

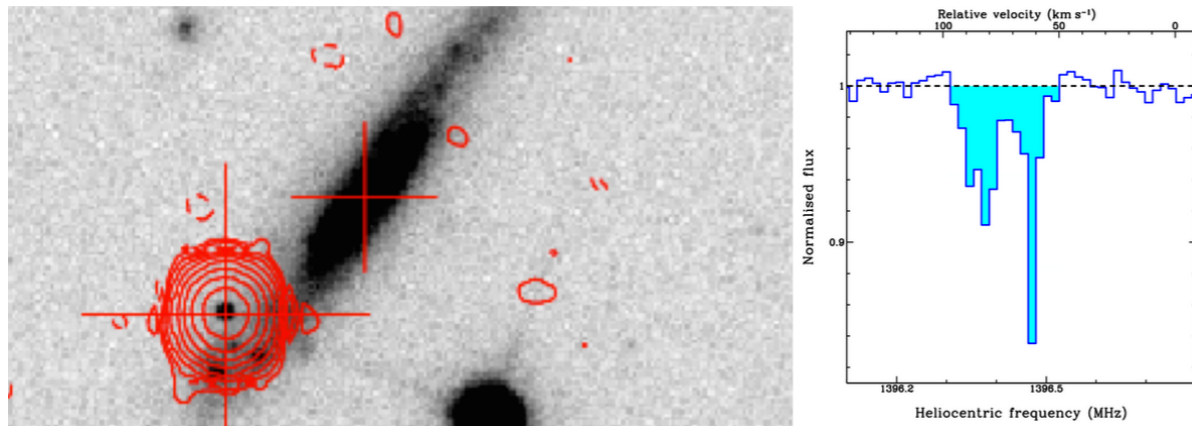
# Blind HI and OH absorption line search: status update on MALS and early results from uGMRT

Neeraj Gupta (IUCAA): on behalf of MALS team

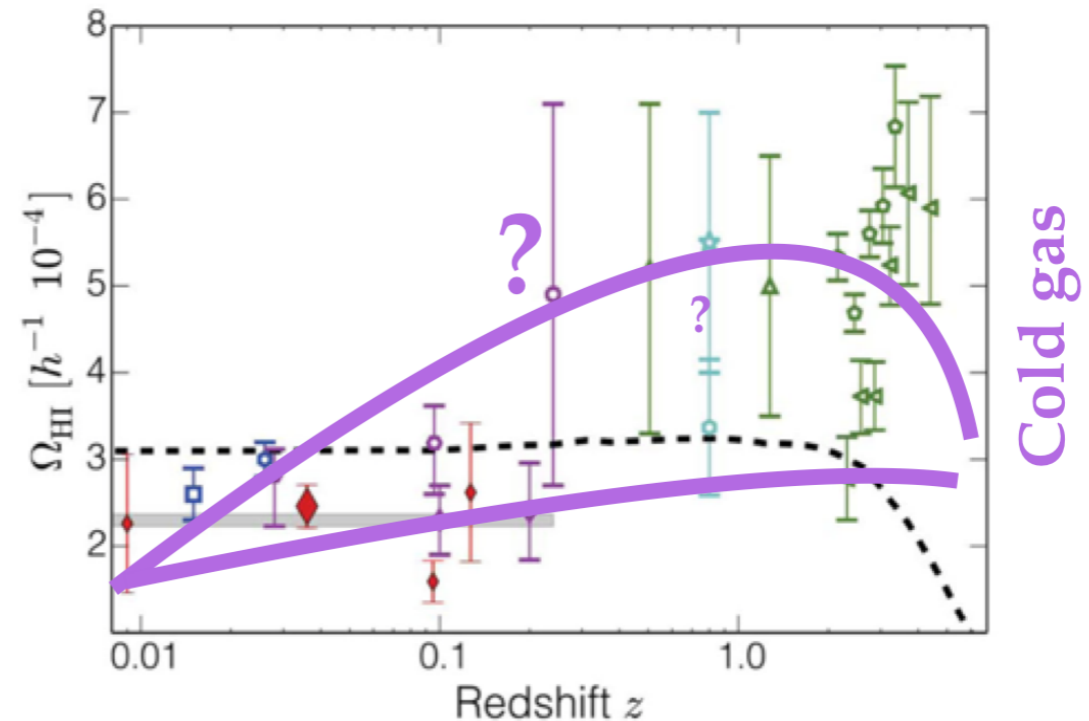
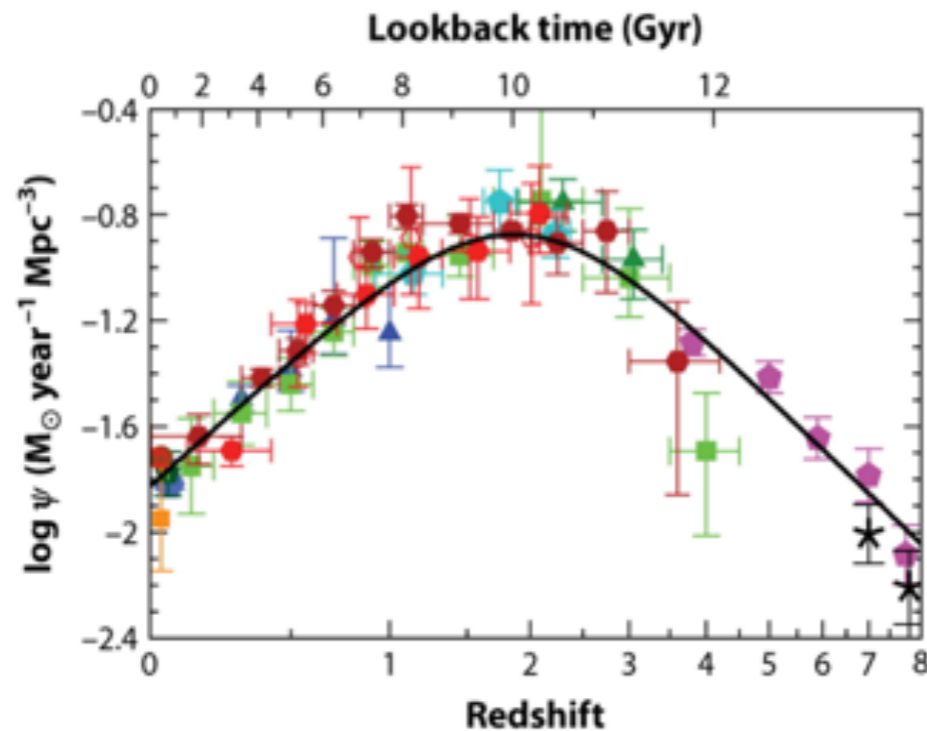


# MALS

## The MeerKAT Absorption Line Survey



Sensitive search of HI 21-cm and OH 18-cm absorption lines to map the evolution of cold atomic and molecular gas in galaxies at  $0 < z < 2$ : the redshift range where most of the evolution in the star-formation rate density takes place.



**MALS:** probe of cold gas in galaxies over the entire  $z$ -range in a luminosity- and dust-unbiased way.

**MALS:** an order of magnitude increase in the number of HI 21-cm and OH 18-cm absorbers (only ~50 intervening 21-cm and 3 intervening OH absorbers known)



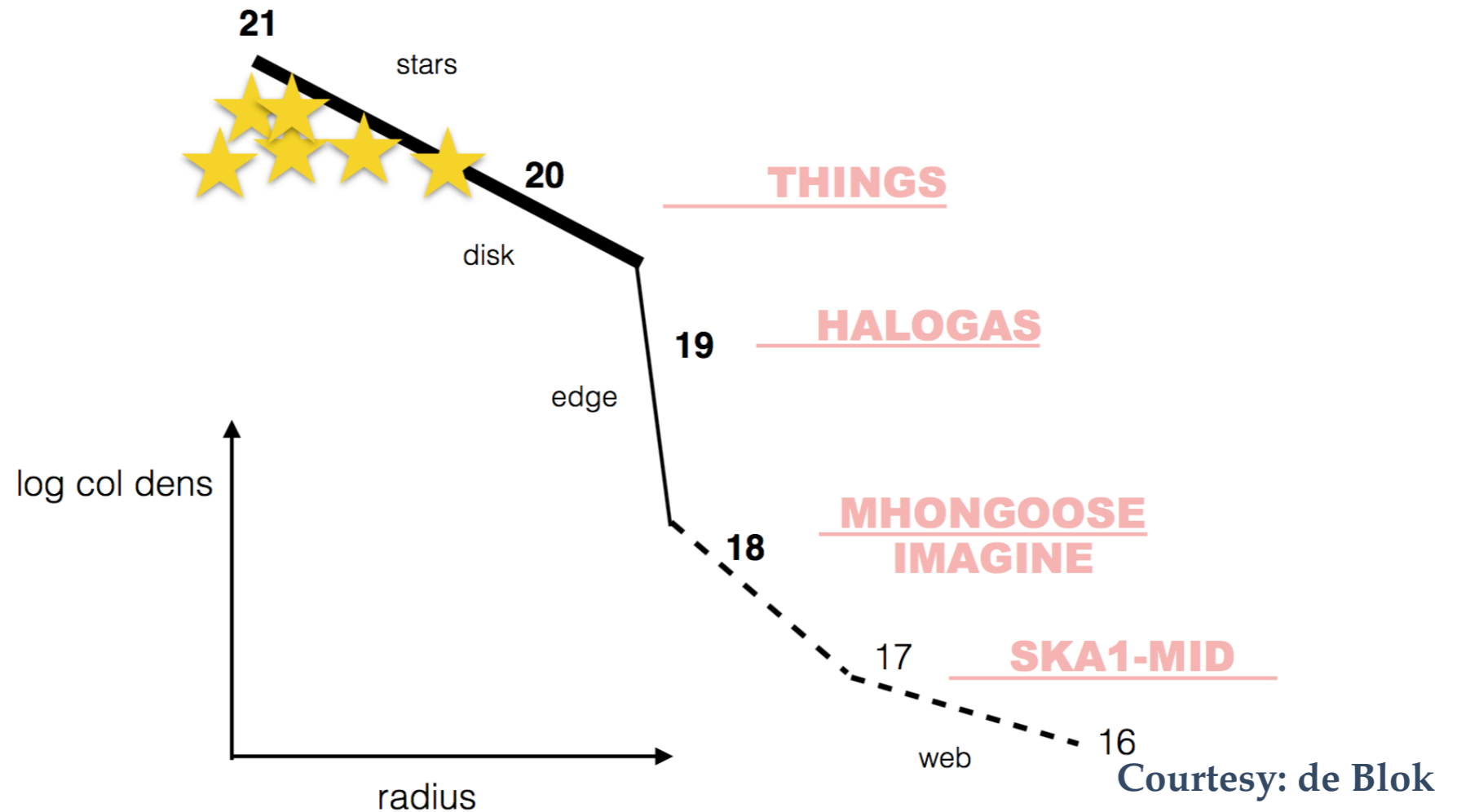
# MALS The MeerKAT Absorption Line Survey

## Main science themes:

- ◆ Evolution of cold gas in galaxies and its relationship with SFR density,
- ◆ Fuelling of AGN, AGN feedback and determining fraction of dust-obscured AGNs,
- ◆ Variation of fundamental constants of physics: most stringent constraints, and
- ◆ Physical modelling of ISM, astrochemistry and cosmology.



# Complementary to various upcoming HI emission line surveys



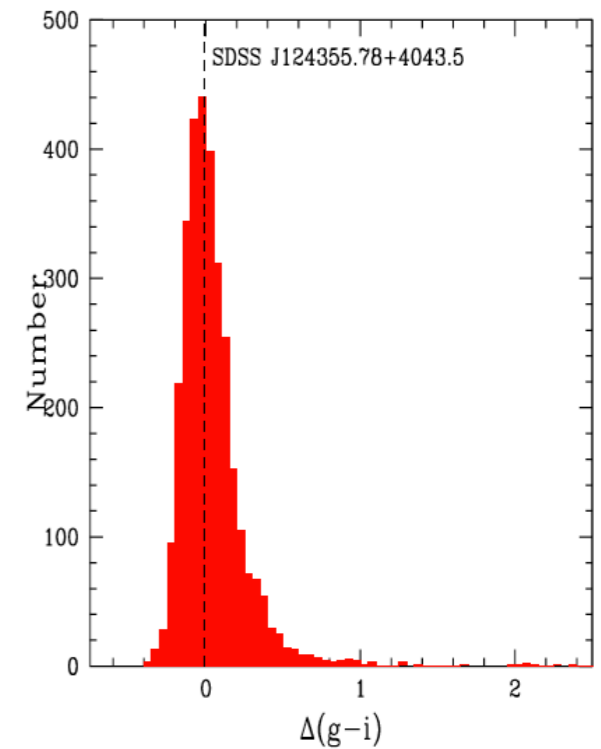
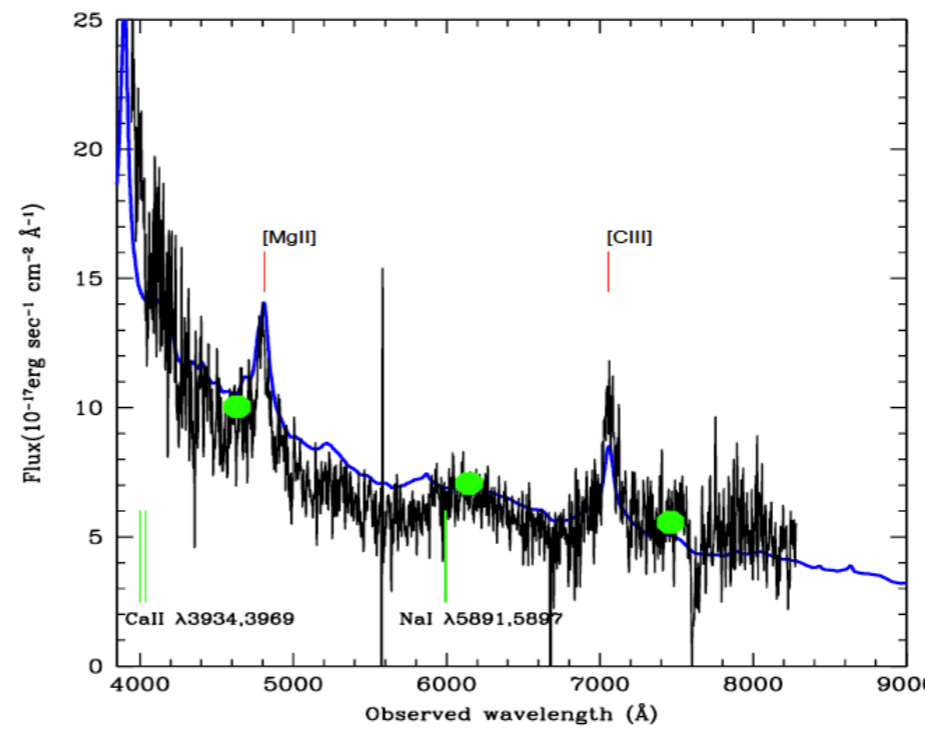
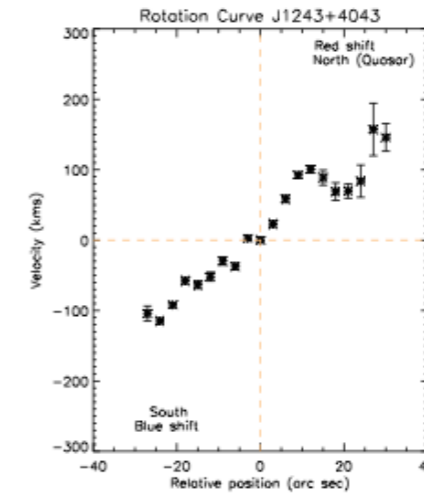
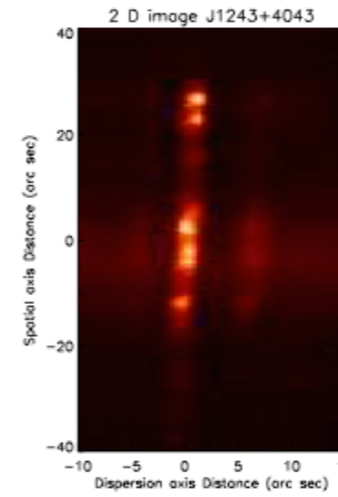
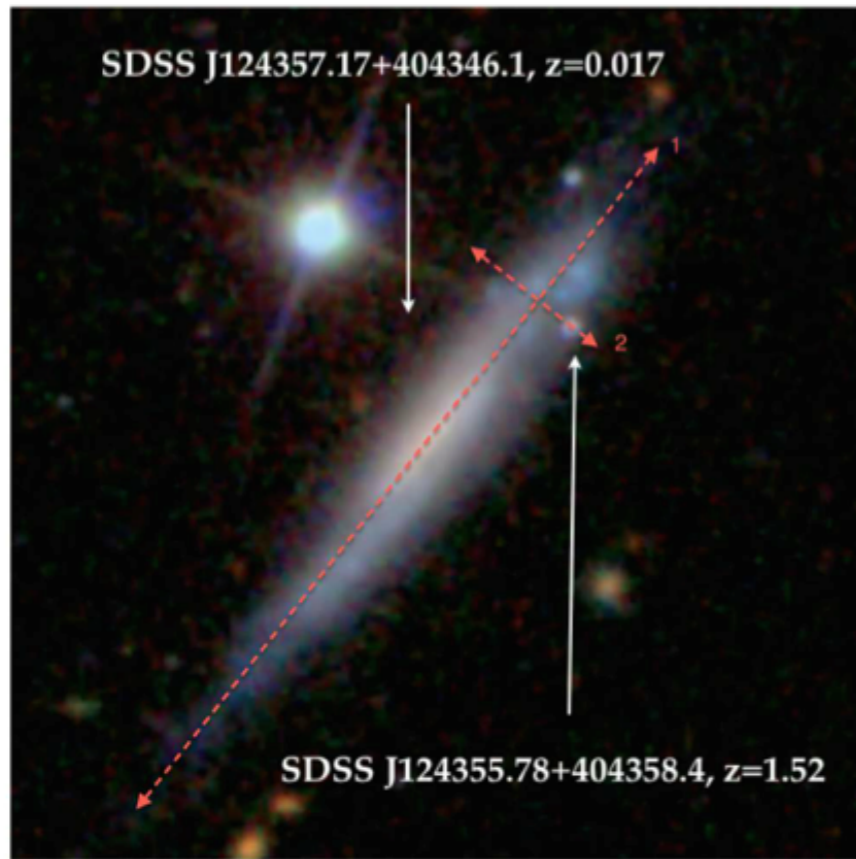
## In short,

- 100 K sensitivity for **subDLAs** or 1000 K in DLAs at **pc scales**
- Sensitive to warm gas in disk as well cold gas in CGM
- Complementary HI emission line surveys.

**Would need multiwavelength data.**



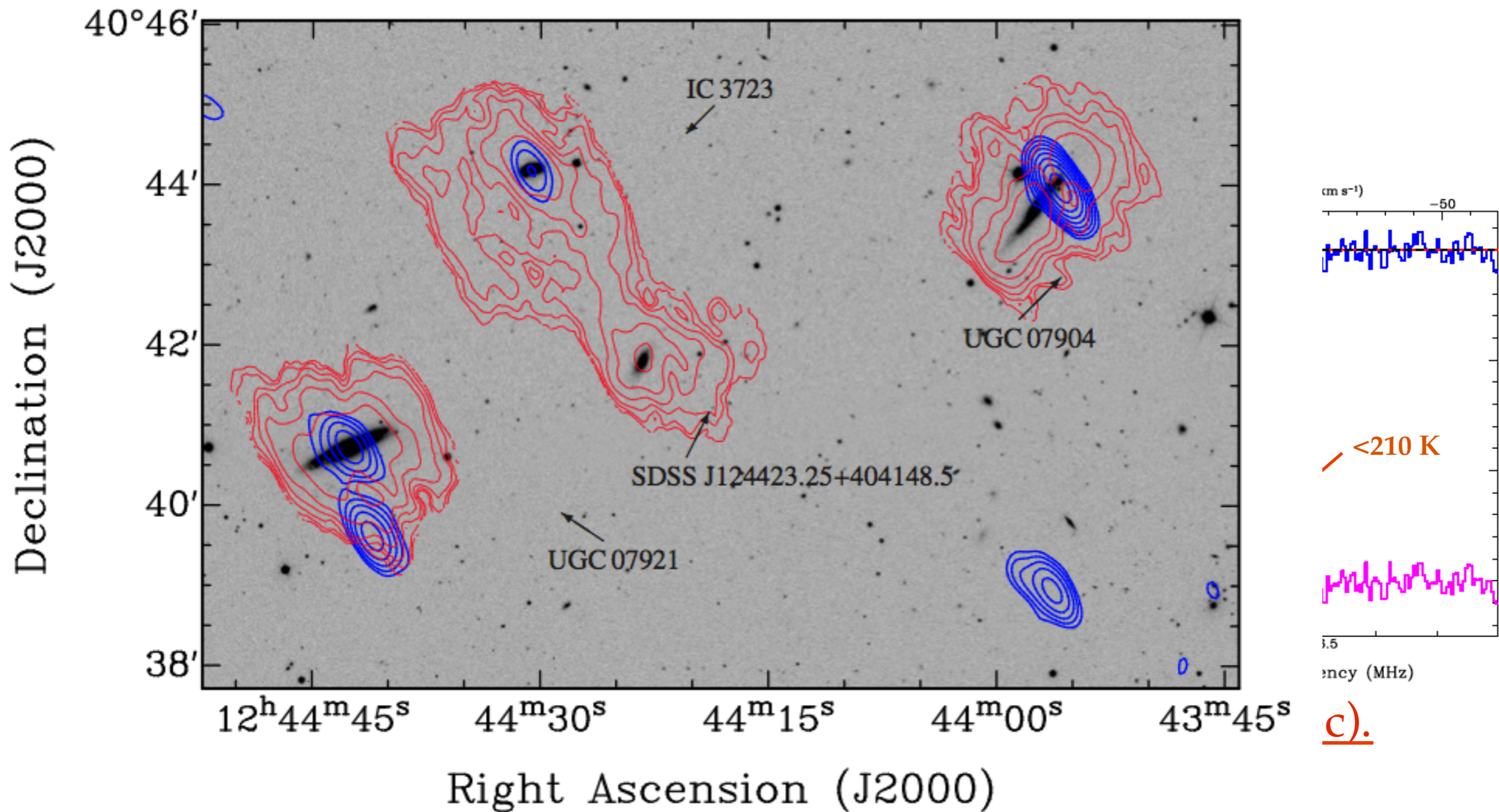
# Quasar-galaxy pair - J1243+4043 ( $b=7$ kpc)



IGO imaging and spectroscopy:  
QSO sightline through region of moderate SF and Solar metallicity. (Gupta et al. in prep.)



# Quasar-galaxy pair - J1243+4043 ( $b=7$ kpc)



**GMRT + VLBI + WSRT**

(Gupta et al. in prep.)



# MALS The MeerKAT Absorption Line Survey

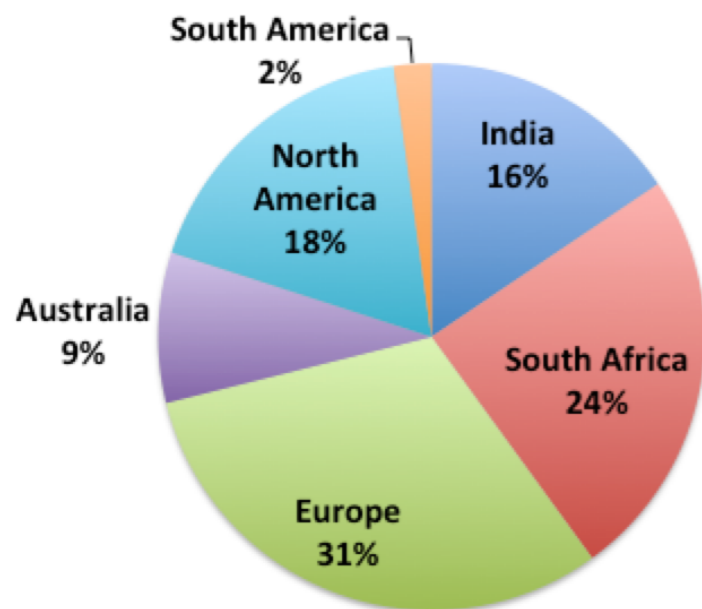
## Main science themes:

- ◆ Evolution of cold gas in galaxies and its relationship with SFR density,
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**Strong synergies with multi-wavelength facilities such as ALMA, GMRT, SALT, VLA, VLT and Keck:** a large survey with SALT to identify targets for MALS is in progress.

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**MALS team composition**

- ◆ MALS will also be a highly competitive HI emission, Radio continuum and polarisation survey.
- ◆ Strong collaboration and participation of South African researchers in all the aspects of the survey.



# Survey design

## Optimise:

- (1) optical depth sensitivity;
- (2) redshift coverage and path

Together, determine detection rate,  $dn/dz$  accuracy and parameter space explored.

Formally, the Absorption line survey speed is driven by:

$$\text{SurveySpeed}(\tau < \tau_0) \propto \underbrace{(A_e / T_{\text{sys}})^2}_{\text{sensitivity}} \times \underbrace{\Delta z}_{\text{redshift coverage}} \times \underbrace{N_t}_{\text{number of targets}}$$





# Survey design (2010 specifications)

MALS phase <sup>a</sup>	Number of pointings <sup>b</sup> × Time per pointing	Primary targets <sup>c</sup>	
		Target $\int \tau dv$ (km s <sup>-1</sup> )	Total redshift path
L-band (900-1670 MHz)	1000 × 2 hrs	0.045	580
UHF (580-1015 MHz)	1000 × 2 hrs	0.045	1000

- 2000 pointings centered at bright (>400 mJy).
- Another >200 fainter sources per pointing.
- Several (300-600) 100 intervening absorbers with 10% accuracy on  $n_{21}$ .



# Comparison of various absorption line surveys

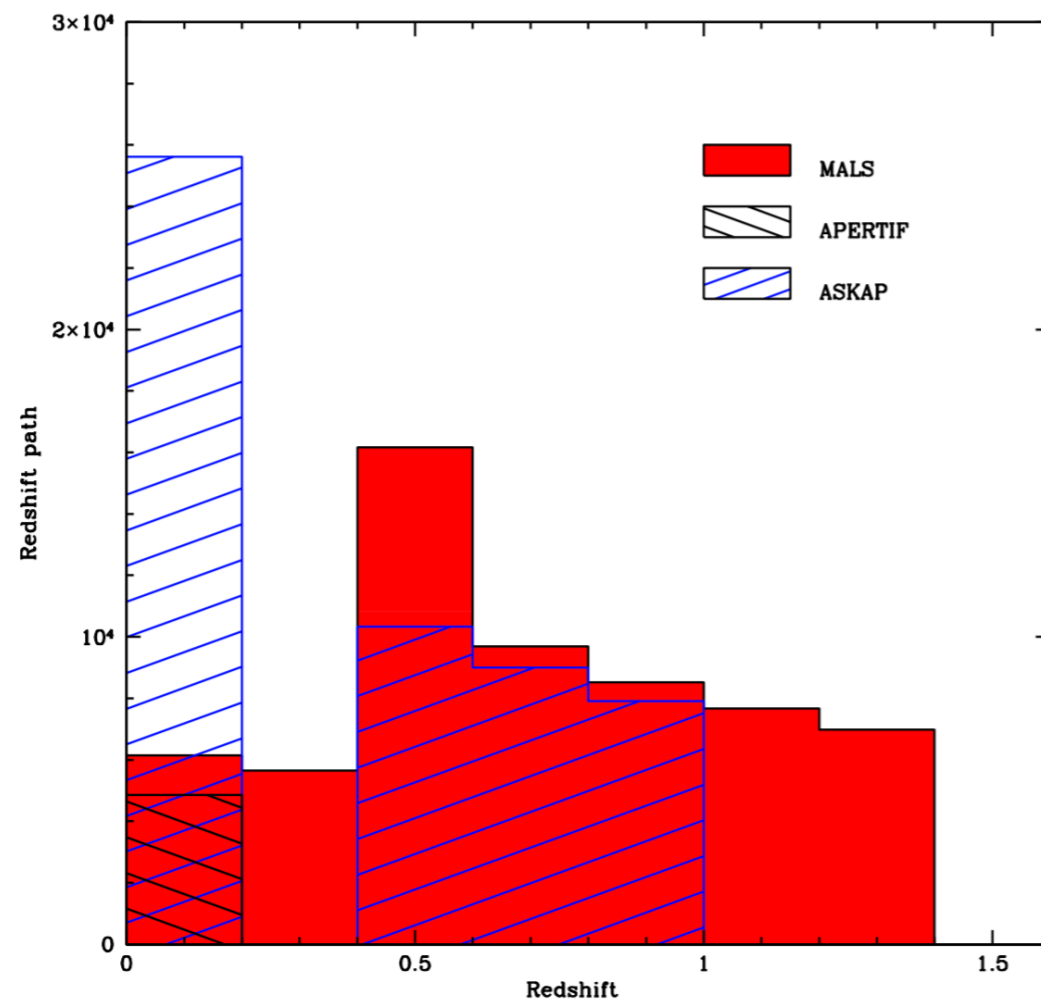
Survey	Frequency coverage (MHz)	Redshift range (HI 21-cm)	Integration time per pointing (hrs)	Spectral rms per ~5 km/s (mJy/b) <sup>a</sup>	Sky coverage (deg <sup>2</sup> )	Total time (hrs)	No. of sightlines <sup>b</sup>
APERTIF SHARP	1130 - 1430	0 - 0.26	12	1.3	4000	6000	25,000 (> 30 mJy)
ASKAP FLASH	700 - 1000	0.5 - 1.0	2	3.8	25,000	1600	65,000 (> 90 mJy)
ASKAP WALLABY	1130 - 1430	0 - 0.26	8	1.6	30,000	8000	1,32,000 (> 40 mJy)
MALS LBAND	900 - 1670	0 - 0.57	2	0.4	1300	2000	22,000 (> 10 mJy)
MALS UHF	580 - 1015	0.40 - 1.44	2	0.6	1950	2000	32,000 (> 15 mJy)

## Considerations:

- Latest technical specifications
- MALS: upto beam FWHM at the center of band considered
- Last column: sight lines with sensitivity to detect 100K gas in DLAs)



# Comparison of various absorption line surveys (latest specifications)



- MeerKAT LSP review/ commissioning in progress.
- TBD: spectral rms (0.4 – 0.7 mJy/beam); number of pointings.



# Large optical survey to maximize the redshift path

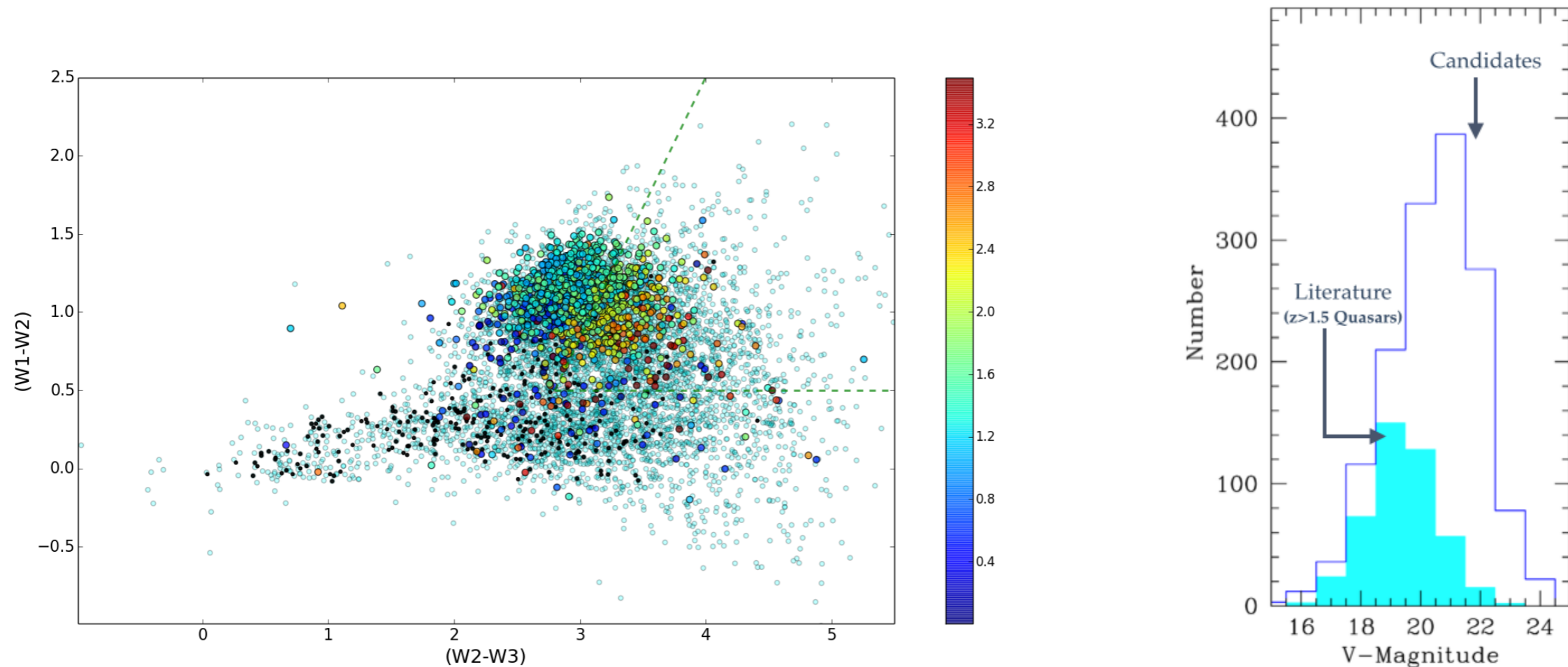
Need bright radio sources for 2000 pointings

- L-band: 1000 at  $z > 0.5$  and UHF-band: 1000 at  $z > 1.5$
- Bright radio sources are scarce ( $< 1$  per sq degree)
- Optical spectroscopic coverage in southern hemisphere is sparse
- With 200 mJy flux density cut-off: short by 400 targets for UHF



# Target selection: large optical survey

- ◆ Use WISE colors to identify  $z > 1.5$  QSO candidates
- ◆ AllWISE catalog provides all sky W1 ( $3.4\mu\text{m}$ ), W2 ( $4.6\mu\text{m}$ ), W3 ( $12\mu\text{m}$ ) and W4 ( $22\mu\text{m}$ ) photometry



**~1500 IR selected candidates to select from; dust unbiased; 75% success rate expected on the basis of SDSS.**



# Target selection: large optical survey

## Survey strategy

$V < 21$ : NOT, NTT and SALT;  $V > 21$ : VLT

## NOT observations (PI: Krogager)

- ◆ 100 candidates observed over 6 nights.

## SALT observations (PI: Gupta)

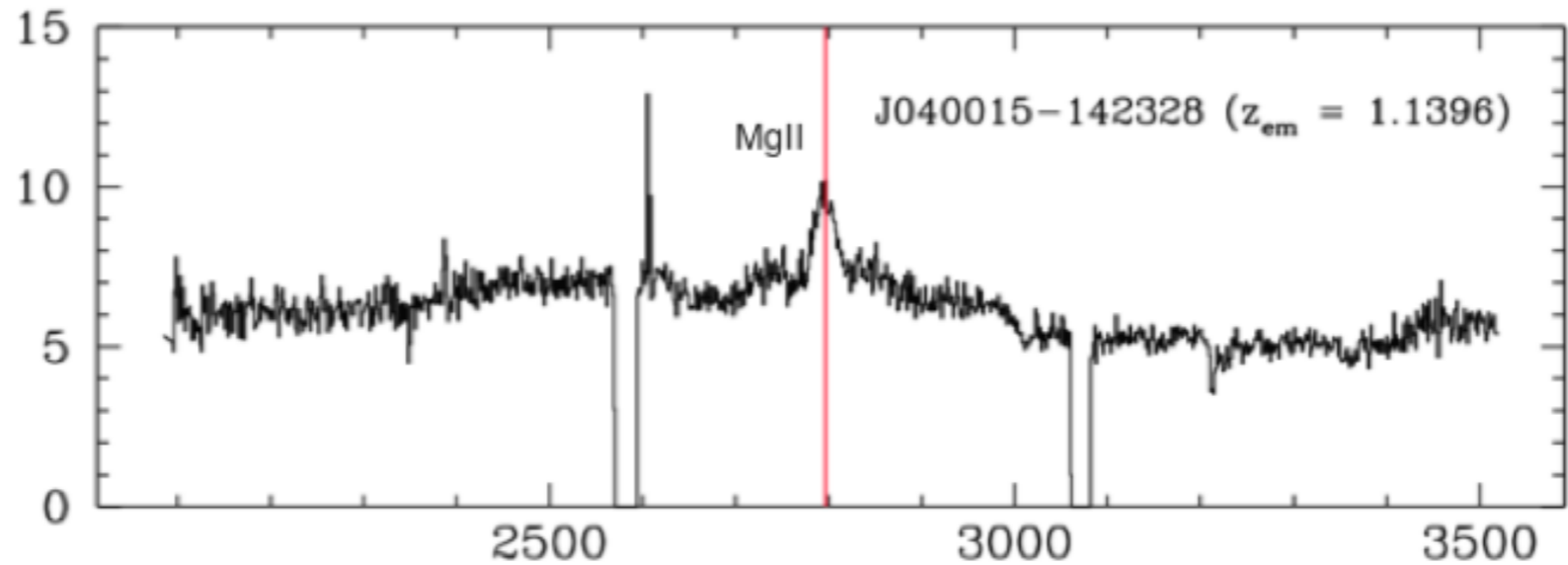
- ◆ Approx 180 hrs through IUCAA, Rutgers and South African time over 2014-2  $\rightarrow$  2016-2.
- ◆ Efficiency of getting useful spectra in initial stages: 50%; now 85% (achieved through working closely with the observers)
- ◆ 320 spectra (202 with emission lines; 25 with no ID; 82 with no flux)
- ◆ Identified  $\sim 120$   $z > 1.5$  RLQs
- ◆ Data reduction at UKZN (Ayanda, Matt) and IUCAA (Tanvir, Anand).

*Ayanda Zunga*: M.Sc. thesis (supervisors: C. Zunckel and N. Gupta)

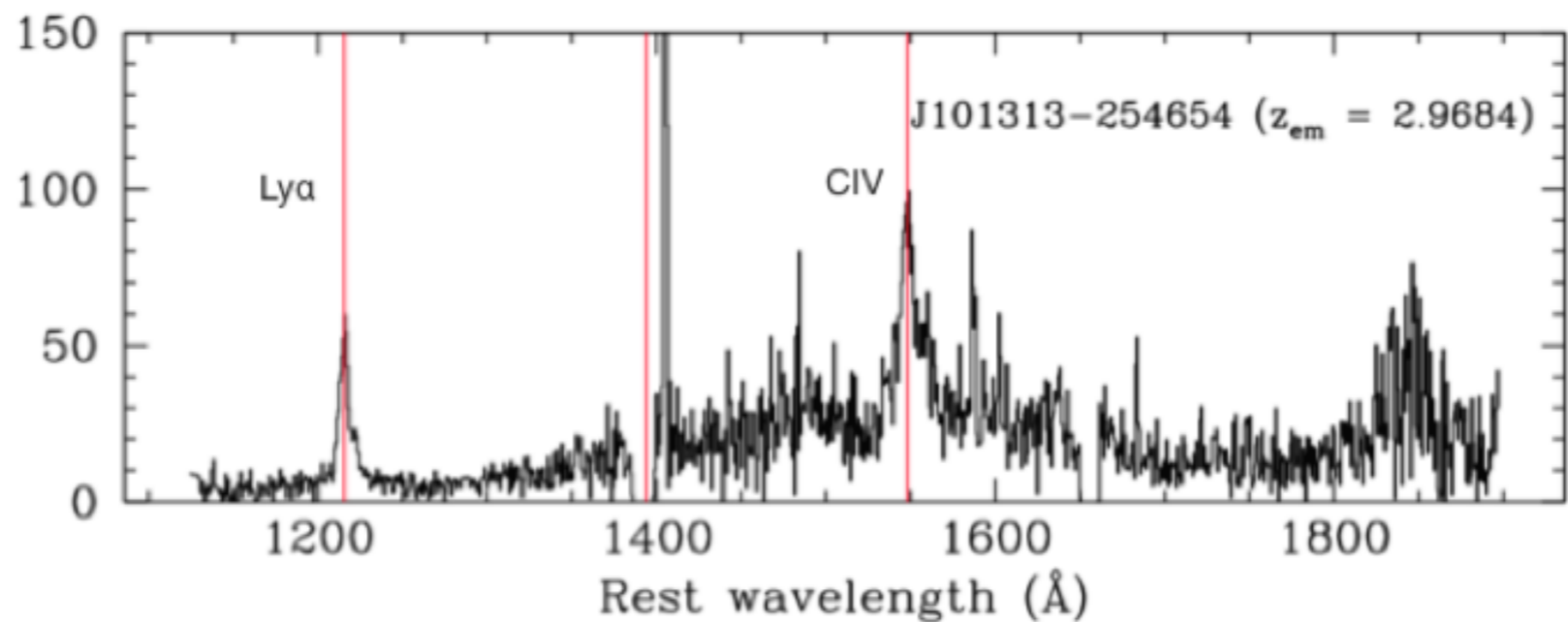
*Tanvir Hussain*: Ph.D. student (supervisor: R. Srianand)



# Target selection: large optical survey



V~19.5



V~21.5

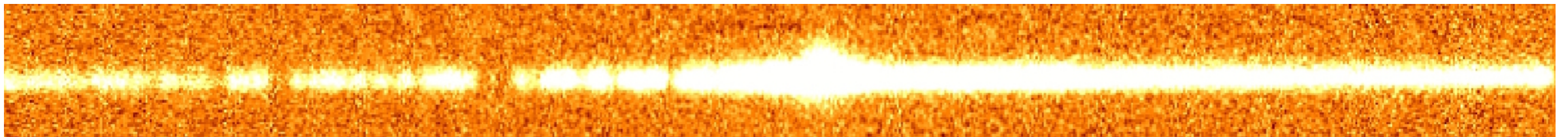
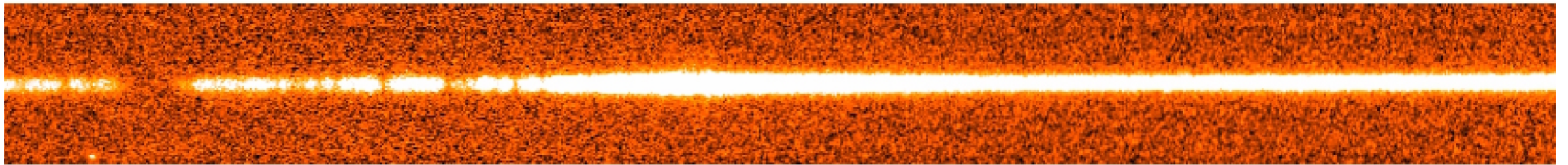
**RSS with same setup and day-time calibrations used throughout.  
(30 mins per target)**



# Serendipitous discovery of Giant Ly $\alpha$ halos at $z\sim 3$

Based on large program to find high- $z$  quasars for MALS – PI: N. Gupta  
([Collaboration between: IUCAA, Rutgers and South Africa](#))

SALT RSS spectra



Discovery of Damped Ly $\alpha$  absorbers and 11 Giant Ly $\alpha$  Halos at  $z\sim 3$

About 50% (??) detection rate at  $z\sim 3$  !

**More to come with SALT, MUSE and GMRT  
follow-ups – and MeerKAT**





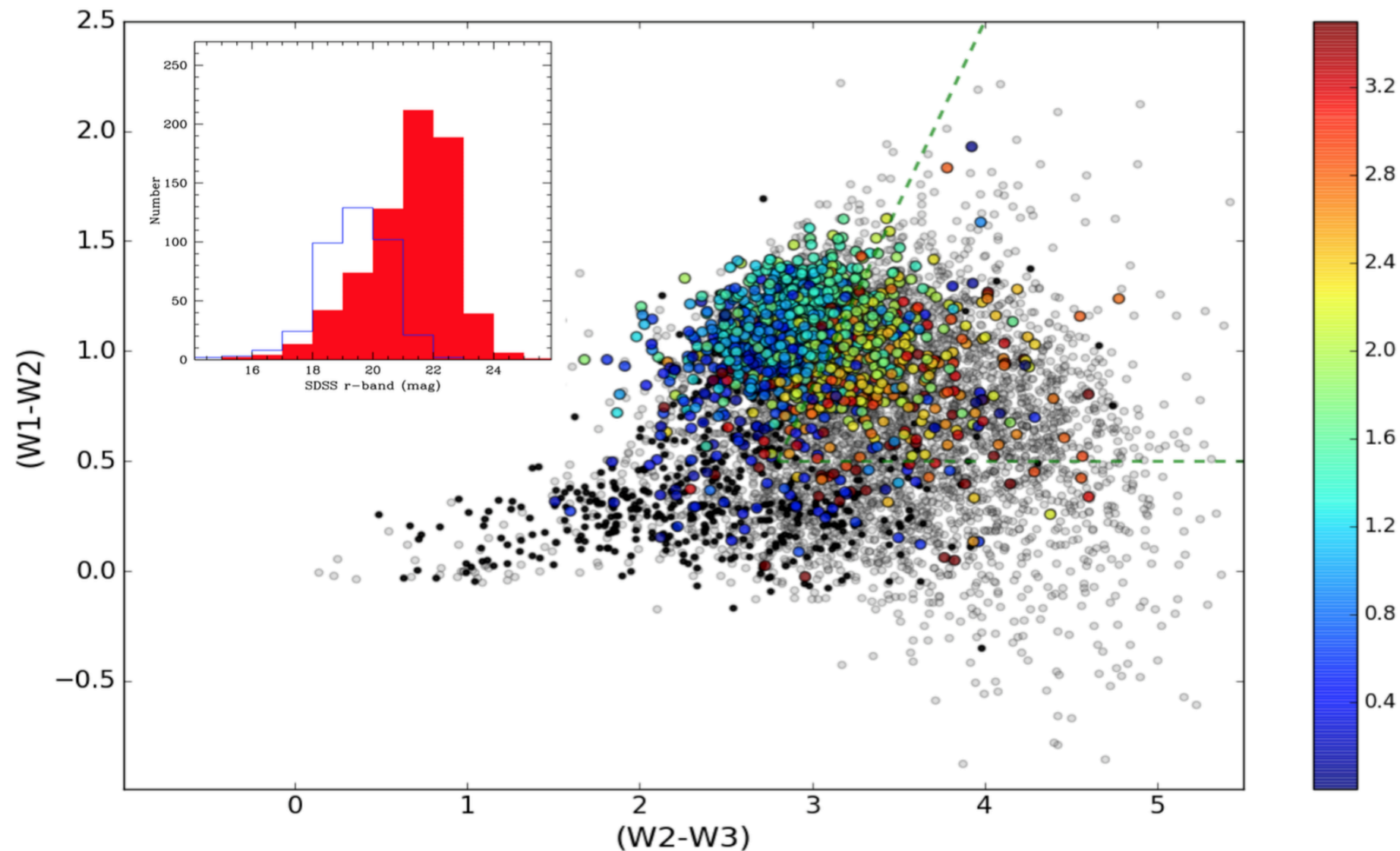
# uGMRT blind absorption line survey



- uGMRT with continuous coverage at 250-1450 MHz
- 30 antennas at 250-500 MHz and 1000-1450 MHz
- >16 antennas at 550-850 MHz
- 200 MHz BW with >8K channels or more in shared-risk mode



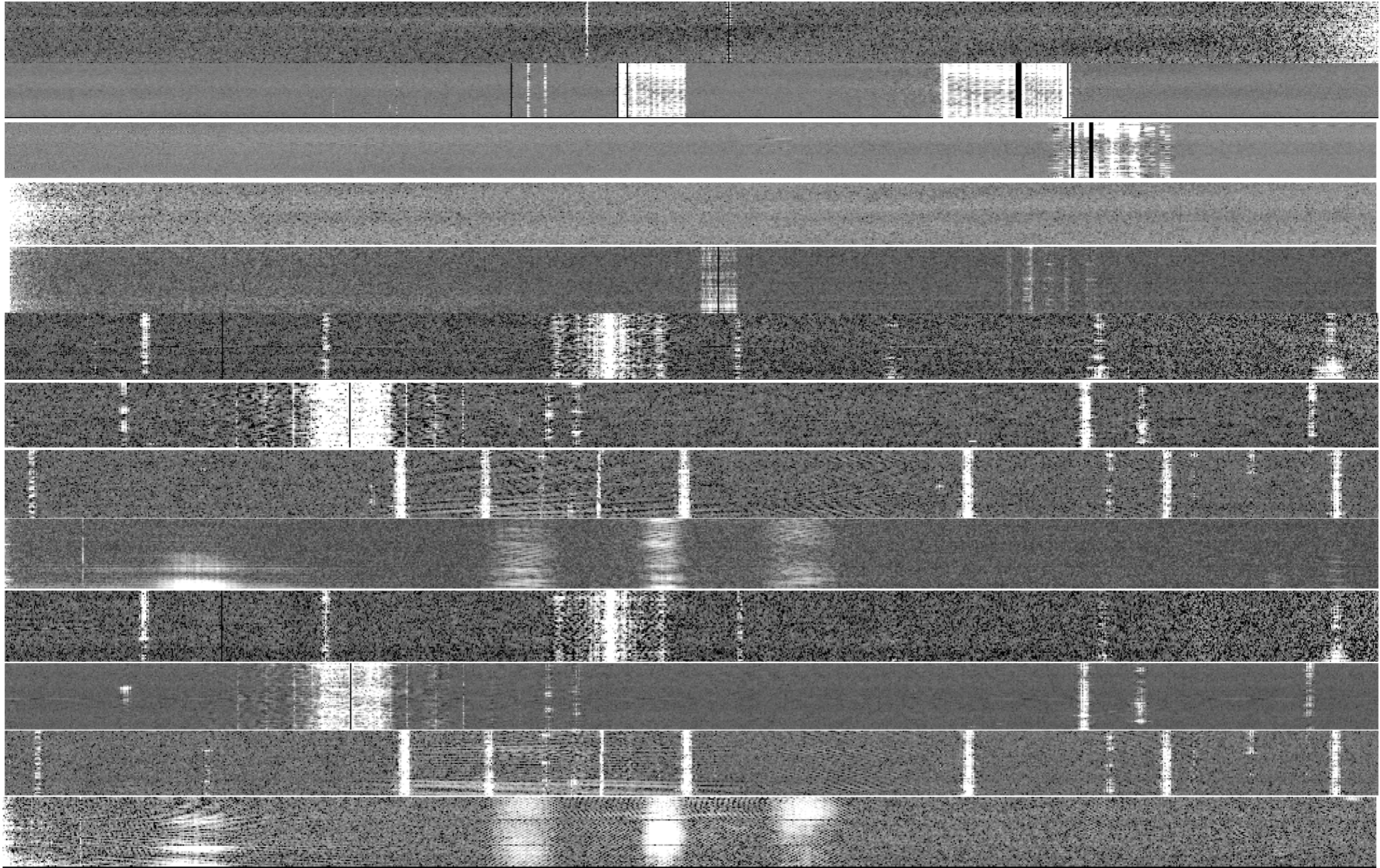
# uGMRT blind absorption line survey



WISE-IR colors for  $\sim 6100$  sources brighter than 100 mJy in FIRST  
Sample of 2025 IR-selected quasars: 400 z-SDSS; 900 undetected  
**Phase I: observations of 75 RLQs with  $>1$  Jy in progress**



# uGMRT (UHF + Lband)



# Summary

- MALS: Evolution of cold atomic and molecular gas; sensitive to CNM in subDLAs at sub-kpc scales; complementary to LADUMA, MHONGOOSE, Fornax, MIGHTEE-HI surveys. LSP review outcomes expected within a month.
- MALS: Optical survey to identify IR selected high-z quasars well underway: **150 new  $z > 1.5$  targets; serendipitous discovery of high-z DLAs, Ly $\alpha$  halos and more.**
- uGMRT: pilot for a blind search using continuous coverage over 250 – 500, 550 – 850 and 1000 - 1450 MHz, in progress.

