First Prompt Optical Observations of Nearest Fast Radio Burst new New Astromonomical Method

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Abstract

With the discovery of gamma ray bursts^{1,2}, it became clear that our Universe flickers with superfast catastrophic events, sometimes lasting for a thousandths of a second. These ultra-fast transients - the peculiar one-day butterflies of the Universe - shine so brightly that they are noticed even on the other end of the Universe and, moreover, by very small telescopes. But in the radio range, the sky remained silent until the beginning of the 21st century. Only in 2007, radio astronomers analyzing archival observations of the Parkes Radio Telescope first encountered fast transients^{3,4}. About a hundred such sources have already been discovered. We report the first optical observation of the closest radio burster FRB 180916.J0158+655-8 synchronously with a radio burst. In total, we obtained about 155,093 images at MASTER Global Robotic Net^{9*}. In the course of our observations, we found a new method for detecting objects deep below the noise level. In addition, using the new method, we found the excess of photons in the FRB direction at a level of 23 m associated with the emission of the host galaxy.

Introduction

The phenomenon of fast millisecond radio bursts (FRB) was actually predicted as a peculiar very short “reincarnation” of a binary system of old inactive magnetic neutron stars before their merging¹⁰. Such one-time radio bursts, accompanied by the death of the object itself, may occur when two neutron stars merge, which was first observed directly on August 17, 2017 by the LIGO/Virgo gravitational-wave collaboration¹¹⁻¹³. Gravitational waves from several neutron star binary mergers have been observed by LIGO/Virgo, although none yet in coincidence with FRBs. However, as always happens, the phenomenon turned out to be complicated. It seems that we are dealing with at least two different classes of sources: unique bursts that never repeat and repeating (FRB repeaters⁵⁻⁸).

Some leading hypotheses for repeating flares involve the activity of extremely powerful magnetic neutron stars – magnetars¹⁴⁻¹⁷. However, so far no optical telescope has been able to detect the optical glow from a source of radio burst¹⁸. The aim of our research was one of the 19 known repeating FRBs. FRB 180916.J0158+65, recently localized with pinpoint radio astronomy accuracy of 2 milliarcseconds¹⁹. Moreover, after detecting about three dozen radio bursts, it turned out that the activity of the FRB appears to be periodical with a period of 16.35 ± 0.18 days²⁰.

Monitoring

All our observations were carried out on 5 northern telescopes of the MASTER network^{9,21}. MASTER network is a network of fully robotic twin wide-field (40-cm MASTER-II, 2x4sq.deg.) and twin very wide-field (MASTER-VWF cameras, 2x384sq.deg.) colored (BVRI+polarization) fast (30deg/s) telescopes with identical scientific equipment²¹⁻²³ and with own real-time auto-detection system^{9,21} distributed all over the Earth.

Fig.1 Schedule of synchronous observations of the FRB180916.J0158+65 radio burst by five MASTER telescopes. The circular stripes show the moments of activity of the radio burster according to the ephemeris¹⁵.

MASTER Global Robotic Net was developed to study the key tasks of modern extreme energy astrophysics: to discover optical counterparts of gamma-ray bursts and to discover polarization of GRB prompt optical emission²⁴⁻²⁹; to independently localize the sources of gravitational wave, detected by LIGO/Virgo^{12,13}, to investigate high energy neutrino sources³⁰, fast radio bursts sources³¹⁻³⁴ and other extreme processes in Universe. MASTER conducted optical observations that reveal strong evidence for high energy neutrino progenitor³⁰.

MASTER is interested to discover possible sources of FRB and to observe their error-boxes since 2014^{11,31-40}. It is possible if one have fully robotic telescope network with full real-time reduction up to discover new optical sources (OT) just after CCD readout and distribution on the Earth, like our network^{9,21}.

We tried several observing strategies of the FRB 180916.J0158+65 before arriving at a final scheme (See Methods). In the course of observations at two observatories, we replaced the slow Apogee CCD from MASTER-II with the fast cameras from our very wide field channel (Prosilica GE4000^{21,22}).

From April 6, 2020, the MASTER-Kislovodsk robot telescope (Caucasus, Russia) began optical monitoring of FRB 180916.J0158+65 at 20:36:16UT. The subsequent schedule and observation regimes were determined by the ephemeris and local weather on the telescopes of the MASTER Global Network located in the northern hemisphere (Methods and Fig. 1).

The date was chosen by us since the next time of radioburster activity calculated by the ephemeris of the CHIME / FRB¹⁸ project was at the time of April 10.4 ± 2.6 .

In total, we obtained about 155,093 images of the radio burster using 5 telescopes located in the northern hemisphere over three periods of activity. Our telescopes are small in diameter, but they are twin and can shoot simultaneously in both tubes^{21,22}. To process the observation results, we used a peculiar scheme of coincidences of the signal from both tubes (see Method).

Results

Detection of a photon excess on two telescopes simultaneously near the position of the coordinates of the radio burst.

We assumed that optical emission could behave in a flash manner. And this activity increases during periods of FRB activity. If the duration of flashes is comparable to the duration of radio bursts, then they are measured in milliseconds, so it is difficult to expect source detection in each frame. A manual

analysis of ~ 10,000 images taken on the night of April (see Table 1) led to the detection of a signal at about 40 frames near the coordinates of the FRB (Fig. 1.)

Fig. 2 Dependence of the number of synchronous coincidences in both tubes at the level of 3 sigma on the radius of the circular analyzed region in angular units. Lilac color shows the area around the FRB. Blue and yellow, control blanks just arcminutes from the FRB. An obvious excess of optical emission from the FRB region is visible.

Analysis of so many images is not possible without automation of this process. Our standard processing was usually intended to search for transients on a small number of frames. But in this case, on our side was the knowledge of the coordinates of a possible source of optical emission. This has greatly reduced the limit of possible transients in the flux. In fact, we collected on each frame in this place all the pixels with a slight excess over the noise.

And here we used the design features of our telescope allowing us to shoot an object simultaneously in both tubes. At the same time, we accumulated cases when the signals were in both tubes. We must note that the signal appeared on several percent of synchronous frames. Such a coincidence scheme made it possible to significantly reduce random “tripping” in individual tubes and made it possible to isolate events at a level of more than $SNR > 3$. Obviously, with so many frames random coincidences are possible.

Among all the telescopes, the highest-quality synchronous survey took place on the MASTER-Kislovodsk telescope. Firstly, there are CCD cameras installed on both tubes with a high quantum efficiency, low readout noise compared to other telescopes, and more stable full frame CCD Apogee Aspen CG16M cooling. On the MASTER-IAC telescope, the repeater was near the horizon and the frame limits were much worse than in the MASTER-Tavrida. On MASTER-Amur and MASTER-Tunka telescopes both tubes worked but each tube had different types of cameras: full frame Apogee U16M cameras and fast Prosilica GE4000. The MASTER-Tavrida telescope at the time had only one operating tube.

To assess the accuracy of measurements, we collected similar information from a randomly selected empty place on those frames (see Methods and Table 1).

Fig 3 Host galaxy by Gemini¹⁹ and MASTER image of FRB place. There is the synthesized image of the host galaxy (image corresponds to Marcote et al. 2020 and was taken from Gemini open source) with FRB from MASTER (the round on the left Gemini square) and Gemini telescope image of the enlarged region of intense star formation around the FRB (red dot) at the right top position.

A total of 6134 double synchronous images were used. We selected events if in each tube there were 3 pixels in place of the FRB or the empty place with an excess of quanta by 1 sigma in each tube on the same frame. As a result, it turned out that in the place of FRB the number of concurrences is 2.0 ± 0.25 times more than in a deliberately random place: 338: 170. So the excess of synchronous samples on the FRB place was at the level of $\text{SNR} = 8$. This excess of photons could be due to the optical emission either of FRB 180916.J0158+65 or of a weak extended source - a star formation region of the host galaxy.

In the first case, we have the first optical observation of a fast radio burst. In the second, we have an upper limit on the brightness of the radio burst in the optical range. In the first case, the ratio of the number of concurrences around the FRB and the empty place should decrease with a decrease in the radius of the region around the radio burst. These data are in good agreement with the region visible in the Gemini image¹⁹. This is equivalent to $\sim 25^m$ per 1 square arcsecond.

In September 2020, the images obtained with the Gemini telescope under the GN-2019A-DD-110 program¹⁹ became public. We used 450 s exposure r – band image obtained by Gemini on 2019-07-14 14:26:29 . We performed aperture photometry of the galactic spot with a step of 1 pixel from the original image to estimate the contribution of the galaxy to the place where the search for candidates in the MASTER telescope was carried out. The results of our assessments are shown in Figure 4 (and Table 1 in Methods).

Figure 4 | The brightness of the extended glow of the host galaxy depending on the radius of the region around FRB. Our FWHM = 2.5 corresponds to a radius of 2.5 since the pixel size is 2 arc seconds.

The average fluence normalized to the exposure turned out to be $0.02 \text{ Ja} \cdot \text{ms}$. Accordingly, the average magnitude is 22.6. An analysis of the highest quality images of $\text{FWHM} \leq 2.5$ limits magnitude to 22.9^m . This corresponds to a surface brightness of 25 magnitude per a square arc second.

Since our cameras are sensitive in a wide range of wavelengths with a large tail in the red region, we take an effective wavelength of 8000 angstroms, in which the absorption is 1.4^m . Thus, the effective average fluence was $0.05 \text{ Ja} \cdot \text{ms}$.

Synchronous optical observation of FRB at the time of a radio burst

On April 23, at 20:11:19.68 (time taking into account the dispersion) by UTC, the VLA Karl Jansky radio telescope detected a radio burst from a repeating FRB 180916.J0158+65⁴¹. At this time, MASTER-Tunka robotic telescope located in Siberia continuously shot the radio burster and two images - on the eastern and western tubes (MASTER-II), turned out to be synchronous with the radio burst. Cameras differed in

their characteristics and in exposure time. The first camera is a standard (full frame), with an exposure time of 10 s. The frame, overlapping the moment of the burst, began at 20:11:11 and ended at 20:11:21. The magnitude limit for color is $G-R = 1.14$ $m_{lim} = 17.7$, for $G-R = 0.61$ $m_{lim} = 17.4$. The second camera - (Prosilica), imaged with an exposure time of 2 s. The frame, affecting the moment of the surge began at 20:11:19 and ended at 20:11:21. The magnitude limit for $G-R = 0.67$ $m_{lim} = 13.6$, for $G-R = 1$ $m_{lim} = 14.5$. These colors are taken from PANSTARRS DR1, the magnitudes are from Gaia DR1. These limits are shown in Figure 5.

Fig. 5 The dependence of the fluence in absolute units on the frequency of observation. This graph shows the limits and typical energies for FRB 180916 and FRB 121102. Half-filled dots represent FRB 121102, fully filled dots represent FRB 180916. Stars - signal detection, triangles - upper limits. Azure Star - observation of FRB 180916 by the VLA radio telescope dated April 23, 2020⁴¹. MASTER Sync - synchronous observation of this burst with the MASTER-Tunka optical telescope. ULTRASPEC - synchronous observations of FRB121102 in bands i' and z' by the ULTRASPEC camera located on the 2.4th Thai National Telescope⁴². MAGIC - synchronous observations of FRB121102 in the U band of MAGIC Collaboration⁴³. ZTF - observations of the FRB180916 Zwicky Transient Facility in bands g and r¹⁸. Chandra and Fermi GBM are synchronous observations of FRB180916 in the ranges of 0.5–10 keV and 10–100 keV, respectively ⁴⁴.

We did not find the source at $SNR > 1.5$ in both synchronous frames. Our full frame cameras are fairly red, so our effective wavelength of unfiltered images is at a wavelength of 8000 angstroms. For this wavelength, effective absorption is equivalent to absorption in the I filter, which in this direction is approximately 1.4 m. Our fast cameras are closer to the V filter where the absorption is 2 times stronger. Accordingly, our limit for the slow Apogee camera of the first camera was the fluence limit $(1 \pm 0.1) \cdot 10^{-12}$ erg/cm², and $(3 \pm 1) \cdot 10^{-11}$ erg/cm². After taking into account absorption according to dust maps ⁴⁵ our best fluence limit for synchronous optical emission was found to be $1.7 \text{ Ja} \cdot \text{ms}$.

The FRB source is located in a fairly close galaxy ¹⁹ but it is invisible in our individual 10 s image. For cosmological parameters⁴⁶, $H_0 = 67.8 \text{ km} / \text{s} / \text{Mpc}$ (the Hubble constant), $W_m = 0.308$, $W_\Lambda = 0.692$ (the matter and vacuum density) redshift $z = 0.0337 \pm 0.0002$ ¹⁹ corresponds to luminosity distance D_L equal to 152.8 Mpc. This corresponds to a limit of the total emitted optical energy of $2.6 \cdot 10^{44}$ erg. Comparison with synchronous fluence in the radio range shows that:

$$\text{Fluence}_{\text{opt}} \cdot \nu_{\text{opt}} / \text{Fluence}_{\text{radio}} \cdot \nu_{\text{radio}} < 4 \cdot 10^5.$$

The obtained restriction on the synchronous optical luminosity of the radio burster does not contradict the assessment in the framework of different scenarios of the generation of electromagnetic radiation of magnetars^{15,16,47}. The experience of studying classical radio pulsars shows that from principle ideas to

real spectra there is a long road that cannot be covered in half a century. It seems to us that it is necessary to continue attempts to detect radio bursters in different ranges and channels of information.

The optical flux recorded by us obtained outside the radio burst is much better and amounts to $1.3 \cdot 10^{40}$ erg/s and is related to birth-like star formation region the heterogeneity of the host galaxy.

Discussion

We presented results of the long monitoring of the FRB. The first synchronous optical observation of the fast radio burster FRB 180916.J0158+65 is presented. Using the design features of the MASTER telescopes, we discovered an optical glow from an area with the size characteristic to that of point sources objects. This is not the first attempt to investigate the optical properties of the FRB 180916.J0158+65 radio burst. The most successful observations with a high frame rate were made on the 1.2-m Galileo telescope using the fast optical photon counter IFI + IQUEYE⁴⁸. However, these observations do not overlap with FRB radio burst. They set an upper limit for optical emission outside the radio bursts of 0.151 Jy ms, which is close to our sensitivity but much better than the ZTF result¹⁸ ($E_{\text{opt}} < 3 \cdot 10^{46}$ erg for a 10 Jy ms, see Fig. 4) due to significantly more short exposure time.

A similar study was conducted with FRB 121102. The 2.4-m Thai National Telescope alongside the radio observations with the 100-m Effelsberg Radio Telescope impose restrictions on the optical flux of another FRB 121102 radio burst using 70 ms overlap with radio observations⁴² $E_{\text{opt}} \sim 10^{43}$ erg (or equivalent ratio coefficient $\eta = 0.02$ for the brightest FRB).

MAGIC Collaboration⁴³ observed FRB 121102 using the basic atmospheric gamma Cherenkov telescope simultaneously with Arecibo. Overlapping 5 radio bursts, they did not find convincing signal explodes with fluence $> 9 \cdot 10^{-3}$ Jy•ms at an exposure time of 1 ms.

There was no explicit mention of the brightness correction of FRB 121102 in optical due to interstellar extinction. It is located not far from the Galactic plane ($b = 0.22$ degrees), where the absorption is 25 times. Provide a large correction band U, which should be taken into account in multiwave modeling of FRB. Our current limit on synchronous optical luminosity does not contradict the predictions of the magnetar mode^{15,16,47}.

The resulting restriction on the synchronous optical luminosity of the radioburster does not contradict the estimates in different scenarios for the generation of electromagnetic radiation of magnetars^{15,16,47}.

The experience of a long study of classical radio pulsars shows that from fundamental ideas to real spectra there is a long road that cannot be covered in half a century. It seems to us that it is necessary to continue attempts to detect radio bursters in different ranges and channels of information.

Methods

Algorithm for searching for weak optical variable emission. Here we will present a new algorithm for searching for weak optical variable emission from a place with known coordinates using double telescopes of the MASTER type.

In modern multiwave astronomy, the problem of finding the emission of an object with known coordinates defined in a different range or even information channel appears more often. So, in recent years there has been a constant search for emission accompanying gravitational waves, gamma-ray bursts, and finally, as in our case, the radio range. In this regard, we note the recent discovery of a radio burst from X-ray magnetar SGR 1935+21544.

In our case, the coordinates of the desired object are known with great accuracy. Therefore, at first we applied a standard search method - just continuous, if possible, mounting. We tried to find traces of two types of optical emission. Firstly, the emission is synchronous with radio bursts. And secondly, a quasistationary optical component is possible.

We assumed to detect optical flares like bursts in the radio range, i.e., durations of the order of one millisecond or longer (~ 1 sec), as discussed in recent models of optical emission of magnetars (Bogovalov 2020). Obviously, to detect such a short phenomenon requires the shortest possible exposure. After all, the constant sources in the star's frame and the noise of the night sky with an increase in exposure will clog useful photons from an ultrashort flash. On the other hand, the minimum short exposures of our cameras in the region of 40-80 milliseconds are practically useless, since the frame reading time is locked on our telescopes and is ~ 8 seconds. This requires a special reduction mode ("CUTTING") frames. But with a very small frame, we lose reference stars, and even with such exposures, the sensitivity decreases due to readout noise. Having two tubes and two CCD cameras, we chose the optimal mode without dead zones in time. Thus, the exposure was chosen so that the subject was shot continuously. That is, while the image was read on the eastern pipe, the exposure was on the western one. It is like walking on a white board on a chessboard.

In addition, on two telescopes (MASTER-Amur and MASTER-Tunka), we put cameras for fast continuous shooting of the sky on one of the tubes. An analysis of the noise of fast cameras showed that the optimal shooting time should not be done less than 2 seconds, due to the limitation of sensitivity by readout noise. On the other hand, with an increase in exposure of more than 5 seconds, we lost sensitivity due to the potentially short flash burst of the radio burster. Thus, we were able to shoot simultaneously with two telescopes the place of the radio burster with an ideal coincidence scheme with a high temporal resolution on one of the pipes. Other MASTER telescopes we left as standard. This allowed us, if desired, to switch from the "checker" mode to synchronous shooting with windows on full frame cameras.

When we finally shot synchronously with the radio burst and got only the upper limit of luminosity (see Fig. 4 in the main article), we began to look for a quasistationary glow from the FRB region. The usual method is that all frames are added together and thus to increase the limit of the total image. In the case of random noise, the signal-to-noise ratio grows as the root of the total exposure time or the root of the number of SNR frames $\sim \sqrt{N}$. However, in reality this is not performed due to the influence of non-Gaussian noise and systematic errors. In addition, optical emission can be flare-like (flickering). As a

result, a new image processing method has appeared. We took only synchronous frames received by both pipes almost simultaneously. The most stable and numerous frames were those obtained with the MASTER-Kislovodsk telescope (Caucasus, Russia). We selected the best - there were more than 6,000 pairs.

Further, from these thousands of pairs, we tried to find such events that simultaneously (that is, within 10 second exposure) in both pipes consist of three connected pixels, the signal on each should slightly exceed noise (1.5 sigma). In this case, for us, in general, the character of emission is not important. Even in the case of aperiodic or periodic pulses due to the coincidence circuit, the reliability of their detection increases sharply. So an experienced amateur astronomer looks at the Saturn for a long time trying to catch rare moments when the Cassini gap is visible.

A new method for finding weak optical weak emission using double telescopes.

Exposures were chosen so as to continuously shot the object, i.e. while frame is being read on the eastern tube, frame is being shot on the western. Since readout time of our CCD cameras is about 8 seconds, minimal exposure time was chosen to be 10 seconds. Results of the analysis of concurrences is shown in Table 2.

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Declarations

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Tables

Table 1

Objects detected synchronously in two MASTER-Kislovodsk east and west cameras in place of the FRB and in two randomly selected empty places. A group of 3 pixels, each of which exceeds the background level by 1 sigma was called an object.

Camera EAST			Camera WEST		
Datetime	Coord J2000	Mag	Coord J2000	Mag	Place
2020-05-19 23:15:21	01 h 58 m 00.42 s, + 65d 43 m 03.1 s	18.3	01 h 58 m 00.54 s, + 65d 43 m 01.3 s	18.8	FRB place
2020-04-26 18:57:19	01 h 58 m 00.82 s, + 65d 42 m 58.1 s	18.5	01 h 58 m 01.19 s, + 65d 42 m 59.2 s	18.1	FRB place
2020-04-26 19:32:55	01 h 58 m 00.16 s, + 65d 42 m 57.7 s	18.2	01 h 58 m 00.10 s, + 65d 43 m 00.1 s	18.5	FRB place
2020-04-25 18:28:28	01 h 58 m 01.20 s, + 65d 43 m 03.6 s	18.5	01 h 58 m 01.14 s, + 65d 43 m 02.8 s	18.2	FRB place
2020-05-19 21:12:48	01 h 58 m 00.40 s, + 65d 43 m 02.2 s	18.6	01 h 58 m 00.51 s, + 65d 43 m 04.7 s	18.1	FRB place
2020-05-17 22:09:32	01 h 58 m 01.34 s, + 65d 43 m 02.2 s	18.3	01 h 58 m 01.11 s, + 65d 43 m 01.6 s	18.4	FRB place
2020-05-19 22:20:23	01 h 58 m 00.33 s, + 65d 43 m 03.8 s	17.5	01 h 58 m 00.63 s, + 65d 43 m 04.1 s	17.9	FRB place
2020-05-15 21:36:03	01 h 58 m 00.49 s, + 65d 43 m 00.0 s	18.3	01 h 58 m 00.21 s, + 65d 43 m 01.2 s	18.4	FRB place
2020-05-15 23:06:57	01 h 58 m 00.12 s, + 65d 42 m 59.9 s	16.9	01 h 58 m 00.16 s, + 65d 42 m 59.9 s	16.9	FRB place
2020-05-19 20:42:39	01 h 58 m 00.52 s, + 65d 42 m 56.7 s	18.0	01 h 58 m 00.86 s, + 65d 42 m 55.6 s	18.6	FRB place
2020-05-19 23:38:00	01 h 58 m 00.18 s, + 65d 42 m 59.0 s	18.0	01 h 58 m 00.35 s, + 65d 43 m 00.0 s	18.2	FRB place
2020-05-15 22:49:36	01 h 58 m 00.27 s, + 65d 42 m 56.8 s	17.3	01 h 58 m 00.52 s, + 65d 42 m 55.6 s	17.0	FRB place
2020-05-15 22:57:59	01 h 58 m 01.15 s, + 65d 43 m 00.3 s	17.3	01 h 58 m 01.25 s, + 65d 42 m 57.7 s	17.8	FRB place
2020-04-26 19:49:31	01 h 58 m 00.59 s, + 65d 42 m 57.0 s	18.1	01 h 58 m 00.18 s, + 65d 42 m 57.1 s	18.5	FRB place
2020-05-19 20:28:57	01 h 58 m 01.00 s, + 65d 43 m 02.5 s	17.9	01 h 58 m 01.23 s, + 65d 43 m 01.3 s	18.4	FRB place
2020-05-15 22:37:31	01 h 58 m 00.72 s, + 65d 43 m 00.5 s	17.4	01 h 58 m 00.38 s, + 65d 43 m 02.6 s	18.4	FRB place

Camera EAST			Camera WEST		
2020-04-26 20:45:53	01 h 58 m 01.22 s, + 65d 43 m 01.3 s	18.1	01 h 58 m 01.43 s, + 65d 42 m 59.5 s	18.4	FRB place
2020-04-24 20:26:39	01 h 58 m 00.55 s, + 65d 42 m 58.0 s	18.2	01 h 58 m 00.91 s, + 65d 42 m 58.6 s	17.8	FRB place
2020-04-25 17:14:41	01 h 58 m 00.53 s, + 65d 42 m 56.0 s	17.5	01 h 58 m 00.34 s, + 65d 42 m 57.0 s	16.8	FRB place
2020-05-17 21:51:20	01 h 58 m 00.39 s, + 65d 43 m 02.6 s	17.5	01 h 58 m 00.48 s, + 65d 43 m 00.9 s	17.8	FRB place
2020-04-26 20:48:15	01 h 58 m 00.61 s, + 65d 43 m 01.7 s	18.5	01 h 58 m 00.27 s, + 65d 43 m 03.0 s	18.4	FRB place
2020-05-17 18:17:20	01 h 58 m 00.96 s, + 65d 43 m 00.0 s	17.1	01 h 58 m 01.19 s, + 65d 43 m 01.6 s	17.8	FRB place
2020-04-25 20:32:58	01 h 58 m 00.95 s, + 65d 43 m 03.2 s	18.1	01 h 58 m 01.11 s, + 65d 43 m 01.8 s	18.4	FRB place
2020-05-15 23:33:44	01 h 58 m 00.43 s, + 65d 42 m 58.1 s	18.1	01 h 58 m 00.28 s, + 65d 42 m 59.0 s	18.5	FRB place
2020-05-15 22:41:18	01 h 58 m 00.10 s, + 65d 43 m 00.7 s	17.8	01 h 58 m 00.31 s, + 65d 42 m 59.9 s	18.5	FRB place
2020-04-24 20:27:48	01 h 58 m 00.94 s, + 65d 42 m 57.7 s	17.8	01 h 58 m 01.15 s, + 65d 43 m 00.3 s	18.5	FRB place
2020-05-15 23:34:20	01 h 58 m 00.25 s, + 65d 42 m 56.8 s	18.1	01 h 58 m 00.71 s, + 65d 42 m 57.2 s	17.9	FRB place
2020-04-24 17:58:00	01 h 58 m 00.75 s, + 65d 43 m 01.0 s	18.6	01 h 58 m 01.14 s, + 65d 43 m 02.6 s	18.3	FRB place
2020-05-19 23:52:54	01 h 58 m 00.64 s, + 65d 43 m 00.9 s	18.5	01 h 58 m 00.66 s, + 65d 43 m 03.3 s	17.5	FRB place
2020-04-25 18:08:29	01 h 58 m 00.87 s, + 65d 42 m 59.7 s	18.3	01 h 58 m 01.25 s, + 65d 42 m 59.6 s	18.2	FRB place
2020-05-17 18:52:36	01 h 58 m 00.47 s, + 65d 43 m 03.0 s	17.3	01 h 58 m 00.43 s, + 65d 43 m 03.7 s	17.9	FRB place
2020-05-17 22:23:31	01 h 58 m 00.94 s, + 65d 43 m 03.5 s	18.1	01 h 58 m 00.77 s, + 65d 43 m 04.2 s	18.1	FRB place
2020-05-14 22:21:22	01 h 58 m 00.48 s, + 65d 43 m 00.6 s	17.8	01 h 58 m 00.25 s, + 65d 42 m 59.9 s	18.0	FRB place
2020-05-14 21:04:48	01 h 58 m 00.74 s, + 65d 42 m 57.2 s	17.5	01 h 58 m 00.49 s, + 65d 42 m 59.4 s	17.7	FRB place

Camera EAST			Camera WEST		
2020-05-14 23:22:29	01 h 58 m 00.71 s, + 65d 43 m 01.5 s	16.2	01 h 58 m 00.79 s, + 65d 42 m 59.3 s	18.4	FRB place
2020-05-14 23:18:03	01 h 58 m 00.65 s, + 65d 43 m 01.1 s	18.1	01 h 58 m 00.51 s, + 65d 43 m 00.9 s	18.2	FRB place
2020-05-19 22:21:36	01 h 58 m 00.76 s, + 65d 42 m 58.9 s	18.7	01 h 58 m 00.68 s, + 65d 42 m 58.4 s	18.4	FRB place
2020-04-26 19:43:46	01 h 58 m 00.57 s, + 65d 42 m 58.1 s	18.1	01 h 58 m 00.36 s, + 65d 42 m 57.8 s	18.2	FRB place
2020-05-19 23:57:04	01 h 58 m 00.69 s, + 65d 43 m 02.4 s	18.1	01 h 58 m 00.52 s, + 65d 43 m 02.7 s	17.9	FRB place
2020-05-14 23:49:46	01 h 58 m 00.75 s, + 65d 43 m 03.9 s	18.2	01 h 58 m 00.84 s, + 65d 43 m 04.5 s	17.7	FRB place
2020-05-15 19:29:30	01 h 58 m 00.80 s, + 65d 42 m 58.0 s	17.4	01 h 58 m 00.93 s, + 65d 42 m 56.0 s	17.4	FRB place
2020-05-15 20:25:25	01 h 58 m 01.47 s, + 65d 43 m 01.5 s	17.7	01 h 58 m 01.12 s, + 65d 43 m 02.9 s	17.8	FRB place
2020-05-14 20:43:12	01 h 58 m 01.40 s, + 65d 42 m 58.5 s	17.3	01 h 58 m 01.35 s, + 65d 42 m 57.0 s	17.4	FRB place
2020-05-19 20:31:18	01 h 58 m 00.25 s, + 65d 42 m 58.9 s	18.1	01 h 58 m 00.14 s, + 65d 43 m 00.2 s	18.4	FRB place
2020-05-19 21:19:21	01 h 58 m 00.92 s, + 65d 43 m 01.5 s	18.1	01 h 58 m 00.89 s, + 65d 43 m 04.4 s	18.8	FRB place
2020-05-15 22:40:50	01 h 58 m 01.26 s, + 65d 43 m 03.1 s	18.4	01 h 58 m 00.85 s, + 65d 43 m 04.3 s	18.6	FRB place
2020-05-17 19:58:03	01 h 58 m 00.32 s, + 65d 42 m 58.3 s	17.3	01 h 58 m 00.22 s, + 65d 42 m 59.9 s	16.9	FRB place
2020-04-06 21:48:45	01 h 58 m 01.08 s, + 65d 43 m 02.6 s	19.0	01 h 58 m 01.21 s, + 65d 43 m 02.2 s	18.7	FRB place
2020-05-14 19:16:44	01 h 58 m 01.10 s, + 65d 43 m 01.2 s	18.2	01 h 58 m 01.19 s, + 65d 43 m 03.5 s	17.7	FRB place
2020-04-26 19:01:48	01 h 58 m 00.40 s, + 65d 42 m 57.2 s	18.1	01 h 58 m 00.67 s, + 65d 42 m 56.2 s	18.4	FRB place
2020-05-14 22:00:18	01 h 58 m 01.29 s, + 65d 43 m 00.5 s	17.9	01 h 58 m 00.96 s, + 65d 42 m 59.8 s	18.0	FRB place
2020-05-19 23:04:32	01 h 58 m 01.38 s, + 65d 42 m 58.8 s	18.7	01 h 58 m 01.51 s, + 65d 42 m 59.9 s	18.7	FRB place

Camera EAST			Camera WEST		
2020-04-24 18:43:31	01 h 58 m 00.84 s, + 65d 42 m 56.1 s	18.2	01 h 58 m 00.37 s, + 65d 42 m 56.4 s	17.9	FRB place
2020-04-25 19:34:03	01 h 58 m 00.57 s, + 65d 42 m 58.0 s	17.1	01 h 58 m 00.66 s, + 65d 42 m 57.5 s	17.8	FRB place
2020-04-24 20:27:16	01 h 58 m 01.16 s, + 65d 43 m 01.6 s	18.6	01 h 58 m 01.11 s, + 65d 43 m 00.4 s	18.0	FRB place
2020-04-26 20:25:11	01 h 58 m 00.68 s, + 65d 42 m 57.6 s	17.8	01 h 58 m 00.30 s, + 65d 42 m 56.8 s	18.6	FRB place
2020-05-15 23:27:03	01 h 58 m 01.20 s, + 65d 43 m 02.9 s	17.3	01 h 58 m 01.13 s, + 65d 43 m 01.8 s	17.4	FRB place
2020-04-26 19:09:47	01 h 58 m 00.45 s, + 65d 42 m 59.0 s	18.2	01 h 58 m 00.04 s, + 65d 43 m 00.0 s	18.1	FRB place
2020-04-24 19:12:01	01 h 58 m 01.36 s, + 65d 43 m 02.0 s	18.5	01 h 58 m 01.22 s, + 65d 43 m 02.2 s	18.1	FRB place
2020-04-24 20:35:59	01 h 58 m 00.86 s, + 65d 43 m 04.0 s	18.4	01 h 58 m 00.88 s, + 65d 43 m 02.5 s	18.0	FRB place
2020-04-26 20:05:09	01 h 58 m 00.86 s, + 65d 43 m 00.4 s	18.4	01 h 58 m 01.07 s, + 65d 43 m 00.7 s	18.5	FRB place
2020-05-19 21:33:09	01 h 58 m 00.45 s, + 65d 42 m 59.6 s	18.1	01 h 58 m 00.74 s, + 65d 42 m 58.1 s	18.4	FRB place
2020-05-20 00:09:53	01 h 58 m 01.01 s, + 65d 42 m 57.0 s	18.4	01 h 58 m 01.31 s, + 65d 42 m 57.0 s	18.5	FRB place
2020-05-17 22:35:03	01 h 58 m 01.16 s, + 65d 43 m 02.1 s	18.2	01 h 58 m 00.87 s, + 65d 43 m 03.3 s	18.5	FRB place
2020-04-25 20:26:49	01 h 58 m 00.21 s, + 65d 43 m 00.8 s	17.6	01 h 58 m 00.47 s, + 65d 43 m 01.0 s	18.1	FRB place
2020-04-25 18:35:15	01 h 58 m 01.09 s, + 65d 43 m 00.8 s	18.5	01 h 58 m 00.71 s, + 65d 42 m 59.7 s	18.5	FRB place
2020-05-19 23:50:08	01 h 58 m 01.14 s, + 65d 42 m 57.2 s	18.4	01 h 58 m 00.99 s, + 65d 42 m 56.4 s	18.1	FRB place
2020-05-19 22:28:53	01 h 58 m 00.56 s, + 65d 42 m 57.7 s	18.7	01 h 58 m 00.25 s, + 65d 42 m 59.3 s	18.5	FRB place
2020-05-19 22:51:59	01 h 58 m 01.35 s, + 65d 43 m 01.3 s	18.7	01 h 58 m 01.30 s, + 65d 43 m 01.3 s	18.8	FRB place
2020-04-26 19:23:14	01 h 58 m 00.96 s, + 65d 42 m 59.6 s	17.8	01 h 58 m 01.03 s, + 65d 42 m 57.6 s	18.0	FRB place

Camera EAST			Camera WEST		
2020-04-26 20:17:51	01 h 58 m 00.98 s, + 65d 43 m 01.7 s	18.5	01 h 58 m 01.33 s, + 65d 43 m 00.3 s	17.6	FRB place
2020-05-14 20:00:38	01 h 58 m 00.66 s, + 65d 43 m 05.1 s	17.8	01 h 58 m 00.79 s, + 65d 43 m 04.5 s	17.6	FRB place
2020-05-14 20:28:42	01 h 58 m 01.28 s, + 65d 42 m 57.5 s	16.6	01 h 58 m 01.18 s, + 65d 42 m 57.4 s	17.0	FRB place
2020-05-19 23:49:41	01 h 58 m 01.21 s, + 65d 43 m 00.3 s	18.3	01 h 58 m 01.54 s, + 65d 42 m 59.8 s	18.6	FRB place
2020-04-25 17:55:21	01 h 58 m 00.66 s, + 65d 43 m 00.8 s	18.4	01 h 58 m 00.55 s, + 65d 42 m 58.4 s	17.4	FRB place
2020-04-25 19:19:59	01 h 58 m 00.73 s, + 65d 42 m 58.8 s	18.0	01 h 58 m 00.34 s, + 65d 42 m 59.9 s	17.8	FRB place
2020-05-15 22:56:46	01 h 58 m 01.08 s, + 65d 42 m 59.3 s	17.7	01 h 58 m 01.18 s, + 65d 42 m 57.8 s	17.7	FRB place
2020-04-26 20:04:07	01 h 58 m 00.83 s, + 65d 43 m 04.5 s	17.7	01 h 58 m 00.95 s, + 65d 43 m 04.2 s	18.2	FRB place
2020-04-26 20:16:31	01 h 58 m 00.50 s, + 65d 42 m 59.7 s	18.5	01 h 58 m 00.26 s, + 65d 43 m 01.7 s	18.2	FRB place
2020-05-15 23:56:51	01 h 58 m 00.19 s, + 65d 43 m 02.0 s	17.6	01 h 58 m 00.35 s, + 65d 43 m 03.1 s	18.3	FRB place
2020-05-19 21:49:11	01 h 58 m 00.45 s, + 65d 42 m 58.2 s	17.8	01 h 58 m 00.37 s, + 65d 43 m 00.1 s	18.5	FRB place
2020-05-14 22:53:05	01 h 58 m 00.21 s, + 65d 43 m 02.5 s	18.2	01 h 58 m 00.41 s, + 65d 43 m 01.6 s	18.3	FRB place
2020-04-25 19:38:31	01 h 58 m 00.24 s, + 65d 42 m 58.7 s	17.4	01 h 58 m 00.46 s, + 65d 42 m 57.2 s	15.7	FRB place
2020-05-14 23:08:23	01 h 58 m 00.33 s, + 65d 42 m 59.3 s	17.6	01 h 58 m 00.39 s, + 65d 42 m 56.5 s	17.7	FRB place
2020-05-14 21:53:47	01 h 58 m 00.71 s, + 65d 42 m 57.6 s	17.0	01 h 58 m 00.89 s, + 65d 42 m 57.5 s	18.2	FRB place
2020-04-24 20:34:01	01 h 58 m 00.40 s, + 65d 42 m 56.1 s	18.7	01 h 58 m 00.81 s, + 65d 42 m 56.5 s	17.7	FRB place
2020-05-17 22:18:53	01 h 58 m 00.63 s, + 65d 42 m 59.5 s	18.1	01 h 58 m 00.85 s, + 65d 43 m 01.0 s	18.2	FRB place
2020-04-24 20:18:19	01 h 58 m 00.36 s, + 65d 43 m 04.2 s	17.7	01 h 58 m 00.20 s, + 65d 43 m 02.9 s	18.6	FRB place

Camera EAST			Camera WEST		
2020-04-26 19:27:17	01 h 58 m 00.91 s, + 65d 43 m 02.6 s	18.5	01 h 58 m 00.84 s, + 65d 43 m 02.3 s	18.5	FRB place
2020-05-15 21:00:43	01 h 58 m 00.13 s, + 65d 43 m 00.2 s	18.3	01 h 58 m 00.36 s, + 65d 43 m 02.0 s	17.9	FRB place
2020-05-14 22:42:32	01 h 58 m 00.55 s, + 65d 43 m 00.5 s	17.5	01 h 58 m 00.87 s, + 65d 43 m 00.1 s	17.3	FRB place
2020-05-15 20:04:43	01 h 58 m 00.78 s, + 65d 42 m 56.7 s	17.8	01 h 58 m 00.82 s, + 65d 42 m 55.5 s	17.2	FRB place
2020-05-19 22:21:06	01 h 58 m 00.90 s, + 65d 43 m 02.3 s	18.6	01 h 58 m 00.75 s, + 65d 42 m 59.6 s	18.1	FRB place
2020-05-14 20:45:38	01 h 58 m 00.44 s, + 65d 42 m 56.6 s	17.1	01 h 58 m 00.81 s, + 65d 42 m 58.4 s	17.6	FRB place
2020-04-25 20:41:10	01 h 58 m 00.61 s, + 65d 42 m 57.4 s	17.5	01 h 58 m 00.89 s, + 65d 42 m 55.6 s	18.5	FRB place
2020-05-19 23:00:32	01 h 58 m 01.32 s, + 65d 43 m 01.0 s	17.8	01 h 58 m 01.40 s, + 65d 43 m 01.6 s	18.7	FRB place
2020-05-17 19:14:42	01 h 58 m 00.20 s, + 65d 42 m 58.5 s	17.7	01 h 58 m 00.32 s, + 65d 42 m 59.2 s	18.4	FRB place
2020-05-19 23:57:46	01 h 58 m 00.82 s, + 65d 42 m 58.6 s	18.4	01 h 58 m 01.15 s, + 65d 42 m 56.9 s	18.6	FRB place
2020-05-19 23:33:23	01 h 58 m 01.18 s, + 65d 42 m 56.6 s	18.3	01 h 58 m 00.97 s, + 65d 42 m 58.1 s	18.8	FRB place
2020-05-14 22:41:32	01 h 58 m 00.86 s, + 65d 42 m 56.8 s	16.8	01 h 58 m 00.86 s, + 65d 42 m 57.8 s	17.5	FRB place
2020-05-15 21:05:29	01 h 58 m 00.44 s, + 65d 43 m 01.0 s	18.0	01 h 58 m 00.28 s, + 65d 42 m 59.7 s	18.3	FRB place
2020-05-17 18:02:58	01 h 58 m 00.05 s, + 65d 43 m 00.1 s	17.3	01 h 58 m 00.15 s, + 65d 43 m 02.9 s	17.5	FRB place
2020-05-19 22:01:59	01 h 58 m 00.26 s, + 65d 42 m 56.5 s	17.5	01 h 58 m 00.22 s, + 65d 42 m 56.6 s	18.5	FRB place
2020-04-25 17:16:32	01 h 58 m 00.66 s, + 65d 43 m 04.5 s	17.7	01 h 58 m 00.53 s, + 65d 43 m 03.4 s	16.9	FRB place
2020-05-19 21:49:54	01 h 58 m 00.46 s, + 65d 42 m 58.8 s	18.6	01 h 58 m 00.14 s, + 65d 43 m 00.3 s	18.7	FRB place
2020-05-15 23:37:26	01 h 58 m 01.13 s, + 65d 43 m 03.1 s	18.5	01 h 58 m 01.14 s, + 65d 43 m 01.9 s	18.6	FRB place

Camera EAST			Camera WEST		
2020-04-25 19:37:05	01 h 58 m 00.59 s, + 65d 43 m 01.5 s	16.7	01 h 58 m 00.34 s, + 65d 43 m 02.4 s	17.5	FRB place
2020-05-17 18:18:14	01 h 58 m 00.79 s, + 65d 43 m 03.0 s	17.8	01 h 58 m 01.21 s, + 65d 43 m 02.1 s	16.8	FRB place
2020-05-19 22:18:31	01 h 58 m 00.87 s, + 65d 42 m 58.4 s	18.1	01 h 58 m 01.00 s, + 65d 42 m 58.3 s	18.8	FRB place
2020-05-20 00:02:10	01 h 58 m 00.74 s, + 65d 42 m 58.4 s	17.7	01 h 58 m 01.05 s, + 65d 42 m 59.3 s	17.6	FRB place
2020-05-19 23:36:23	01 h 58 m 00.57 s, + 65d 43 m 02.7 s	18.4	01 h 58 m 00.44 s, + 65d 43 m 01.6 s	17.8	FRB place
2020-04-06 21:00:25	01 h 58 m 00.76 s, + 65d 42 m 58.8 s	18.9	01 h 58 m 00.97 s, + 65d 43 m 01.1 s	17.4	FRB place
2020-04-24 20:27:32	01 h 58 m 00.72 s, + 65d 42 m 57.0 s	17.7	01 h 58 m 00.94 s, + 65d 42 m 58.6 s	18.6	FRB place
2020-05-15 22:07:04	01 h 58 m 00.65 s, + 65d 43 m 04.7 s	17.3	01 h 58 m 00.92 s, + 65d 43 m 02.7 s	18.4	FRB place
2020-05-19 21:29:54	01 h 58 m 00.38 s, + 65d 43 m 00.9 s	18.6	01 h 58 m 00.06 s, + 65d 43 m 01.1 s	18.0	FRB place
2020-05-19 22:04:36	01 h 58 m 00.53 s, + 65d 43 m 04.4 s	18.0	01 h 58 m 00.66 s, + 65d 43 m 01.8 s	18.8	FRB place
2020-05-20 00:12:15	01 h 58 m 00.61 s, + 65d 42 m 56.9 s	17.9	01 h 58 m 01.01 s, + 65d 42 m 56.0 s	18.1	FRB place
2020-04-25 17:41:24	01 h 58 m 00.86 s, + 65d 42 m 58.6 s	18.4	01 h 58 m 00.41 s, + 65d 42 m 58.6 s	18.4	FRB place
2020-05-19 21:43:16	01 h 58 m 00.62 s, + 65d 42 m 56.0 s	18.6	01 h 58 m 00.95 s, + 65d 42 m 57.7 s	18.5	FRB place
2020-04-26 19:52:26	01 h 58 m 01.15 s, + 65d 43 m 00.0 s	18.5	01 h 58 m 01.25 s, + 65d 43 m 00.3 s	17.8	FRB place
2020-05-14 19:05:35	01 h 58 m 00.24 s, + 65d 42 m 59.1 s	18.0	01 h 58 m 00.42 s, + 65d 42 m 58.9 s	17.7	FRB place
2020-04-26 19:07:31	01 h 58 m 01.06 s, + 65d 42 m 57.9 s	18.0	01 h 58 m 00.69 s, + 65d 42 m 59.3 s	17.8	FRB place
2020-04-26 20:08:49	01 h 58 m 01.42 s, + 65d 43 m 02.4 s	17.9	01 h 58 m 01.33 s, + 65d 43 m 03.4 s	18.2	FRB place
2020-05-19 20:33:38	01 h 58 m 00.50 s, + 65d 43 m 01.1 s	18.5	01 h 58 m 00.54 s, + 65d 42 m 58.3 s	17.8	FRB place

Camera EAST			Camera WEST		
2020-04-25 18:24:52	01 h 58 m 00.99 s, + 65d 43 m 00.7 s	18.2	01 h 58 m 00.90 s, + 65d 43 m 00.7 s	17.8	FRB place
2020-05-15 19:48:12	01 h 58 m 00.95 s, + 65d 43 m 04.2 s	17.1	01 h 58 m 00.66 s, + 65d 43 m 04.8 s	18.0	FRB place
2020-05-19 22:23:29	01 h 58 m 00.89 s, + 65d 43 m 02.9 s	18.3	01 h 58 m 01.27 s, + 65d 43 m 03.4 s	18.7	FRB place
2020-05-20 00:25:36	01 h 58 m 01.23 s, + 65d 42 m 59.7 s	17.0	01 h 58 m 01.48 s, + 65d 42 m 58.7 s	17.3	FRB place
2020-05-14 22:17:16	01 h 58 m 00.35 s, + 65d 42 m 56.8 s	17.7	01 h 58 m 00.37 s, + 65d 42 m 56.9 s	18.2	FRB place
2020-05-19 22:01:11	01 h 58 m 00.74 s, + 65d 42 m 58.2 s	18.4	01 h 58 m 00.75 s, + 65d 42 m 56.5 s	18.3	FRB place
2020-05-15 20:26:26	01 h 58 m 01.24 s, + 65d 43 m 02.2 s	18.0	01 h 58 m 01.34 s, + 65d 42 m 59.9 s	17.3	FRB place
2020-04-26 19:10:34	01 h 58 m 01.54 s, + 65d 43 m 00.5 s	17.4	01 h 58 m 01.21 s, + 65d 43 m 01.8 s	18.4	FRB place
2020-04-25 18:56:52	01 h 58 m 00.51 s, + 65d 42 m 58.4 s	18.5	01 h 58 m 00.86 s, + 65d 42 m 58.3 s	18.3	FRB place
2020-05-14 22:20:54	01 h 58 m 00.21 s, + 65d 43 m 01.0 s	18.0	01 h 58 m 00.52 s, + 65d 43 m 02.2 s	18.2	FRB place
2020-05-15 22:49:16	01 h 58 m 00.48 s, + 65d 42 m 59.5 s	17.8	01 h 58 m 00.69 s, + 65d 42 m 59.2 s	18.2	FRB place
2020-05-17 18:42:10	01 h 58 m 01.19 s, + 65d 43 m 00.5 s	18.0	01 h 58 m 01.04 s, + 65d 42 m 58.0 s	18.0	FRB place
2020-05-15 18:42:22	01 h 58 m 00.63 s, + 65d 43 m 02.0 s	17.7	01 h 58 m 00.40 s, + 65d 43 m 02.1 s	18.2	FRB place
2020-04-25 19:50:51	01 h 58 m 01.21 s, + 65d 42 m 56.9 s	17.6	01 h 58 m 01.48 s, + 65d 42 m 58.7 s	17.7	FRB place
2020-05-14 19:48:37	01 h 58 m 00.57 s, + 65d 43 m 03.8 s	17.9	01 h 58 m 00.51 s, + 65d 43 m 04.6 s	18.0	FRB place
2020-04-26 19:15:04	01 h 58 m 00.59 s, + 65d 43 m 04.5 s	17.8	01 h 58 m 00.42 s, + 65d 43 m 04.7 s	17.1	FRB place
2020-05-17 19:20:23	01 h 58 m 00.93 s, + 65d 42 m 59.0 s	16.7	01 h 58 m 01.12 s, + 65d 42 m 59.5 s	17.9	FRB place
2020-04-24 18:30:35	01 h 58 m 00.99 s, + 65d 42 m 58.1 s	18.3	01 h 58 m 01.00 s, + 65d 42 m 56.7 s	17.7	FRB place

Camera EAST			Camera WEST		
2020-05-19 22:51:16	01 h 58 m 01.28 s, + 65d 42 m 60.0 s	18.1	01 h 58 m 01.25 s, + 65d 42 m 58.3 s	18.8	FRB place
2020-05-20 00:37:44	01 h 58 m 00.63 s, + 65d 43 m 03.5 s	16.9	01 h 58 m 00.41 s, + 65d 43 m 02.1 s	17.3	FRB place
2020-05-14 22:41:04	01 h 58 m 00.56 s, + 65d 42 m 57.6 s	18.2	01 h 58 m 00.11 s, + 65d 42 m 57.4 s	17.9	FRB place
2020-05-19 23:49:01	01 h 58 m 01.34 s, + 65d 43 m 02.2 s	18.1	01 h 58 m 01.30 s, + 65d 43 m 00.7 s	18.7	FRB place
2020-05-19 22:14:11	01 h 58 m 00.01 s, + 65d 42 m 59.2 s	18.7	01 h 58 m 00.08 s, + 65d 43 m 01.0 s	18.8	FRB place
2020-04-06 20:40:01	01 h 58 m 01.18 s, + 65d 43 m 02.2 s	18.7	01 h 58 m 00.90 s, + 65d 43 m 03.4 s	18.5	FRB place
2020-04-24 18:26:02	01 h 58 m 01.15 s, + 65d 42 m 58.9 s	17.8	01 h 58 m 00.96 s, + 65d 42 m 59.2 s	17.9	FRB place
2020-05-14 22:32:44	01 h 58 m 00.56 s, + 65d 43 m 01.4 s	17.2	01 h 58 m 00.51 s, + 65d 43 m 00.3 s	17.8	FRB place
2020-05-19 23:33:09	01 h 58 m 00.32 s, + 65d 43 m 04.0 s	18.5	01 h 58 m 00.90 s, + 65d 42 m 59.6 s	18.4	FRB place
2020-05-15 19:19:50	01 h 58 m 00.75 s, + 65d 42 m 57.3 s	18.2	01 h 58 m 01.04 s, + 65d 42 m 56.8 s	18.1	FRB place
2020-05-15 22:32:06	01 h 58 m 00.48 s, + 65d 43 m 01.4 s	18.5	01 h 58 m 00.18 s, + 65d 42 m 59.3 s	18.2	FRB place
2020-04-06 21:33:59	01 h 58 m 00.83 s, + 65d 43 m 01.1 s	18.3	01 h 58 m 00.89 s, + 65d 43 m 03.6 s	18.1	FRB place
2020-04-06 21:29:58	01 h 58 m 01.15 s, + 65d 42 m 58.4 s	18.0	01 h 58 m 01.45 s, + 65d 42 m 57.8 s	17.9	FRB place
2020-05-14 22:17:45	01 h 58 m 01.05 s, + 65d 42 m 59.2 s	17.5	01 h 58 m 01.20 s, + 65d 42 m 58.0 s	17.9	FRB place
2020-04-26 18:56:47	01 h 58 m 00.60 s, + 65d 43 m 00.4 s	17.9	01 h 58 m 00.59 s, + 65d 42 m 60.0 s	18.1	FRB place
2020-04-24 20:41:38	01 h 58 m 00.54 s, + 65d 42 m 59.4 s	18.7	01 h 58 m 00.22 s, + 65d 43 m 00.3 s	18.7	FRB place
2020-04-24 18:08:21	01 h 58 m 00.04 s, + 65d 43 m 00.0 s	18.7	01 h 58 m 00.10 s, + 65d 43 m 02.1 s	18.7	FRB place
2020-04-25 20:10:32	01 h 58 m 01.14 s, + 65d 42 m 57.8 s	17.7	01 h 58 m 01.39 s, + 65d 43 m 00.2 s	18.2	FRB place

Camera EAST			Camera WEST		
2020-05-20 00:20:08	01 h 58 m 00.17 s, + 65d 43 m 03.1 s	17.4	01 h 58 m 00.18 s, + 65d 43 m 01.1 s	17.3	FRB place
2020-04-25 18:56:04	01 h 58 m 00.49 s, + 65d 43 m 02.2 s	18.3	01 h 58 m 00.58 s, + 65d 43 m 00.6 s	18.5	FRB place
2020-04-25 18:28:43	01 h 58 m 00.43 s, + 65d 42 m 59.8 s	18.6	01 h 58 m 00.51 s, + 65d 43 m 02.0 s	18.6	FRB place
2020-04-25 19:38:15	01 h 58 m 01.42 s, + 65d 43 m 01.4 s	16.7	01 h 58 m 01.19 s, + 65d 43 m 01.6 s	17.1	FRB place
2020-05-15 19:55:07	01 h 58 m 00.35 s, + 65d 42 m 59.8 s	17.4	01 h 58 m 00.68 s, + 65d 42 m 57.7 s	16.3	FRB place
2020-05-15 22:53:35	01 h 58 m 01.04 s, + 65d 42 m 57.8 s	18.0	01 h 58 m 01.10 s, + 65d 42 m 60.0 s	17.8	FRB place
2020-05-17 22:12:40	01 h 58 m 00.47 s, + 65d 42 m 58.9 s	18.3	01 h 58 m 00.64 s, + 65d 42 m 56.9 s	18.4	FRB place
2020-04-26 18:58:26	01 h 58 m 00.62 s, + 65d 42 m 58.9 s	17.7	01 h 58 m 00.20 s, + 65d 42 m 59.8 s	17.8	FRB place
2020-04-24 18:08:02	01 h 58 m 01.38 s, + 65d 42 m 58.9 s	18.3	01 h 58 m 01.15 s, + 65d 42 m 56.4 s	18.7	FRB place
2020-05-17 17:54:02	01 h 58 m 13.14 s, + 65d 46 m 24.5 s	17.7	01 h 58 m 13.20 s, + 65d 46 m 23.5 s	18.0	Emphly place 1
2020-04-25 17:57:20	01 h 58 m 13.33 s, + 65d 46 m 24.2 s	18.2	01 h 58 m 13.39 s, + 65d 46 m 23.6 s	18.6	Emphly place 1
2020-05-14 23:46:26	01 h 58 m 12.82 s, + 65d 46 m 28.8 s	17.7	01 h 58 m 12.90 s, + 65d 46 m 26.0 s	17.5	Emphly place 1
2020-05-17 22:31:19	01 h 58 m 13.01 s, + 65d 46 m 23.9 s	17.8	01 h 58 m 13.24 s, + 65d 46 m 25.3 s	17.1	Emphly place 1
2020-05-17 22:28:58	01 h 58 m 13.03 s, + 65d 46 m 27.3 s	17.9	01 h 58 m 12.97 s, + 65d 46 m 26.7 s	17.7	Emphly place 1
2020-04-25 19:27:51	01 h 58 m 13.90 s, + 65d 46 m 29.4 s	17.8	01 h 58 m 13.81 s, + 65d 46 m 28.3 s	17.5	Emphly place 1
2020-05-15 18:33:42	01 h 58 m 13.00 s, + 65d 46 m 23.5 s	18.1	01 h 58 m 13.41 s, + 65d 46 m 25.0 s	18.2	Emphly place 1
2020-05-15 20:51:59	01 h 58 m 13.22 s, + 65d 46 m 25.6 s	18.1	01 h 58 m 13.26 s, + 65d 46 m 27.1 s	18.4	Emphly place 1
2020-04-25 20:15:00	01 h 58 m 13.41 s, + 65d 46 m 29.9 s	17.3	01 h 58 m 13.11 s, + 65d 46 m 27.7 s	17.6	Emphly place 1

Camera EAST			Camera WEST		
2020-05-14 22:25:07	01 h 58 m 13.44 s, + 65d 46 m 26.9 s	17.7	01 h 58 m 13.43 s, + 65d 46 m 25.9 s	17.5	Empty place 1
2020-05-19 23:26:03	01 h 58 m 12.83 s, + 65d 46 m 30.3 s	18.3	01 h 58 m 12.91 s, + 65d 46 m 30.5 s	18.5	Empty place 1
2020-05-14 19:06:44	01 h 58 m 12.81 s, + 65d 46 m 25.9 s	17.2	01 h 58 m 12.76 s, + 65d 46 m 24.6 s	17.4	Empty place 1
2020-05-17 19:07:40	01 h 58 m 13.31 s, + 65d 46 m 30.5 s	17.8	01 h 58 m 13.65 s, + 65d 46 m 30.3 s	17.7	Empty place 1
2020-05-17 18:46:17	01 h 58 m 13.78 s, + 65d 46 m 28.1 s	18.2	01 h 58 m 13.87 s, + 65d 46 m 28.7 s	18.1	Empty place 1
2020-04-24 19:34:42	01 h 58 m 12.87 s, + 65d 46 m 30.5 s	18.6	01 h 58 m 13.05 s, + 65d 46 m 28.2 s	18.4	Empty place 1
2020-05-15 22:57:32	01 h 58 m 13.48 s, + 65d 46 m 27.5 s	17.0	01 h 58 m 13.15 s, + 65d 46 m 29.6 s	17.2	Empty place 1
2020-05-15 21:28:07	01 h 58 m 12.90 s, + 65d 46 m 28.6 s	18.4	01 h 58 m 12.74 s, + 65d 46 m 30.6 s	17.7	Empty place 1
2020-05-20 00:23:21	01 h 58 m 13.21 s, + 65d 46 m 29.6 s	17.0	01 h 58 m 13.23 s, + 65d 46 m 27.7 s	17.9	Empty place 1
2020-04-25 19:34:03	01 h 58 m 13.41 s, + 65d 46 m 26.6 s	18.2	01 h 58 m 13.75 s, + 65d 46 m 26.2 s	17.9	Empty place 1
2020-05-19 22:07:30	01 h 58 m 12.61 s, + 65d 46 m 27.3 s	18.2	01 h 58 m 13.07 s, + 65d 46 m 27.4 s	17.9	Empty place 1
2020-05-15 18:22:12	01 h 58 m 13.71 s, + 65d 46 m 31.8 s	18.2	01 h 58 m 13.35 s, + 65d 46 m 31.7 s	18.2	Empty place 1
2020-05-19 23:06:48	01 h 58 m 13.22 s, + 65d 46 m 27.5 s	18.4	01 h 58 m 13.29 s, + 65d 46 m 25.7 s	17.8	Empty place 1
2020-05-14 23:38:07	01 h 58 m 13.47 s, + 65d 46 m 24.2 s	17.0	01 h 58 m 13.32 s, + 65d 46 m 25.2 s	18.2	Empty place 1
2020-05-19 22:44:47	01 h 58 m 13.11 s, + 65d 46 m 29.8 s	18.7	01 h 58 m 13.03 s, + 65d 46 m 29.1 s	18.7	Empty place 1
2020-05-14 18:45:07	01 h 58 m 13.97 s, + 65d 46 m 30.9 s	17.6	01 h 58 m 13.88 s, + 65d 46 m 31.1 s	18.0	Empty place 1
2020-05-15 20:54:29	01 h 58 m 12.71 s, + 65d 46 m 25.2 s	17.9	01 h 58 m 12.85 s, + 65d 46 m 26.0 s	18.2	Empty place 1
2020-05-14 20:23:06	01 h 58 m 13.24 s, + 65d 46 m 27.2 s	16.6	01 h 58 m 13.40 s, + 65d 46 m 27.7 s	17.4	Empty place 1

Camera EAST			Camera WEST		
2020-05-15 23:26:35	01 h 58 m 13.10 s, + 65d 46 m 28.0 s	15.8	01 h 58 m 13.03 s, + 65d 46 m 30.1 s	16.2	Empty place 1
2020-05-14 23:14:08	01 h 58 m 13.04 s, + 65d 46 m 25.7 s	18.3	01 h 58 m 13.16 s, + 65d 46 m 26.0 s	17.4	Empty place 1
2020-05-15 19:00:52	01 h 58 m 13.04 s, + 65d 46 m 28.6 s	18.2	01 h 58 m 13.15 s, + 65d 46 m 29.3 s	17.9	Empty place 1
2020-05-17 18:35:26	01 h 58 m 12.77 s, + 65d 46 m 30.0 s	17.8	01 h 58 m 12.69 s, + 65d 46 m 29.0 s	17.5	Empty place 1
2020-05-14 23:14:56	01 h 58 m 13.78 s, + 65d 46 m 30.7 s	18.4	01 h 58 m 13.48 s, + 65d 46 m 31.0 s	17.8	Empty place 1
2020-05-17 18:00:45	01 h 58 m 13.36 s, + 65d 46 m 26.6 s	17.8	01 h 58 m 13.37 s, + 65d 46 m 26.6 s	17.4	Empty place 1
2020-05-14 23:22:43	01 h 58 m 13.43 s, + 65d 46 m 28.4 s	17.6	01 h 58 m 13.74 s, + 65d 46 m 26.1 s	17.5	Empty place 1
2020-05-15 21:03:33	01 h 58 m 13.75 s, + 65d 46 m 25.7 s	18.2	01 h 58 m 13.38 s, + 65d 46 m 27.5 s	17.5	Empty place 1
2020-05-20 00:36:03	01 h 58 m 13.60 s, + 65d 46 m 24.0 s	17.2	01 h 58 m 13.50 s, + 65d 46 m 23.2 s	17.4	Empty place 1
2020-05-20 00:31:56	01 h 58 m 13.19 s, + 65d 46 m 31.2 s	17.6	01 h 58 m 13.50 s, + 65d 46 m 30.0 s	17.0	Empty place 1
2020-04-25 17:55:21	01 h 58 m 13.24 s, + 65d 46 m 28.6 s	18.3	01 h 58 m 13.53 s, + 65d 46 m 28.1 s	17.9	Empty place 1
2020-05-17 21:39:07	01 h 58 m 13.62 s, + 65d 46 m 30.5 s	17.8	01 h 58 m 13.42 s, + 65d 46 m 29.1 s	17.7	Empty place 1
2020-04-24 19:23:10	01 h 58 m 14.00 s, + 65d 46 m 26.8 s	18.6	01 h 58 m 13.84 s, + 65d 46 m 25.3 s	18.5	Empty place 1
2020-05-15 23:30:56	01 h 58 m 14.06 s, + 65d 46 m 30.2 s	17.9	01 h 58 m 13.86 s, + 65d 46 m 31.3 s	17.9	Empty place 1
2020-05-14 18:34:57	01 h 58 m 13.25 s, + 65d 46 m 25.7 s	17.8	01 h 58 m 12.89 s, + 65d 46 m 25.1 s	18.1	Empty place 1
2020-04-25 19:18:11	01 h 58 m 13.60 s, + 65d 46 m 29.7 s	18.4	01 h 58 m 13.61 s, + 65d 46 m 32.1 s	18.0	Empty place 1
2020-05-19 22:04:36	01 h 58 m 13.95 s, + 65d 46 m 25.3 s	18.8	01 h 58 m 13.56 s, + 65d 46 m 24.4 s	18.1	Empty place 1
2020-04-25 18:51:15	01 h 58 m 13.61 s, + 65d 46 m 31.2 s	18.6	01 h 58 m 13.32 s, + 65d 46 m 32.0 s	18.1	Empty place 1

Camera EAST			Camera WEST		
2020-05-15 19:16:46	01 h 58 m 13.66 s, + 65d 46 m 27.5 s	17.9	01 h 58 m 13.39 s, + 65d 46 m 26.4 s	17.8	Empty place 1
2020-05-17 17:57:15	01 h 58 m 13.30 s, + 65d 46 m 27.9 s	17.2	01 h 58 m 13.74 s, + 65d 46 m 28.5 s	18.1	Empty place 1
2020-04-24 18:46:48	01 h 58 m 12.94 s, + 65d 46 m 27.3 s	18.6	01 h 58 m 12.88 s, + 65d 46 m 29.3 s	18.7	Empty place 1
2020-04-25 20:51:53	01 h 58 m 12.95 s, + 65d 46 m 27.8 s	18.2	01 h 58 m 12.64 s, + 65d 46 m 25.7 s	18.5	Empty place 1
2020-05-15 23:46:34	01 h 58 m 13.37 s, + 65d 46 m 31.1 s	18.5	01 h 58 m 12.98 s, + 65d 46 m 30.2 s	18.6	Empty place 1
2020-05-19 20:45:38	01 h 58 m 13.14 s, + 65d 46 m 30.5 s	18.6	01 h 58 m 12.71 s, + 65d 46 m 30.1 s	18.1	Empty place 1
2020-05-20 00:18:09	01 h 58 m 13.64 s, + 65d 46 m 27.1 s	18.1	01 h 58 m 13.61 s, + 65d 46 m 29.6 s	18.0	Empty place 1
2020-05-15 18:55:59	01 h 58 m 12.75 s, + 65d 46 m 25.6 s	18.4	01 h 58 m 12.77 s, + 65d 46 m 26.9 s	18.3	Empty place 1
2020-04-25 18:23:48	01 h 58 m 13.67 s, + 65d 46 m 25.5 s	17.9	01 h 58 m 13.79 s, + 65d 46 m 26.8 s	18.0	Empty place 1
2020-05-17 21:39:35	01 h 58 m 13.49 s, + 65d 46 m 26.4 s	17.8	01 h 58 m 13.20 s, + 65d 46 m 25.7 s	17.2	Empty place 1
2020-05-15 23:32:34	01 h 58 m 13.47 s, + 65d 46 m 28.4 s	17.4	01 h 58 m 13.15 s, + 65d 46 m 27.7 s	18.4	Empty place 1
2020-05-14 23:42:50	01 h 58 m 13.82 s, + 65d 46 m 28.4 s	18.1	01 h 58 m 13.68 s, + 65d 46 m 28.9 s	18.3	Empty place 1
2020-05-17 18:24:59	01 h 58 m 13.75 s, + 65d 46 m 25.3 s	16.5	01 h 58 m 13.48 s, + 65d 46 m 27.6 s	17.8	Empty place 1
2020-04-26 20:35:31	01 h 58 m 13.40 s, + 65d 46 m 30.7 s	18.3	01 h 58 m 13.31 s, + 65d 46 m 32.3 s	18.1	Empty place 1
2020-05-17 21:37:08	01 h 58 m 13.71 s, + 65d 46 m 31.3 s	17.8	01 h 58 m 13.36 s, + 65d 46 m 31.2 s	17.6	Empty place 1
2020-05-17 21:38:40	01 h 58 m 13.23 s, + 65d 46 m 29.6 s	16.9	01 h 58 m 12.88 s, + 65d 46 m 29.4 s	17.9	Empty place 1
2020-05-14 23:41:25	01 h 58 m 13.02 s, + 65d 46 m 27.4 s	18.4	01 h 58 m 13.32 s, + 65d 46 m 28.1 s	17.8	Empty place 1
2020-05-14 22:18:20	01 h 58 m 12.63 s, + 65d 46 m 26.6 s	18.1	01 h 58 m 13.00 s, + 65d 46 m 26.4 s	17.9	Empty place 1

Camera EAST			Camera WEST		
2020-05-15 22:04:58	01 h 58 m 13.27 s, + 65d 46 m 30.0 s	18.1	01 h 58 m 13.47 s, + 65d 46 m 31.5 s	17.8	Emphly place 1
2020-05-14 22:56:41	01 h 58 m 13.10 s, + 65d 46 m 25.8 s	18.0	01 h 58 m 13.08 s, + 65d 46 m 27.0 s	17.7	Emphly place 1
2020-04-24 19:02:27	01 h 58 m 13.28 s, + 65d 46 m 24.7 s	18.6	01 h 58 m 13.70 s, + 65d 46 m 24.4 s	18.5	Emphly place 1
2020-05-14 17:51:58	01 h 58 m 13.62 s, + 65d 46 m 25.3 s	16.9	01 h 58 m 13.28 s, + 65d 46 m 25.3 s	17.4	Emphly place 1
2020-05-14 17:49:09	01 h 58 m 13.71 s, + 65d 46 m 27.3 s	16.9	01 h 58 m 13.33 s, + 65d 46 m 27.4 s	16.8	Emphly place 1
2020-05-20 00:16:49	01 h 58 m 13.29 s, + 65d 46 m 28.3 s	18.0	01 h 58 m 13.25 s, + 65d 46 m 26.0 s	17.4	Emphly place 1
2020-04-26 18:48:37	01 h 58 m 12.85 s, + 65d 46 m 31.6 s	18.0	01 h 58 m 12.99 s, + 65d 46 m 31.9 s	17.4	Emphly place 1
2020-05-14 23:50:43	01 h 58 m 13.43 s, + 65d 46 m 25.1 s	18.1	01 h 58 m 13.46 s, + 65d 46 m 27.9 s	17.8	Emphly place 1
2020-05-14 19:08:12	01 h 58 m 13.34 s, + 65d 46 m 25.9 s	16.8	01 h 58 m 13.16 s, + 65d 46 m 23.5 s	16.9	Emphly place 1
2020-05-14 20:48:04	01 h 58 m 13.80 s, + 65d 46 m 30.0 s	17.6	01 h 58 m 13.37 s, + 65d 46 m 29.0 s	17.8	Emphly place 1
2020-05-15 22:08:06	01 h 58 m 13.16 s, + 65d 46 m 26.6 s	17.8	01 h 58 m 13.48 s, + 65d 46 m 26.4 s	18.6	Emphly place 1
2020-05-19 21:51:05	01 h 58 m 13.42 s, + 65d 46 m 30.0 s	18.5	01 h 58 m 13.50 s, + 65d 46 m 32.4 s	18.0	Emphly place 1
2020-05-14 19:29:19	01 h 58 m 13.51 s, + 65d 46 m 31.5 s	17.9	01 h 58 m 13.67 s, + 65d 46 m 31.1 s	18.0	Emphly place 1
2020-04-25 20:10:54	01 h 58 m 13.47 s, + 65d 46 m 26.4 s	17.7	01 h 58 m 13.20 s, + 65d 46 m 27.9 s	17.8	Emphly place 1
2020-05-19 23:05:23	01 h 58 m 13.65 s, + 65d 46 m 23.7 s	18.6	01 h 58 m 13.67 s, + 65d 46 m 23.4 s	18.7	Emphly place 1
2020-05-17 18:21:48	01 h 58 m 13.68 s, + 65d 46 m 28.2 s	17.7	01 h 58 m 13.61 s, + 65d 46 m 29.9 s	17.9	Emphly place 1
2020-05-19 21:17:01	01 h 58 m 13.38 s, + 65d 46 m 29.6 s	18.2	01 h 58 m 13.36 s, + 65d 46 m 31.8 s	18.4	Emphly place 1
2020-04-24 18:06:43	01 h 58 m 13.46 s, + 65d 46 m 27.5 s	18.6	01 h 58 m 13.45 s, + 65d 46 m 27.0 s	18.7	Emphly place 1

Camera EAST			Camera WEST		
2020-05-19 23:30:19	01 h 58 m 13.52 s, + 65d 46 m 26.5 s	17.8	01 h 58 m 13.17 s, + 65d 46 m 24.8 s	18.5	Empty place 1
2020-05-14 22:05:53	01 h 58 m 13.46 s, + 65d 46 m 26.8 s	18.1	01 h 58 m 13.28 s, + 65d 46 m 24.2 s	18.1	Empty place 1
2020-05-15 22:53:35	01 h 58 m 13.34 s, + 65d 46 m 28.0 s	17.4	01 h 58 m 13.38 s, + 65d 46 m 30.1 s	17.9	Empty place 1
2020-05-14 23:44:33	01 h 58 m 13.71 s, + 65d 46 m 26.9 s	18.0	01 h 58 m 13.76 s, + 65d 46 m 25.7 s	18.2	Empty place 1
2020-04-25 19:36:50	01 h 57 m 57.60 s, + 65d 43 m 51.5 s	16.9	01 h 57 m 57.54 s, + 65d 43 m 48.9 s	17.3	Empty place 2
2020-05-15 22:44:32	01 h 57 m 57.30 s, + 65d 43 m 53.1 s	18.4	01 h 57 m 57.28 s, + 65d 43 m 52.9 s	18.2	Empty place 2
2020-05-14 18:59:00	01 h 57 m 57.62 s, + 65d 43 m 46.1 s	17.9	01 h 57 m 57.72 s, + 65d 43 m 48.0 s	18.3	Empty place 2
2020-05-14 22:33:04	01 h 57 m 57.33 s, + 65d 43 m 48.4 s	18.2	01 h 57 m 57.16 s, + 65d 43 m 50.7 s	17.4	Empty place 2
2020-04-24 19:05:37	01 h 57 m 57.36 s, + 65d 43 m 49.7 s	18.6	01 h 57 m 57.35 s, + 65d 43 m 51.1 s	18.7	Empty place 2
2020-05-17 18:56:50	01 h 57 m 56.57 s, + 65d 43 m 50.1 s	18.0	01 h 57 m 56.84 s, + 65d 43 m 50.6 s	18.3	Empty place 2
2020-05-19 21:51:33	01 h 57 m 57.18 s, + 65d 43 m 50.7 s	17.8	01 h 57 m 57.62 s, + 65d 43 m 49.6 s	18.1	Empty place 2
2020-04-25 18:24:04	01 h 57 m 57.64 s, + 65d 43 m 49.3 s	18.0	01 h 57 m 57.54 s, + 65d 43 m 50.0 s	18.0	Empty place 2
2020-05-19 20:45:54	01 h 57 m 57.95 s, + 65d 43 m 48.3 s	18.5	01 h 57 m 57.73 s, + 65d 43 m 46.2 s	18.6	Empty place 2
2020-05-15 23:35:48	01 h 57 m 57.56 s, + 65d 43 m 47.6 s	18.4	01 h 57 m 57.66 s, + 65d 43 m 49.0 s	18.4	Empty place 2
2020-05-15 20:17:32	01 h 57 m 56.60 s, + 65d 43 m 48.3 s	17.5	01 h 57 m 56.68 s, + 65d 43 m 51.1 s	18.0	Empty place 2
2020-05-14 19:47:40	01 h 57 m 56.69 s, + 65d 43 m 48.3 s	17.5	01 h 57 m 56.91 s, + 65d 43 m 46.8 s	17.2	Empty place 2
2020-04-26 19:20:59	01 h 57 m 57.39 s, + 65d 43 m 45.1 s	18.0	01 h 57 m 57.05 s, + 65d 43 m 47.1 s	18.5	Empty place 2
2020-05-14 17:57:00	01 h 57 m 57.07 s, + 65d 43 m 53.5 s	17.5	01 h 57 m 57.30 s, + 65d 43 m 51.0 s	17.4	Empty place 2

Camera EAST			Camera WEST		
2020-05-14 19:37:47	01 h 57 m 57.36 s, + 65d 43 m 48.5 s	17.5	01 h 57 m 57.41 s, + 65d 43 m 46.9 s	17.8	Emphthy place 2
2020-05-14 22:31:20	01 h 57 m 56.87 s, + 65d 43 m 46.1 s	17.9	01 h 57 m 57.26 s, + 65d 43 m 46.8 s	17.9	Emphthy place 2
2020-05-14 23:44:33	01 h 57 m 57.53 s, + 65d 43 m 52.6 s	17.0	01 h 57 m 57.31 s, + 65d 43 m 52.2 s	17.6	Emphthy place 2
2020-05-19 22:53:39	01 h 57 m 56.96 s, + 65d 43 m 45.0 s	18.2	01 h 57 m 57.28 s, + 65d 43 m 45.9 s	18.8	Emphthy place 2
2020-05-15 22:48:05	01 h 57 m 57.52 s, + 65d 43 m 46.3 s	18.2	01 h 57 m 57.43 s, + 65d 43 m 46.0 s	17.0	Emphthy place 2
2020-04-24 20:31:52	01 h 57 m 57.73 s, + 65d 43 m 51.4 s	17.5	01 h 57 m 57.78 s, + 65d 43 m 50.8 s	17.7	Emphthy place 2
2020-05-17 17:53:20	01 h 57 m 57.48 s, + 65d 43 m 53.1 s	17.6	01 h 57 m 57.09 s, + 65d 43 m 51.6 s	18.1	Emphthy place 2
2020-05-14 23:15:51	01 h 57 m 56.86 s, + 65d 43 m 47.3 s	17.8	01 h 57 m 56.84 s, + 65d 43 m 45.5 s	17.5	Emphthy place 2
2020-04-25 18:59:46	01 h 57 m 57.75 s, + 65d 43 m 47.5 s	18.2	01 h 57 m 57.71 s, + 65d 43 m 46.0 s	18.1	Emphthy place 2
2020-04-24 19:47:26	01 h 57 m 56.79 s, + 65d 43 m 49.6 s	18.7	01 h 57 m 56.48 s, + 65d 43 m 49.3 s	17.9	Emphthy place 2
2020-05-14 20:22:35	01 h 57 m 57.13 s, + 65d 43 m 52.4 s	17.3	01 h 57 m 56.86 s, + 65d 43 m 52.6 s	17.7	Emphthy place 2
2020-04-24 19:44:36	01 h 57 m 56.79 s, + 65d 43 m 46.4 s	18.1	01 h 57 m 57.11 s, + 65d 43 m 45.1 s	17.8	Emphthy place 2
2020-04-25 20:30:04	01 h 57 m 57.64 s, + 65d 43 m 49.6 s	18.4	01 h 57 m 57.25 s, + 65d 43 m 49.6 s	18.1	Emphthy place 2
2020-05-17 21:38:11	01 h 57 m 57.68 s, + 65d 43 m 52.0 s	17.5	01 h 57 m 57.29 s, + 65d 43 m 52.4 s	17.0	Emphthy place 2
2020-05-20 00:15:04	01 h 57 m 57.63 s, + 65d 43 m 47.5 s	17.5	01 h 57 m 57.86 s, + 65d 43 m 50.0 s	17.9	Emphthy place 2
2020-04-26 18:52:39	01 h 57 m 57.30 s, + 65d 43 m 45.9 s	18.2	01 h 57 m 56.88 s, + 65d 43 m 45.4 s	18.4	Emphthy place 2
2020-04-25 19:19:59	01 h 57 m 57.85 s, + 65d 43 m 48.5 s	18.2	01 h 57 m 58.02 s, + 65d 43 m 49.2 s	17.8	Emphthy place 2
2020-05-19 21:28:19	01 h 57 m 57.13 s, + 65d 43 m 51.2 s	18.3	01 h 57 m 56.98 s, + 65d 43 m 52.4 s	18.6	Emphthy place 2

Camera EAST			Camera WEST		
2020-04-24 17:57:29	01 h 57 m 56.97 s, + 65d 43 m 50.3 s	18.6	01 h 57 m 56.73 s, + 65d 43 m 49.3 s	18.4	Emphy place 2
2020-04-25 19:39:18	01 h 57 m 57.34 s, + 65d 43 m 50.6 s	16.4	01 h 57 m 57.54 s, + 65d 43 m 52.2 s	17.7	Emphy place 2
2020-05-14 23:00:33	01 h 57 m 57.32 s, + 65d 43 m 52.7 s	18.2	01 h 57 m 57.11 s, + 65d 43 m 51.2 s	17.5	Emphy place 2
2020-05-15 21:35:49	01 h 57 m 57.43 s, + 65d 43 m 51.9 s	18.3	01 h 57 m 57.24 s, + 65d 43 m 51.8 s	18.5	Emphy place 2
2020-05-19 22:20:52	01 h 57 m 56.85 s, + 65d 43 m 51.5 s	17.3	01 h 57 m 57.16 s, + 65d 43 m 50.0 s	18.8	Emphy place 2
2020-05-17 22:07:06	01 h 57 m 56.73 s, + 65d 43 m 50.8 s	18.1	01 h 57 m 57.10 s, + 65d 43 m 52.5 s	18.0	Emphy place 2
2020-05-15 23:30:13	01 h 57 m 57.01 s, + 65d 43 m 51.1 s	18.3	01 h 57 m 56.93 s, + 65d 43 m 51.9 s	18.2	Emphy place 2
2020-05-19 21:47:43	01 h 57 m 57.17 s, + 65d 43 m 53.5 s	18.7	01 h 57 m 57.35 s, + 65d 43 m 54.1 s	17.9	Emphy place 2
2020-04-25 19:50:51	01 h 57 m 56.98 s, + 65d 43 m 52.8 s	17.7	01 h 57 m 57.01 s, + 65d 43 m 52.7 s	17.3	Emphy place 2
2020-05-14 21:54:20	01 h 57 m 57.40 s, + 65d 43 m 48.5 s	17.2	01 h 57 m 57.04 s, + 65d 43 m 50.4 s	17.1	Emphy place 2
2020-05-14 19:29:33	01 h 57 m 57.38 s, + 65d 43 m 46.0 s	17.1	01 h 57 m 57.84 s, + 65d 43 m 46.8 s	17.7	Emphy place 2
2020-04-25 18:08:45	01 h 57 m 56.80 s, + 65d 43 m 49.5 s	18.5	01 h 57 m 57.02 s, + 65d 43 m 49.2 s	18.5	Emphy place 2
2020-05-19 22:40:58	01 h 57 m 56.97 s, + 65d 43 m 50.8 s	18.7	01 h 57 m 57.29 s, + 65d 43 m 52.3 s	18.3	Emphy place 2
2020-05-15 19:51:03	01 h 57 m 56.86 s, + 65d 43 m 48.3 s	17.5	01 h 57 m 56.64 s, + 65d 43 m 45.7 s	16.8	Emphy place 2
2020-05-15 19:42:10	01 h 57 m 56.92 s, + 65d 43 m 53.1 s	17.7	01 h 57 m 56.72 s, + 65d 43 m 52.5 s	18.3	Emphy place 2
2020-04-26 20:40:55	01 h 57 m 57.04 s, + 65d 43 m 49.4 s	18.5	01 h 57 m 57.37 s, + 65d 43 m 47.5 s	18.3	Emphy place 2
2020-05-15 19:47:44	01 h 57 m 57.53 s, + 65d 43 m 51.8 s	17.5	01 h 57 m 57.37 s, + 65d 43 m 49.2 s	17.6	Emphy place 2
2020-05-17 22:04:34	01 h 57 m 56.78 s, + 65d 43 m 51.7 s	16.9	01 h 57 m 56.75 s, + 65d 43 m 48.9 s	17.4	Emphy place 2

Camera EAST			Camera WEST		
2020-05-19 21:04:21	01 h 57 m 57.78 s, + 65d 43 m 50.5 s	18.4	01 h 57 m 57.57 s, + 65d 43 m 48.5 s	18.1	Emphy place 2
2020-05-15 19:36:27	01 h 57 m 57.84 s, + 65d 43 m 49.5 s	17.9	01 h 57 m 57.83 s, + 65d 43 m 51.1 s	18.0	Emphy place 2
2020-05-15 22:09:05	01 h 57 m 57.58 s, + 65d 43 m 47.2 s	18.1	01 h 57 m 57.40 s, + 65d 43 m 45.9 s	18.3	Emphy place 2
2020-04-25 20:14:43	01 h 57 m 57.70 s, + 65d 43 m 52.0 s	17.2	01 h 57 m 57.28 s, + 65d 43 m 51.6 s	17.1	Emphy place 2
2020-05-20 00:23:21	01 h 57 m 57.28 s, + 65d 43 m 49.5 s	18.0	01 h 57 m 57.36 s, + 65d 43 m 48.6 s	18.0	Emphy place 2
2020-05-14 22:48:23	01 h 57 m 57.40 s, + 65d 43 m 49.1 s	18.2	01 h 57 m 57.34 s, + 65d 43 m 46.4 s	18.0	Emphy place 2
2020-05-14 20:33:06	01 h 57 m 56.55 s, + 65d 43 m 48.6 s	17.2	01 h 57 m 56.71 s, + 65d 43 m 49.7 s	16.6	Emphy place 2
2020-05-19 22:31:17	01 h 57 m 56.60 s, + 65d 43 m 47.8 s	18.7	01 h 57 m 56.85 s, + 65d 43 m 48.1 s	18.6	Emphy place 2
2020-04-06 21:31:19	01 h 57 m 57.50 s, + 65d 43 m 50.6 s	18.9	01 h 57 m 57.89 s, + 65d 43 m 49.5 s	18.7	Emphy place 2
2020-04-25 19:45:36	01 h 57 m 56.71 s, + 65d 43 m 51.2 s	17.7	01 h 57 m 56.85 s, + 65d 43 m 50.4 s	18.0	Emphy place 2
2020-05-17 19:12:57	01 h 57 m 56.95 s, + 65d 43 m 51.2 s	18.2	01 h 57 m 56.96 s, + 65d 43 m 49.8 s	18.3	Emphy place 2
2020-04-25 17:16:48	01 h 57 m 57.11 s, + 65d 43 m 47.7 s	16.5	01 h 57 m 57.44 s, + 65d 43 m 48.6 s	17.6	Emphy place 2
2020-05-17 18:59:25	01 h 57 m 57.48 s, + 65d 43 m 45.8 s	18.4	01 h 57 m 57.56 s, + 65d 43 m 47.3 s	18.5	Emphy place 2
2020-04-25 17:50:36	01 h 57 m 57.35 s, + 65d 43 m 50.8 s	18.5	01 h 57 m 57.47 s, + 65d 43 m 50.8 s	18.6	Emphy place 2
2020-04-26 18:54:20	01 h 57 m 57.67 s, + 65d 43 m 46.2 s	18.4	01 h 57 m 57.70 s, + 65d 43 m 46.6 s	17.7	Emphy place 2
2020-04-26 18:59:23	01 h 57 m 57.36 s, + 65d 43 m 48.5 s	18.0	01 h 57 m 57.64 s, + 65d 43 m 47.4 s	18.4	Emphy place 2
2020-05-19 22:58:54	01 h 57 m 57.70 s, + 65d 43 m 50.5 s	18.5	01 h 57 m 58.01 s, + 65d 43 m 48.8 s	18.4	Emphy place 2
2020-04-25 17:43:35	01 h 57 m 57.20 s, + 65d 43 m 52.6 s	17.8	01 h 57 m 57.13 s, + 65d 43 m 51.9 s	18.6	Emphy place 2

Camera EAST			Camera WEST		
2020-04-26 19:19:04	01 h 57 m 57.19 s, + 65d 43 m 45.6 s	18.3	01 h 57 m 57.39 s, + 65d 43 m 47.5 s	18.4	Emphthy place 2
2020-05-17 18:26:47	01 h 57 m 57.94 s, + 65d 43 m 48.4 s	17.7	01 h 57 m 57.84 s, + 65d 43 m 46.8 s	17.7	Emphthy place 2
2020-05-17 18:43:21	01 h 57 m 56.90 s, + 65d 43 m 50.3 s	17.9	01 h 57 m 56.76 s, + 65d 43 m 50.3 s	17.9	Emphthy place 2
2020-05-14 19:55:53	01 h 57 m 57.06 s, + 65d 43 m 51.9 s	17.6	01 h 57 m 57.23 s, + 65d 43 m 51.9 s	17.9	Emphthy place 2
2020-05-17 18:00:03	01 h 57 m 56.46 s, + 65d 43 m 51.0 s	18.0	01 h 57 m 56.60 s, + 65d 43 m 52.1 s	18.0	Emphthy place 2
2020-05-14 17:54:50	01 h 57 m 56.80 s, + 65d 43 m 48.1 s	17.8	01 h 57 m 56.74 s, + 65d 43 m 49.5 s	16.4	Emphthy place 2
2020-04-25 19:52:34	01 h 57 m 56.85 s, + 65d 43 m 48.2 s	17.8	01 h 57 m 56.95 s, + 65d 43 m 48.1 s	18.4	Emphthy place 2
2020-05-14 22:11:34	01 h 57 m 57.50 s, + 65d 43 m 46.8 s	17.8	01 h 57 m 57.47 s, + 65d 43 m 45.3 s	17.7	Emphthy place 2
2020-05-17 18:14:31	01 h 57 m 57.77 s, + 65d 43 m 48.6 s	18.0	01 h 57 m 57.58 s, + 65d 43 m 47.5 s	17.5	Emphthy place 2
2020-05-14 21:22:09	01 h 57 m 57.26 s, + 65d 43 m 54.2 s	16.8	01 h 57 m 57.62 s, + 65d 43 m 53.2 s	16.6	Emphthy place 2
2020-05-15 19:57:20	01 h 57 m 57.89 s, + 65d 43 m 47.2 s	18.0	01 h 57 m 57.63 s, + 65d 43 m 48.2 s	18.5	Emphthy place 2
2020-05-17 18:03:41	01 h 57 m 57.19 s, + 65d 43 m 48.4 s	17.4	01 h 57 m 57.26 s, + 65d 43 m 49.3 s	18.0	Emphthy place 2
2020-05-19 21:35:26	01 h 57 m 56.98 s, + 65d 43 m 48.7 s	18.3	01 h 57 m 56.96 s, + 65d 43 m 51.6 s	18.3	Emphthy place 2
2020-04-25 17:37:50	01 h 57 m 57.06 s, + 65d 43 m 49.1 s	17.8	01 h 57 m 57.20 s, + 65d 43 m 47.2 s	17.6	Emphthy place 2
2020-04-26 19:07:15	01 h 57 m 56.84 s, + 65d 43 m 49.3 s	18.3	01 h 57 m 56.58 s, + 65d 43 m 49.7 s	18.6	Emphthy place 2
2020-05-14 20:17:47	01 h 57 m 57.49 s, + 65d 43 m 50.2 s	17.5	01 h 57 m 57.69 s, + 65d 43 m 52.5 s	17.5	Emphthy place 2
2020-04-24 18:14:20	01 h 57 m 56.80 s, + 65d 43 m 47.7 s	18.7	01 h 57 m 57.03 s, + 65d 43 m 47.4 s	18.0	Emphthy place 2
2020-04-24 20:40:16	01 h 57 m 57.29 s, + 65d 43 m 47.8 s	18.6	01 h 57 m 57.32 s, + 65d 43 m 50.0 s	18.7	Emphthy place 2

Camera EAST			Camera WEST		
2020-04-24 20:16:48	01 h 57 m 57.88 s, + 65d 43 m 47.7 s	17.4	01 h 57 m 57.93 s, + 65d 43 m 49.1 s	18.6	Empty place 2
2020-05-17 18:46:03	01 h 57 m 56.96 s, + 65d 43 m 48.5 s	18.3	01 h 57 m 56.83 s, + 65d 43 m 47.6 s	18.1	Empty place 2
2020-05-17 18:09:15	01 h 57 m 56.53 s, + 65d 43 m 50.7 s	17.8	01 h 57 m 56.78 s, + 65d 43 m 49.9 s	18.1	Empty place 2
2020-05-15 21:35:05	01 h 57 m 57.26 s, + 65d 43 m 45.4 s	18.2	01 h 57 m 57.32 s, + 65d 43 m 44.9 s	17.8	Empty place 2
2020-05-17 22:15:38	01 h 57 m 57.74 s, + 65d 43 m 52.8 s	17.9	01 h 57 m 57.62 s, + 65d 43 m 51.3 s	18.4	Empty place 2
2020-04-26 19:42:43	01 h 57 m 57.03 s, + 65d 43 m 46.8 s	18.4	01 h 57 m 57.00 s, + 65d 43 m 45.7 s	17.8	Empty place 2
2020-04-25 17:37:02	01 h 57 m 56.70 s, + 65d 43 m 50.9 s	18.3	01 h 57 m 56.97 s, + 65d 43 m 53.2 s	18.3	Empty place 2
2020-05-19 21:11:54	01 h 57 m 57.78 s, + 65d 43 m 47.6 s	18.1	01 h 57 m 57.69 s, + 65d 43 m 49.4 s	18.3	Empty place 2

Table 2
The photometry of the galactic star formation
region from Gemini fit.

Radius, arcsec	mag	mag / sq. arcsec
0.32	26.50	25.30
0.49	26.23	25.91
0.65	25.55	25.85
0.81	25.28	26.06
0.97	25.04	26.22
1.13	24.62	26.13
1.30	24.24	26.05
1.46	23.87	25.93
1.62	23.57	25.86
1.78	23.32	25.82
1.94	23.09	25.77
2.11	23.05	25.91
2.27	22.97	25.99
2.43	22.77	25.94
2.59	22.80	26.11
2.75	22.77	26.21
2.92	22.61	26.18
3.08	22.39	26.07
3.24	22.30	26.10

Figures

Figure 1

Schedule of synchronous observations of the FRB180916.J0158+65 radio burst by five MASTER telescopes. The circular stripes show the moments of activity of the radio burster according to the ephemeris15.

Figure 2

Dependence of the number of synchronous coincidences in both tubes at the level of 3 sigma on the radius of the circular analyzed region in angular units. Lilac color shows the area around the FRB. Blue and yellow, control blanks just arcminutes from the FRB. An obvious excess of optical emission from the FRB region is visible.

Figure 3

Host galaxy by Gemini19 and MASTER image of FRB place. There is the synthesized image of the host galaxy (image corresponds to Marcote et al. 2020 and was taken from Gemini open source) with FRB from MASTER (the round on the left Gemini square) and Gemini telescope image of the enlarged region of intense star formation around the FRB (red dot) at the right top position.

Figure 4

The brightness of the extended glow of the host galaxy depending on the radius of the region around FRB. Our FWHM = 2.5 corresponds to a radius of 2.5 since the pixel size is 2 arc seconds.

Figure 5

The dependence of the fluence in absolute units on the frequency of observation. This graph shows the limits and typical energies for FRB 180916 and FRB 121102. Half-filled dots represent FRB 121102, fully filled dots represent FRB 180916. Stars - signal detection, triangles - upper limits. Azure Star - observation of FRB 180916 by the VLA radio telescope dated April 23, 2020⁴¹. MASTER Sync - synchronous observation of this burst with the MASTER-Tunka optical telescope. ULTRASPEC - synchronous observations of FRB121102 in bands i' and z' by the ULTRASPEC camera located on the 2.4th Thai National Telescope⁴². MAGIC - synchronous observations of FRB121102 in the U band of MAGIC Collaboration⁴³. ZTF - observations of the FRB180916 Zwicky Transient Facility in bands g and r¹⁸. Chandra and Fermi GBM are synchronous observations of FRB180916 in the ranges of 0.5–10 keV and 10–100 keV, respectively ⁴⁴.

Figure 6

Interaction of physics experiments to search FRB sources. 8 MASTER Global Robotic-Telescopes are marked by flags. Common FOV is equal to 64 square degree's. From East to West: MASTER-Amur, -Tunka, -Ural, -Kislovodsk, -Tavrida, -SAAO, -IAC, Oafa. MASTER is a wide-field twin (2x4sq.deg. and 2x384sq.deg.) fully robotic colored (BVRI+polarization) fast (30deg/s) 40cm telescopes with identical scientific equipment³⁶ and own real-time auto-detection system distributed all over the Earth. Three sites in Canada, Hawaii and New Mexico are CHIME/FRB6-8, Gemini North¹⁹, VLA. The physical map was taken from google/NatGeo. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.