Observation Report: PSR B0531+21 Crab Pulsar

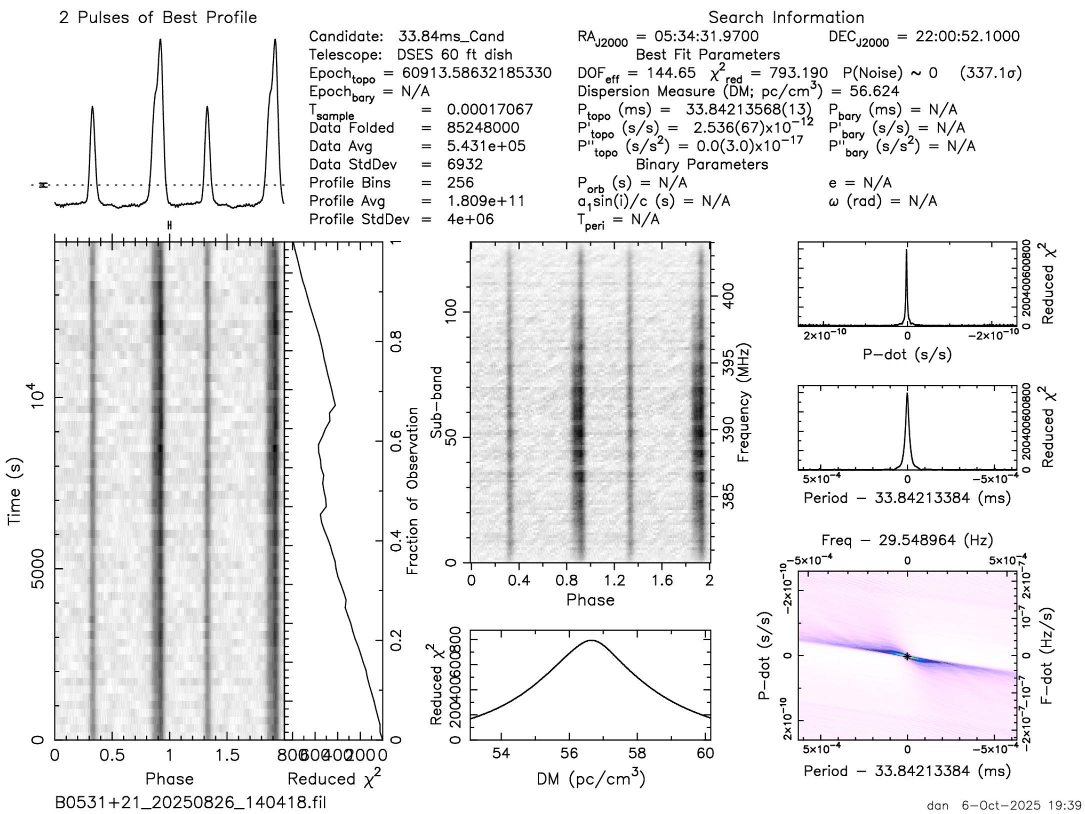
The Crab pulsar (B0531+21) is the visible neutron star in the center of the Crab supernova (1054 A.D.) remnant, shown below in the NASA image combining Hubble and Chandra imagery. Young pulsars, such as the Crab, are more dynamic than older, stable pulsars, such as B0329+54.

The Crab pulsar emits three kinds of pulses, all of which DSES detected on August 26, 2025. This pulsar emits a main pulse with a period of 33 msec and a mean flux density of 550 mJy at 400 MHz. A smaller interpulse trails the main pulse by 4/10 of the period (~140°). Additionally, the Crab randomly emits "giant pulses," which are single, narrow pulses that can exceed the mean flux density by factors of 10 or more. Giant pulses are known to be emitted at both the main pulse and interpulse phases of the pulsar's rotation. All three pulse types are generated by the extreme magnetic fields on the neutron star's surface, exceeding 10^{12} Gauss.

Main pulse and interpulse

The Presto prepfold plot shown below is for a 4 hour collection with the 408 MHz antenna. It shows both the main pulse and the interpulse. The data collection had very little RFI, and it was masked out (rfifind).

At lower frequencies (such as 408 MHz) the Crab pulse profile exhibits both dispersive scattering and additional pulse broadening due to multi-path scattering from the ISM and the expanding plasma shell from the supernova that the radio signals transit. Dispersive scattering is corrected by applying the DM (notice the phase traces are straight, which means DM is correct). The broadening of the pulse may be verified by comparing with other amateur sites (e.g., K5SO, OE5JFL), the EPN Database of Pulsar Profiles (Jodrell Bank), or in the literature ("Scattering features and variability of the Crab pulsar," L.N. Driessne, et.al., Monthly Notices of the Royal Astronomical



Society 483, 2019).

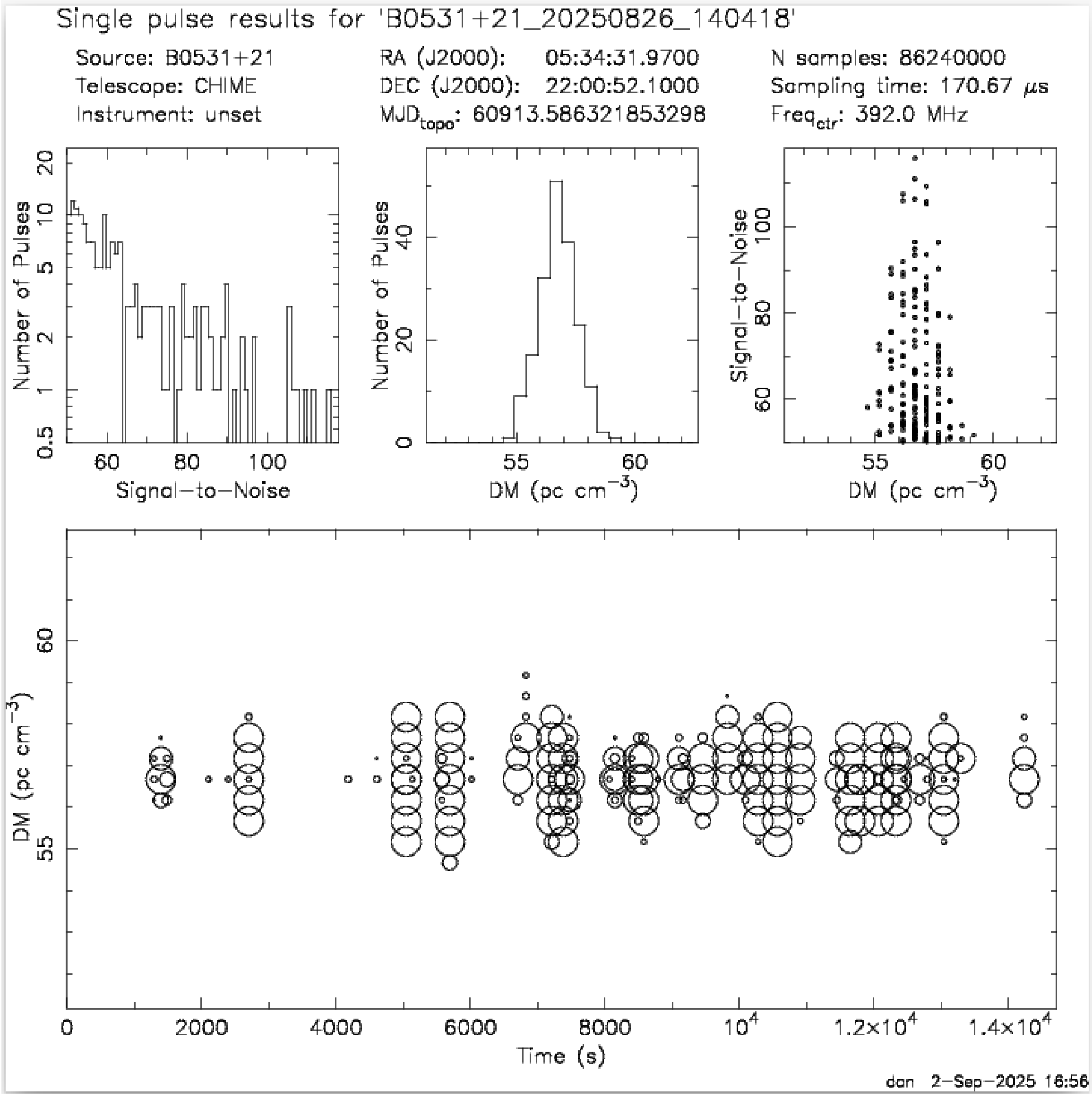
Collection parameters are listed in the table below.

B0531+21 "Crab" Parameters	Values
Date & Time (UTC)	20250826, 140418
Source distance; Flux density	2.0 kpc = 6,520 light years; S400 = 550 mJy
Source period; Dispersion measure	P = 0.334 sec; DM = 56.7
Source RA, DEC (J0534+2200)	05h 34m 31.9s ; +22° 00’ 52.1’’
Observers	Ray, Rick, Bill M., Dan
Telescope	DSES 60 ft. dish (18.3 m) Haswell, CO
Dish pointing and tracking	System1 (Glen, Lewis, Phil)

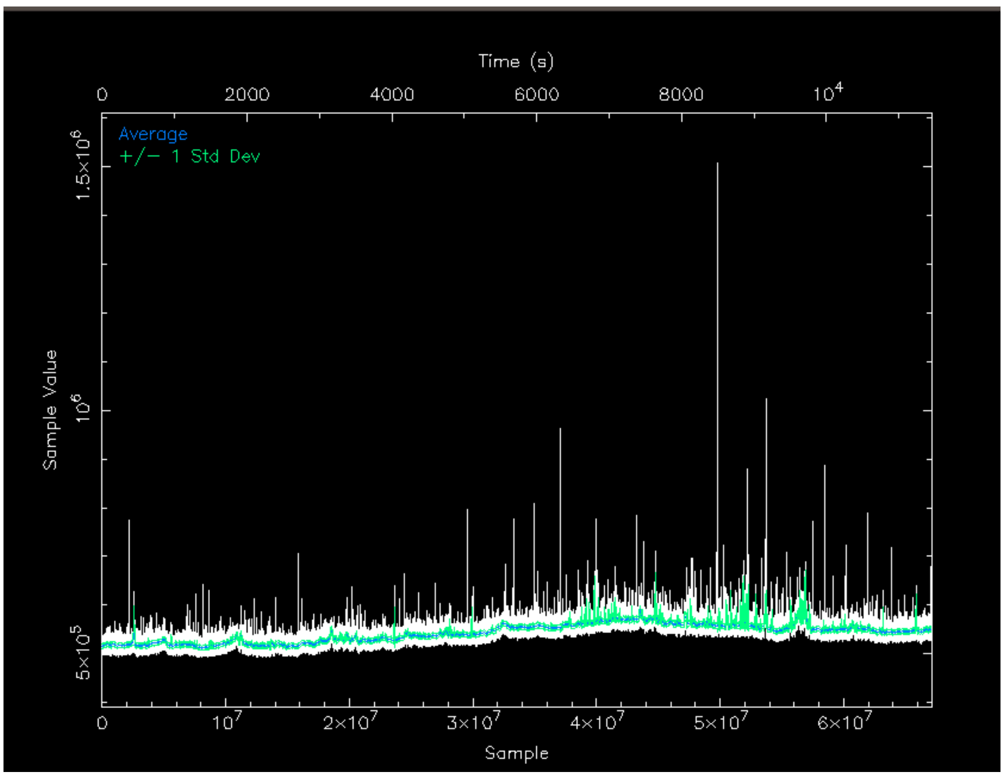
Antenna	408 MHz dual dipole, +30 dB LNA, 90 MHz filter
Polarization; Beamwidth (HPBW)	Linear; 2.7°
Receiver	B210+GPS, BW = 24 MHz. Freq = 392 MHz, Gain = 48
Computer	System76 desktop, 16 core, Pop!_OS (Ubuntu 22.04)
Planning software	I0NAA Murmur, Stellarium, ATNF pulsar catalog
Data collection & processing software	GnuRadio 3.10, Python 3.10, PRESTO 4.0
Run time; # channels, width	14,400 seconds (4 hours); 256, 0.094 MHz

Giant pulses

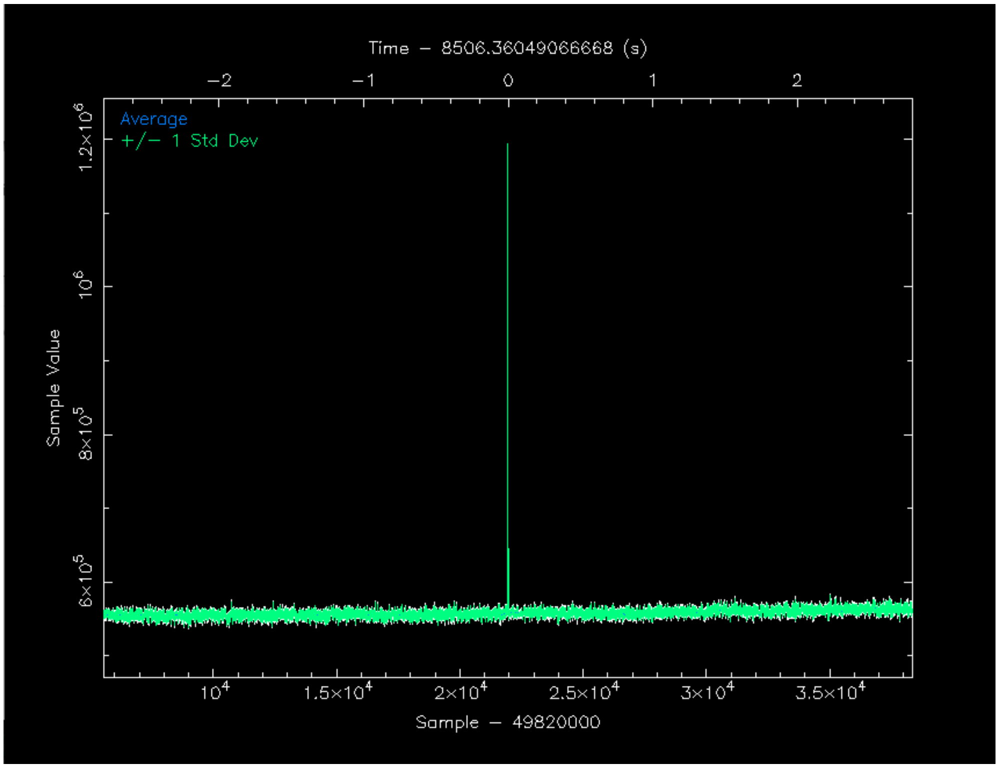
The time of occurrence for giant pulses is shown in the SinglePulse plot below. Peak SNR is used to verify that each giant pulse has the same dispersion measure as the pulsar. If the peak SNR for a single pulse occurs at the same dispersion measure (DM) as the pulsar, then it originates from the same place. On the other hand, if DM is zero, then local RFI caused the pulse. The top middle plot shows the number of pulses peaks as a function of DM, and the top right plot shows that SNR peaks at the correct DM. The bottom plot indicates the time when single pulses were detected. This diagram plots candidate pulses with SNR > 50. There are many more below 50.


Single pulse results for 'B0531+21_20250826_140418'
Source: B0531+21
Telescope: CHIME
Instrument: unset
RA (J2000): 05:34:31.9700
DEC (J2000): 22:00:52.1000
MJD$_{topo}$: 60913.586321853298
N samples: 86240000
Sampling time: 170.67 μs
Freq$_{ctr}$: 392.0 MHz
Number of Pulses
Signal-to-Noise
Number of Pulses
DM (pc cm^{-3})
Signal-to-Noise
DM (pc cm^{-3})
DM (pc cm^{-3})
Time (s)
dan 2-Sep-2025 16:56

The time series plot below (exploredat) shows the distribution of giant pulses in the 4 hour collection.



Using the time indication from the SinglePulse plot, we can zoom in the time series at time 8,506 seconds to see a giant, narrow pulse (below). In lieu of calibration scans for intensity, we use the SNR of the resulting profile. This giant pulse has SNR more than 10 times greater than the average pulse.



Time − 8506.36049066668 (s)
−2
−1
0
1
2
Average
+/− 1 Std Dev
Sample Value
1.2×10^6
10^6
8×10^5
6×10^5
10^4
1.5×10^4
2×10^4
2.5×10^4
3×10^4
3.5×10^4
Sample − 49820000