International Centre for Radio Astronomy Research

Potential of MWA for spectral line observations

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Science (likely incomplete)

- High redshift HI sources
- Radio Recombination Lines
  - Diffused warm gas (CII)
  - HII envelops
- Molecular lines and masers

Radio Recombination Lines

Rydberg atoms, or atoms with a single electron at a high quantum number, occur in interstellar medium.

As the electron cascades to lower energy levels, each transition creates a radio recombination line, or RRL.

At frequencies above 100 MHz these lines appear in emission.

At frequencies below 100 MHz, the excitation temperature of the atoms approaches the typical gas kinetic temperature and the lines appear in absorption.

Low Frequency Galactic RRLs

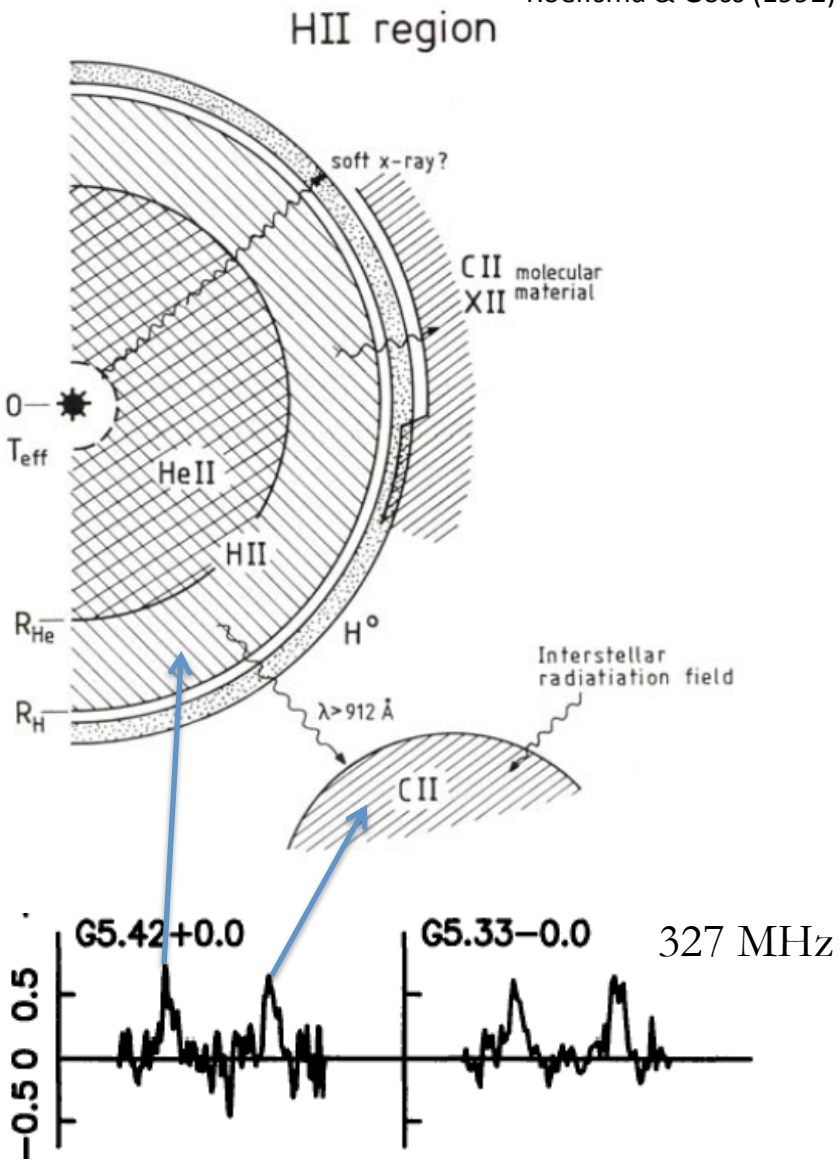
HII regions

- N_e~1-10 cm^{-3}
- T_e~7000K
- Observed down to 327MHz

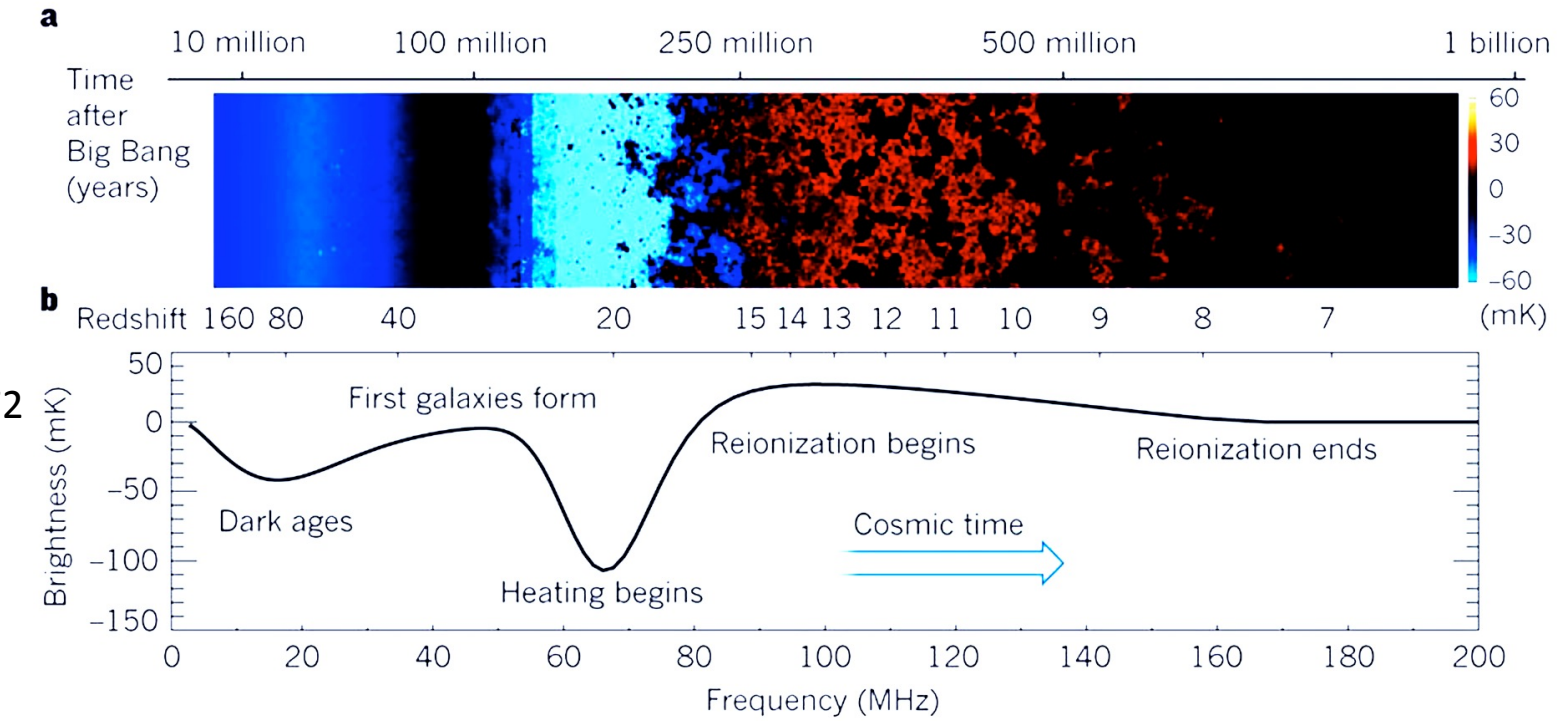
Atomic clouds

- N_e~0.1 cm^{-3}
- T_e~25÷100K
- Photodissociation regions - not enough UV to ionize HI
- Diffuse emission
- Observed down to 25 MHz

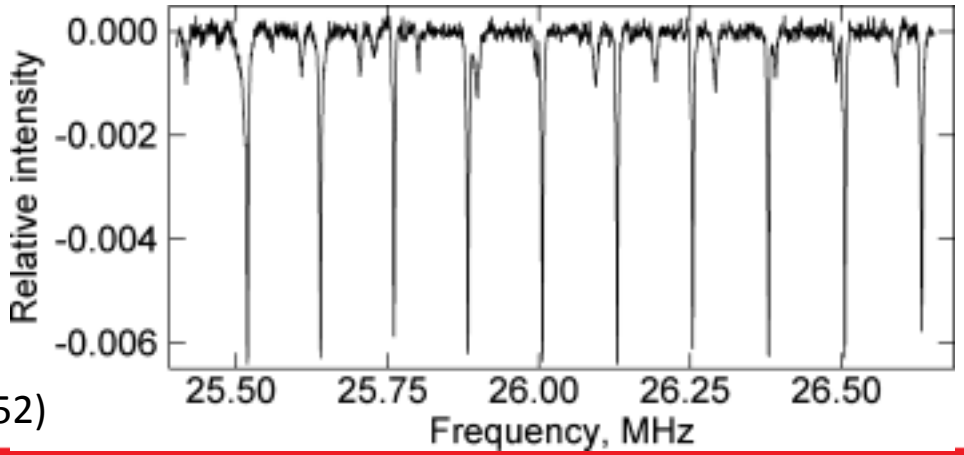
Roelfsma & Goss (1992)



RRLs - EoR Contaminant



Pritchard & Loeb, 2010 Nature 469 772



(Stepkin et al. 2007 MNRAS 374, 852)

The line spacing for the α lines is $\Delta\upsilon \sim 3\upsilon/n$ (~1MHz @150MhZ and ~150KHz @50KHz), and other transitions are also going to be present.

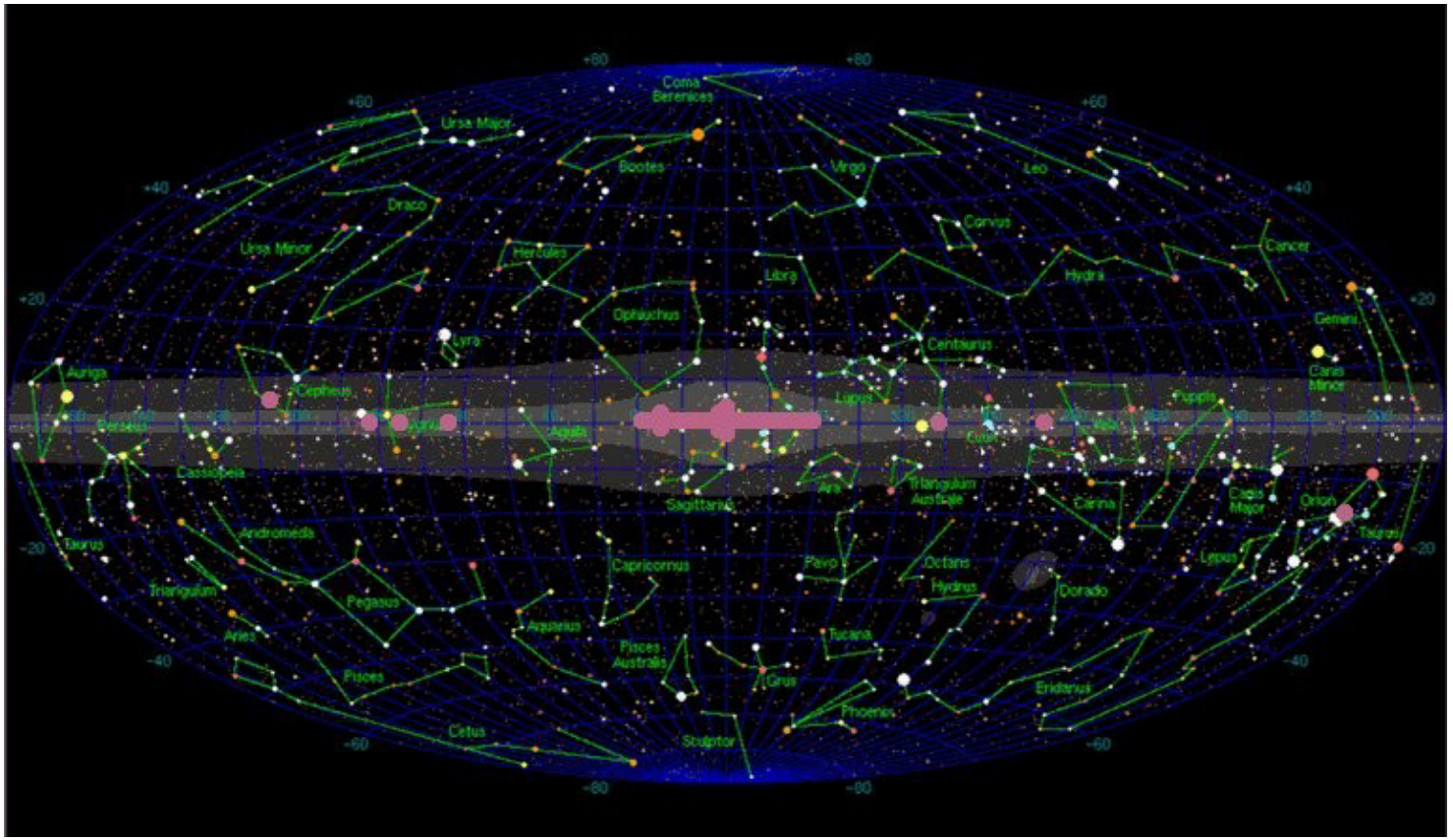
How bad?

The magnitude of the spectral fluctuations expected from the HI signals for the dark ages, first stars and epoch of reionisation is roughly in the range 10^{-4} to 10^{-5}.

The magnitude of the spectral fluctuations from RRLs would be of order 10^{-3} to 10^{-4}.

If there is RRL-hosting gas at high Galactic latitudes, the spectral fluctuations arising from RRLs could be comparable to or exceed those from the desired HI signals.

What we know so far



CRRLs in the plane are seen from -20< l < 20, but only on isolated sightlines elsewhere.

Peters et al, 2011 A&A 525 128

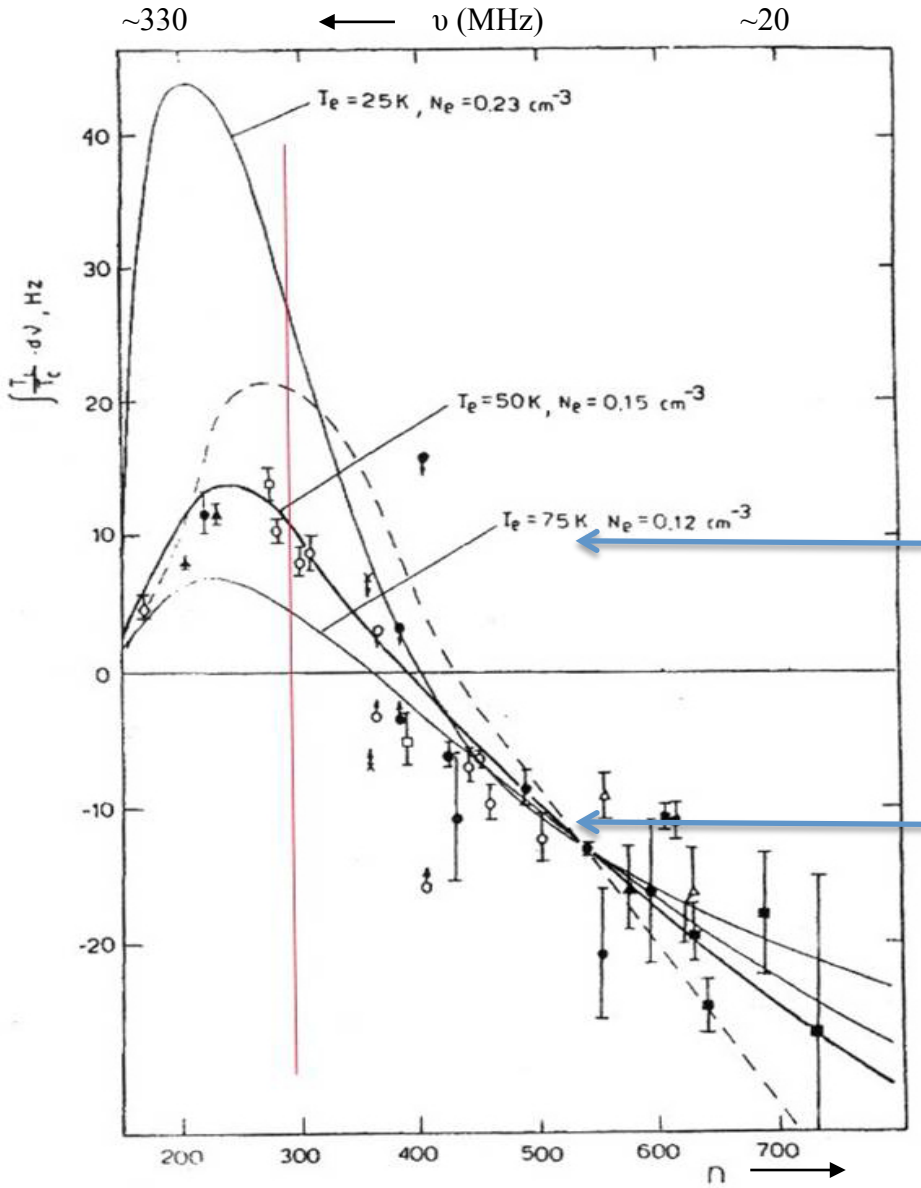
Why to study CRRLs?

At large n (>300 for MWA band), the atoms are very big and fragile. Variations in pressure, temperature and density as well as radiation broadening affect the line profile. This makes these lines a sensitive probe for ISM.

Warm gas is thought to be the major component of Galactic gas, however, the distribution in the larger Galaxy is very poorly known.

When RRLs at multiple frequencies are combined with information from HI, molecular, and CII observations, a comprehensive picture of the absorbing clouds in Galaxy can be built.

Frequencies and resolution



Line width ~50-70 km/s

CRRL - 10KHz is OK

requires at least 3KHz frequency resolution

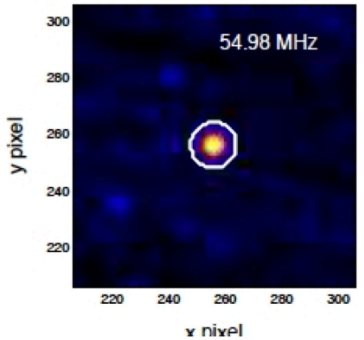
Expanding to 50MHz would be great!

Gordon & Sorochenko (2002)

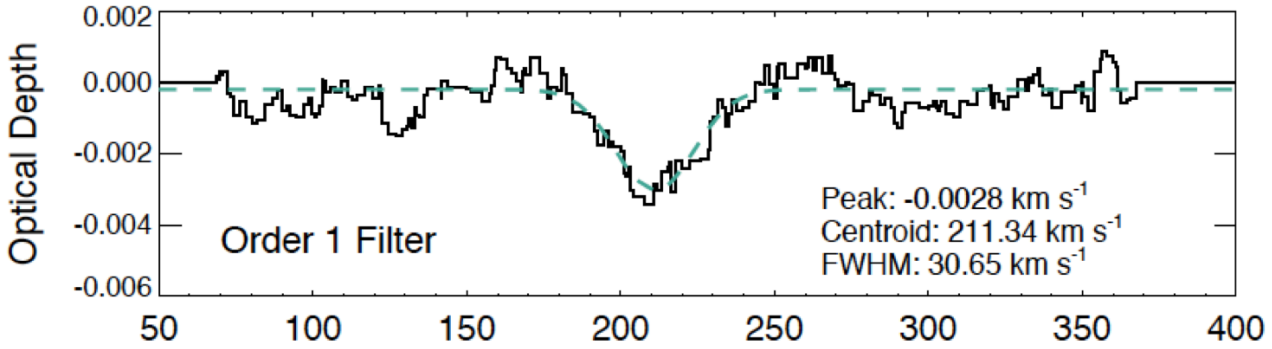
CRRL from extragalactic sources (M82)

LBA measurements (30-78 MHz)

Morabito et al. (in prep):



First detection of CRRLs from an extragalactic source



(32channels/subband, stacking 22 subbands)

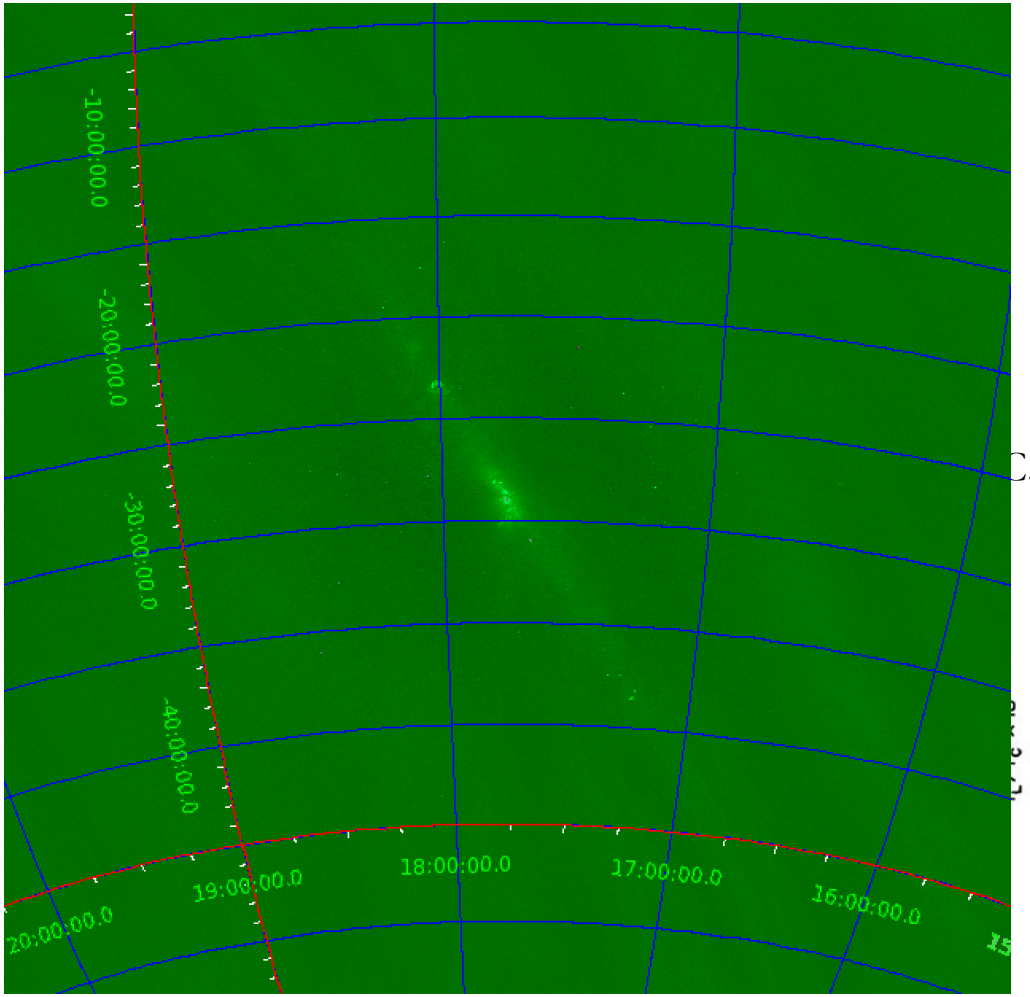
M. C. Toribio

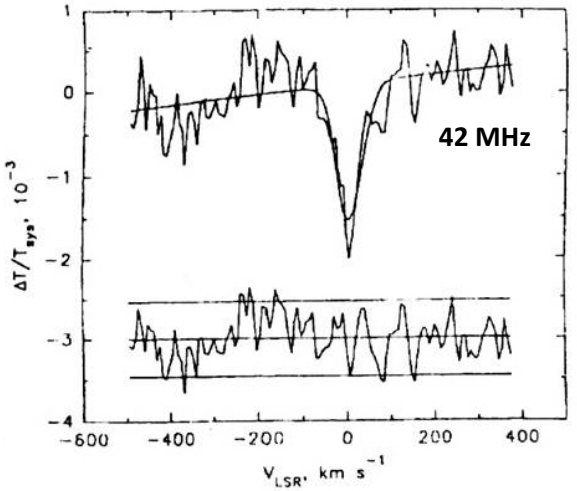
LOFAR Status Meeting, ASTRON
August 20th, 2014

Why to study HRRLs?

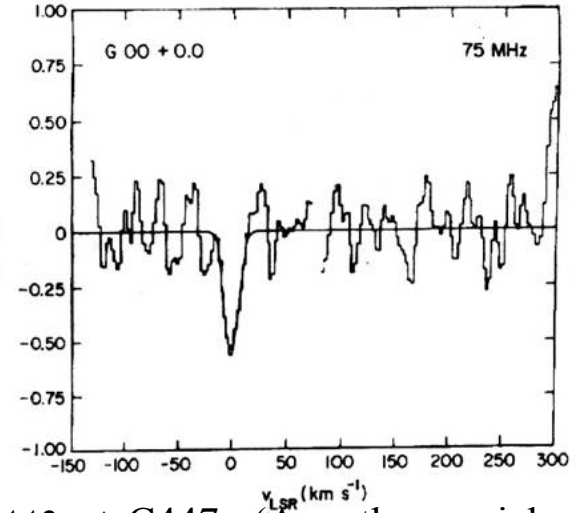
- Envelops of normal HII areas
- Interacting HII bubbles in star formation regions (requires better that 10KHz frequency resolution)

MWA: RRLs towards the Galactic Centre





C537α + C538 + C539α (Smirnov & Kitaeff, 1996)



C443α + C447α (Anantharamaiah et al., 1988)

Detectability with 128T

Surface brightness is critical

$$\Delta t_{\text{int}} = \left(\frac{m}{f \times DF} \frac{T_{\text{sys}}}{\Delta T} \right)^2 \frac{1}{N_{\text{pol}} N_{\text{lines}} \Delta \nu}$$

5σ detection, of 10^{-3} optical depth lines

128T

- 32 tiles within 100m radius – 13 hours per line
- 50 tiles within 250m radius – 250 hours per line
- Stacking- 27 lines in band

Impact of PFB channelization

Cnα line	Freq (MHz)	Coarse Channel	Channel
338	169.6333	x	x
339	168.1435	131	2925
340	166.6664	130	2777
341	165.2066	129	2631
342	163.7637	128	2487
343	162.3376	127	2344
344	160.928	126	2203
345	159.5347	125	2064
346	158.1575	124	1926
347	156.796	122	1790
348	155.4501	121	1656
349	154.1196	120	1522
350	152.8042	119	1391
351	151.5037	118	1261
352	150.218	117	1132
353	148.9468	116	1005
354	147.6898	115	879
355	146.447	114	755
356	145.2181	113	632
357	144.0029	113	511
358	142.8012	112	391
359	141.6128	111	272
360	140.4376	110	154
361	139.2754	109	39
362	138.1259	108	x
363	136.9891	107	x
364	135.8647	x	x

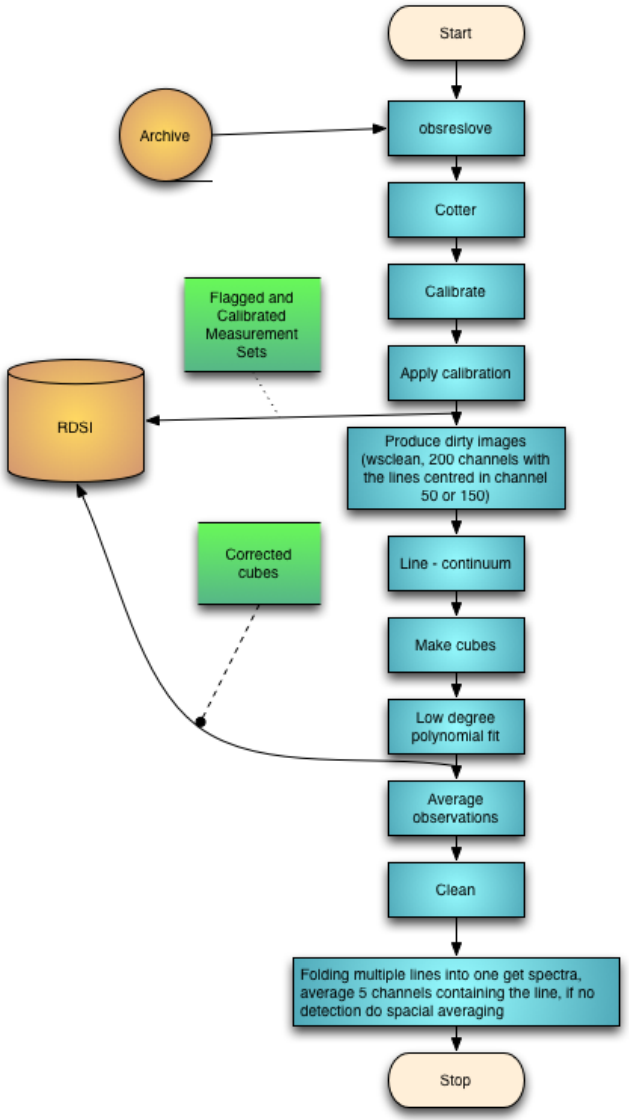
- 27 lines in total
- 10 can not be used (37%of data)
- One “fat” band would be great!

Required integration time with MWA-X

- With 100 tiles within 250m radius, and all 27 lines the integration time ~2 hours

- MWA-X would make RRL survey possible

Data reduction



- 1700 channels to image - computationally expensive
- About 1 hour of data has been imaged
- Some strategies for averaging, stacking and continuum subtraction are developed but not fully tested.

Molecular line emission with the MWA

- In addition to radio recombination lines, there are a number of spectral lines from molecules that are expected to be easily detectable. These include:

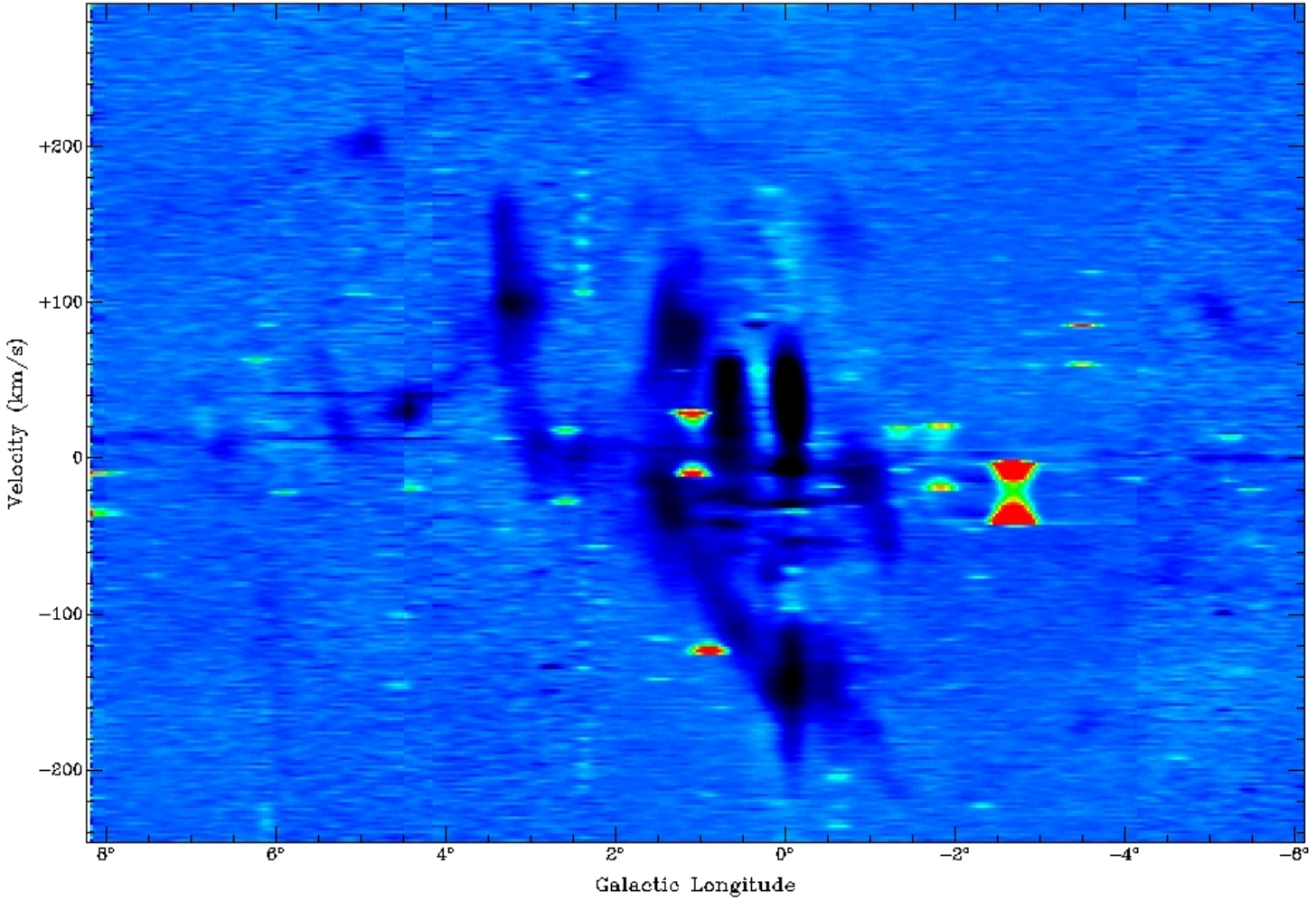
- SH, H_2CO, HNCO, CH_2NH, H_2S, H_2CS (and many more, like OH at 55MHz, if the band is expanded)

- The ratio of these simple molecules can tell us about the basic physical conditions in the ISM (density, temperature, ionisation rate etc.)

SH – the mercapto radical

- Four spectral lines at 100.29, 111.48, 111.55, 122.37MHz
- Equivalent to the four OH ground-state line at 1612, 1665, 1667 and 1720MHz
- OH lines are widespread and seen as masers, thermal emission and absorption
- SH likely to be 1/25 the abundance of OH, so SH can fill in places where OH is optically thick
- If the band is expanded to 50MHz, it would enable simultaneous observations of OH and SH

OH in the Centre of the Galaxy from SPLASH



Summary

- MWA should be able to detect both HRRL and CRRL
- Mapping CRRL is important for EoR
- Extragalactic RRLs might be possible to observe with MWA-X
- Molecular lines can be observed
- Wishes for MWA-X
  - More tiles in the central area
  - Better frequency resolution (ideally 1KHz)
  - Better spatial resolution
  - One “fat” band