The Galaxy

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- **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

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**Our Galaxy**

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

- 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

The Our Galaxy presentations from the 2014 SKA Science Meeting can be found [here](#).
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
Radio Recombination Lines

- SKA will be a recombination line mapping machine:
  - Can simultaneously map 50 Hα (+ Heα + Cα 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$_2$CO
  - Very sensitive due to anti-inversion
  - Even absorption against CMB

![Diagram showing spectral lines and band details]
Radio stars

- Exciting prospect to detect many more
  - Currently ~420 radio detected stars (Guedel 2002)
  - B field & topology in flare stars, RS CVn
  - HII region in dust enshrouded sources
  - Wind-wind interactions
  - Stellar magnetospheres
  - Planetary nebulae shaping by jets?

- SKA will address current problems of limited sensitivity & selection bias
(Commensal) surveys

- Ideas for surveys developing
- Galactic plane narrow spectral
  - 5-10 GHz (6-10-15 GHz followup)
    - 0.1 K rms in 0.1 km/s (line)
  - Main science driver spectral line:
    - RRL, H$_2$CO absorption, CH$_3$OH masers?
- Galactic plane wide continuum
  - 5-10 GHz, 3 μJy 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
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

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 $1.3\times10^9$ entries and VLBI only $2\times10^2$…
  • 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$_2$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$_3$OH
    - 22 GHz H$_2$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

Reid et al. 2014; Sanna et al. 2017
Green et al., 2011
Simulations got some exposure...
• Supposed to uses the 10GHz band to find HII regions
  • Also 12 GHz CH$_3$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 < l < 350 and |b| < 1
    • 3 epochs with 1 year cadence
      • Single epoch 5σ:
        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(?)