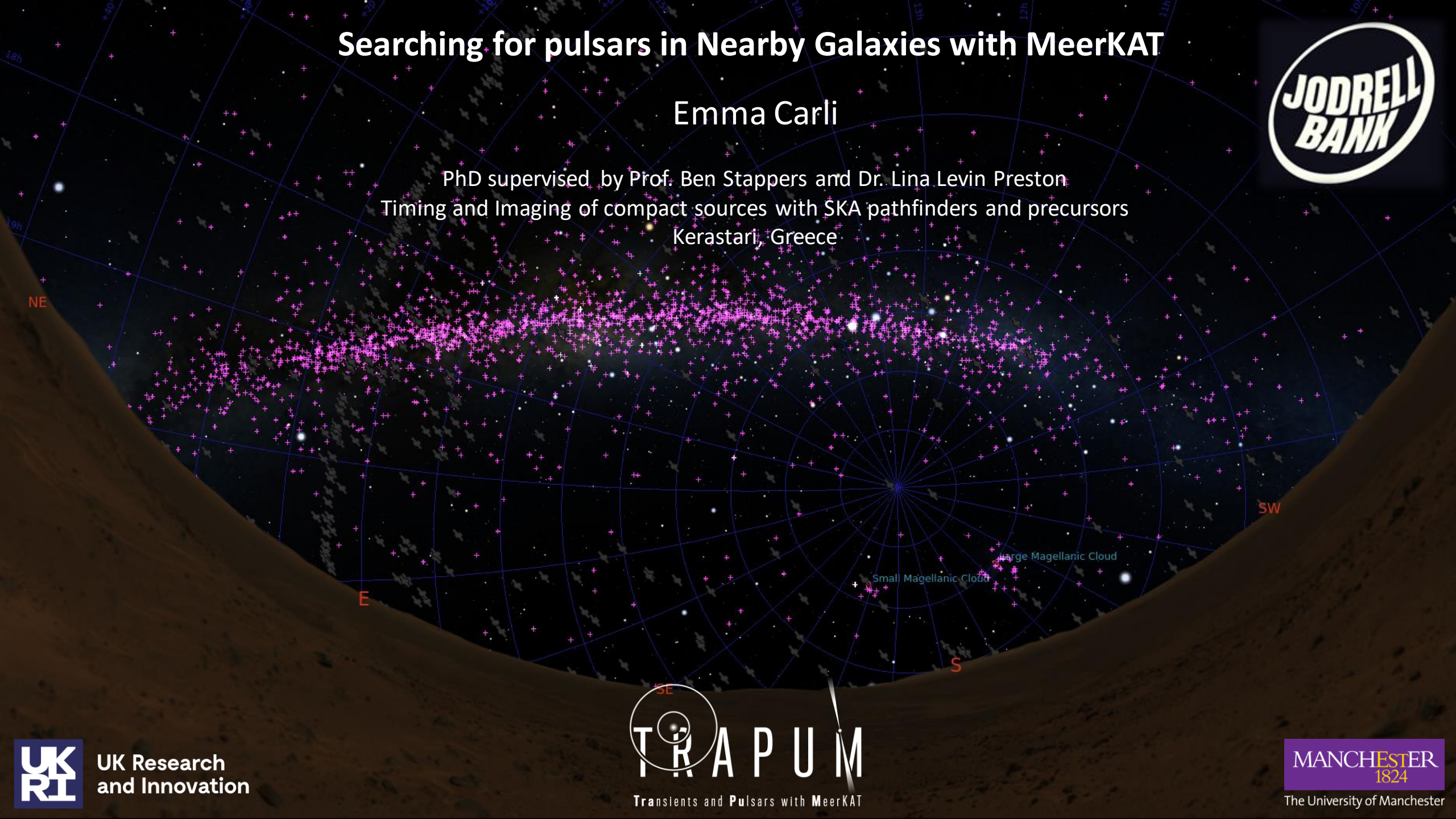


# Searching for pulsars in Nearby Galaxies with MeerKAT

Emma Carli

PhD supervised by Prof. Ben Stappers and Dr. Lina Levin Preston  
Timing and Imaging of compact sources with SKA pathfinders and precursors  
Kerastari, Greece



UK Research  
and Innovation



# TRAPUM: a MeerKAT Large Survey Project



## Transients and Pulsars with MeerKAT

**TOTAL DISCOVERIES: 191**

**EXGAL: 13**

**FERMI: 27**

**GC: 72**

**MGPS-L: 78**

**TEV/SNR/PWNE: 1**

LAST UPDATED: 2023-05-31 00:02



***TRAPUM.ORG/DISCOVERIES/***

PIs: Michael Kramer and Ben Stappers

Project Scientist: Ewan Barr

Builders: W. Chen, Y.P. Men, P. Voraganti Padmanabh, L. Kuenkel, V. Ventakraman Krishnan, J. Behrend, D. Horn and more...

Pulsar and transient searches:

- Fermi gamma-ray sources (Chair: Rene Breton)
- 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)

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Pulsar and transient searches:

- Fermi gamma-ray sources: **talk by Marta Tuesday**
- Galactic plane: **talk by Miquel Wednesday, Prajwal Thursday**
- Supernova Remnants, Pulsar Wind Nebulae, TeV sources (**James Turner**)
- Globular clusters: **talk by Arunima Wednesday**
- Nearby Galaxies: **this talk**
- Follow-up (Marta Burgay)



# The MeerKAT telescope

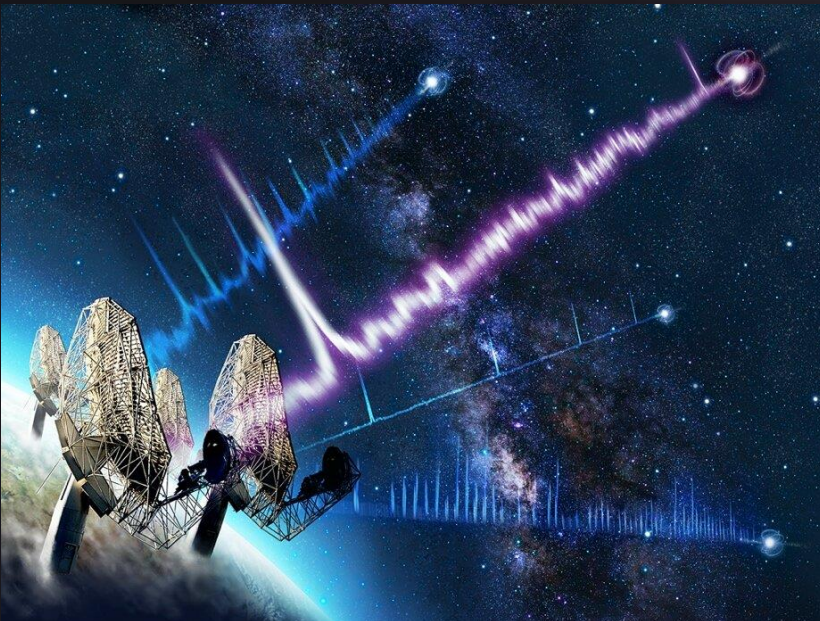


Enrico Sacchetti



SKA South Africa

Thank you to SARAO, especially to Sarah Buchner for scheduling observations!



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 higher sensitivity : more pulsars to find!
- Different galaxies: properties impact pathways to Neutron Stars and population
- Compare with extragalactic NS merger rates from GW
- FRBs are linked to NS, one repeater in a similar galaxy to the MCs

# Beamforming with FBFUSE

(MOSAIC, Chen et al. 2021)

ASKAP EMU radio image of the Small Magellanic Cloud  
(Joseph et al. 2019)

Known pulsars

Magnetar

SNRs

PWNe

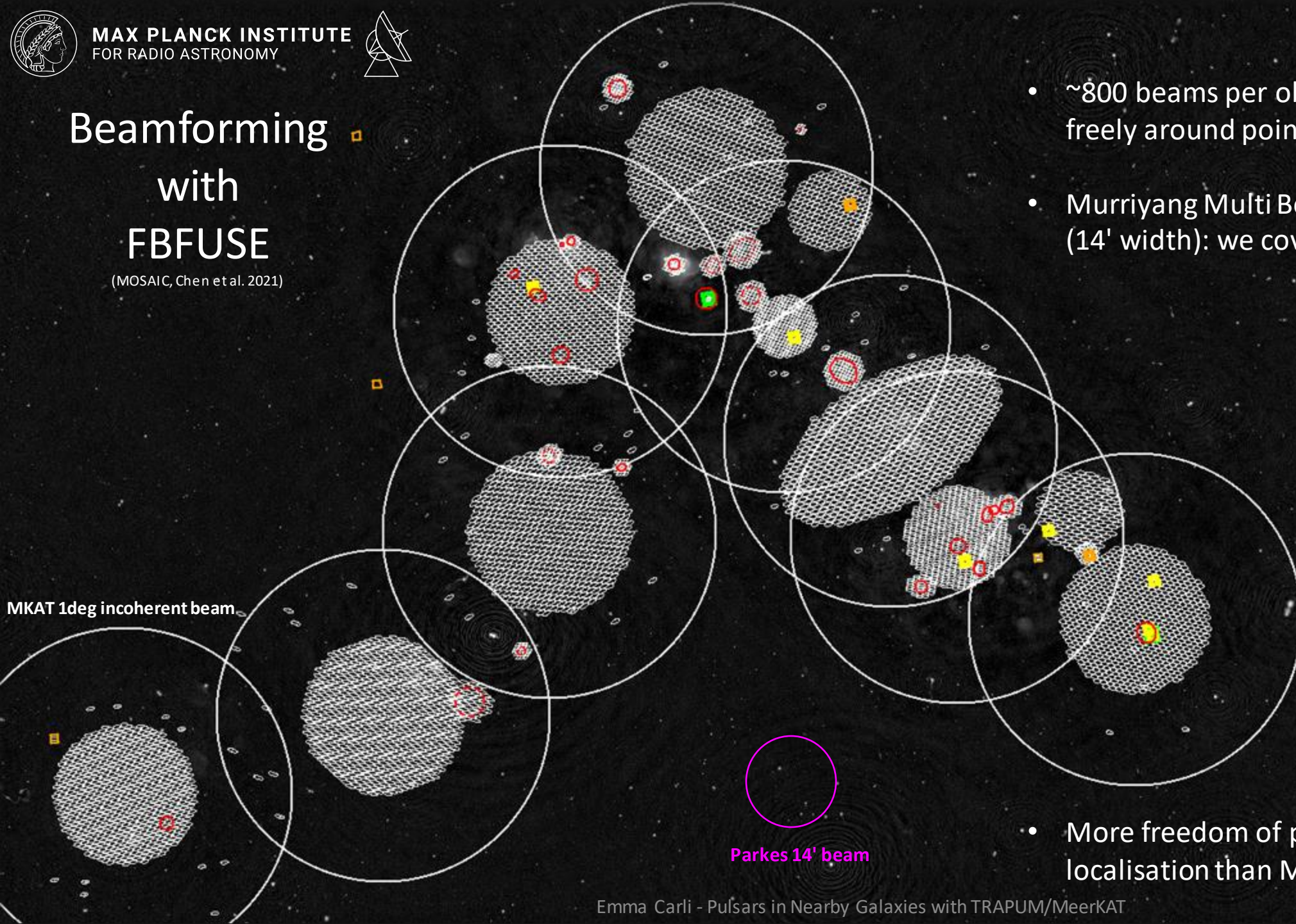
- Recent star formation: many Supernova Remnants, Pulsar Wind Nebulae



# Beamforming with FBFUSE

(MOSAIC, Chen et al. 2021)

MKAT 1deg incoherent beam



- ~800 beams per obs (<1' width), placed freely around pointing direction.
- Murriyang Multi Beam has 13 beams (14' width): we cover 5x less area

- More freedom of placement and easier localisation than Murriyang





# Searching on APSUSE



SKA South Africa

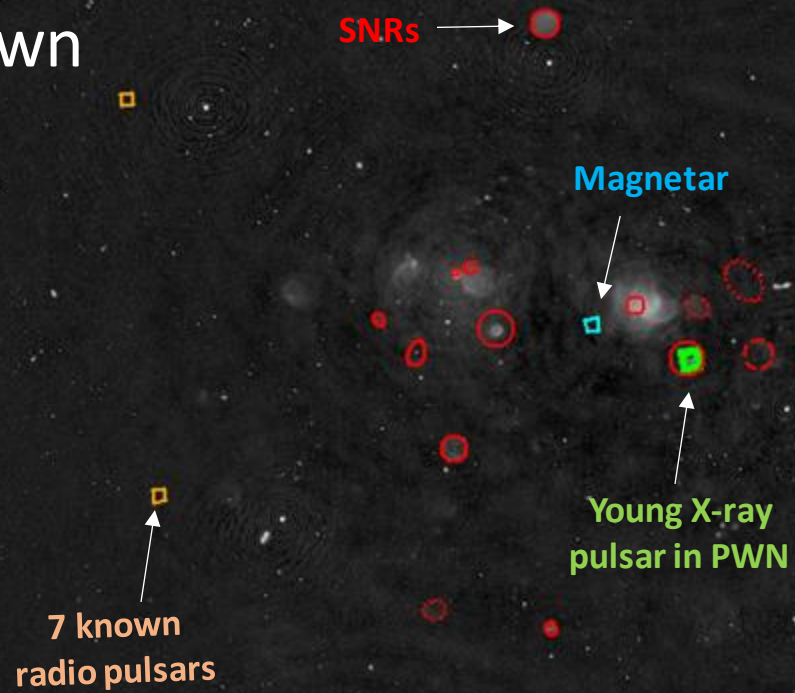


Ewan Barr

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



# Previously known in the SMC



- Irregular dwarf galaxy 60 kpc away
- 7 radio pulsars; median DM  $115 \text{ pc cm}^{-3}$
- Prediction to find 10 additional radio pulsars with MeerKAT if scan whole galaxy (Titus et al. 2020)

PWN

# Discoveries in the SMC

New pulsars !

Young X-ray pulsar in PWN  
Radio upper limit (Carli et al.2022)

PWN pulsar  
found ! Too  
faint in X-rays

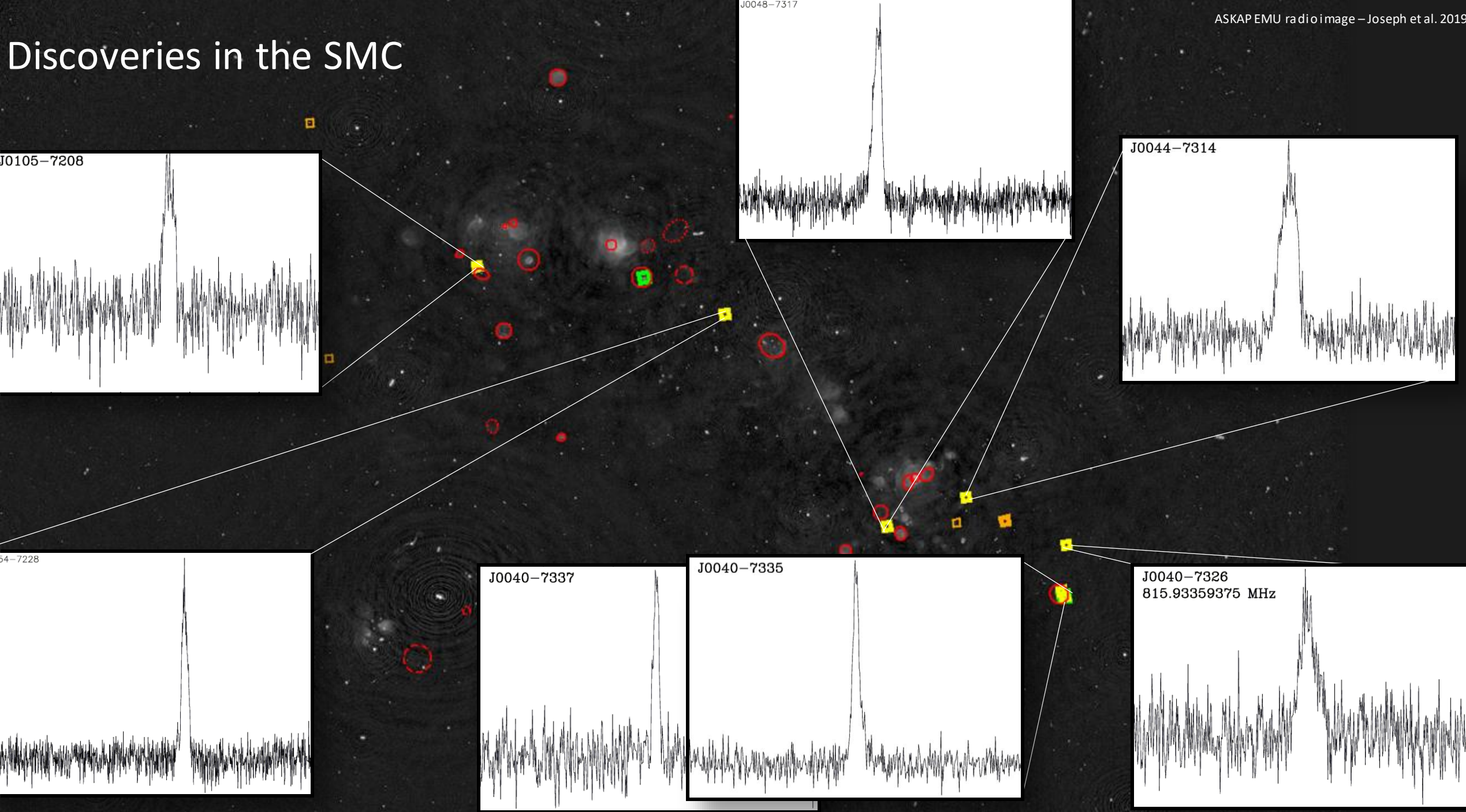
- 7 rotation powered radio pulsar discoveries, **3 of which are <100kyr old**
- Highlights: Two young Big Glitchers, one in PWN, one young antiglitcher?
- All localised to a few arcseconds upon discovery: SeeKAT

(Bezuidenhout et. al., 2022, RASTI, submitted)

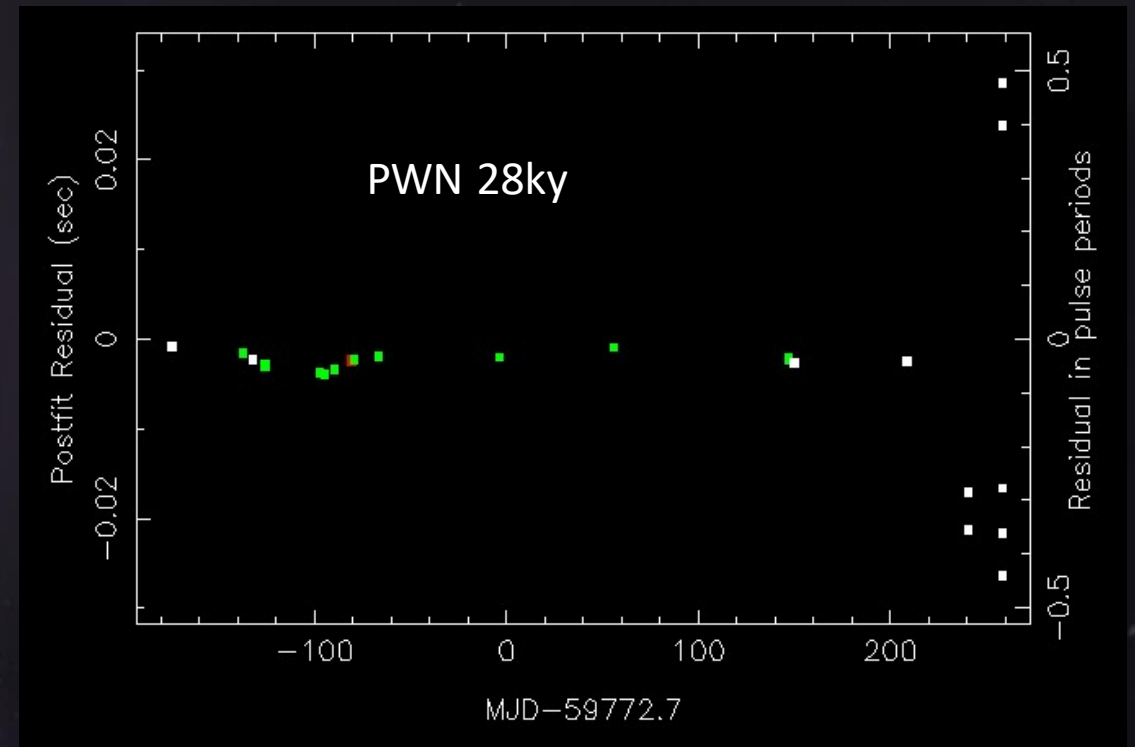
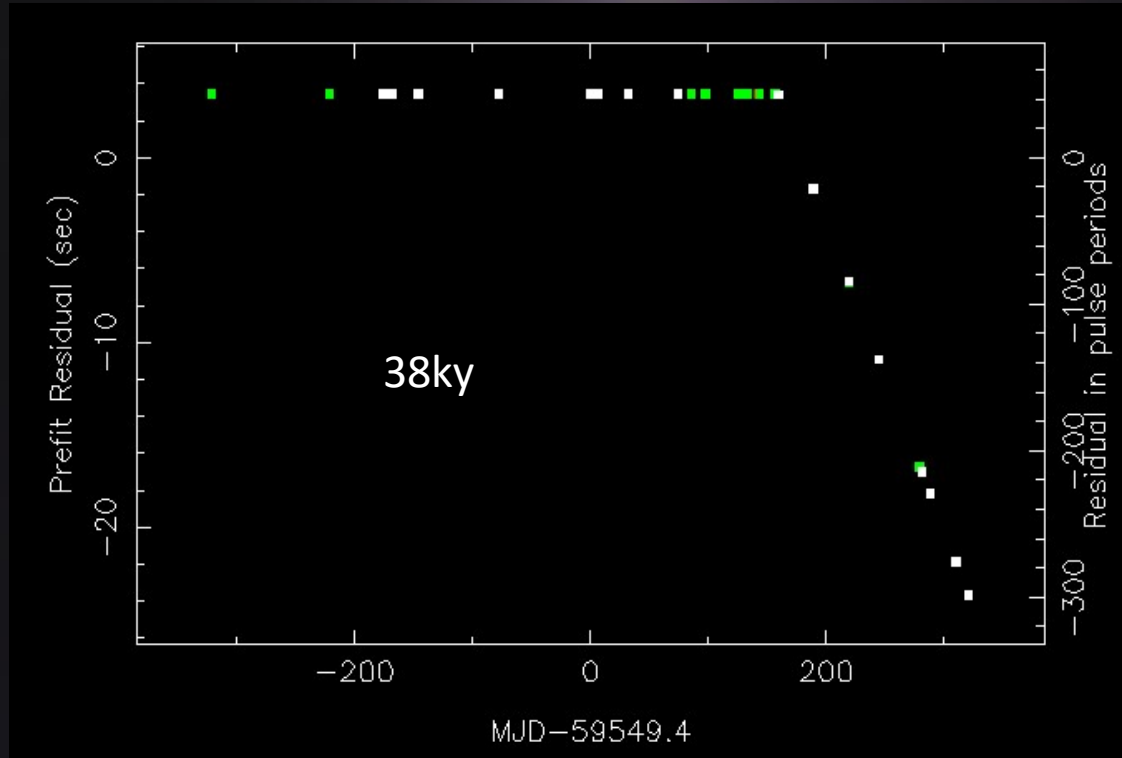
- All have timing solutions (MeerKAT and Murriyang timing campaigns)



# Discoveries in the SMC



# Glitch monitoring of pulsars @ Murriyang





# Previously known pulsars in the LMC



Venu

Only part of LMC shown!

Known  
PWNe+PSRs

Known  
radio pulsars

- Work led by Venu Prayag and Marisa Geyer (UCT)
- Irregular dwarf galaxy 50kpc away
- 25 radio pulsars known, mean DM  $107 \text{ pc cm}^{-3}$
- 5 Pulsar Wind Nebulae, 2 with pulsars
- LMC Crab pulsar twin: seen in X-rays, gamma-rays, optical & giant pulses

# Discoveries in the LMC



Venu



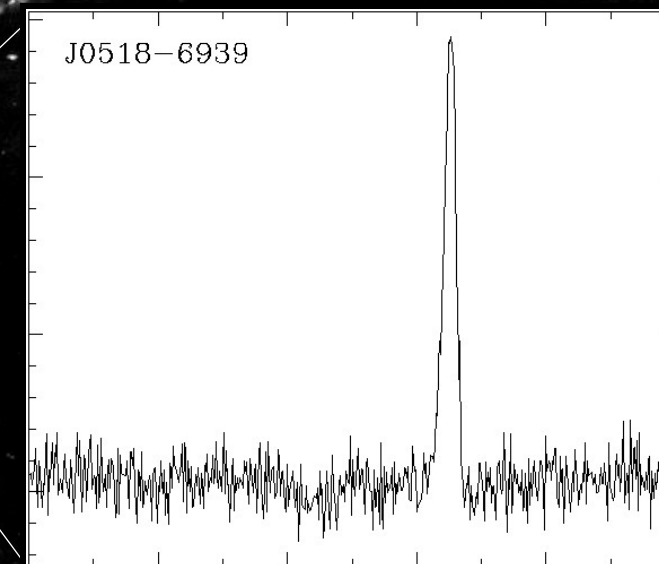
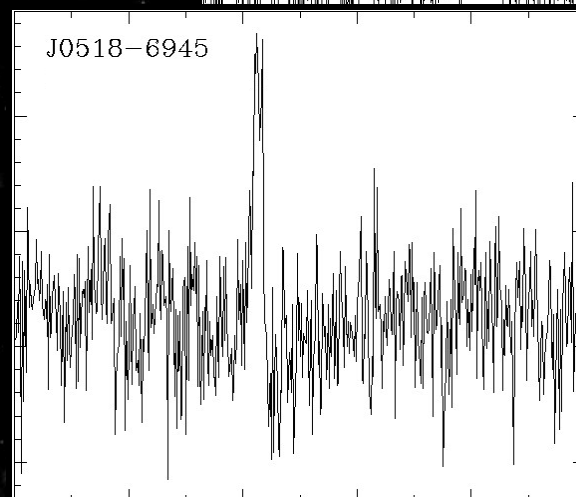
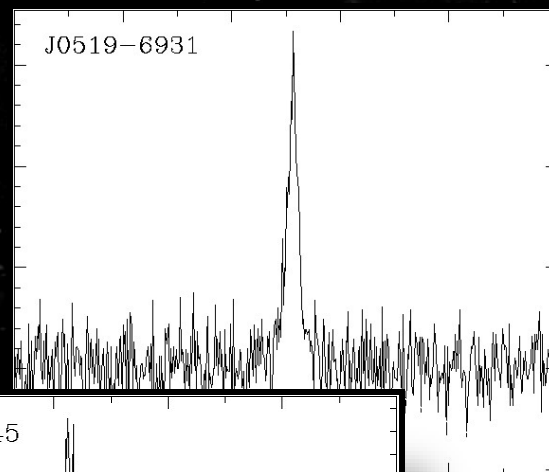
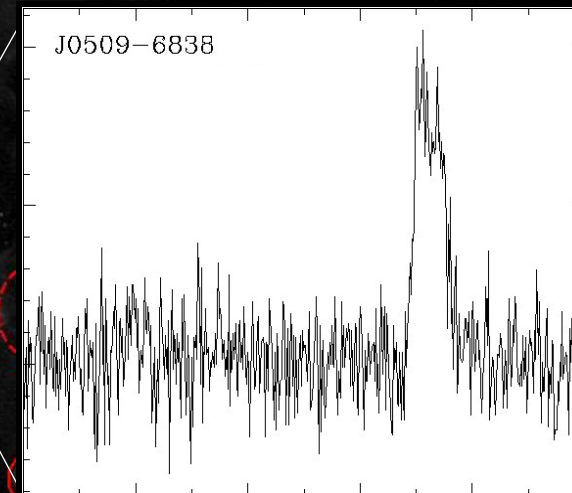
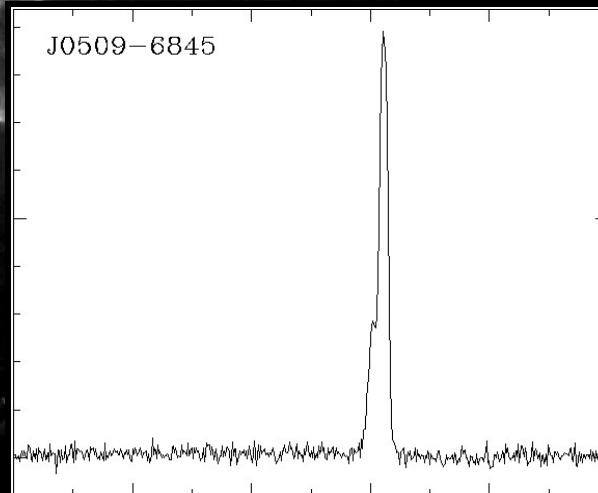
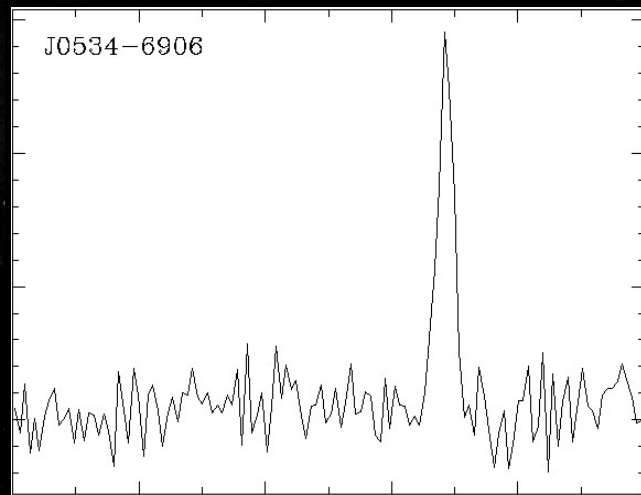
Only part of LMC shown!

New pulsars !

- 4/26! observations complete
- 7 pulsar discoveries: 300ms to 1.6s
- One ~20ky pulsar
- No associations yet
- No detection in SN1987A yet
- All have solutions except for one faint pulsar

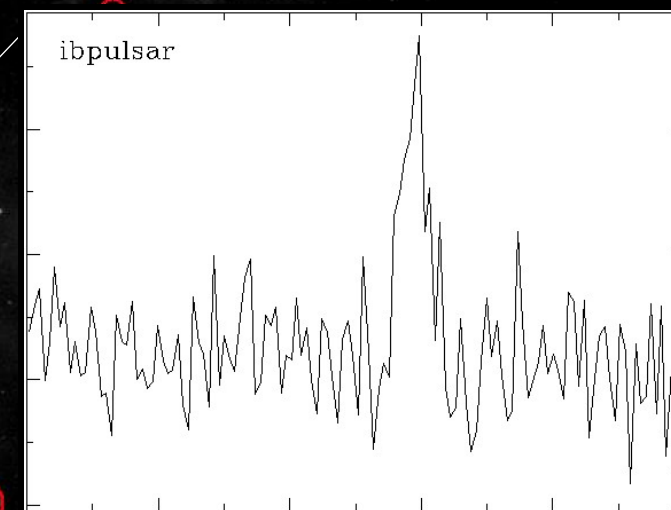


# Discoveries in the LMC



# Discoveries in the LMC

- Incoherent beam discovery
- Incoherent beam  $\sim$  Murriyang sensitivity
- Not found in Murriyang archival data of previous LMC surveys

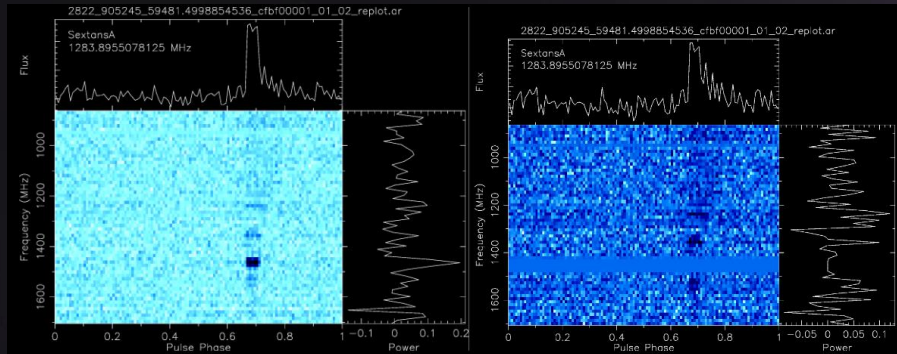




# Other galaxies



NoirLab



- Sextans A and B: serendipitous background FRB discovery. Localisation in progress



Heinrich

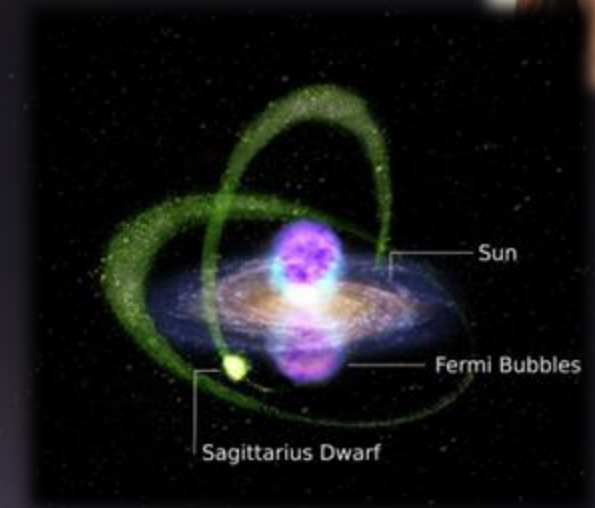


- Sculptor Galaxy : upper limits (Heinrich Hurter & Christo Venter, NWU, South Africa)



Lucia

A. Tsuboi/Kavli IPMU  
Nature Astronomy - Crocker et al. 2022



- Sagittarius dSph gamma-ray galaxy search for millisecond pulsars under way (Francesca Calore and Lucia Gebauer, CNRS Annecy, France)

# Summary

- TRAPUM Nearby Galaxies has so far doubled the Small Magellanic Cloud galaxy pulsar population
- SMC survey nearly finished, now searching a Globular Cluster of the SMC
- Large Magellanic Cloud Survey has 4/26 observations complete and has already discovered 7 pulsars
- Currently searching for Millisecond Pulsars in the Gamma-Ray emitting nearby Sagittarius dSph galaxy
- Set deep limits on other galaxies + serendipitous FRB discovery



Gilbert Vancell Nature Photography



Zemeckis 1997