1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: FRB sources in the local Universe.

1.1. Project goals

The main goal of this project is to describe the statistic of low-luminosity fast radio burst (FRB) sources in the Local Volume. We will study the radio activity of selected magnetars (i.e. highly magnetised neutron stars) located in the Milky Way and search for FRB events in the nearest galaxies (like M81, M82 or NGC2403) with the use of RT4 32-m NCU radio telescope. We also plan to make first direct estimation of the distance to the active galactic magnetar XTE J1810-197 (the source of FRB-like low-luminosity events) – this is esential to estimate the luminosity of detected bursts. We also will monitor XTE J1810-197 in coordinatend multiband observations with the Westerbork and Onsala radio telescopes. We plan to answer the question "Are FRB phenomena a separate group of astrophysical phenomena, or are we witnessing the tip of the iceberg of the fast transient radio burst luminosity distribution?". All local observations will be carried out in the L band (21 cm), where the statistics of FRB phenomena are poorly described.

1.2. Outline

Since the discovery of the first fast radio burst (FRB) in 2007, and their confirmation as an abundant extragalactic population in 2013. Research into understanding the origins, mechanisms and applications of fast radio bursts is currently one of the most rapidly evolving areas in astrophysics. The diverse burst phenomenology (Pleunis et al. 2021), including a relatively small fraction (> 4%) of FRB sources exhibiting repeating bursts (repeaters, Spitler et al. 2016), potentially indicates multiple FRB origins. Although FRBs are highly luminous, their large extragalactic, cosmic distances, mean that current blind surveys are strongly sensitivity limited, and therefore only detect the bright end of the distribution of potentially observable fast radio transients.

FRBs in the local Universe (distances a few tens of Mpc) provide us with the unique opportunity to connect our knowledge of fast radio transients in the Milky Way and its near vicinity. The discovery of FRB-like bursts for the Galactic magnetar SGR 1935+21 (e.g. Bochenek et al. 2020) or a repeater in nearby galaxy M81 (FRB 20200120E/M81R, Bhardwaj et al. 2021, Kirsten et al. 2022) shows the new detection will connect those low-luminosity bursts to the much more distant FRB population. We can do this through detailed characterisation of their local environments (Kirsten et al. 2022), by applying strong constraints on multi-band wavelength counterparts to the radio emissions (Scholz

et.al 2020) and by conducting targeted searches for low-luminosity FRBs (Nimmo et al, 2022). The recent detection of FRB-like bursts for the Galactic magnetar SGR 1935+21 (e.g. Bochenek et al. 2020) or repeater in nearby galaxy M81 (FRB 20200120E/M81R, Bhardwaj et al. 2021, Kirsten et al. 2022) shows the new detection will connect link those low-luminosity bursts to the much more distant FRB population. We can do this through detailed characterisation of their local environments (Kirsten et al. 2022), by applying strong constraints on multi-band wavelength counterparts to the radio emissions (Scholz et.al 2020) and by conducting targeted searches for low-luminosity FRBs (Nimmo et al, 2022). The recent M81R localisation using the European Very Long baseline interferometry (VLBI) Network (EVN) to a globular cluster in the M81 galactic system put into question the paradigm of magnetars as sources of FRB, but the globular cluster origin of FRB 20200120E is in stark contrast to the star-forming environments of other well-studied repeating FRBs in more distant galaxies. Also, the luminosities of the M81R bursts are 1–2 orders of magnitude weaker than those observed from other repeaters, and even less luminous than the bright FRB-like transient from SGR 1935+21 (Nimmo et al. 2022).

The dedicated searches with medium-sized radio telescopes (like RT4 in Piwnice) will help to describe the bursts statistic in local galaxies, and even negative outcomes will put strong limits on low-luminosity FRB statistics. The Galactic magnetars, as a possible source of FRBs, may also play a useful role as a link to "classic" luminous FRBs. XTE J1810-197 is well known for its bursting occasional radio activity (e.g. Caleb et al. 2022). For over a year, this object has been regularly observed by RT4, which resulted in the detection of dozens of bursts at 21-cm and 6-cm radio bands. The precise distance estimation to XTE J1810-197 is crucial for a valid description of its burst luminosity distribution. This allows us to link the Galactic magnetars burst to the global view of the FRB phenomenon.

1.3. Work plan

Analyze the collected data and publish the results of blind and targeted L-band FRB searches. Estimate the distance to XTE J1810-197 using EVN observations and astrometry. Describe the energy statistics of the XTE J1810-197 L- and C-band burst in terms of possible analogues in nearby galaxies. Propose further EVN observations of any newly detected FRB sources in nearby galaxies.

1.4. Literature *(max. 10 listed, as a suggestion for a PhD candidate)*

Bhardwaj M., et al., 2021, ApJL, 910, 18 (10.3847/2041-8213/abeaa6)

Bochenek C. D., et al., 2020, Nature, 587, 59 (10.1038/s41586-020-2872-x)

Caleb. N, et al., 2022, MNRAS, 510, 2 (10.1093/mnras/stab3223)

Kirsten F., et al., 2021, Nature Astronomy, 5, 414 (10.1038/s41550-020-01246-3)

Kirsten F., et al., 2022, Nature, 602, 585 (10.1038/s41586-021-04354-w)

Nimmo K., et al., 2022, Nature Astronomy, 6, 393 (10.1038/s41550-021-01569-9)

Petroff E., Hessels J. & Lorimer D., 2022, A&AR, 30, a.2 (10.1007/s00159-022-00139-w)

Pleunis Z., et al., 2021, ApJ, 923, 1 (10.3847/1538-4357/ac33ac)

Spitler L., et al., 2016, Nature, 531,202 (10.1038/nature17168)

1.5. Required initial knowledge and skills of the PhD candidate

The candidate should have some basic knowledge about the Fast Radio Burst phenomenon (e.g. Petrov et al. 2022) and some experience with radio observations. She/he must have basic skills in using Python software. The analysis of the data will be carried out in IA NCU and JIVE & ASTRON (Netherlands), therefore, English is desirable.

1.6. Expected development of the PhD candidate's knowledge and skills

The candidate will be supported by the supervisors and collaborators from JIVE & ASTRON. The data reduction process and analysis will take place mainly in IA NCU with the use of open-source software like FETCH or DSPSR (or other codes from the GitHub repositories) - support will be offered. The candidate will develop her/his knowledge about magnetars and sources of FRB in the Local Universe and in a global view.