Galactic and Magellanic Evolution with the SKA
Co-Authors:

Snezana Stanimirovic & Claire Murray (UWisc, USA)
John Dickey (UTas, Australia)
Josh Peek, Mary Putman & Susan Clark (Columbia Uni, USA)
Marc-Antoine Mivilles-Deschenes
Joss Bland-Hawthorn (USyd, Australia)
Enrique Vazquez-Semadeni (UNAM, Mexico)
Di Li (NAOC, China)

... on behalf of HI SWG
Circum-Galactic Medium

Stars
How do galaxies work?
How do galaxies work?
What are the flow rates to and from the disk?
Gas Accretion

Putman, Peek, & Joung (2012 ARA&A); Westmeier (2007); LAB data
Galaxy Fuelling: The Magellanic Template

Milky Way in Hydrogen
Galaxy Fuelling: The Magellanic Template

Galactic All-Sky Survey
Δν=1 km/s
-400 km/s to 500 km/s
Angular resolution: 16’
rms T_b~55 mK

Milky Way in Hydrogen
How do galaxies lose their gas?

M82. Credit: NASA, ESA, and The Hubble Heritage Team (STScI/AURA)

MW GSH277+00+36: McClure-Griffiths et al. (2003)
 Triggered Accretion?

Can cool gas expelled trigger cooling?

- Measure $T$ along clouds
- Association with disk events

Fraternali et al. (2013)
What is the hydrogen cycle of galaxies?
How much unstable gas?

From Millenium Survey of 79 sources we believe (with big error bars):

- 60% of HI is WNM
- 48% of WNM is unstable

Millennium Survey (Heiles & Troland 2003)
Heating and Cooling in the Magellanic Clouds

Demography and phase mix driven by heating and cooling processes

- UV radiation field in SMC and LMC 4 - 10 times higher than MW
- Rates should vary with metallicity and UV field
- But no variation in MW to R<25 kpc, so:

Census of CNM, UNM and WNM in the LMC and SMC as a test

Wolfire et al. (1995)
The Temperature of the WNM and Lyα Radiation Field

Murray et al. (2014)
SKA will tell us about the transition of cold atomic to molecular...
The Structure of Cold Gas
How do you form a molecular cloud?

Atomic to molecular transition

- Distribution of cold gas around molecular clouds?
- Temperature of the gas?
- How does this differ with metallicity?
- Does the HI influence the outcome?

Simulations by Heiner, Vazquez-Semadeni et al
How do you form a molecular cloud?

Atomic to molecular transition

- Distribution of cold gas around molecular clouds?
- Temperature of the gas?
- How does this differ with metallicity?
- Does the HI influence the outcome?

Simulations by Heiner, Vazquez-Semadeni et al
How do you form a molecular cloud?

Atomic to molecular transition

• Distribution of cold gas around molecular clouds?
• Temperature of the gas?
• How does this differ with metallicity?
• Does the HI influence the outcome?

Simulations by Heiner, Vazquez-Semadeni et al
Flow rate and molecular cloud formation

If large velocity width of molecular clouds indicates gravitational contraction, SFR of Galaxy would be 100x observed!

• Is the linewidth turbulence?
• Variations in optical depth and velocities toward close sources measure turbulence

Zamora-Aviléz, Vázquez-Semadeni, Colín 2012
\[
\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0
\]
\[ \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \]

Kinetic Tomography
Stars from GAIA/Pan-STARRS/LSST

> $10^{12}$ elements
Stars from GAIA/Pan-STARRS/LSST

position

> 10^12 elements

velocity

dimension

velocity
Stars from GAIA/Pan-STARRS/LSST

> $10^{12}$ elements
SKA puts it all together
Strawman SKA1 and SKA2 surveys
One spiral, one dwarf, one irregular...

SMC: Stanimorivc et al 1999

MW model credit: NASA/Hurt
The Galactic HI Absorption Grid
The Galactic HI Absorption Grid

T > 4000K
The Galactic HI Absorption Grid

$T > 4000K$

$1000K < T < 4000K$
The Galactic HI Absorption Grid

T > 4000K
1000K < T < 4000K
T > 200K
The HI Absorption Grid

Absorption measured towards 5-10 sources deg\(^{-2}\)
4000+ sources (>700mJy) with \(\tau<10^{-4}\) for WNM measurements
Commensal with extragalactic HI and/or continuum

- Needs 1.5 kHz channels over 5 MHz around 1420 MHz
ASKAP - BETA Galactic HI

BETA+PKS

-30.7616 km/s

ATCA primary beam
ASKAP - BETA Galactic H

ATCA primary beam
ASKAP - BETA Galactic H

Galactic Evolution

with the SKA

Naomi McClure-Griffiths

ASKAP - BETA Galactic H

BETA+PKS

$\text{J}1555-7940$

$\nu_{\text{LSR}} \text{ (MHz)}$

$S \text{ (Jy)}$

$\text{J}1556-7914$

$\nu_{\text{LSR}} \text{ (MHz)}$

$\nu_{\text{LSR}} \text{ (km s}^{-1}\text{)}$

$S \text{ (Jy)}$

Bright Ascension

$00^h 15^h 40^m 20^m 00^m$
The multi-scale SKA meets the multi-scale ISM

A 10”, sub-K emission survey over $3\pi$ str

Distribution of the CNM with $\sim 15'$ res
## Targeted SKA1 GHI Survey

<table>
<thead>
<tr>
<th>Area</th>
<th>Dwell Time (hr)</th>
<th>$\sigma_T$ (30&quot;)</th>
<th>$\sigma_S$ (5&quot;)</th>
<th># absorption deg$^{-2}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCs</td>
<td>200</td>
<td>0.3 K</td>
<td>0.3 mJy</td>
<td>25</td>
</tr>
<tr>
<td>Galactic Plane</td>
<td>50</td>
<td>0.6 K</td>
<td>0.6 mJy</td>
<td>14</td>
</tr>
</tbody>
</table>
Relevant Survey Speeds

Surface brightness survey speed for $\Delta v = 0.3$ km/s

Survey speed for $\Delta v = 0.3$ km/s

$\sim 1$ kHz spectral resolution = 0.3 km/s
Galactic and Magellanic Evolution with the SKA

Naomi McClure-Griffiths
Galactic and Magellanic Evolution with the SKA | Naomi McClure-Griffiths
Galactic and Magellanic Evolution with the SKA | Naomi McClure-Griffiths
Summary

With SKA we can use the Milky Way and Magellanic Clouds to understand how galaxies evolve

SKA1 will tell us:
- about the thermal state of gas moving in and out of the disk
- where all of the cold gas is in the Milky Way and measure its properties
- the flow of hydrogen from circumgalactic medium through all physical scales to molecular clouds
- whether gas escapes the disk to the circumgalactic medium or recycles
- how the phase distributions vary with metallicity and UV radiation field

SKA1 will also give us:
- 4D maps of the ISM within ~2kpc
- Foreground for cosmology
  - NH at <20” accurate estimates of reddening, X-ray absorption, etc.
  - measurements of gas distribution and temperature from 50 K to 10000K at <15’ res

SKA2 will give us:
- All-sky distribution and temperature calibration of hydrogen to 5” resolution