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An extreme magneto–ionic environment associated with the fast radio burst source FRB 121102

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Fast radio bursts are millisecond-duration, extragalactic radio flashes of unknown physical origin[1–3]. The only known repeating fast radio burst source[4–6]—FRB 121102—has been localized to a star-forming region in a dwarf galaxy[7–9] at redshift 0.193 and is spatially coincident with a compact, persistent radio source[7,10]. The origin of the bursts, the nature of the persistent source and the properties of the local environment are still unclear. Here we report observations of FRB 121102 that show almost 100 per cent linearly polarized emission at a very high and variable Faraday rotation measure in the source frame (varying from $+1.46\times10^5$ radians per square metre to $+1.33\times10^5$ radians per square metre at epochs separated by seven months) and narrow (below 30 microseconds) temporal structure. The large and variable rotation measure demonstrates that FRB 121102 is in an extreme and dynamic magneto-ionic environment, and the short durations of the bursts suggest a neutron star origin. Such large rotation measures have hitherto been observed[11,12] only in the vicinities of massive black holes (larger than about 10,000 solar masses). Indeed, the properties of the persistent radio source are compatible with those of a low-luminosity, accreting massive black hole[10]. The bursts may therefore come from a neutron star in such an environment or could be explained by other models, such as a highly magnetized wind nebula[13] or supernova remnant[14] surrounding a young neutron star.

Using the 305-m William E. Gordon Telescope at the Arecibo Observatory, we detected 16 bursts from FRB 121102 at radio frequencies in the range 4.1–4.9 GHz (Table 1). Complete polarization parameters were recorded at a 10.24-μs time resolution. See Methods and Extended Data Figs 1–6 for observation and analysis details.

The 4.5-GHz bursts have typical widths smaller than about 1 ms, which are narrower than the 2–9-ms bursts previously detected at lower frequencies[5,15]. In some cases they show multiple components and structures close to the sampling time of the data. Burst 6 (Table 1) is particularly striking, with a width smaller than about 30 μs (which constrains the size of the emitting region to below about 10 km, assuming no other geometric or relativistic effects). The evolution of burst morphology with frequency complicates the determination[5] of the dispersion measure ($\mathrm{DM}=\int_0^d n_e(l)\mathrm{d}l$, where d is the distance to the source in parsec, l is the line-of-sight position and n_e is the electron density in electrons per cubic centimetre), but aligning the narrow component in burst 6 results in $\mathrm{DM}=559.7\pm0.1\ \mathrm{pc\,cm^{-3}}$, which is consistent[4,5,15,16] with other bursts detected since 2012 and suggests that any real dispersion measure variations are below the level of about 1%.

After correcting for Faraday rotation and accounting for about 2% depolarization from the finite channel widths, the bursts are consistently linearly polarized to about 100% (Fig. 1). The polarization angles $\mathrm{PA}=\mathrm{PA}_\infty+\theta$ (where PA_∞ is a reference angle at infinite frequency, $\theta=\mathrm{RM}\lambda^2$ is the rotation angle of the electric field vector, RM is the Faraday rotation measure and λ is the observing wavelength) are flat across the observed frequency range and burst envelopes (ΔPA smaller than about $5^\circ\ \mathrm{ms}^{-1}$). This could mean that the burst durations reflect the timescale of the emission process and not the rate of a rotating beam sweeping across the line of sight. Any circular polarization is lower than a few per cent of the total intensity. The Faraday rotation measure is defined as $\mathrm{RM}=0.81\int_d^0 B_\parallel(l)n_e(l)\mathrm{d}l$, where $B_\parallel$ is the line-of-sight magnetic field strength (in microgauss); by convention, the rotation measure is positive when the magnetic field points towards the observer. On average, the observed rotation measure is $\mathrm{RM_{obs}}=(+1.027\pm0.001)\times10^5\ \mathrm{rad\ m^{-2}}$ and varies by about 0.5% between Arecibo observing sessions spanning a month (Fig. 2; Table 1). The lack of polarization in previous burst detections[15,16] at 1.1–2.4 GHz is consistent with the relatively coarse frequency channels that cause bandwidth depolarization and constrains $|\mathrm{RM_{obs}}|$ to above about $10^4\ \mathrm{rad\ m^{-2}}$ at those epochs.

Confirmation of this extreme Faraday rotation comes from independent observations at 4–8 GHz with the 110-m Robert C. Byrd Green Bank Telescope (GBT), which give $\mathrm{RM_{obs}}=(+0.935\pm0.001)\times10^5\ \mathrm{rad\ m^{-2}}$ at an epoch seven months after the Arecibo detections. The GBT and Arecibo $\mathrm{RM_{obs}}$ values differ with high

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