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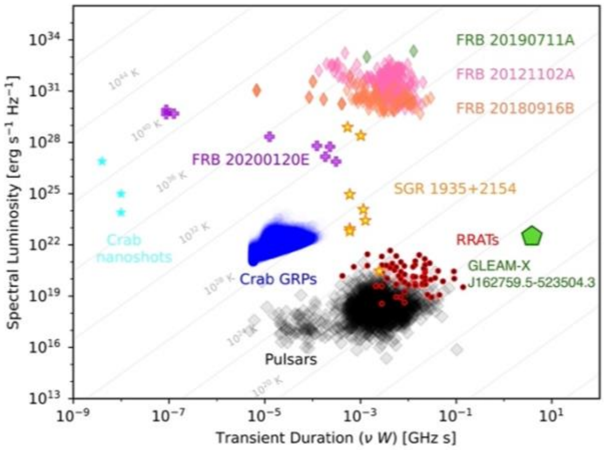
Hi! ☺ I'm a Professor at the University of Amsterdam's Anton Pannekoek Institute (API) and Chief Astronomer at the Netherlands Institute for Radio Astronomy (ASTRON). I have over 20 years of experience studying pulsars[1-3] and fast radio bursts[4-7] (FRBs), and I lead the AstroFlash team with about 15 students and researchers at UvA/API, ASTRON, and the Joint Institute for VLBI ERIC (JIVE). Together we are exploring the transient radio sky on timescales of seconds down to nanoseconds, and are currently focusing on:

- Pinpointing FRB locations on milliarcsecond angular scales to study their local environment[8-10]. Here we use an *ad-hoc* array of European VLBI Network (EVN) dishes as part of the PRECISE project.
- Searching for FRBs on timescales of microseconds, or less, to understand their emission mechanism and to explore the transient phase space[11-13]. Here we use voltage data from EVN dishes, the Nançay Radio Telescope (NRT), and archival data from, e.g., the Green Bank telescope.
- Ultra-high-cadence monitoring to explore the highest FRB energies as well as FRB-like sources in our own Milky Way[14,15]. Here we use the 25-m and 32-m dishes at Westerbork, Onsala and Toruń.
- Low-frequency FRB observations to understand their spectra and local environment via propagation effects[16,17]. Here we use the Low-Frequency Array (LOFAR) and NenuFAR.

Charting new phase space for FRB-like flashes

(also on behalf of Kenzie Nimmo & AstroFlash)



FRBs are signposts of extreme astrophysical environments[18-20]. They provide a novel and unique way to study the extremes of the Universe and to probe the intervening magneto-ionised material. We have only just begun exploring their scientific utility. Though magnetars are certainly responsible for some fraction of the observed FRBs[21,22], the diverse properties and locations of FRBs suggest that this is far from the complete answer[10,23]. Rather, we are confronted with a rich and multi-faceted puzzle with proposed links to other extreme astrophysical phenomena like super-luminous supernovae[24], compact object mergers[25,26], and relativistic shocks[27]. In the coming decade, we should aim to greatly expand the parameter space we are searching for fast radio transients.

Figure 1: The 'fast transient parameter space' of spectral luminosity vs. transient duration. Pulsars, giant pulses, magnetar radio bursts and FRBs span 18 orders-of-magnitude in spectral luminosity and 8 orders-of-magnitude in timescale. Diagonal grey lines show the implied brightness temperature. The magnetar SGR 1935+2154 produces bursts that span 8 orders-of-magnitude in spectral luminosity – bridging Galactic pulsars and extragalactic FRBs[14,21,22]. The globular cluster FRB 20200120E makes bursts that are tens of nanoseconds up to milliseconds. The recently discovered[28] GLEAM-X J162759.5–523504.3 demonstrates the parameter space that can still be explored on timescales of seconds. *Adapted from Nimmo et al. (2022).*[12]

The seminal discoveries of pulsars[29] and FRBs[30] were both enabled by opening new parameter space in terms of the range of timescales, luminosities, electromagnetic frequencies and event rates we can observe. The currently known sample of fast radio transients span timescales of nanoseconds to seconds and over 18 orders-of-magnitude in spectral luminosity (Figure 1). FRBs have been detected at radio frequencies of 110 MHz[16] up to 8 GHz[31] (over 6 octaves) and with rates from hundreds per hour to only 1 burst per hundreds of hours of observation. The diverse properties of the known FRBs strongly suggest that we have still only scratched the surface of what is out there to find. Repeating and non-repeating FRBs have statistically different properties and may come from physically distinct progenitors[23]. At the same time, oddball FRBs like a 3-s event showing periodic peaks spaced at 217 ms[32], and an exceptionally faint FRB hosted in a globular cluster[10], are also hinting at a rich variety of source types and environments. Dozens of FRB theories have been proposed[33], with both a range of progenitor types and emission mechanisms investigated. I argue that we have every reason to believe that nature is highly creative and that it produces a diversity of FRB emitters beyond just the proven example of magnetars. To quote a colleague working on FRB theory: "radio bursts are cheap" (in terms of their energetics), and hence they can be expected in many different contexts. FRB models often invoke neutron stars or black holes, to satisfy the energy density requirements imposed by the luminosities and durations of FRBs. However, neutron stars and black holes come in many varieties and astrophysical contexts; there is yet no consensus on which of these can generate FRBs.

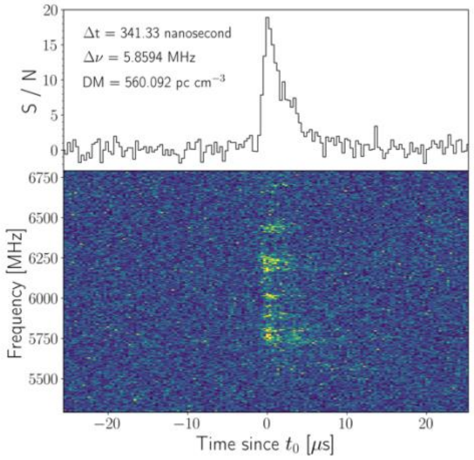
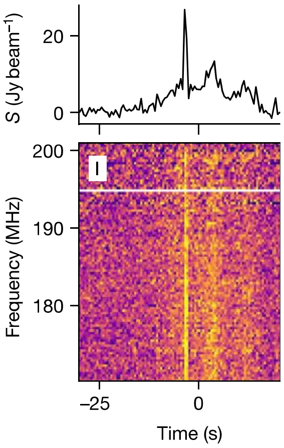


Figure 2: An isolated 5-microsecond-wide burst from the repeater FRB 20121102A. Note that the time resolution is 341 nanoseconds[13].

Discovering populations of ultra-fast radio bursts (uFRBs) and ultra-young, obscured FRBs: Work by my group and others has demonstrated that not only can FRBs exhibit (sub-)microsecond structure, but that there are also radio bursts whose *entire duration* is only a few microseconds (Figure 2). Current FRB searches are mostly blind to such events because they use relatively coarse sampling time (0.1 – 1 ms) and low radio frequencies (< 2 GHz), where scattering from the Milky Way foreground and other intervening plasma limits the effective time resolution. My goal is to create a wide-field radio telescope system operating at ~5 GHz which will allow the first untargeted search for (sub-)microsecond uFRBs. Such a system could conceivably be created using dense-packed arrays of 1-m commercial satellite dishes equipped with low-noise ambient temperature amplifiers and piggybacking on the infrastructure of the LOFAR and/or CHIME/FRB Outrigger and CHORD sites. The goal is to discover a new, physically distinct class of FRB-like emitters whose exceptionally short-duration bursts provide unparalleled probes of the intervening magneto-ionic medium and gravitational lensing effects. At the same time, the high observing frequency will allow us to peer into dense star-forming regions and galactic center environments, where a large population of young FRB sources may exist. Current low-frequency searches are insensitive to this population.



Discovering a population of not-so-fast radio bursts (nsFRBs): Conversely, recent discoveries like the 18-min transient GLEAM-X J162759.5–523504.3 (Figure 3), with its 10s of seconds bursts, are showing us that there is a population of much longer-duration FRB-like signals to be discovered. Low-frequency radio interferometric telescopes are well poised to open this parameter space because they can effectively separate these signals from human-made interference using both dispersive delay and spatial filtering. My goal is to discover this population of nsFRBs by developing fast imaging (10ms visibilities) capabilities for LOFAR in the coming years and then for the Square Kilometre Array (SKA) Low telescope on the timescale of 5-10 years. The putative population of nsFRBs could stem from, e.g., ultra-long-period magnetars, white dwarf pulsars, and nearby flare stars.

Figure 3: A dynamic spectrum and frequency-integrated burst profile of the MWA-discovered transient GLEAM-X J162759.5–523504.3. The remarkable brightness and tens of seconds duration of this source place it in a previously unpopulated part of the fast transient parameter space (see also Figure 1). *From Hurley-Walker et al. (2022).* [28]

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