SKA HI Key Projects after Herschel

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In 2015 SKA Science Book, in the chapter on HI surveys, Meyer et al. list 83 multi-wavelength instruments that are relevant to SKA HI surveys.
Specific star formation rate = star formation rate/stellar mass

Star-forming Galaxy Main Sequence

Z=2
Z=1
Z=0

Red and Dead

Motion of galaxy along the Galaxy Main Sequence

Catastrophic ‘quenching’ of star formation
The Herschel ATLAS

- The widest area extragalactic survey with Herschel (~ 550 sq deg)

- Covers 5 bands with PACs and SPIRE (100, 160, 250, 350, 500 μm)

- Five fields: North Galactic Pole (150 deg²), South Galactic Pole (250 deg²), and three fields (50 deg² each) coincident with the field surveyed in the deep spectroscopic survey of the Galaxy and Mass Assembly (GAMA) project

- Detects half a million sources

- All data released for the GAMA fields (h-atlas.org): 113,937 sources, 44,835 identifications, 23,778 spectroscopic redshifts
Two Herschel Samples

• The Herschel Reference Survey – a survey designed to contain most of the stellar mass in a volume of the local Universe (323 galaxies)
  
• The Herschel ATLAS – a submm survey of the relatively nearby Universe (∼120,000 galaxies at z<0.4)
  
Photometry in 21 bands from the ultraviolet to the submm

Photometry in 16 bands from the ultraviolet to the submm

The Herschel ATLAS for z<0.1

- No clear distinction between a star-forming galaxy main sequence and a region of passive galaxies
- Galaxy morphology varies gradually along the distribution of galaxies
Evidence for rapid cosmic evolution

- From the luminosity function (Dye et al. 2010; Wang et al. 2016)
- From the dust-mass function (Dunne et al. 2011)
- From the star-formation function estimated from bolometric luminosities (Marchetti et al. 2016)
- From star-formation-rate function estimated from continuum radio observations (Hardcastle et al. 2016)
New Results on Galaxy Evolution from Herschel

- Rapid galaxy evolution at low redshift (even significant evolution by a redshift of 0.1), whether one looks at the submm luminosity function (Dye et al. 2010, Wang et al. 2016), dust masses (Dunne et al. 2011) or star-formation rates (Hardcastle et al. 2016; Marchetti et al. 2016).
- 20-30% of galaxies in Herschel ATLAS have red optical colours and would have been classified as ‘passive galaxies’ using optical criteria
- Rather than a star-forming galaxy main sequence (GMS) and a separate region of passive galaxies, galaxies lie on a single extended main sequence
- Galaxy morphology varies gradually along the GMS
- Star-formation efficiency falls along the GMS

Other evidence that galaxies form a single population

• ATLAS3D survey of early-type galaxies shows kinematic evidence of a disk in 86% of cases, and for 92% of these ‘fast rotators’ there is photometric evidence of a disk.
• Herschel observations show 50% of early-type galaxies contain a cool ISM (Smith et al. 2012).
• Integral-field spectroscopy from the SAMI survey (Cortese et al. 2016) implies early- and late-type galaxies form continuos class.
Why all the theoretical models fail

• Models that invoke rapid quenching naturally explain a star-forming GMS and a separate region of passive galaxies but do not explain a continuum of galaxy properties

• Models such as the gas-regulator (bathtub) model in which gas is continuously supplied to galaxies can not explain the rapid low-redshift evolution because dark-matter halos are not evolving much at low redshift.
The Flaky Faucet Model

- Model in which gas supply is cut off from galaxies with a probability proportional to stellar mass
- After the gas is cutoff, galaxies evolve as ‘closed boxes’
- Naturally explains the curved GMS and the fast low-redshift evolution
Basic Lessons for HI Key Projects

• Not just enough to observe HI because that only gives you the atomic phase. The dust mass gives you a useful measurement of the total mass of the ISM (Eales et al. 2012; Genzel et al. 2015; Scoville et al. 2016).

• Really important to study the evolution of the low-z Universe (z < 0.4) because (a) you can get much more detailed information and (b) none of the theoretical models work
One Possible Slice of the Wedding Cake

- Survey the GAMA23 region, which is at \( \delta = -32^\circ \) and covers 50 square degrees
- Tens of thousands of redshifts
- Coverage by Herschel, VIKING (near infrared) and the KIDS (optical).
- \( \approx 200 \) hours in SKA Phase 1 would detect \( 10^9 M_\odot \) of atomic gas at \( z = 0.4 \)
Things to do

• Not all galaxies have spectroscopic redshifts, so need photometric redshifts from VIKING, KIDS and possibly LSST.

• An investigation of the ratio of HI mass and dust mass – what does it tell you about the molecular component? How does this ratio depend on metallicity?

• We are following up Herschel galaxies out to $z=0.4$ with ALMA to measure CO. Will the SKA precursors be able to provide useful complementary measurements of HI, because we would then have measurements of CO, dust and HI