# OUR GALAXY

## RAYMOND OONK

*(HELP FROM G. UMANA, INAF)*

* INTRODUCTION SWG
* CASE:  SCORPIO (ASKAP)
* CASE:  RRL's (LOFAR)
* PROCESSING SDP / SRC
* REFLECTIONS

# SKA Science Working Group : Our Galaxy (aka the Milky Way)

## Key science topics

Milky Way ISM and molecular cloud studies (incl. flow of material)

Proper motions of young stars in nearby clusters/clouds (incl. tomography)

Parallax and distance measurements of objects throughout the Galaxy

Variability studies throughout stellar evolution (young, MS, evolved, SNR)

Detailed (resolved) studies of individual low- and high-mass SF regions

=> Exquisite physics lab for detailed studies of: stars, the ISM and their interfaces

- 70 members & the co-chairs are: G. Umana (INAF) , M. Thompson (Hertfortshire)

- Links to all SWGs, but in particular: HI Galaxy Science, Magnetism, Pulsars, Cradle of Life, Epoch of Reionization.

# The impact of SKA on Galactic science : Large area Surveys

**Statistical studies of different populations of radio emitting Galactic Objects**

All-sky/deep

The place where you look at ***makes the difference***.
most of the Galactic sources localised in/close the GP

***The concept of generic surveys:***

- Maximize the return for "priority Science"
- Maximize the commensality

| Survey | Freq (GHz) | Band (MHz) | Area (deg$^2$) | Time (khr) | $S(\theta_S)$ (μJy) | $S_{Max}$ (μJy) | $\theta_S$ (") | $\theta_{Min}$ (") | $lg(N_C)$ | $\theta_{10K}$ (") | $\theta_{1K}$ (") |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SKA1-Mid-A | 0.95 – 1.76 | 1000 | 31000 | 8 | 5 | 3.4 | 0.8 | 0.3 | 8.3 | 12 | 30 |
| SKA1-Mid-A1 | 0.35 – 1.05 | 300 | 15000 | 8 | 5 | 3.6 | 1.0 | 0.5 | 8.1 | - | - |
| SKA1-Mid-A2 | 0.95 – 1.76 | 1000 | 20000 | 8 | 4 | 2.8 | 0.8 | 0.3 | 8.1 | - | - |
| "EMU+WLBY" | 1.1 – 1.4 | 300 | 31000 | 10 | 45 | 40 | 10 | 5 | 7.3 | - | - |
| "THOR" | 1.0 – 2.0 | 800 | 480/Gal | 1 | 18 | 18 | 15 | 8 | 5.9 | 20 | 100 |
| SKA1-Mid-D | 4.6 – 13.8 | 5000 | 480/Gal | 2 | 6 | 4 | 0.2 | 0.05 | 6.0 | 2 | 9 |
| "GLOSTAR" | 4 – 8 | 2000 | 480/Gal | 2 | 40 | 35 | 1 | 0.6 | 5.0 | 8 | 20 |

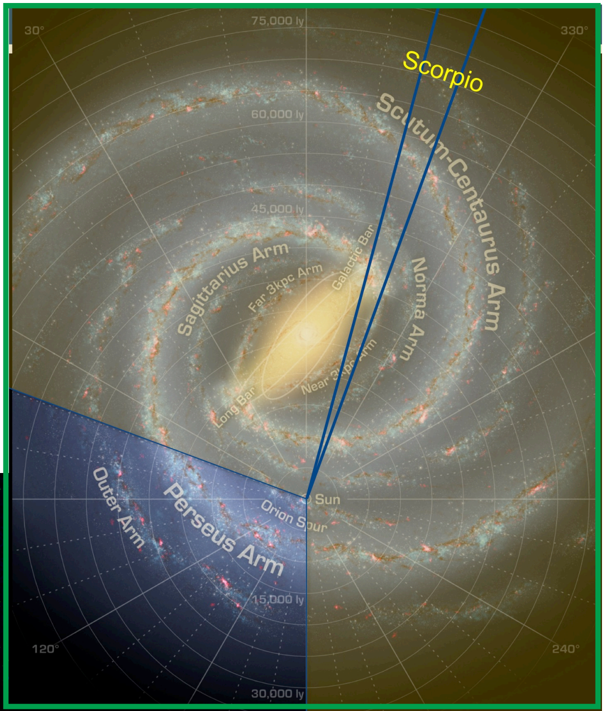
* SKA1-Low

(Oonk+2015)

Better angular resolution and sensitivity (Continuum & Spectral) than any ongoing/planned survey of the Galactic Plane

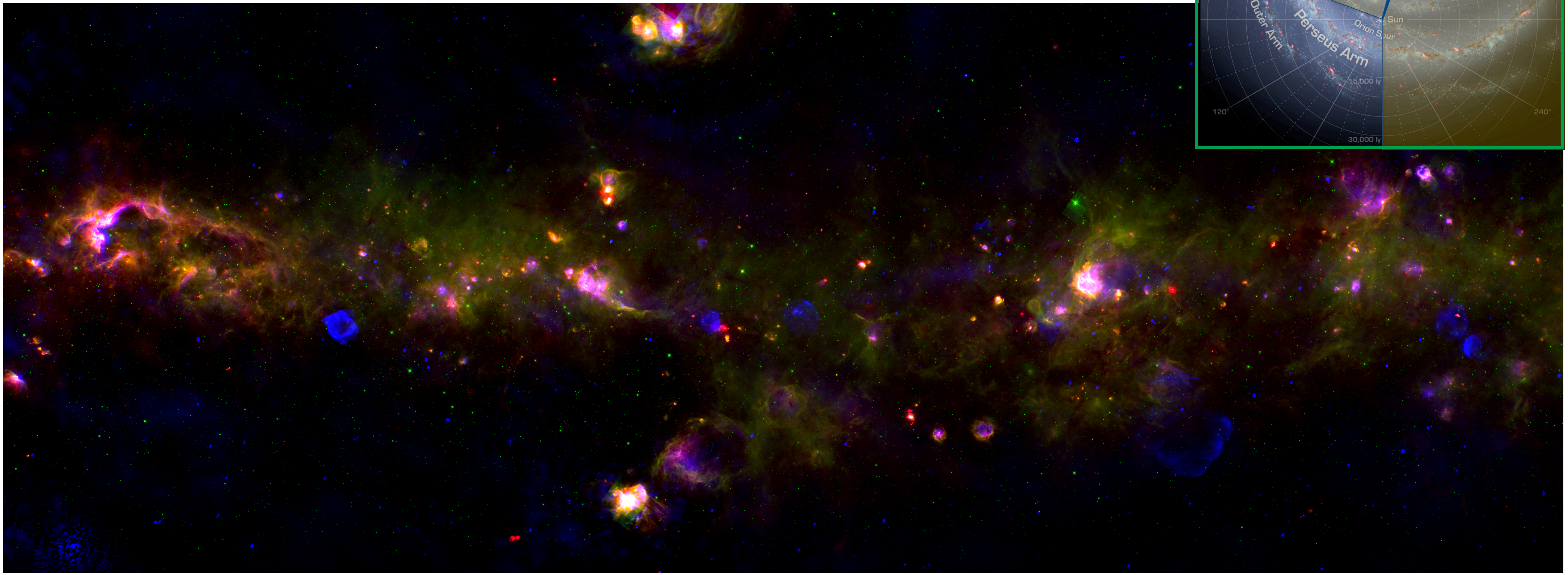
(G. Umana)

# SWG – Our Galaxy: Stellar Continuum Originating from Radio Physics in Ourgalaxy




SCORPIO (Umana+2019)
Field center 343.8 -0.2
Dimensions 5.4x1.3 $deg^2$

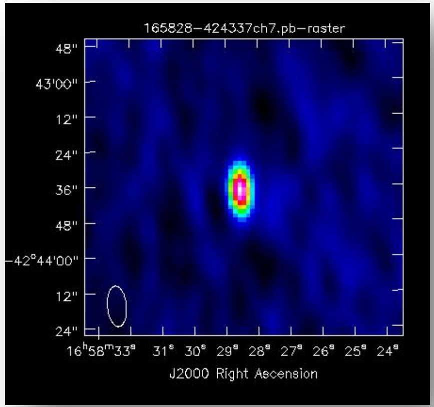
Green 8µm GLIMPSE
Red 70µm Hi-GAL
Blue ASKAP 912 MHz

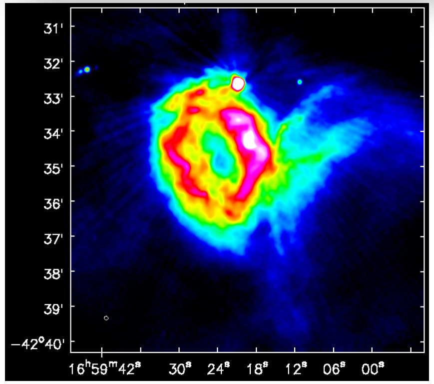


# The SCORPIO zoo - signaling the need for automation!

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

Stars:

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

***Point Sources***

6 pulsars

30 UCHII/HCHII

6 PNe

**≈ 1900 without classification**

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

***Extended Sources***

*99 in total*

*35 new detections* *64 known objects*

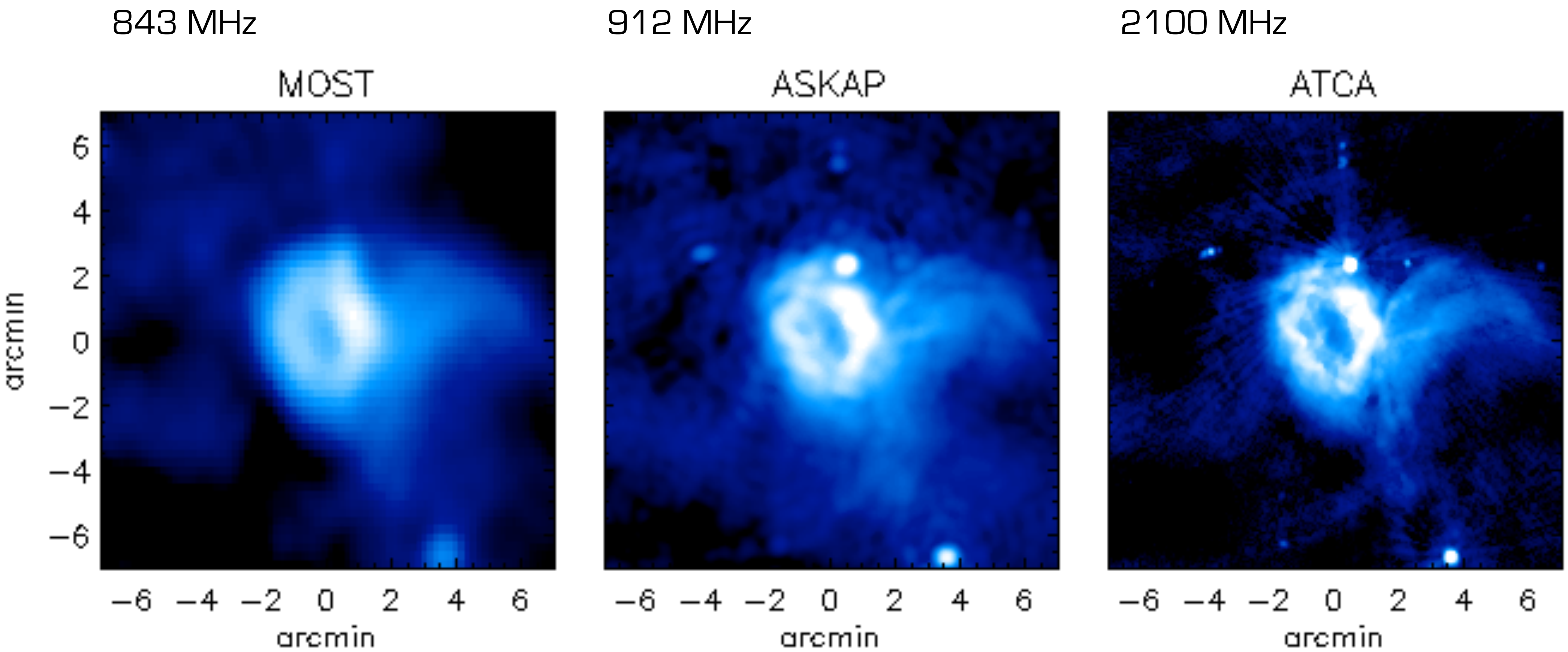
41 classified - 15 unclassified

- 39 classical HII
- 1 PNe
- 1 SNRs

(G. Umana)

# SWG – Our Galaxy: Missing zero spacings

Bubble S17 (Churchell et al., 2006)




ASKAP provides a good <u>compromise</u> between fine details and diffuse emission (Courtesy G. Umana)

# Pre-SKA : LOFAR Cassiopeia A - RRL atlas and mapping [IF]

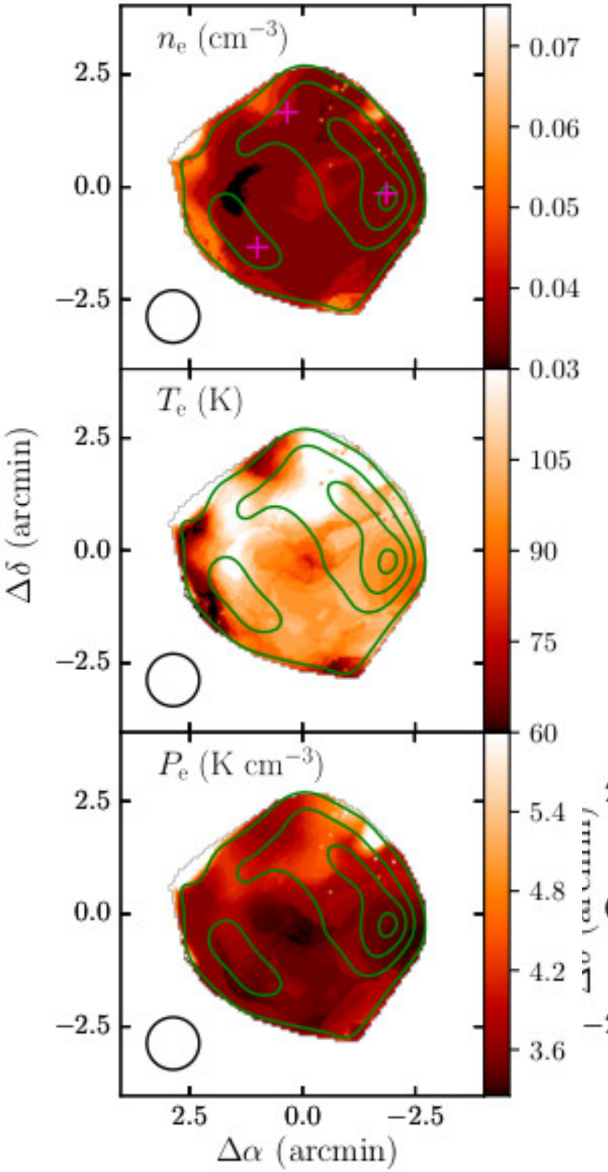
**LOFAR - IF** (0.38 kHz chn)

LBA=138 TB / HBA=357 TB

1. CREATE MODEL (VLA)
2. CALIBRATE & IMAGE[1]
3. LINE LIST / FINDER
4. LINE STACKING 2/3D
5. LINE FITTING (VOIGT)
6. RRL MODELS
7. ANALYSE & COMPARE[2]

[1] (3 MONTHS ON 5 NODES)

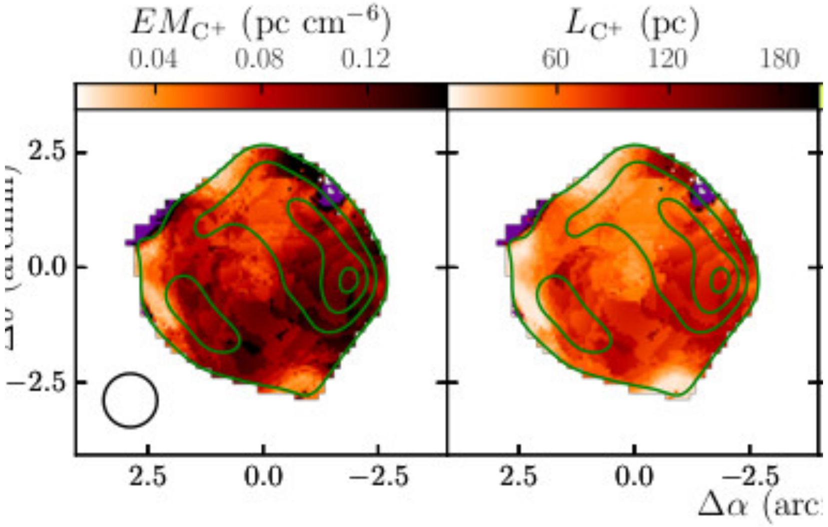
[2] (EXTERNAL DATA, E.G. CO,HI)

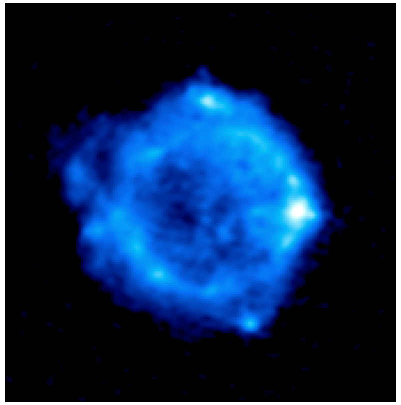



**Physical conditions** (-47 km/s, 3 CRRL) *(P. Salas)*

| | | | |
|---|---|---|---|
| $n_e$ | ~ | 0.04 – 0.06 $cm^{-3}$ | (0.04 $cm^{-3}$) |
| $T_e$ | ~ | 70 – 100 K | (85 K) |
| $EM_{CII}$ | ~ | 0.04 – 0.12 pc $cm^{-6}$ | (0.06 pc $cm^{-6}$) |
| $L_{CII}$ | ~ | 10 – 80 pc | (35 pc) |
| $N_{CII}$ | ~ | (2-6)x$10^{18}$ $cm^{-2}$ | (4x$10^{18}$ $cm^{-2}$) |

** CRRL velocity maps follow the (saturated) HI absorption*



# Pre-SKA : LOFAR Cygnus X - RRL maps with tied-array beams [TA]

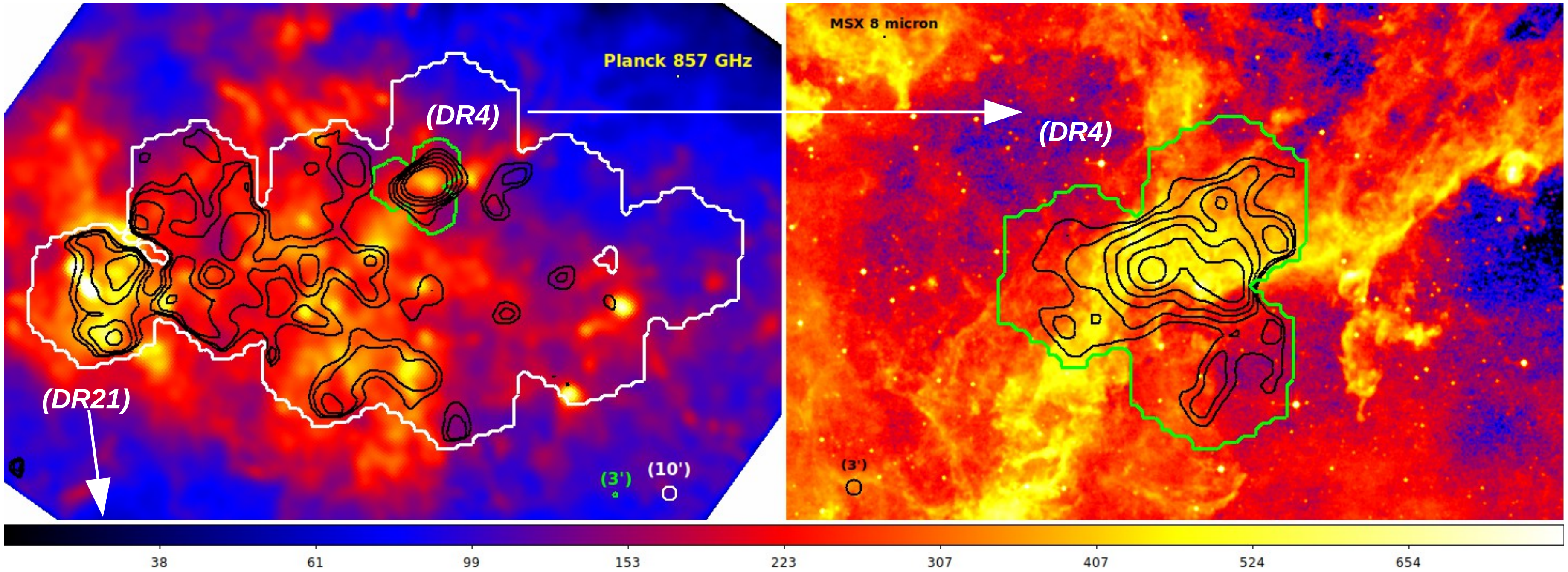
**LOFAR - TA** (0.76 kHz chn)

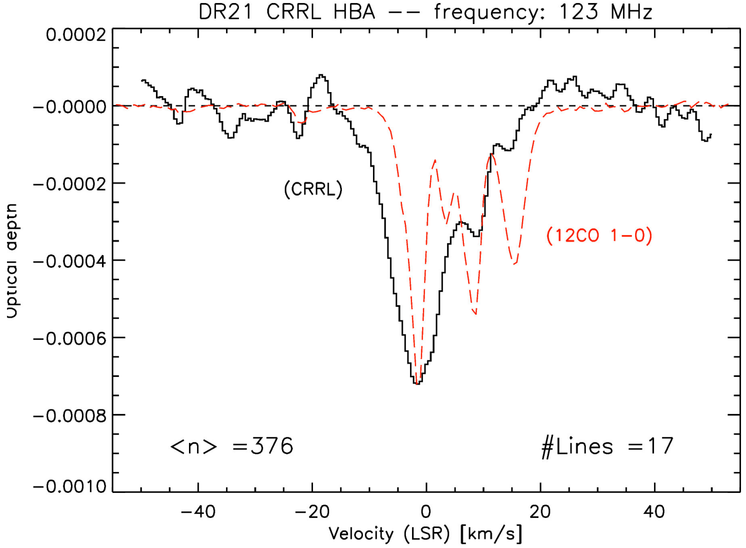
LBA=234 TB / HBA=312 TB

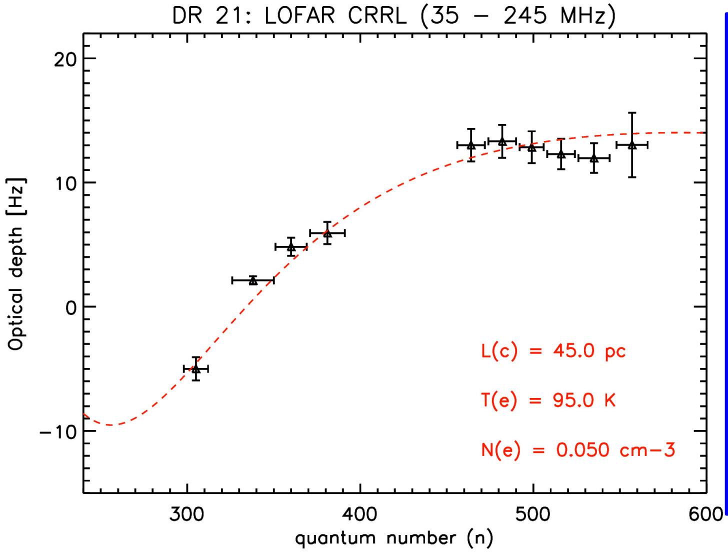
1. CREATE POINTING GRID
2. CONVERT HDF5 TO MS[1]
3. FLAG/FILTER/FLATTEN
4. LINE LIST+STACK 2/3D
5. BEAM GRIDDING
6. RRL MODELS
7. ANALYSE & COMPARE[2]

[1] (TO RUN AOFLAGGER)

[2] (EXTERNAL DATA, E.G. CO,HI)




LOFAR CRRL

* filamentary
* diffuse

best corr. (F)IR

$n_H \sim 300\ cm^{-3}$

CO – dark gas?

# SWG – Our Galaxy : Data sizes, types & processing

**Questions:**

→ Where does SDP stop and SRC start ? Appears very uncertain !!
→ Correlator capacity, compression, UV data vs. imaging products

( DIRECTLY INFLUENCES REQ's for [E]SRC )

Example: "high spectral resolution Galactic plane data with SKA1-Low"

**Imaging Products:**

*cube with 65536 channels*
*5 deg FoV*
*1 arcsec pixels*
*Req. spaxels = 2.2d13*
*32 bits spaxels*
*1 cube = 7e14 bits = 85 TB*
*XY & YY pol cubes -> 190 TB*
*Full stokes cubes -> 380 TB*
*+ continuum subtracted cubes -> 760 TB*

**UV data (512 stations, 8 hrs)**

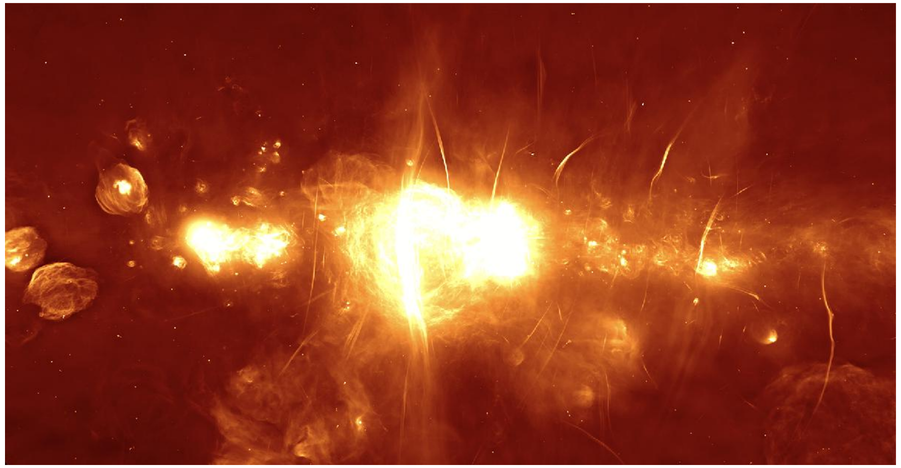
*1s-sampling, full stokes, 65536chn = 4.2 PB*
*10s prefactor calibration -> 420 TB*
*Dysco compression (/3) -> 140 TB*
*Only XX, YY pol's for lines -> 70 TB*


* Going deep may require keeping calibrated UV data to avoid being limited by image-plane artifacts
* Proper data interpretation (e.g. validating artifacts) may require many imaging products

# SWG – Our Galaxy: Summary & Reflection

**Observation Setup**

1) IF data scales with BW & n*(n-1)/2 baselines (SKA/LOFAR=300) , TA data only scales with #TA-beams & BW
2) High resolution spectroscopy (cold gas, little velocity smearing)
3) Large bandwidth (sensitivity , lines)
4) VLBI (high spatial resolution)
5) Time critical observations (variability)
6) Co-observing with other SWG/KSP



⇒ *Potentially some of the largest SKA data sets !!*

**Processing Issues**

1) All spatial scales are present and can be important (complexity)
2) Detailed calibration models do not (yet?) exist
3) Multi-scale imaging (deconvolution) for >10^2 range in scales is not robust (manual)
4) Zero spacing addition via single dish data is non-trivial

⇒ *Processing to science-quality products requires complex orchestration and iteration of tasks that have not (yet) been automated (i.e. human setup & validation)*

⇒ *Embarassing parallelization of flow is important, but not always possible (map complex/demanding pipelines)*

⇒ *Radio processing (algorithms) are going through a major renaissance in many sub-fields. How important will CI/CD and dev/ops be in 2025 and how will the 'generic user' benefit ?*

SURF