

The MPIfR-MeerKAT Galactic Plane Survey (MMGPS)

— current status and future



Partners
Max-Planck Institut für Radioastronomie
&
Thüringer Landessternwarte

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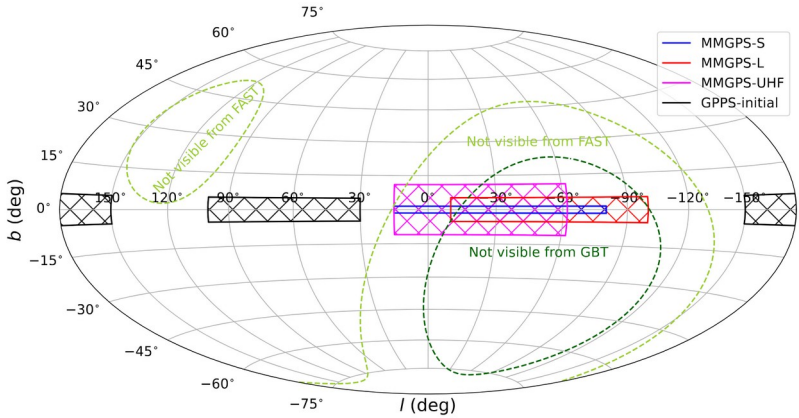


Michael Kramer, Hans-Rainer Klöckner, Matthias Hoeft, Olaf Wucknitz

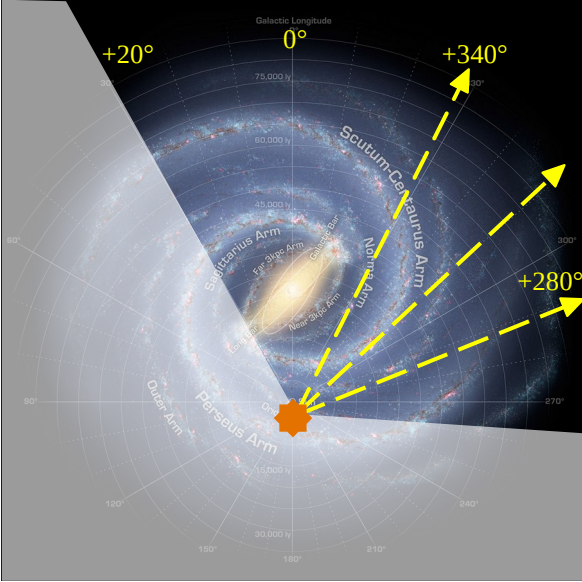
Karl Menten, Carsten König, Jonah Wagnveld, Sarwar Khan, Isabella Rammala, Yik Ki (Jackie) Ma, Sui Ann Mao, Akriti Sinha, Kamalpreet Kaur, Michael Rugel, Andreas Brunthaler, Albert Genest, Ewan Barr, Vishnu Balakrishnan, Denisha Pillay, Arshia Jacob, Anahat Cheema, Shilpa Ranchod, Sarrvesh Sridhar, Ancor Damas... + the MMGPS imaging team

14th November 2024, Radio2024, Erlangen

The MMGPS survey: optimised backend use



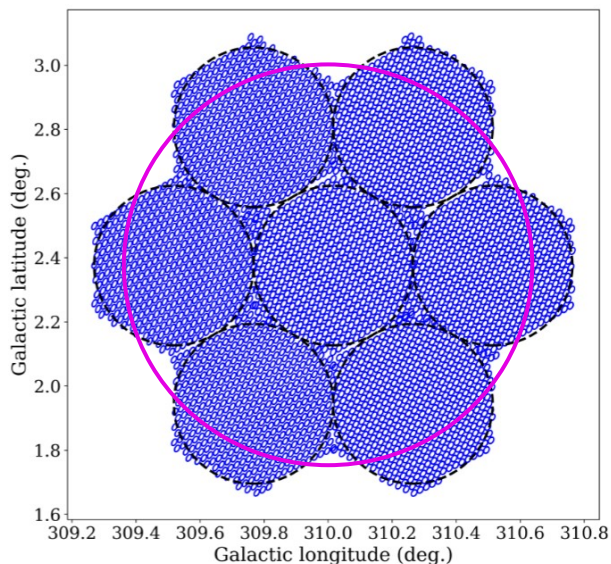
Padmanabh et al., MNRAS (2023)



- UHF band [0.54-1.08 GHz]: 400 h
- L band [0.86-1.7 GHz]: 800 h
- S band [1.97-2.84 GHz]: 1380 h
- [receivers funded and developed by MPIfR + backend dev]
- + Sgr A*: 200 h + spectral lines: 55 h

A 3000-h survey of the inner Galactic plane with the MeerKAT
 → covers Pulsars, Continuum (+polarisation), Spectral lines (CH/HI/OH)

The MMGPS pulsar data



State-of-the-art pulsar search back-end using Filter Bank data from the beamformer → [APSUSE](#) [developed by MPIfR]

[Accelerated Pulsar Search User Supplied Equipment] → used for TRAPUM LSP

MMGPS has densely packed pointings

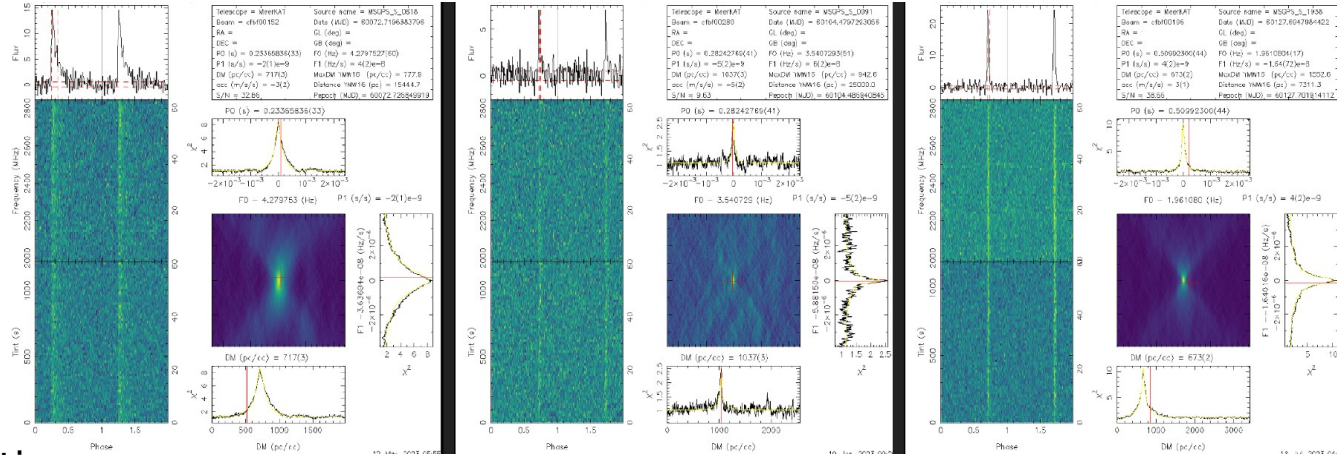
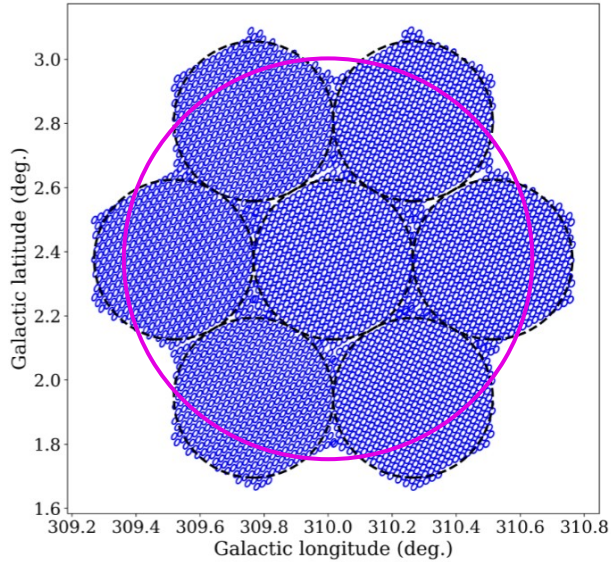
→ $\text{FWHM}/\sqrt{5}$

To optimise pulsar search efficiency

The MMGPS pulsar data



Denisha Pillay Vivek Krishnan Ewan Barr Vishnu Balakrishnan



MMGPS has densely packed pointings

$$\rightarrow \text{FWHM}/\sqrt{5}$$

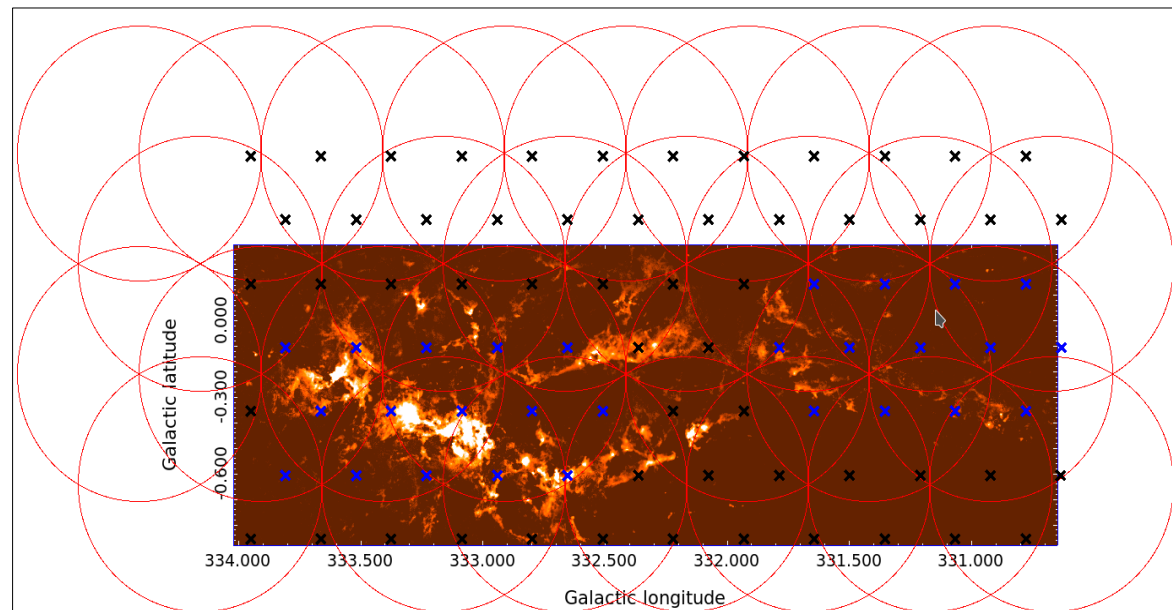
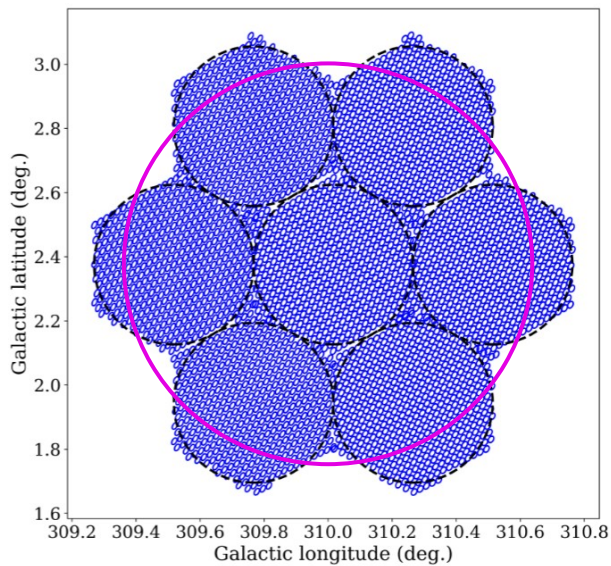
New pulsars are already being discovered near real-time!

~80 discovered so far at L and S-bands [binaries, double NS, γ -ray]

To optimise pulsar search efficiency



The MMGPS continuum data



MMGPS has densely packed pointings

$$\rightarrow \text{FWHM}/\sqrt{5}$$

To optimise pulsar search efficiency, but amazing for image mosaicing [10–20 min of snapshots]!

The MMGPS workflow manager



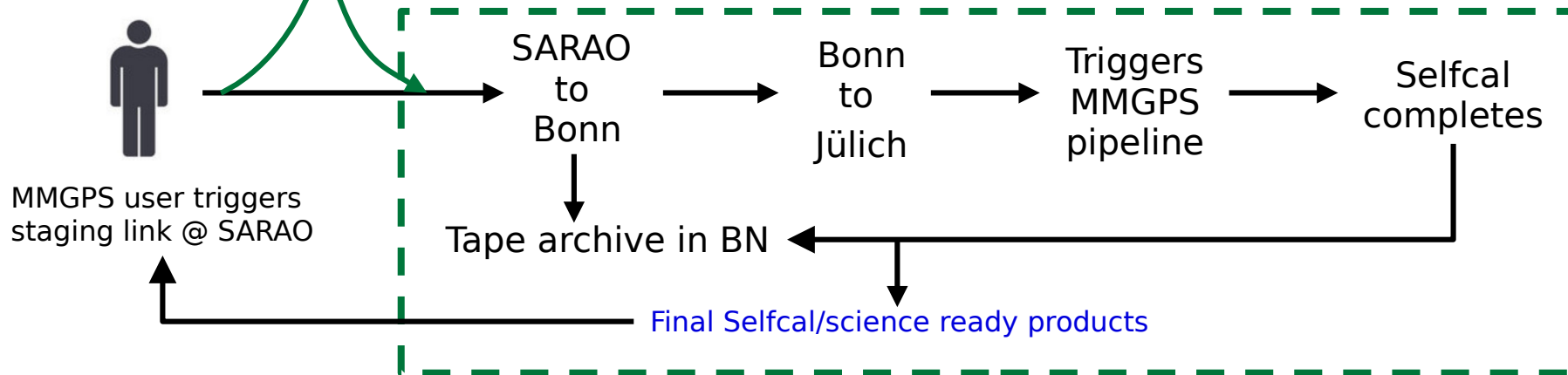
Carsten König

MPIIR-MeerKAT Galactic Plane Survey
Live Observation Processing States (S BAND)
Number of observations: 44

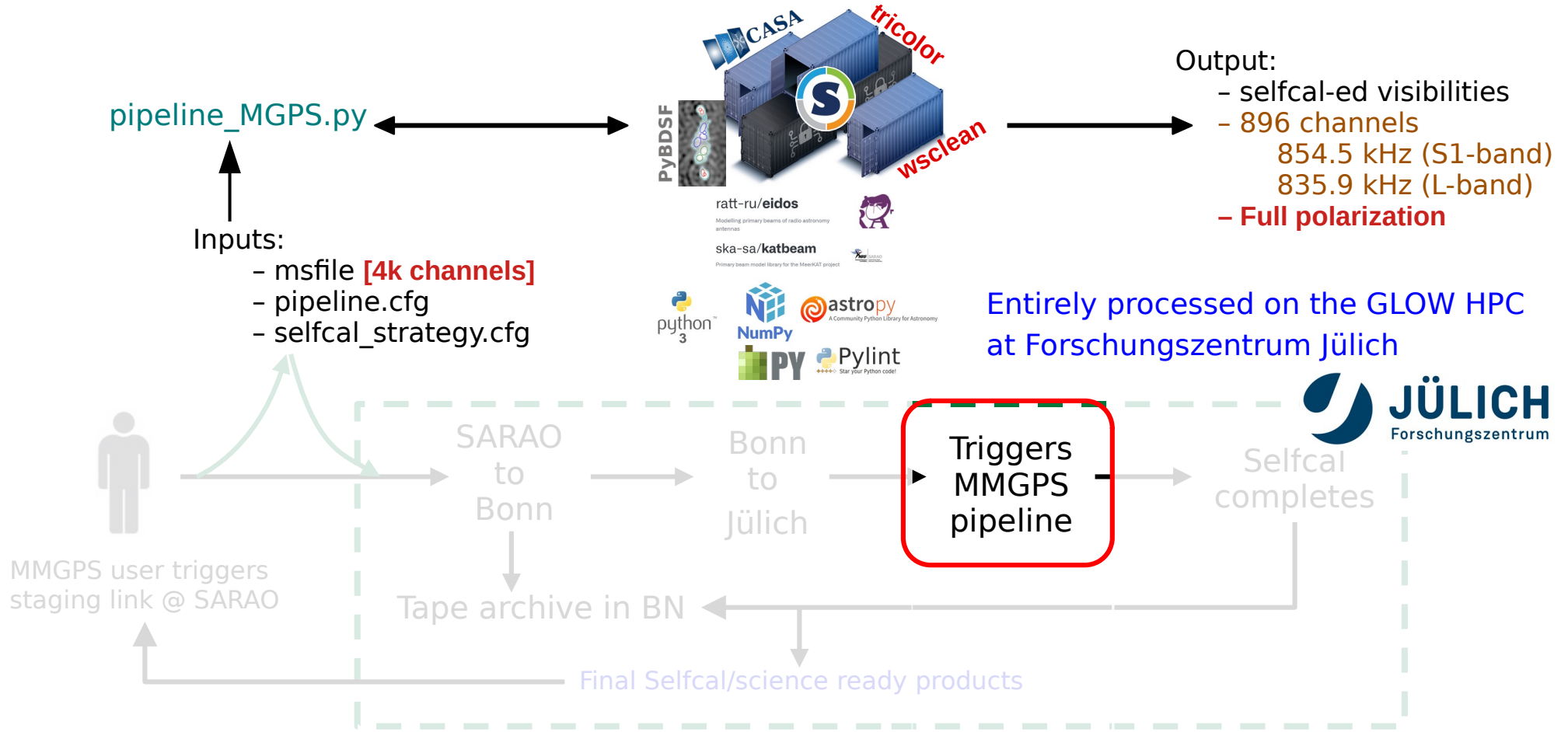
Note that this is not a database, but live status, actively checking the existence of data or execution of tasks every 5 minutes. If connection to a server or NFS mounted directory is lost, the state would likely be wrong here, but be correct again, as soon as the connection comes back. Hover your mouse over the column heads, to see where the data is expected to be.

Schedule ID	Capture ID	Download available	Raw in BN	Archived raw in BN	Raw in J.L.	Processing in J.L.	Calibrated in J.L.	Transformed calibrated to BN	Archived calibrated in BN	Finished
20240403-0013	1718883795	✓	✓	✓	✓	✓	✓	✓	✓	✓
20240129-0003	1711303052	✓	✓	✓	✓	✓	✓	✓	✓	✓
20240124-0031	1706478314	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0060	1705096154	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230822-0035	1699154778	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0058	1695321259	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0062	1694028744	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230910-0024	1694838436	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0055	1694325679	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0057	1692430679	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0056	1692000769	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0054	1691223985	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0053	1690879322	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0052	1690534580	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0051	1690275972	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0050	169017442	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0048	1688897254	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0047	168828114	✓	✓	✓	✓	✓	✓	✓	✓	✓
20230502-0049	1688035642	✓	✓	✓	✓	✓	✓	✓	✓	✓
20220818-0055	1687684998	✓	✓	✓	✓	✓	✓	✓	✓	✓
20220502-0045	1687426582	✓	✓	✓	✓	✓	✓	✓	✓	✓

Fully automated end-to-end workflow manager pipeline



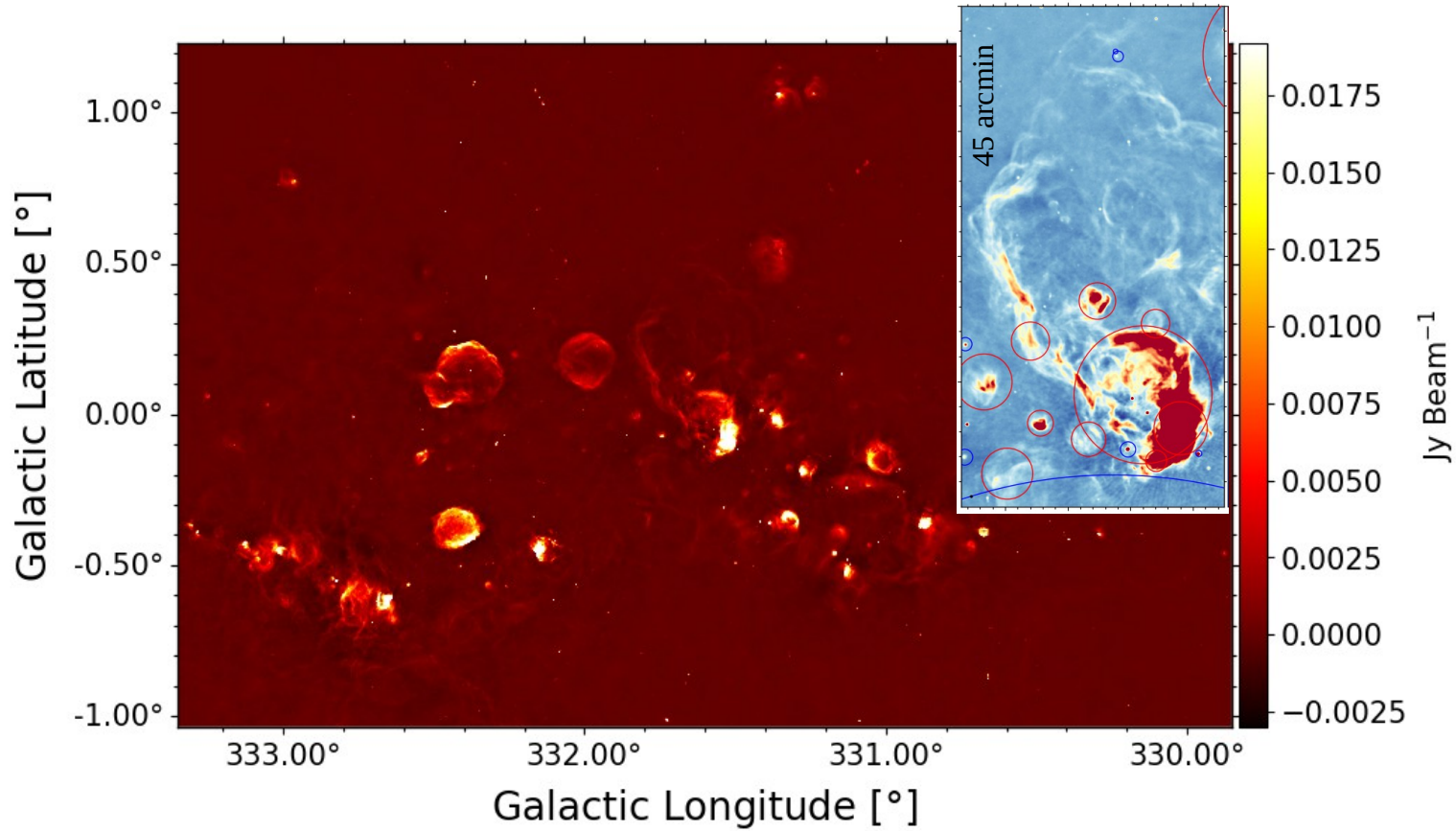
The MMGPS imaging pipeline [developed in-house]



Preliminary results



Sarwar Khan

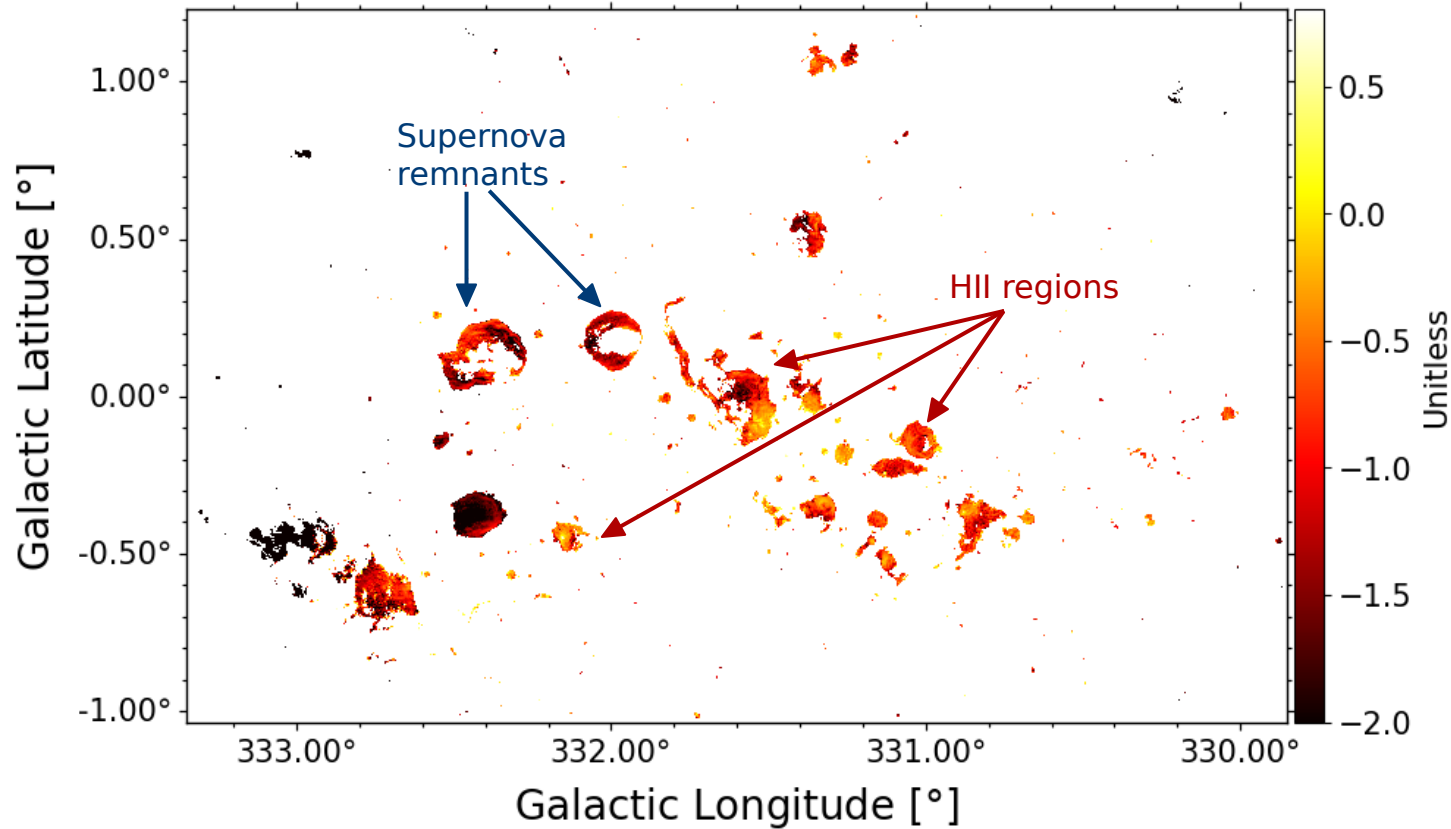


High image fidelity and sensitive to low surface brightness emission

Preliminary results



Sarwar Khan



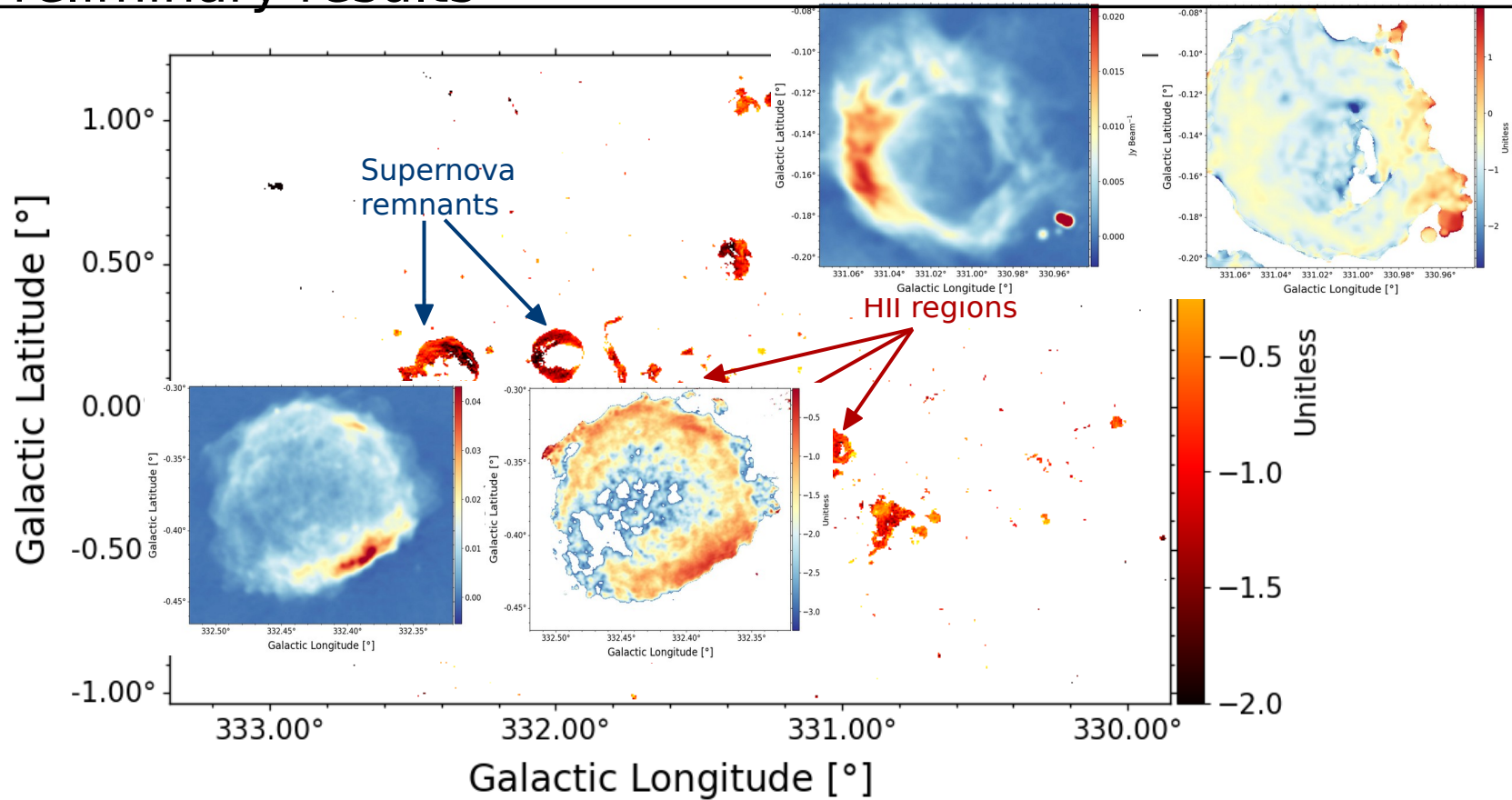
Accurate in-band spectral indices for extended emission up to ~ 30 arcmin (L-band) and ~ 20 arcmin (S-band)
→ identify Supernova remnants, HII regions, starforming complexes from MMGPS alone



Preliminary results



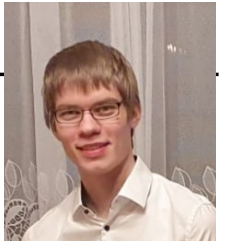
Sarwar Khan



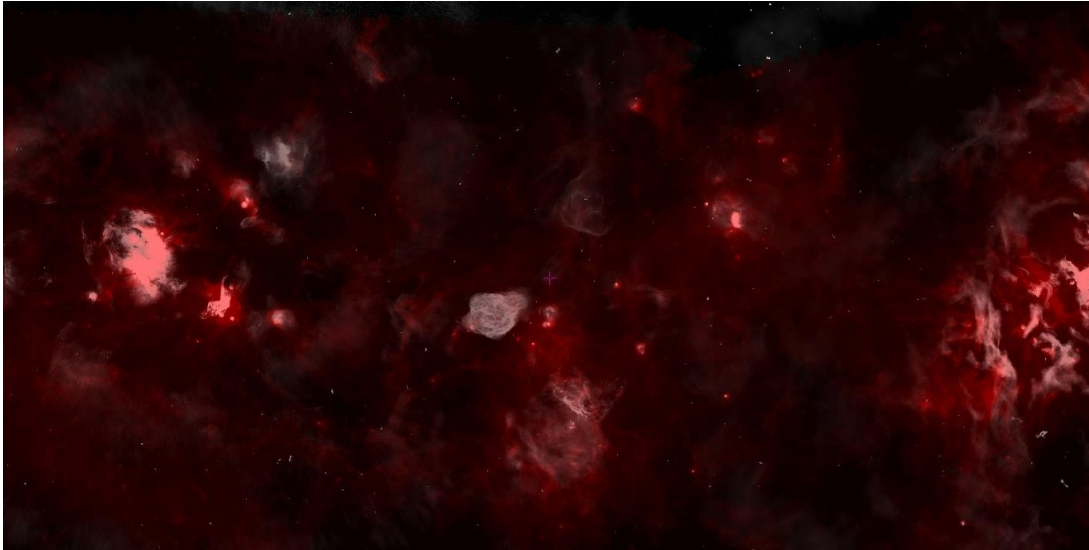
Accurate in-band spectral indices for extended emission up to ~ 30 arcmin (L-band) and ~ 20 arcmin (S-band)
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Broadband SEDs of HII regions



Albert Genest



Morphological correspondence between *Herschel* FIR and radio maps distinguishes HII regions and SNRs

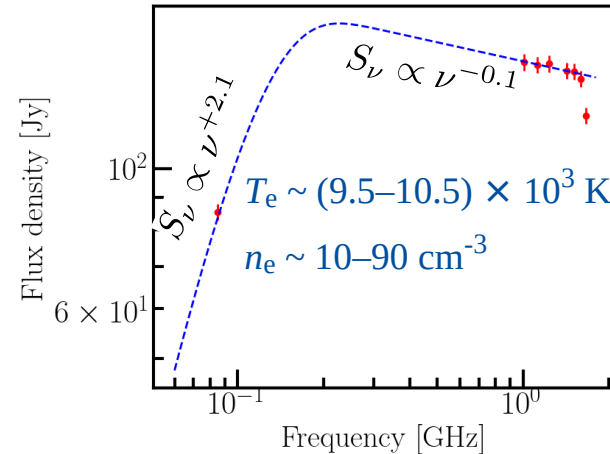
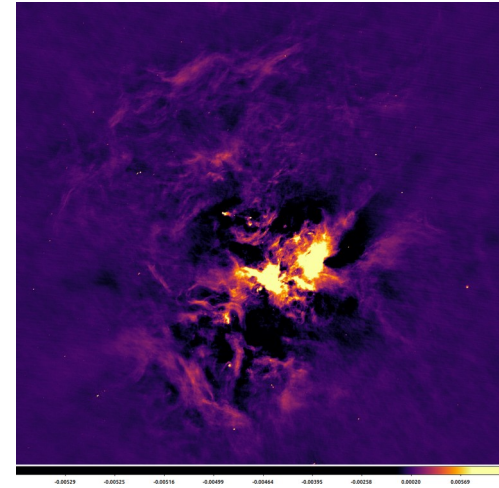
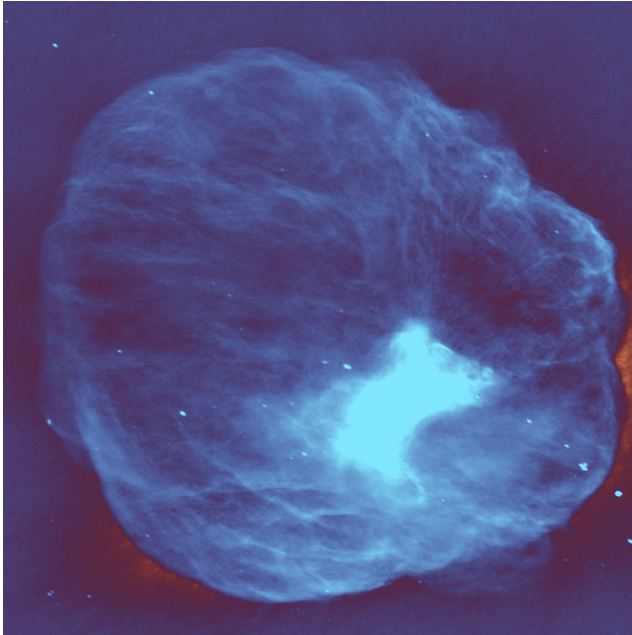
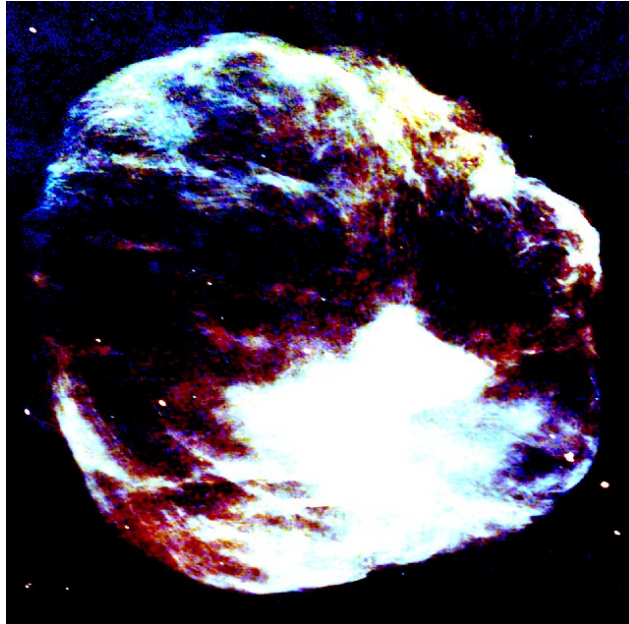


Image fidelity

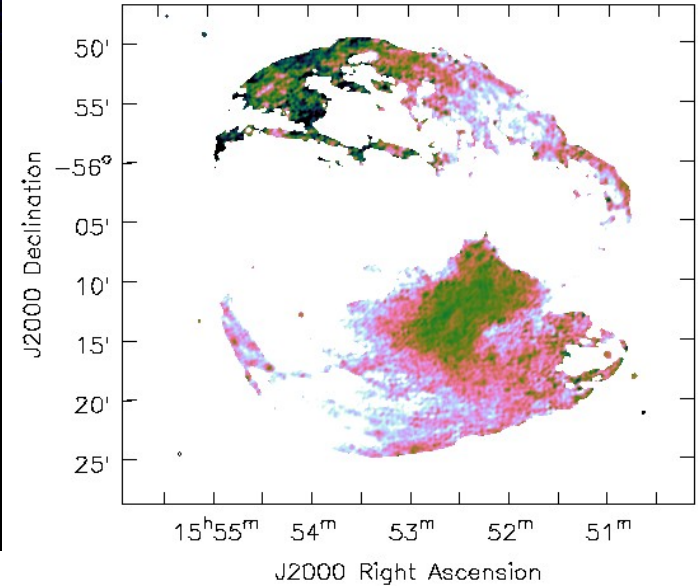
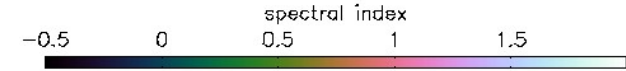
MFS image



In-band RGB

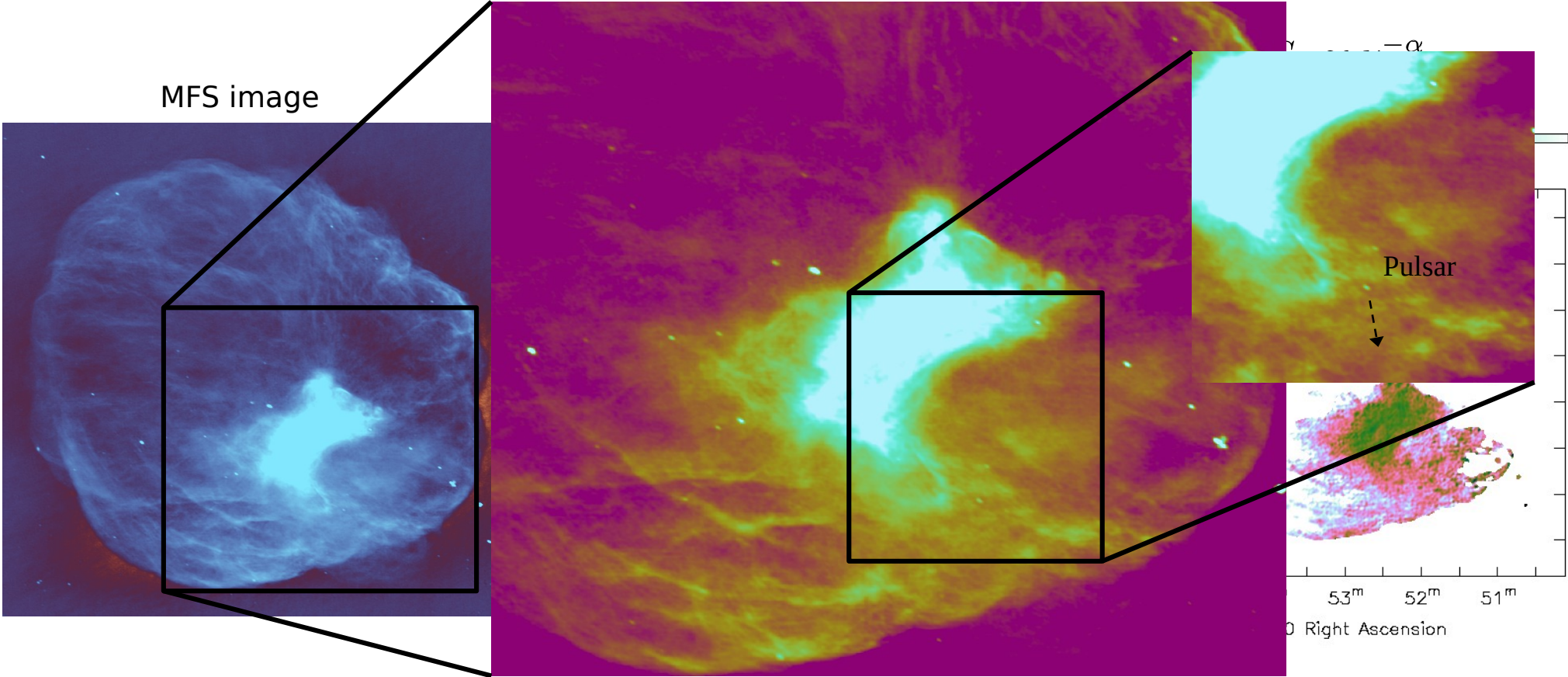


$$S_\nu \propto \nu^{-\alpha}$$



Supernova remnant: MSH 15-56

Image fidelity



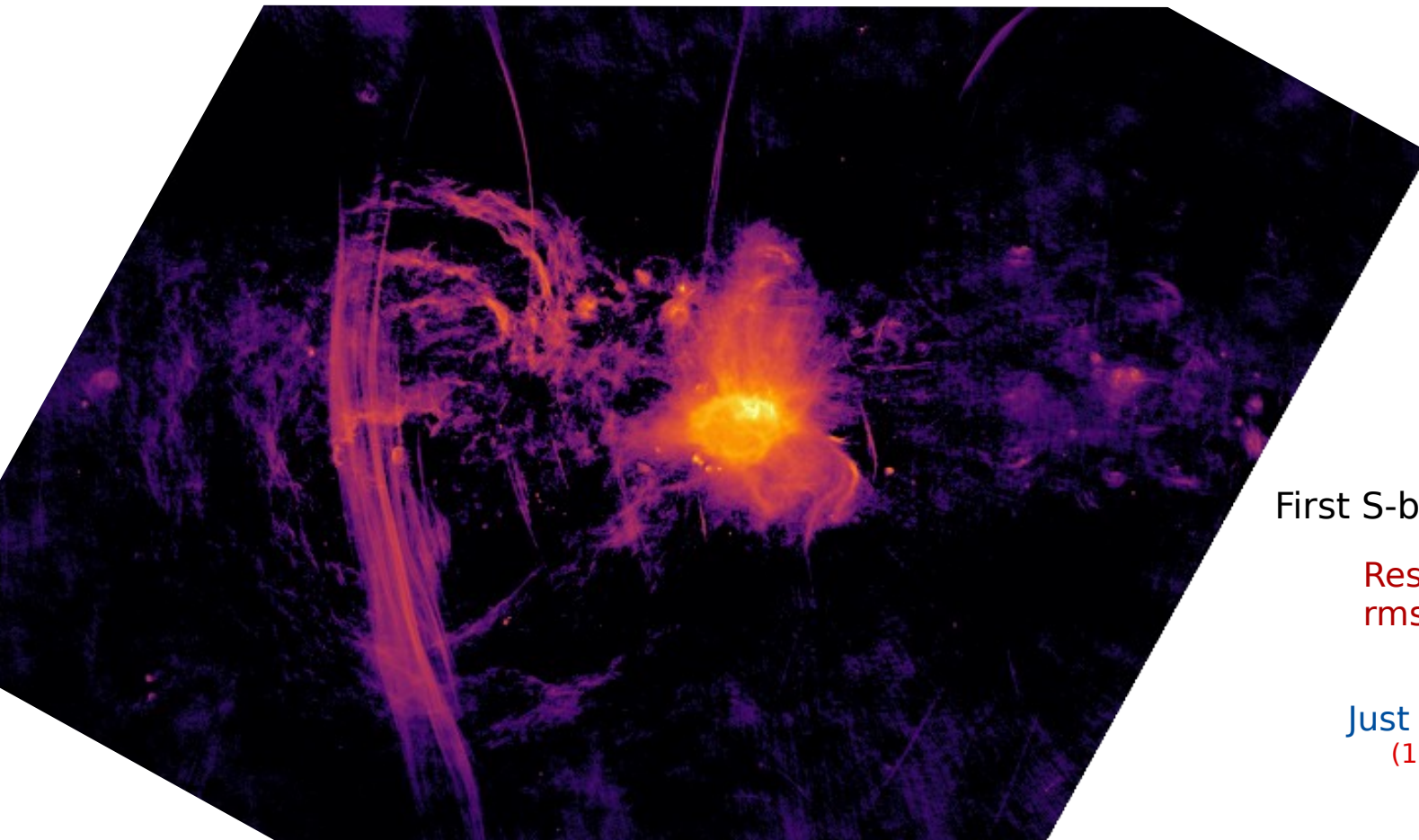
Typical dynamic range — Median: 5000 [2000 to 80,000]



The Galactic Center



Isabella Rammala



First S-band data of MMGPS

Resolution: 2 arcsec
rms : 24 μ Jy/beam!!!

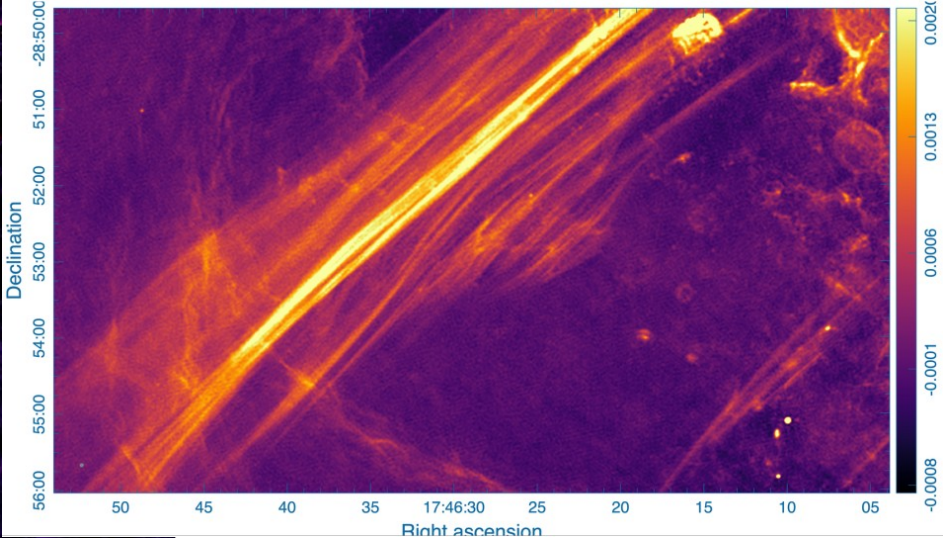
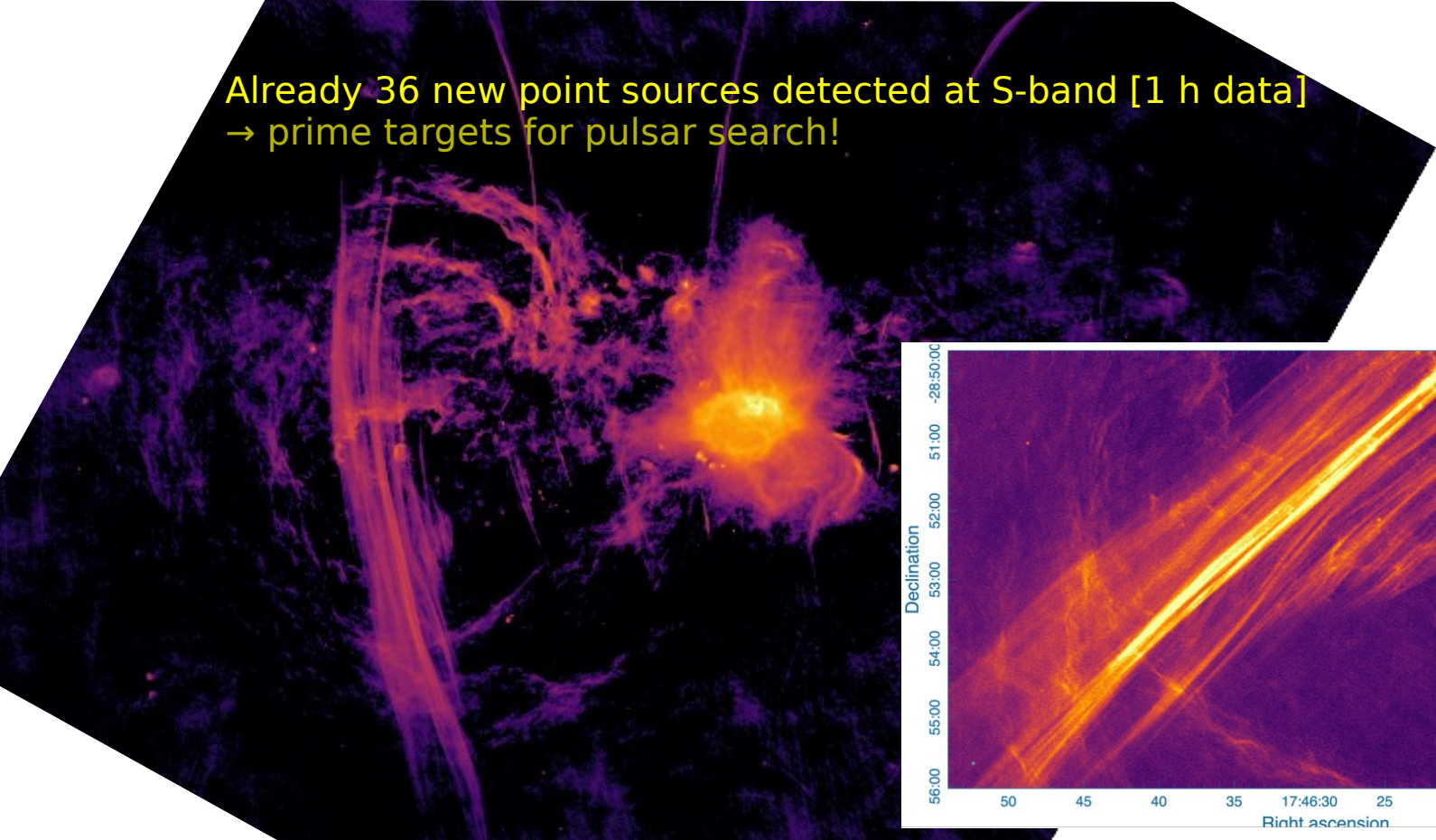
Just 3 \times 20 min pointing
(199-h more to come!)

The Galactic Center



Isabella Rammala

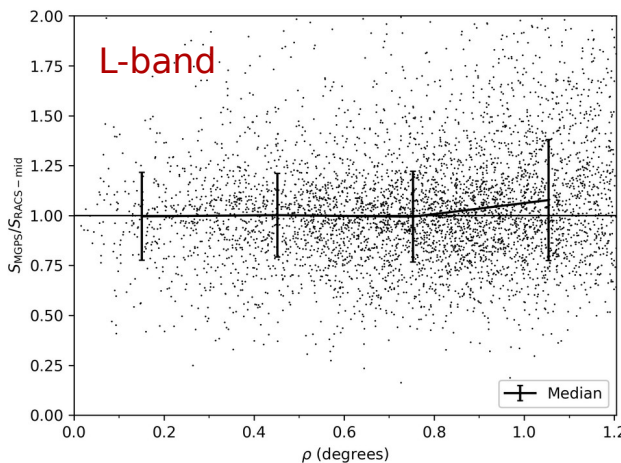
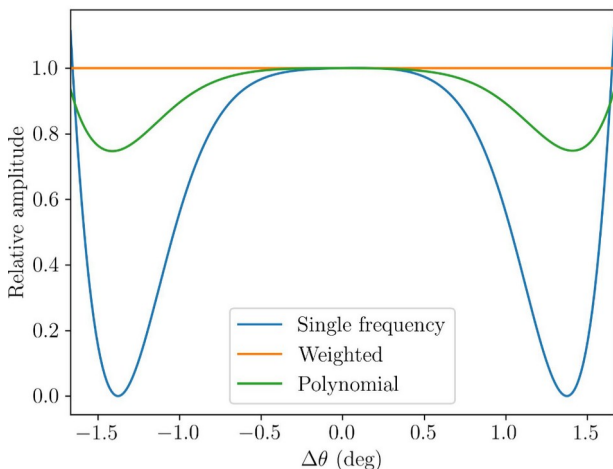
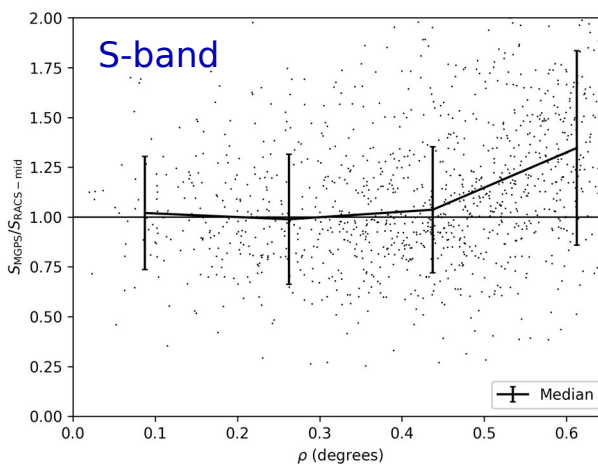
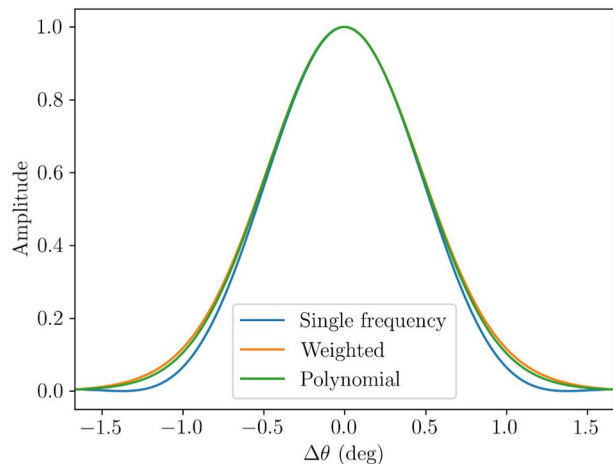
Already 36 new point sources detected at S-band [1 h data]
→ prime targets for pulsar search!



Wideband primary beam correction



Jonah Wagenveld

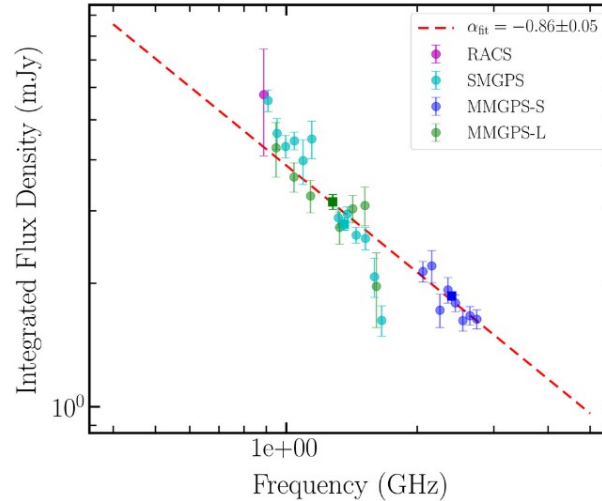
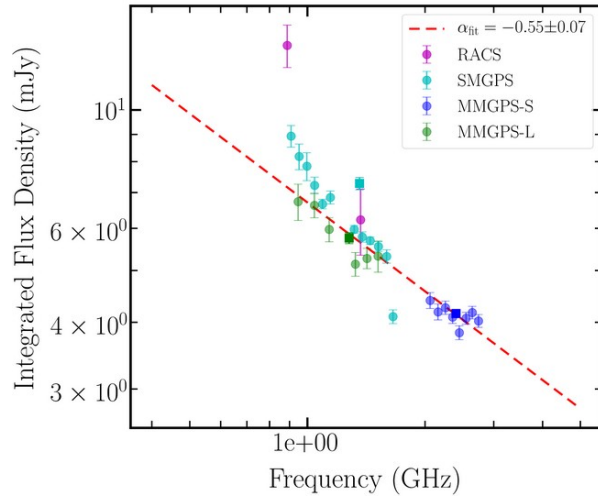


Reliable flux densities down to 20% level of the primary beam

Broadband radio SEDs

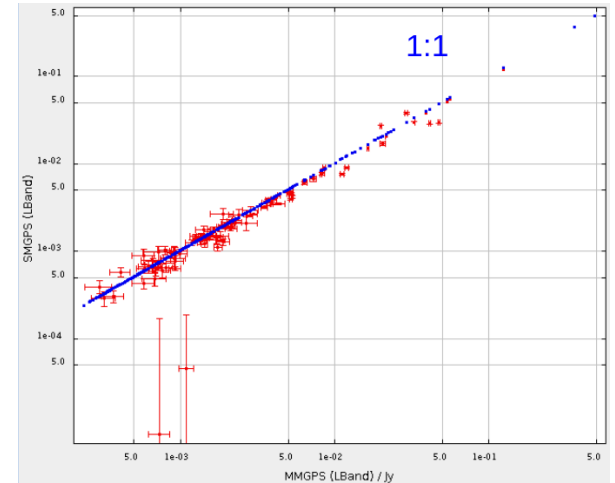


Akriti Sinha



The broadband SEDs of MMGPS between L- and S-bands are consistent

Agrees well with the SARAO MeerKAT Galactic Plane Survey (SMGPS)



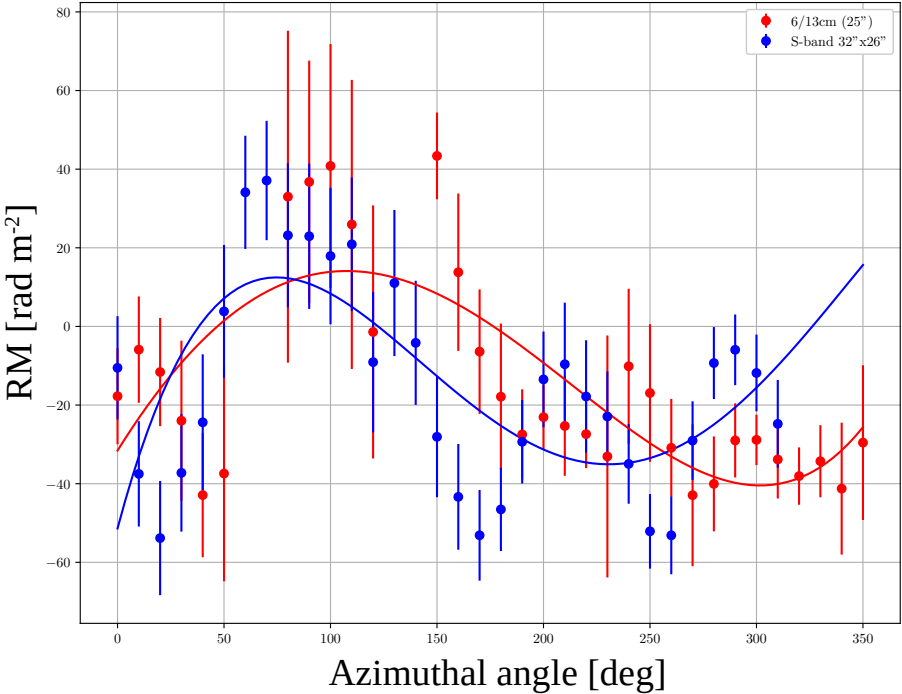
MMGPS is expected to provide broadband SEDs for up to 1×10^6 sources!

Towards polarisation



Ancor Damas Segovia

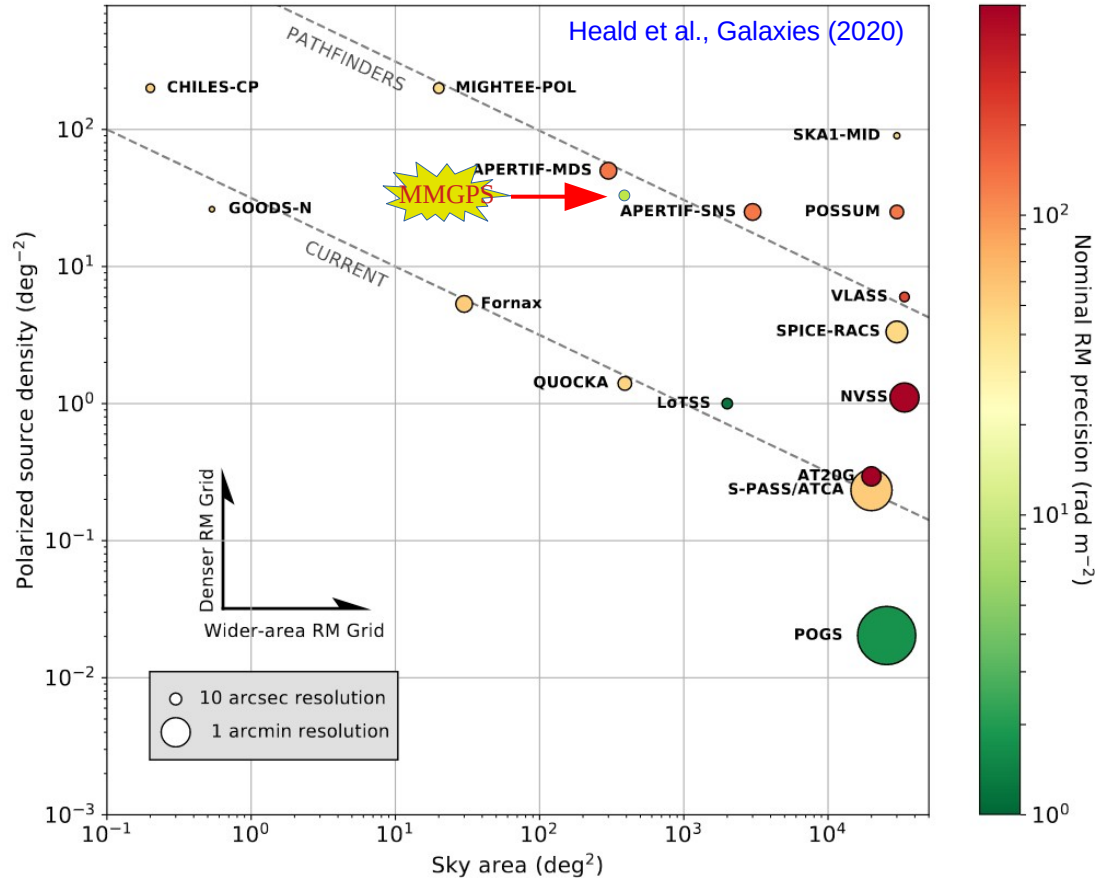
NGC 2997 — polarisation demonstrator at MeerKAT's S-band



On-axis polarisation calibration from MMGPS pipeline works well [$<0.2\%$ on-axis leakage]!

→ widefield off-axis leakage correction being incorporated

MMGPS towards SKA-era



Expected RM-grid density: $\sim 25\text{--}40 \text{ RM/deg}^2$

Sensitive to extreme RM in Galactic plane

$$|\text{RM}| < 2 \times 10^5 \text{ rad m}^{-2}$$

$$\sigma_{\text{RM}} \sim 200 \text{ rad m}^{-2}$$

$$\text{RM precision} \sim 0.5\text{--}20 \text{ rad m}^{-2}$$

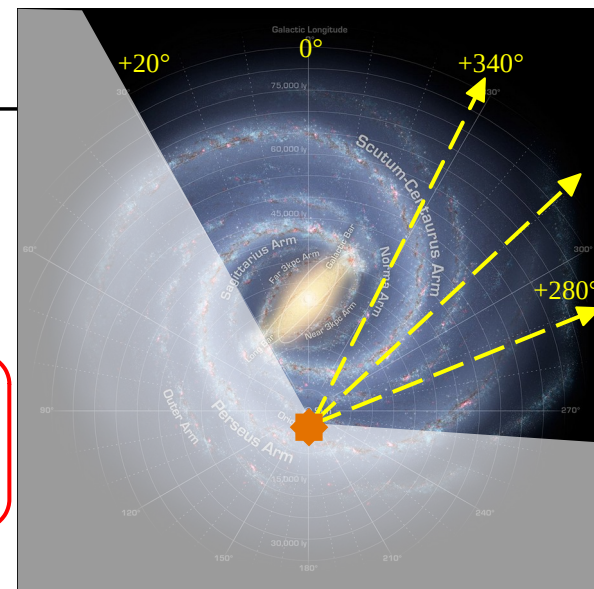


MMGPS will probe an unprecedented parameter space in polarisation studies of the inner Galactic plane!

Summary and outlook

Current status: **L-band** observations completed [processing ongoing]
S-band observations ongoing [processing ongoing]
UHF-band survey starting soon!

rms → **L-band** : 25 $\mu\text{Jy}/\text{beam}$ at 10x10 arcsec resolution
S-band : 15 $\mu\text{Jy}/\text{beam}$ at 5x5 arcsec resolution
UHF-band: expected ~ 40 $\mu\text{Jy}/\text{beam}$ at $\sim 15 \times 15$ arcsec resolution



MMGPS is providing an unprecedented, unobscured view of the inner Galactic plane

- study emission processes in diffuse structures → SNRs, HII and molecular cloud regions, Nebulae, filaments, etc.
- broadband SEDs, along with high fidelity will allow us to study the turbulent Galactic ISM
- unbiased constrain on the star formation rates → connection with CRs and *B*-fields on sub-parsec scales

Polarisation data would be a game changer in terms of understanding the magnetised ISM

- *B*-field structures and CRE acceleration/propagation → SNRs, HII and molecular cloud regions, Nebulae, filaments, etc.
- The connection between small-scale and large-scale dynamo [~ 0.2 to 100 pc scales]
- Faraday complexity and depolarisation in foreground → crucial to understand CMB foregrounds