Bevezetés a csillagászatba IV

1. Alapfogalmak, Naprendszer I.

I. Alapgondolatok

- I/1. Háttérsztori 1: gamma-villanások (Gamma Ray Bursts, GRB)

  1963: Vela-műholdak
  1967. július 2.: Vela-4 és Vela-3 gamma-sugárzás hirtelen megnőtt
  1973 - első publikáció

THE ASTROPHYSICAL JOURNAL, **182**:L85–L88, 1973 June 1

OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

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ABSTRACT

Sixteen short bursts of photons in the energy range 0.2–1.5 MeV have been observed between 1969 July and 1972 July using widely separated spacecraft. Burst durations ranged from less than 0.1 s to $\sim$30 s, and time-integrated flux densities from $\sim 10^{-5}$ ergs cm^{-2} to $\sim 2 \times 10^{-4}$ ergs cm^{-2} in the energy range given. Significant time structure within bursts was observed. Directional information eliminates the Earth and Sun as sources.

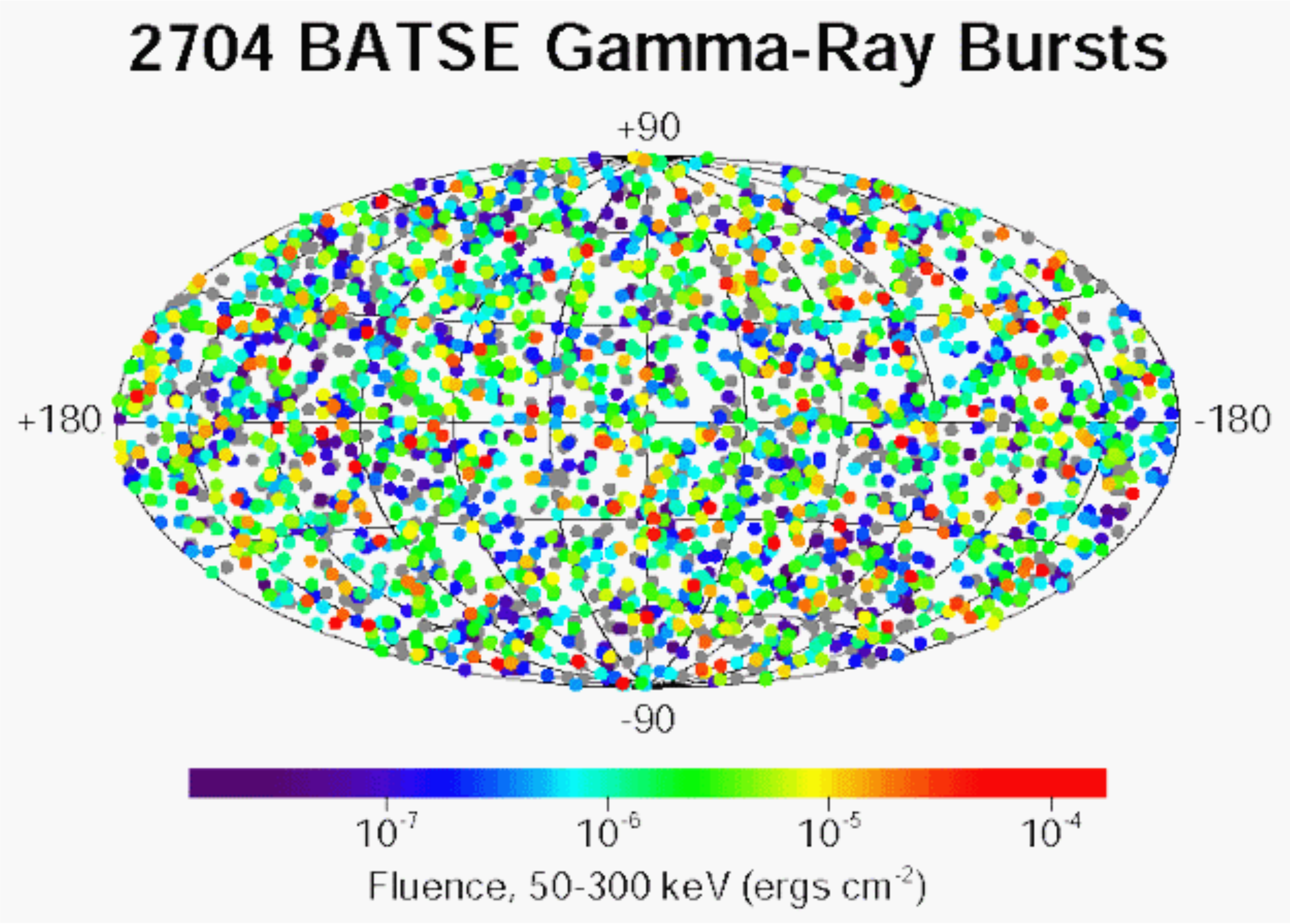
Subject headings: gamma rays — X-rays — variable stars

I. INTRODUCTION

On several occasions in the past we have searched the records of data from early *Vela* spacecraft for indications of gamma-ray fluxes near the times of appearance of supernovae. These searches proved uniformly fruitless. Specific predictions of gamma-ray emission during the initial stages of the development of supernovae have since been made by Colgate (1968). Also, more recent Vela spacecraft are equipped with much improved instrumentation. This encouraged a more general search, not restricted to specific time periods. The search covered data acquired with almost continuous coverage between 1969 July and 1972 July, yielding records of 16 gamma-ray bursts distributed throughout that period. Search criteria and some characteristics of the bursts are given below.

II. INSTRUMENTATION

The observations were made by detectors on the four *Vela* spacecraft, *Vela 5A*,



2704 BATSE Gamma-Ray Bursts
+90
+180
-180
-90
10^{-7}
10^{-6}
10^{-5}
10^{-4}
Fluence, 50-300 keV (ergs cm^{-2})

Letter

Transient optical emission from the error box of the γ-ray burst of 28 February 1997

J. van Paradijs, P. J. Groot, T. Galama, C. Kouveliotou, R. G. Strom, J. Telting, R. G. M. Rutten, G. J. Fishman, C. A. Meegan, M. Pettini, N. Tanvir, J. Bloom, H. Pedersen, H. U. Nørdgaard-Nielsen, M. Linden-Vørnle, J. Melnick, G. van der Steene, M. Bremer, R. Naber, J. Heise, J. in't Zand, E. Costa, M. Feroci, L. Piro, F. Frontera, G. Zavattini, L. Nicastro, E. Palazzi, K. Bennet, L. Hanlon & A. Parmar - Show fewer authors

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Abstract

For almost a quarter of a century[1], the origin of γ-ray bursts— brief, energetic bursts of high-energy photons—has remained unknown. The detection of a counterpart at another wavelength has long been thought to be a key to understanding the nature of these bursts (see, for example, ref. 2), but intensive searches have not revealed such a counterpart. The distribution and properties of the bursts[3] are explained naturally if they lie at cosmological distances (a few Gpc)[4], but there is a countervailing view that they are relatively local objects[5], perhaps distributed in a very large halo around our Galaxy. Here we report the detection of a transient and fading optical source in the error box associated with the burst GRB970228, less than 21 hours after the burst[6,7]. The optical transient appears to be associated with a faint galaxy[7,8], suggesting that the burst occurred in that galaxy and thus that γ-ray bursts in general lie at cosmological distance.

Távolságok nélkül: közeli bolha vs. távoli elefánt problémája

Háttérsztori 2: gyors rádiókitörések (Fast Radio Bursts, FRB)
Felfedezés: (Lorimer et al. 2007)

A Bright Millisecond Radio Burst of Extragalactic Origin

D. R. Lorimer,[1,2]* M. Bailes,[3] M. A. McLaughlin,[1,2] D. J. Narkevic,[1] F. Crawford[4]

Pulsar surveys offer a rare opportunity to monitor the radio sky for impulsive burst-like events with millisecond durations. We analyzed archival survey data and found a 30-jansky dispersed burst, less than 5 milliseconds in duration, located 3° from the Small Magellanic Cloud. The burst properties argue against a physical association with our Galaxy or the Small Magellanic Cloud. Current models for the free electron content in the universe imply that the burst is less than 1 gigaparsec distant. No further bursts were seen in 90 hours of additional observations, which implies that it was a singular event such as a supernova or coalescence of relativistic objects. Hundreds of similar events could occur every day and, if detected, could serve as cosmological probes.

Transient radio sources are difficult to detect, but they can potentially provide insights into a wide variety of astrophysical phenomena (*1*). Of particular interest is

The burst was discovered during a search of archival data from a 1.4-GHz survey of the Magellanic Clouds (*5*) using the multibeam receiver on the 64-m Parkes Radio Telescope

ratios greater than 4 with the use of a matched filtering technique (*7*) optimized for pulse widths in the range 1 to 1000 ms. The burst was detected in data taken on 24 August 2001 with DM = 375 cm^{-3} pc contemporaneously in three neighboring beams (Fig. 1) and was located ~3° south of the center of the Small Magellanic Cloud (SMC).

The pulse exhibited the characteristic quadratic delay as a function of radio frequency (Fig. 2) expected from dispersion by a cold ionized plasma along the line of sight (*8*). Also evident was a significant evolution of pulse width across the observing frequency band. The behavior we observed, where the pulse width W scales with frequency f as $W \propto f^{-4.8 \pm 0.4}$, is consistent with pulse-width evolution due to interstellar scattering with a Kolmogorov power law [$W \propto f^{-4}$ (*9*)]. The filter-bank system has finite frequency and time resolution, which effectively sets an upper limit to the intrinsic pulse width W_{int} = 5 ms. We represent this

Parkes 64 m-es antenna, 2001. augusztus 24.

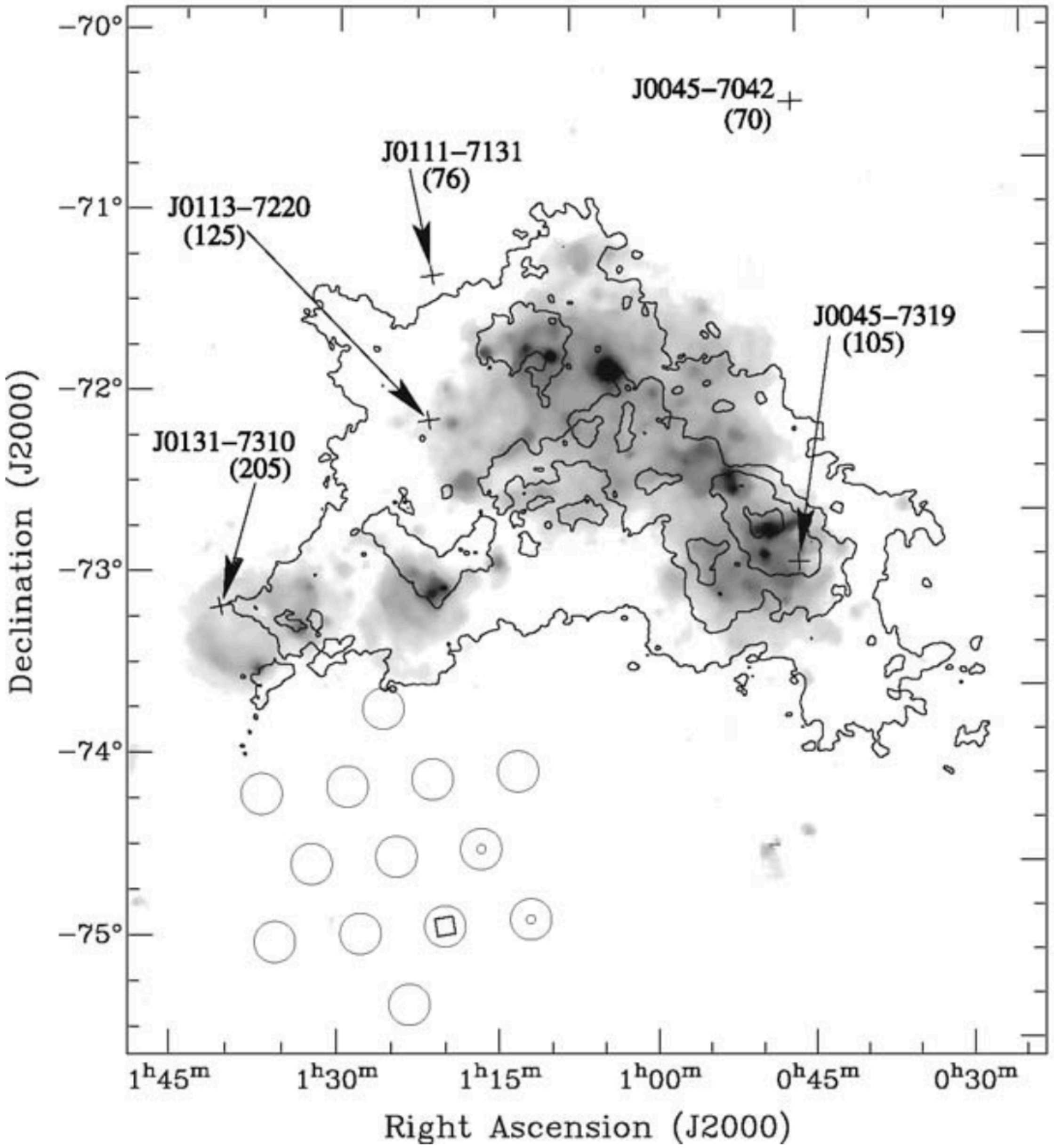
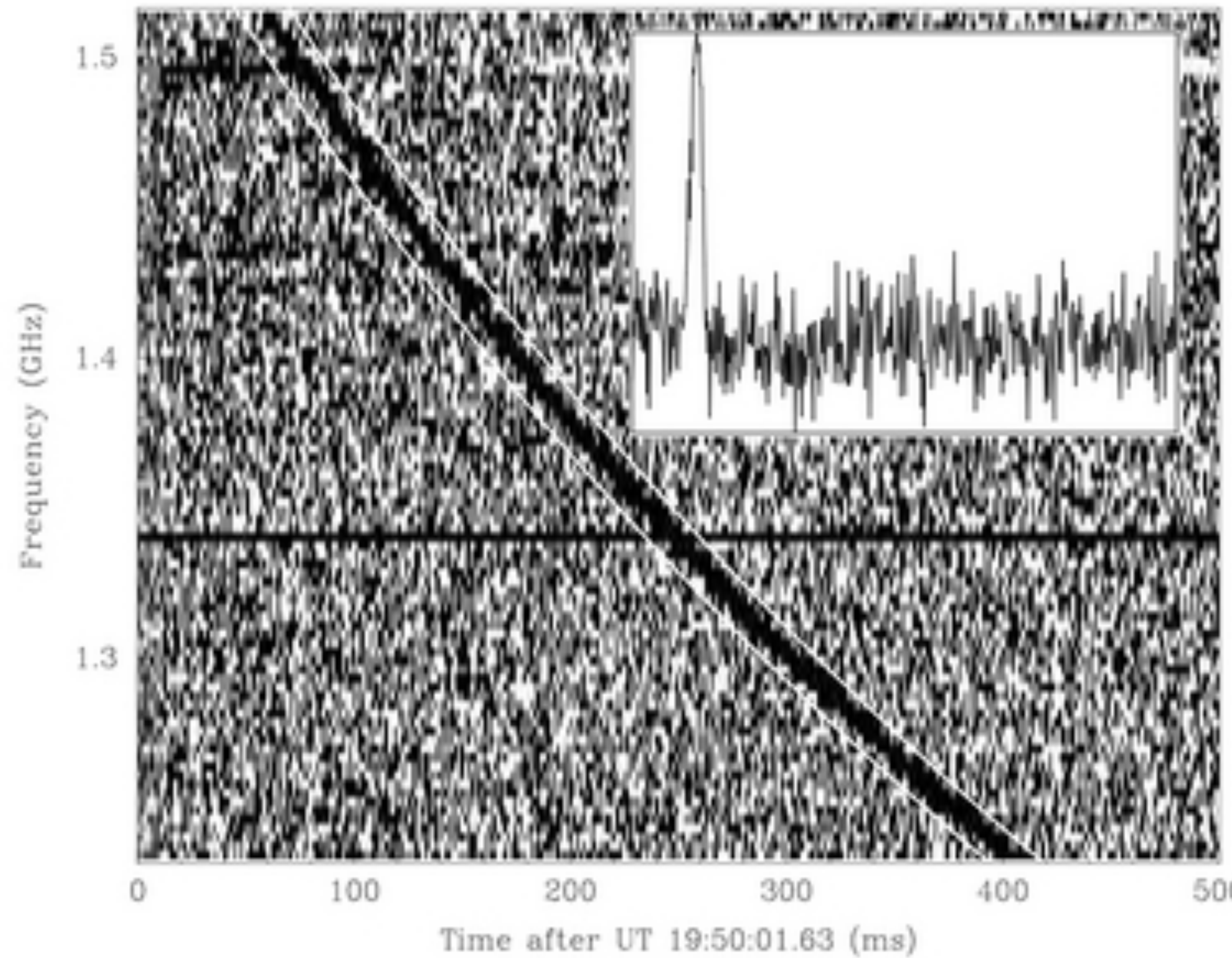


Fig. 1. Multiwavelength image of the field surrounding the burst. The gray scale and contours respectively show Hα and H I emission associated with the SMC (*32*, *33*). Crosses mark the positions of the five known radio pulsars in the SMC and are annotated with their names and DMs in parentheses in units of cm^{-3} pc. The open circles show the positions of each of the 13 beams in the survey pointing of diameter equal to the half-power width. The strongest detection saturated the single-bit digitizers in the data acquisition system, indicating that its S/N >> 23. Its location is marked with a square at right ascension $01^h\ 18^m\ 06^s$ and declination –75° 12′ 19″ (J2000 coordinates). The other two detections (with S/Ns of 14 and 21) are marked with smaller circles. The saturation makes the true position difficult to localize accurately. The positional uncertainty is nominally ±7′ on the basis of the half-power width of the multibeam system. However, the true position is probably slightly (a few arcmin) northwest of this position, given the nondetection of the burst in the other beams.



A “Fast Radio Burst” kifejezés megalkotása: ez egy populáció (Thornton et al. 2013)

A Population of Fast Radio Bursts at Cosmological Distances

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Searches for transient astrophysical sources often reveal unexpected classes of objects that are useful physical laboratories. In a recent survey for pulsars and fast transients, we have uncovered four millisecond-duration radio transients all more than 40° from the Galactic plane. The bursts' properties indicate that they are of celestial rather than terrestrial origin. Host galaxy and intergalactic medium models suggest that they have cosmological redshifts of 0.5 to 1 and distances of up to 3 gigaparsecs. No temporally coincident x- or gamma-ray signature was identified in association with the bursts. Characterization of the source population and identification of host galaxies offers an opportunity to determine the baryonic content of the universe.

The four fast radio bursts (FRBs) (Fig. 1) reported here were detected in the high Galactic latitude region of the High Time Resolution Universe (HTRU) survey (*1*), which was designed to detect short-time-scale radio transients and pulsars (Galactic pulsed radio sources). The survey uses the 64-m Parkes radio telescope and its 13-beam receiver to acquire data across a bandwidth of 400 MHz centered at 1.382 GHz (table S1). We measured minimum fluences for the FRBs of $F = 0.6$ to 8.0 Jy ms (1 Jy = 10^{-26} W m^{-2} Hz^{-1}) (*2*). At cosmological distances, this indicates that they are more luminous than bursts from any known transient radio source (*3*). Follow-up observations at the original beam positions have not detected any repeat events, indicating that the FRBs are likely cataclysmic in nature.

Candidate extragalactic bursts have previously been reported with varying degrees of plausibility (*4–7*), along with a suggestion that FRB 010724 (the “Lorimer burst”) is similar to other signals that may be of local origin (*8*, *9*). To be consistent with a celestial origin, FRBs should exhibit certain pulse properties. In particular, observations of radio pulsars in the Milky Way (MW) have confirmed that radio emission is delayed by propagation through the ionized interstellar medium (ISM), which can be considered a cold plasma. This delay has a power law dependence of $\delta t \propto \mathrm{DM}\cdot\nu^{-2}$ and a typical frequency-dependent width of $W \propto \nu^{-4}$. The dispersion measure (DM) is related to the integrated column density of free electrons along the line of sight to the source and is a proxy for distance. The frequency-dependent pulse broadening occurs as an astrophysical pulse is scattered by an inhomogeneous turbulent medium, causing a characteristic exponential tail. Parameterizing the frequency dependence of δt and W as α and β, respectively, we measured $\alpha = -2.003 \pm 0.006$ and $\beta = -4.0 \pm 0.4$ for FRB 110220 (Table 1 and Fig. 2), as expected for propagation through a cold plasma. Although FRB 110703 shows no evidence of scattering, we determined $\alpha = -2.000 \pm 0.006$. The other FRBs do not have sufficient

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Fig. 2. A dynamic spectrum showing the frequency-dependent delay of FRB 110220. Time is measured relative to the time of arrival in the highest frequency channel. For clarity we have integrated 30 time samples, corresponding to the dispersion smearing in the lowest frequency channel. (**Inset**) The top, middle, and bottom 25-MHz-wide dedispersed subband used in the pulse-fitting analysis (*2*); the peaks of the pulses are aligned to time = 0. The data are shown as solid gray lines and the best-fit profiles by dashed black lines.

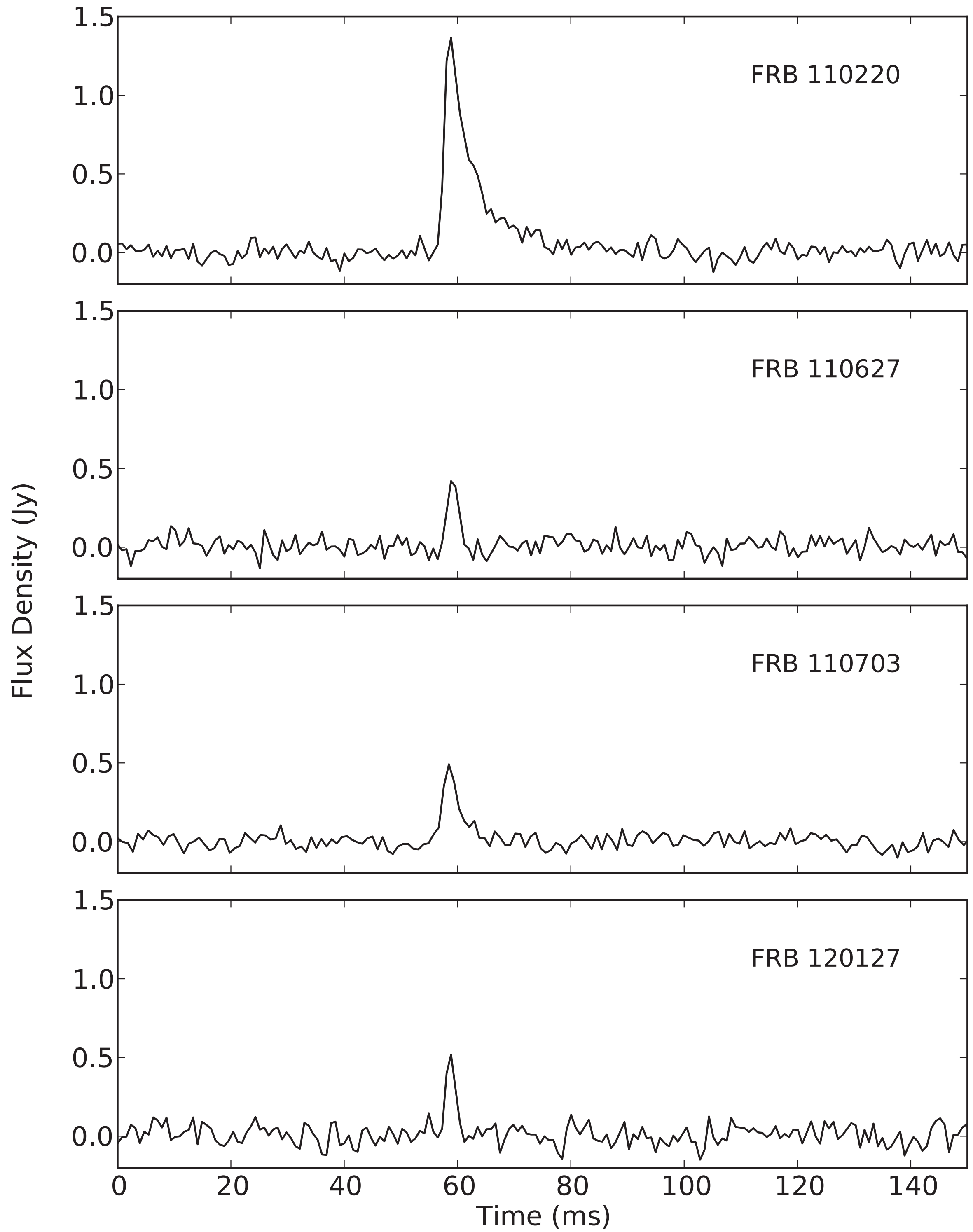
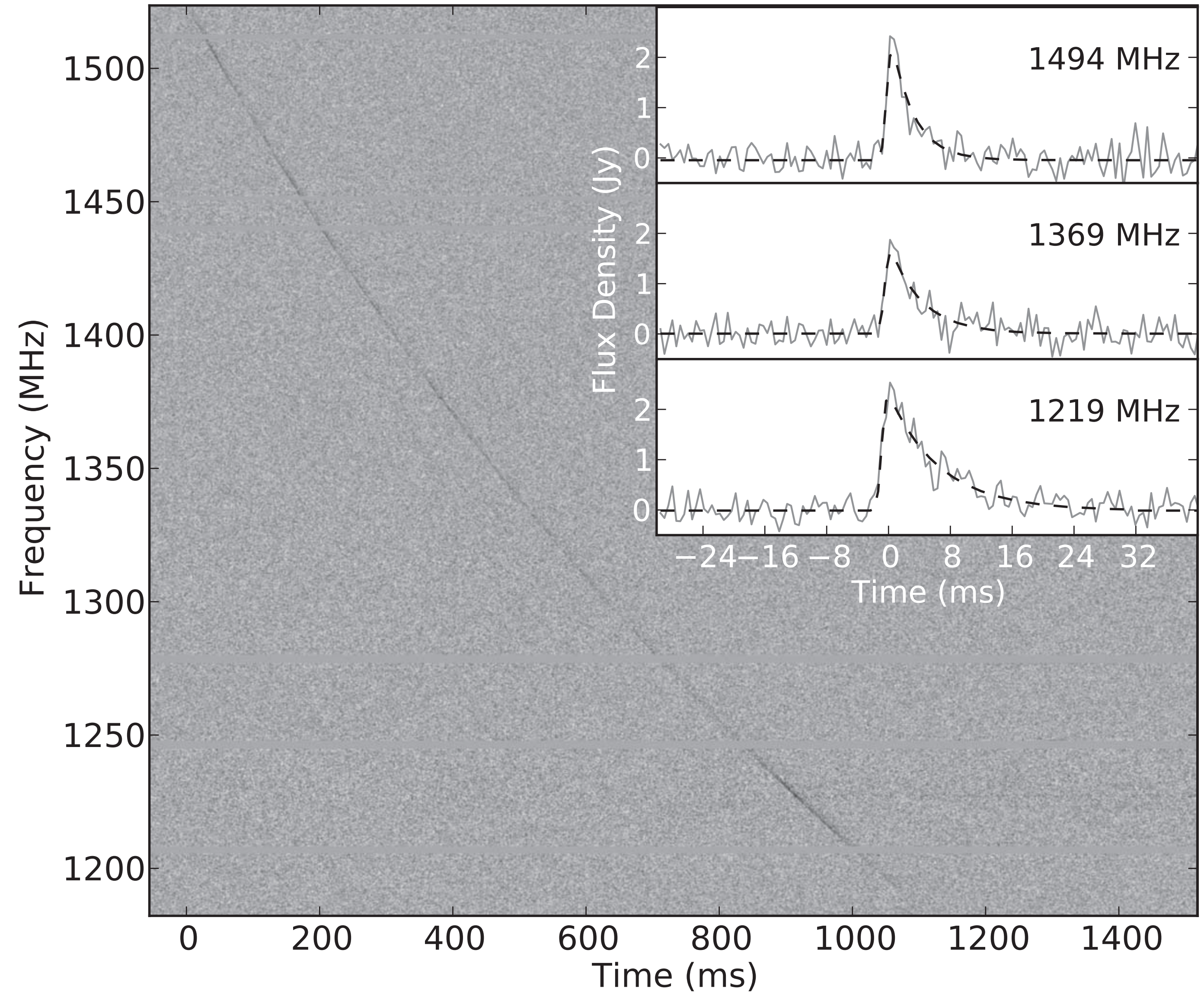


Fig. 1. The frequency-integrated flux densities for the four FRBs. The time resolutions match the level of dispersive smearing in the central frequency channel (0.8, 0.6, 0.9, and 0.5 ms, respectively).



Az első ismétlődő FRB: a forrás nem semmisül meg a kataklizmában (Spitler et al. 2016)

LETTER

doi:10.1038/nature17168

A repeating fast radio burst

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Fast radio bursts are millisecond-duration astronomical radio pulses of unknown physical origin that appear to come from extragalactic distances[1–8]. Previous follow-up observations have failed to find additional bursts at the same dispersion measure (that is, the integrated column density of free electrons between source and telescope) and sky position as the original detections[9]. The apparent non-repeating nature of these bursts has led to the suggestion that they originate in cataclysmic events[10]. Here we report observations of ten additional bursts from the direction of the fast radio burst FRB 121102. These bursts have dispersion measures and sky positions consistent with the original burst[4]. This unambiguously identifies FRB 121102 as repeating and demonstrates that its source survives the energetic events that cause the bursts. Additionally, the bursts from FRB 121102 show a wide range of spectral shapes that appear to be predominantly intrinsic to the source and which vary on timescales of minutes or less. Although there may be multiple physical origins for the population of fast radio bursts, these repeat bursts with high dispersion measure and variable spectra specifically seen from the direction of FRB 121102 support an origin in a young, highly magnetized, extragalactic neutron star[11,12].

and label each burst chronologically starting with the original detection.

The ten newly detected bursts were observed exclusively in two adjacent sky positions of the telescope pointing grid located ~1.3′ apart (Fig. 1 and Extended Data Table 1). The unweighted average J2000 position from the centres of these two beams is right ascension $\alpha = 05$ h 31 min 58 s and declination $\delta = +33° 08' 04''$, with an uncertainty radius of about 3′. The corresponding Galactic longitude and latitude are $l = 174.89°$, $b = -0.23°$. This more accurate position is 3.7′ from the beam centre of the discovery burst[4], meaning that FRB 121102 burst 1 was detected well off-axis, as originally concluded[4].

The measured DMs of all 11 bursts are consistent to within the uncertainties, and the dispersion indices (dispersive delay $\Delta t \propto \nu^{-\xi}$, where ν is the radio frequency) match the $\xi = 2.0$ value expected for radio waves travelling through a cold, ionized medium. This is strong evidence that a single astronomical source is responsible for the events. In addition, the ~0.002 DM index uncertainty we calculate for burst 11 (see Methods) is slightly less than that reported for FRB 110523 (ref. 8), making this the most precise determination of dispersion index for any FRB thus far. The upper bound on the dispersion index is identical to that of FRB 110523

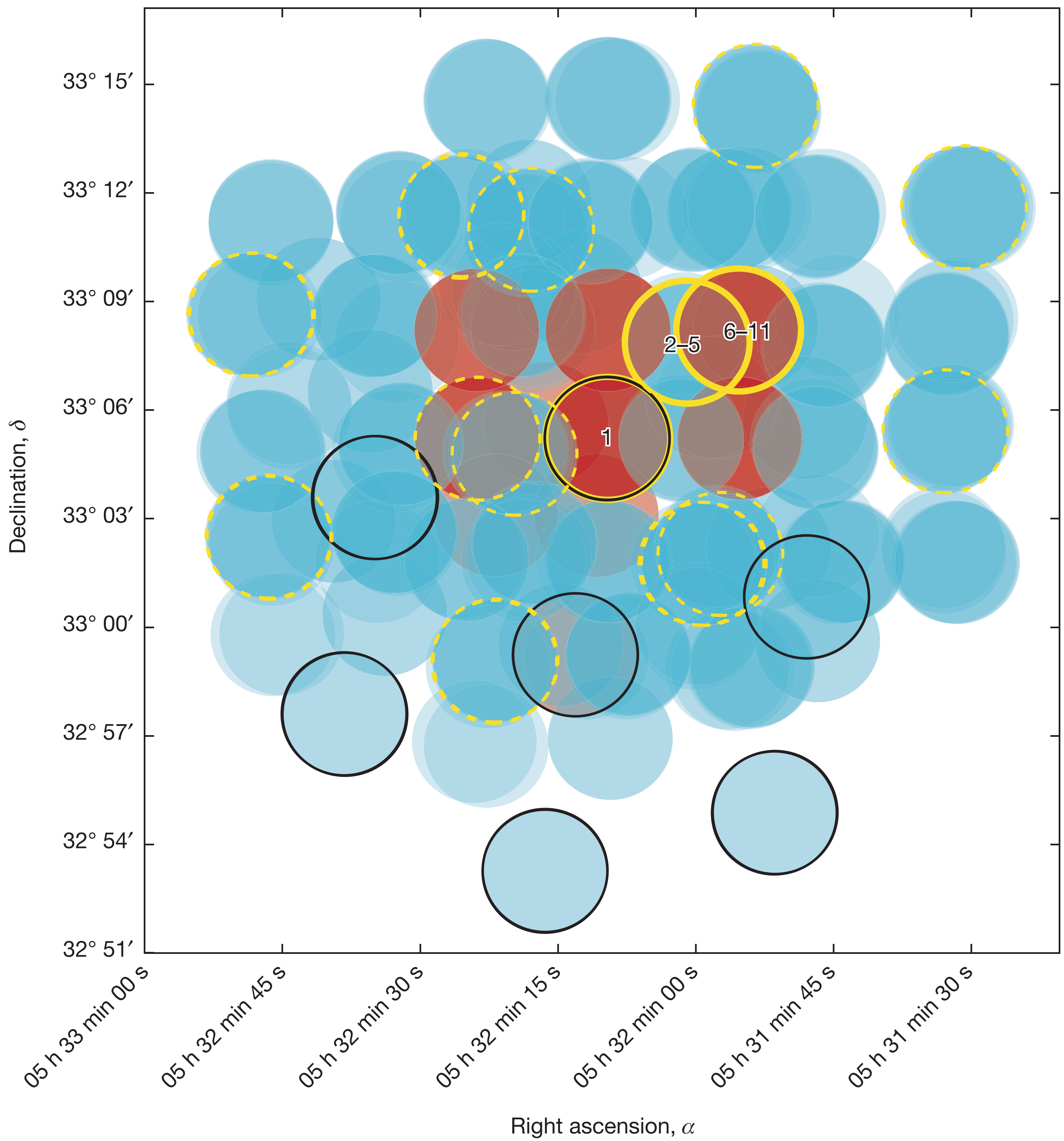

Figure 1 | Discovery and follow-up detections of FRB 121102. For each seven-beam ALFA pointing, the central and outer six beams are shown schematically, in red and blue, respectively (see Extended Data Tables 1 and 2). The circles indicate the ~3.5′ half-power widths of the beams at 1.4 GHz. Darker shading indicates sky positions with multiple grid observations at roughly the same position. The initial discovery pointing[4] and second survey observation are outlined in black (these overlap). Beam positions in which bursts were detected are outlined in solid yellow (dashed yellow outlines for the other six beams from the same pointing) and the corresponding burst identifier numbers (Table 1) are given.

Pontos lokalizáció és anyagalaxis beazonosítása (Chatterjee et al. 2017)

LETTER

doi:10.1038/nature20797

A direct localization of a fast radio burst and its host

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Fast radio bursts[1,2] are astronomical radio flashes of unknown physical nature with durations of milliseconds. Their dispersive arrival times suggest an extragalactic origin and imply radio luminosities that are orders of magnitude larger than those of all known short-duration radio transients[3]. So far all fast radio bursts have been detected with large single-dish telescopes with arcminute localizations, and attempts to identify their counterparts (source or host galaxy) have relied on the contemporaneous variability of field sources[4] or the presence of peculiar field stars[5] or galaxies[4]. These attempts have not resulted in an unambiguous association[6,7] with a host or multi-wavelength counterpart. Here we report the subarcsecond localization of the fast radio burst FRB 121102, the only known repeating burst source[8–11], using high-time-resolution radio interferometric observations that directly image the bursts. Our precise localization reveals that FRB 121102 originates within 100 milliarcseconds of a faint 180-microJansky persistent radio source with a continuum spectrum that is consistent with non-thermal emission, and a faint (twenty-fifth magnitude) optical counterpart. The flux density of the persistent radio source varies by around ten per cent on day timescales, and very long baseline radio interferometry yields an angular size of less than 1.7 milliarcseconds. Our observations are inconsistent with the fast radio burst having a Galactic origin or its source being located within a prominent star-forming galaxy. Instead, the source appears to be co-located with a low-luminosity active galactic nucleus or a previously unknown type of extragalactic source. Localization

These bursts were initially detected with real-time de-dispersed imaging and confirmed by a beam-formed search (Fig. 1). From these detections, the average J2000 position of the burst source is right ascension $\alpha = 05\,\mathrm{h}\ 31\,\mathrm{min}\ 58.70\,\mathrm{s}$, declination $\delta = +33°\ 08'\ 52.5''$, with a 1σ uncertainty of about $0.1''$, consistent with the Arecibo localization[9] but with three orders of magnitude better precision. The dispersion measure (DM) for each burst is consistent with the previously reported value[9] of $558.1 \pm 3.3\,\mathrm{pc\,cm^{-3}}$, with comparable uncertainties. Three bursts detected at the VLA (2.5–3.5 GHz) had simultaneous coverage at Arecibo (1.1–1.7 GHz). After accounting for dispersion delay and light travel time, one burst is detected at both telescopes (Extended Data Table 1), but the other two show no emission in the Arecibo band, implying frequency structure at scales of approximately 1 GHz. This finding provides new constraints on the broadband burst spectra, which previously have shown highly variable structure across the Arecibo band[8–10].

Radio images at 3 GHz produced by integrating the VLA fast-sampled data reveal a continuum source within $0.1''$ of the burst position, which we refer to hereafter as the persistent source. A cumulative 3-GHz image (root-mean-square (r.m.s.) of $\sigma \approx 2\,\mu\mathrm{Jy}$ per beam; Fig. 2) shows 68 other sources within a $5'$ radius, with a median flux density of $26\,\mu\mathrm{Jy}$. Given the agreement between the positions of the detected bursts and the continuum counterpart, we estimate a probability of chance coincidence of less than 10^{-5}. The persistent source is detected in follow-up VLA observations over the entire frequency range from 1 GHz to 26 GHz. The radio spectrum is broadly consistent with

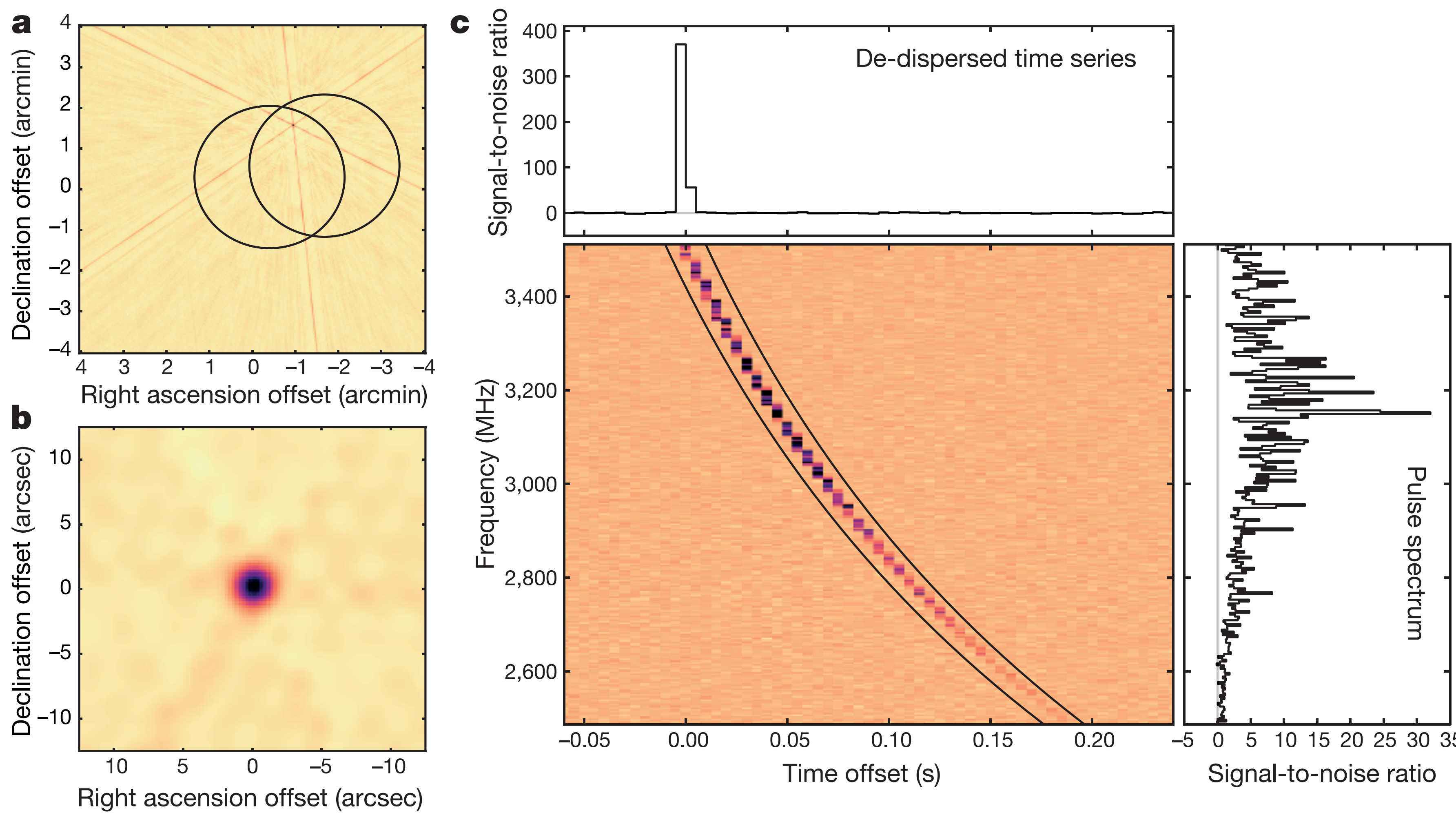
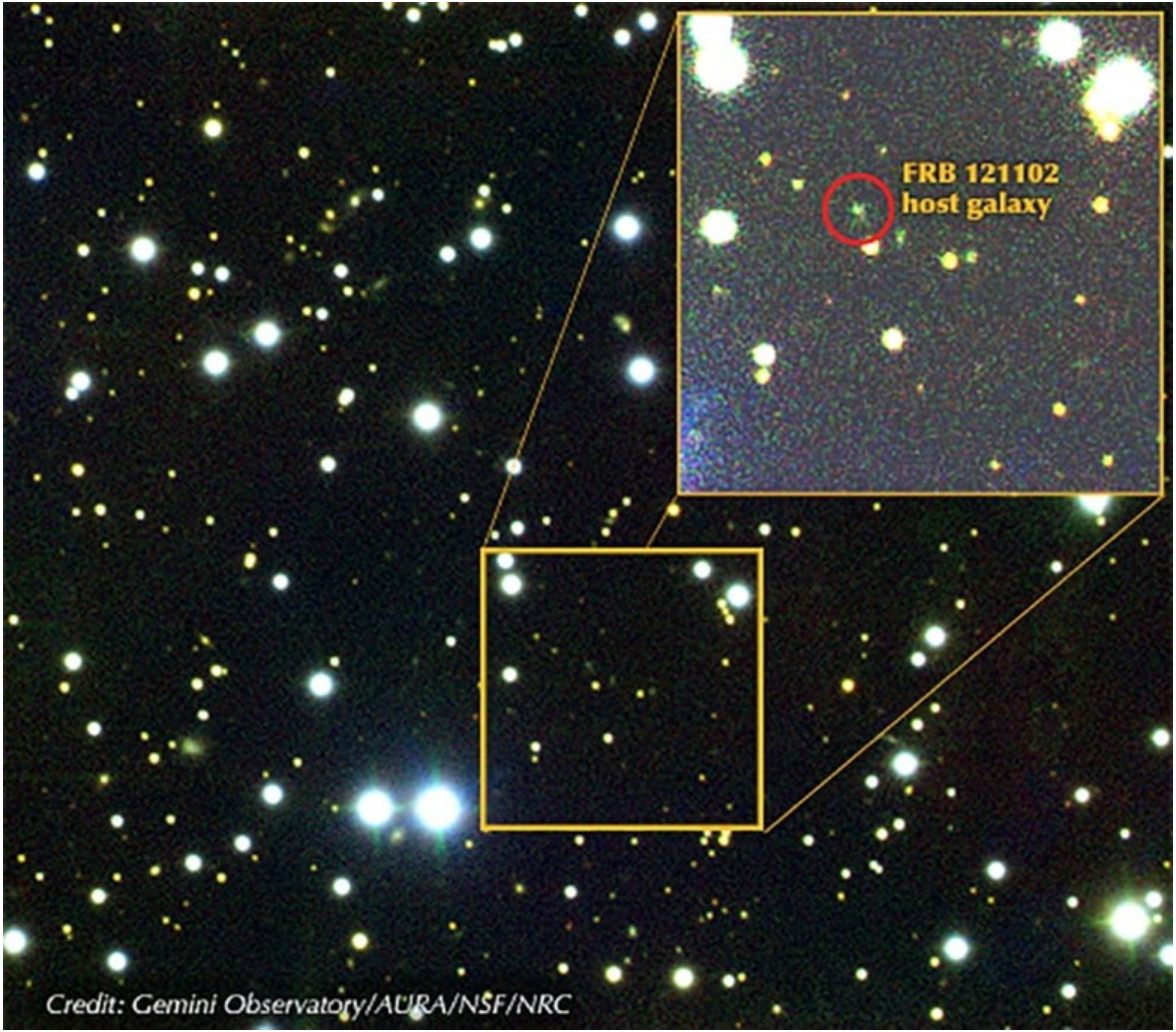


Figure 1 | VLA detection of FRB 121102. a, A 5-ms dispersion-corrected dirty image showing a burst from FRB 121102 at MJD 57633.67986367 (2016 September 2). The approximate localization uncertainty from previous Arecibo detections[9] (3′ beam full-width at half-maximum (FWHM)) is shown with overlapping circles. **b**, A zoomed-in portion of **a**, deconvolved and re-centred on the detection, showing the approximately 0.1″ localization of the burst. **c**, Time–frequency data extracted from phased VLA visibilities at the burst location shows the ν^{-2} dispersive sweep of the burst. The solid black lines illustrate the expected sweep for $DM = 558$ pc cm^{-3}. The de-dispersed lightcurve and spectra are projected to the upper and right panels, respectively. In all panels, the colour scale indicates the flux density.


FRB 121102
host galaxy
Credit: Gemini Observatory/AURA/NSF/NRC

A második ismétlődő FRB (CHIME/FRB Collaboration 2019)

LETTER

https://doi.org/10.1038/s41586-018-0864-x

A second source of repeating fast radio bursts

The CHIME/FRB Collaboration*

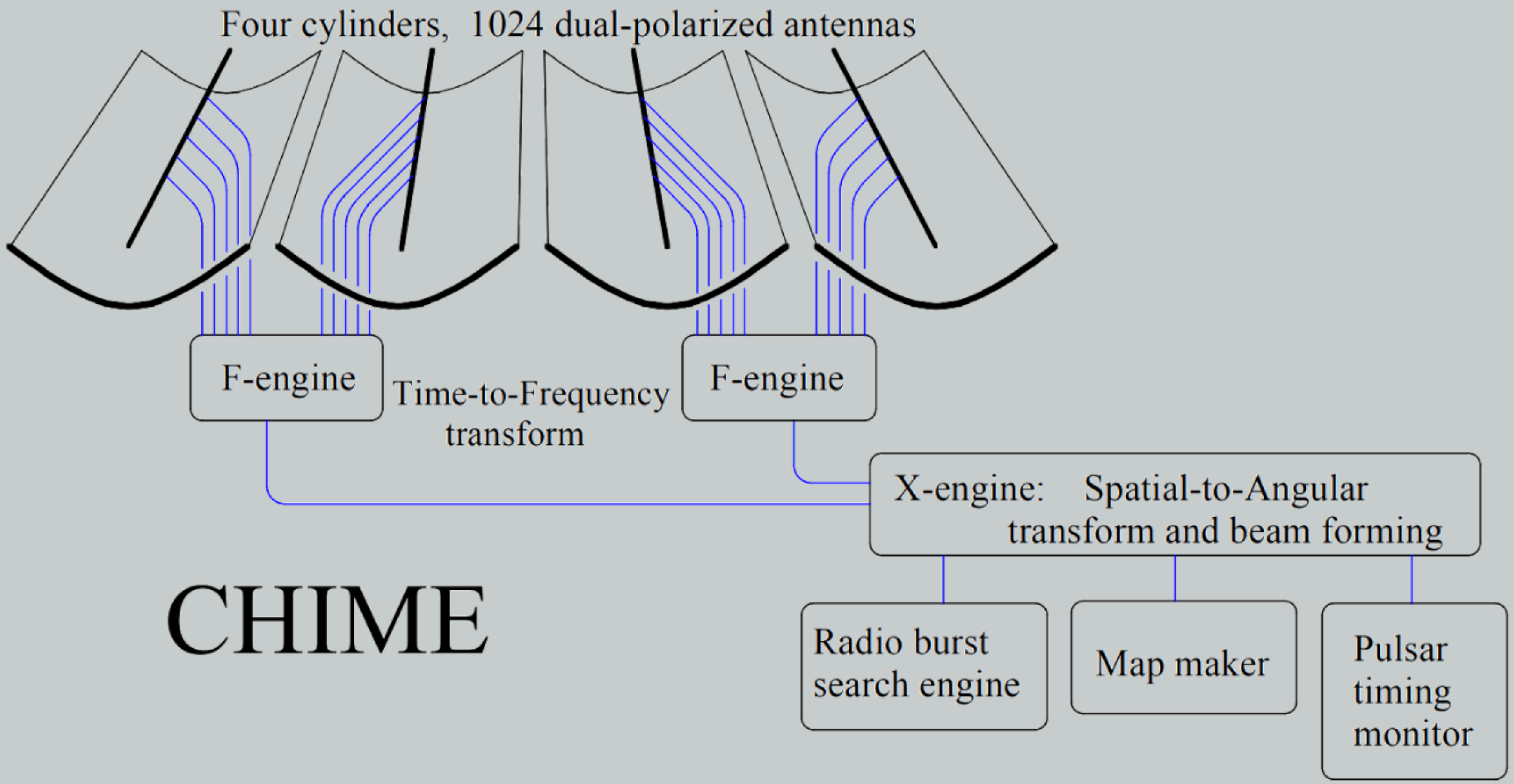
The discovery of a repeating fast radio burst (FRB) source[1,2], FRB 121102, eliminated models involving cataclysmic events for this source. No other repeating FRB has hitherto been detected despite many recent discoveries and follow-ups[3–5], suggesting that repeaters may be rare in the FRB population. Here we report the detection of six repeat bursts from FRB 180814.J0422+73, one of the 13 FRBs detected[6] by the Canadian Hydrogen Intensity Mapping Experiment (CHIME) FRB project[7] during its pre-commissioning phase in July and August 2018. These repeat bursts are consistent with its origin from a single position on the sky, with the same dispersion measure, about 189 parsecs per cubic centimetre. This line of sight traces approximately twice the expected Milky Way column density of free electrons, which implies an upper limit on the source redshift of 0.1, showing it to be closer to Earth by a factor of at least 2 than FRB 121102[8]. In some of the repeat bursts, we observe subpulse frequency structure, drifting and spectral variation reminiscent of that seen in FRB 121102[9,10], suggesting similar emission mechanisms or propagation effects. This second repeater, found among the first few CHIME/FRB discoveries, suggests that there exists—and that CHIME/FRB and other wide-field, sensitive radio telescopes will find—a substantial population of repeating FRBs.

FRB 180814.J0422+73 was discovered by the CHIME/FRB project[6,7] in August 2018 when the FRB instrument was in a pre-commissioning phase. CHIME is a transit telescope and has an effective instantaneous field of view (FOV) of about 250 square degrees. During the remainder of the summer pre-commissioning, and during September and October commissioning periods, the position of this source was observed semi-regularly, with daily exposures (when not interrupted by commissioning activities) of about 36 min. The large exposure is beam and was initially assigned an incorrect RA and not classified as extragalactic. As the CHIME/Pulsar data has higher time resolution, we show that in Fig. 2.

We have searched for repeat bursts from the other 12 sources discovered during the pre-commissioning phase[6] by looking for events of similar DM when their best-estimated position was in the main lobes of the formed beams. We found no events exceeding our signal-to-noise (SNR) threshold of 10. Each of the 12 was subject to a different exposure and sensitivity; two have higher declinations, hence more exposure, than for FRB 180814.J0422+73, so are likely to have substantially lower observed repeat rates, if they are repeaters. A detailed discussion of this will be presented elsewhere.

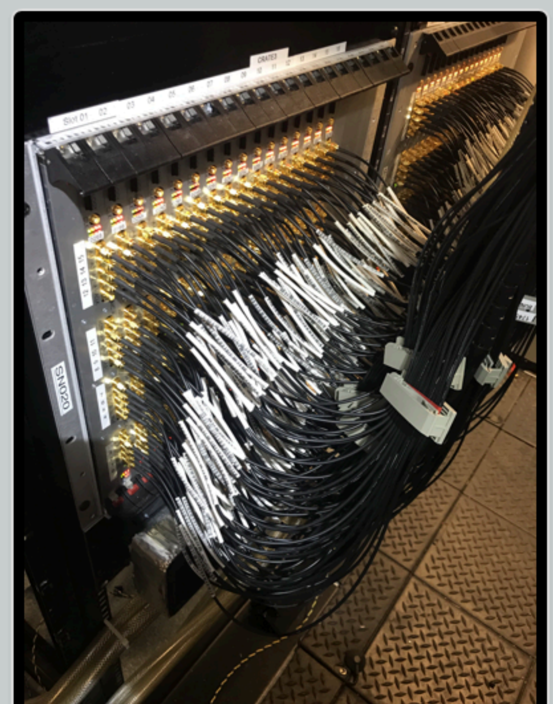
The automated pipeline[7] recorded raw intensity data to disk for all CHIME/FRB repeat events from FRB 180814.J0422+73 except for the burst on 6 September, for which the system failed to record to disk. The events with intensity data allow us to examine their dynamic spectra (see Fig. 2) and measure refined burst parameters (see Table 1). The 6 September event has only metadata determined by the automated pipeline and therefore we have only coarse estimates of its properties; however, these are sufficient to verify that it was from the same source. Polarimetry of FRB 121102 revealed one of the highest rotation measures ever seen[9], an important clue about the source environment. No polarization information was available for the events reported here, but functionality to record data with a higher time resolution and polarization information is currently being deployed for both the CHIME/FRB and CHIME/Pulsar systems.

The four events with raw intensity data show complexities in their burst profiles (Fig. 2). The events on 17 September and 28 October exhibit multiple spectro-temporal structures, reminiscent of bursts from FRB 121102[9,10,13] and FRB 170827[14]. Because of this structure, the



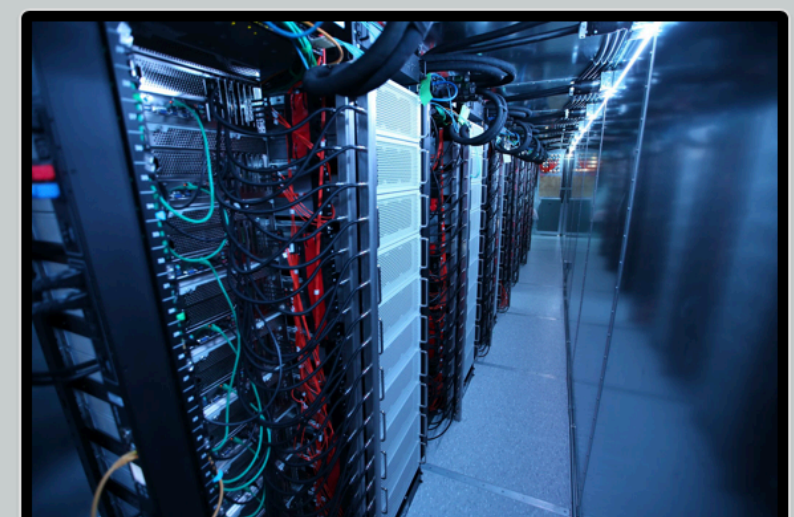
TELESCOPE

CHIME consists of four adjacent 20m x 100m cylindrical reflectors oriented north-south. The focal axis of each cylinder is lined with 256 dual-polarization antennas, each of which



F-ENGINE

The FPGA-based F-Engine is housed in two specially shielded 20-foot shipping containers



X-ENGINE

The GPU-based X-Engine is housed in two specially-shielded 40-foot shipping containers located just east of the cylinders. Each container contains 128 compute nodes housed in 15 refrigerator-sized racks. Each

FAST RADIO BURST DETECTOR

To search for FRBs, CHIME will continuously scan 1024 separate points or “beams” on the sky 24/7. Each beam is sampled at 16,000 different frequencies and at a rate of 1000 times per second, corresponding to 130 billion bits of data per second to be sifted through in real time. The data are packaged in the X-engine and shipped via a high-speed network to the FRB backend search engine, which is housed in its own 40-foot shipping container under the CHIME telescope. The FRB search backend will consist of 128 compute nodes with over 2500 CPU cores and 32,000 GB of RAM. Each compute node will search eight individual beams for FRBs. Candidate FRBs are then passed to a second stage of processing which combines information from all 1024 beams to determine the location, distance and characteristics of the burst. Once an FRB event has been detected, an automatic alert will be sent, within seconds of the arrival of the burst, to the CHIME team and to the wider astrophysical community allowing for rapid follow up of the burst.

chime-experiment.ca

…és még 8 ismétlődő, közülük egy forráslokalizációval…

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CrossMark

CHIME/FRB Discovery of Eight New Repeating Fast Radio Burst Sources

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Abstract

We report on the discovery of eight repeating fast radio burst (FRB) sources found using the Canadian Hydrogen Intensity Mapping Experiment (CHIME) telescope. These sources span a dispersion measure (DM) range of 103.5–1281 pc cm^{-3}. They display varying degrees of activity: six sources were detected twice, another three times, and one 10 times. These eight repeating FRBs likely represent the bright and/or high-rate end of a distribution of infrequently repeating sources. For all sources, we determine sky coordinates with uncertainties of $\sim 10'$. FRB 180916.J0158+65 has a burst-averaged DM $= 349.2 \pm 0.3$ pc cm^{-3} and a low DM excess over the modeled Galactic maximum (as low as $\sim$20 pc cm^{-3}); this source also has a Faraday rotation measure (RM) of -114.6 ± 0.6 rad m^{-2}, which is much lower than the RM measured for FRB 121102. FRB 181030.J1054+73 has the lowest DM for a repeater, 103.5 ± 0.3 pc cm^{-3}, with a DM excess of $\sim$70 pc cm^{-3}. Both sources are interesting targets for multi-wavelength follow-up due to their apparent proximity. The DM distribution of our repeater sample is statistically indistinguishable from that of the first 12 CHIME/FRB sources that have not yet repeated. We find, with 4σ significance, that repeater bursts are generally wider than those of CHIME/FRB bursts that have not repeated, suggesting different emission mechanisms. Many of our repeater events show complex morphologies that are reminiscent of the first two discovered repeating FRBs. The repetitive behavior of these sources will enable interferometric localizations and subsequent host galaxy identifications.

Article

A repeating fast radio burst source localized to a nearby spiral galaxy

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Fast radio bursts (FRBs) are brief, bright, extragalactic radio flashes[1,2]. Their physical origin remains unknown, but dozens of possible models have been postulated[3]. Some FRB sources exhibit repeat bursts[4–7]. Although over a hundred FRB sources have been discovered[8], only four have been localized and associated with a host galaxy[9–12], and just one of these four is known to emit repeating FRBs[9]. The properties of the host galaxies, and the local environments of FRBs, could provide important clues about their physical origins. The first known repeating FRB, however, was localized to a low-metallicity, irregular dwarf galaxy, and the apparently non-repeating sources were localized to higher-metallicity, massive elliptical or star-forming galaxies, suggesting that perhaps the repeating and apparently non-repeating sources could have distinct physical origins. Here we report the precise localization of a second repeating FRB source[6], FRB 180916.J0158+65, to a star-forming region in a nearby (redshift 0.0337 ± 0.0002) massive spiral galaxy, whose properties and proximity distinguish it from all

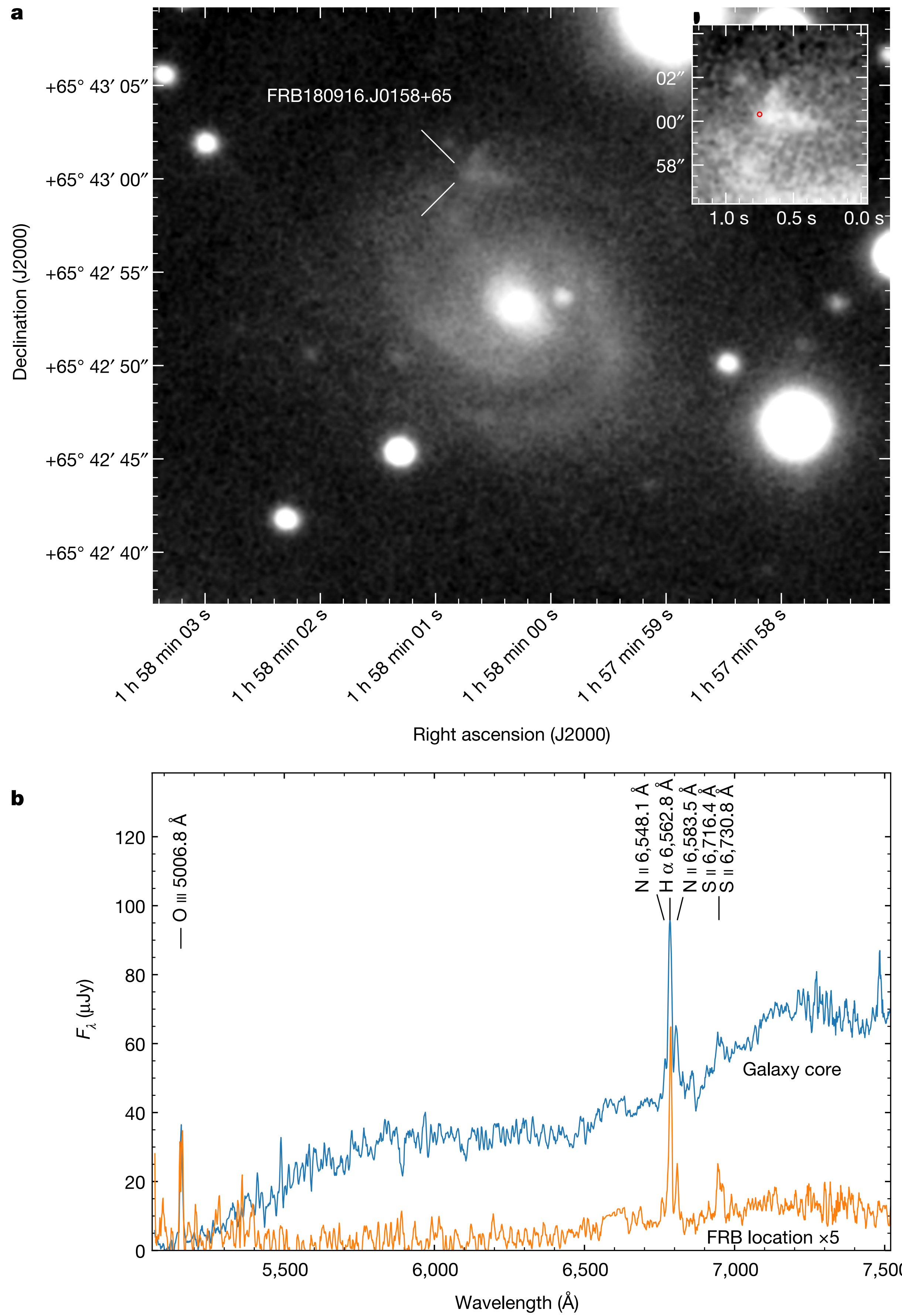
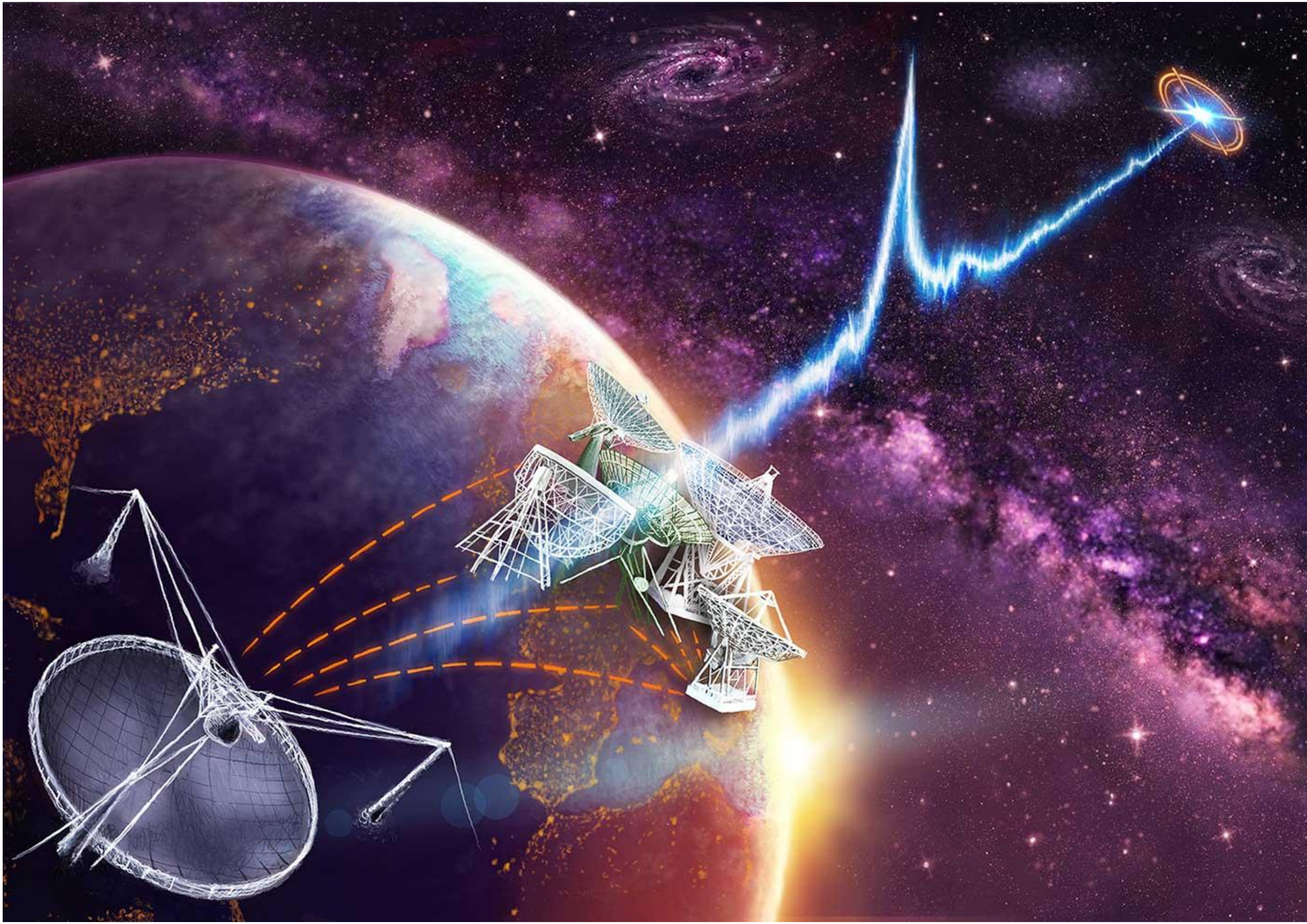
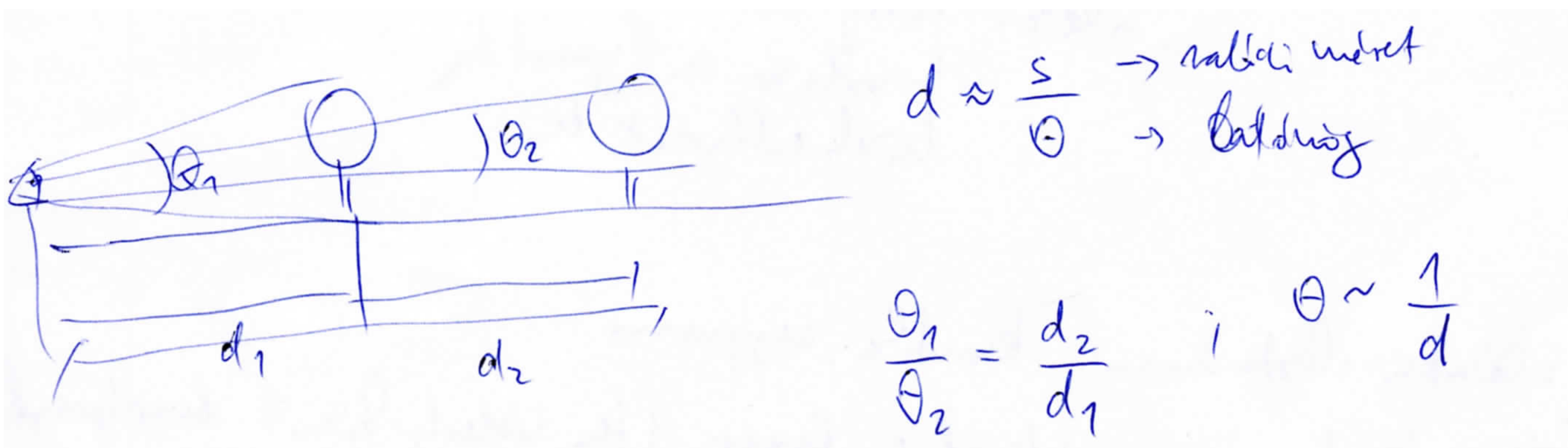


Fig. 3 | Gemini-North host galaxy image and optical spectrum. a, Image of the host galaxy using the *r′* filter. The position of FRB 180916.J0158+65 is marked. The inset shows a higher-contrast zoom-in of the star-forming region containing FRB 180916.J0158+65 (marked by the red circle). The uncertainty in the position of FRB 180916.J0158+65 is smaller than the resolution of the image. **b**, Sky-subtracted spectrum extracted from a 5-arcsec aperture around the host galaxy core (blue) and a 2-arcsec aperture around the location of FRB 180916.J0158+65 (orange, scaled by a factor of five for clarity). Emission lines are identified along with their rest-frame wavelengths in air. Owing to the complicated shape of the galaxy, the flux densities, F_λ, have not been corrected for slit losses.

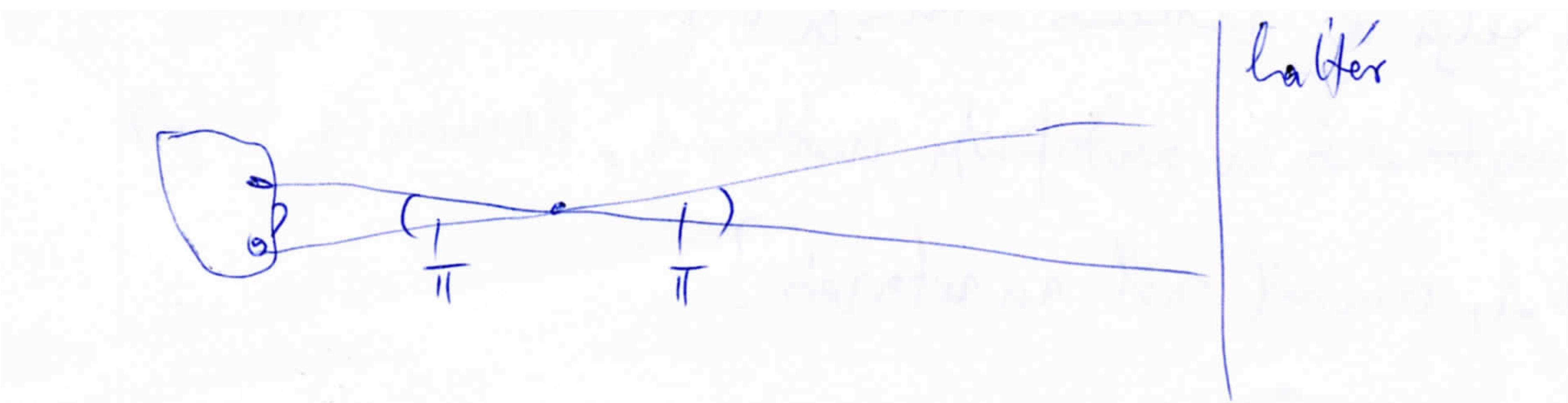


- <u>I/2. Távolságok a mindennapi életben</u>

  Valódi méreteket természetes tanulással megtanuljuk -> **“standard méterrúd”** koncepciója. Ha ez a tudás megvan, a látószögek alapján becsüljük a távolságot.



Parallaxis: ugyanazon objektumot két látószögből is megfigyeljük. Térlátásunk alapja.



- Sötétben mindez nem működik.
  “Standard gyertya”: az abszolút fényesség és látszó fényesség összevetésével következtetünk a távolságra.
  A kurzus igen nagy hányada a standard gyertyák kalibrálásáról szól (cefeidák, RR Lyrae-k, planetáris ködök, gömbhalmazok, szupernóvák…)

  A hétköznapi életben agyunk folyamatosan dolgozza fel a perspektívákat, relatív méreteket és sebességeket, parallaxist.

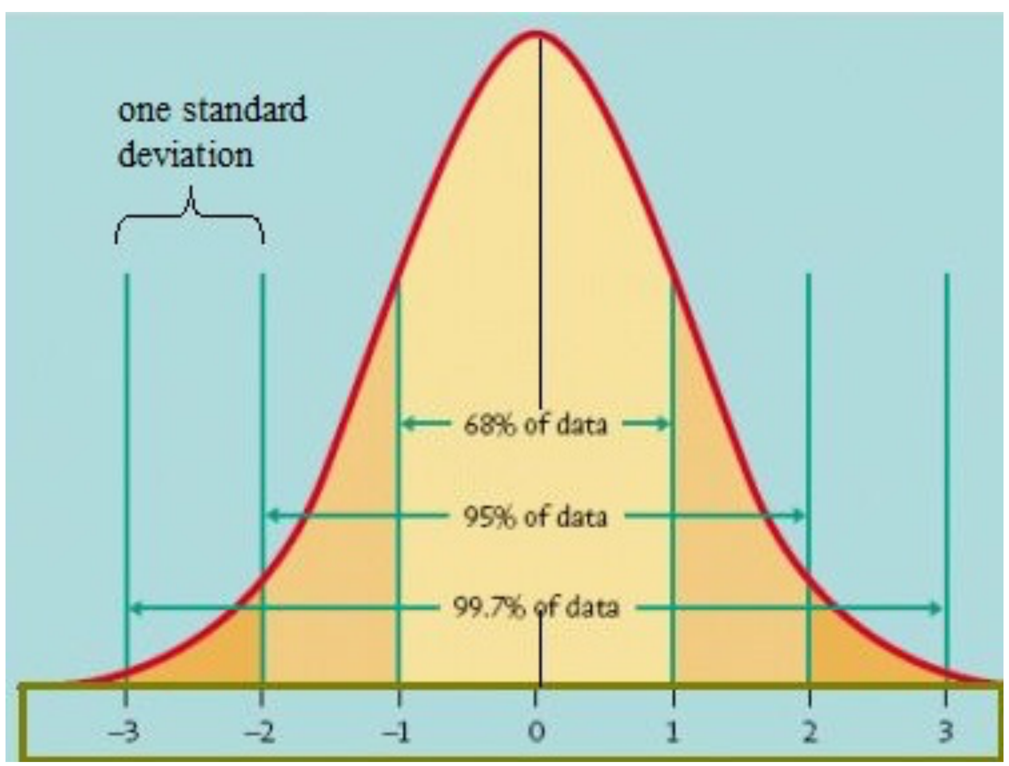
- I/3. Távolságegységek
  Történelmi fejlődés
  Metrikus rendszer: 1984-es definíció (Bay Zoltán javaslata)

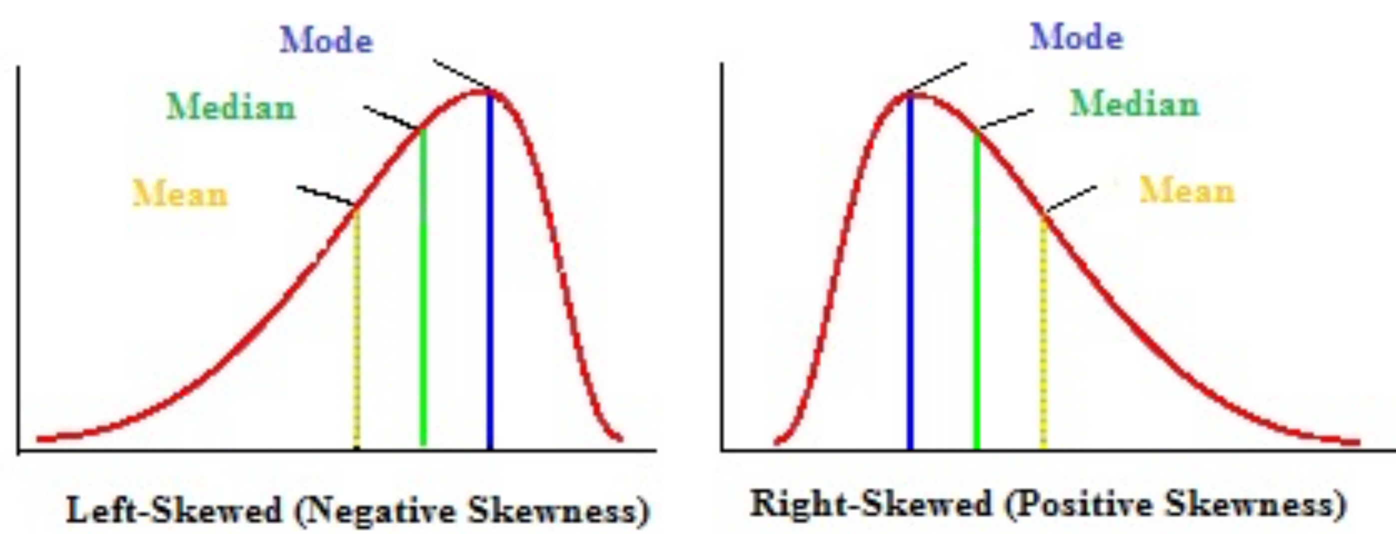
  1 m=a fény vákuumban megtett útja 1/299792452 s alatt
  1 s=az alapállapotú cézium-133 atom két hiperfinom energiaszintje közötti átmenetnek megfelelő sugárzás 9 192 631 770 periódusának időtartama

  Csillagászatban: nem metrikus rendszer
  - kilométer: égitestek átmérője
  - csillagászati egység: égitestek távolsága a Naprendszerben
  - fényév: szemléletes egység a csillagok között
  - parszek: képletekben egyszerűbb összefüggések

- <u>I/4. Pár gondolat a mérések bizonytalanságáról</u>
  1+/-0.001 m Mit is jelent ez pontosan?

  Véletlen (random) vs. szisztematikus hibák.
  A csillagászatban a standard méterrúdak és standard gyertyák téves kalibrálása hatalmas szisztematikus hibákat okozott.





Normál eloszlás **Ferde eloszlások**

II. Első lépés: a Föld

Ókori egyiptomiak: a Nílus áradásai után adókötelezettség-besoroláshoz kellettek a földbirtokok méretei -> földmérés alapjai (geometria). Kísérleti tudomány volt náluk, a matematikai geometriát nem dolgozták ki.

Még ősibb civilizáció: Babilónia. Tőlük ered a 60-as számrendszer. 360 nap egy év, 360 fok a teljes kör, 1 fok 60 ívperc, 1 ívperc 60 ívmásodperc (5000 éves mértékegységek!)

Látszó méretek, távolságok az égen szögekben.

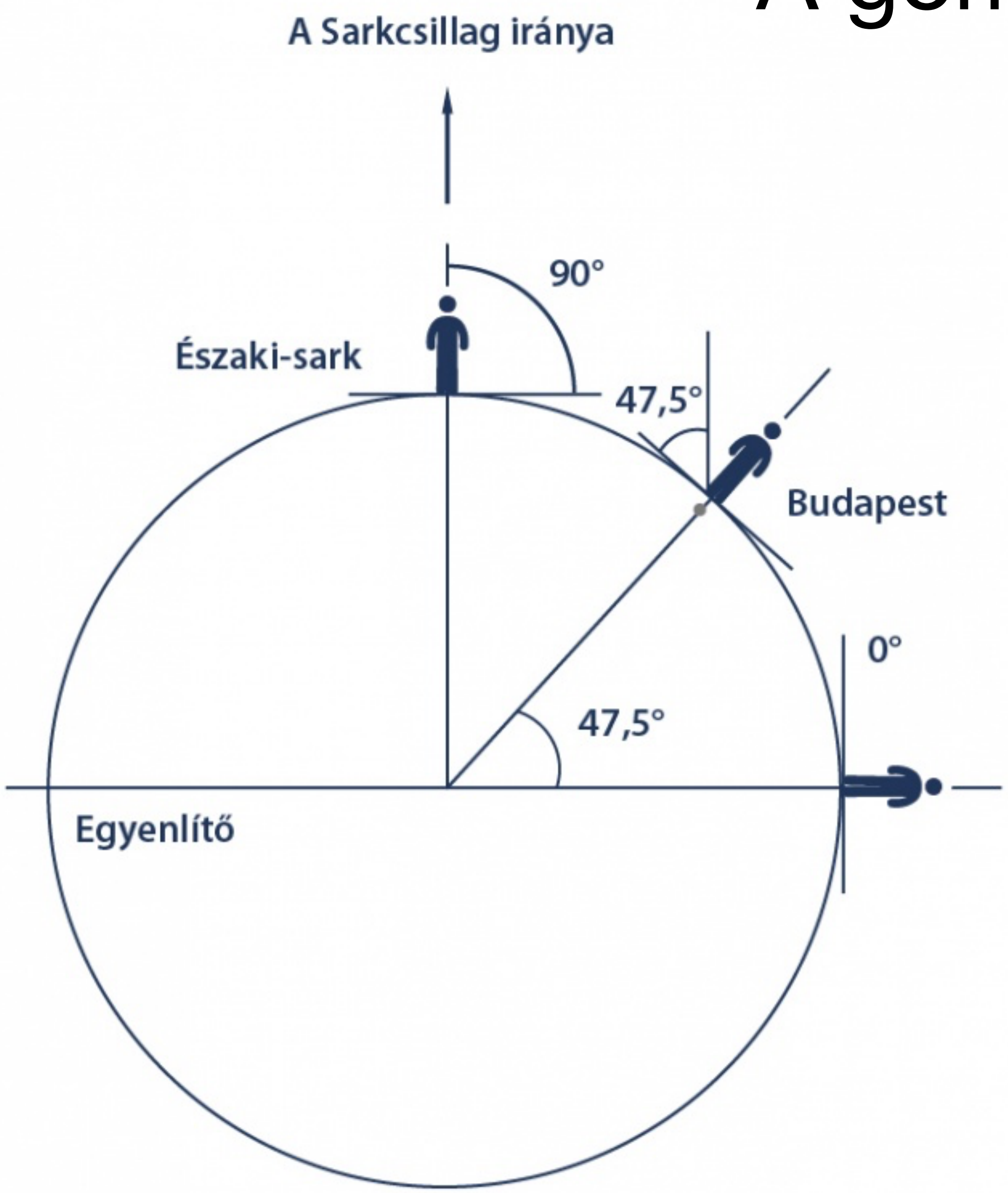
Pl. Nap, Hold kb. 0.5 fok=30’.

Fizikai egység: radián

$$2\pi \text{ rad} = 360^\circ \rightarrow 1 \text{ rad} = \frac{180^\circ}{\pi} \approx 57.3^\circ$$

$$1^\circ = \frac{\pi}{180} \text{ rad} \rightarrow 1'' = \frac{1}{3600} \cdot \frac{\pi}{180} \text{ rad} \approx 4.85 \cdot 10^{-6} \text{ rad} = 4.85 \, \mu\text{rad}$$

A gömb alakú Föld



Számoszi Pithagórász
(i.e. 582-497)

mta.hu

BELFÖLD

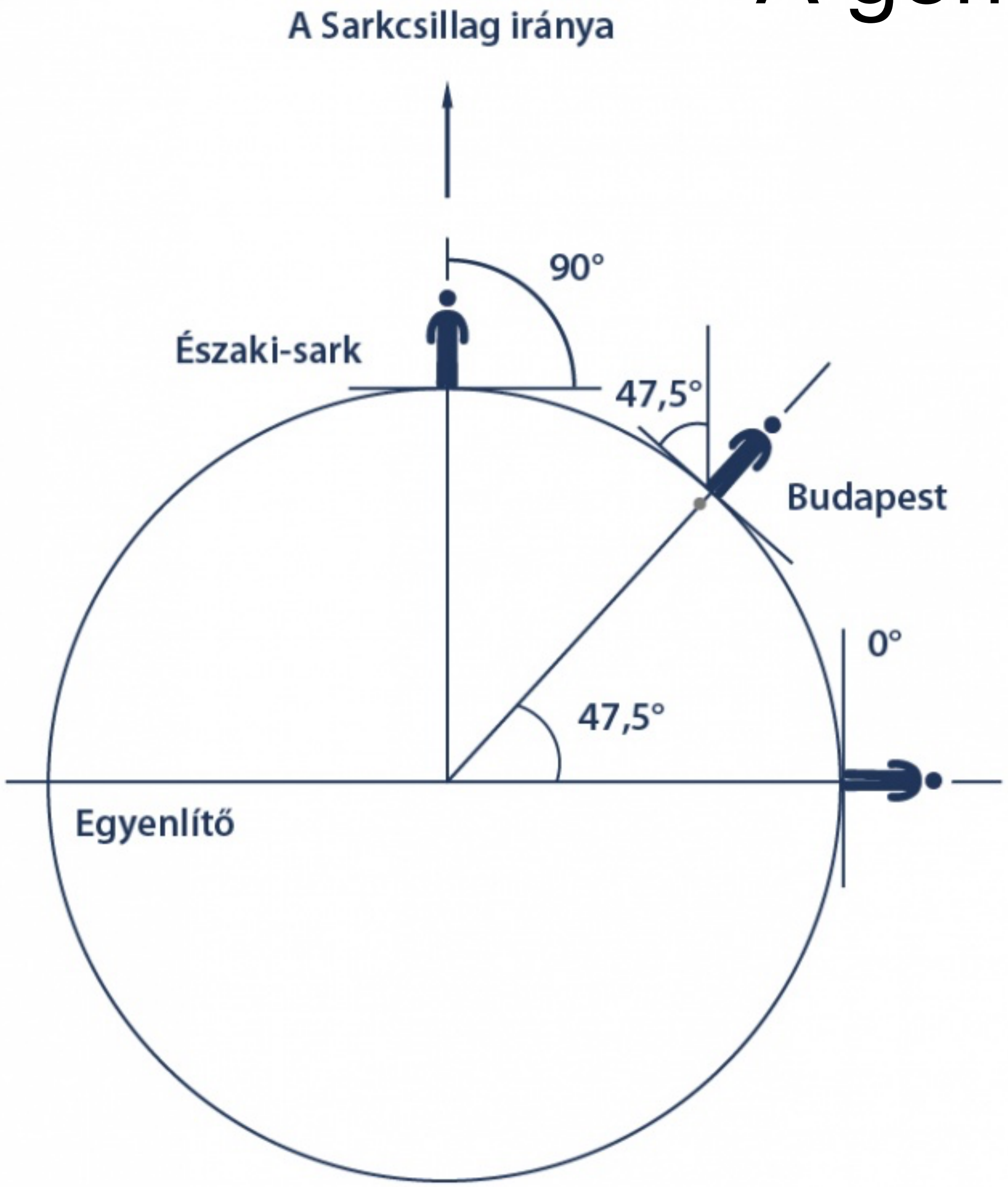
TUDOMÁNY # ÖSSZEESKÜVÉS-ELMÉLET # VATIKÁN # BALATON

És mégis lapos a Föld?

Balavány György
2017. 08. 06. 15:00

A Balaton vize vízszintes, tehát a Föld is – állítják a laposföld-hívők. A mozgalom magyarországi vezetőivel beszélgettünk, de megkérdeztünk igazi kutatókat is. Felkavaró tartalom!

A gömb alakú Föld



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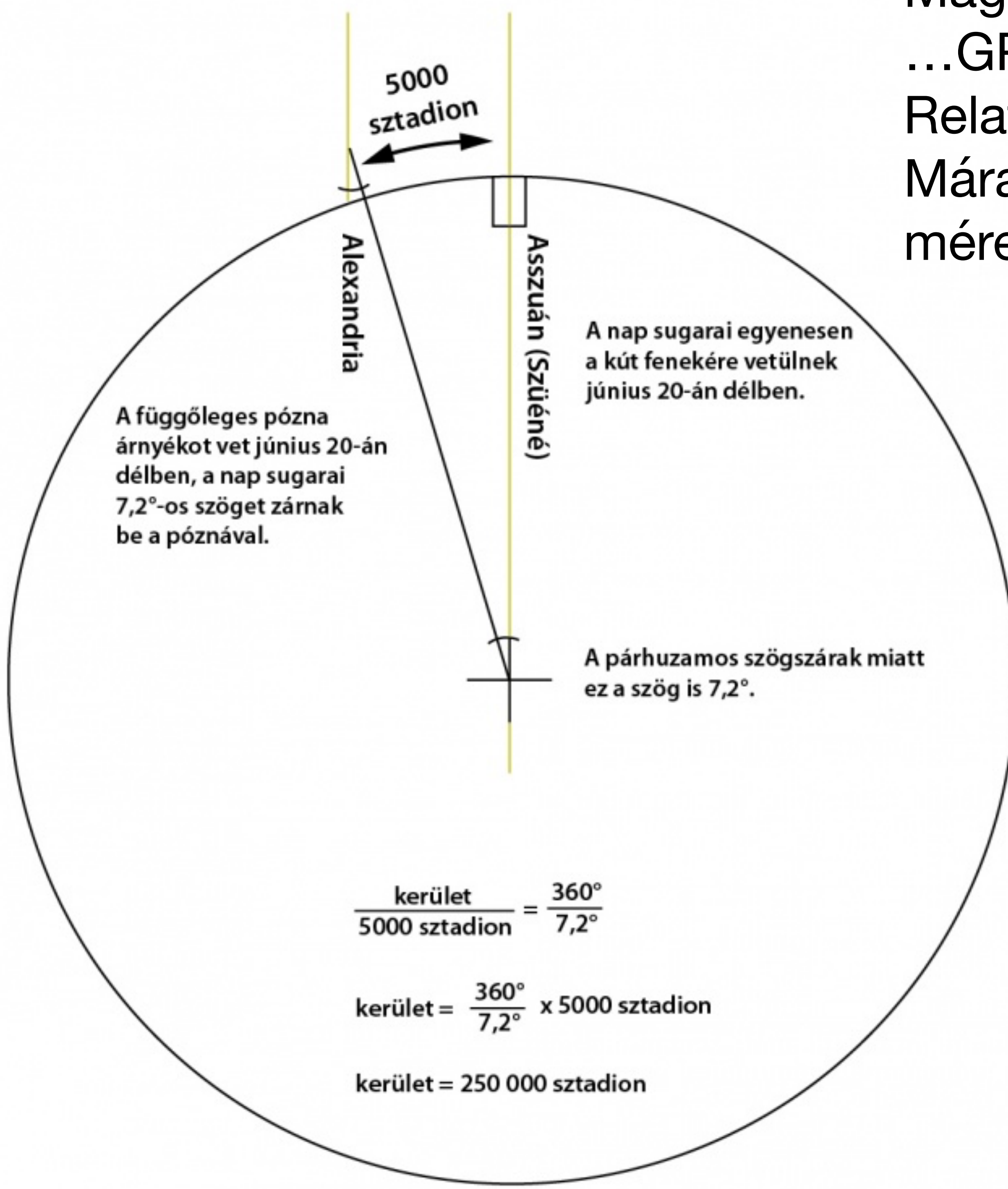
Erathosztenész (i.e. 240 körül)



Magellán (1519-1522)…
…GPS: Global Positioning System
Relativisztikus korrekciókkal.
Mára alkalmazott tudomány a Föld mérete

mta.hu

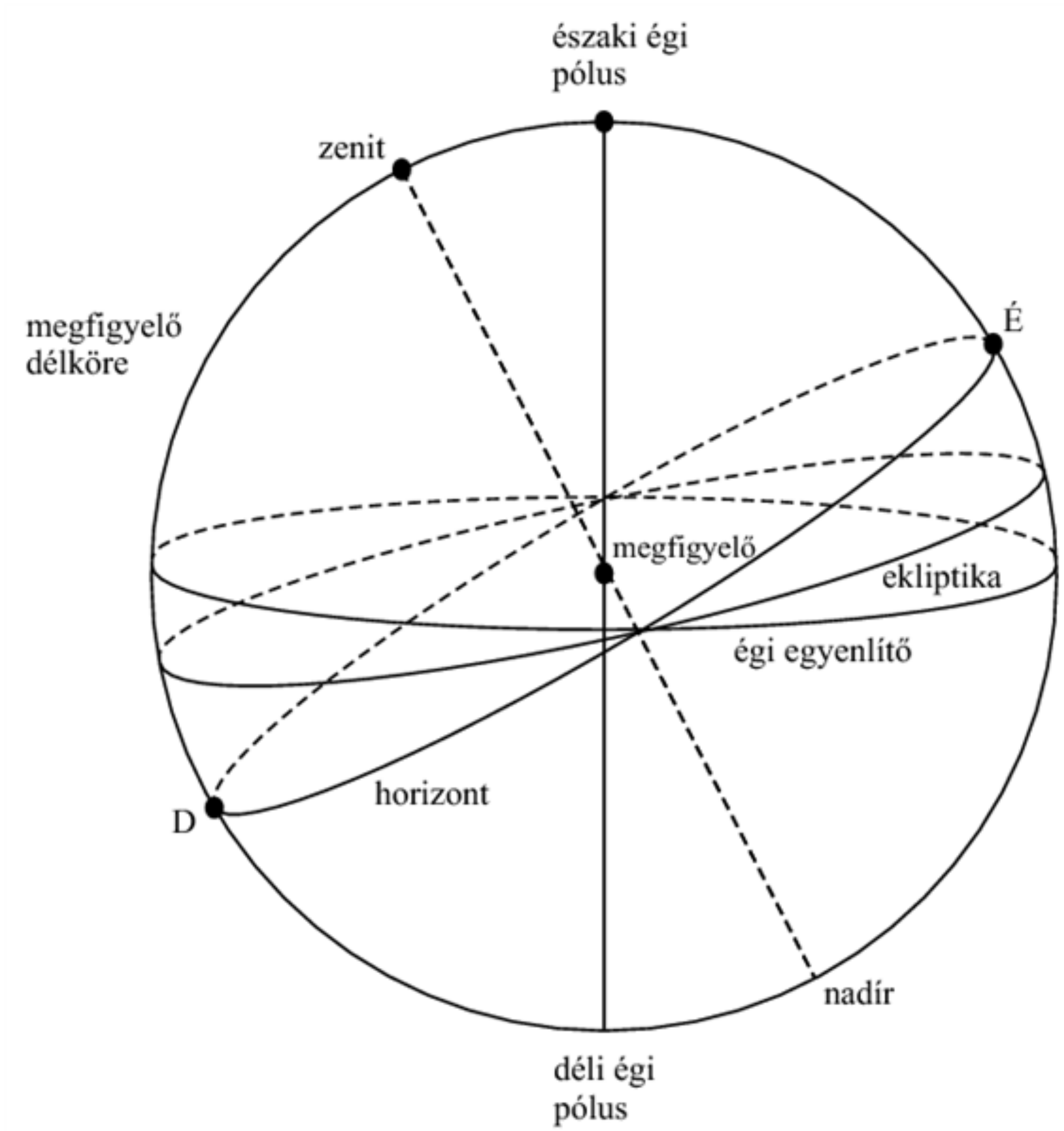
III. Második lépés: a Naprendszer

Az éggömb koncepciója

Bolygók: mozognak
Éggömb körbefordulási ideje 23h56m4s -> minden nap előre csúszik a látható ég 3m56s-cel. Egy év alatt teljes kör.

Szabadszemes bolygók: Merkúr, Vénusz, Mars Jupiter, Szaturnusz (Nap, Hold)

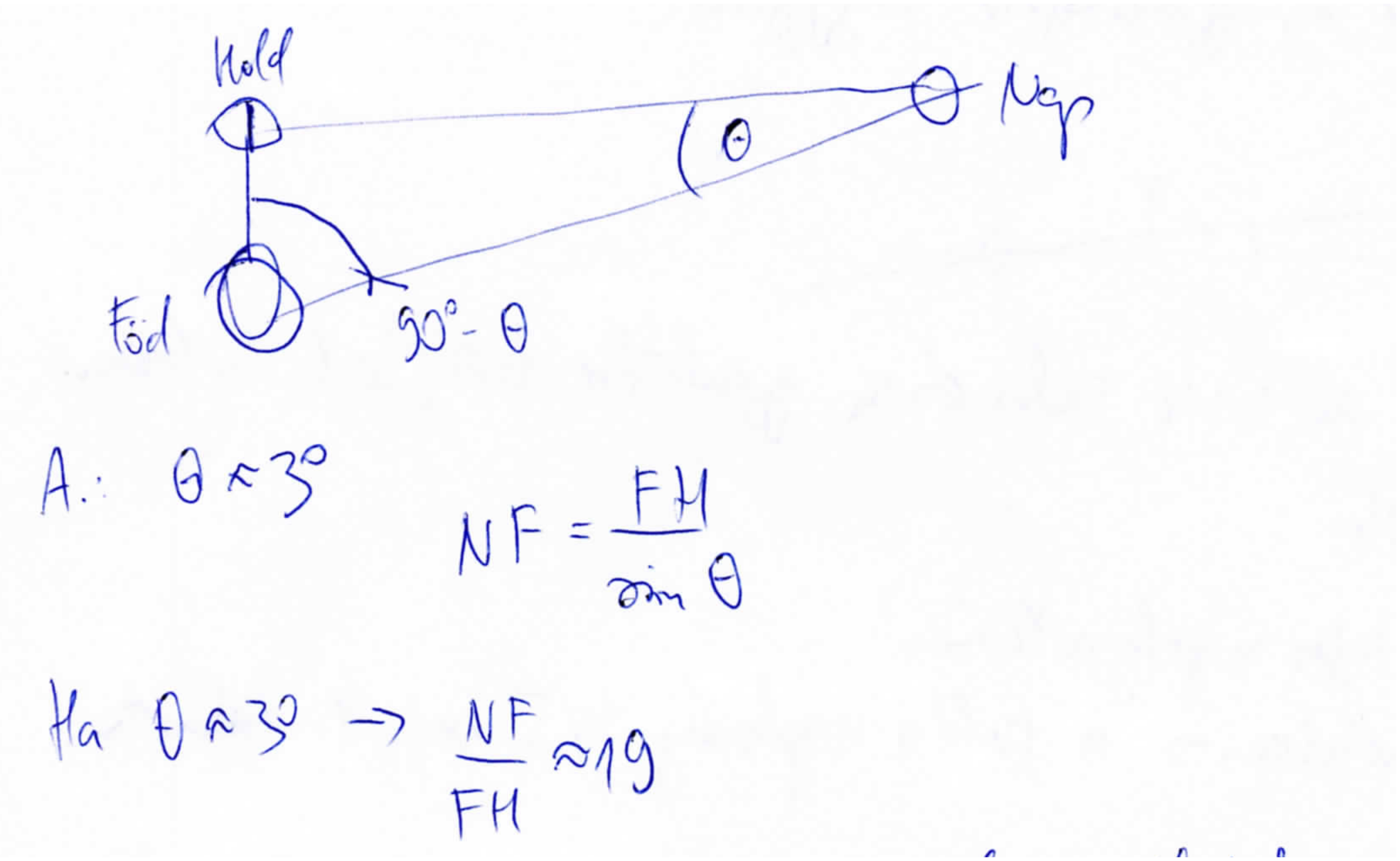
Az éggömbön vándorlás sebessége távolság szerint sorba rendezi a “bolygókat”. Továbbá a Hold eltakar bolygókat, de a bolygók soha nem vonulnak át a Hold előtt.



Éggömb

Három görög: Arisztarkhosz, Hipparkhosz, Ptolemaiosz

Arisztarkhosz (i.e. 320-250): Föld kering a Nap körül; relatív távolságok a Naprendszerben.
Lunáris dichotómia módszere: Nap-Föld távolság Föld-Hold egységben

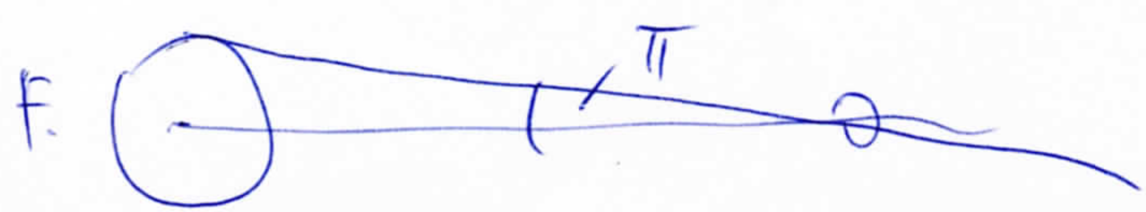


(astronomynotes.com)

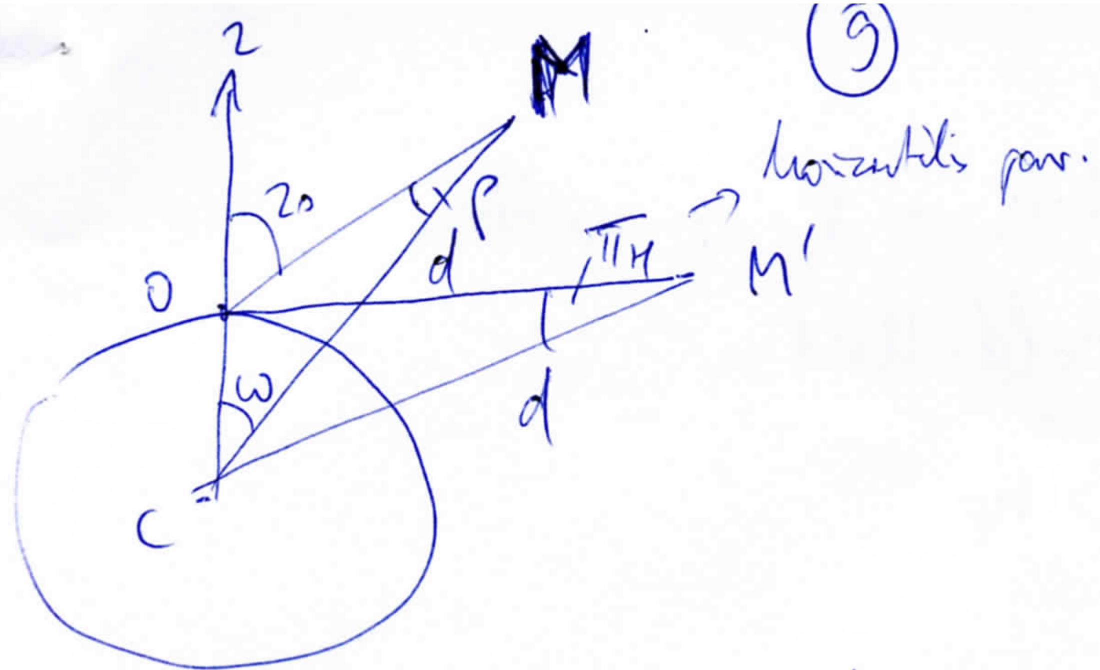
Hipparkhosz (i.e. 190-120): az asztrometria megalapozója; az első csillagkatalógus összeállítója; a precesszió felfedezője.

Első parallaxismérés: i.e. 189. március 14., Hellészpontosz (é.sz. 41 fok) teljes napfogyatkozás, Alexandriában (é.sz. 31 fok) részleges, 4/5 napkorong kitakarása. Hipp. megmérte a Hold átlagos átmérőjét (33’15”), amiből a Hold parallaxisa 6’40”.

Naprendszerben: horizontális parallaxis: a látóiránybeli különbség a Föld pólusáról és egyenlítőjéről megfigyelve.



(9)



d - geocentrikus távolság ; z_0 - zenittávolság

OMC ∠ → p

OC - R_F

ΔOCM:

$$\frac{\sin p}{R_F} = \frac{\sin(180° - z_0)}{d}$$

$$\Rightarrow \sin p = \frac{R_F}{d} \sin z_0$$

Hold bel: $z_0 = 90°$

$\angle COM' = 90°$

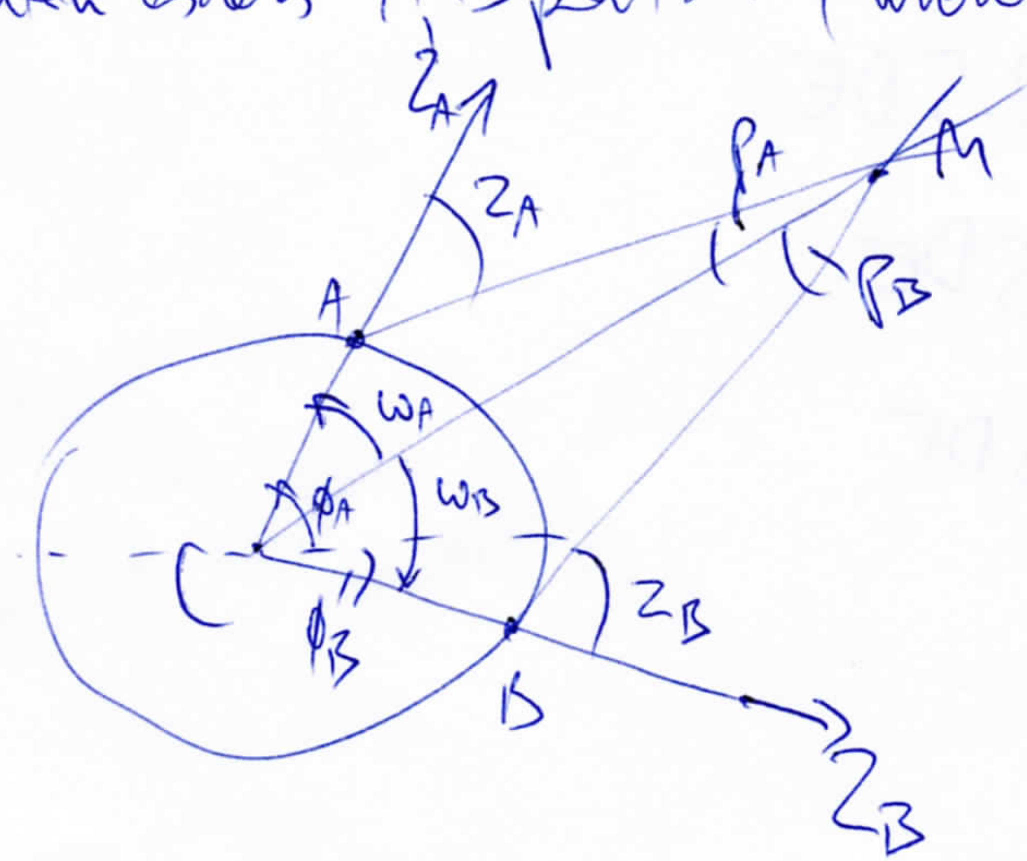
$CM' = d$

$$\sin \Pi_H = \frac{R_F}{d}$$

$$\sin p = \sin \Pi_H \cdot \sin z_0$$

kis szögek: $p = \Pi_H \cdot \sin z_0$

Szimultán észlelés A, B pontból (azonos hosszúság, de különböző szélesség)



ϕ_A, ϕ_B: szélesség

$$\rho_A = z_A - \omega_A \; ; \; \rho_B = z_B - \omega_B$$

$$\rho_A + \rho_B = z_A + z_B - (\omega_A + \omega_B)$$

$$\omega_A + \omega_B = \phi_A + |\phi_B|$$

$$\rho_A + \rho_B = z_A + z_B - (\phi_A + |\phi_B|)$$

$$\rho_A + \rho_B = \Pi_h (\sin z_A + \sin z_B)$$

$$\Downarrow$$

$$\Pi_h = \frac{z_A + z_B - (\phi_A + |\phi_B|)}{\sin z_A + \sin z_B}$$

← minden mérhető!

A Hold horizontális parallaxisa megmérhető -> R_F ismeretében abszolút távolságot kapunk a Föld-Hold rendszerre. Hipparkhosz: FH~71-83 R_F. Pontosítás a fogyatkozásokkal: FH~60-67 R_F. (60 x 6378 km = 382680 km!)