Fossils and Monsters in the Hubble Frontier Fields (South)
An ATCA Legacy Proposal Expression of Interest

March 16, 2016
Contact: ian.heywood@csiro.au, mlacy@nrao.edu, mao@jive.eu

1 Targets and Motivation

The Hubble Space Telescope (HST) is currently engaged in 560 orbit campaign to obtain deep images of six strong gravitational lensing clusters in multiple photometric bands. This Hubble Frontier Fields[1] (HFF) program reaches depths comparable to that of the original Hubble Deep Field observations, but uses the natural magnification of background sources provided by the lensing to probe an intrinsically fainter source population, with the goal of characterising the first galaxies beyond redshifts of 10. The clusters were chosen based on their lensing strength and favourable locations, able to be targeted by a range of ground-based observatories including ALMA and those on Mauna Kea. The *Spitzer* space telescope has also used 800 hours of Director's Time to image the HFF clusters; these observations are complete and archived. Detailed lensing models derived using multiple methods are available[2] for the HFFs, allowing accurate reconstruction of the intrinsic source characteristics. These fields will remain cutting-edge for studies of the high-z Universe until well into the era of the James Webb Space Telescope. We propsose to use the 7 mm system on the ATCA to add a unique high radio frequency dataset to the three southernmost fields: Abell 2744 (RA = 00:14:21.2, Dec = -30:23:50.1, z = 0.308), Abell S1063 (RA = 22:48:44.4, Dec = -44:31:48.5, z = 0.348) and MACSJ0416.1-2403 (RA = 04:16:08.9, Dec = -24:04:28.7, z = 0.396). Deep (sub-μJy) and high resolution (0.5″) Very Large Array imaging at S and C band are available for one of these fields, and we will propose regular ATCA L/S and C/X projects to obtain deep, wide band radio imaging for the remaining two southern clusters at the next proposal cycle.
The headline science goals of this legacy project are:

1. Conduct a blind search for ^{12}CO line emission in galaxies both at the peak epoch of star formation (2.2< z <2.6, ∼18000 Mpc^3) and approaching the cosmic reionization epoch (5.4< z <6.2, ∼27000 Mpc^3), offering observational constraints on the cosmic evolution of the CO luminosity functions (and thus H_2 mass).

2. Obtain deep (∼4 micro-Jy per beam RMS) 32 GHz continuum imaging of three massive galaxy clusters, detecting redshifted dust and free-free emission, and investigating (directly or via stacking) the dominant source population at the faint end of the high frequency source counts.

3. Search (either directly or via stacking) for other spectral lines, including HCN/HCO+ and ^{13}CO at high redshift, and CS and SiO in the lensing clusters.

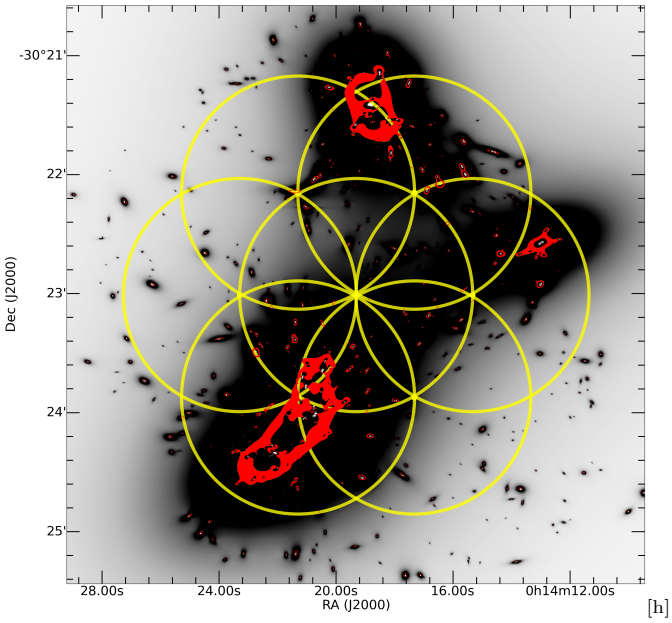

Figure 1: Plausible ATCA pointing setup overlaid on the lens model for Abell 2744. The greyscale saturates black at a magnification (μ) of 2 for a source at $z = 2$, the red region shows $\mu = 10$. We benefit from a $\mu > 1$ sensitivity boost over a majority fraction of the survey area.

[1] http://www.stsci.edu/hst/campaigns/frontier-fields/
[2] http://archive.stsci.edu/prepds/frontier/lensmodels/

2 Technical Specifications

Number of objects:	3 clusters, each of which will be covered by a 7-pointing mosaic 21 pointing centres in total
LST ranges:	**Abell S1063:** 16.7h<LST<5.0h **Abell 2744** 18.7<LST<5.9 **MACSJ0416** 23.0<LST<9.6 (all for elevations above 20°)
Frequency:	32 – 36 GHz
CABB mode:	2 × 2 GHz basebands, 2048 × 1 MHz channels each
Array configurations:	H75, H168, H214, 750m (1.5k)
Observing strategy:	Single observing runs covering the full LST range are desirable in order to minimise overheads and ensure complete (u,v) plane coverage. Observing blocks will target a single pointing of the 21 total. No zoom modes are required therefore making automated observing more viable for this project.
Required sensitivity:	A total of 70 hours (plus overheads) per pointing will yield a 1σ CO luminosity sensitivity of 10^9 K km s^{-1} pc^2 in the deepest part of the mosaic, in a 50 km s^{-1} channel. This is sufficient to detect the general population of high-z CO emitters at high significance, and does notinclude the natural sensitivity boost afforded by the lensing. The corresponding continuum depth from such a set of observations is $\sim$4 μJy beam^{-1}. With the lensing benefits this translates to 5σ detections of $z = 2$ sources with an intrinsic flux densities of 10 μJy beam^{-1} over >50% of the survey area and 2 μJy beam^{-1} over a few percent of the area.
Total time:	2940 h in total, assuming a 100% calibration overhead. This gives 367.5 h per semester over four years, or 490 h per semester over 6 years.

3 Team (so far)

Our international team (which is sure to expand) has the necessary skill set to deal with this project already. There are no unusual observing modes involved, and the data rate and volume are absolutely manageable over the execution time of the survey. We are well placed to deal with the challenge of calibrating, combining and imaging the final data cubes, with a track record in both conventional and cloud HPC environments, as well as novel calibration and imaging strategies and the automation thereof.

Ian Heywood (Co-PI)	CASS / Rhodes U.	Calibration and imaging, radio continuum and line surveys
Mark Lacy (Co-PI)	NRAO	AGN, galaxy evolution
Minnie Mao (Co-PI)	JIVE	Galaxy evolution, molecular lines, surveys
Roger Deane	Rhodes U.	Gravitational lensing, calibration and imaging
Bjorn Emonts	INTA-CSIC	ATCA 7mm expert, high redshift molecular line observations
Matt Jarvis	Oxford U. / UWC	Multiwavelength surveys, galaxy evolution, cosmology
Eric Murphy	NRAO	Star formation, galaxy evolution, PI of VLA HFF large survey
Danail Obreschkow	ICRAR / UWA	High-z atomic and molecular lines, observations and theory
Oleg Smirnov	Rhodes U. / SKA SA	Calibration and imaging dungeon master