December 30, 2001

From: C. Carilli (ccarilli@nrao.edu)
to: SKA Bologna Conference attendees
re: Galaxy Evolution SKA Working Group 4

You have received this message since you have expressed interest in working group 4 (galaxy evolution) at the up-coming SKA conference in Bologna in January 2002. As chair of the group, I am requesting that you consider some of the issues that have been discussed with regards to this group. The text below outlines some of the SKA scientific topics relating to galaxy formation and distant galaxies. These topics were originally considered in the SKA science case document (Taylor and Braun 1999), and further refined during the Berkeley SKA meeting in June 2001, where this working group was formulated. I am using the 1999 science case document as a starting point for discussion. The 1999 document can be found at:

http://www.skatelescope.org/ska_science.shtml

If anyone feels that a critical area relating to the general topic of galaxy formation has been missed, then it should be addressed in Bologna. Please send me any suggestions prior to the meeting, so as I can circulate them to the group.

We have been given the specific mandates of:

- Delineate unique science programs which will be enabled by the SKA.
- Prioritize those items along the lines of: (I) essential, (II) desirable, or (III) useful.
- Determine telescope parameters that are required to meet the science goals.

The first two items have received considerable attention, both in the 1999 science case document and again in Berkeley. The focus of the working group in Bologna will be primarily that of delineating the technical specifications demand by the priority I science goals. Of course, we should not preclude further refinement of the science goals where deemed necessary.

Similar working groups were assembled for the EVLA workshops over the last few years, and our experience at NRAO has been that familiarizing the working group members with the topics and goals prior to the meeting is critical to making progress at the meeting. Familiarity with the design concepts and capabilities of the telescope is also fundamental to meaningful discussion. The technical details, as far as they have evolved, can be found at:

http://www.skatelescope.org/ska_concept.shtml
http://usska.org/techreports/index.html

Some of the telescope parameters we should be considering are: sensitivity, frequency coverage, bandwidth, spectral channelization, field-of-view, array design (eg. max. baseline length, T_B sensitivity), dynamic range, timing requirements. A worksheet should be available at the meeting so that we can address the hardware issues in detail.

Following is a summary of the high priority items in the science case for working group 4 as it currently stands.

Priority I: Deep and Wide (redshifted) HI 21cm surveys

The capability to study the HI 21cm line from low to high redshift has always been one of the main science drivers for a future large area radio telescope. The science cases for two HI surveys, a wide field surveys covering 1000 square degree, and a narrow but very deep pencil beam survey, are spelled out very clearly in the 1999 science case document (section 2.2). The consensus in Berkeley was that these programs are still the highest priority in terms of working group 4. There is some overlap with working group 3 (large scale structure). A gross separation between the two is that the pencil beam survey is more applicable to the topic of galaxy evolution while the wide field survey will be most useful for large scale structure studies.

Much of the ground work has been done in sections 2.2.1 and 2.2.2 in the science case document. We should review these sections for completeness and consistency, and delineate the telescope requirements in detail. In particular, the current document uses very disparate integration times for the two surveys (1 vs 12 months). Is this justified/reasonable? Also, we should look in detail at the relative sensitivities of these surveys and the capabilities of other future instruments (NGST, ALMA) in terms of detecting 'normal' galaxies.

With regards to the HI surveys, three areas that could be better represented in the current science case document are:

- Low redshift Ly α forest (section 2.2.3) and high velocity clouds: Study of the low redshift 'cosmic web' in HI will be a natural bi-product of the deep surveys.

- OH megamasers (section 2.6.2): Such sources will present a 'contaminant' to the HI surveys, but a very interesting one, given their correlation with star formation.

- HI 21cm absorption line systems: The current science case considers almost exclusively HI 21cm emission studies. The proposed sensitivity of the surveys will probe to low column densities in absorption against even mJy continuum sources.

We need to consider the capabilities of the instrument, and interesting science implied by such studies.

Priority I: Deep and Wide Radio continuum surveys

A nano-Jy sensitivity radio continuum survey comes for free during the HI 21cm surveys. Again, the 1999 book has a thorough treatment of this topic (section 2.3), which we should review and edit.

One topic I think is not covered adequately in the current document is is that of optically obscured galaxies. The current section 2.3 emphasizes detection of known galaxies, eg. optically detected galaxies as seen in the HDF. The power of radio astronomy is that we see through the dust. Extensive work since the first science case was written has revealed the existence of a population of high redshift galaxies that are not seen to the deepest optical levels, and may represent an important phase in spheroidal galaxy formation.

Synthesis of survey science

HI 21cm and radio continuum surveys to the unprecedented depths set by the SKA represents a major advance in the study of galaxy formation, and enable truly unique science that can only be done with the SKA. To review some of the science high-lights:

- The combination of redshifts and gas masses, derived from the HI 21cm data, and star formation rates, derived from the radio continuum luminosities, will provide a powerful and unique means of making a self-consistent determination of how and when galaxies convert their gas into stars, without the difficulties arising from dust obscuration.

- Dynamical masses from HI studies can be used to study the evolution of the dark matter content of galaxies.

- The large number of galaxies detected over cosmologically unprecedented volumes will provide the best sample (by far) for studying cosmic structure evolution on scales from kpc to Gpc.

- Tully-Fisher distances can be used to study large scale velocity flows, thereby constraining models of biased galaxy formation and Ω_m.

- Answers to questions such as the origin of the Hubble sequence and the density-morphology relation, and the evolution of the galaxy merger rate, will be natural consequences of the surveys.

The next generation of telescopes present us with an amazing prospect: to make a complete inventory of the contents of galaxies out to the edge of the 'dark ages'. This includes study of the stars and ionized gas with the NGST and Owl, and study of the dust and molecular gas with ALMA and SIRTF. The SKA will play a pivotal role in this endevour by probing the neutral and relativistic gas, dark matter, and star formation.

Priority II: Molecular (thermal) emission lines

The sensitivity of the SKA will allow for study of thermal molecular emission lines from galaxies at very high redshift (principally CO and HCN). The capabilities of the SKA for such studies depends strongly on the high frequency limit of the telescope. Upper frequency limits ranging from 10 to 50 GHz have been discussed, with the strawman design being 22 GHz.

Section 2.2.4 in the current science case document considers CO emission studies for the strawman spec of 22 GHz. This section needs to be completely rewritten, given the recent rapid advance in the field of high redshift, dusty galaxies. These types of studies may be a key science driver pushing the SKA to frequencies higher than 20 GHz. A thorough treatment of the topic is required.

A related topic is molecular absorption studies. Such studies provide the most detailed probe of the dense (pre-) star forming ISM in high redshift galaxies. Many interesting questions in astrochemistry can be addressed, as well as problems in basic physics such as the evolution of fundamental constants and the temperature of the cosmic microwave background. We should consider if this topic is worthy of mention in the science case.

Other issues

The topic of galaxy formation can construed in many ways, and one might say that much of extragalactic astronomy falls under this rubric. The science case document has focused primarily on the topics listed above. Clearly, there are many other issues which may fall under this general catagorie and may warrant further discussion, such as radio continuum studies of starburst galaxies and extragalactic supernovae, magnetic fields in galaxies, galaxy halos, HI in nearby galaxies of all sorts, etc... Our duty is to determine the most interesting areas that rely fundamentally on the SKA for further progress, and communicate the telescopes requirements to the engineers. I urge everyone involved to familiarize themselves with the documentation, and come to the Bologna meeting enthused by the staggering possibilities.