METHODS

The analyses described here were based on the PRESTO[31], PSRCHIVE[32] and DSPSR[33] pulsar software suites, as well as custom-written Python scripts for linking utilities into reduction pipelines, fitting the data and plotting.

Observations and burst search. *Arecibo.* We made the observations using the Arecibo 'C-band' receiver (dual linear receptors) in the frequency range 4.1–4.9 GHz and the Puerto-Rican Ultimate Pulsar Processing Instrument (PUPPI) backend recorder. The full list of observations is reported in Extended Data Table 1. We operated PUPPI in its 'coherent search' mode, which produced 10.24 μs samples and 512×1.56 MHz frequency channels, each coherently dedispersed to dispersion measure 557.0 pc cm^{-3}. Coherent dedispersion within each 1.56-MHz channel means that the intra-channel dispersive smearing is smaller than 2 μs even if the dispersion measure of the burst is 10 pc cm^{-3} higher or lower than the fiducial value of 557.0 pc cm^{-3} used in the PUPPI recording. The raw PUPPI data also provide auto- and cross-correlations of the two linear polarizations, which can be converted to the Stokes parameters I, Q, U and V during post-processing. Before each observation, we performed a test scan on a known pulsar (PSR B0525+21) and a noise diode calibration scan (for polarimetric calibration).

Dedispersed time series with dispersion measure from 461 pc cm^{-3} to 661 pc cm^{-3} were searched using trial steps of 1 pc cm^{-3} and the PRESTO routine *single_pulse_search.py*, which applies a matched-filter technique to look for bursts with durations between 81.92 μs and 24,576 μs (for any putative burst that only has a single peak with width below 81.92 μs, the sensitivity will be degraded by a factor of a few at most). The resulting data points (dispersion measure, time, signal-to-noise ratio) were grouped into plausible astrophysical burst candidates using a custom sifting algorithm and then a dynamic spectrum of each candidate was plotted for manual inspection and grading. We found 16 bursts of astrophysical origin and used the DSPSR package to form full-resolution, full-polarization PSRCHIVE 'archive' format files for each burst.

Green Bank Telescope. On 26 August 2017, we observed FRB 121102 using the GBT 'C-band' receiver (4–8 GHz, with dual linear receptors) as part of a programme of monitoring known FRB positions. Observations were conducted with the Breakthrough Listen Digital Backend[34], which allowed recording of baseband voltage data across the entire nominal 4-GHz bandwidth of the selected receiver. Scans of a noise diode calibration, of the flux calibrator 3C161 and of the bright pulsar PSR B0329+54 supplemented the observations.

In post-processing, a total-intensity, low-resolution filterbank data product was searched for bursts with dispersion measure in the range 500–600 pc cm^{-3} using trial dispersion measure values in steps of 0.1 pc cm^{-3} and a search package implemented on an accelerated graphics processing unit to perform incoherent dedispersion[35]. We detected[36] 15 bursts with signal-to-noise ratio higher than 10. Here we present the properties of just the two brightest GBT bursts in order to confirm the large rotation measure observed by Arecibo and to quantify its variation in time. A detailed analysis of all GBT detections is in progress (V.G. *et al.*, manuscript in preparation). A section of raw voltage data (1.5 s) around each detected burst was extracted and coherently dedispersed to a nominal dispersion measure of 557.91 pc cm^{-3} using the DSPSR package. The final PSRFITS format data products have time and spectral resolutions of 10.24 μs and 183 kHz, respectively.

Data analysis. *Calculation of burst rotation measures.* We calibrated the burst 'archives' using the PSRCHIVE utility *pac* in 'SingleAxis' mode. This calibration strategy uses observations of a locally generated calibration signal (pulsed noise diode) to correct the relative gain and phase difference between the two polarization channels, under the assumption that the noise source emits equal power and has zero intrinsic phase difference in the two polarization channels. This calibration scheme does not correct for cross-coupling or leakage between the polarizations. While leakage must be present at some level, the high polarization fraction, complete lack of circular polarization, and consistency of the test pulsar observations with previous work give us confidence that calibration issues are not a substantial source of error for the rotation measure determination. In addition, the flux density of GBT observations was calibrated using the flux calibrator.

We initially performed a brute-force search for peaks in the linear polarization fraction (Extended Data Fig. 3) and discovered that $\mathrm{RM_{obs}} \approx +10^5$ rad m^{-2} in the Arecibo data. Each burst was corrected for Faraday rotation using the best-fit rotation measure value for that burst. Residual variations in the resulting polarization angle PA(λ) were used to refine the initial values by fitting

$$\mathrm{PA}(\lambda) = \mathrm{RM}\lambda^2 + \mathrm{PA}_\infty \tag{1}$$

and then

$$\hat{\boldsymbol{L}} = \exp[i2(\mathrm{RM}\lambda^2 + \mathrm{PA}_\infty)] \tag{2}$$

where $\hat{\boldsymbol{L}}$ is the unit vector of the linear polarization. We used equation (2) to fit the whole sample of bursts, imposing a different rotation measure per day and a different PA_∞ per telescope. The results of these fits are reported in Table 1 and an example is shown in Fig. 2.

By applying the optimal rotation measure value to each burst, we produced polarimetric profiles showing that each burst is almost 100% linearly polarized, after accounting for the finite widths of the PUPPI frequency channels (Fig. 1; Extended Data Fig. 2). In fact, the measured Arecibo bursts are depolarized to about 98%, in agreement with an uncorrected intra-channel Faraday rotation of

$$\Delta\theta = \frac{\mathrm{RM_{obs}} c^2 \Delta\nu}{\nu_c^3} \tag{3}$$

where c is the speed of light, $\Delta\nu$ is the channel width and ν_c is the central channel observing frequency. At 4.5 GHz, this corresponds to about 9°, and the depolarization fraction is

$$f_{\mathrm{depol}} = 1 - \frac{\sin(2\Delta\theta)}{2\Delta\theta} = 1.6\% \tag{4}$$

We supplemented the above analysis with a combination of the RM Synthesis method and the deconvolution procedure RMCLEAN (for example, Extended Data Fig. 4). Ensuring the presence of minimal Faraday complexity is possible by integrating across the full bandwidth and taking advantage of a Fourier transform relation between the observed $\boldsymbol{L}(\lambda^2)$ values and the Faraday spectrum (the polarized brightness as a function of rotation measure). This approach is known as RM Synthesis[37] and can be coupled with RMCLEAN to estimate the intrinsic Faraday spectrum[38]. Although RM Synthesis and RMCLEAN can have difficulty in properly reconstructing the intrinsic Faraday spectrum under certain circumstances, the spread of clean components is a reliable indicator of spectra that contain more than a single Faraday-unresolved source[39].

At each observed frequency, we integrated the Stokes parameters Q and U across the pulse width and normalized using the Stokes I profile. Owing to the normalization, we used only frequency bins that had a Stokes I signal-to-noise ratio of at least 5. We computed a deconvolved Faraday spectrum for each burst separately on a highly oversampled rotation measure axis (RM sampling $\delta\mathrm{RM} \approx 10^{-4}$ of the nominal full-width at half-maximum of the rotation measure resolution element). We used a relatively small gain parameter (0.02) and terminated the deconvolution when the peak of the residual decreased to 2σ above the mean. The algorithm typically required 50–80 iterations to converge. This combination of settings permits us to carefully consider the cumulative distribution of RMCLEAN components along the rotation measure axis and thus constrain the intrinsic width of the polarized emission to below about 0.1% of the typical rotation measure uncertainty. We found that this value scales with δRM because the peak of the Faraday spectrum rarely lands precisely on an individual pixel. To a high degree of confidence, there is evidence neither of emission at more than one rotation measure value, nor of a broadened ('Faraday-thick') emitting region; we therefore forgo more complicated fitting of the Q and U parameters[19]. The results of this analysis, shown in Extended Data Table 2, are consistent with the simplified fitting results described above.

Calculation of burst properties. As in previous studies[5,15], a search for periodicity in the burst arrival times remains inconclusive. Determining the exact dispersion measures of the bursts is complicated by their changing morphology with radio frequency[5,15]. Measuring the dispersion measure based on maximizing the peak signal-to-noise ratio of the burst often leads to blurring of the burst structure and, in the case of FRB 121102, an overestimation of the dispersion measure. We have thus chosen to display all bursts dedispersed to the same nominal dispersion measure of burst 6 (Fig. 1 and Extended Data Fig. 1). Taking advantage of the narrowness of burst 6, we estimated its optimal dispersion measure by minimizing its width at different dispersion measure trials. We measured burst widths at half the maximum of the peak value by fitting them with von Mises functions using the PSRCHIVE routine *paas* (Table 1). These widths correspond to the burst envelope in the case of multi-component bursts.

The flux densities of the Arecibo bursts were estimated using the radiometer equation to calculate the equivalent root-mean-square flux density of the noise

$$\sigma_{\mathrm{noise}} = \frac{T_{\mathrm{sys}}}{G\sqrt{2Bt_{\mathrm{int}}}} \tag{5}$$

where $T_{\mathrm{sys}} \approx 30$ K and $G \approx 7$ K Jy^{-1} are the system temperature and gain of the receiver, respectively, $B = 800$ MHz is the observing bandwidth and $t_{\mathrm{int}} = 10.24$ μs is the sampling time. The GBT observations were calibrated using a flux calibrator, as discussed earlier. Because of the complicated spectra of the bursts, we quote average values across the frequency band (Table 1).