COMPACT EFFELSBERG SEARCH FOR PULSARS IN GLOBULAR CLUSTERS

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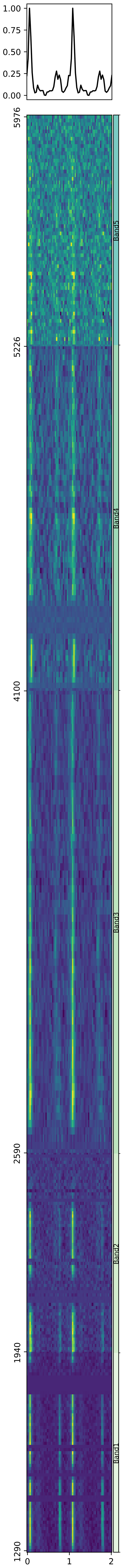


Fig 1: Blind re-detection of NGC6626 (M28) Pulsar A in all bands of Effelsberg UBB in search mode.

COMPACT GLOBULAR CLUSTER SURVEY

COMPACT is a tailor-made pulsar search programme to discover pulsars in "compact" binary orbits with orbital periods ranging from a few minutes to a few hours around other neutron stars, white dwarves or black holes. Such discoveries will provide insights into a multitude of fundamental physics and astrophysics[2]. We aim to discover these via targeted observations of Globular Clusters (GCs) with high stellar density. COMPACT uses both the MeerKAT (South Africa) and Effelsberg (Germany) telescopes with complementary strategies. MeerKAT targets globular clusters with known pulsars for tailored short-period binary searches, while Effelsberg surveys clusters without known pulsars to discover new ones for deeper follow-up.

Why Globular Clusters?

- Extreme stellar densities (≲10^6 × Solar neighbourhood) fuel frequent dynamical encounters makes them efficient "pulsar factories"[1]
- High rate of exchanges & captures → exotic binary & trinary systems
- Unique discoveries: fastest[5] and most massive NS[4], eccentric PSR–WDs, double-NS from exchange interactions[7]

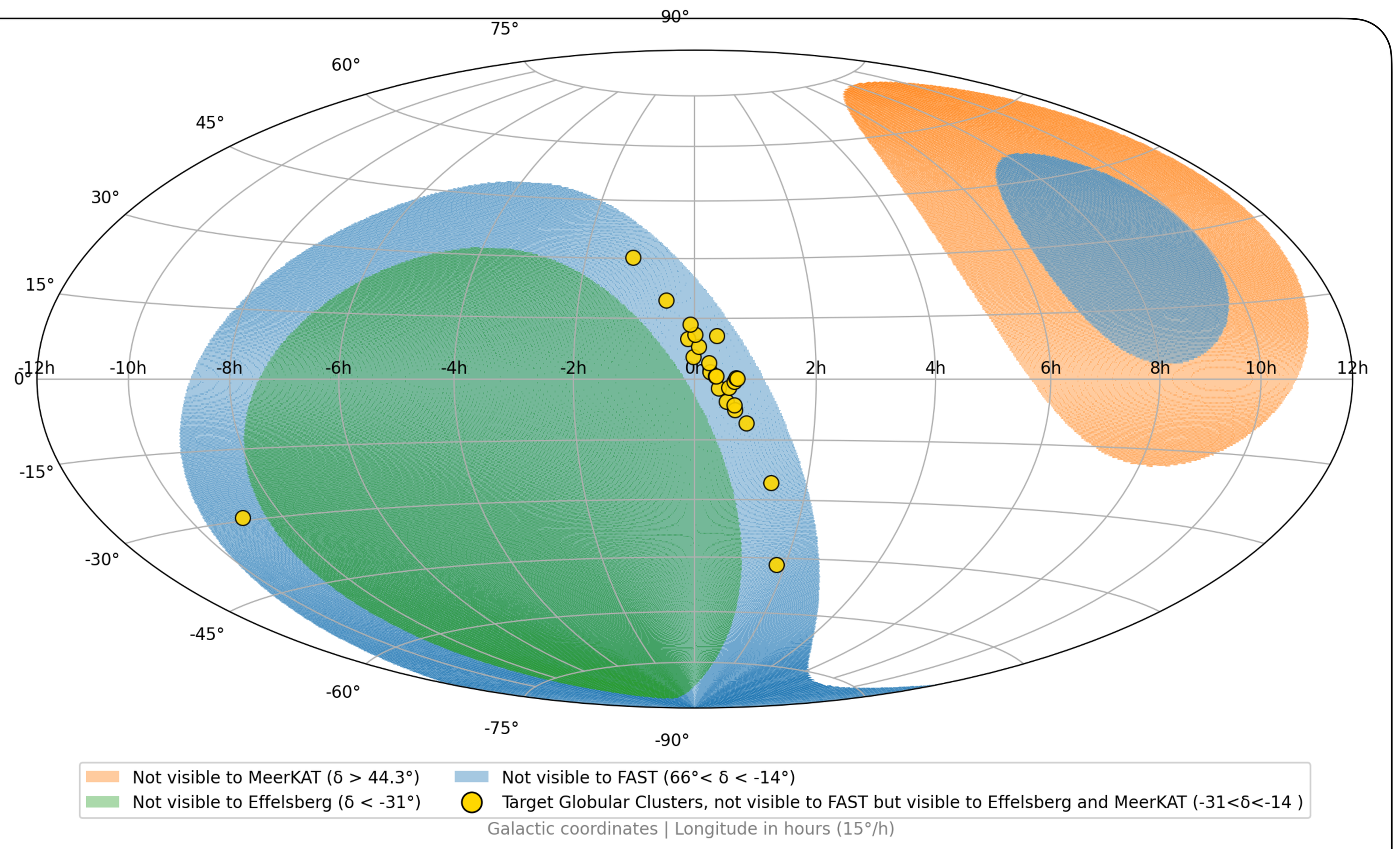


Fig 1: Target Globular Clusters of COMPACT Effelsberg survey, with visibility maps of telescopes

THE EFFELSBERG SURVEY

For the first phase, we select a subset of GCs based on the following criteria:

1. Bulge GCs with high expected DMs
2. High total & per-binary interaction rate
3. Below the FAST telescope's horizon and are not planned to be observed with MeerKAT in the near future.
4. No previously known pulsars, where even a single discovery will enable much deeper searches

WHY EFFELSBERG?

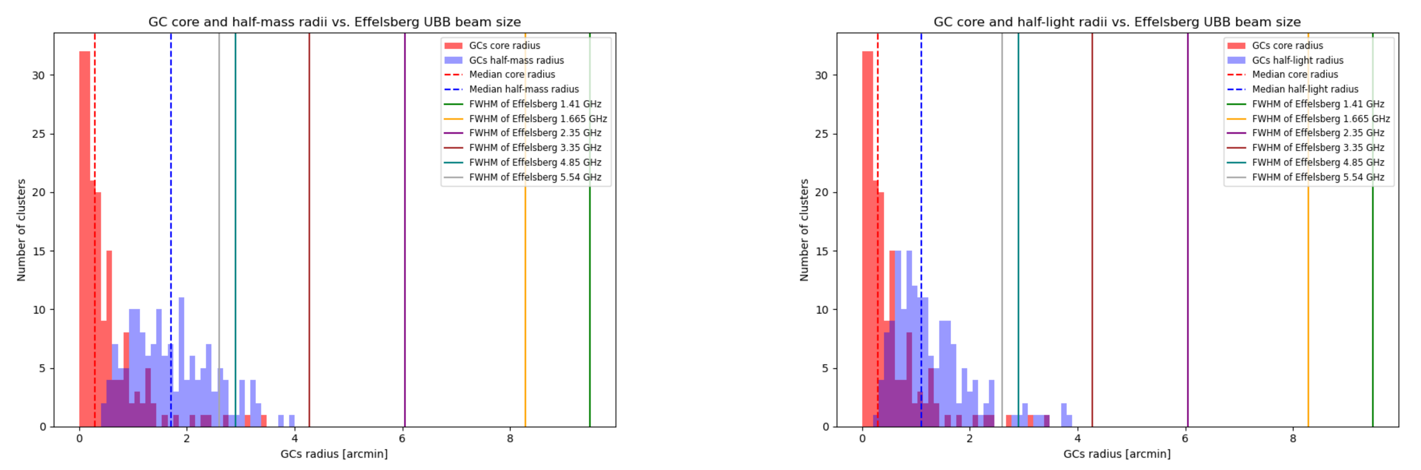


Fig 4: GC half mass and half light radius in the Effelsberg beam. Most cluster's half light/mass radii fit within a single UBB beam/pointing even at high frequencies.[8]

1. Upgraded Instruments
   - EDD backend: simultaneous coherently-dedispersed search-mode and baseband recording
   - UBB receiver: ultra-wideband coverage (1.3–6 GHz), opening flat-spectrum and dust-obscured pulsar discovery
   - No previous systematic GC survey has been conducted at the frequency range ~3–6GHz
2. High Sensitivity
   - System gain of 1.6 K Jy^{-1} → 10-σ flux limit ≈ 5 μJy in 2 h on-source
   - Perfect for deep millisecond-pulsar searches in globular clusters
3. Fast Turnaround & Strategy
   - Pipeline requires ≈ 1 week of compute per 2 h pointing (to search DM ≤ 2000 pc cm^{-3})
   - Phase 1 plan: two 2 h visits on 27 clusters (≈ 130 h total including 10% overhead and test scans)

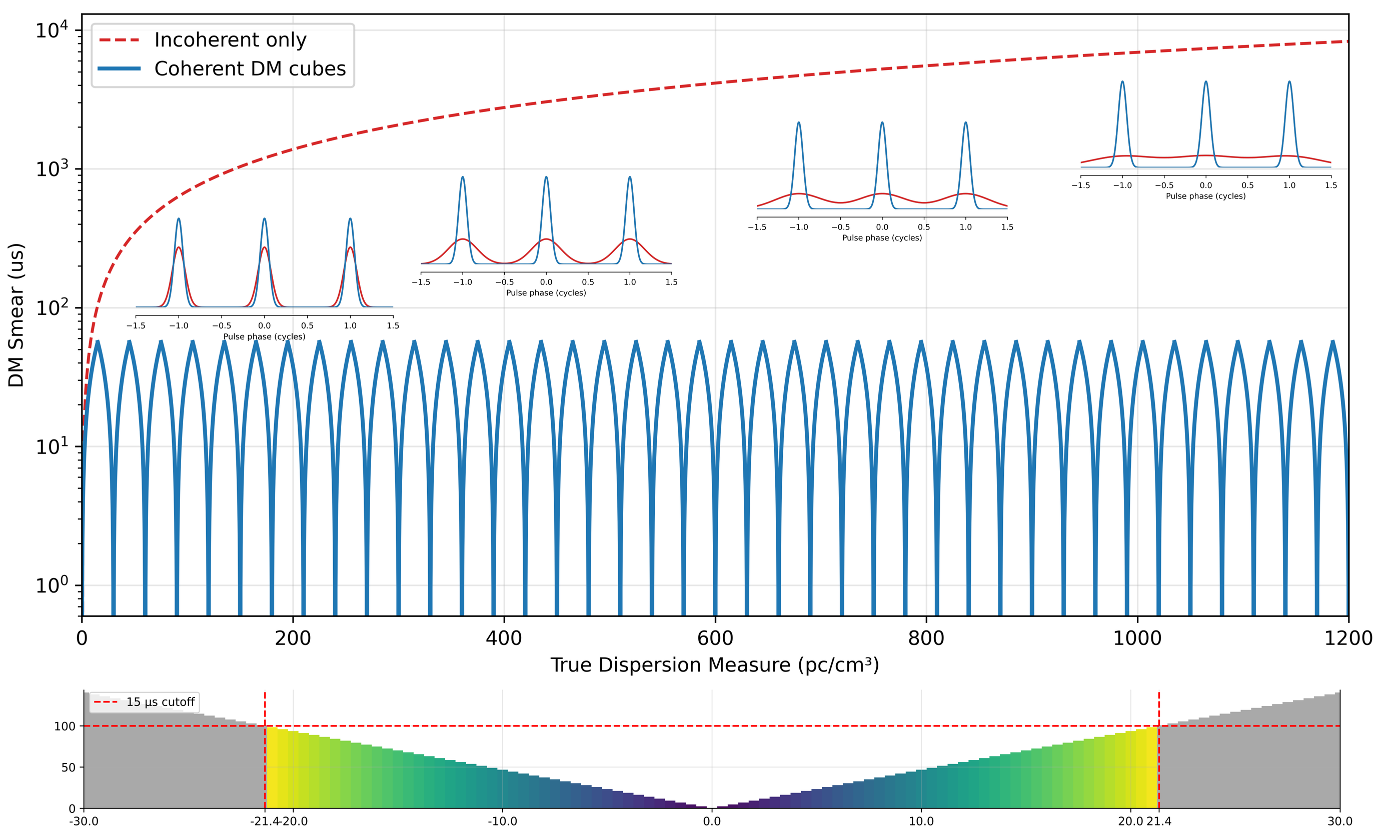


Fig 2: Effect of coherent de-dispersion cubes using baseband recording capability of Effelsberg UBB compared to incoherent de-dispersion used in conventional pulsar searches. CDM cubes spaced out every 44 DM units limit the maximum dispersion smearing within 100 microseconds, thereby increasing our sensitivity to MSPs at high DMs.

Terzan 5	NGC 6626	NGC 6544	NGC 6656
NGC 7099	NGC 1904	NGC 6401	NGC 6864
Terzan 12	NGC 6235	UKS 1	2MASS-GC02
NGC 6355	NGC 6325	NGC 6642	NGC 6333
NGC 6284	NGC 6093	VVV-CL001	NGC 5897
NGC 6287	NGC 6717	VVV-CL160	2MASS-GC01

Observed GCs with known pulsars — Observed GCs without known pulsars

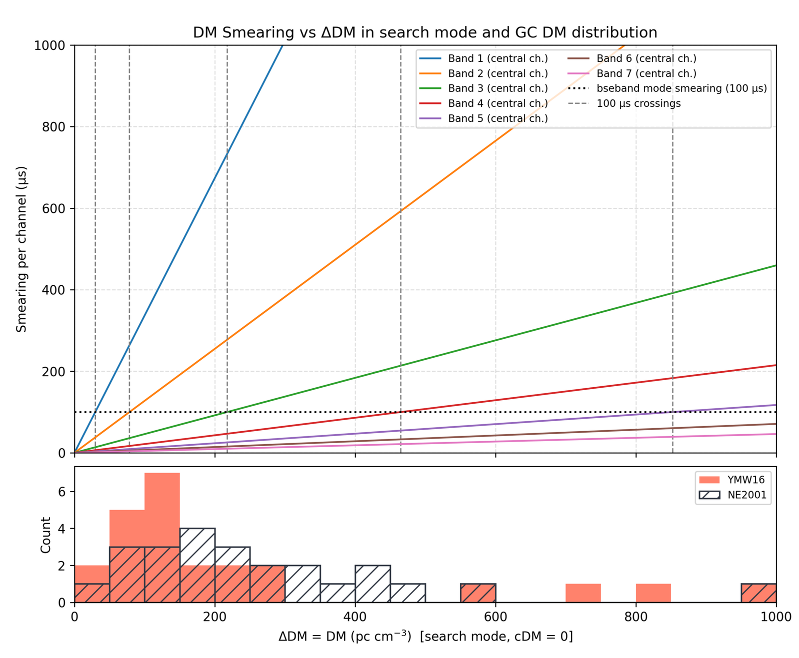


Table 1: Planned sources for the survey

Fig 3: DM smear for each band in search mode compared to baseband mode. The histogram shows the distribution of expected DM of target Globular Clusters with NE2001 and YMW16 Models.

ELDEN RING: Effelsberg Large-scale Data Exploration with Nextflow for Robust Identification of New Globular cluster pulsars.

- Automated and scalable pipeline to search, fold and follow up candidates using HPC clusters.
- Reduces the processing time to ~1 Week/2hrs observation.

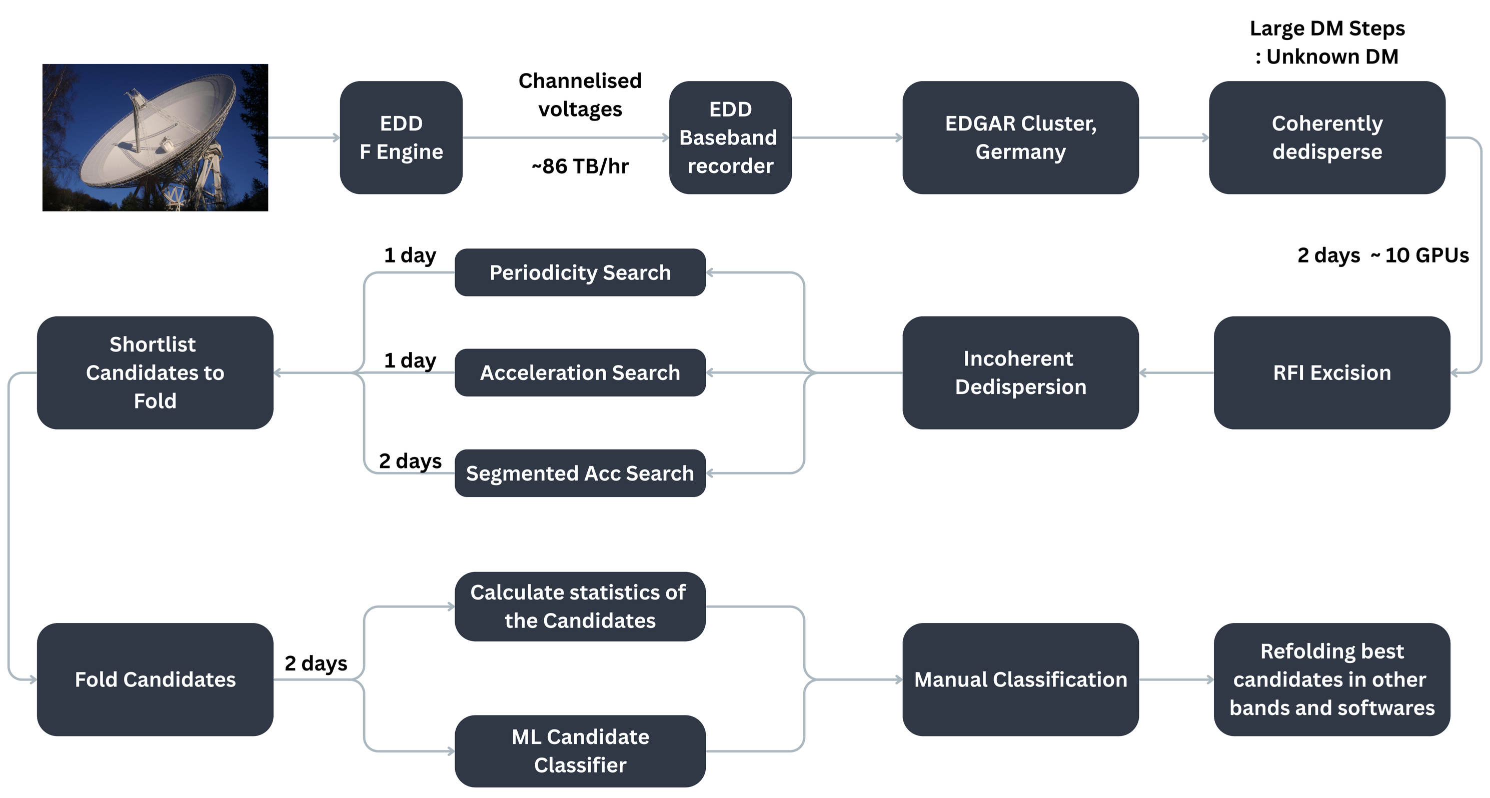


Fig 5: Automated data reduction, search and folding pipeline using nextflow on HPC clusters

RESULTS

We obtained search mode data of 5 GCs to get the realistic sensitivity curves for our search pipeline and the UBB receiver. Some detections are not perfect as they are very short period spider systems that are not fully corrected for orbit with acceleration search

Globular Cluster	Blind detection with Effelsberg UBB (Search Mode)				
	Band 1	Band 2	Band 3	Band 4	Band 5
TERZAN 5	9	3	1	4	3
NGC6544	2	2	2	1	2
NGC6626	4	3	2	1	1
NGC6656	2	0	0	0	0

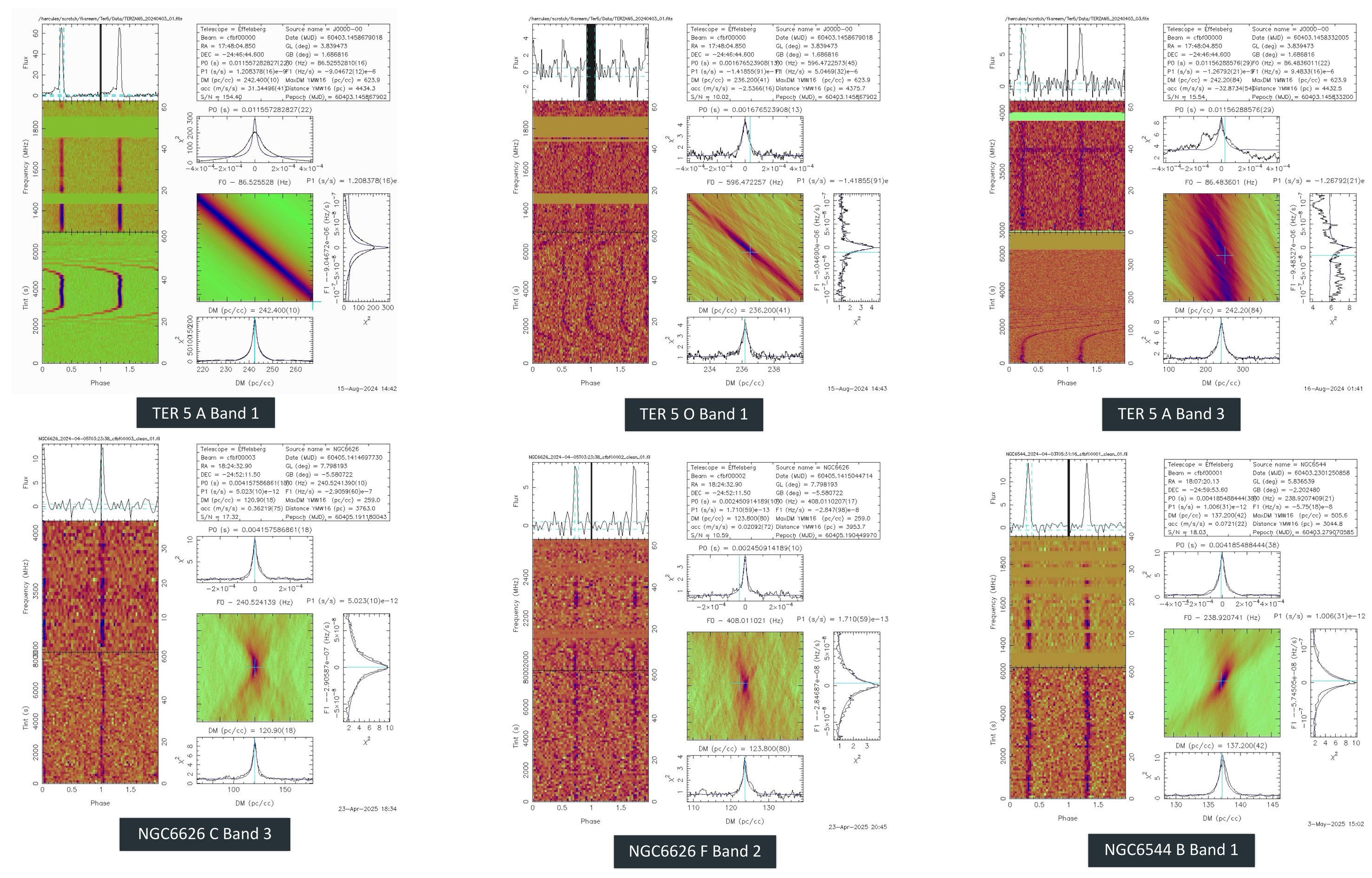
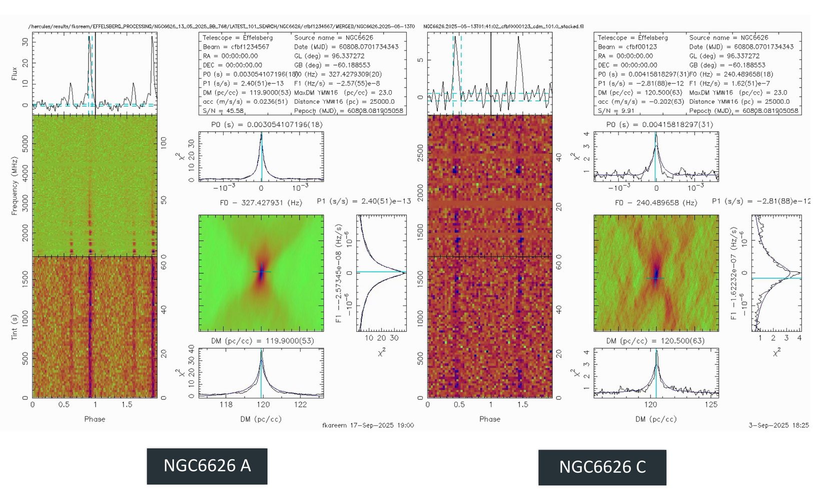
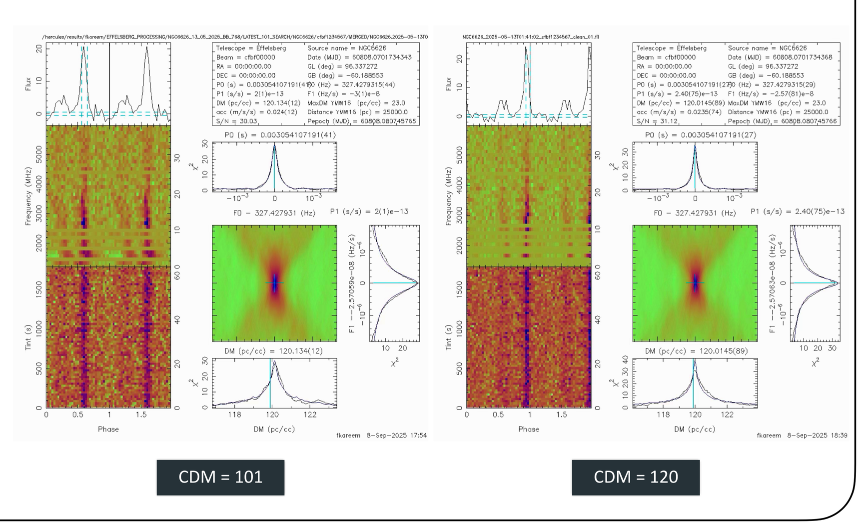


Table 2: Blind detection of pulsars using 2 hr search mode data obtained for pipeline development and testing.
Fig 6: Some detection plots of pulsars from 4 different GCs using search mode data.

In baseband mode we were able to blindly re-detect NGC6626A and NGC6626C



Re-detection of NGC6626A at two different CDM cubes, showing a small residual smear



1. Ransom, S. M. 2008, Vol. 246, 291–300
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3. Ransom, Scott M., et al. *Science* (2005)
4. Holger Baumgardt., et al. 2023
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6. Zhichen Pan et al 2021 ApJL 915 L28
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