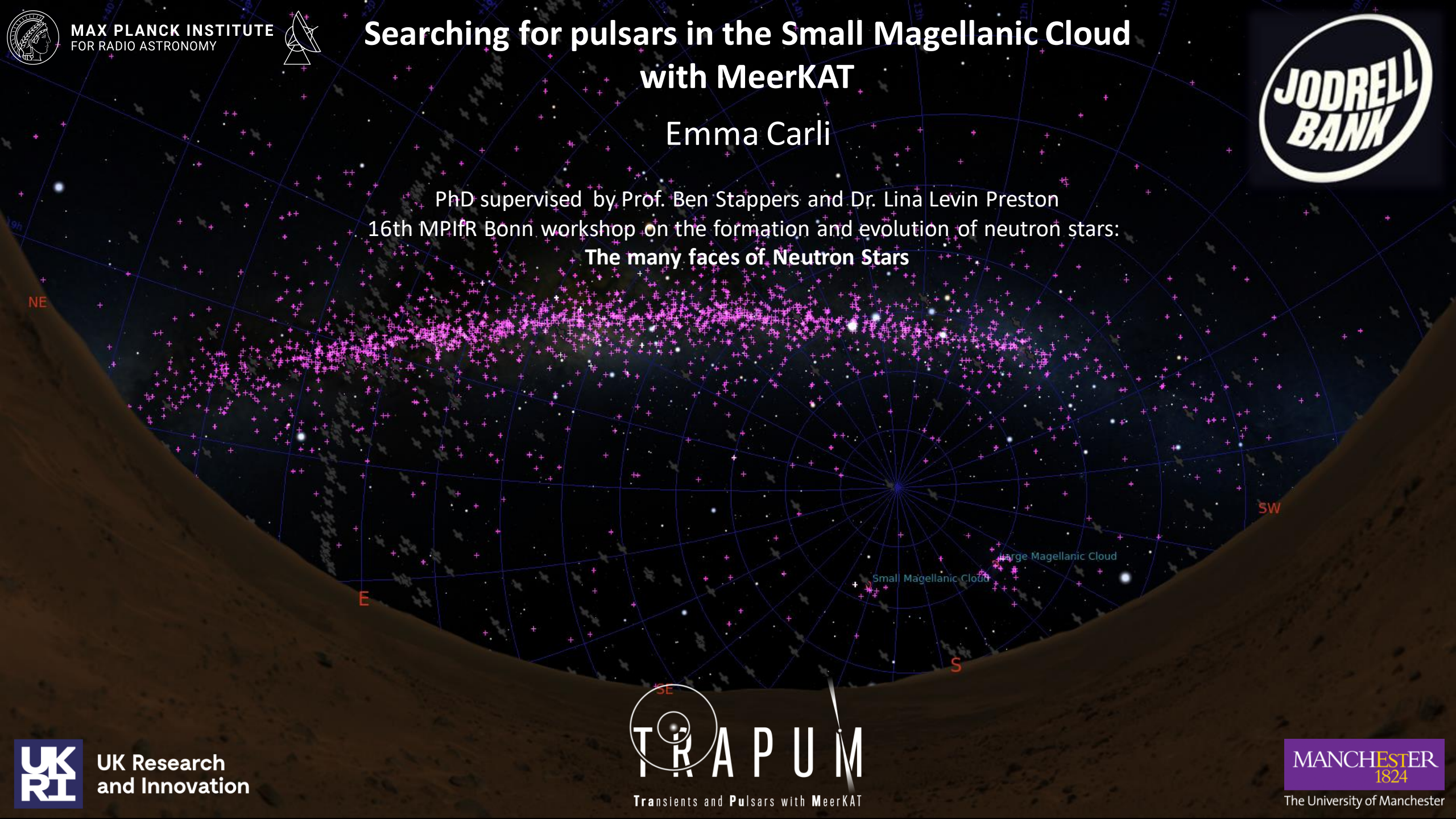

MAX PLANCK INSTITUTE
FOR RADIO ASTRONOMY

Searching for pulsars in the Small Magellanic Cloud with MeerKAT

Emma Carli

PhD supervised by Prof. Ben Stappers and Dr. Lina Levin Preston

16th MPIfR Bonn workshop on the formation and evolution of neutron stars:
The many faces of Neutron Stars

JODRELL BANK

UK Research and Innovation

TRAPUM
Transients and Pulsars with MeerKAT

MANCHESTER 1824
The University of Manchester

TRAPUM: a MeerKAT Large Survey Project

TRAPUM

Transients and **Pu**lsars with **M**eerKAT

TOTAL DISCOVERIES: 187
EXGAL: 13 **FERMI:** 25 **GC:** 69 **MGPS-L:** 78 **TEV/SNR/PWNE:** 1
LAST UPDATED: 2023-04-12 22:02

TRAPUM.ORG/DISCOVERIES/

<u>PIs: Michael Kramer and Ben Stappers</u>
<u>Project Scientist: Ewan Barr</u>

Pulsar and transient searches:

- Fermi gamma-ray sources (Chairs: Rene Breton, Colin Clark)
- Galactic plane (Chair: Ewan Barr)
- Supernova Remnants, Pulsar Wind Nebulae, TeV sources (Chair: Ben Stappers)
- Globular clusters (Chair: Alessandro Ridolfi)
- Nearby Galaxies (Chair: Lina Levin Preston)
- Follow-up (Chair: Marta Burgay)

TRAPUM: a MeerKAT Large Survey Project

TRAPUM

Transients and **Pu**lsars with **M**eerKAT

PIs: Michael Kramer and Ben Stappers
Project Scientist: Ewan Barr

Pulsar and transient searches:

- Fermi gamma-ray sources: **previous talk by Colin, and talk by Oliver after break**
- Galactic plane: **first talk by Michael**
- Supernova Remnants, Pulsar Wind Nebulae, TeV sources: **next talk by James**
- Globular clusters: **talk by Prajwal after break**
- Nearby Galaxies: **this talk**
- Follow-up (Chair: Marta Burgay)

TOTAL DISCOVERIES: 187
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TRAPUM.ORG/DISCOVERIES/

The MeerKAT telescope

Enrico Sacchetti

SKA South Africa

Danielle Futselaar

- Precursor of the mid-frequency component of the Square Kilometer Array
- MeerKAT: interferometer in the Karoo desert in South Africa
- 64 dishes of ~14m diameter, 8km longest baseline
- L-band, S-band, UHF receivers
- Pulsar timing and searching backends

Why extragalactic pulsars?

Jacques C Astrophotography

CSIRO

- Rare: Of 3k pulsars discovered, 31 are extragalactic
- All in the Magellanic Clouds, radio discoveries with Murriyang 1983-2022
- New observatory with better sensitivity : more pulsars to find!
- Different galaxy: properties impact pathways to Neutron Stars and population
- Compare with extragalactic NS merger rates from GW
- FRB are linked to NS, one repeater in a similar galaxy to the MCs

The Small Magellanic Cloud

VISTA-ESO

- Irregular dwarf galaxy 60 kpc away
- Unobstructed by galactic plane -> MW DM contribution 30 pc cm^{-3}
- 20% of MW metallicity: high mass star formation
- Recent star formation: younger pulsar population
- 7 radio pulsars, median DM 115 pc cm^{-3}
- 1 magnetar
- 1 young X-ray pulsar in a PWN
- Prediction to find 10 additional radio pulsars with MeerKAT if scan whole galaxy (Titus et al. 2020)

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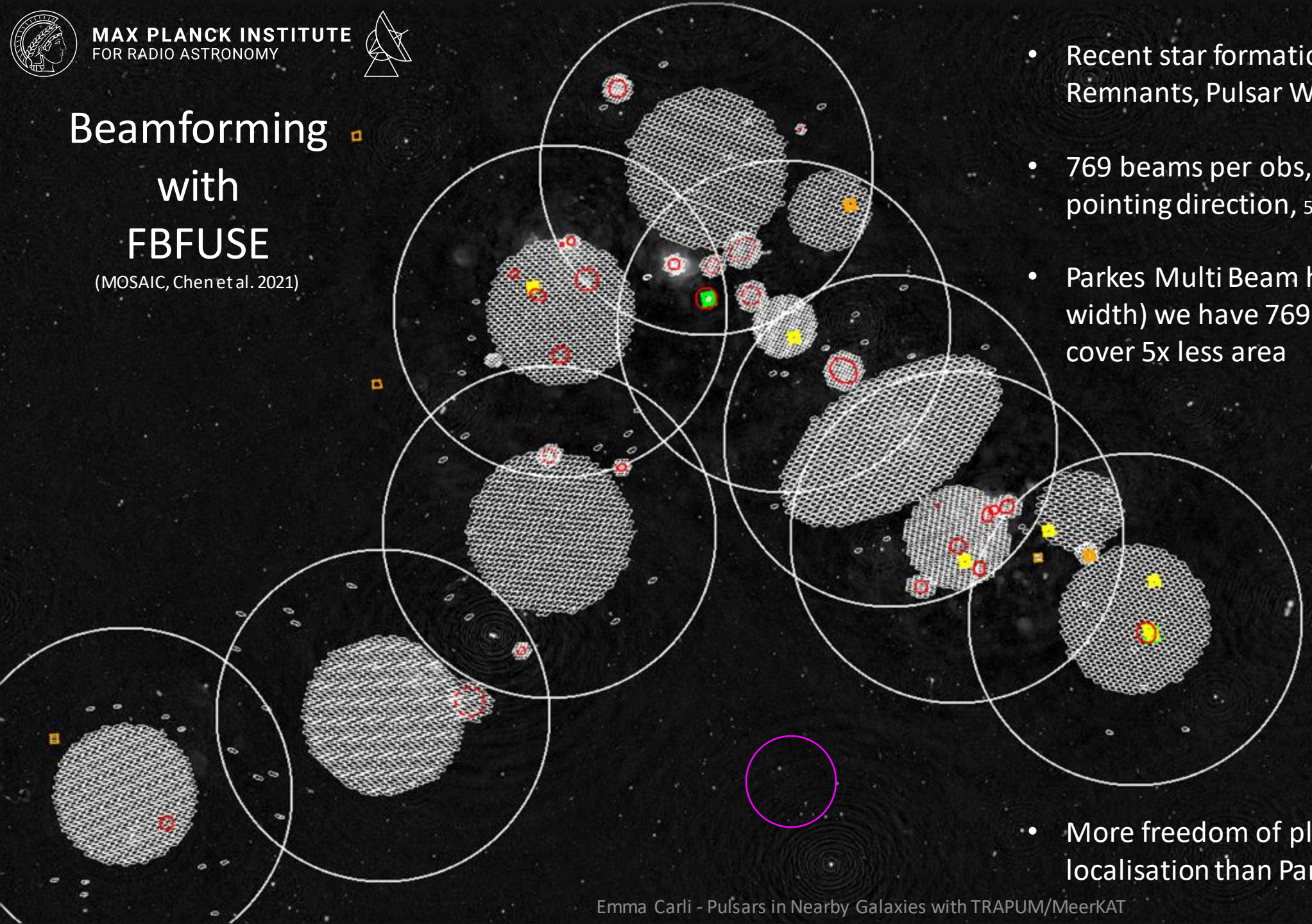
Beamforming with FBFUSE

(MOSAIC, Chen et al. 2021)



- Recent star formation: many Supernova Remnants, Pulsar Wind Nebulae to target
- 769 beams per obs, placed freely around pointing direction, 50-70% overlap
- Parkes Multi Beam has 13 beams (14 arcmin width) we have 769 (<1 arcmin width): we cover 5x less area
- More freedom of placement and easier localisation than Parkes

ASKAP EMU radio image

Searching on APSUSE

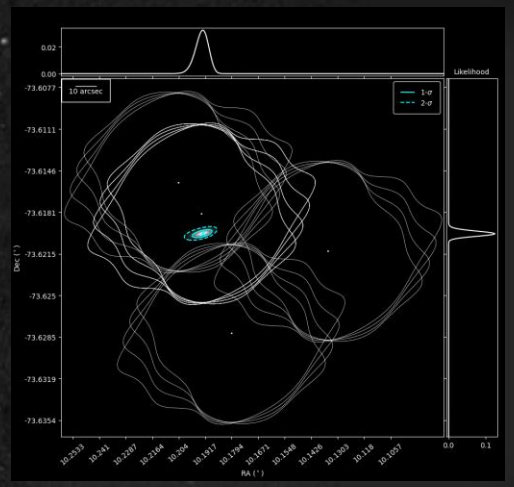
SKA South Africa

Ewan Barr

- On-site processing in computing cluster undergound
- Periodicity search and acceleration searching
- About a month of processing before see candidates, then raw data deleted
- Data kept in reduced resolution for potential future reprocessing e.g. FFA

Discoveries

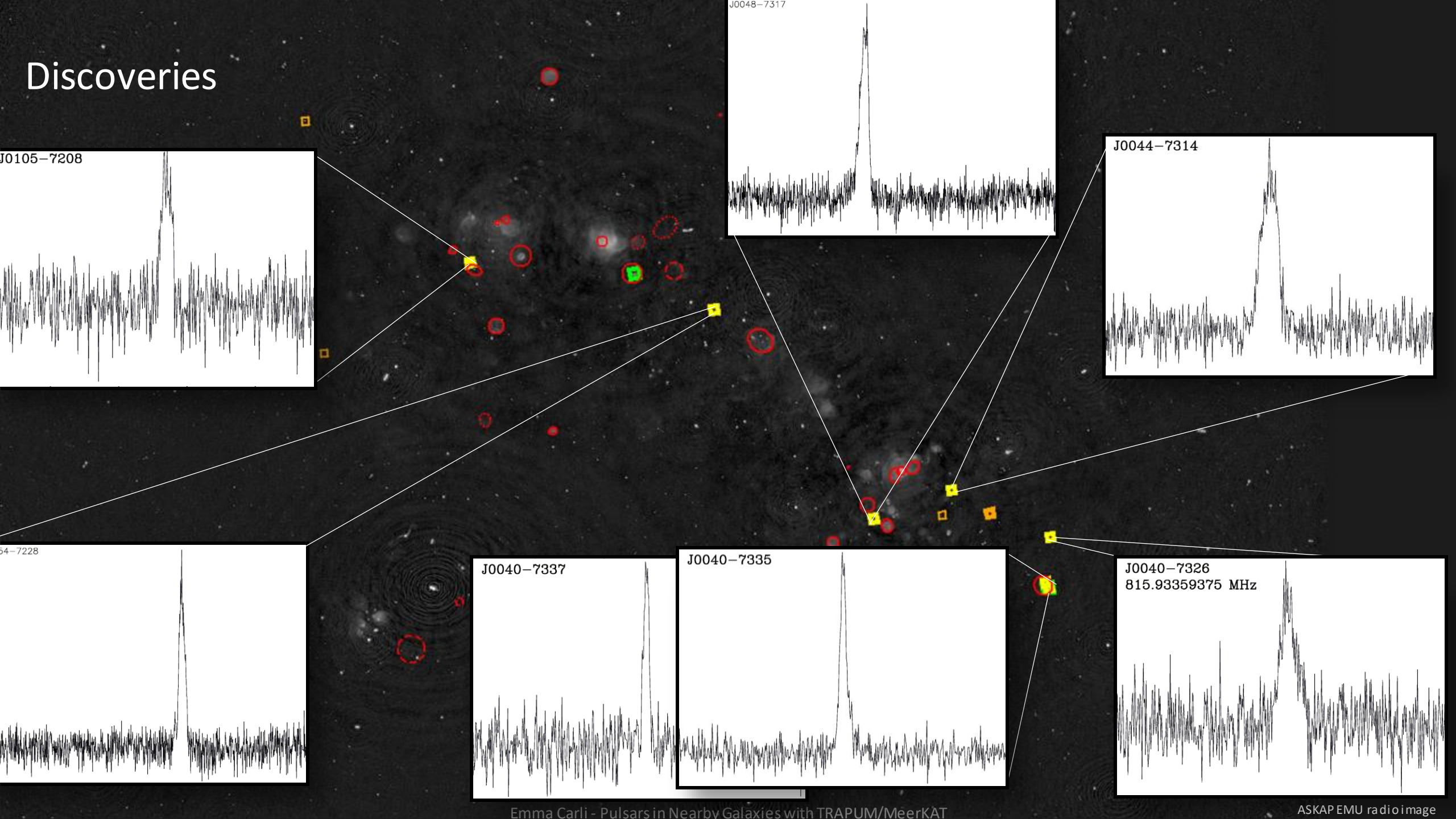
- 7 rotation powered radio pulsar discoveries, **3 of which are <100kyr old**
- Highlights: Two young Big Glitchers (~ 26 and 40 μHz), one in PWN (not detectable in X-rays)
- All localised to a few arcseconds: SeeKAT
  (Bezuidenhout et. al., 2022, RASTI, submitted)



- All have timing solutions
- Non detection of X-ray pulsar in PWN (Carli et al. 2022)

ASKAP EMU radio image

Discoveries



Gilbert Vancell Nature Photography

Zemeckis 1997

Conclusion

- This survey so far doubles the Small Magellanic Cloud galaxy pulsar population: 7 new pulsars bringing the total population to 14!
- Number of pulsars discovered in SMC is as expected from Titus et al. 2020, with large proportion of young objects
- Could be pessimistic prediction: will see with FFA reprocessing and UHF survey
- Survey nearly finished, now searching a Globular Cluster of the SMC
- Other surveys of Nearby Galaxies by Venu Prayag and Heinrich Hurter (SA)

Any questions?

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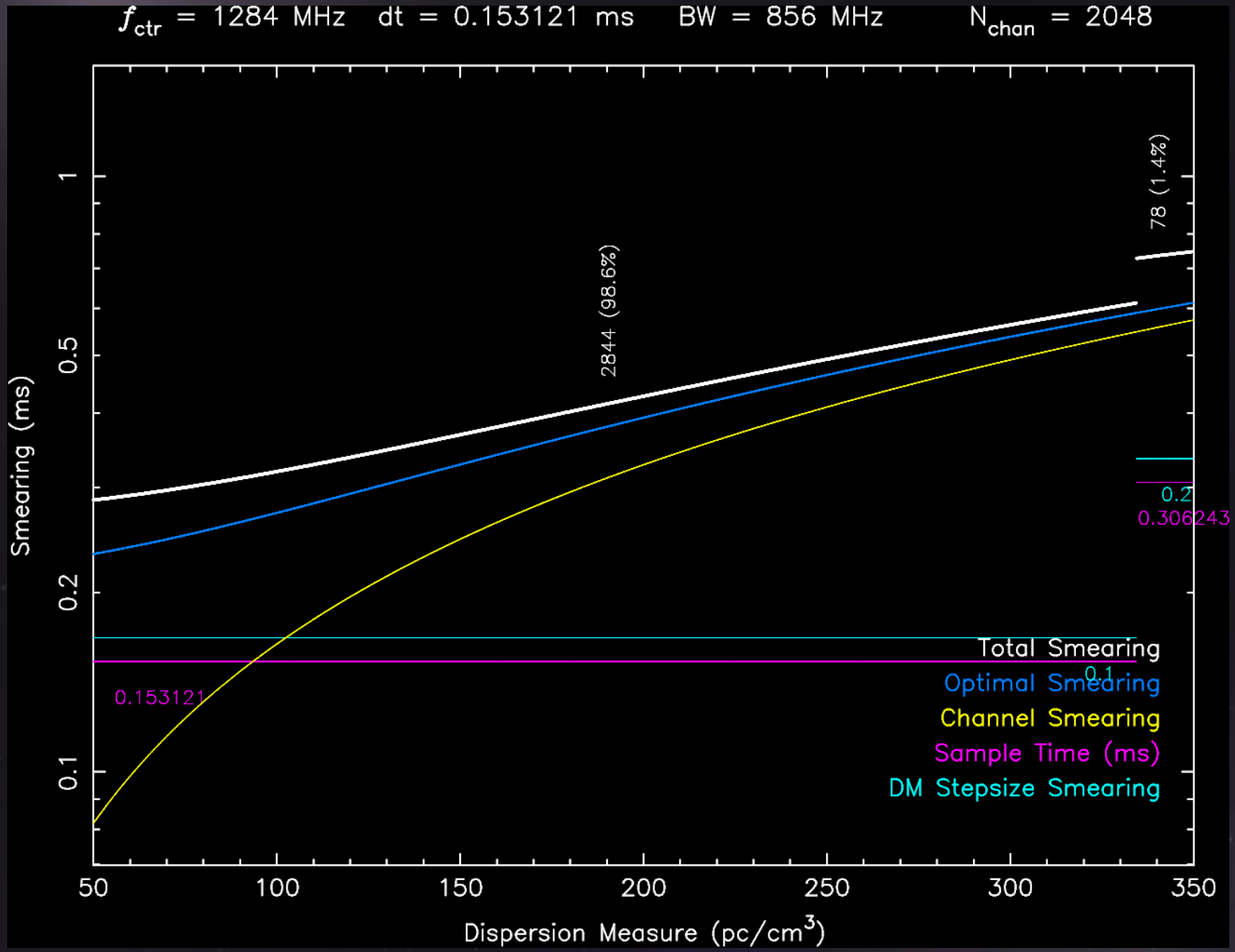
Searching on APSUSE

SKA South Africa

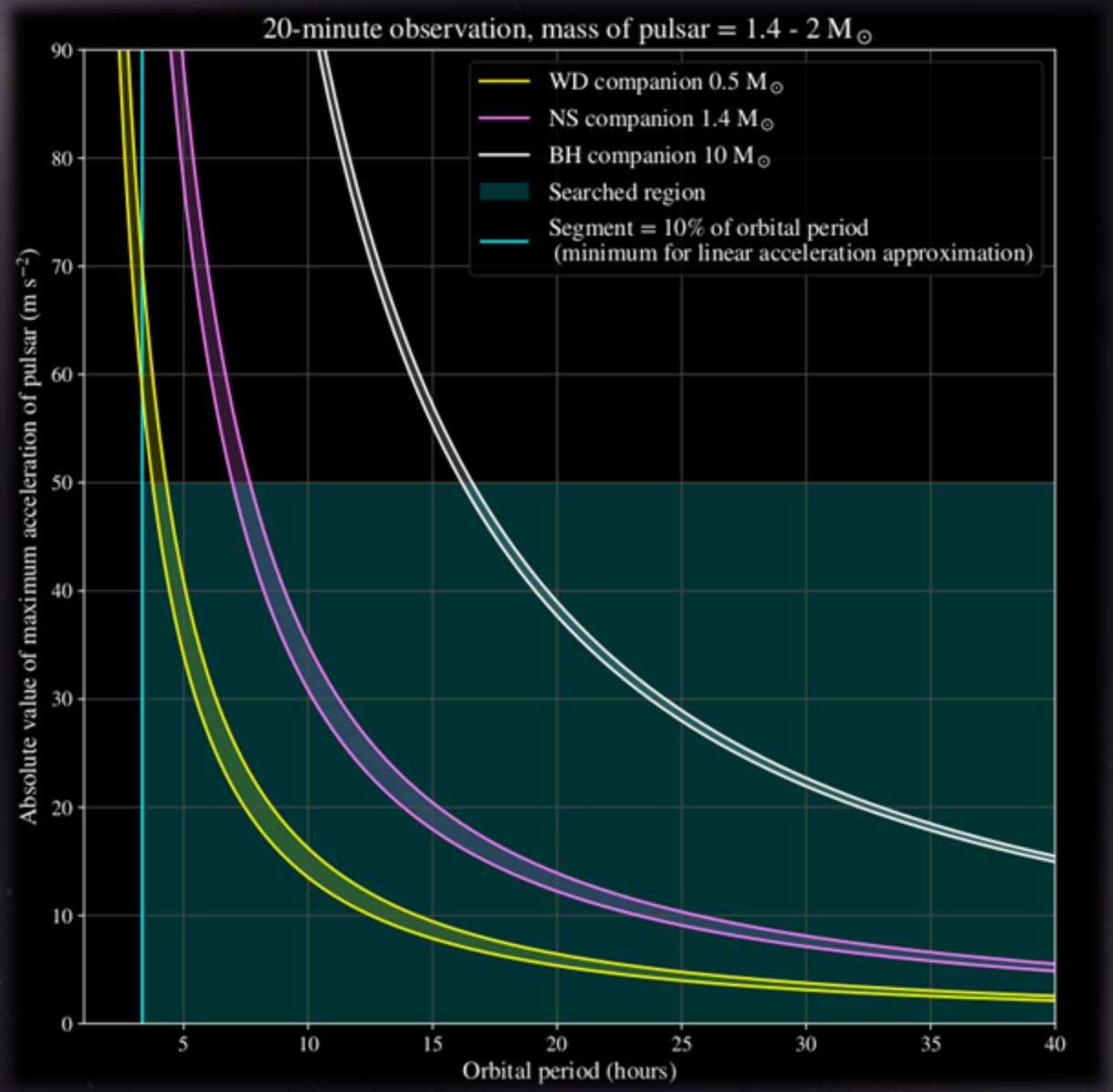
Ewan Barr

- **On-site processing** in computing cluster undergound
- We use L-band, 44 core dishes, 2k channels, 153 μs sampling, 769 beams → 2x2h observation 132 Tb
- **About a month of processing before see candidates, then raw data deleted**
- Full 2h periodicity search + 20 min segment **acceleration searching**
- Cleaning/folding/single pulse search by PulsarX (Yunpeng Men), searching with PEASOUP (Ewan Barr), multibeam sifting (Lars Kuenkel), Machine Learning separates human signals from pulsars (PICS, Zhu et al. 2014)
- Data kept in reduced resolution for **potential future reprocessing** e.g. FFA

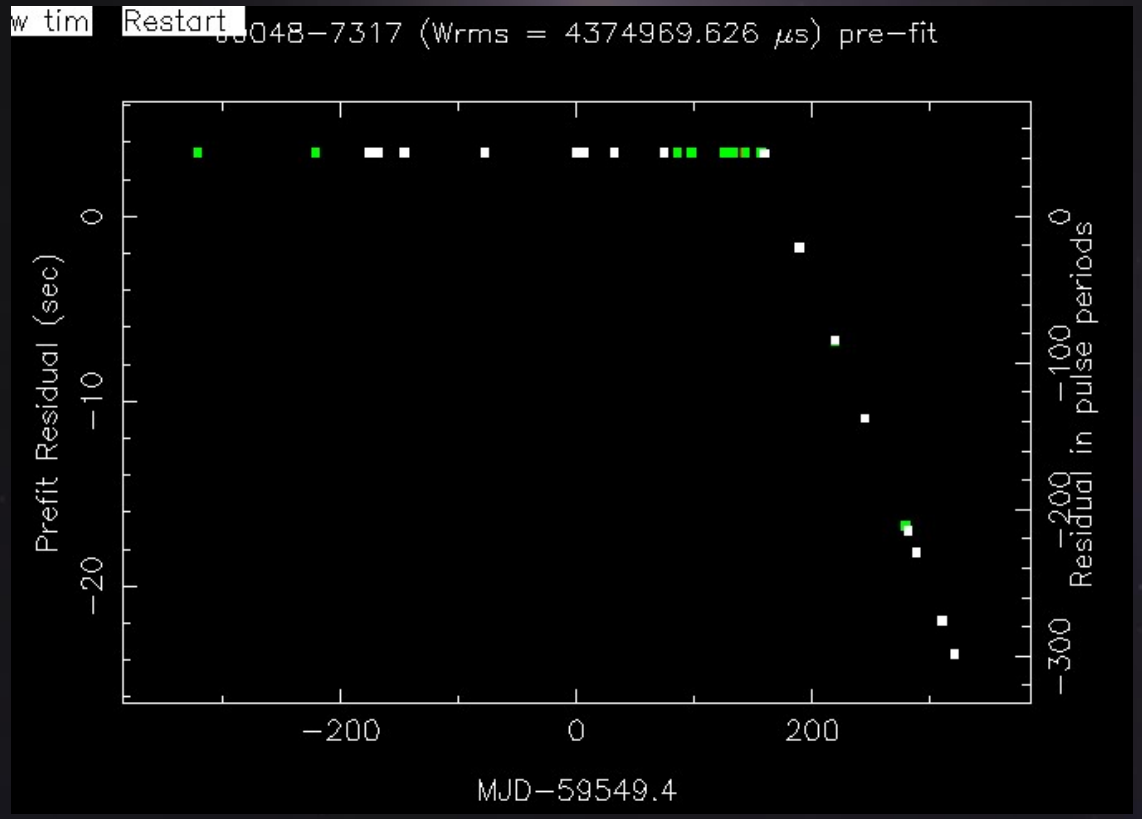
De-dispersion plan

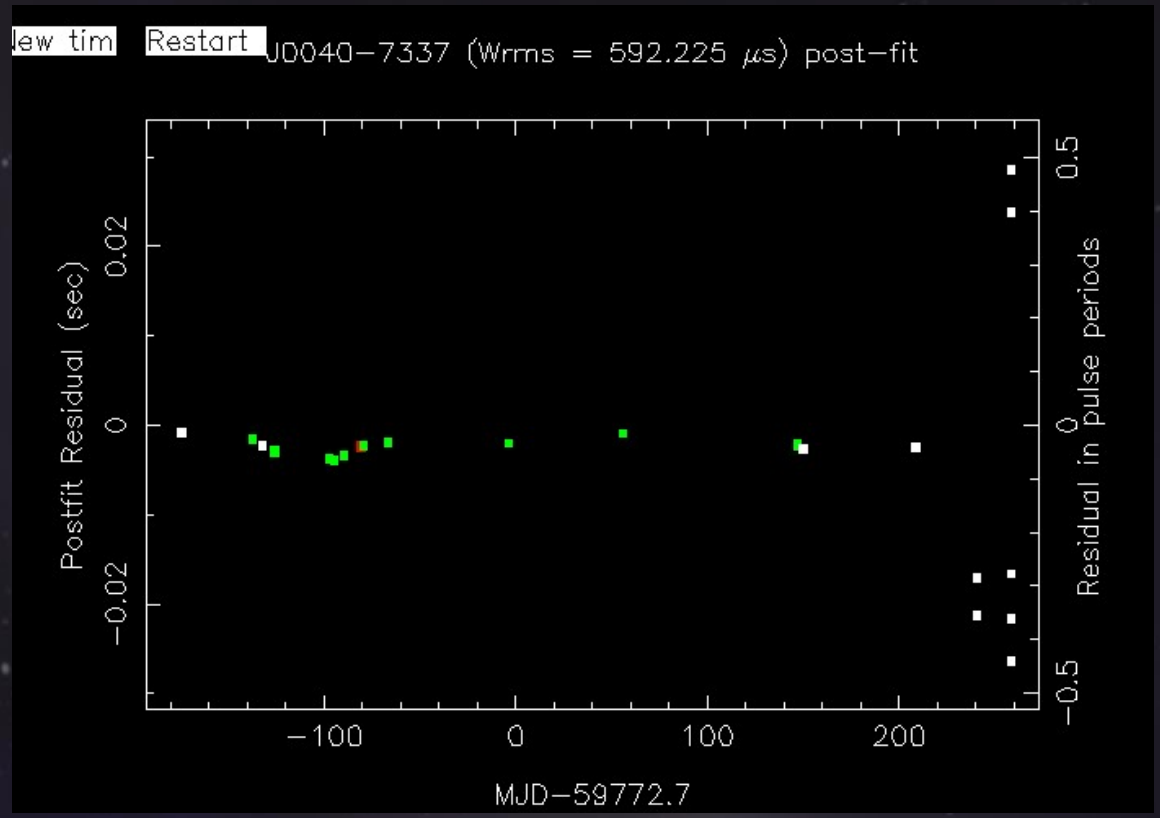


Acceleration search



Glitches


w tim
Restart
J0048−7317 (Wrms = 4374969.626 μs) pre−fit
Prefit Residual (sec)
0
−10
−20
−200
0
200
MJD−59549.4
0
−100
−200
−300
Residual in pulse periods


lew tim
Restart
J0040−7337 (Wrms = 592.225 μs) post−fit
Postfit Residual (sec)
0.02
0
−0.02
−100
0
100
200
MJD−59772.7
0.5
0
−0.5
Residual in pulse periods

Candidate numbers

For 769 beams, 1 pointing, 153 us sampling time, 2k channels, ~3k DD steps, ~200 accel steps, 8 S/N cut, RFI cleaned data:

- 2h periodicity search: over 1 million candidates
- 20 min segment search with acceleration trials: 7 million candidates

- After multibeam candidate filter: 2 million candidates (400 per search)

- 700k candidates in total after 9 S/N cut (>100 per search)

- 500k candidates to fold in total after 1.225 ms period cut (<100 per search).

- 2000 candidates to view after folding S/N cut and AI filtering