# The Galaxy

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## SWG the Galaxy

#### Late addition to working groups

- Not represented in the early science goals
  - Most science topics in SKA book under CoL
- Overlap with science in other SWG
  - e.g. HI, Magnetism, CoL

### But exciting and fundamental

• After all a lot of what we know about the Galaxy originates from radio astronomy



includes:

The Our Galaxy presentations from the 2014 SKA Science Meeting can be found here.

SKA-NL Science Meeting, Dwingeloo, 24 May 2018



#### **Our Galaxy**

This is the listing of the Galactic (note the capital 'G') science working group, addressing science within the Milky Way. This

 Milky Way ISM and molecular cloud studies (including the flow of material, Galactic spectral line work) Proper motions of young stars in nearby clusters/clouds (including 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 star-forming regions







## SWG the Galaxy team:

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Broad representation and expertise
Lots of overlap with other SWGs

## Main theme, baryonic cycle

- How do galaxies work?
- What is the flow of material from & to the Circum-Galactic Medium, the Interstellar Medium and stars?
- What powers the ionisation of the Warm Ionised Medium?
- How do molecular clouds form?
- What is the relation between molecular clouds and star formation "laws"?
- How do stars drive turbulence & energy into the ISM?
- What can the structure of stellar clusters tell us about star formation?
- What is the SNR/PNe formation rate in the Milky Way?



## Galactic HI

- SKA to detect HI reservoir accreting onto Galaxy
- Measure cold ISM through absorption on high extinction lines





Putman, Peek & Joung (2012 ARA&A); Westmeier (2007);





## Radio Recombination Lines

- SKA will be a recombination line mapping machine:
  - Can simultaneously map 50 H $\alpha$  (+ He $\alpha$  + C $\alpha$  RRLs) in Band 2 and 25 in Band 5
  - Band 2 RRL mapping speed of SKA1-mid comparable to VLA continuum mapping speed
  - SKA-Low unique probe of diffuse ISM via low frequency Carbon lines
  - Broad frequency coverage traces different electron densities
  - Multiple lines from multiple atoms allows metallicity, abundance, radiation field to be measured





## And molecular absorption

#### • For example in H<sub>2</sub>CO

- Very sensitive due to anti-inversion
- Even absorption against CMB









- limited sensitivity & selection bias



## (Commensal) surveys

### • Ideas for surveys developing

### Galactic plane narrow spectral

- 5-10 GHz (& 10-15 GHz followup)
  - 0.1 K rms in 0.1 km/s (line)
- Main science driver spectral line:
  - RRL, H<sub>2</sub>CO absorption, CH<sub>3</sub>OH masers?

#### • Galactic plane wide continuum

- 5-10 GHz, 3 µ]y rms (continuum)
- Galactic Bulge |b| < 10?
- Main science driver continuum:
  - Stellar evolution, from Cradle (YSO) to Grave (PNs etc)

## Targeted observations of nearby clusters

• Variability of Pre-Main Sequence stars



#### Special survey of the Galactic Centre



## Astrometry of (non-thermal) stars

- Many pre-main sequence stars active radio emitters
  - Can map depth of molecular clouds
  - History/gradient of star-formation

#### • Synergy with CoL

- Grain growth vs
- Ionisation, HII regions
- Magnetic, non-thermal activity, binaries



SKA-NL Science Meeting, Dwingeloo, 24



#### Recent results on Ophiucus, Ortiz-Leon et al 2017a,b



## In the age of Gaia?

#### • In many case in synergy with Gaia

- Although Gaia catalogue has 1.3E9 entries and VLBI only 2E2...
- Not a subset of Gaia sample

### Gaia will revolutionise samples

- Of PMS stars
- And evolved stars
- Gaia poses new question on the assembly of Galaxy
  - Recent and past mergers...
  - Stellar populations and kinematic structures

#### Gaia confirmation of the hard work put into VLBI astrometry



## **Evolved stars**

#### Mira-like AGB stars with circumstellar shells

- Have (optical &) IR counterparts
  - OH, H<sub>2</sub>O and SiO masers
- Probe the (relaxed) stellar content

#### • BAaDE project

- Using 28000 targets, ±70% detection rate
- After dynamics of the Galactic Bar

#### • Example of coverage by Gaia

- From overlapping samples
- Limited to 4kps radius

#### • But astrometry at GC distance?

- Probably requires coverage of the 43GHz
- If not with SKA?
  - ALMA (band 1 or 86 GHz in band 2)
  - ngVLA (also include long baselines)





## High mass star formation

### Ideal for measuring size of Galaxy

- Distance scale & rotation curve
  - Full Galaxy not accessible to Gaia
- BeSSel project
  - 6.7, 12 GHz CH<sub>3</sub>OH
  - 22 GHz H<sub>2</sub>O masers

### And location of the Spiral arms

- Classification of Milky Way
- Induced star formation?

### Practically limited to Northern Sky

- Checked against biases
- But inner Galaxy largely unexplored



## Simulations got some exposure...



SKA-NL Science Meeting, Dwingeloo, 24 May 2018





## Precursor ... MeerGAL survey...

## Supposed to uses the 10GHz band to find HII regions

- Also 12 GHz CH<sub>3</sub>OH masers
- But not 6.7 GHz...
- In the Southern hemisphere
- But receivers for this not (yet) funded

3300 hours of MeerKAT awarded

- Survey the Carina, Crux & Norma Arms
  - 280 < I < 350 and |b| <1
- 3 epochs with 1 year cadence
  - Single epoch 5 $\sigma$ :
  - 60 µJy/bm (cont)
  - 7 mJy/bm (line)
- Stacking of RRLs







## Wrap up

### • The Galaxy is asking for

- Band 5 receivers
  - Some require long, some compact baselines
  - And even higher frequencies
- VLBI capabilities
- SWG activity should be ramping up
- Clusters being defined to address KSP topics:
  - Stellar evolution (radio stars etc.)
  - Star formation (census of star formation across Galaxy)
  - Galactic HI (also covered in HI SWG)
  - ISM (RRL, molecular lines, absorption)
  - Galactic centre
  - Galactic structure (spiral structure, bar)
- 'Ambassadors' to communicate with other SWG
- Most focus on commensal surveys in the Galactic plane
  - Interest in the higher frequencies
  - Interest in VLBI
- Meeting in Catania this July(?)

