The II National Workshop of SKA science and technology

The SCORPIO project: the first ASKAP glimpse in the Galactic plane

Milena Bufano, INAF-OACT
on behalf of ASKAP-SCORPIO project members

Outline

- Info and update about **ASKAP,** the Australian SKA Pathfinder;
- **EMU: the Evolutionary Map of the Universe,** the ASKAP unprecedent radio survey ever designed at the planned depth of 10 μJy/beam
- **SCORPIO** project: from ATCA to ASKAP… and beyond

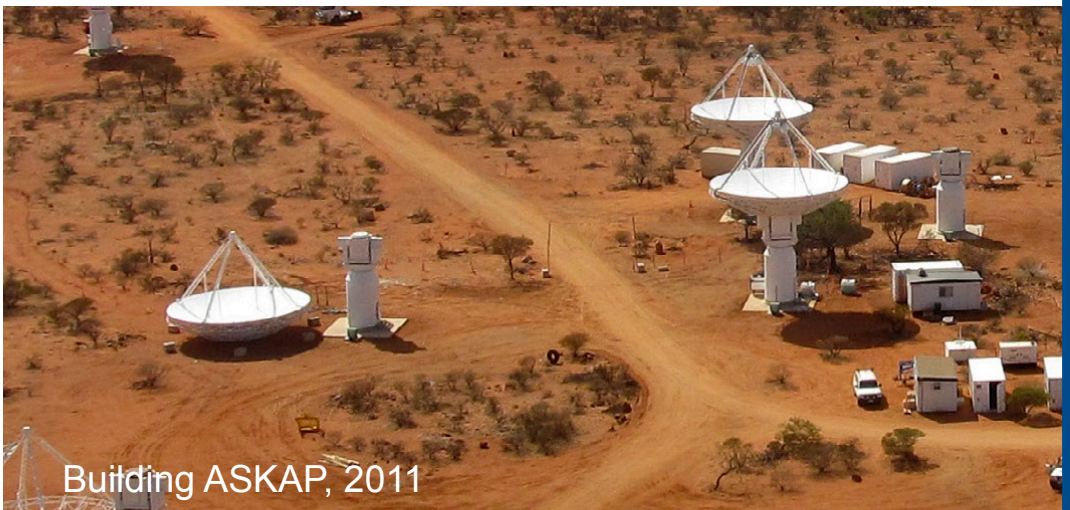
Australian SKA Pathfinder

Design specifications:

Design goals:

- **High dynamic-range imaging**
- **Wide field of view science**

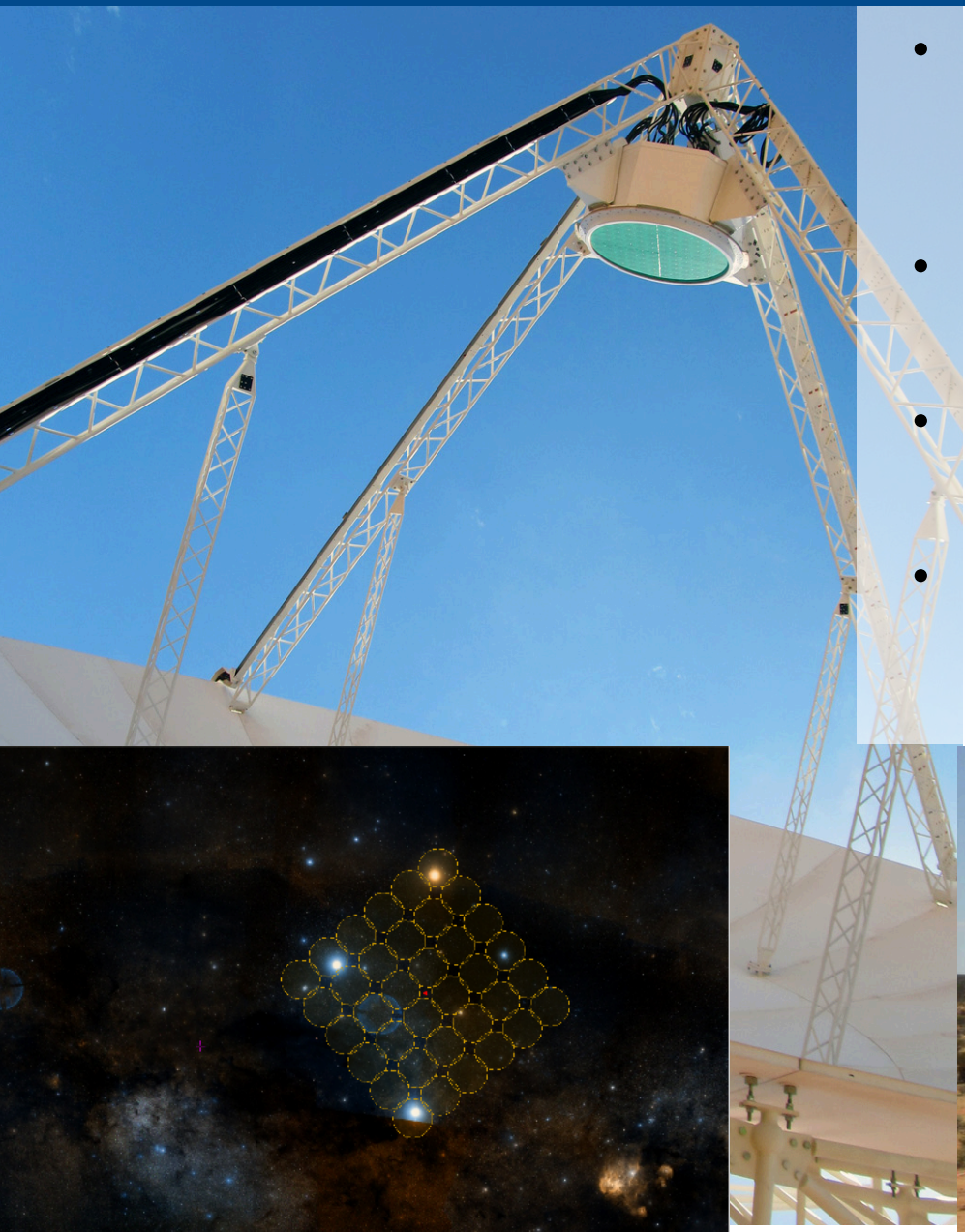
→ ***SURVEYS***



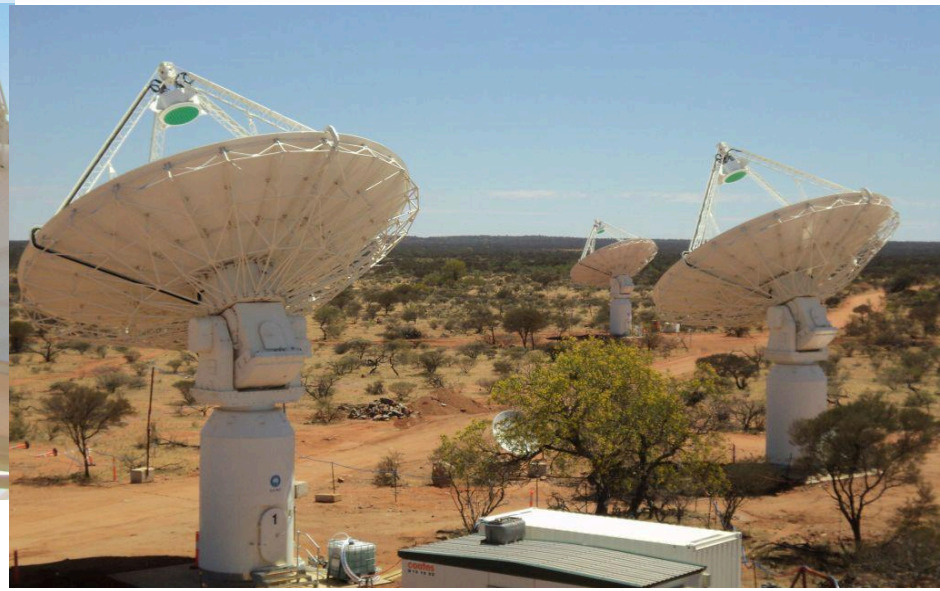
Building ASKAP, 2011

Number of dishes	**36**
Dish diameter	**12m**
Field of view	**30 deg^2**
Maximum baseline	**6 km**
Resolution	**10” @1250MHz**
Sensitivity (288 MHz, 1 hr, 10”)	**37 μJy/bm**
Survey speed (288 MHz, 100 μJy)	**220 deg^2/hr**
Observing freq.	**700-1800 MHz**
Bandwidth	**288 MHz**
Spectral channels	**16384**

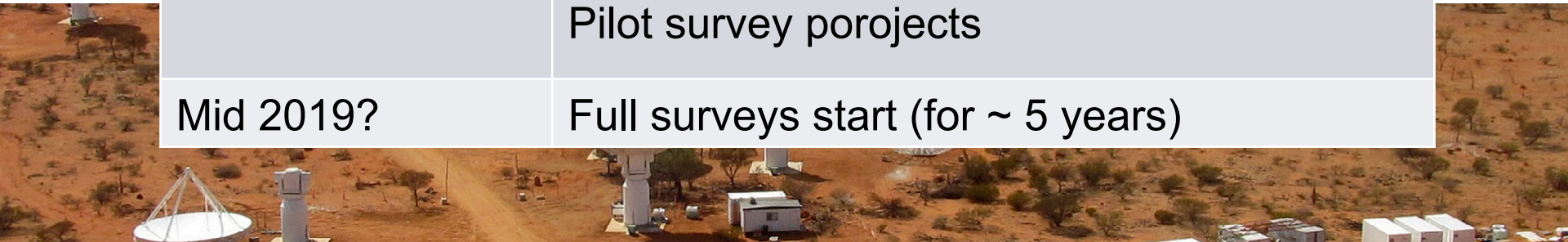
ASKAP



- Phased Array Feeds (PAF) give 30 sq deg FOV and an amazing survey speed
- All 36 antennas & infrastructure completed
- All 36 PAFS complete and installed
- Currently debugging and commissioning backend and processing pipeline



	ASKAP TIMELINE
2009	Project initiated
2014-2016	BETA operational (6 antennas)
2017-mid 2018	Early Science Phase 1 (12-14 antennas) plus commissioning and debugging
mid-late 2018	Early Science Phase 2 (28 antennas) plus commissioning and debugging
Jan 2019	Commissioning of final survey array 36 antennas, 36 beams, 300 MHz bandwidth Pilot survey porojects
Mid 2019?	Full surveys start (for ~ 5 years)



ASKAP Selected Project:

At highest priority:

- **EMU**: **E**volutionary **M**ap of the **U**niverse

Continuum survey of the sky
PI: R. Norris

- **Wallaby**: **W**ide-field **A**SKAP **L**-band **L**egacy **A**ll-sky **B**lind surve**Y**

Neutral Hydrogen survey of the sky
PI Bärbel Koribalski & Lister Staveley-Smith

ASKAP-FLASH: The First Large Absorption Survey in H I

VAST: An ASKAP Survey for Variables and Slow Transients

GASKAP: The Galactic ASKAP Spectral Line Survey

POSSUM: Polarization Sky Survey of the Universe's Magnetism

CRAFT: Commensal Real-time ASKAP Fast Transients survey

DINGO: Deep Investigations of Neutral Gas Origins

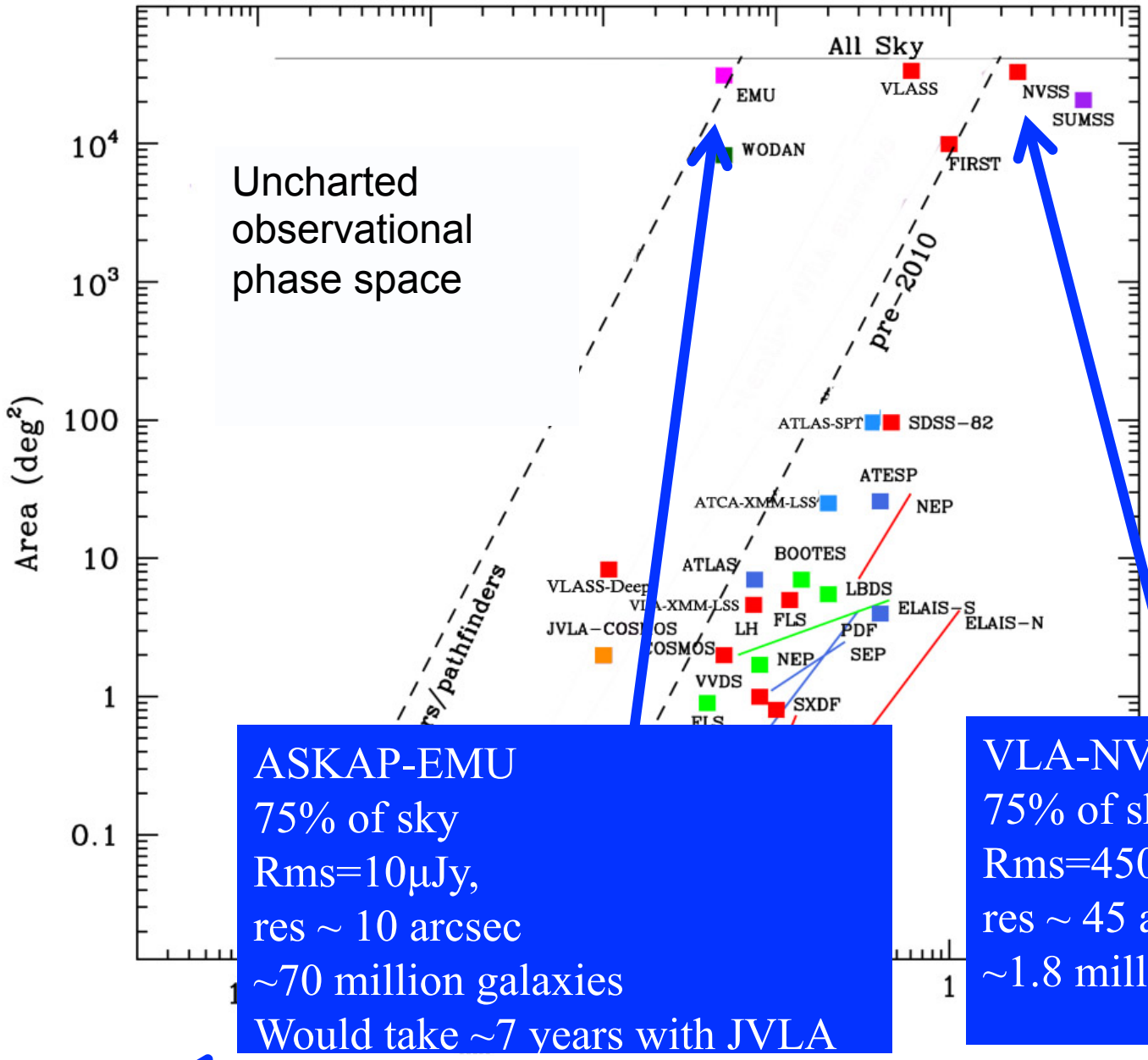
VLBI

COAST: Compact Objects with ASKAP: Surveys and Timing

the ASKAP continuum survey (P.I. R. Norris)

- Deep radio image of 75% of the sky (to declination +30°)
- Frequency range: ~ 1100-1400 MHz
- Expect to detect and image ~70 million galaxies at 20cm
  - c.f. 2.5 million detected over the entire history of radio-astronomy so far
- All data to be processed in real-time pipeline
- Images and catalogues to be placed in public domain
- The EMU team has over 300 members in 21 countries

EMU



Credit R.Norris

The impact of EMU on Galactic Science

EMU results will address several science goals:

- A complete census of the early stage of massive stars formation in the SGP
- Giant HII and interaction with their environments: triggered star formation
- Detection of SNRs
- Detection of PNs
- Serendipitous discoveries

To derive accurate space density and rate formation need for robust identification

Particularly important for synergy

MIPSGAL survey at 24 μm (Carey et al., 2009)
HI-GAL survey at 70+ μm (Molinari et al., 2010)

Stellar Continuum Originating from Radio Physics In Ourgalaxy (SCORPIO)

A deep radio survey with the ATCA (320 hrs)

P.I. Grazia Umana (INAF-OACT)

C. Trigilio, T. M. O. Franzen, R. P. Norris, P. Leto, A. Ingallinera, C. S. Buemi, C. Agliozzo, F. Cavallaro, L. Cerrigone (Umana+2015)

Scientific Goal

Provide a good estimation of the scientific potential of deep radio surveys in the field of stellar/Galactic radio astronomy.

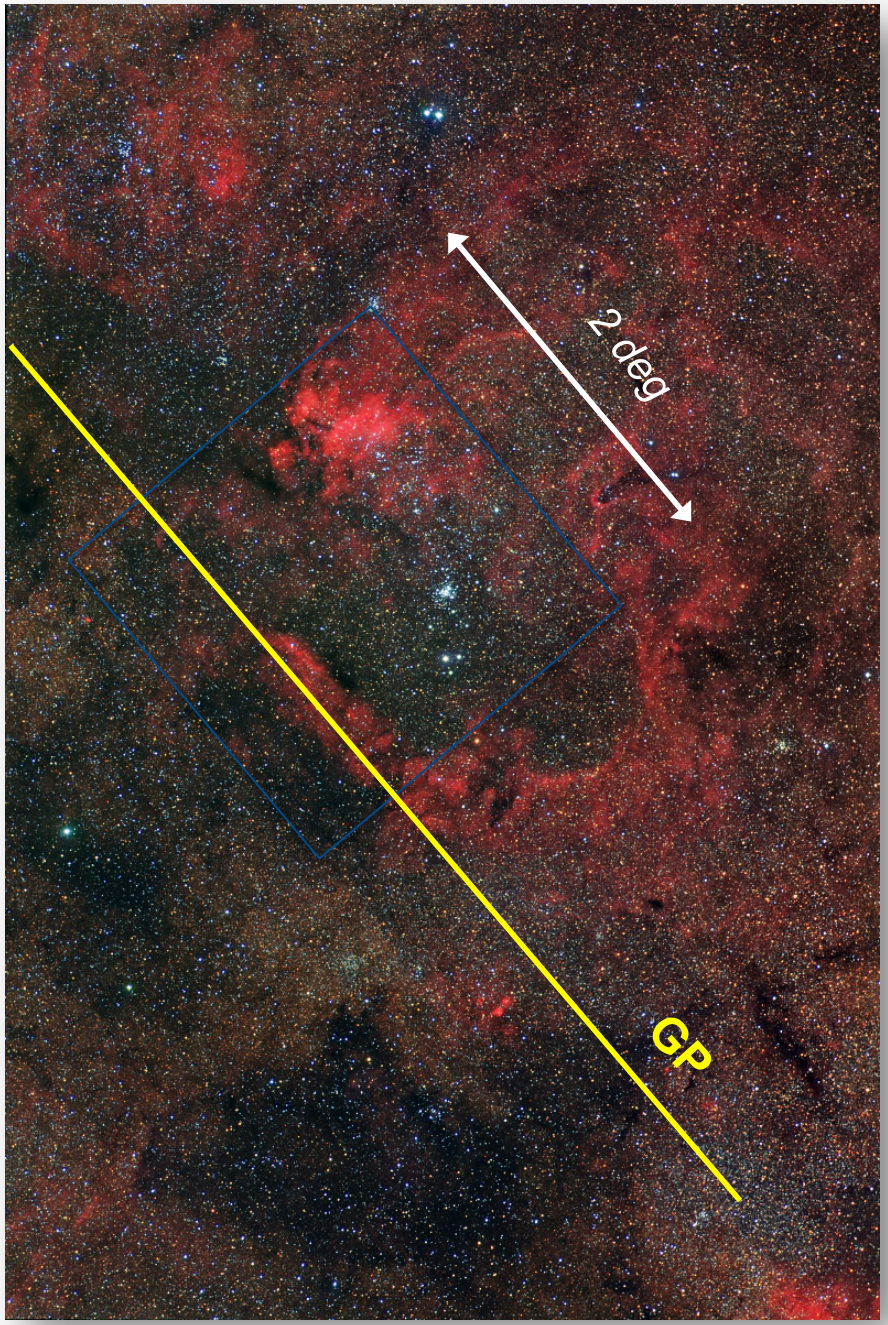
- *Catalogues of different population of Galactic radio sources*
- *Define detection rates for different classes of radio stars.*
- *Prove the importance (uniqueness) of radio observations in the field of Stellar Astrophysics*

Technical Goal

Test bed for the EMU/SKA surveys: strategy for the GP section

- *Source complexity: issues due to complex structures in the GP*
- *Source variability: issues due to the variable sources in the GP*
- *Source finding: issues due to the diffuse emission in the GP*
- *Source identification: how to identify/discriminate different populations (e.g. Galactic vs Extragalactic, different type of stars)?*

SCORPIO with ATCA



Specifics Required:

- Frequency L-Band, comparable to EMU
- High Sensitivity: similar to new radio facilities
- At low Galactic latitude, well suited for stellar work

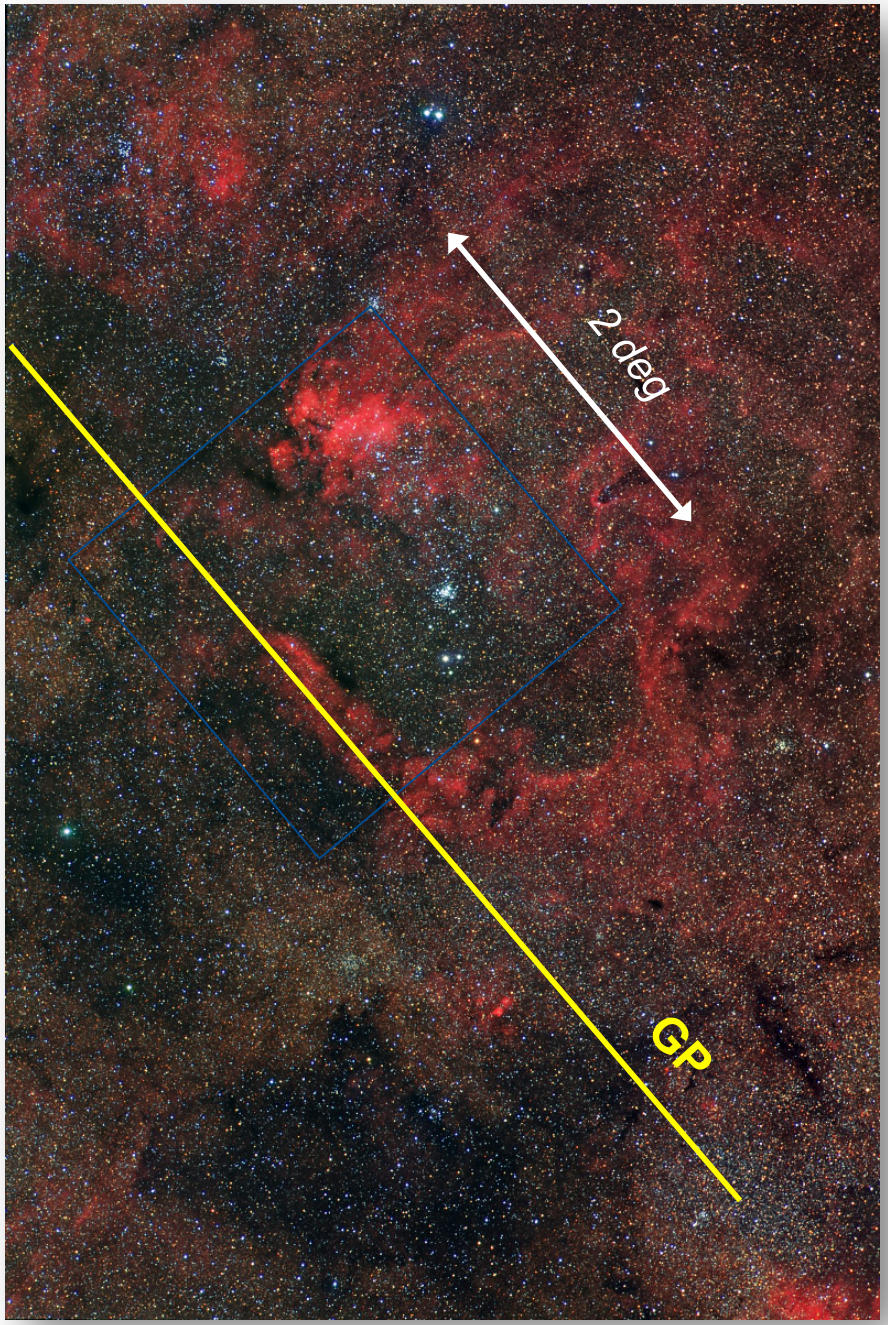
Field Selected:

- Close to the GP, extending to higher b
- A “sufficient” number of stars, good spread in potentially radio emitting objects.
- Few radio sources already detected in it: to be used as check
- Multi-λ observations available for comparative studies.

In the tail of SCORPIO

2 x 2 deg^2 @ l=343.5, b=0.75

SCORPIO with ATCA



Part of the sky patch has been surveyed by:

Spitzer GLIMPSE 3.6, 4.5, 5.8, 8.0 μm
MIPSGAL 24, 70 μm
(Benjamin et al., 2003, Carey et al., 2009)

HERSCHEL
Hi-GAL 70, 160, 250, 350, 500 μm
(Molinari et al., 2010)

MOLONGLO
834 MHz (MGPS)
Sydney University Molonglo Sky Survey

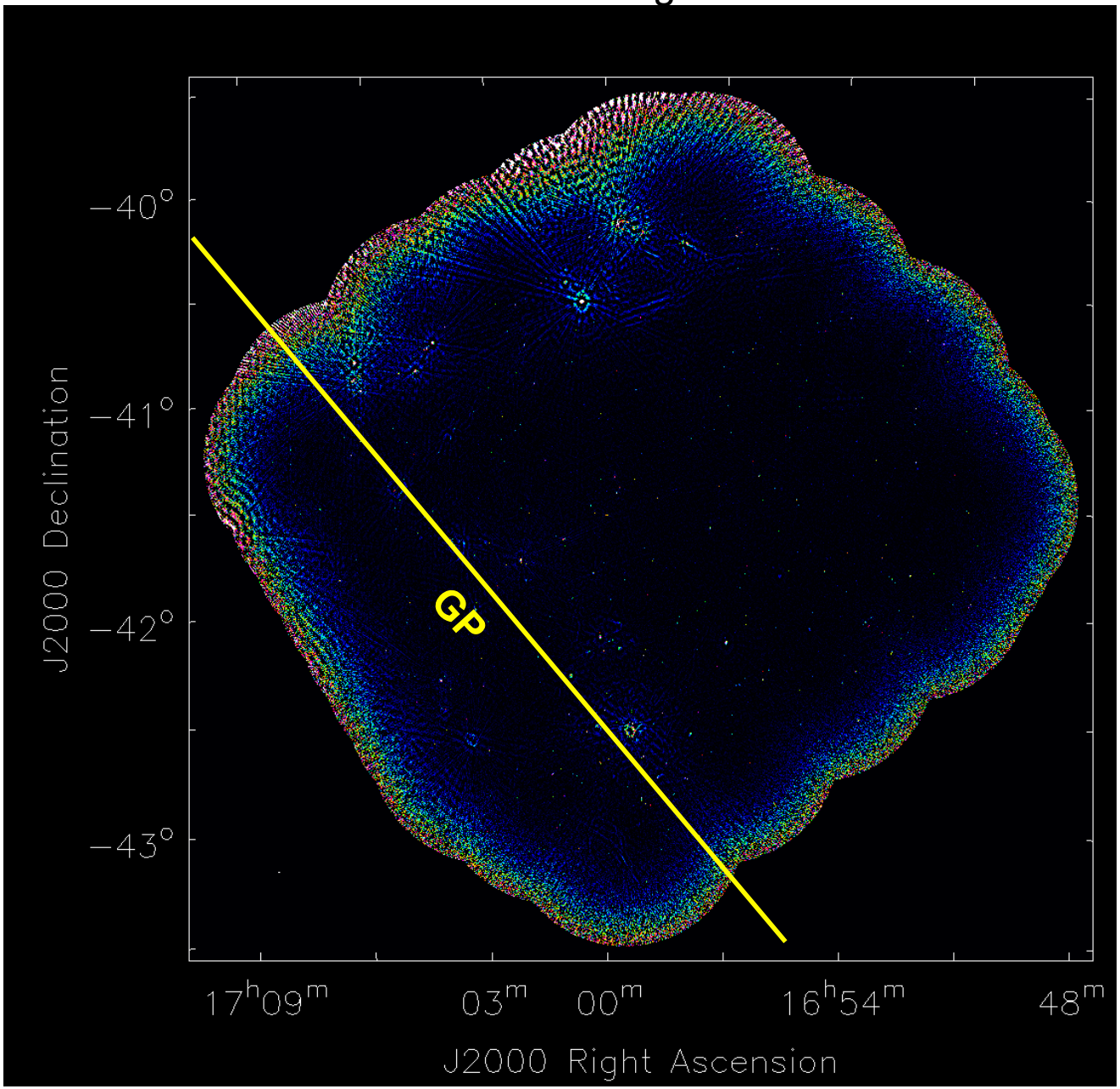
Multi-wavelength observations will help:

The classification of new detections

Detailed studies of classified objects

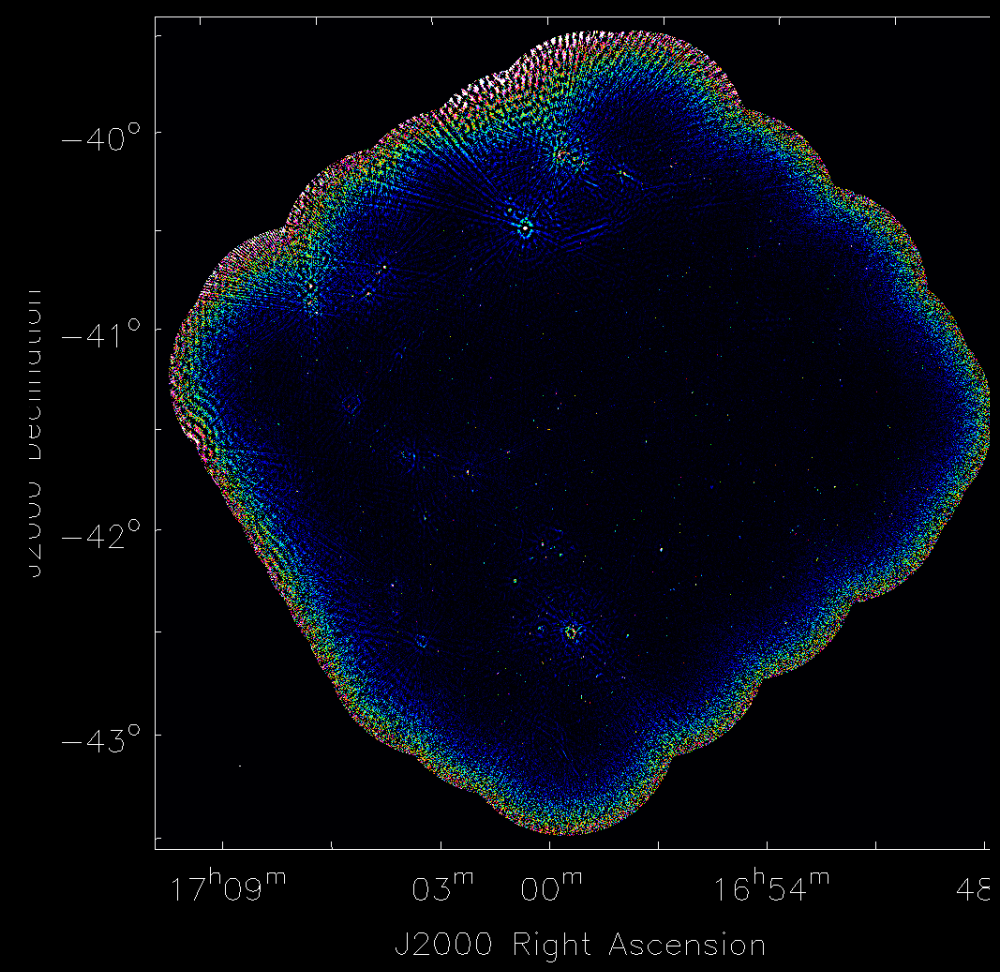
The entire field map

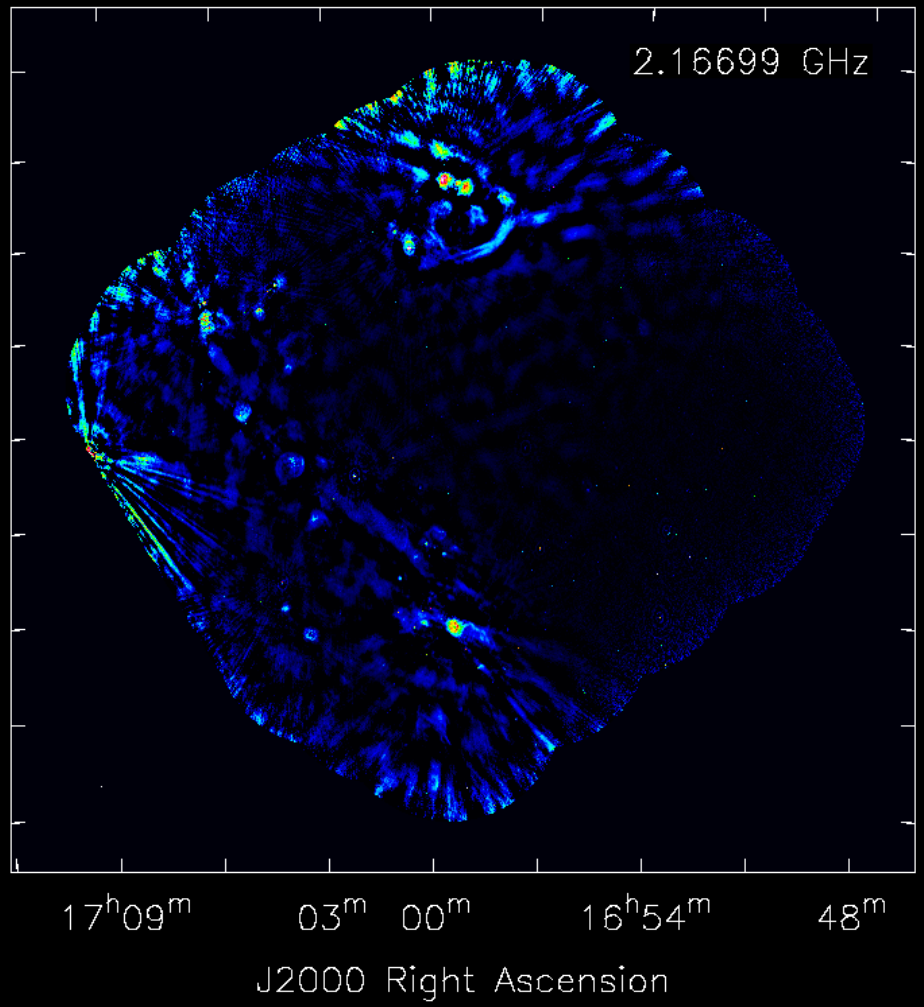
Extended configuration



SCORPIO

Extended configuration vs Extended+Compact configuration





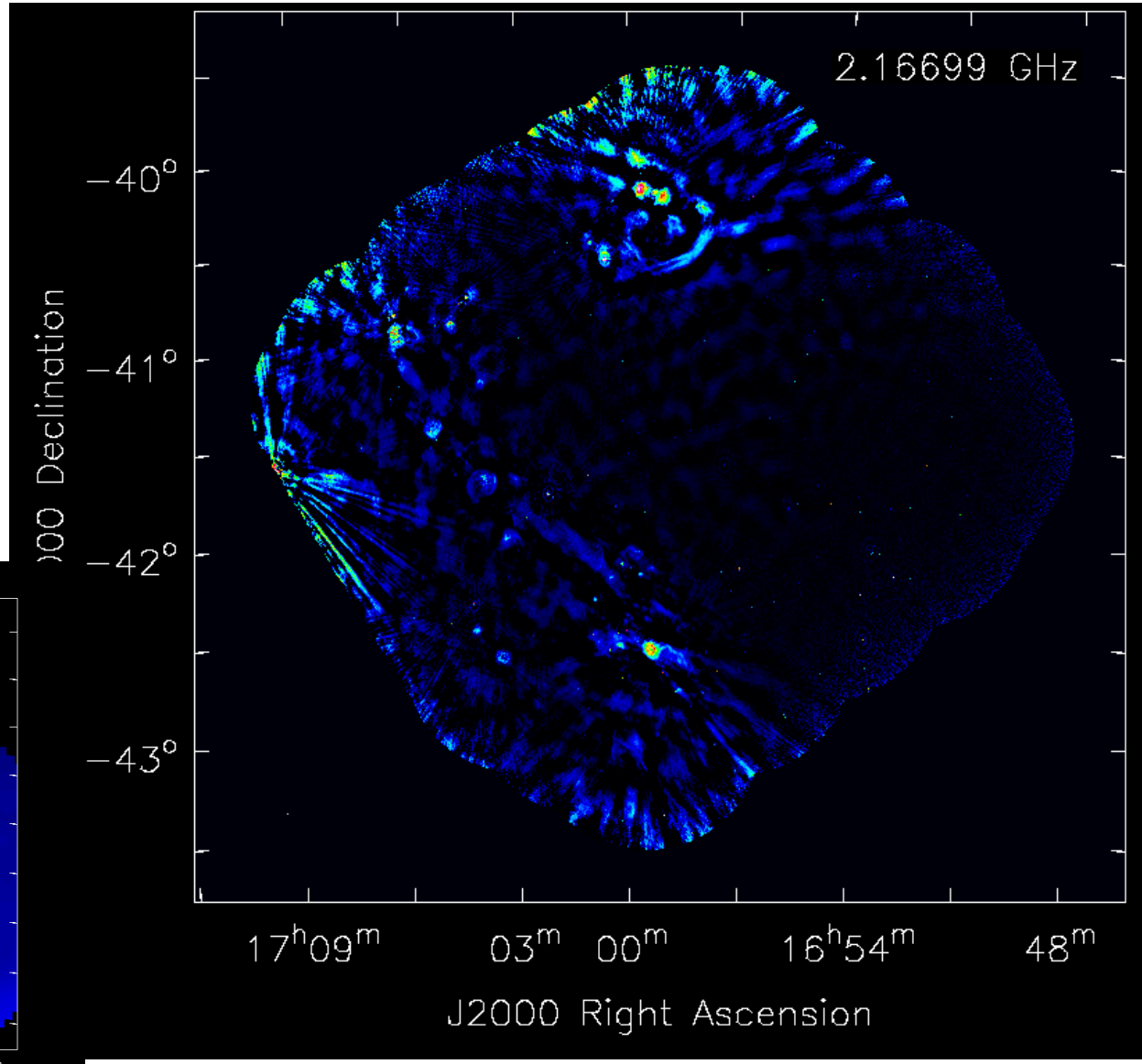
200 hrs

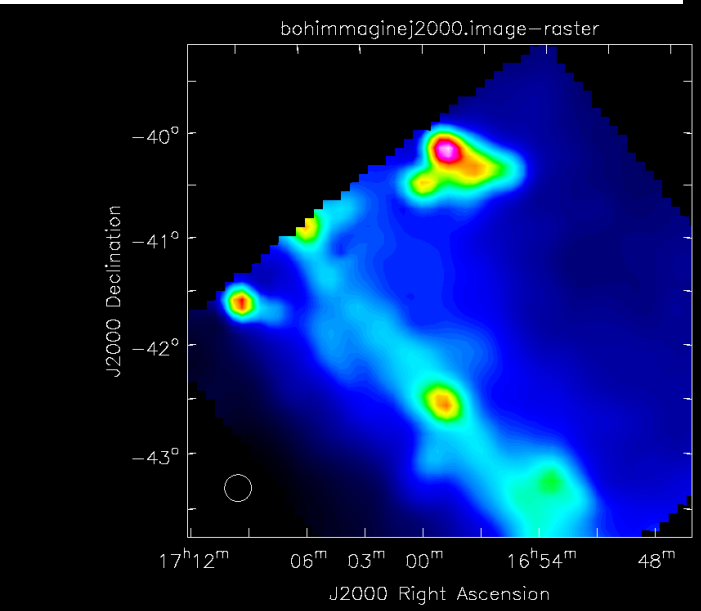
320 hrs extended + compact configuration

ATCA- Map with extended plus compact configuration

Need to include baseline zero
Parkes /5 hrs/ August 2017
(P.I. Ingallinera)

Work in progress

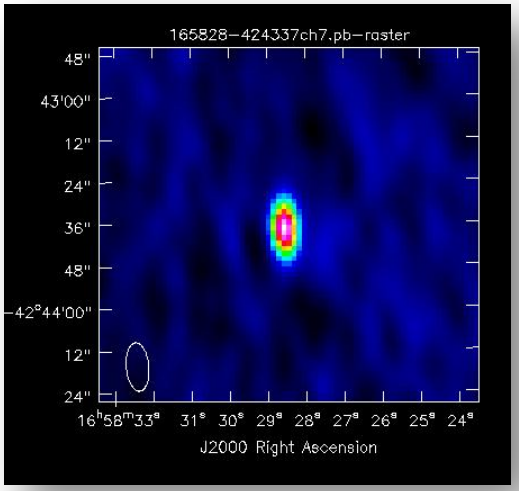




see next talk by F.Cavallaro

Extraction software by T. Franzen (10C survey)
(Franzen et al., 2011)

Found **2206** "point-like sources", with a cut of 5σ
614 in the pilot experiment (Umana et al., 2015)



matches with SIMBAD

Stars
PNe
Pulsars
IR
HII

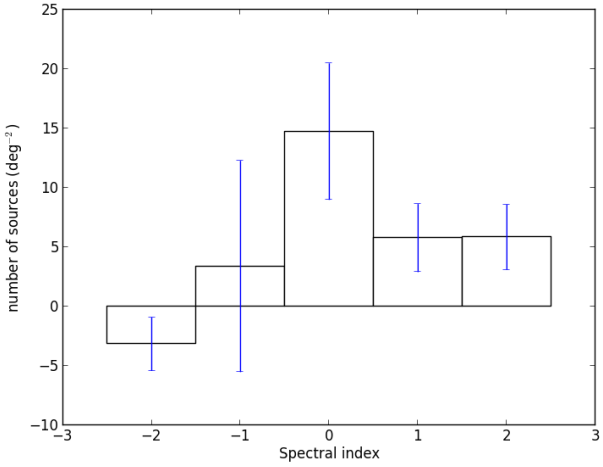
1Variable (ζ^1 Sco)
2 WR
3 in Open Cluster (in NGC6231)
1 YSO
1 Be
1 Cp star
13 stars with no references

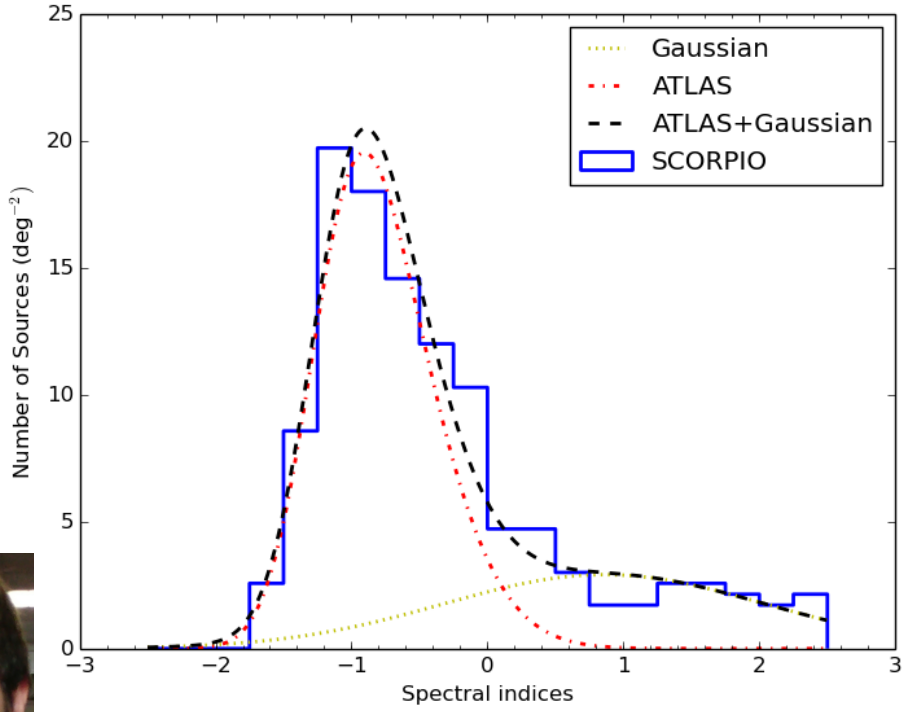
6 pulsars
30 UCHII/HCHII
6 PNe
≈ 1900 without classification

Expected **many** extragalactic "*contaminants*"

Radio spectral index analysis to characterize the point source emission
-disentagle between Galactic and extragalactic population?

- -automatic procedure (run in Casa- *imfit, imstat*) to estimate the spectral index of source from multi frequency radio images.





Comparison with ATLAS:

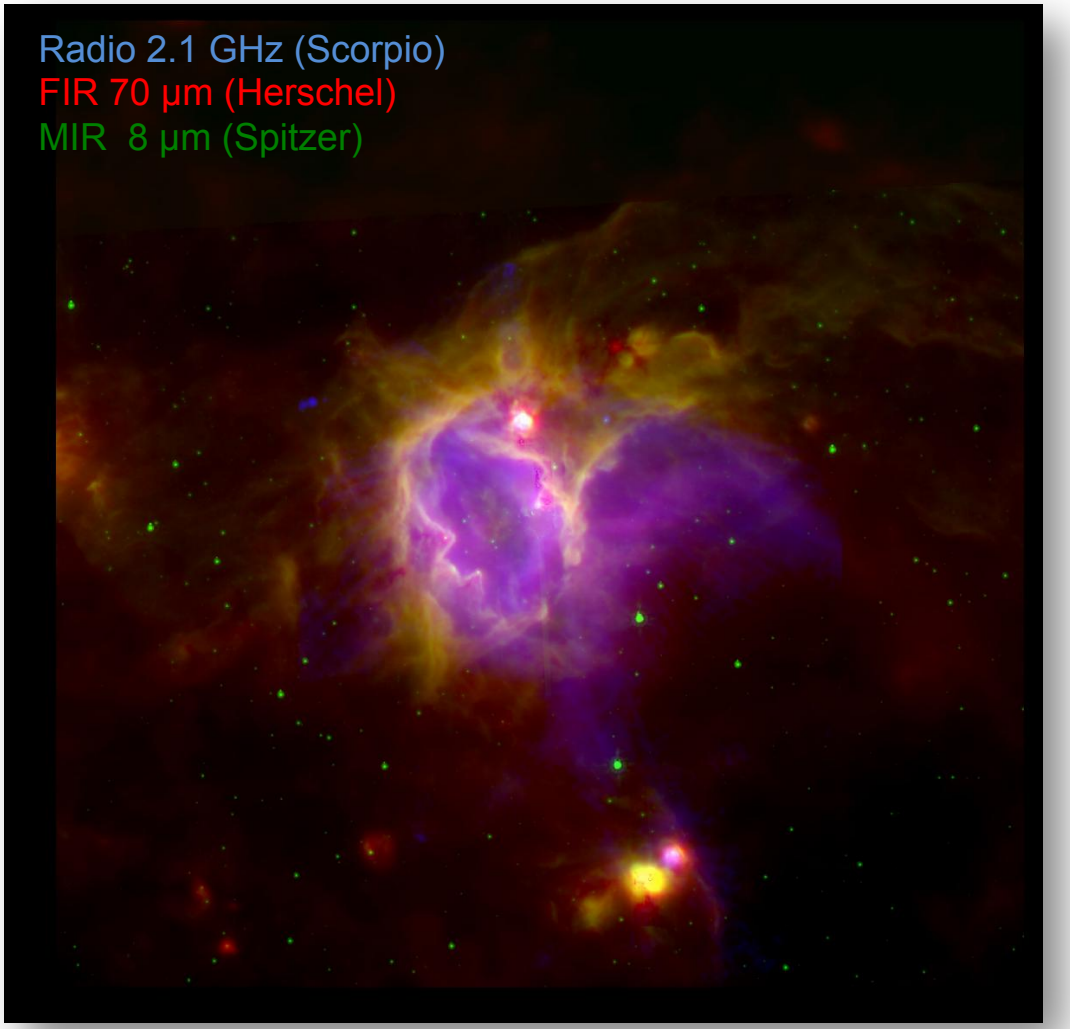
- no difference for α << 0
- source excess for α ≥ 0

Cavallaro + 2018

Above 1 mJy, the source density in SCORPIO is 20% greater than in a typical extragalatic field

Found 83 *Bubbles/Extended Sources*

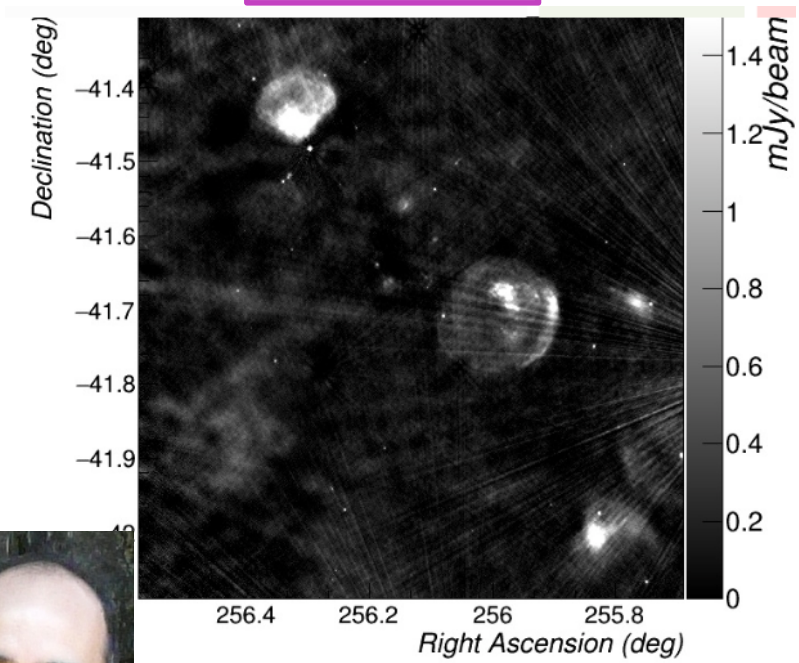
49 classified compact and classical HII
4 PNe
4 SNRs/candidates
2 WR/LBV candidates
24 without classification



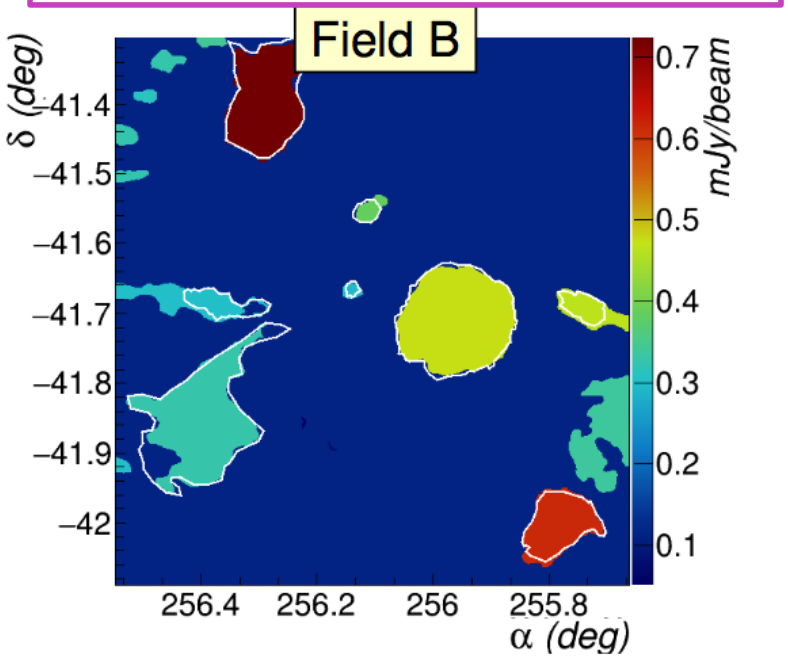
SCORPIO field is:

- Small enough to allow source identification by visual inspection
- sufficiently large for testing and training automated algorithms
- human-driven visual inspection can be used as a verification check of the automated algorithms.

From a field



To a list of extended sources

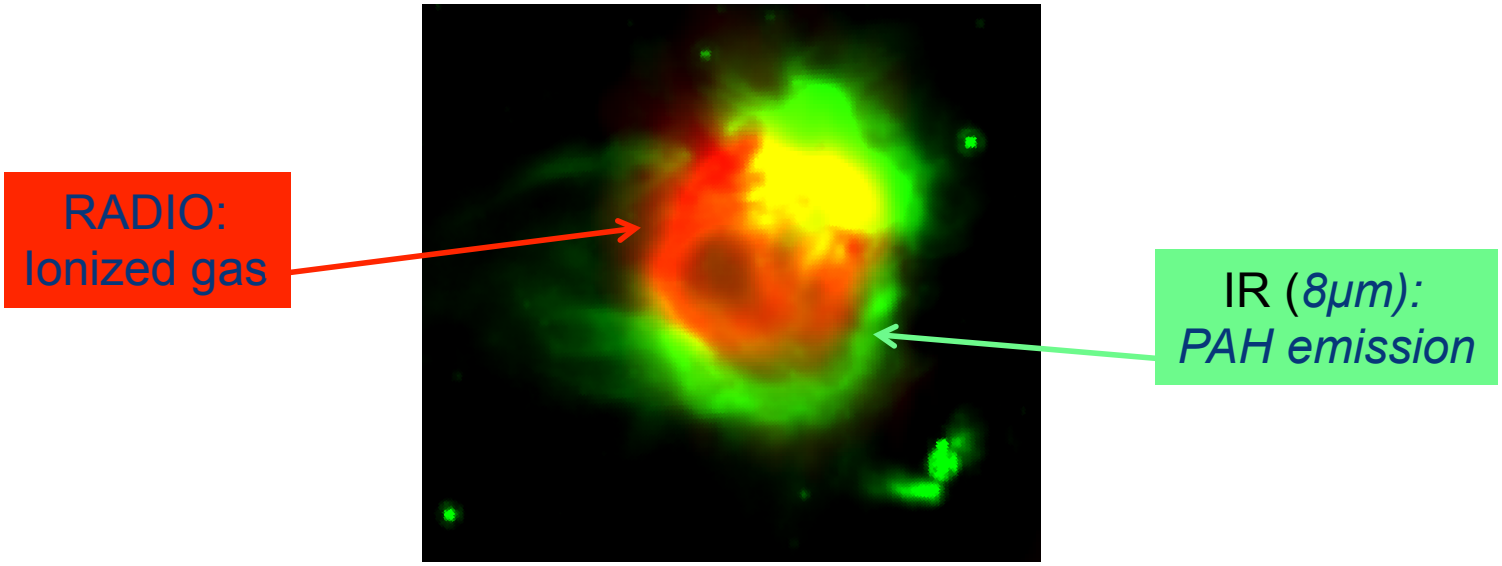


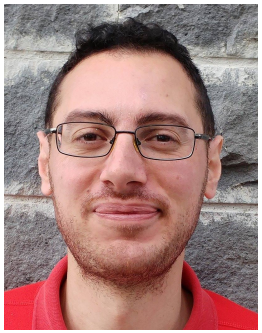
Riggi et al., 2016 Uses SCORPIO to test the automated extraction algorithms CAESAR (Compact And Extended Source Automated Recognition)

see next talk by F.Cavallaro

Comparing radio and IR morphology, is possible to distinguish HII from evolved stars

- *In HII, radio emission wrapped by 8μm emission (Deharveng +2010)*
- *In PN radio and 8μm are cospatial (Ingallinera +, 2016)*





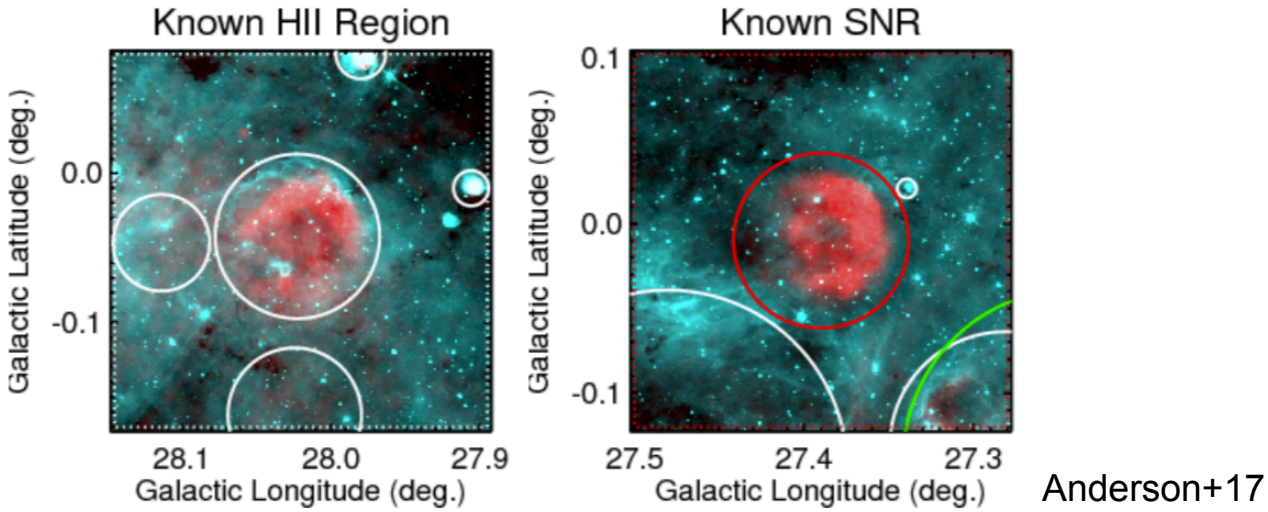
- Exploiting the use of radio and IR morphology to automated source classification for large surveys by means of edge-sensitive algorithms
- SCORPIO field of the “right” dimension for the human-driven visual inspection be used as a verification check.

Ingallinera +, in preparation

Comparing radio and IR morphology is possible to spot Supernova Remnant

- *In HII, radio emission wrapped by 8μm emission (Deharveng +2010)*
- *In SNR the 8μm emission in essentially absent and MIR/radio ratio much lower than HII regions (e.g. Anderson+2017)*

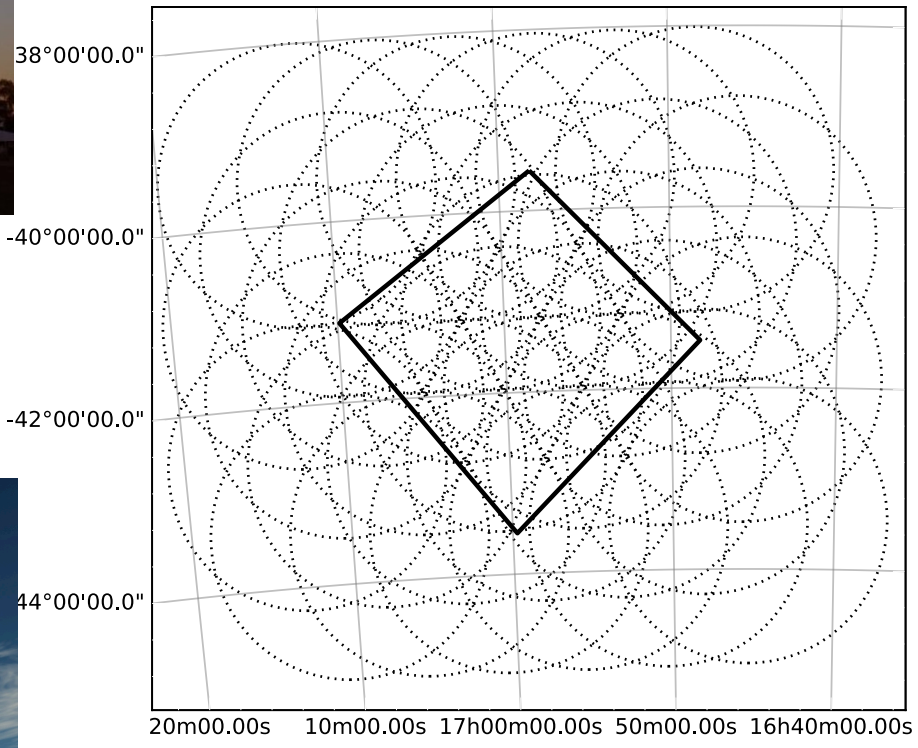
GLIMPSE 8 μm
THOR+VGPS 21 cm



Anderson+17

- Finding Missing SNR population: use of radio and IR morphology to individuate new SNR candidates in SCORPIO field (ASKAP vs Hi-Gal images)
- Study of the origin of dust in SNRs: use of IR data to produce 2D maps of the dust physical properties (T, β and τv) distribution, from the pixel to pixel SED (Bufano+in prep.)

A much larger region of SCORPIO field observed during ASKAP Early Science
Freq: 792-1032 MHz (240MHz)
Ang. Res. 24.1x 21.1 arcsec^2



ATCA- 133 pointings, 3σ= 90 μJy, 4 deg^2

ASKAP-12 1 pointing! 40 deg^2
Jan 2018- 3 pointings

Total integration time: 32 hrs
(including overheads for calibration)
rms ≅ 130μJy (outside GP)

Got new data @ 1630MHz, waiting for the third obs block within 2018

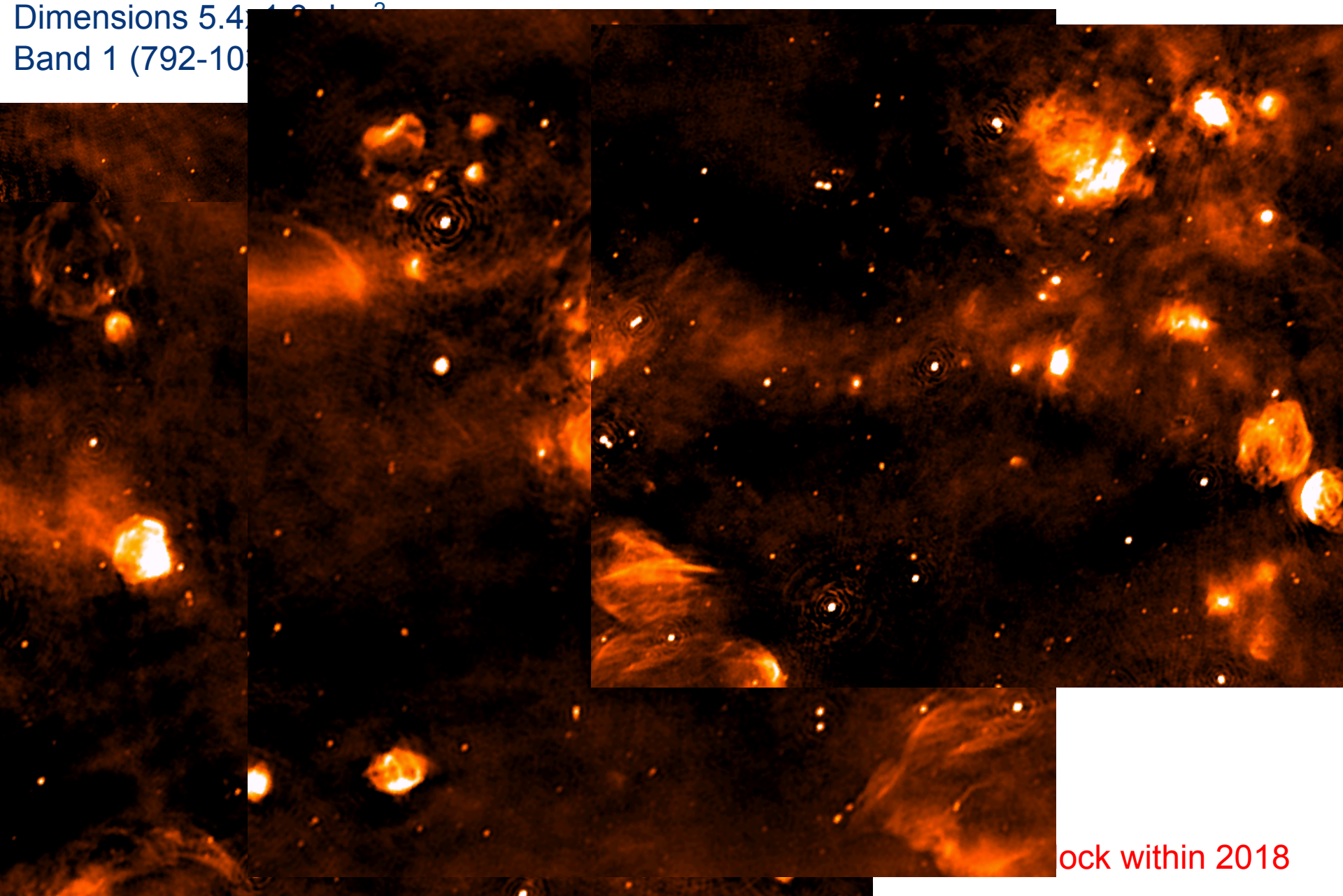
The SCORPIO field

ASKAP map

Field center 343.8 -0.2

Dimensions 5.4

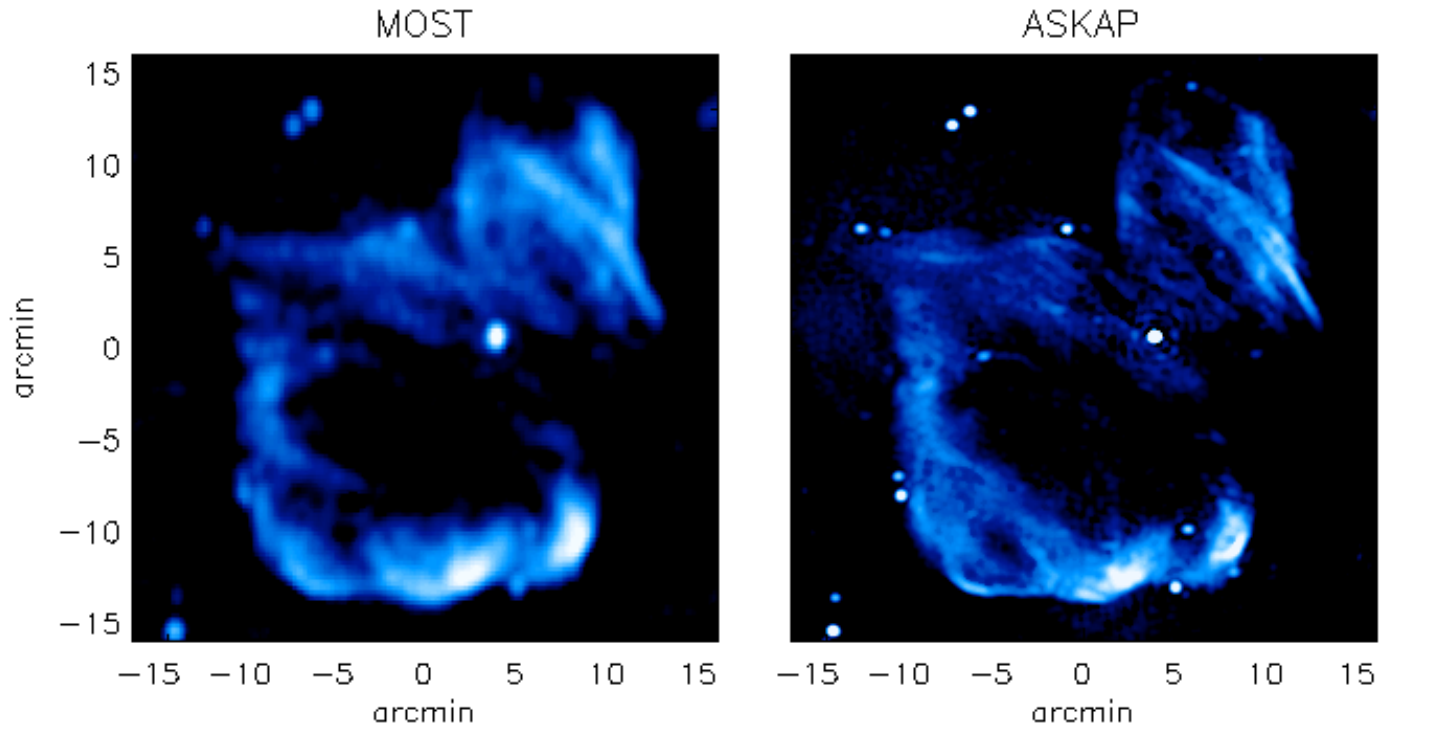
Band 1 (792-10



ock within 2018

MGPS conducted with the Molongo Observatory Synthesis Telescope

843 MHz 912 MHz

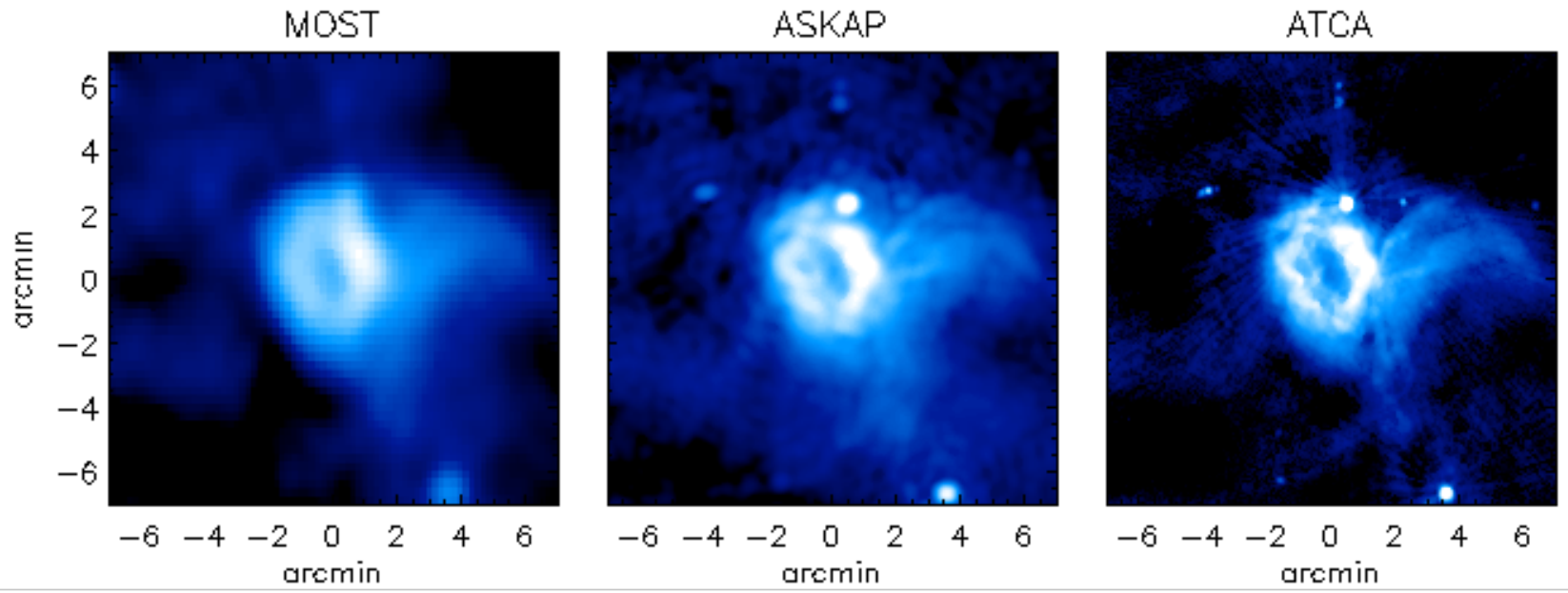


Overall structure of the remnant recovered by the two instruments

The better resolution of ASKAP (20” vs 45”) allows to appreciate fine details

Umana, in prep.

Bubble S17 (Churchell et al., 2006)

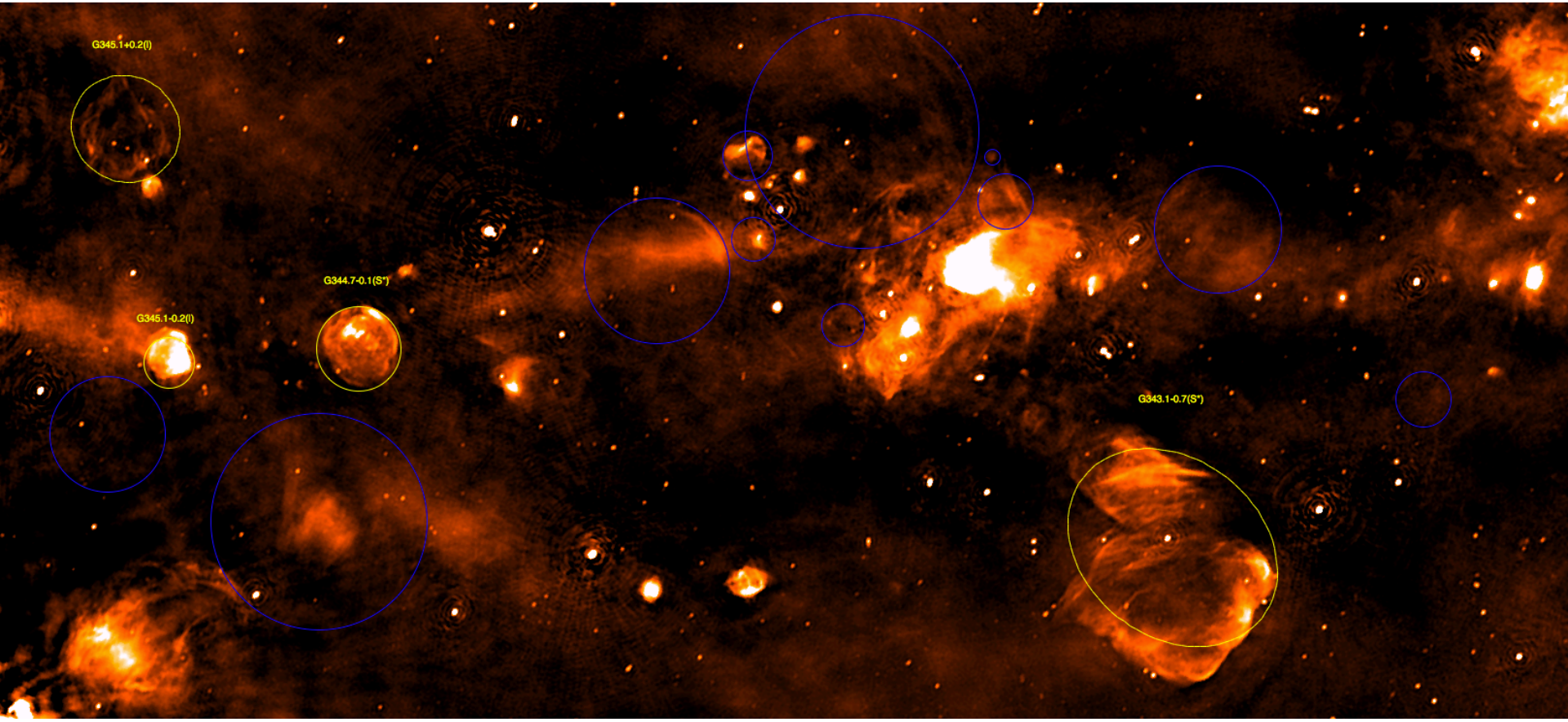


ASKAP provide the best compromise between fine details and diffuse emission

Umana, in prep.

The SCORPIO field ASKAP map

Field center 343.8 -0.2
Dimensions 5.4x1.3 deg^2



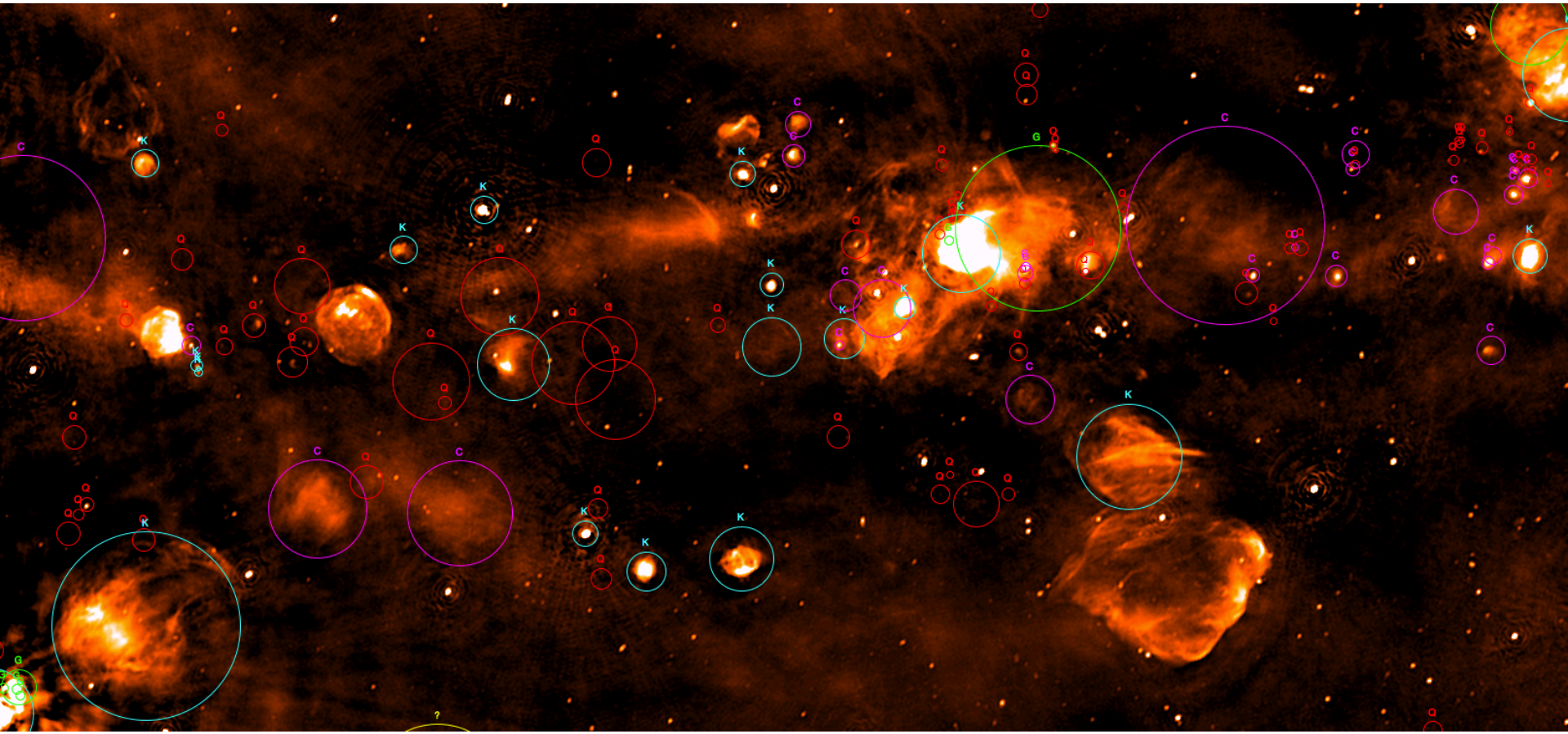
Yellow – 17 Known SNRs from Green et al. 2014
Blue – 23 new SNRs *candidates*

(Umana+ in prep.)

The SCORPIO field — ASKAP map

Field center 343.8 -0.2
Dimensions 5.4x1.3 deg^2

HII Regions as from the WISE catalog (Anderson+2014)



Light-blue	K	Known HII
Green	G	Group
Purple	C	Candidate
Red	Q	radio quiet

A total of **388 HII** are included in ASKAP map
220/388 are Q HII regions
99/220 (**45%**) are detected in ASKAP

The SCORPIO field

ASKAP map

Field center 343.8 -0.2
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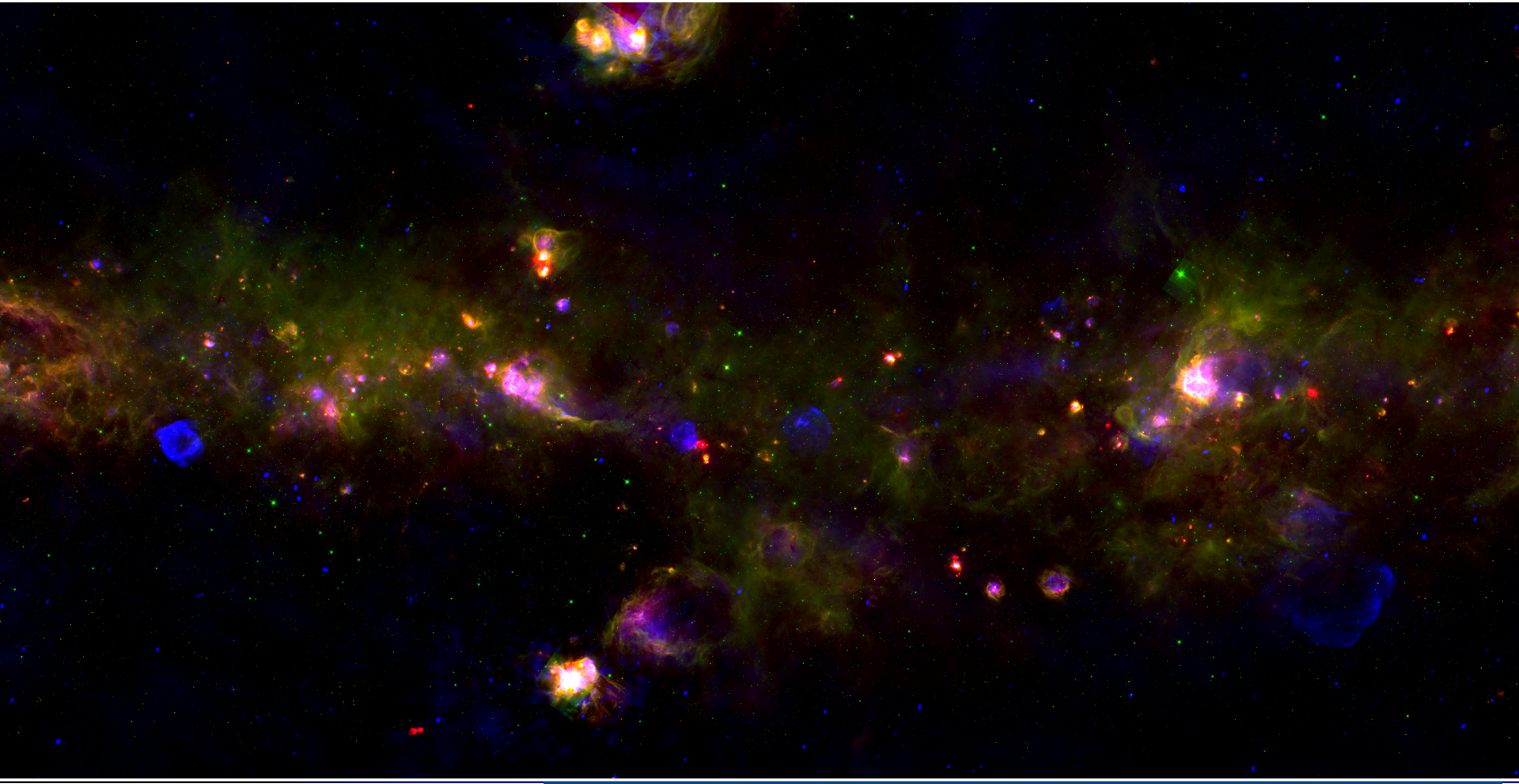
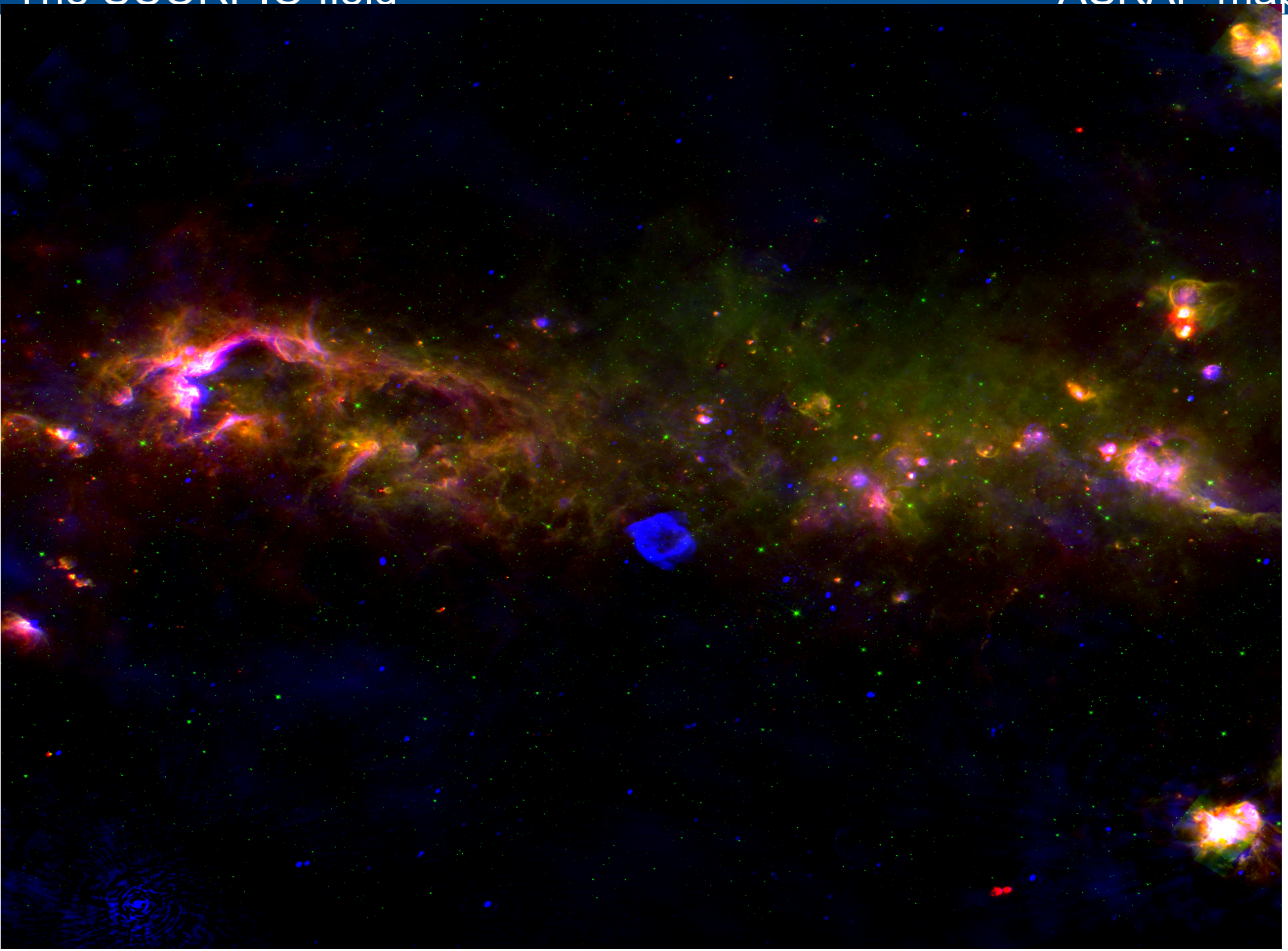
Green 8μm GLIMPSE
Red 70μm Hi-GAL
Blue ASKAP 912MHz



see next talk by S.Molinari on synergy with IR

The SCORPIO field

ASKAP map



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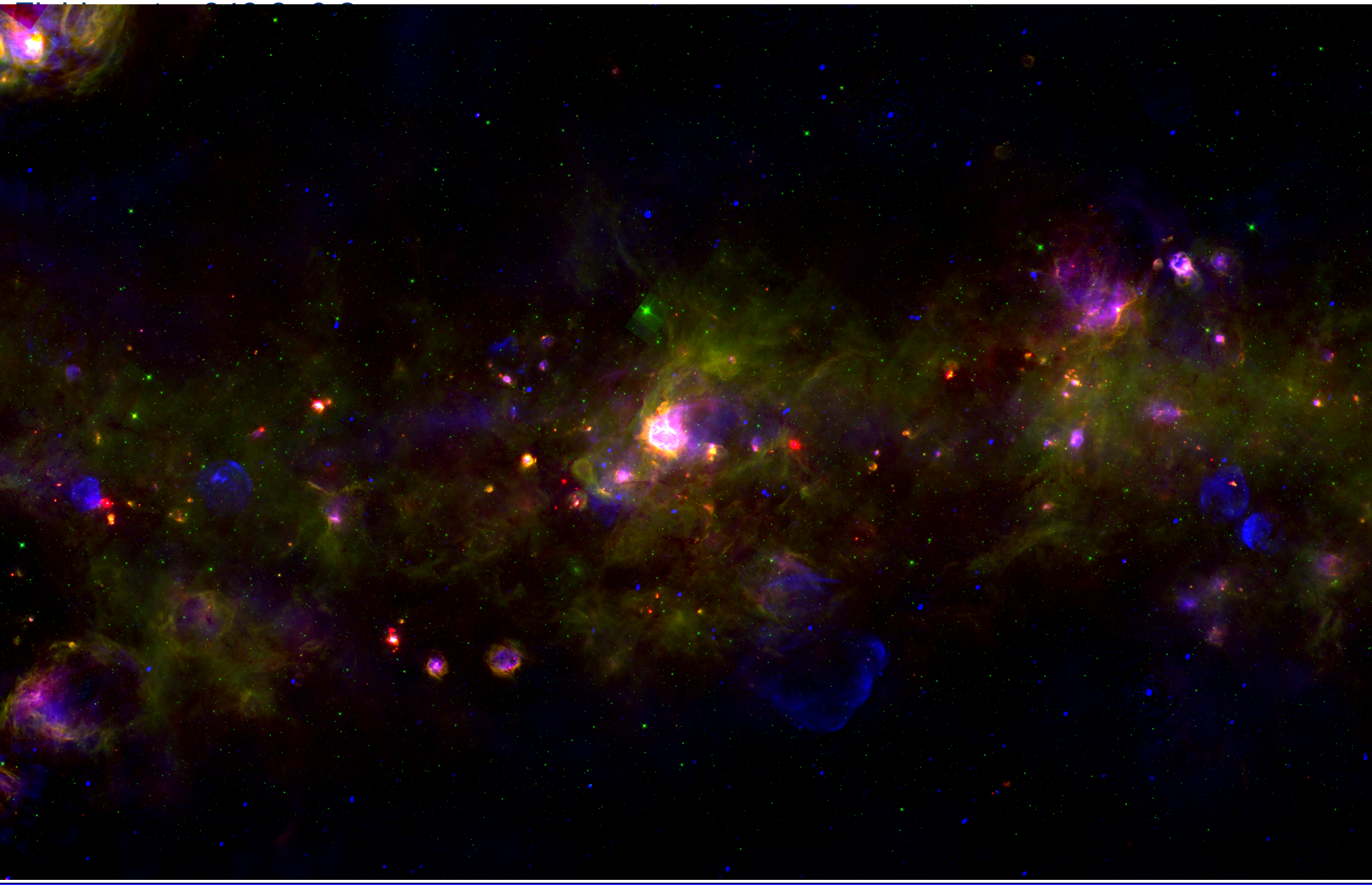


Thank you and stay tuned!

6 Staff and 2 post-doc members

Collaborators: ICT- Group (Catania): Ugo Becciani, Eva Sciacca, Fabio Vitello;
Claudia Agliozzo, Luciano Cerrigone,
Ray Norris, Thomas Franzen, Joshua Marvil
+ EMU Collaboration

ASKAP

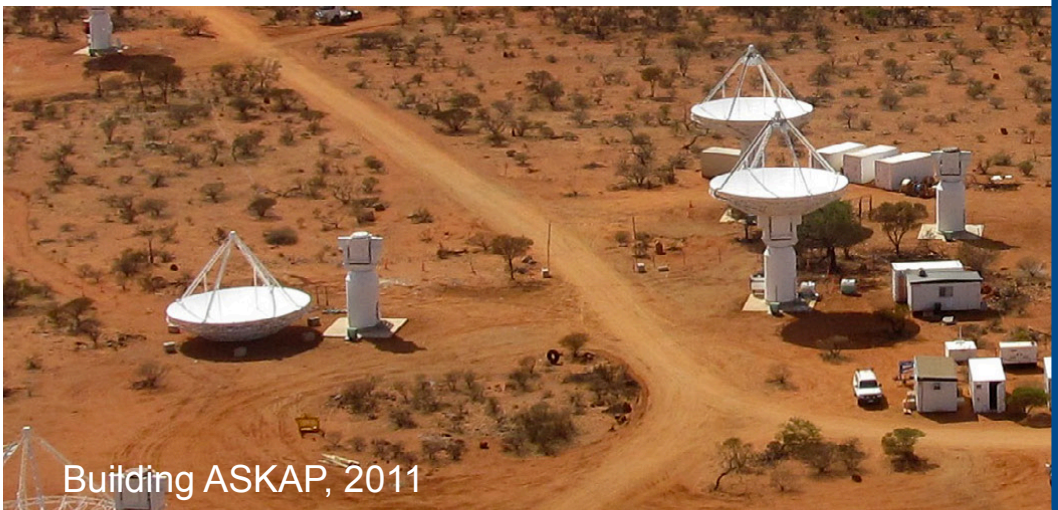
Australian SKA Pathfinder

Design specifications:

Design goals:

- **High dynamic-range imaging**
- **Wide field of view science**

→ ***SURVEYS***



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Survey speed (288 MHz, 100 μJy)	**220 deg^2/hr**
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Bandwidth	**288 MHz**
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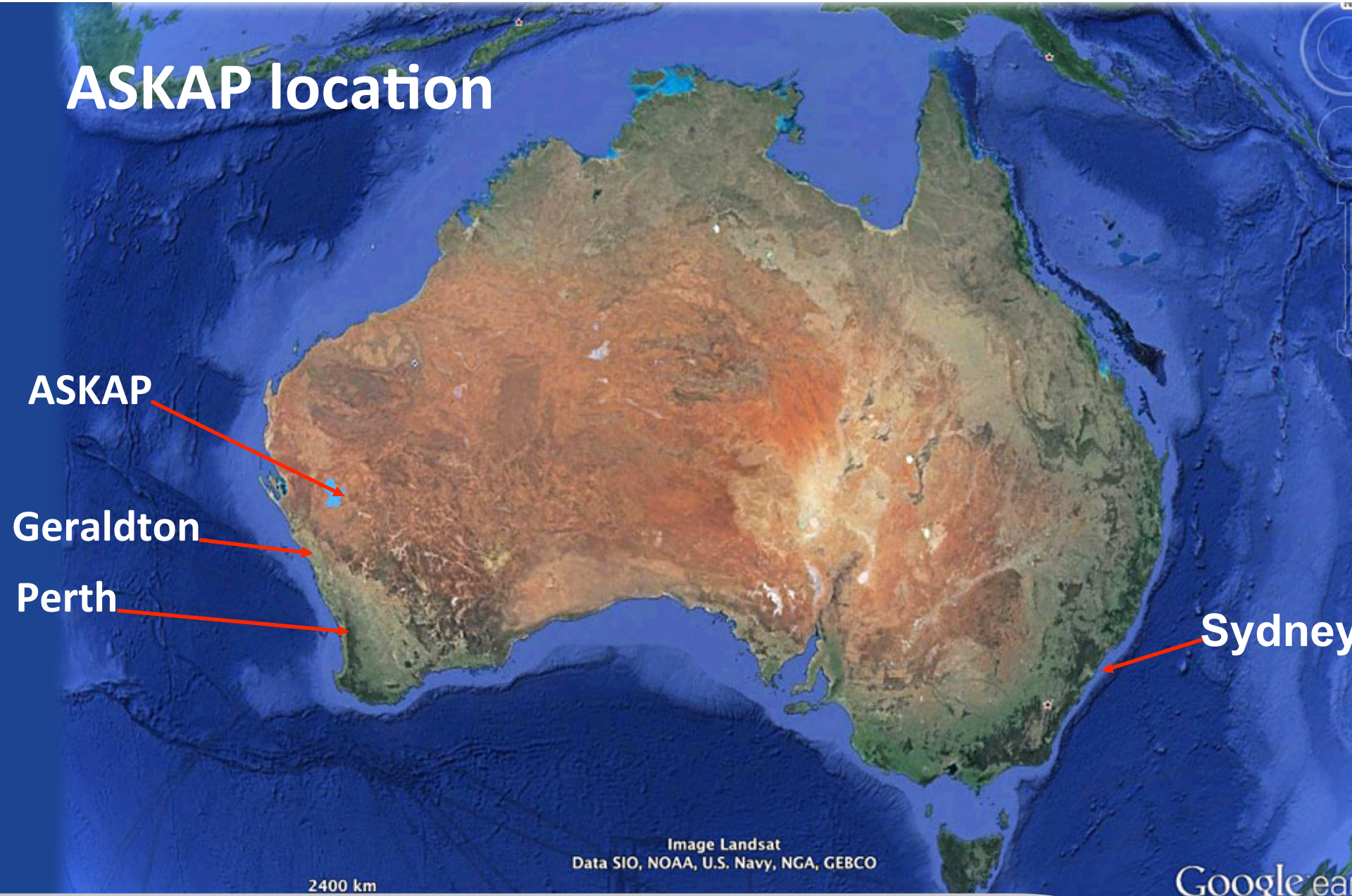
ASKAP Location



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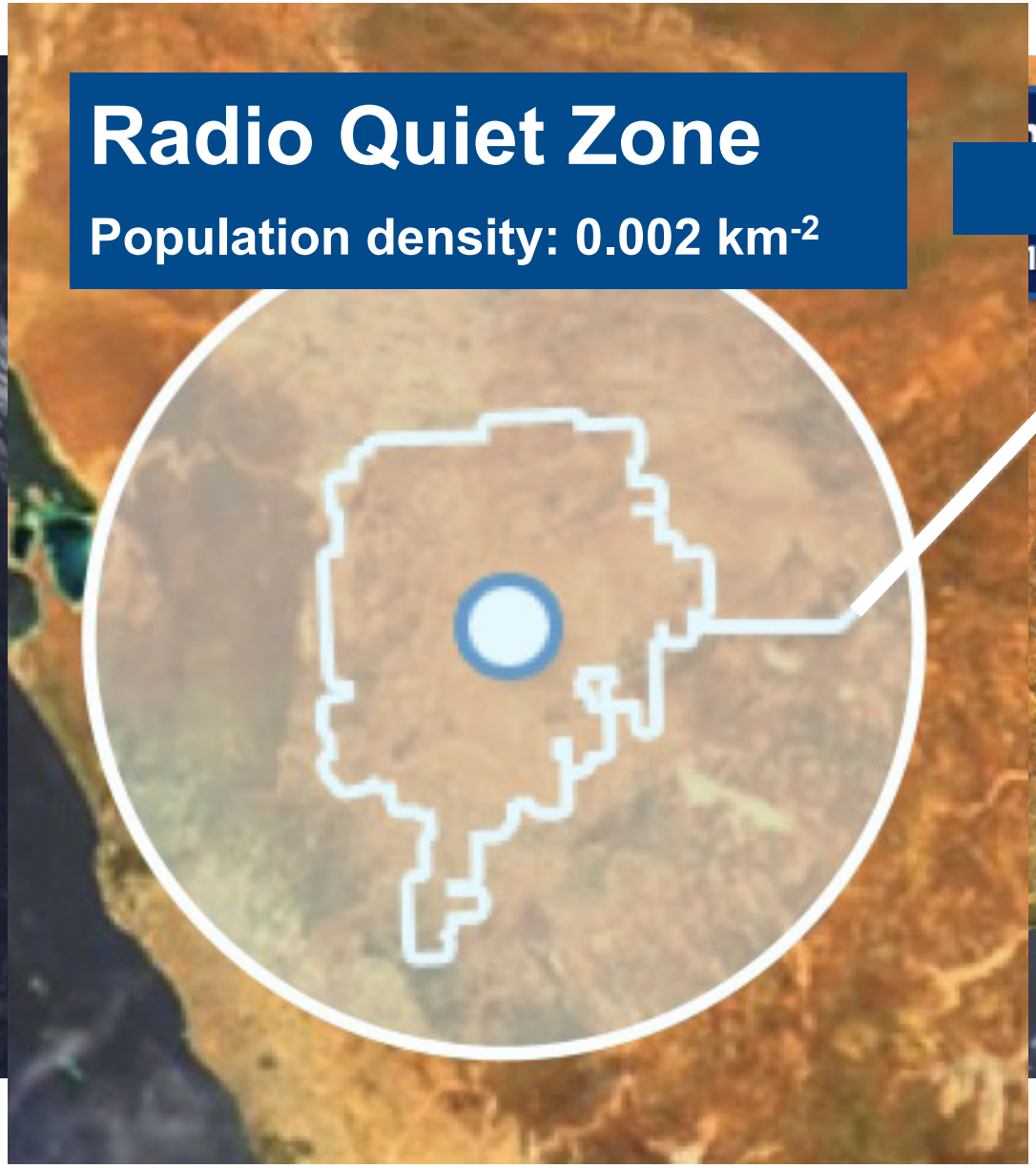


ASKAP Location

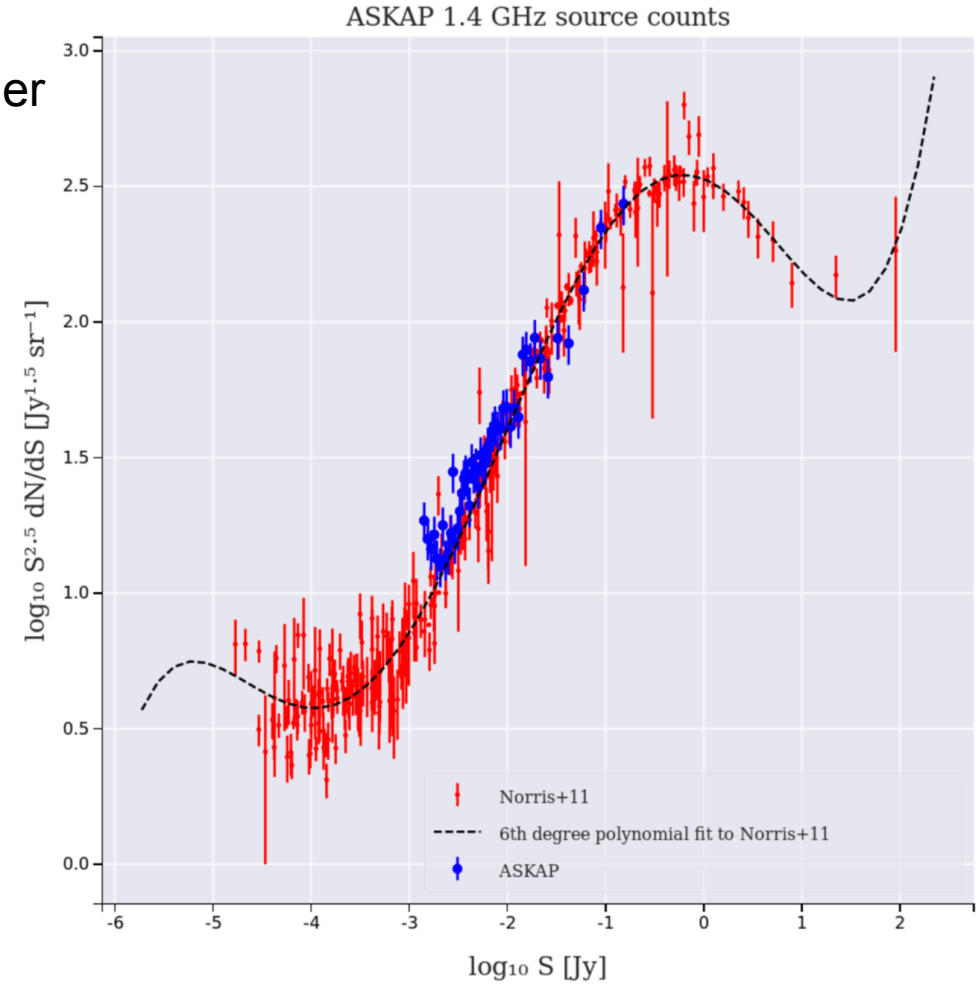
ASKAP Location

ASKAP Science Verification

ASKAPSOFT/SELAVY source finder extracted 1843 sources

Comparison with source count expected distribution (Norris+11) we found excess due to presence of Galactic objects

Distribution found assuming a α=-0.8, introducing a sistematic error.



Umana, in prep.

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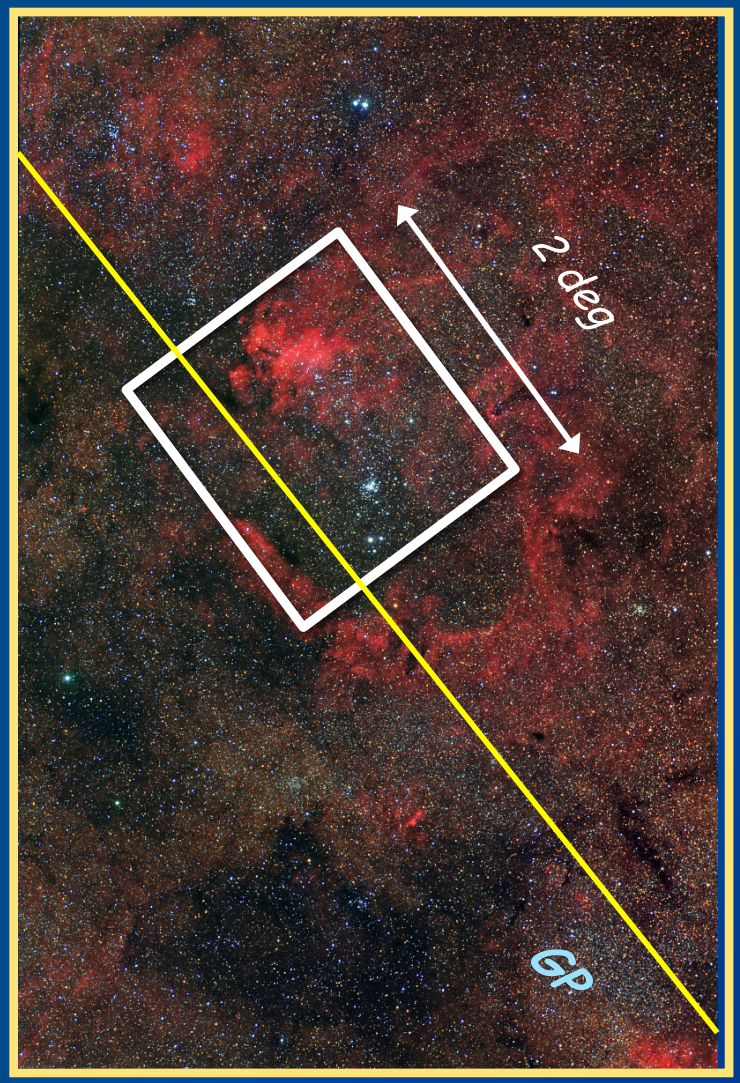
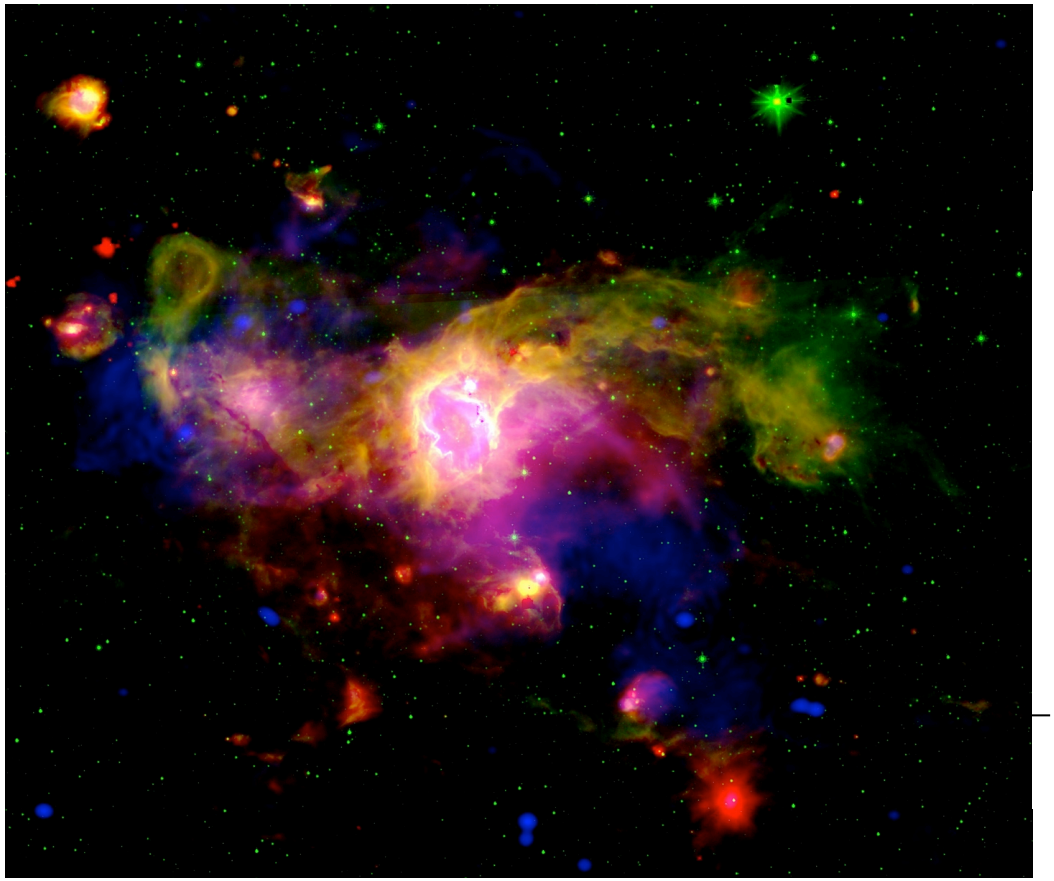
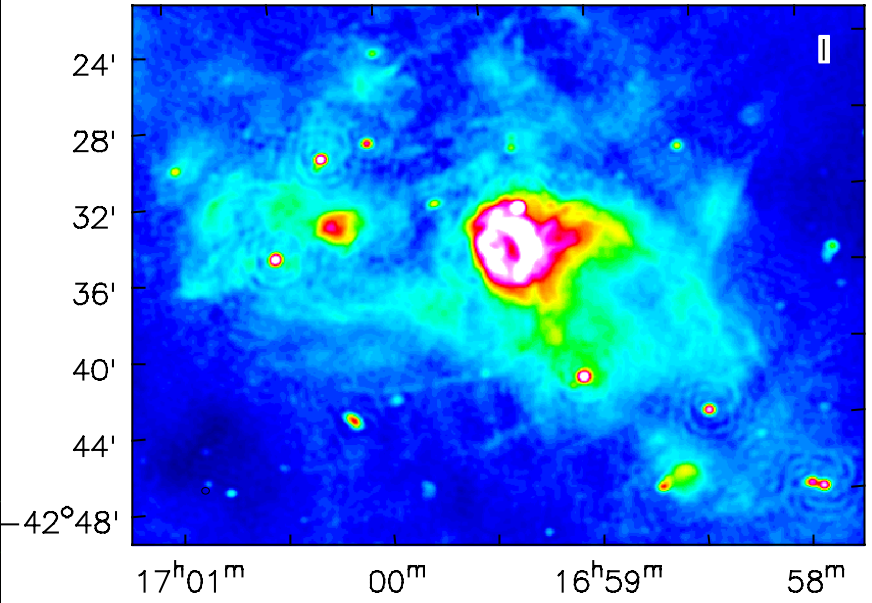


Bubble S17 -Churchell et al., 2006)

Green 8μm GLIMPSE
Red 70μm Hi-GAL
Blue ASKAP 912MHz

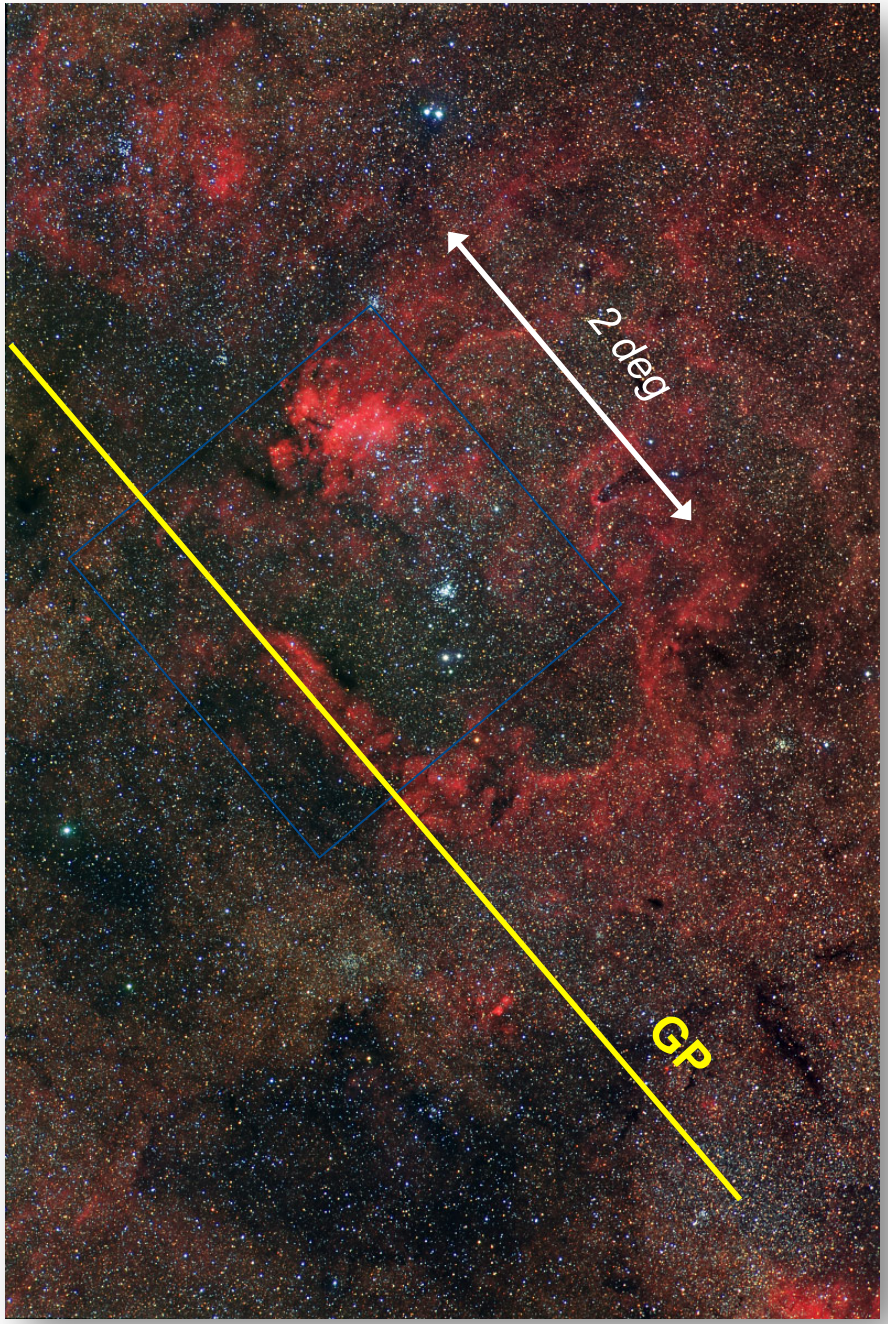


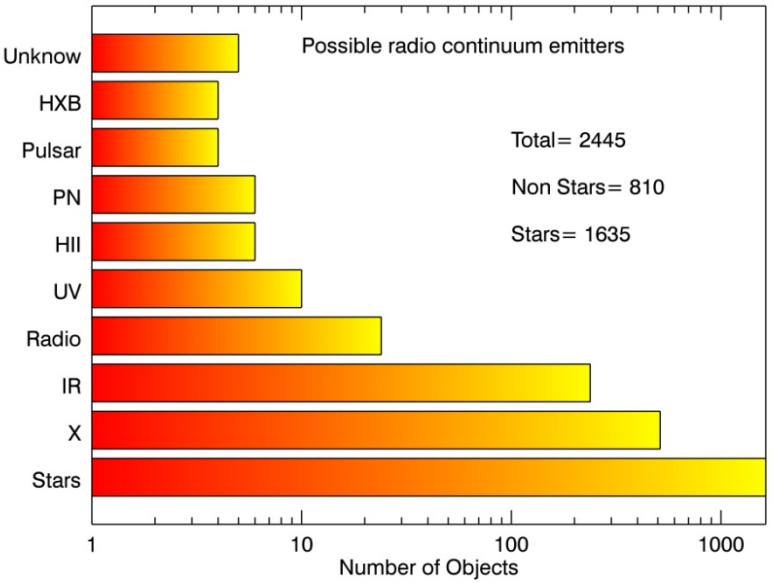


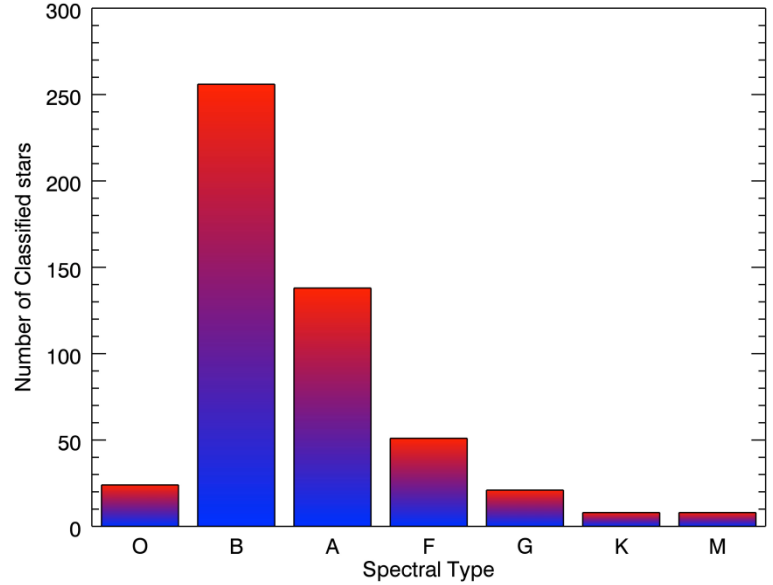
The VIALACTEA knowledgebase: a unique tool for source identification and classification

SCORPIO with ATCA

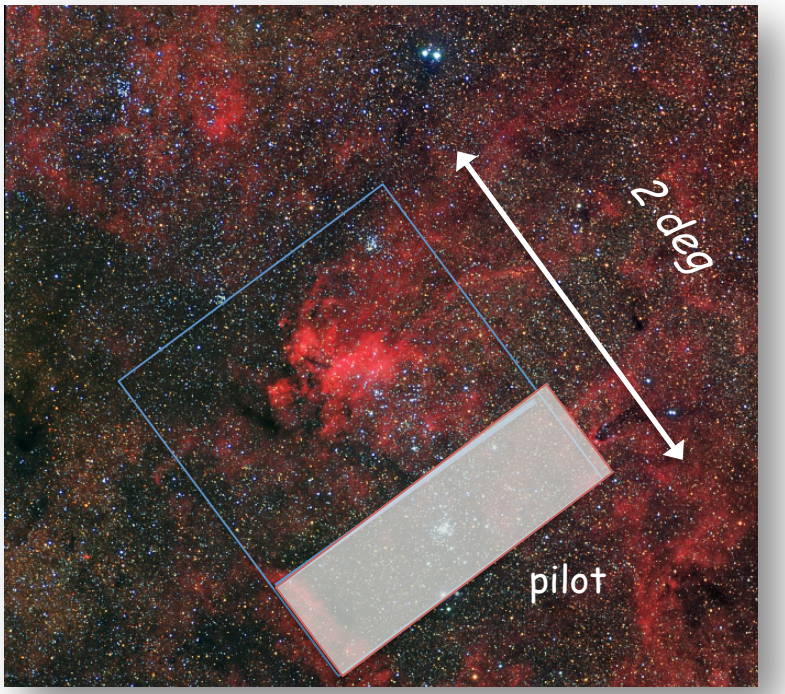
The selected field







From SIMBAD database



ATCA L-Band

total observing time= 319 hrs

Pilot experiment

¼ of the field
2011-2012
38 pointings
Configurations: 6A, 6B
(Umana + 2015)

Whole Field

2012-2013
95 pointings
Configurations: 6A, 6B

Galactic Plane, Rest

2014, 2016
51 pointings, 82 pointings
Compact Configurations:
EW367, EW352

Δν= 1.1-3.1 GHz (2.1 GHz)
CABB: 2048 chs, 1 MHz each

Mosaicing mode

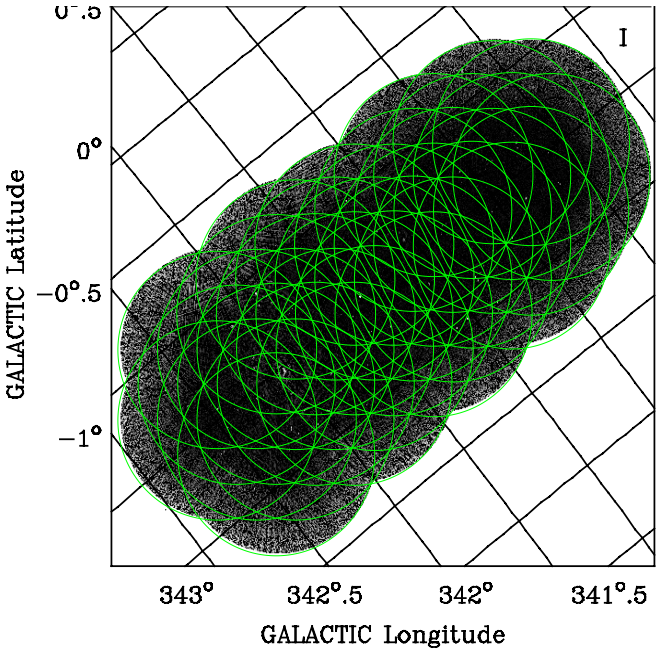
8.8’ spacing hexagonal grid
Duty cycle=1min/pointing +cal
total integration time/pointing 1.2 hr

data flagging and calibration in MIRIAD
strong RFI 1100-1400 MHz - mirflag used
MOSAICKING: individual approach (LINMOS)
each pointing divided in 7 sub-bands

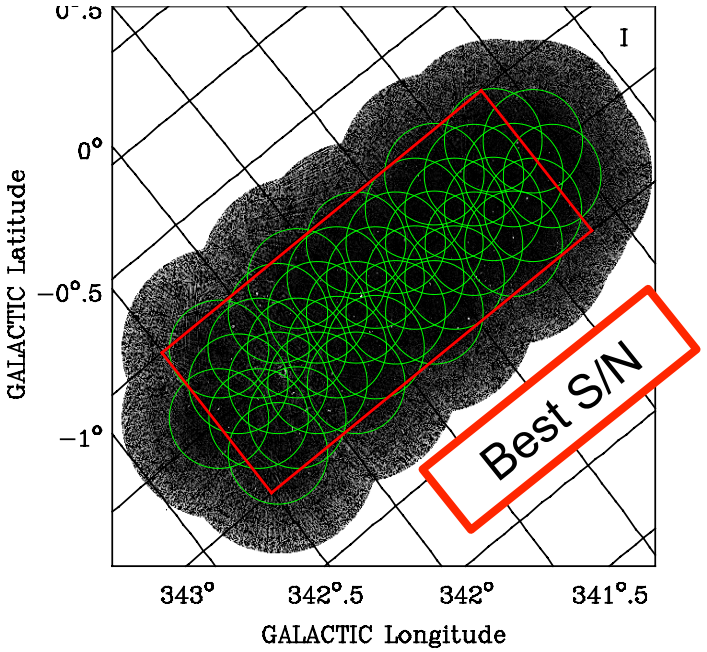
self-cal (p, p&a) in each field (with flag)
mf-cleaned and mapped
all the pointings linearly combined
all the sub-band merged

Different primary beam across the band

Lowest Frequency



Highest Frequency



ASKAP Current Status: Technical

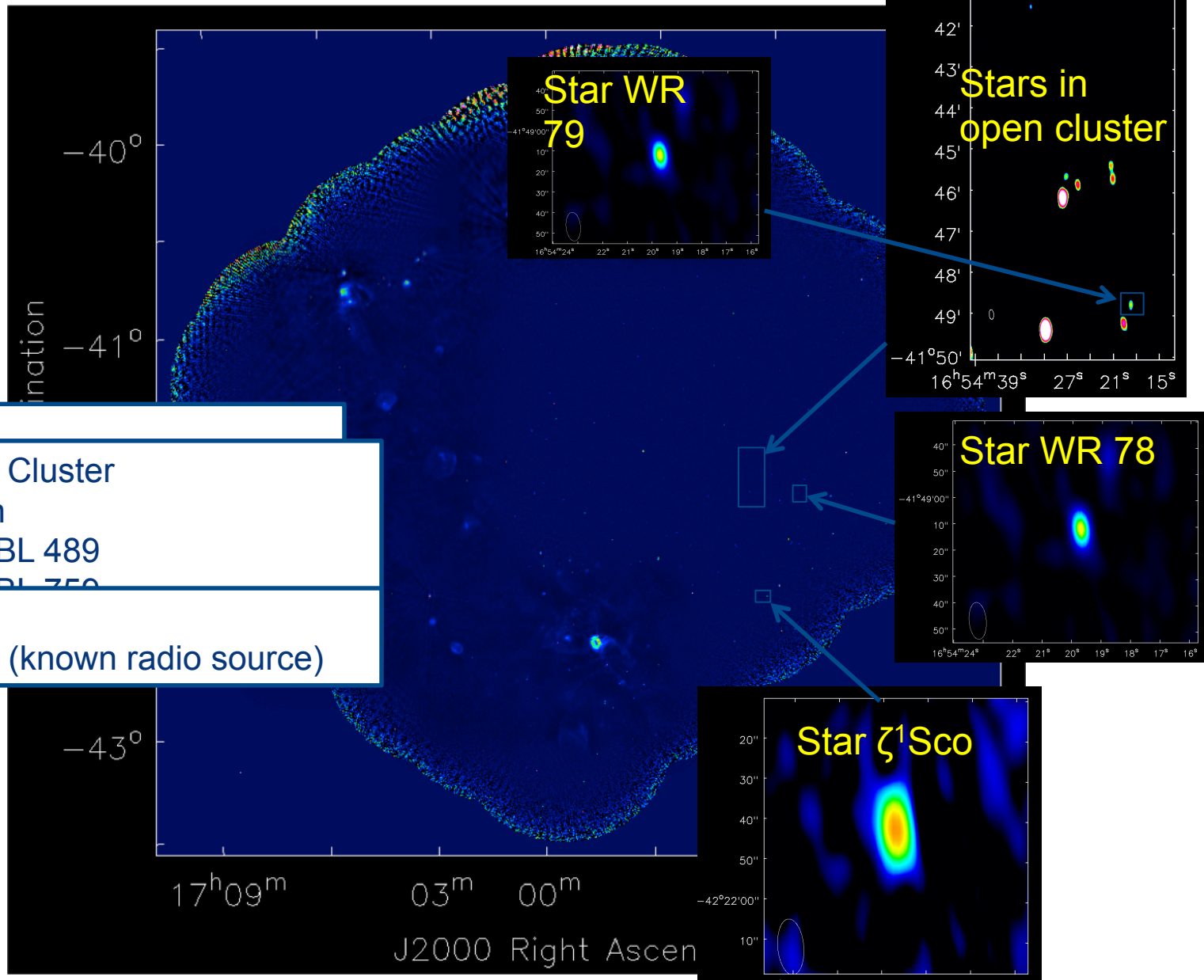
Wins:

- All 36 antennas now equipped with PAFs
- Backends complete for most of them
- Can currently observe with up to 16 antennas at 288 MHz BW
- Band 3 commissioning (1.5-1.8 GHz) completed

Need more work:

- Significant processing limitation because of limited throughput and disk space on *galaxy* at the Pawsey Centre
- RFI flagging not yet optimum
- Beam-forming and calibration not yet optimum

The SCORPIO zoo

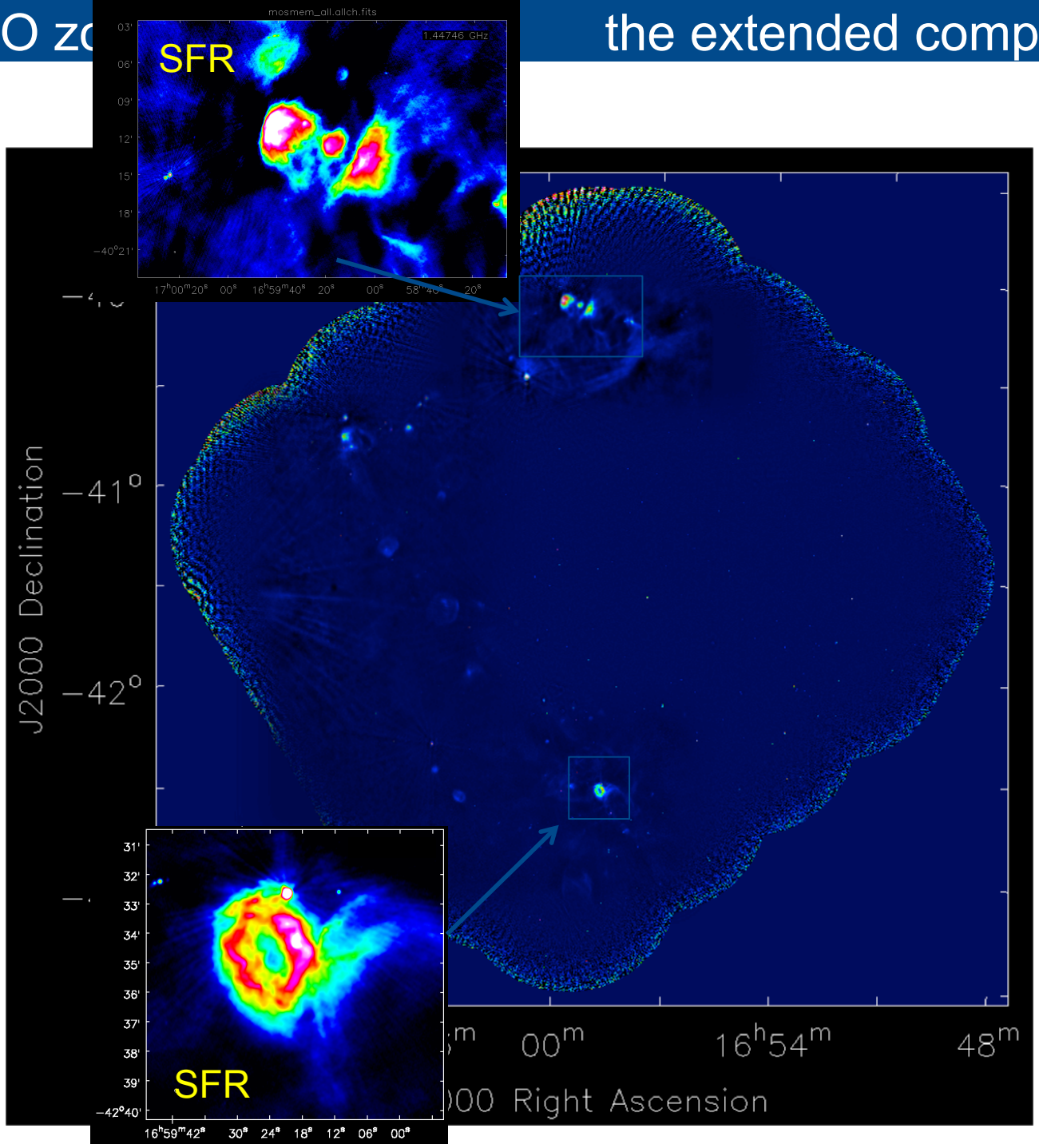


WR78

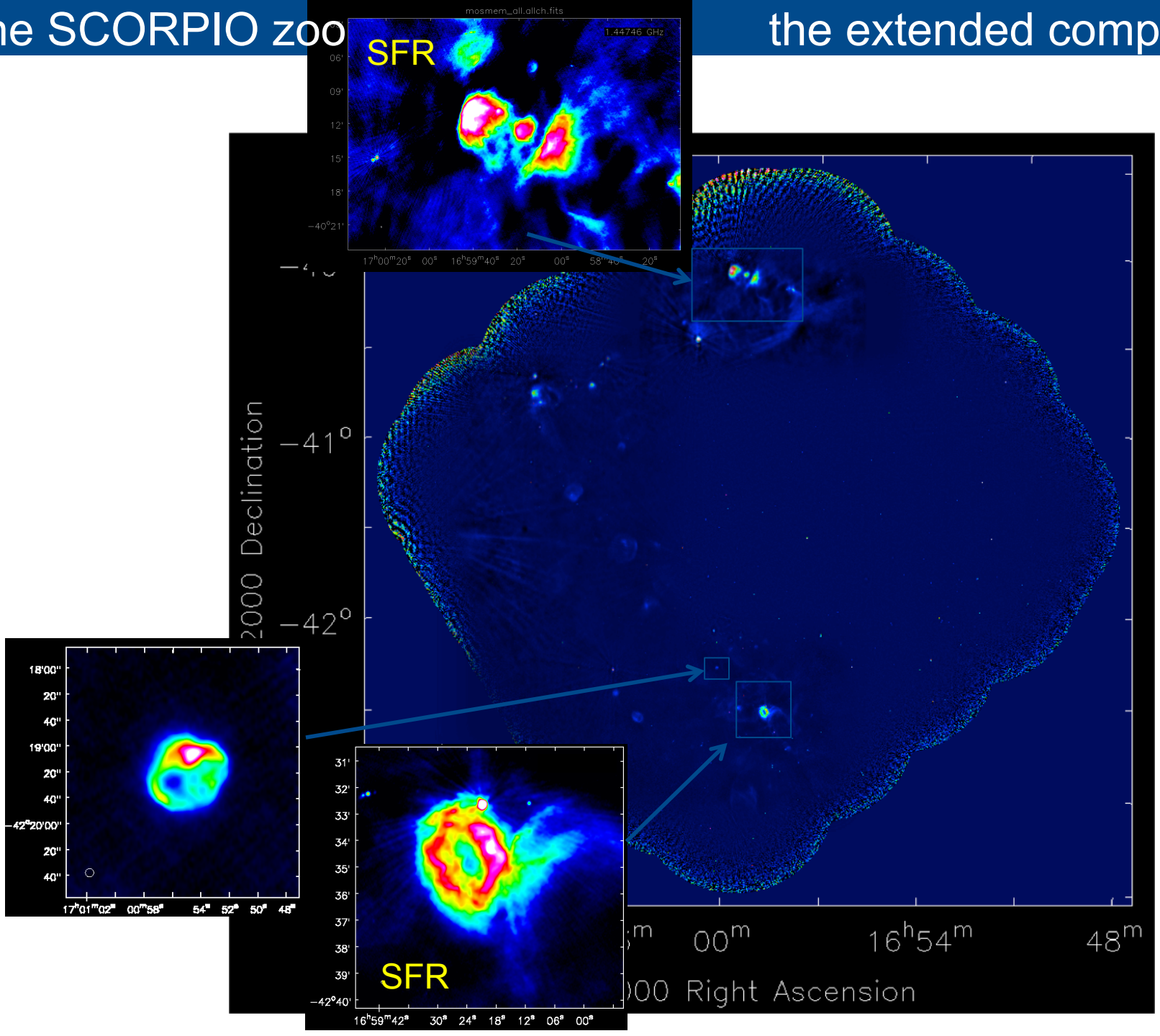
Stars in Open Cluster
New detection
-NGC 6231 SBL 489

WR 79
sp WC7+O6V (known radio source)

The SCORPIO zo… the extended components



The SCORPIO zoo — the extended components



The SCORPIO zoo — the extended components