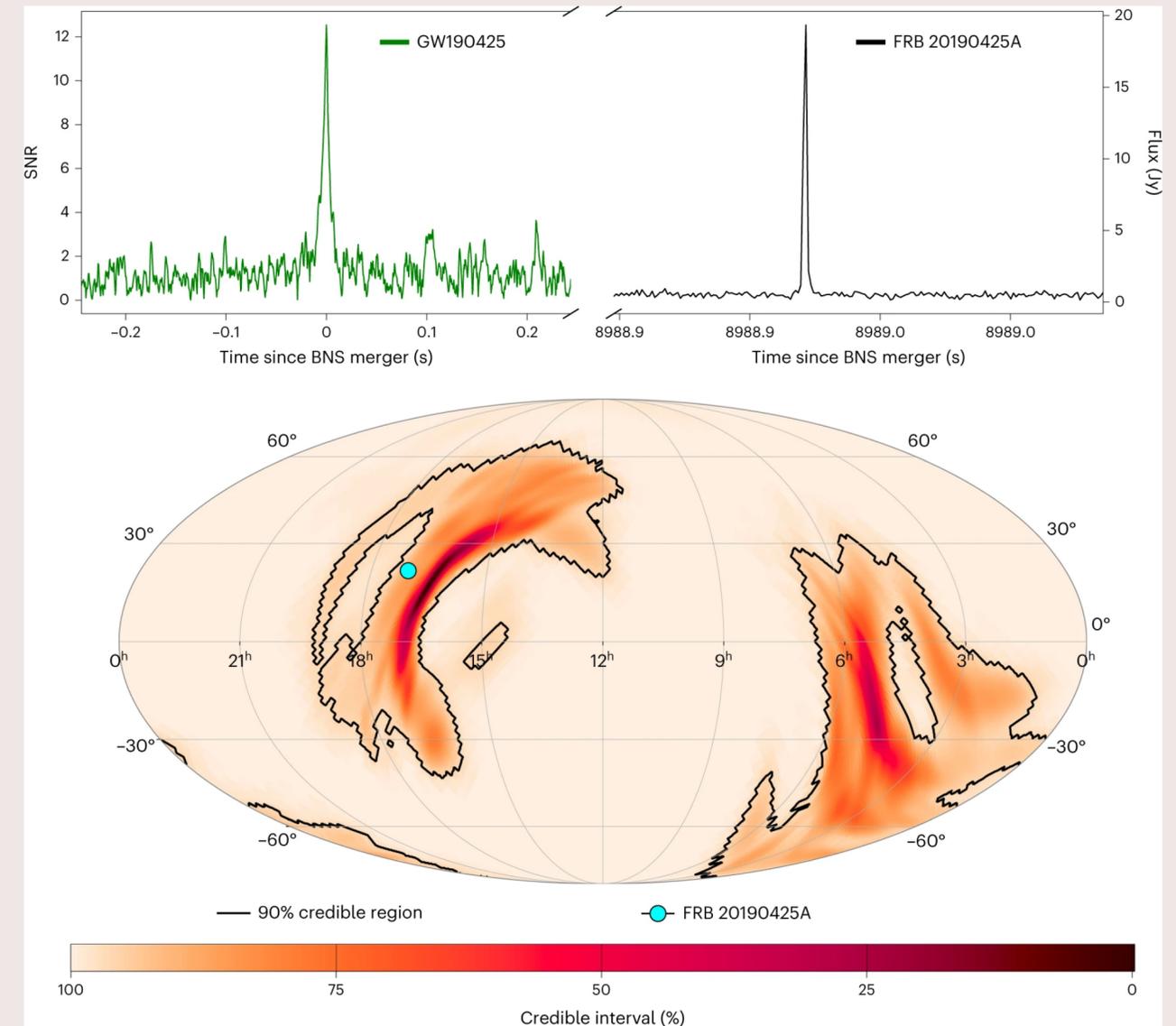
- Blitzar (Falcke & Rezzolla 2014)

The connection between FRBs and GWs (or GRBs)

FRB \longleftrightarrow GW

Moroianu et al. 2023

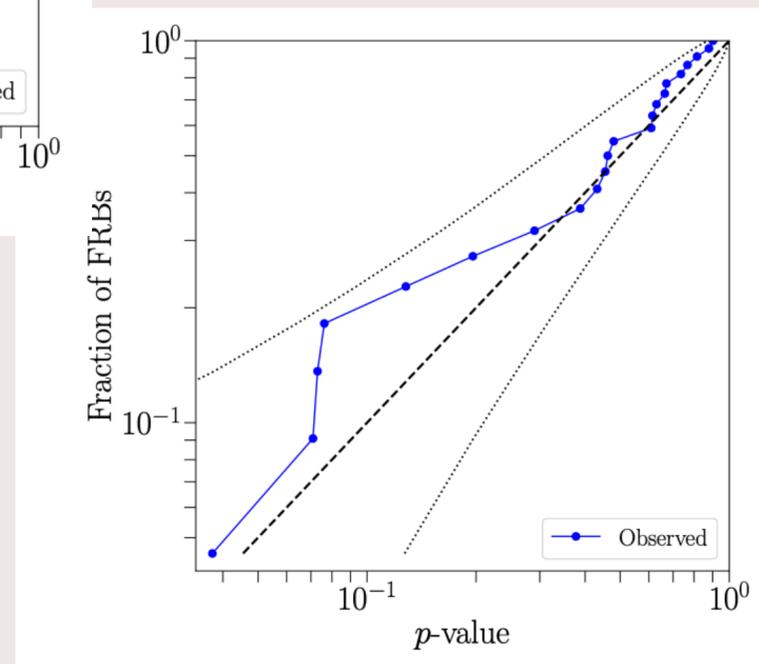
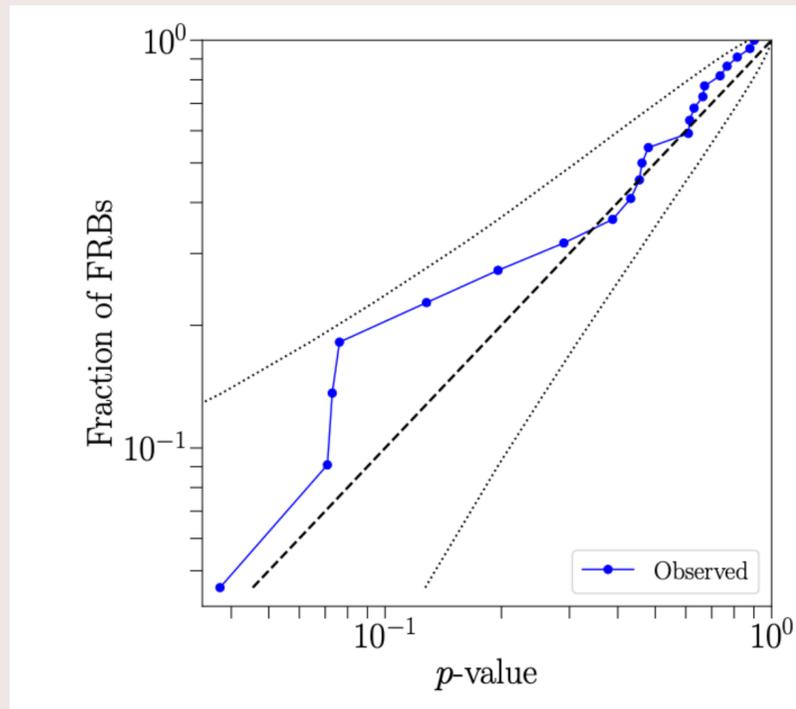
- Coincidences between O3 events and CHIME FRBs.
- -2h +24h
- One tentative association within the 68% localisation region of NSBH merger GW 190425 which was detected solely by Livingstone



FRB \longleftrightarrow GW

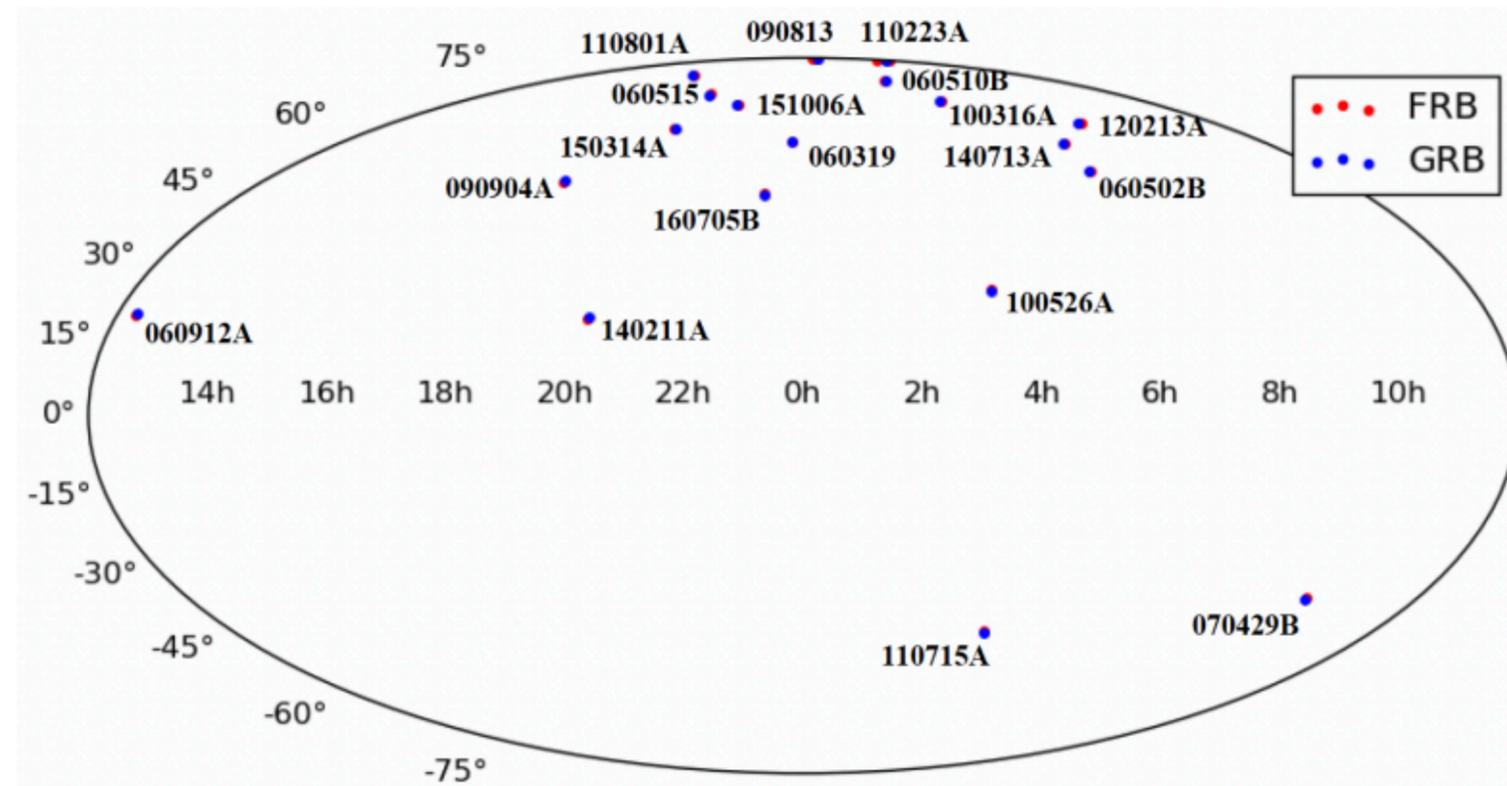
LIGO/Virgo Collaboration 2023

- In-depth reanalysis of CHIME FRBs events within the O3a data
- -600s +120s
- -600 +600 around FRB 20200120E
- Upper limits on GW energy based on FRB distance estimate ($\sim 10^{54} - 10^{55}$ erg)



GRB \longleftrightarrow FRB

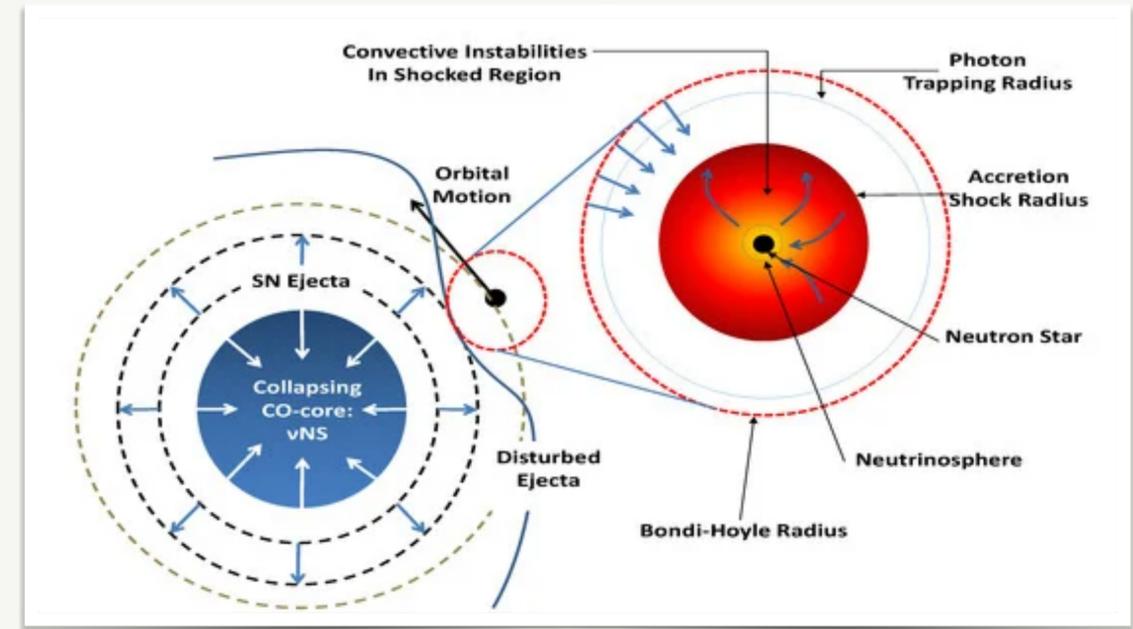
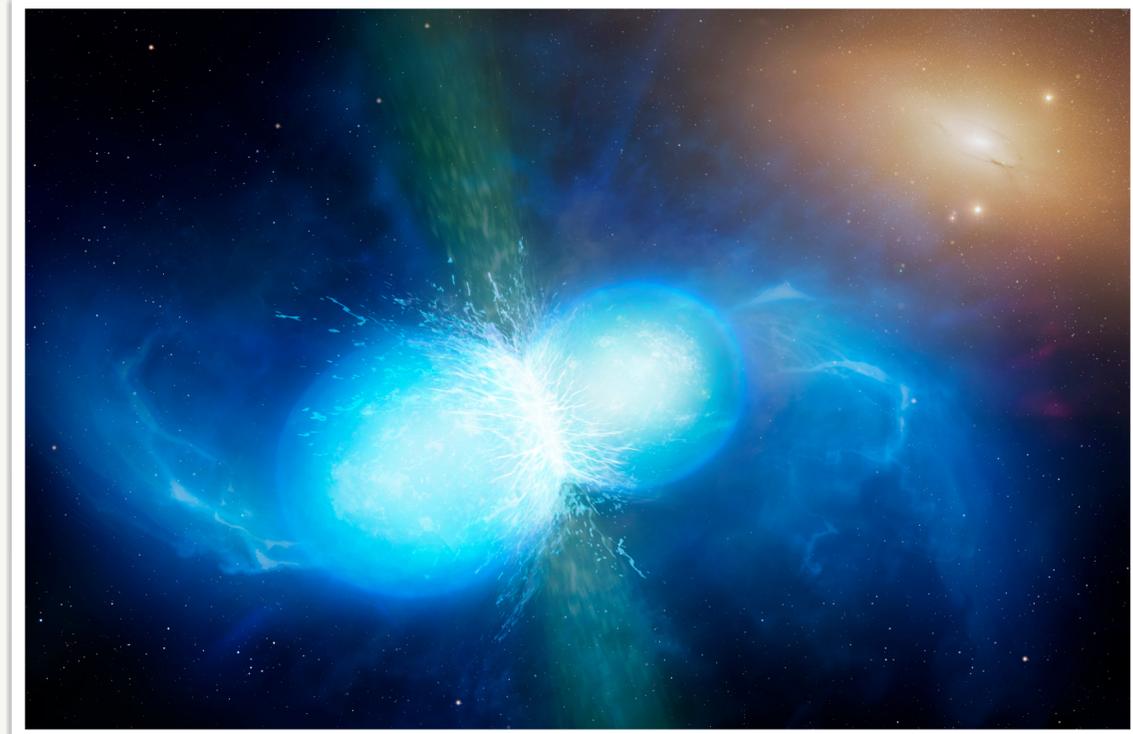
Patricelli, Bernardini. & Ferro 2024



A case for repeaters

The repeater scenario

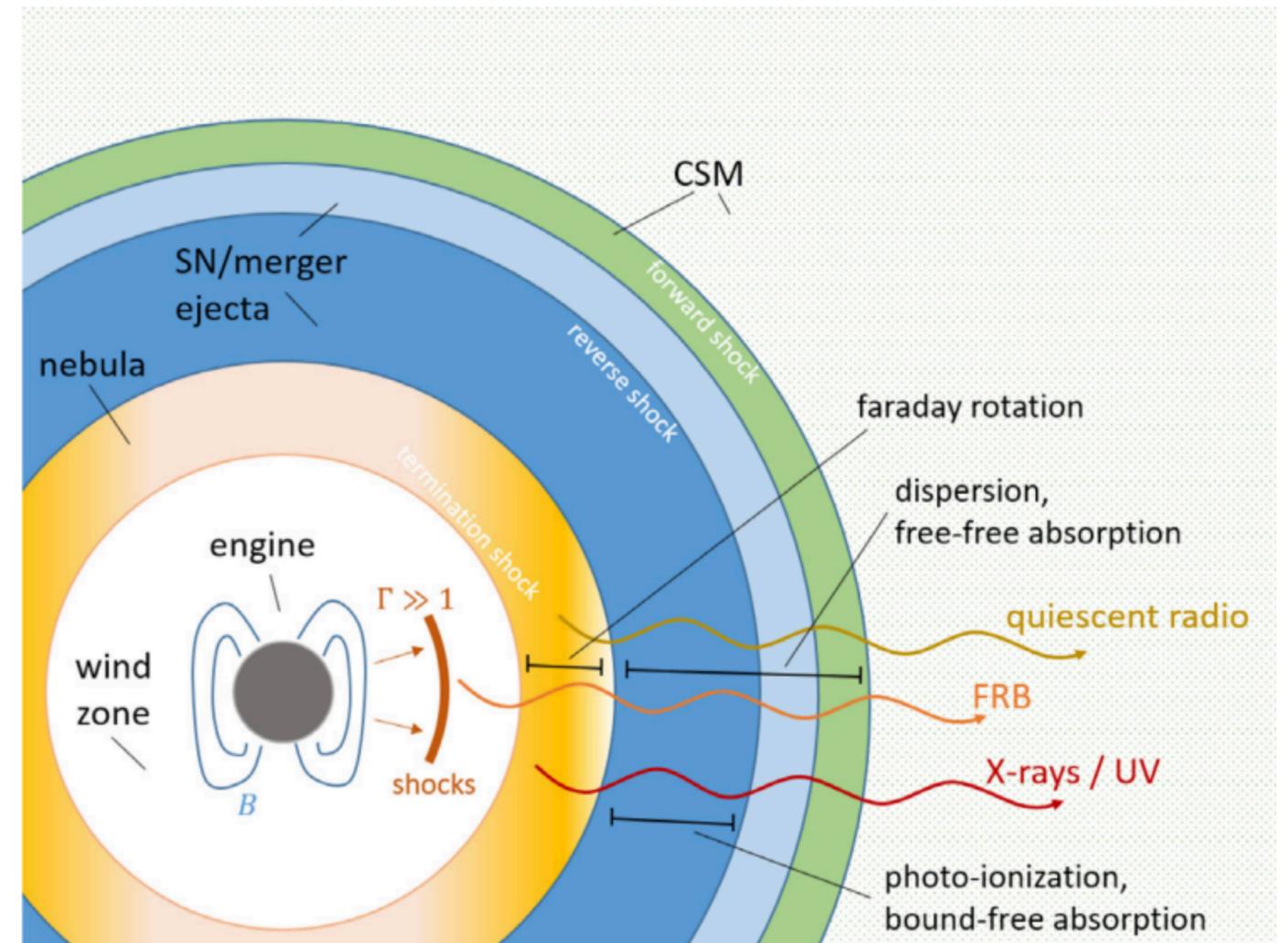
- Some time after the cataclysmic event the power source can turn on and we can be able to see it past the absorbing medium
- BNS
- AIC
- WD - WD
- (Metzger, Berger & Margalit 2019)



The central engine

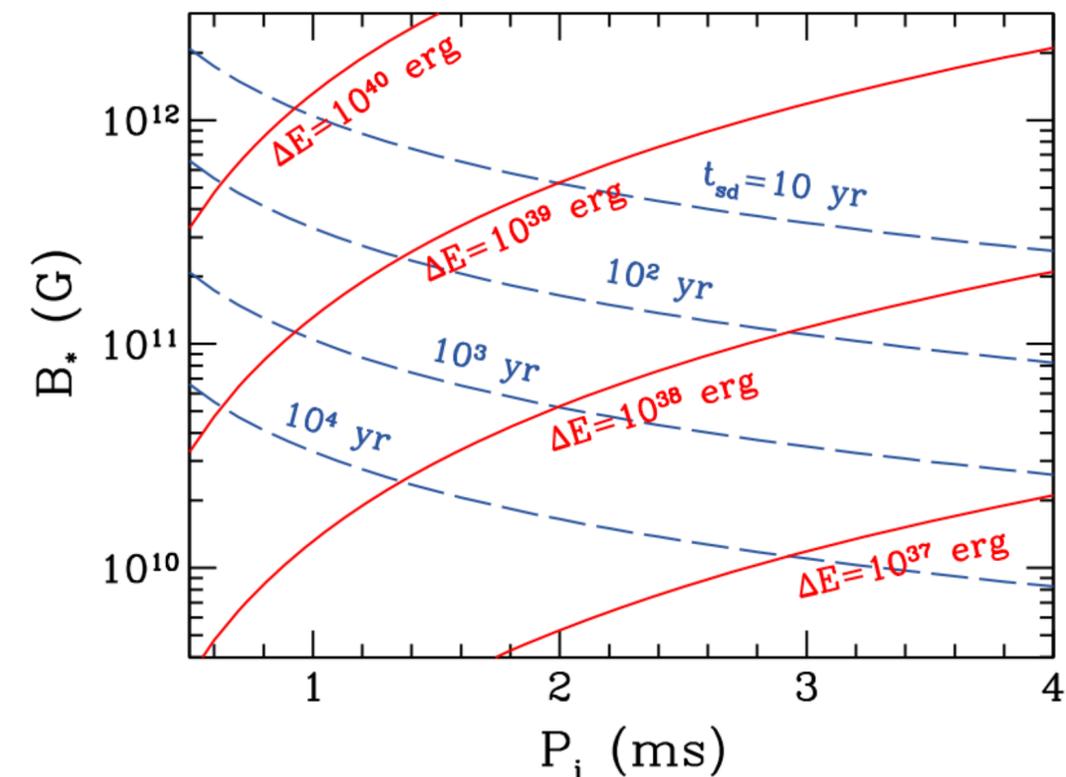
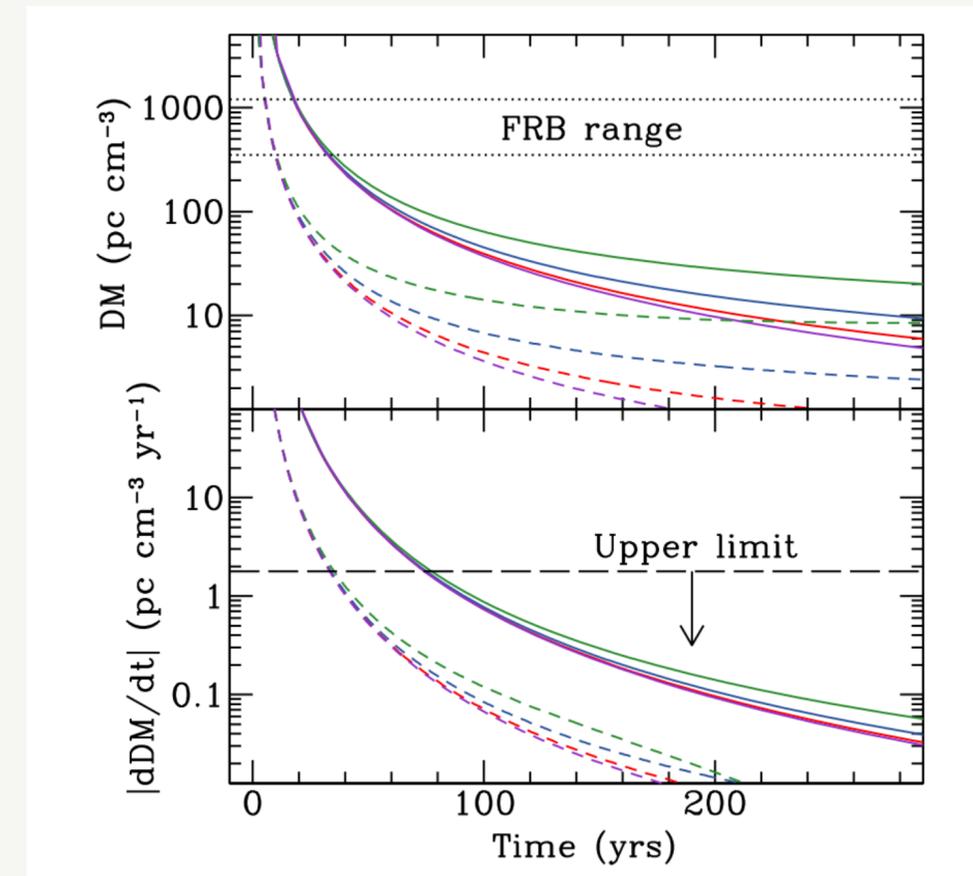
Margalit et al. 2018

We have examined the photoionization of homologously expanding ejecta by a central ionizing radiation source, with application to GRBs, Type I SLSNe, NS mergers (specifically GW170817), FRBs (focusing on the repeating source FRB 121102), and the very luminous transient ASASSN-15lh. These diverse phenomena share a commonality – the possibility that their driving power source is a newly born magnetar, or an otherwise similarly acting central engine like an accreting black hole.



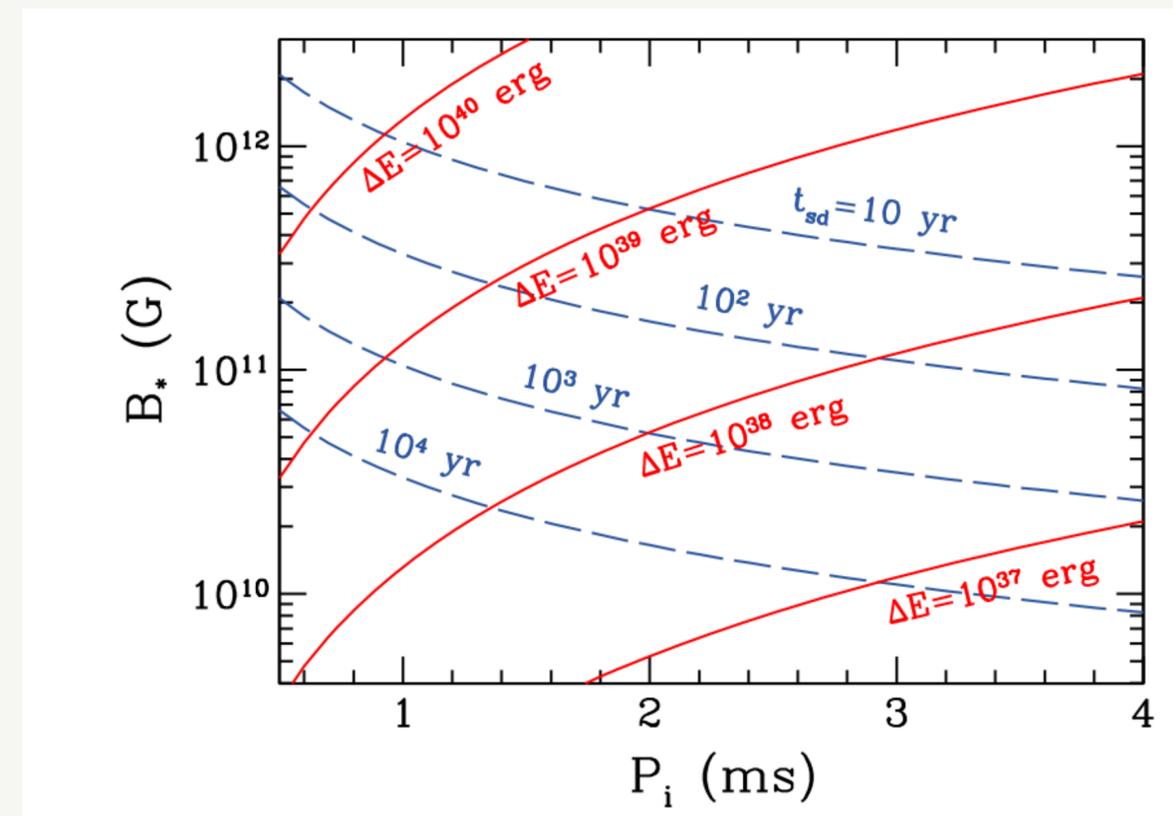
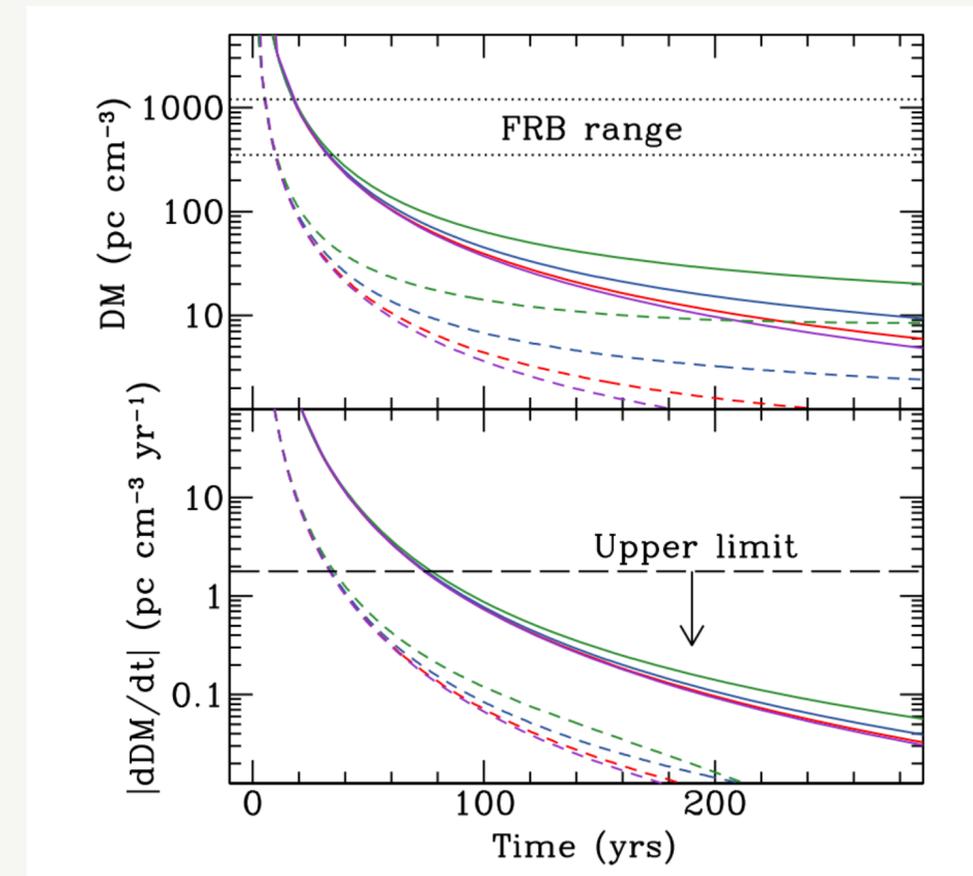
The repeater scenario

- Some time after the cataclysmic event the power source can turn on and we can be able to see it past the absorbing medium
- The times when DM is high are generally overshadowed by free–free absorption, which, depending on the mass of the ejecta and the density of the ISM, may be probed at frequencies of 400 MHz–1.4 GHz on timescales of ~100–500 years after the SN.



The repeater scenario

- Some repeaters appear to be very young and still possibly enshrouded in their wind nebula.
- These repeaters are a very limited class and, contrary to most, they emit preferentially at high radio frequencies.
- **SRT observations of the site of GW170817**



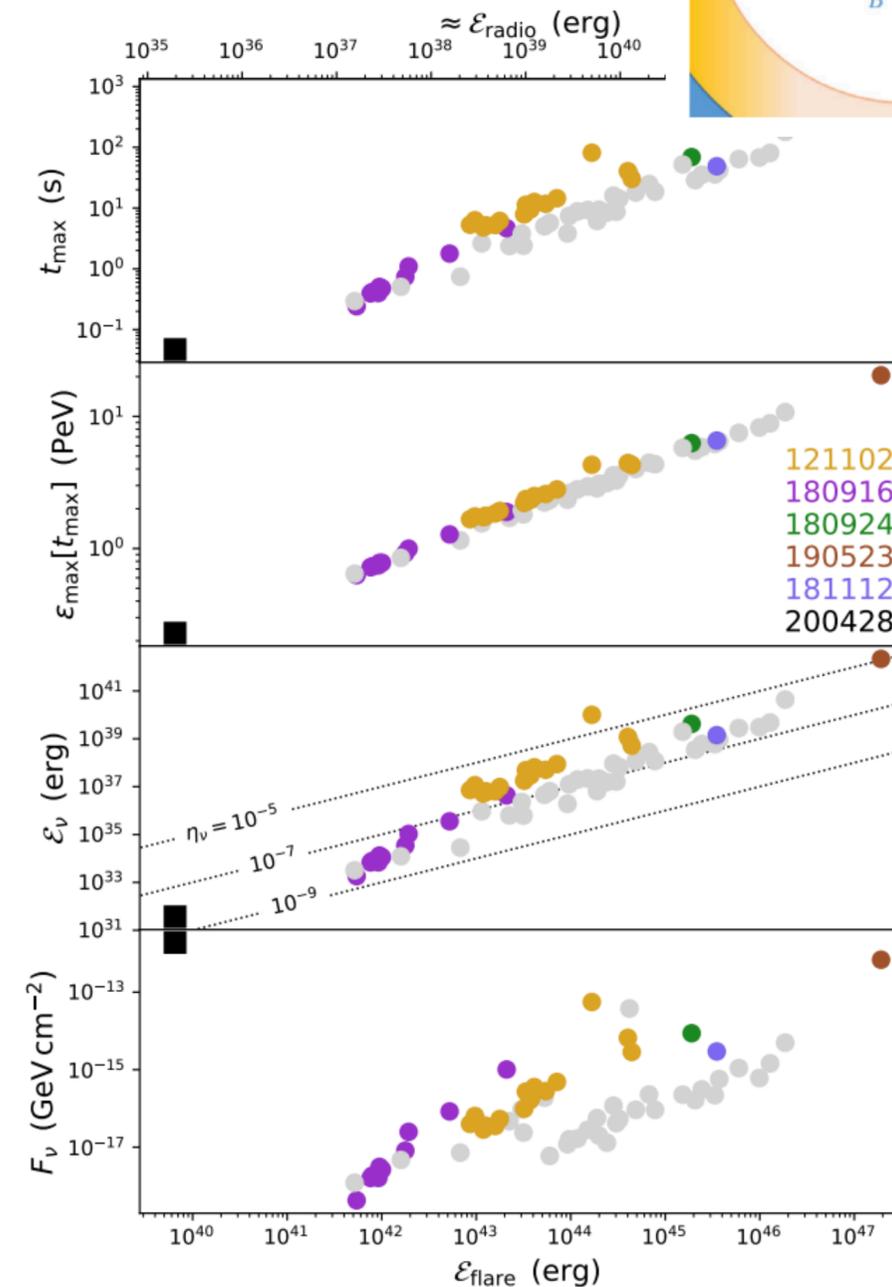
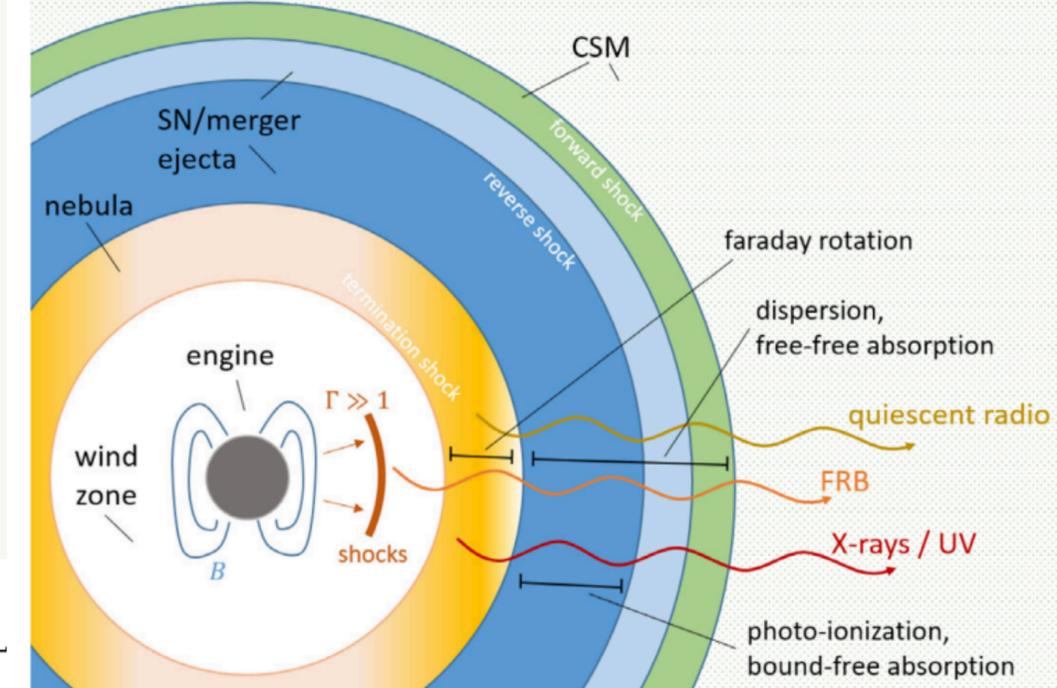
Neutrinos

Metzger, Fang & Margalit 2020

A unique prediction of baryon-loaded shock-powered FRB models (Metzger et al. 2019; Margalit et al. 2020b) are neutrinos generated by ions heated or accelerated at the shock interact with thermal synchrotron shock photons via the photo-hadronic process.

We predict a burst of \sim TeV–PeV neutrinos of total energy $E_\nu \approx 10^{35} - 10^{44}$ erg (depending most sensitively on the FRB isotropic energy; eq. 36) which lasts for a timescale $t_{\max} \sim 0.1 - 1000$ s (eq. 25) following the radio burst (once accounting for the time delay due to the finite propagation speed of the radio waves as inferred from the dispersion measure). Our calculations make several optimistic assumptions.

Although the detection prospects with present neutrino observatories are extremely challenging (to put it lightly), the detection of even a single neutrino from an FRB would be a smoking gun for this model. The most promising potentiality is a giant flare from a nearby Galactic magnetar with the fortuitous geometry of the shock-generating plasmoid being directed along our line of sight.



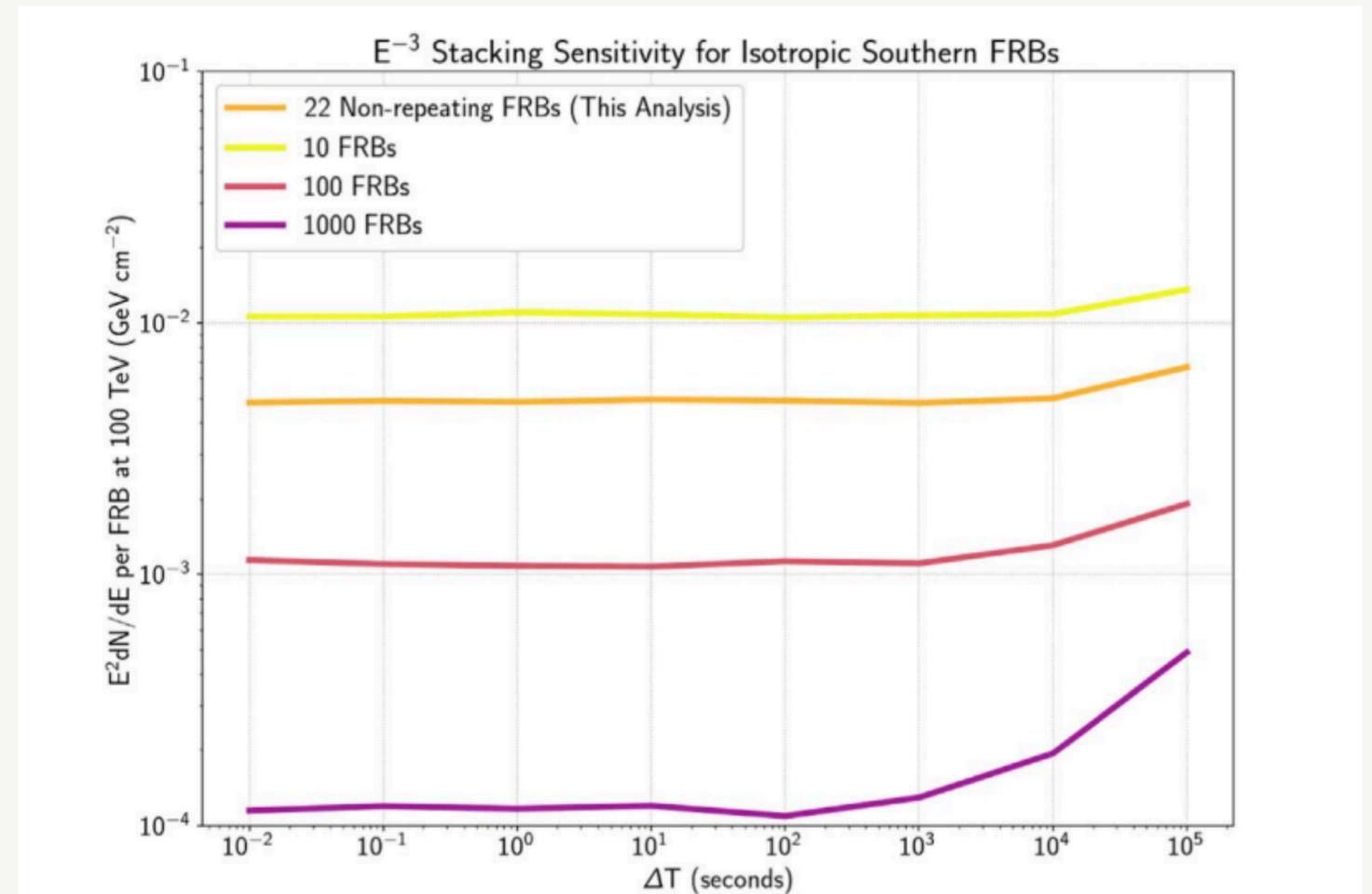
Neutrinos

Abbasi et al. 2023

A search for coincidences in seven years of IceCube data

In two independent searches for neutrino emission from 22 unique, nonrepeating FRBs and 26 unique bursts from FRB 121102, no significant correlation was found. We provide upper limits on the time-integrated neutrino flux at the 90% confidence level for various spectral indices.

Overall, this analysis shows that cascades offer sensitive upper limits when performing transient stacking searches. Given that cascades have a low background rate and are considered independent of track events, IceCube's future analyses would benefit from combining track and cascade events when searching for time-dependent neutrino emission from FRBs.

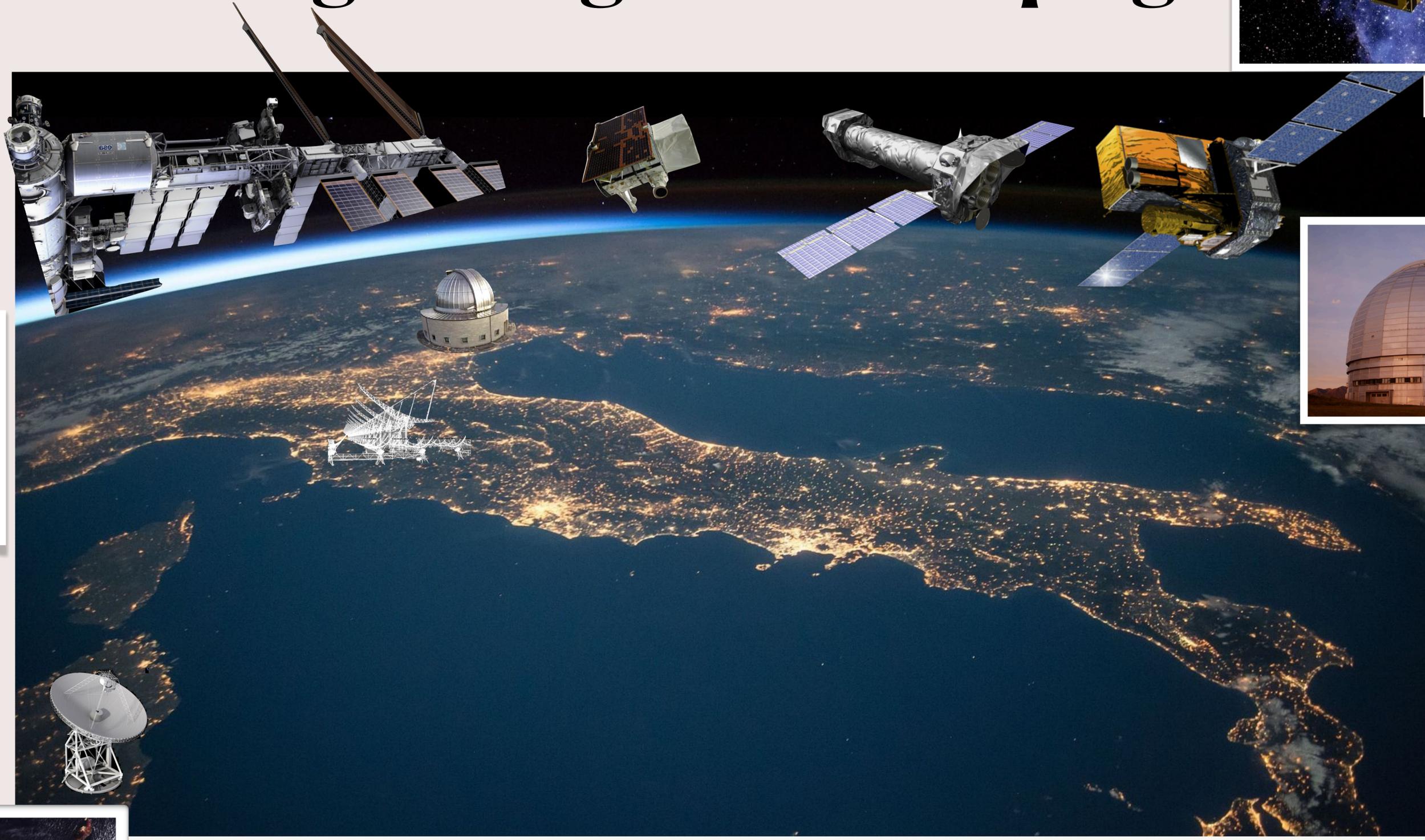


The study of FRBs can benefit from multi-wavelength/messenger follow-up providing much needed insights from another perspective

The study of FRBs can complement current studies of multi-messenger phenomena as it seems they can be related to the same/similar progenitors

GRAWITA 2.0 and FRBs

A long-lasting MWL campaign



CHIME Fast Radio Burst Notices

The CHIME Team and the GCN Team are pleased to announce the availability of a new CHIME Fast Radio Burst (FRB) notice type via the [new GCN](#) in JSON format. We welcome this new transient type to the GCN community and encourage follow-up observations. These notices can be streamed via [Kafka](#). They are not available via GCN Classic.

The [Canadian Hydrogen Intensity Mapping Experiment \(CHIME\)](#) is a transit radio telescope located in Penticton, BC, Canada. It consists of 4 semi-cylindrical reflectors, each with 2000 square meters of collecting area and 256 dual-polarization antennas. The telescope observes between 400 MHz and 800 MHz and covers an instantaneous field of view of ~200 square degrees. CHIME houses several electronic backends, which are tailored for specific scientific goals, such as generating cosmological maps of hydrogen density, detecting Fast Radio Bursts, and observing and timing pulsars. In particular, the FRB backend operates at ~1 ms time resolution and ~ 0.4 MHz frequency resolution.

The new CHIME notices provide FRB detection details including ~arcminute localization with a latency of ~1 minute. The detection rate is ~600 per year. Notices will be distributed on the Kafka topic:
`gcn.notices.chime.frb`

A more extensive description of the information provided in these new notices is available at <https://gcn.nasa.gov/missions/chime>

DSA-110 Fast Radio Burst Notices

The DSA-110 Team and the GCN Team are pleased to announce the availability of DSA-110 notice types via the [new GCN](#) in JSON format. These notices can be streamed via [Kafka](#).

The [Deep Synoptic Array-110 \(DSA-110\)](#) is a radio interferometer purpose-built for fast radio burst (FRB) detection and direct localization. The array is located at the [Owens Valley Radio Observatory \(OVRO\)](#) comprised of 96 4.65-m dishes that continuously survey for FRBs at frequencies between 1280 to 1530 MHz. Over a three-year science program, the DSA-110 will deliver a sample of more than 300 FRBs, each localized to regions ~1 arcminute radius within 1 minute of detection. This is made possible by a suite of novel instrumentation, including precisely engineered antennas, ultra-low noise ambient-temperature receivers, and a powerful real-time, autonomous data-analysis system.

A bright future

Iqueye @ Gemini South



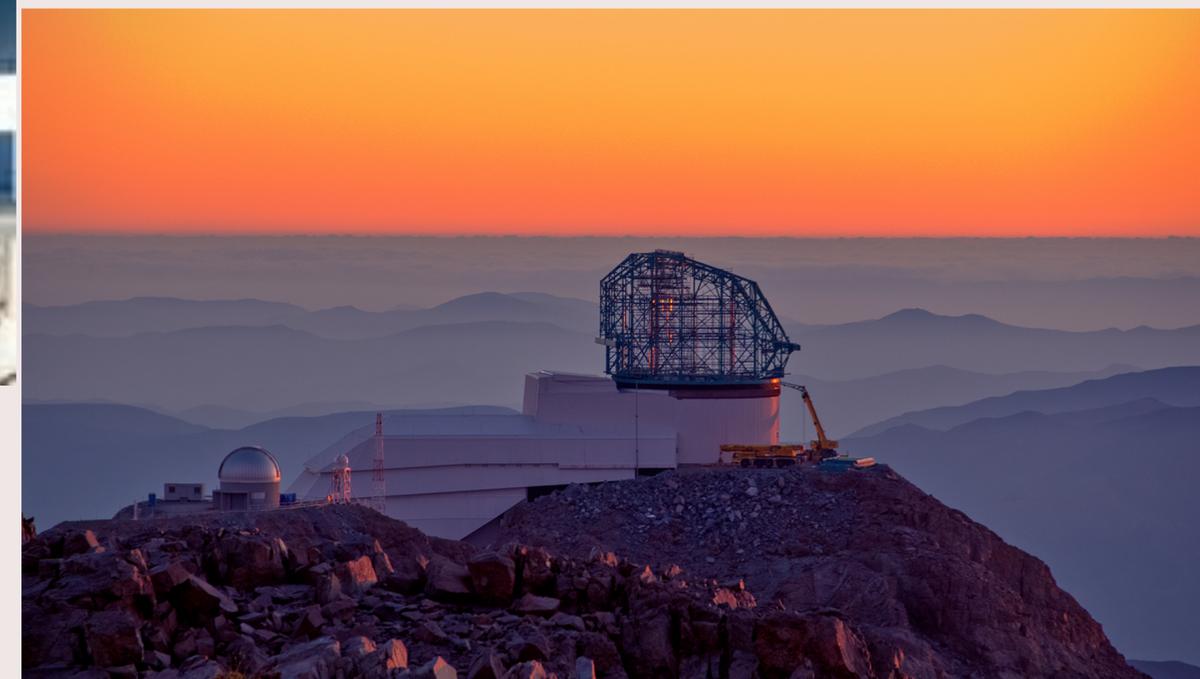
A bright future

SOXS @ NTT



A bright future

Vera Rubin

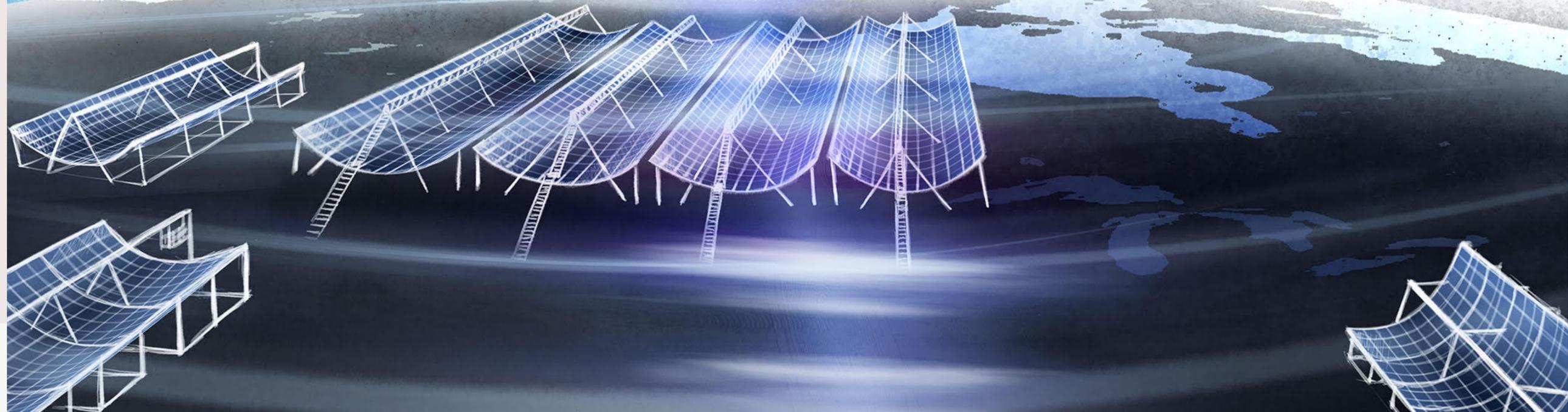


Localising FRBs

Cosmology with FRBs

Dispersion Measure

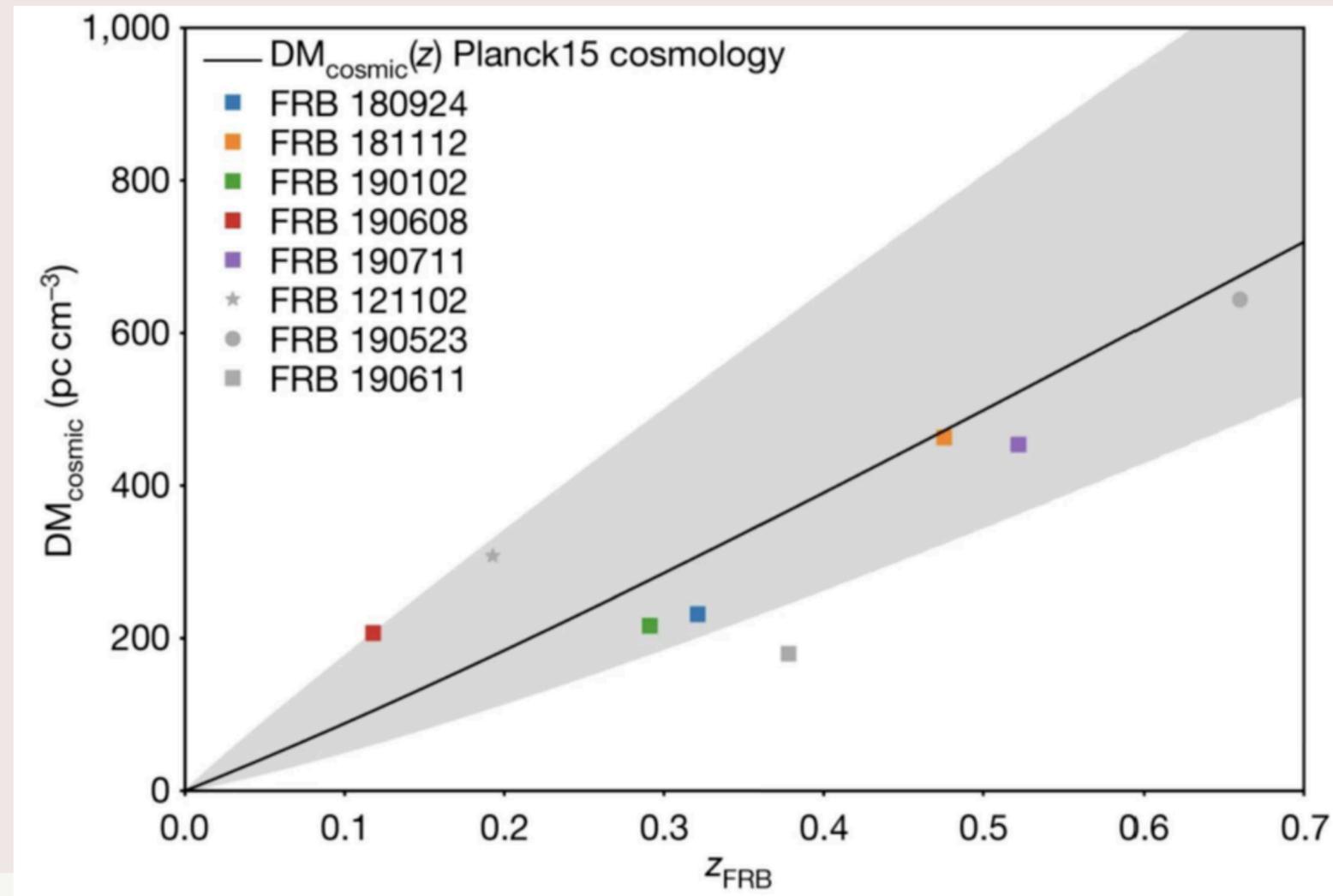
$$DM = DM_{MW} + DM_{cosmic} + DM_{host}$$



Cosmology with FRBs

Macquart et al. 2020

$$DM = DM_{MW} + DM_{cosmic} + DM_{host}$$



FRBs and their host galaxies

146 FRB hosts

catsweb.oas.inaf.it

The screenshot shows the INAF TOcats HiPS catalogues browser interface. The main view is a sky map showing 146 objects in a field, with a central galaxy. The interface includes a search bar, a table of objects, and a detailed view of a selected object.

DB Table: **hosts_and_frb_full** – 0.001434 objs/deg² > Upload

Ref. Cat. **Hosts+FRB full params** Options

Show 10 entries Search:

Label	RA	Dec	z	Sep
20200428A	293.7500	21.9000	0.000e+0	4449.2
20200120E	149.4780	68.8169	1.300e-4	8035.1
20181030A	158.5962	73.7650	0.00385	7901.5
20250316A	182.4479	58.8489	0.006354	7017.9
20200723B	190.1538	-5.1328	0.008469	4027.4
20171020A	333.8531	-19.5853	0.00867	4191.8
20220319D	32.1700	71.0360	0.0112	8688
20221022A	48.5887	86.8658	0.0149	8111.2
20231229A	26.4677	35.1078	0.019	8578.7
20240210A	8.7770	-28.2721	0.023686	5252.9

Showing 1 to 10 of 146 entries

Selected objects

- 2. **hosts_and_frb_full** 22:15:24.75 -19:35:07.0 (333.853125, -19.585280)
FRB: 20171020A z: 0.00867 Sep: 4191.8' (70°)
Select & center here Select **Tools**
- 1. **hosts_and_frb_full** 12:40:36.92 -05:07:58.0 (190.153830, -5.132769)
FRB: 20200723B z: 0.008469 Sep: 4027.4' (67°)
Select & center here Select Tools

Additional tools

Custom listing

List server list of fields to retrieve order by

https://catsweb.oas.inaf.it/?catname=hosts_and_frb_full&coords=253.645,-42.362&radius=10800&project_name=frbhosts&pri

Credits: L. Nicastro

Cinus et al. in prep.

FRBs and their host galaxies

FRB 20200723B

INAF TOCats – HiPS catalogues browser, V. 2.3 – Developed using DIF and Aladin Lite v3.6

frbusr@frbhosts Sign out

253.645 -42.362 11000 Where SQL clause DB Table: hosts_and_frb_full – 0.001434 objs/deg² Upload

Ref. Cat. **Hosts+FRB full params** Options

Show 10 entries Search:

Label	RA	Dec	z	Sep
20200428A	293.7500	21.9000	0.000e+0	4449.2
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Showing 1 to 10 of 146 entries

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FRB: 20200723B z: 0.008469 Sep: 4027.4' (67°)
Select & center here Select Tools

hosts_and_frb_full

- _id: 33
- FRB: 20200723B
- GaID: NGC 4602
- RAJ2000s: 12:40:36.92
- DEJ2000s: -05:07:58.0
- RA_deg: 190.15383
- Dec_deg: -5.132769
- errRA: 0.0185
- errDec: 0.0193
- ref_coord: PanSTARRS
- E(B-V): 0.0207
- z: 0.008469
- err_z: 1.500e-4
- ref_z: NED
- P_host: 0.985
- ref_P_host: Shin2024
- Semixis_a: 271
- err Semixis_a: 10
- Semixis_b: 102
- err Semixis_b: 10
- PosAngle: 100.73
- errPosAngle: 1
- Reff:
- errReff:
- Reff_kpc:
- errReff_kpc:
- Morphology: Sp
- ref_morph:
- g-Mag:
- err_g-Mag:
- ref_g-Mag:
- r-Mag:
- err_r-Mag:
- ref_r-Mag:
- i-Mag:
- err_i-Mag:
- ref_i-Mag:

List server list of fields to retrieve order by

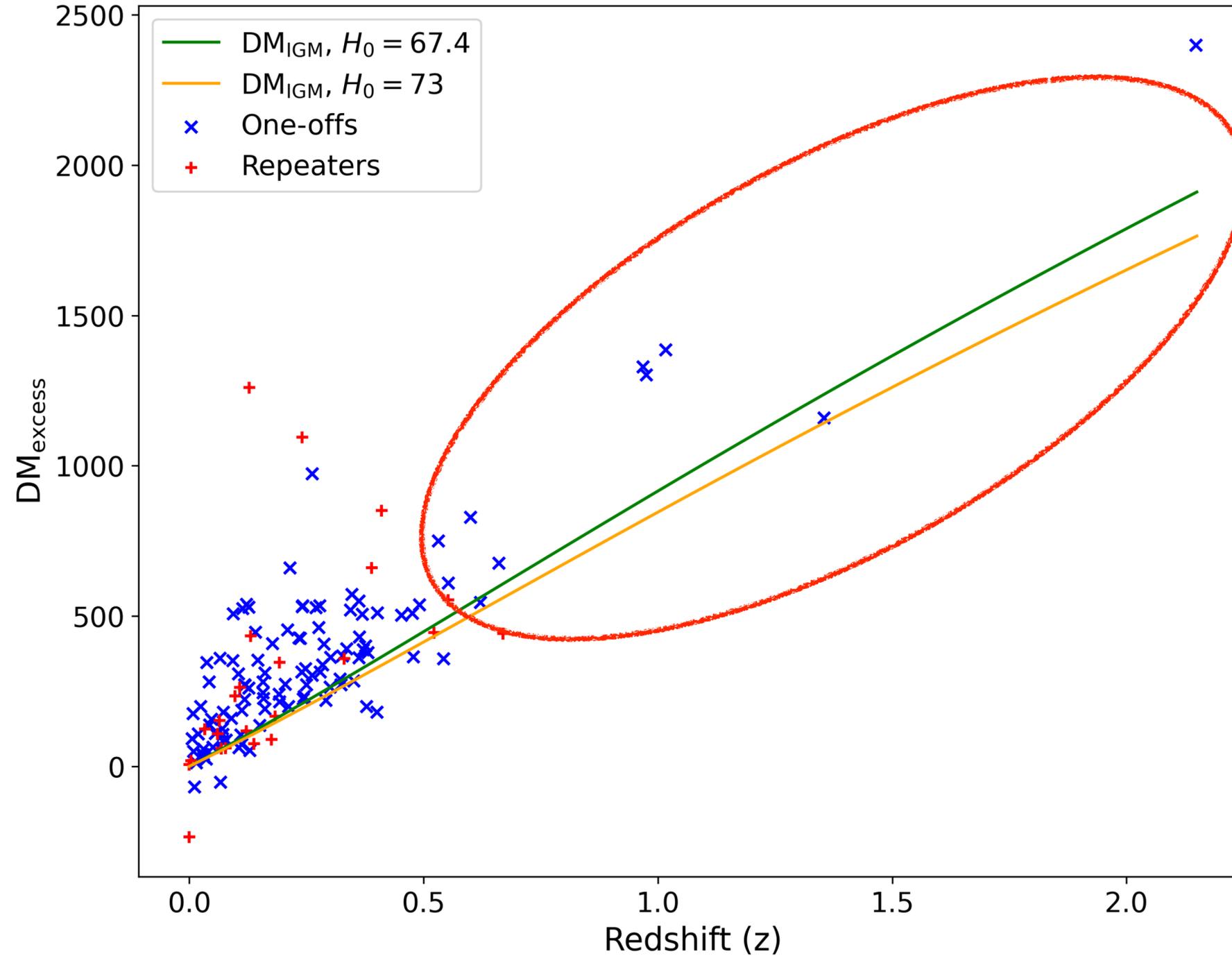
Share URL of current view (refreshed at each Redraw):
https://catsweb.oas.inaf.it/?catname=hosts_and_frb_full&coords=253.645,-42.362&radius=10800&project_name=frbhosts&pri

FRB uncertainty reg.

Credits: L. Nicastro

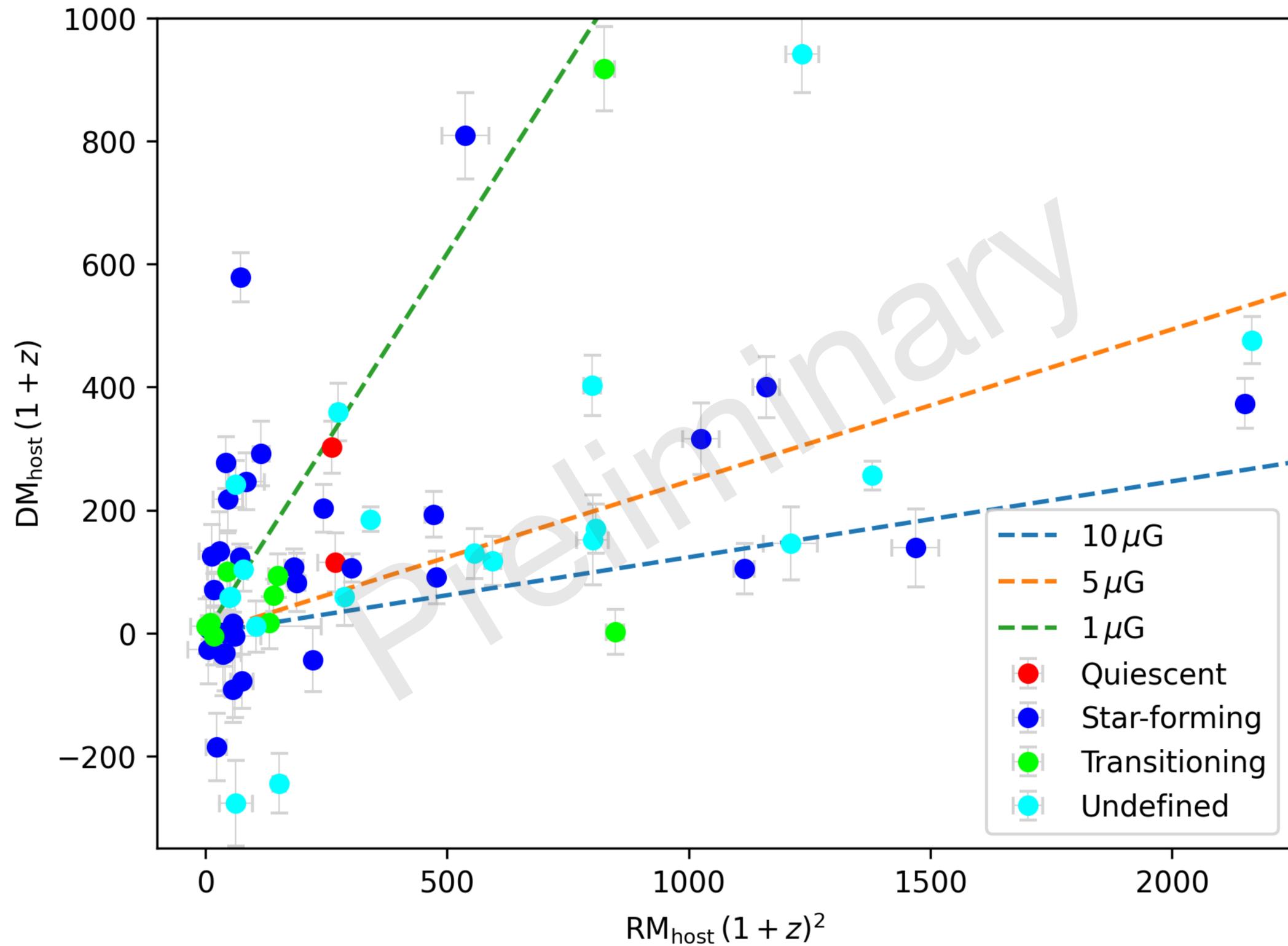
$$DM = \cancel{DM_{MW}} + DM_{cosmic} + DM_{host}$$

$$DM \equiv \int_0^{z_{FRB}} \frac{n_e(z)}{1+z} \frac{c}{H(z)} dz$$

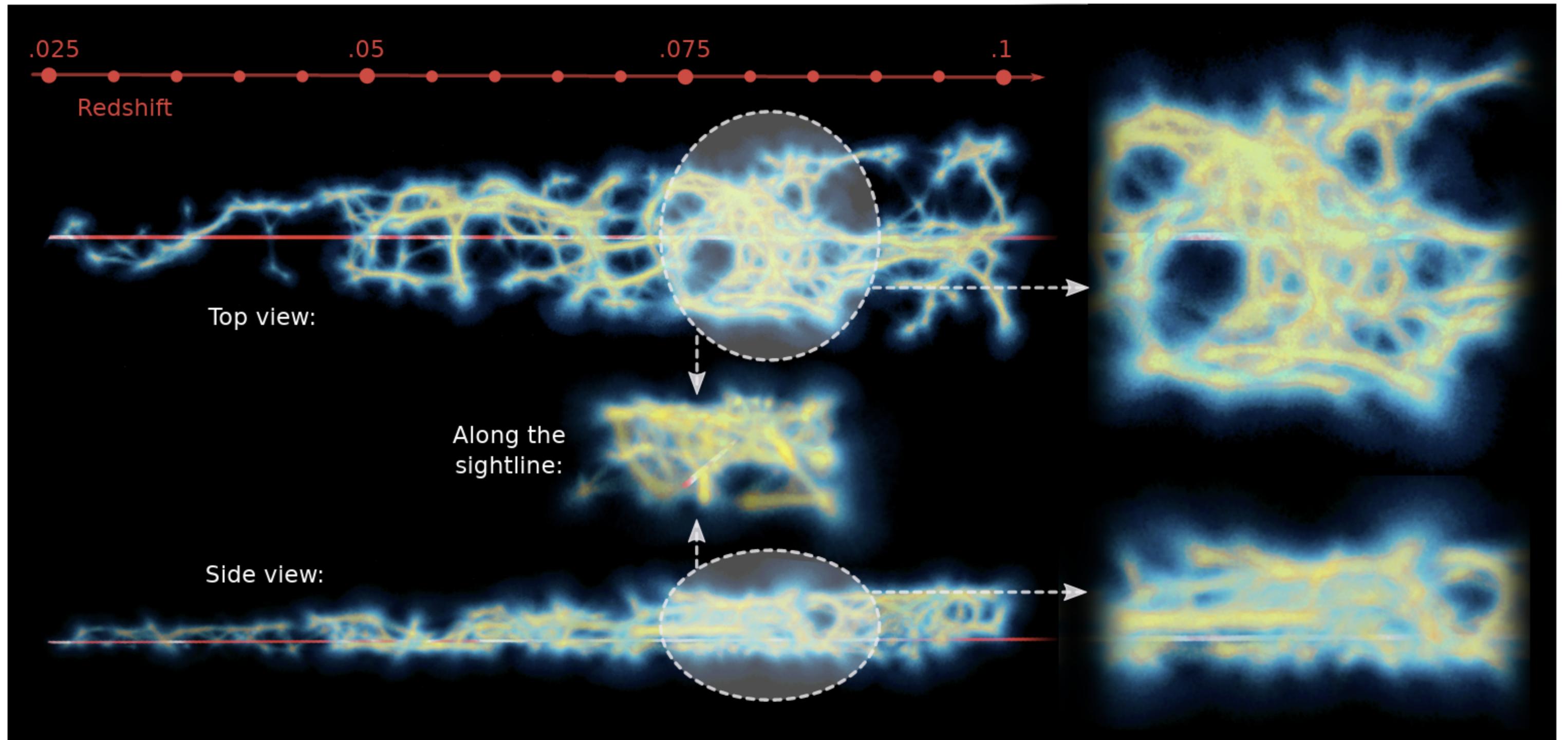


Credits: M. Cinus

$$DM = \cancel{DM_{MW}} + DM_{cosmic} + \cancel{DM_{host}} \quad ?$$



Tomographic reconstruction of the cosmic web (SDSS map) intercepted by the sightline of FRB 20190608B

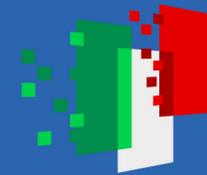




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dell'Università
e della Ricerca



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DI RIPRESA E RESILIENZA



INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

The Canadian Hydrogen Observatory and Radio transient Detector

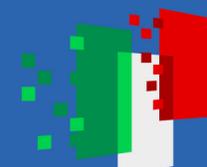




Finanziato dall'Unione europea
NextGenerationEU



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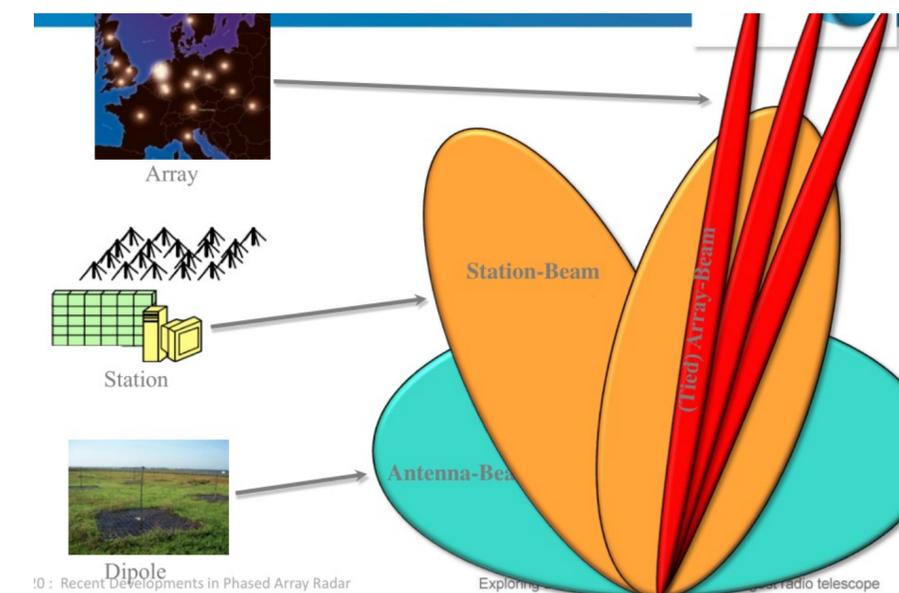
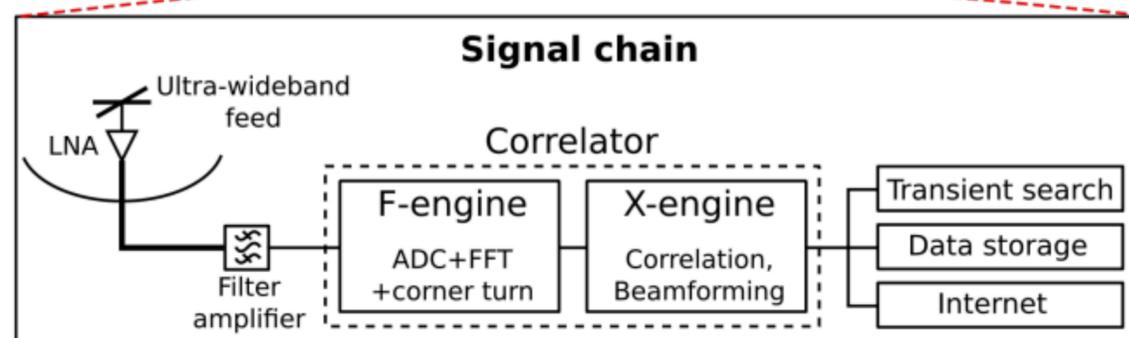
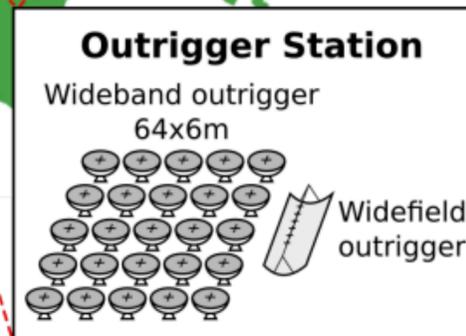
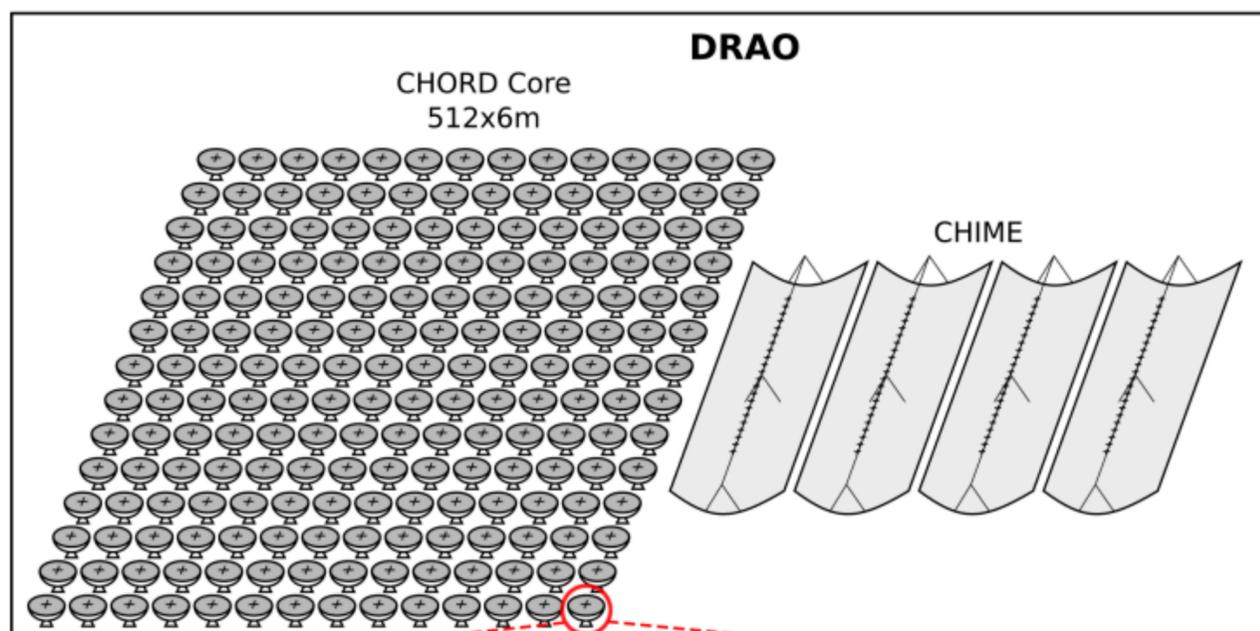


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INAF
ISTITUTO NAZIONALE DI ASTROFISICA

The importance of interferometry



Vanderlinde et al. 2020, CASCA

Credits: Bij de Vaate

The CHORD telescope

Dishes 512 x 6-m

SEFD ~ 10 Jy

Band 300 - 1500 MHz

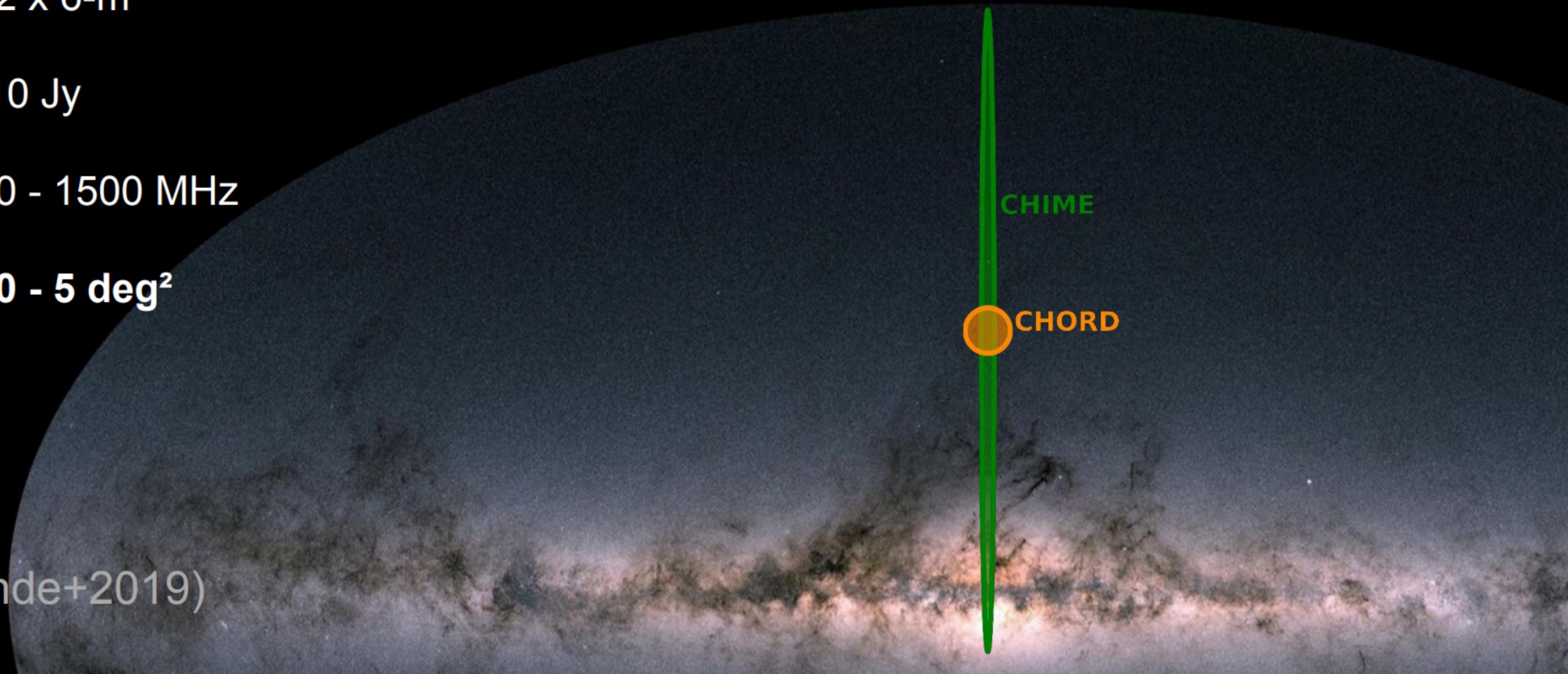
FoV 130 - 5 deg²

@ 600 MHz

CHIME

CHORD

(Vanderlinde+2019)



Roadmap

Pathfinder
64 dishes



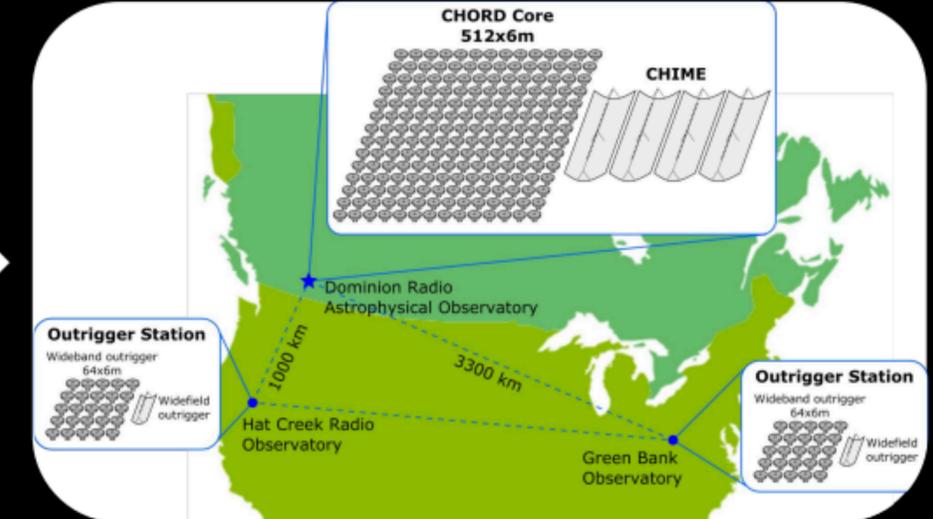
Spring 2026
Early science

Full array
512 dishes



End of 2027
Full sensitivity

Outrigger stations
64 dishes each



2028?
Transient mas localization

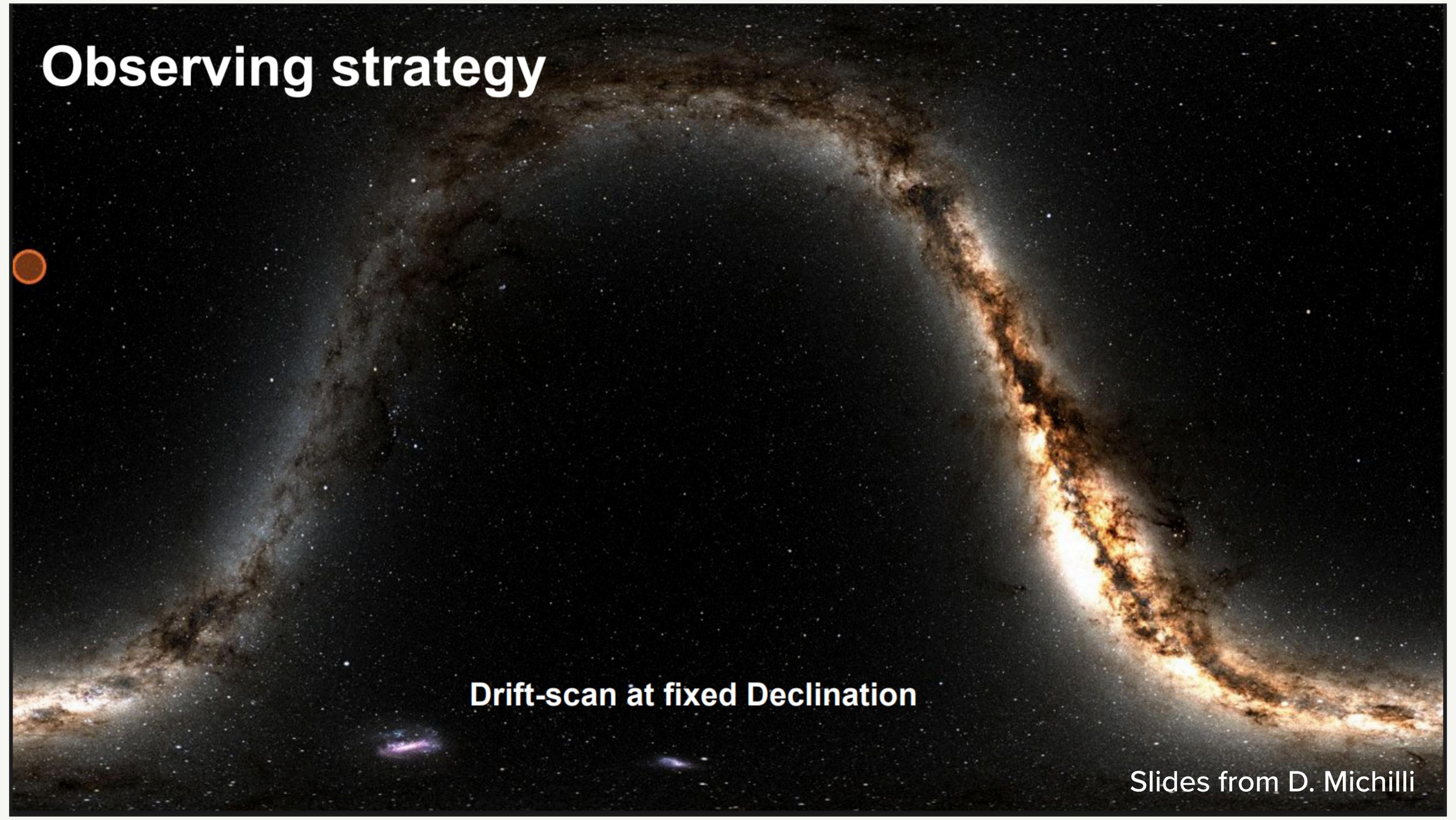
Current status



Observing strategy

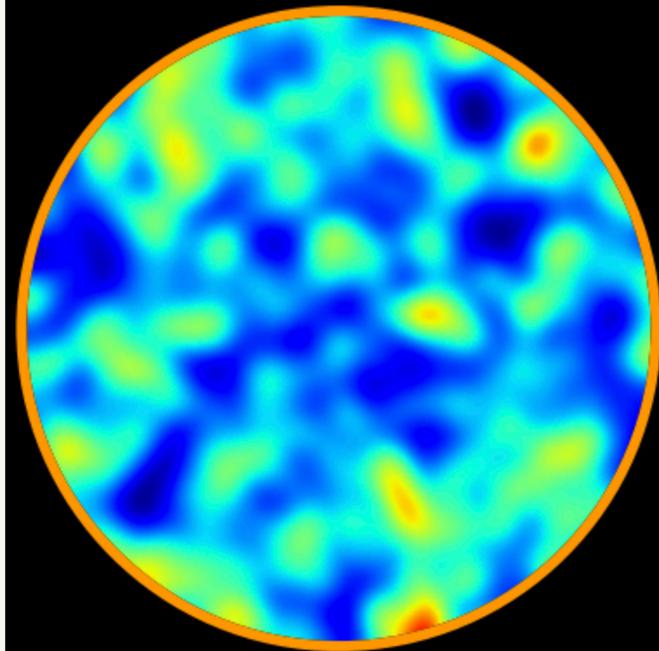
Drift-scan at fixed Declination

Slides from D. Michilli

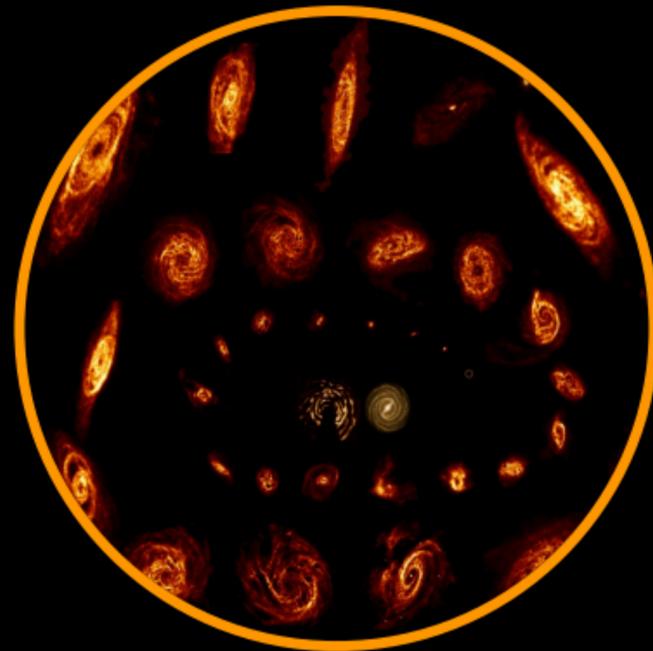


Main science goals

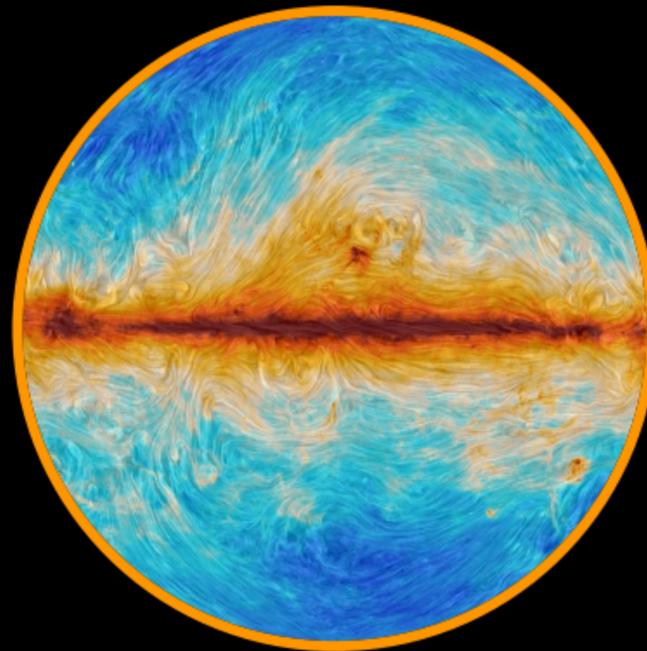
21 cm
intensity mapping



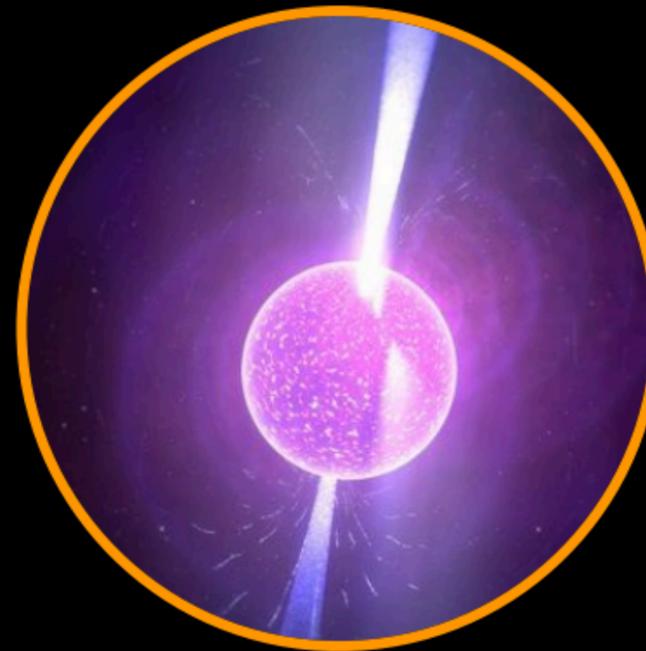
Galaxy survey



Milky Way
tomography



Pulsars



Fast radio bursts

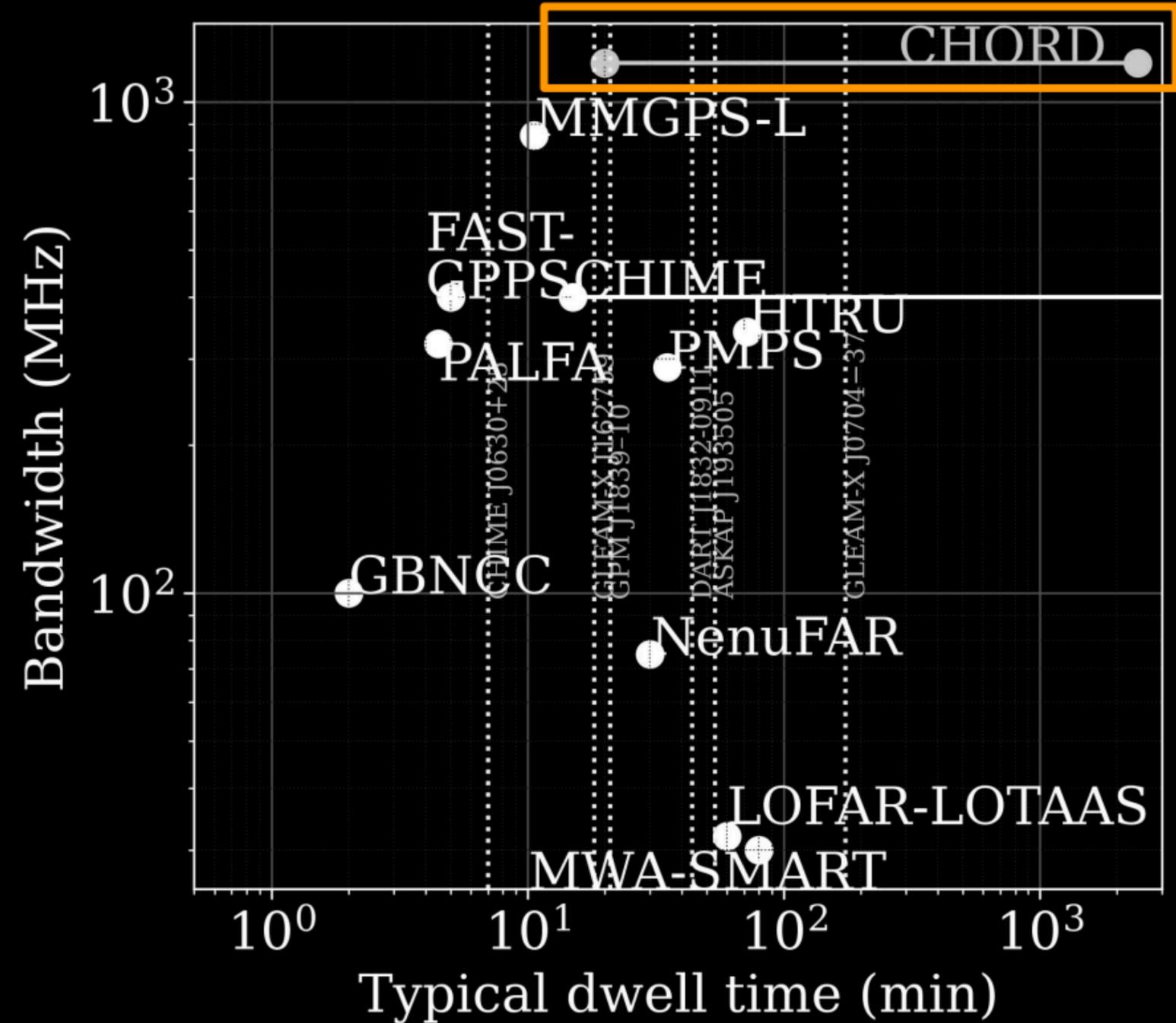


Pulsars



Potential to discover thousands of new pulsars

E.g., long period transients ($P > 10s$)

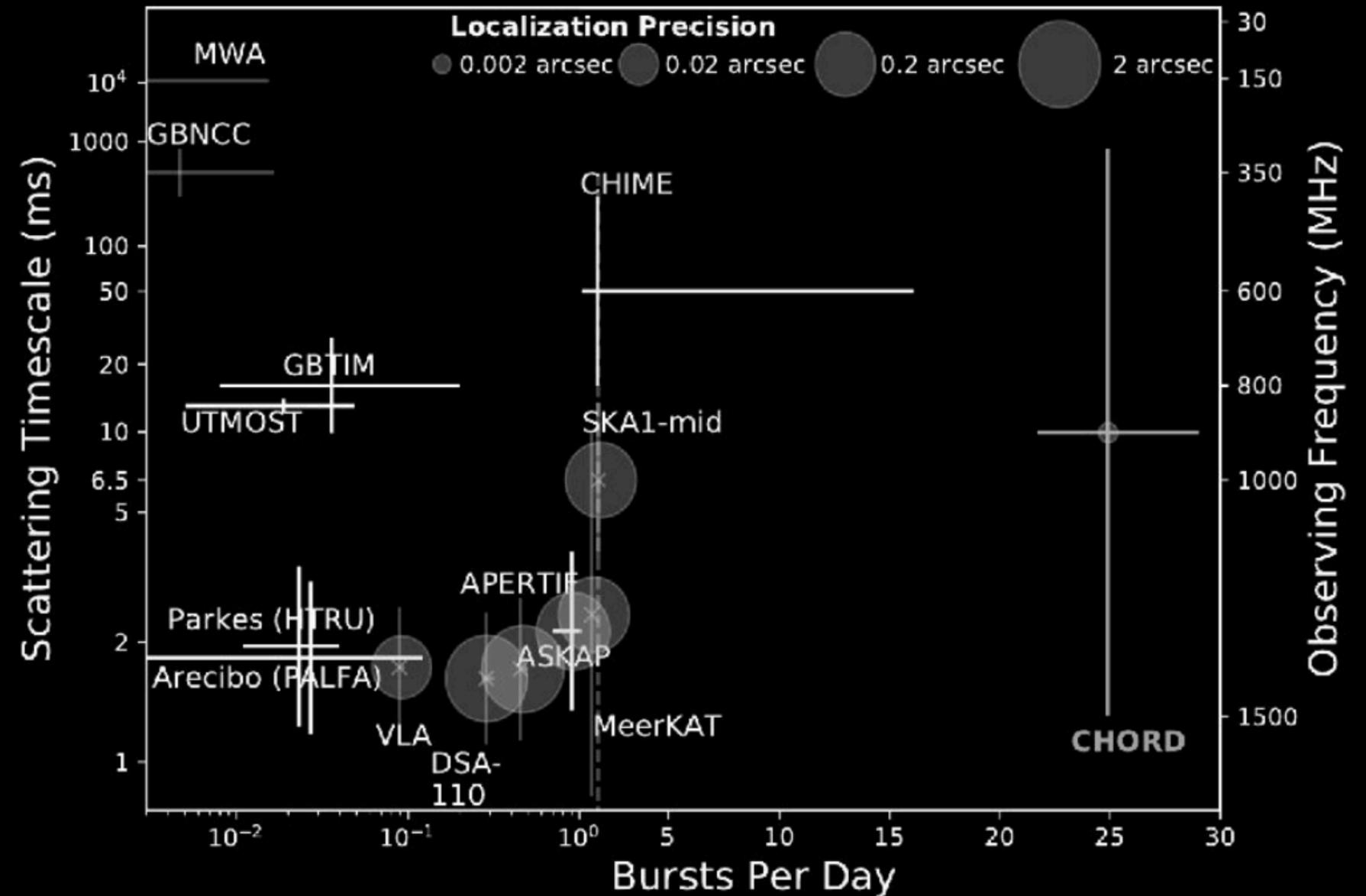


Fast radio bursts



Tens per day with milliarcsecond localization

Most from $z \sim 2$



Hundreds of FRBs will be discovered by
CHORD with arcsec spatial resolution, up
to $z \sim 4$

Complementing the radio detection with
the identification of the optical galaxy is
the first step towards the awaiting science!



Thank you!