KENZIE NIMMO

I am a Kavli fellow at MIT. I recently completed my PhD at ASTRON (Netherlands Institute for Radio Astronomy) and the University of Amsterdam as part of the AstroFlash team (led by Jason Hessels). My PhD thesis is titled "Zooming-in on the sources of fast radio transients" and is primarily focused on studying fast radio bursts (FRBs) at the highest possible time (down to tens of nanoseconds) [1, 2, 3] and spatial (down to milliarcsecond) [4, 5, 6] resolutions. We use both single-dish Effelsberg observations running in "baseband" mode to record the raw voltages, as well as global very-long-baseline interferometric (VLBI) observations using the European VLBI Network (EVN). This work has provided insights into both the emission mechanism and progenitor of FRBs. As a postdoctoral fellow, I have joined the CHIME/FRB collaboration to scale up this work using the CHIME Outrigger project and already existing large CHIME FRB sample.

BRIDGING THE GAP BETWEEN GALACTIC NEUTRON STARS AND FRBS

Despite over a decade of research [7], the nature of FRB emission remains an incredibly exciting open problem in modern astrophysics. FRBs are more than 10 orders of magnitude brighter compared with emission typically seen from Galactic neutron stars on comparable timescales. FRBs therefore represent an extreme physical process. Could more extreme neutron stars (perhaps in their magnetic field strengths or spin periods; e.g. [8]) be responsible for this jump in luminosity or are FRBs coming from other astrophysical objects/systems?

Nearby sources of FRBs are incredibly valuable for bridging the gap in knowledge from Galactic sources of short-duration radio transients to the much more distant FRBs. One example is the Galactic magnetar SGR 1935+2154, which produced an FRB-like radio burst detected by both the CHIME/FRB [9] and STARE2 telescopes [10]. This shows that at least some FRBs must come from highly magnetised neutron stars in other galaxies. Despite being many orders of magnitude brighter than other fast radio transients previously seen from magnetars, this event was still 1—2 orders of magnitude weaker than extragalactic FRBs, hence the term "FRB-like" as opposed to simply "FRB". Until recently, there still remained a huge jump from a known magnetar at a distance of 9 kpc [11] to the nearest FRB source FRB 20180916B at 149 Mpc [5].

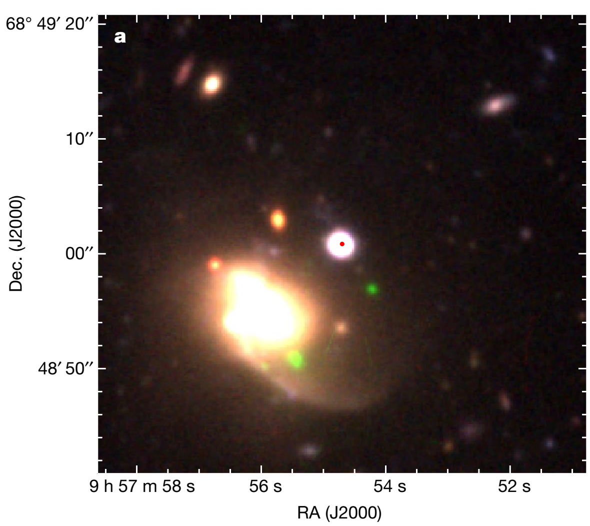

Figure 1: The PRECISE localisation of FRB 20200120E to a globular cluster in the M81 galactic system. Optical image of the host obtained using Hyper Suprime-Cam, with the FRB position shown by the red marker [6].

More recently, the CHIME/FRB team discovered a repeating FRB (FRB 20200120E) coming from the direction of the grand-design spiral galaxy M81 [12], which is at a distance of *only* 3.6 Mpc. Using an ad-hoc array of radio telescopes (project PRECISE; PI Franz Kirsten), we precisely localised this repeating FRB to a globular cluster in the M81 galactic system (Figure 1) [6]. Not only did this confirm the FRB's association with M81, but the globular cluster origin is in stark contrast to other well-localised repeating FRBs, which live in close proximity to star formation (e.g. [13, 14]). This sparks the question: does FRB 20200120E have the same type of progenitor as other repeating FRBs? If it is a magnetar, it was not created through the typical core-collapse of a massive star but perhaps through the merger of compact objects or accretion-induced collapse of a white dwarf.

Using the 100-m Effelsberg telescope, we have been monitoring FRB 20200120E to study the distribution of burst properties and temporal evolution of the source, to compare with similar studies of repeating FRBs. We find that, observationally, FRB 20200120E shares a number of properties with other repeating FRBs including: burst clustering in time, with rates varying per observing epoch; a bimodal wait time distribution; a variety of burst morphologies; and distinctive polarimetric properties (high linear, no circular and flat polarisation angles) [2, 3]. In addition to the globular cluster origin, however, there are notable differences: the bursts are at least 100 times less luminous and 30 times shorter in duration than other repeating FRBs.

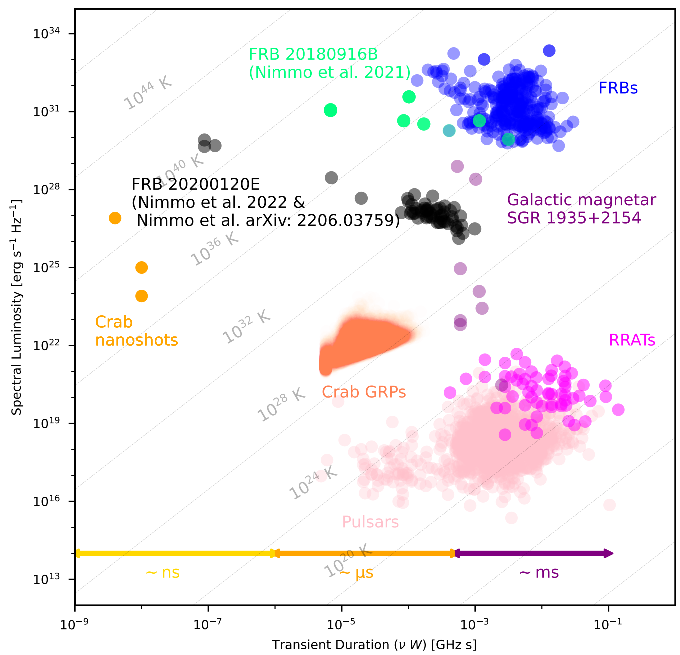

Figure 2: The transient phase space of short-duration radio transients. Adapted from [2] for my PhD thesis.

The FRB 20200120E luminosities are weaker than SGR 1935+2154's "FRB-like" event (Figure 2), further strengthening the connection between extragalactic FRBs and magnetars. Additionally, we probe timescales down to 30 ns, showing a *spectrum* of short-duration radio transients spanning many orders of magnitude in both timescales and luminosity (Figure 2). These shortest timescales, however, are somewhat rare, with only one burst exhibiting sub-µs structure out of 65 bursts.

It will be interesting to explore whether FRB 20200120E can produce even brighter bursts, more comparable to other repeating FRBs through continued monitoring (although our current observations of the energy distribution does not suggest this). Similar studies of other nearby repeating FRBs (< 100 Mpc), and conducting FRB searches in Milky Way globular clusters, may help to populate the "middle" luminosity gap of the transient phase space, where current radio telescopes cannot reach for the extremely distant FRBs.

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