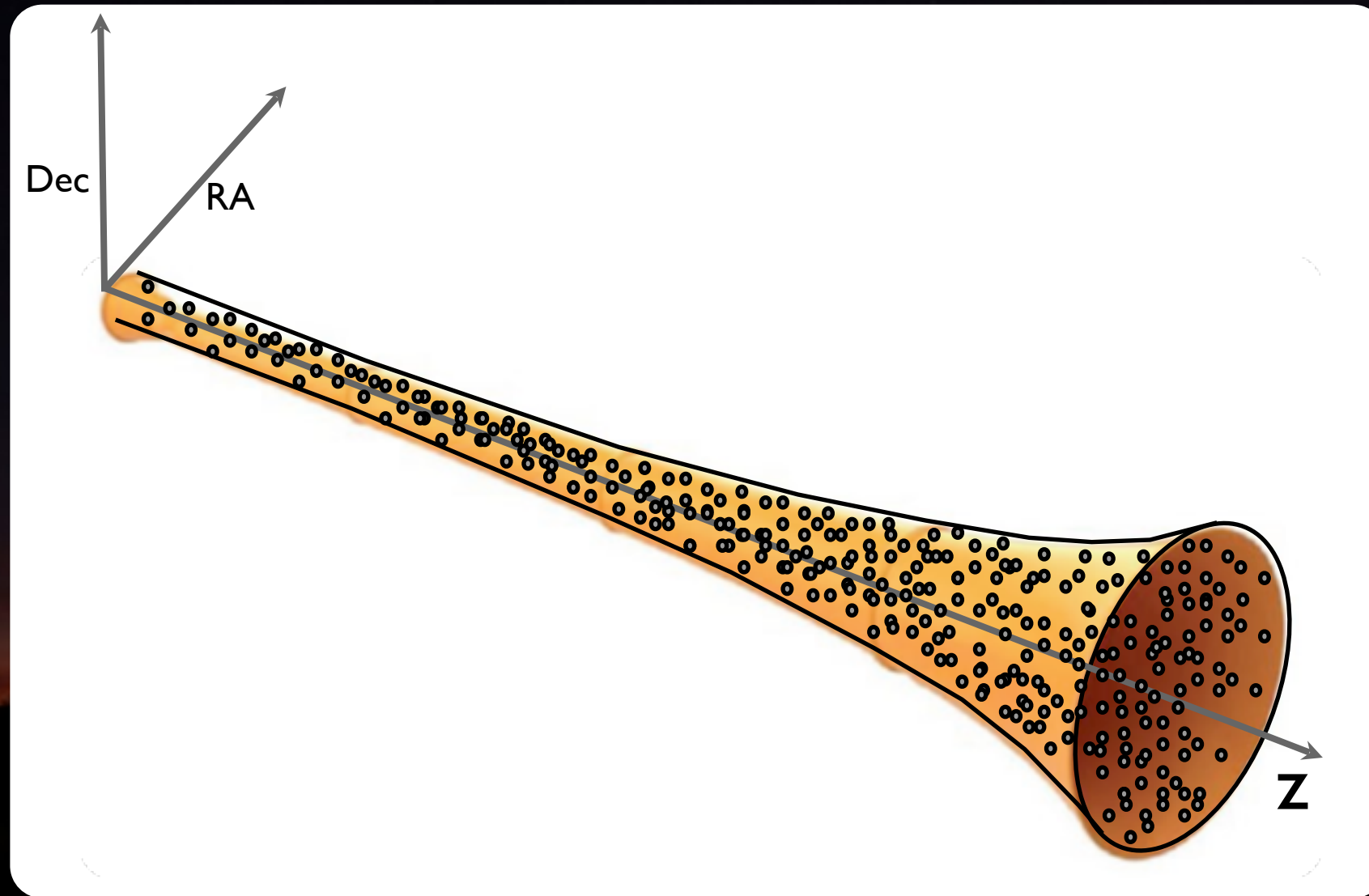


LADUMA

Looking at the Distant Universe with the MeerKAT Array



B.W. Holwerda⁽¹⁾, S.-L. Blyth⁽²⁾ & A. J. Baker⁽³⁾

1) Leiden Observatory

2) Astrophysics, Cosmology and Gravity Centre (ACGC), University of Cape Town

3) Rutgers, the State University of New Jersey



LADUMA Team

MeerKAT TAC rating: Priority1
Awarded 5000 hours for a single pointing.

PIs: S.-L. Blyth, B. W. Holwerda, A. J. Baker,

co-Is: B. Bassett, M. Bershad, A. Bouchard, F.H. Briggs, B. Catinella, L. Chemin,
S. Crawford, C. Cress, D. Cunnama, J. Darling, R. Davé, R. Deane,
E. de Blok, E. Elson, A. Faltenbacher, S. February, X. Fernández
B. Frank, E. Gawiser, E. Giovannoli, T. Henning, K. Hess, I. Heywood, J. Hughes, M.
Jarvis, R. Johnston, S. Kannappan, N. Katz, D. Kereš,
H-R. Klöckner, R. Kraan-Korteweg, P. Lah, M. Lehnert, A. Leroy, N. Maddox, S.
Makhathini, G. Meurer, M. Meyer, K. Moodley, R. Morganti, D. Obreschkow, S.-H.
Oh, T. Oosterloo, D.J. Pisano, A. Popping, G. Popping,
S. Ravindranath, E. Schinnerer, A. Schröder, K. Sheth, O. Smirnov, M. Smith, R.
Somerville, R. Srianand, L. Staveley-Smith, I. Stewart, M. Vaccari,
P. Väisänen, K. van der Heyden, W. van Driel, M. Verheijen, F. Walter,
E. Wilcots, T. Williams, P. Woudt, M. Zwaan, J. Zwart

The Team



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Active Team

- Pls meet every week over Skype.
- working on:
 - Outreach activities
 - Ancillary data.
- Promotion of survey, Meerkat & SKA.



PI tag...



Blyth & Holwerda



Baker & Blyth



Baker & Holwerda

This has happened only once before...



PHISCC at ASTRON (photo: Lister Stavelly-Smith)

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Wavefront was
scheduled to
collapse again day
after tomorrow...

Not to say it's been a long time....



Born when
proposal was
submitted

Going to
school
now...



Tiered Cake of Surveys



Main Questions

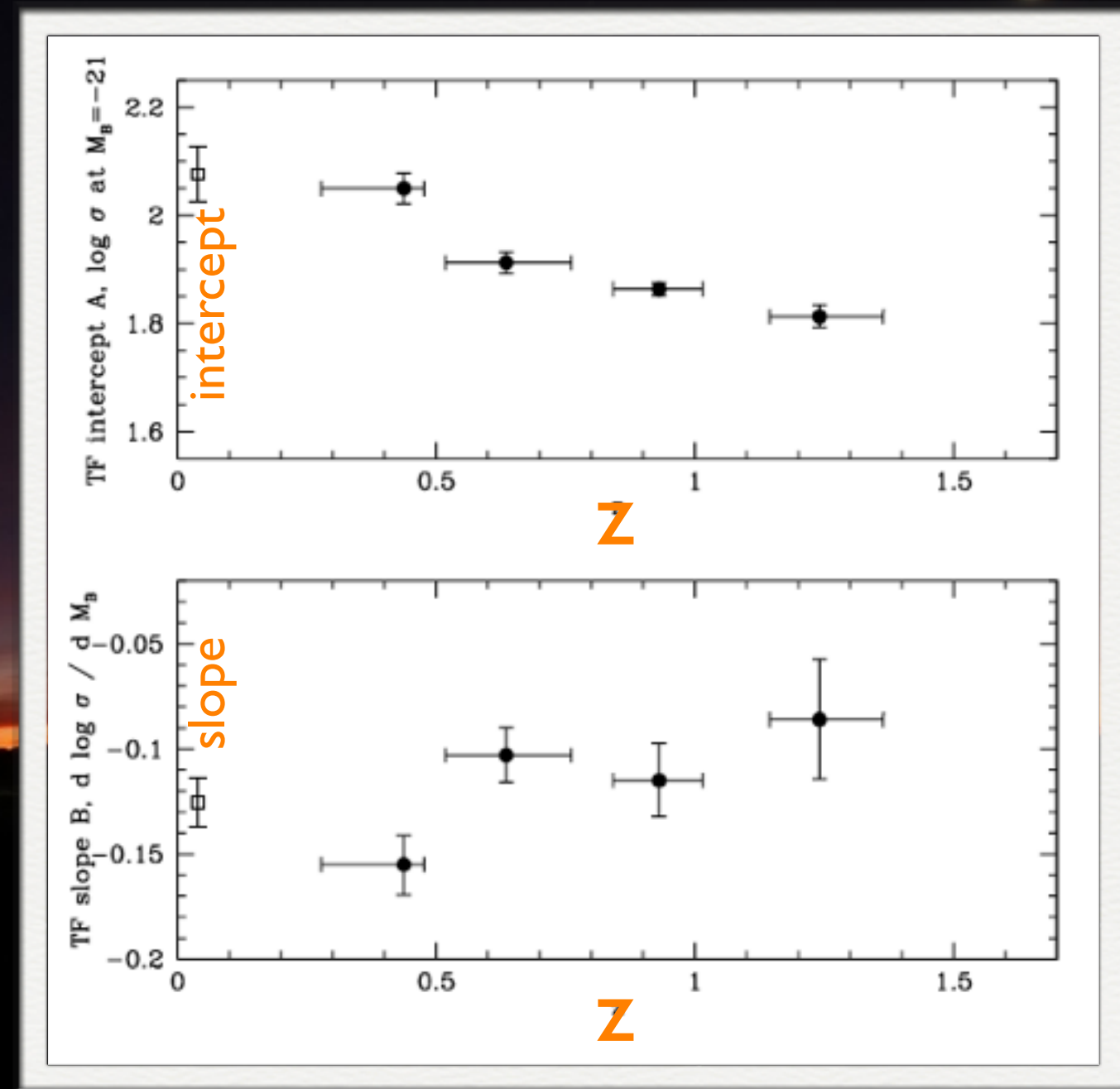
- How does the (baryonic) Tully-Fisher relation evolve with redshift?
- How does the HI mass function (HIMF) vary with redshift and environment?
- How does the cosmic HI density (Ω_{HI}) evolve with redshift?
- How do galaxies' HI masses depend on their stellar and/or host halo masses, environment, and redshifts?

The Science Case

- Essentials unchanged since the proposal in 2009.
- Updated and adapted to new instrumentation realities.
- Keeping a “living document” between the PIs that will be the basis for the Survey Description Paper (May 2016).

Baryonic Tully-Fisher Relation

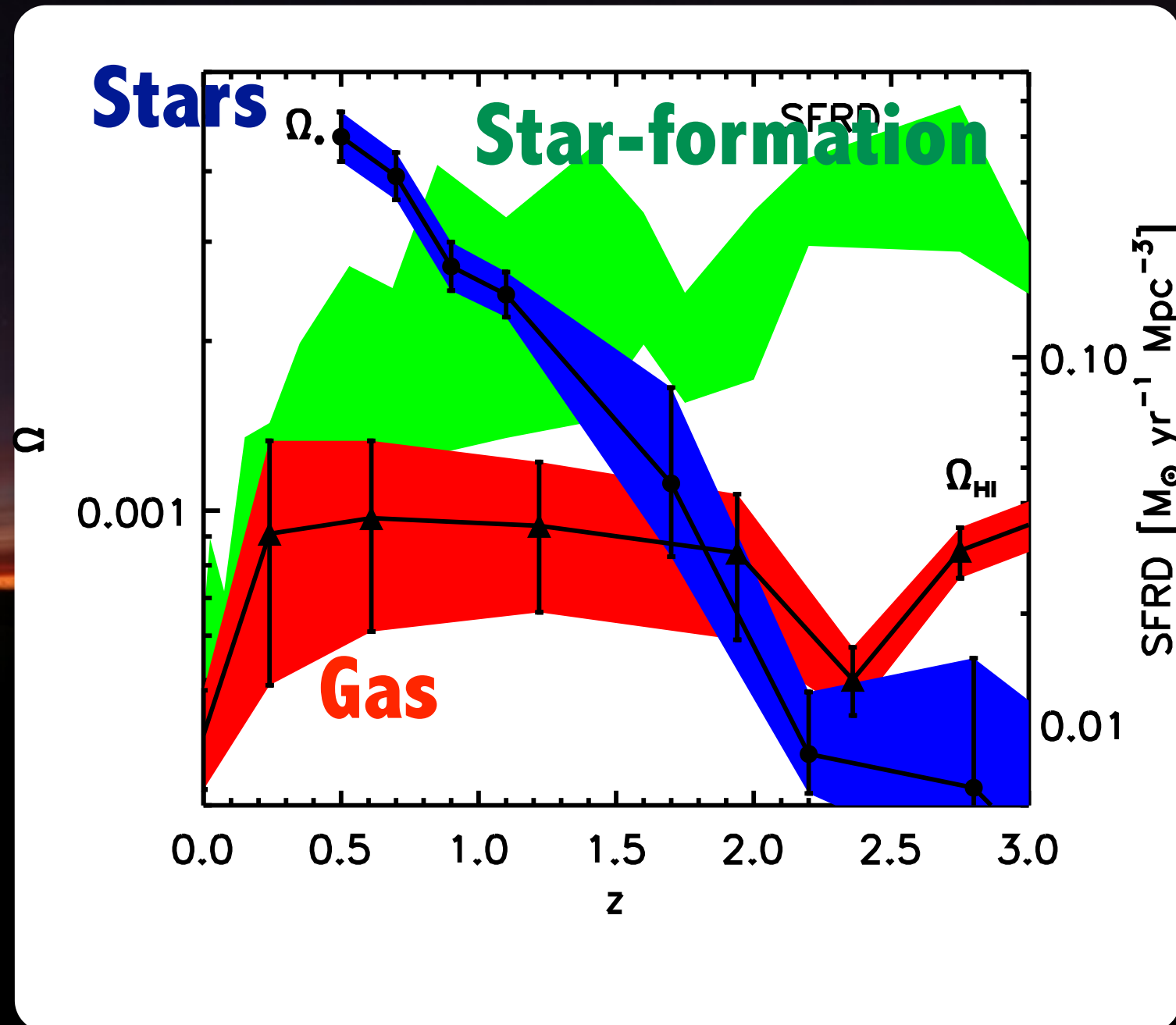
- Galaxies rotate since $z > 1$
- Stellar mass TFR shows evolution for $0 < z < 1.3$
- H α does not trace well into the halo
- Unknown how the **Baryonic TFR** evolves over cosmic time.
- LADUMA will observe 1000s of HI profiles.



Weiner et al. (2006)

Fueling Star-formation

- Star-formation declines, slow then fast.
- Stellar mass increases
- Gas supply constant?

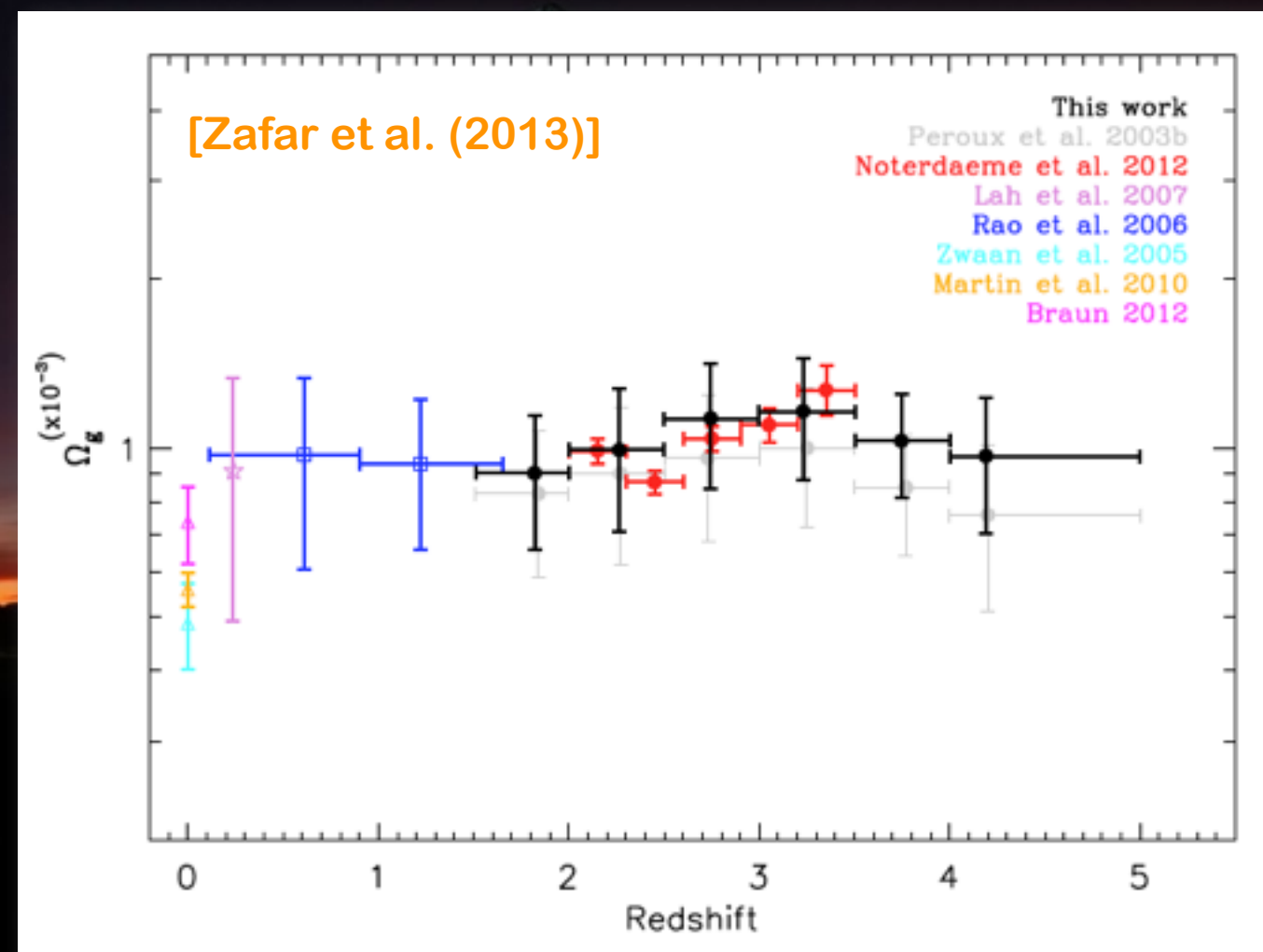


Science: Cosmic HI Density (Ω_{HI})

What is the average amount of HI at different z ?

Ω_{HI} vs. z

- What is the trend for $0.2 < z < 0.6$ where SFR is decreasing?
- How will HI measurements compare to Ly α and MgII absorber results at high z ?



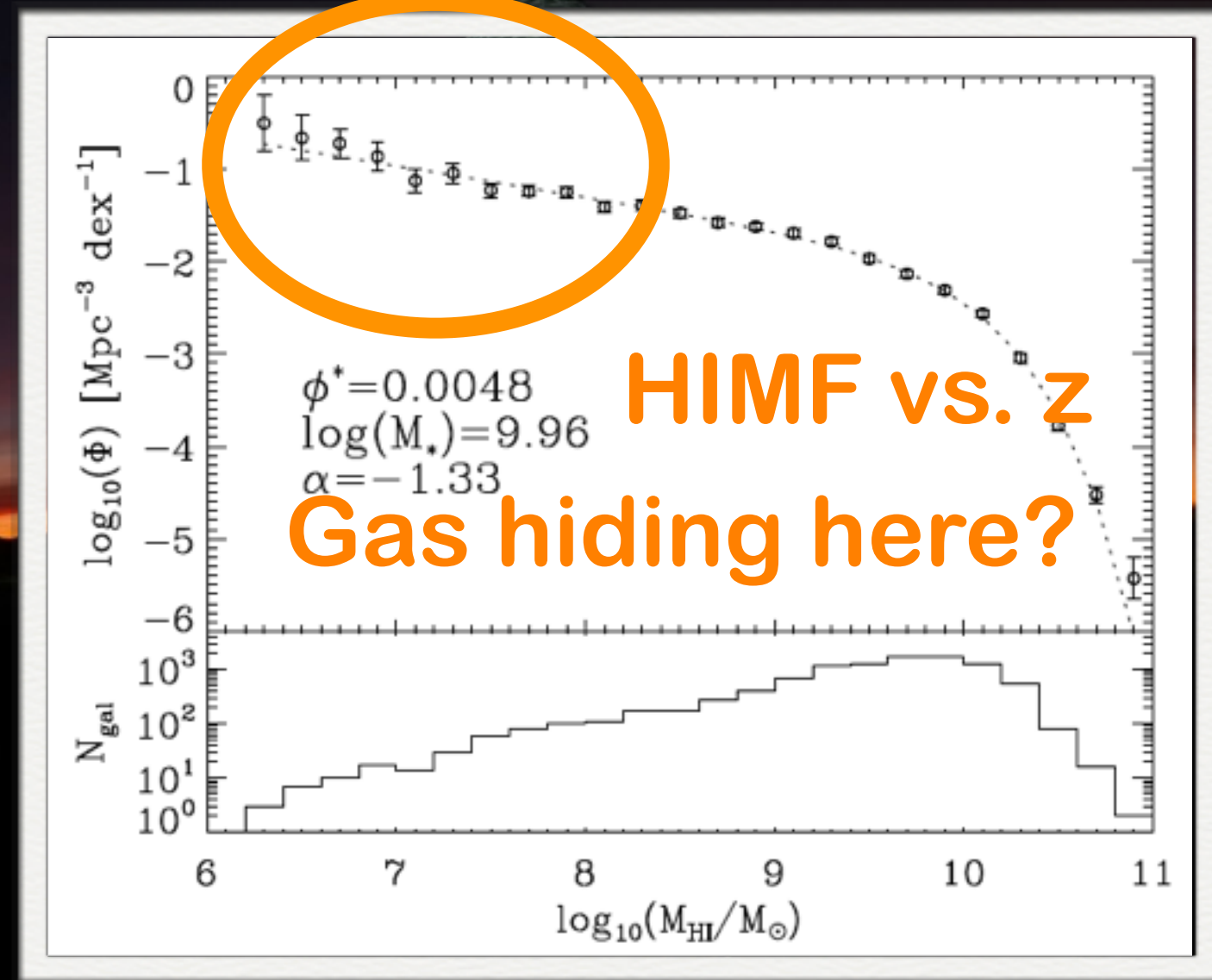
Science: HI Mass Function

To study galaxy evolution over cosmic time, we need to understand where & how much HI exists...

How is HI distributed within galaxies?

- How do M_{HI}^* , α & normalization vary?
- Help to constrain hierarchical galaxy formation models
- Differences with environment?

Martin et al. (2010)



(measured for $z < 0.06$)

MeerKAT



Not a computer generated image!



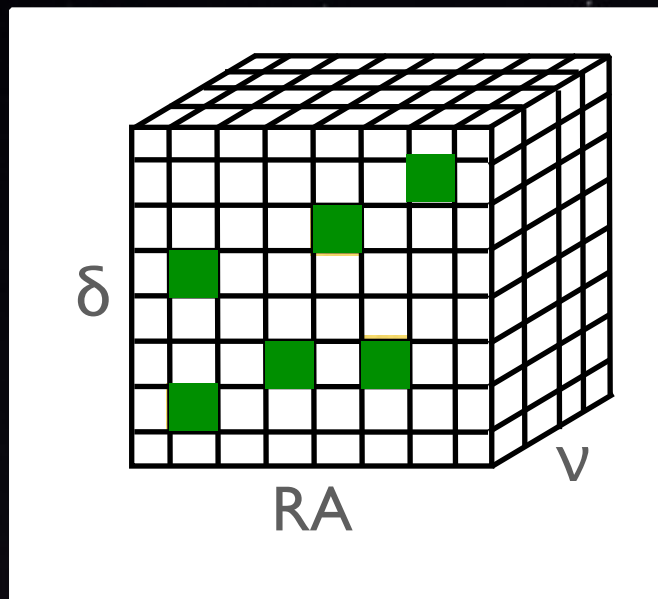
Expected Numbers

Phase II Phase I

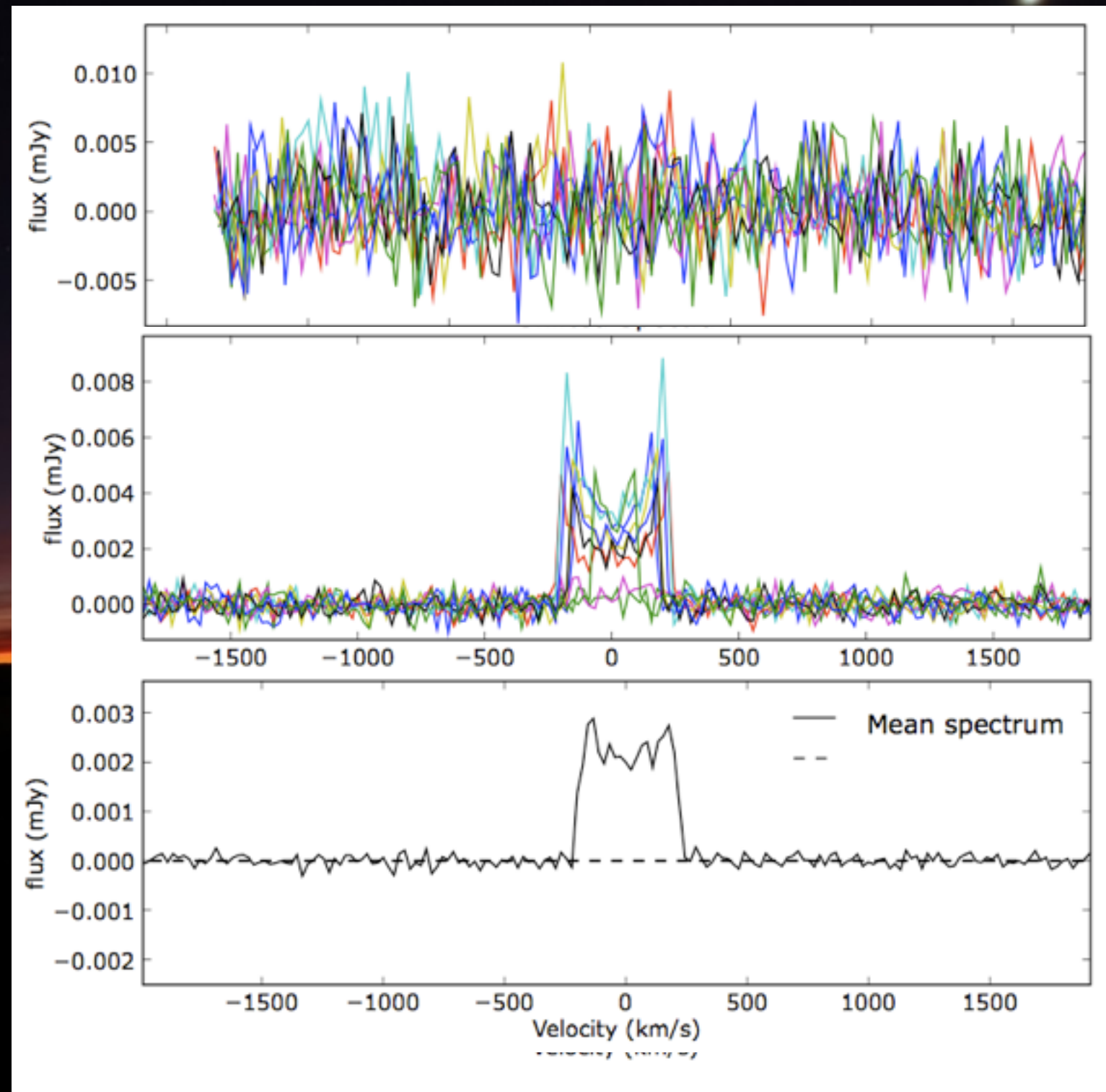
Redshift Range (z)	Integration Time hours	Direct detections (5σ)	Direct detections (4σ)
<0.4	1000	2218	2986
0.4-0.58	5000	1974	2769
0.58-1.44	4000	1725	3021

Yes lots...big volume but direct detections diminish with redshift and not the only science driver.

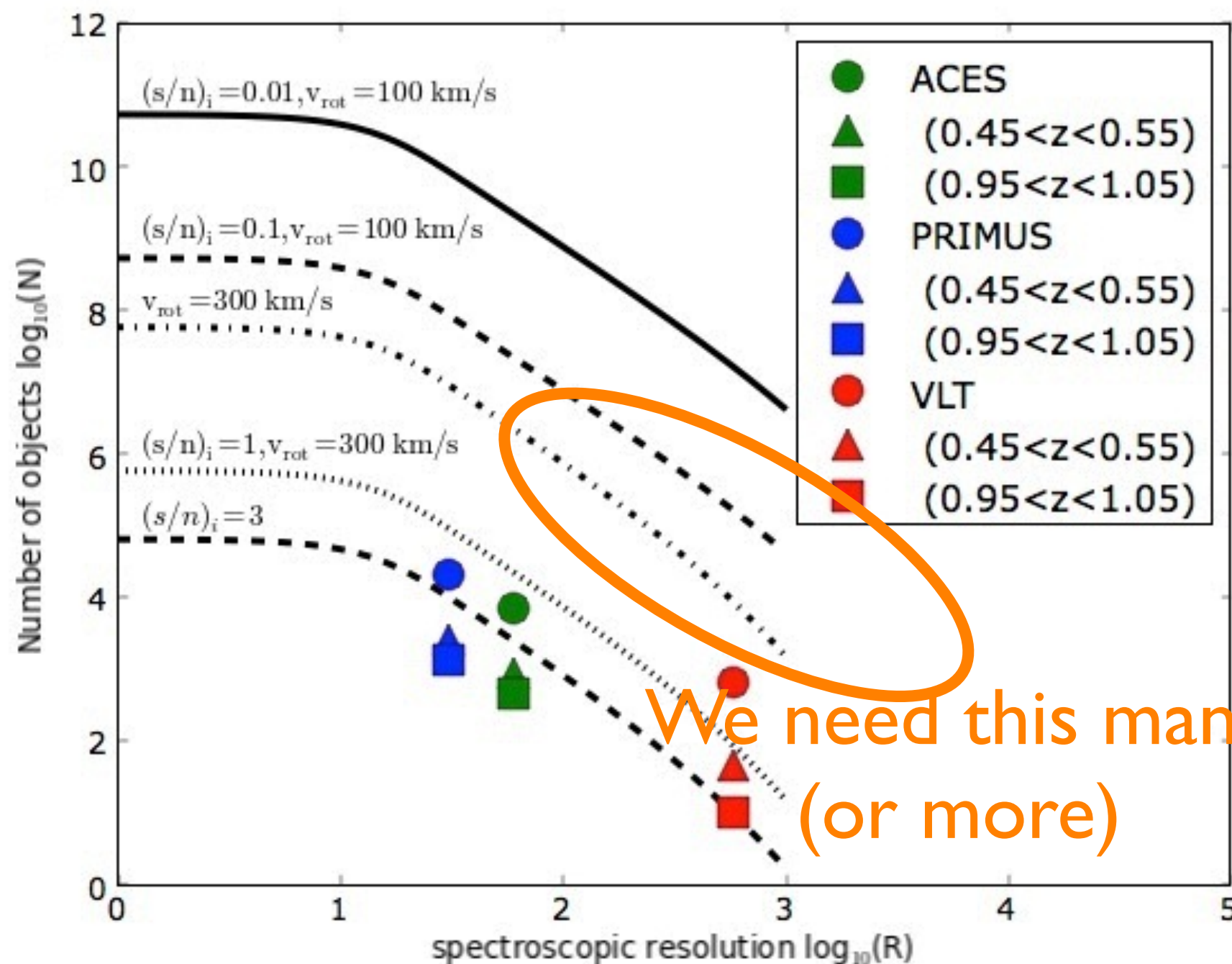
HI Line Stacking



- **STEP 1:** extract spectra using known positions and redshifts.
- **STEP 2:** shift all spectra to common frame.
- **STEP 3:** Co-add spectra
- **STEP 3A:** More = better.
- See J. Healy's talk tomorrow!

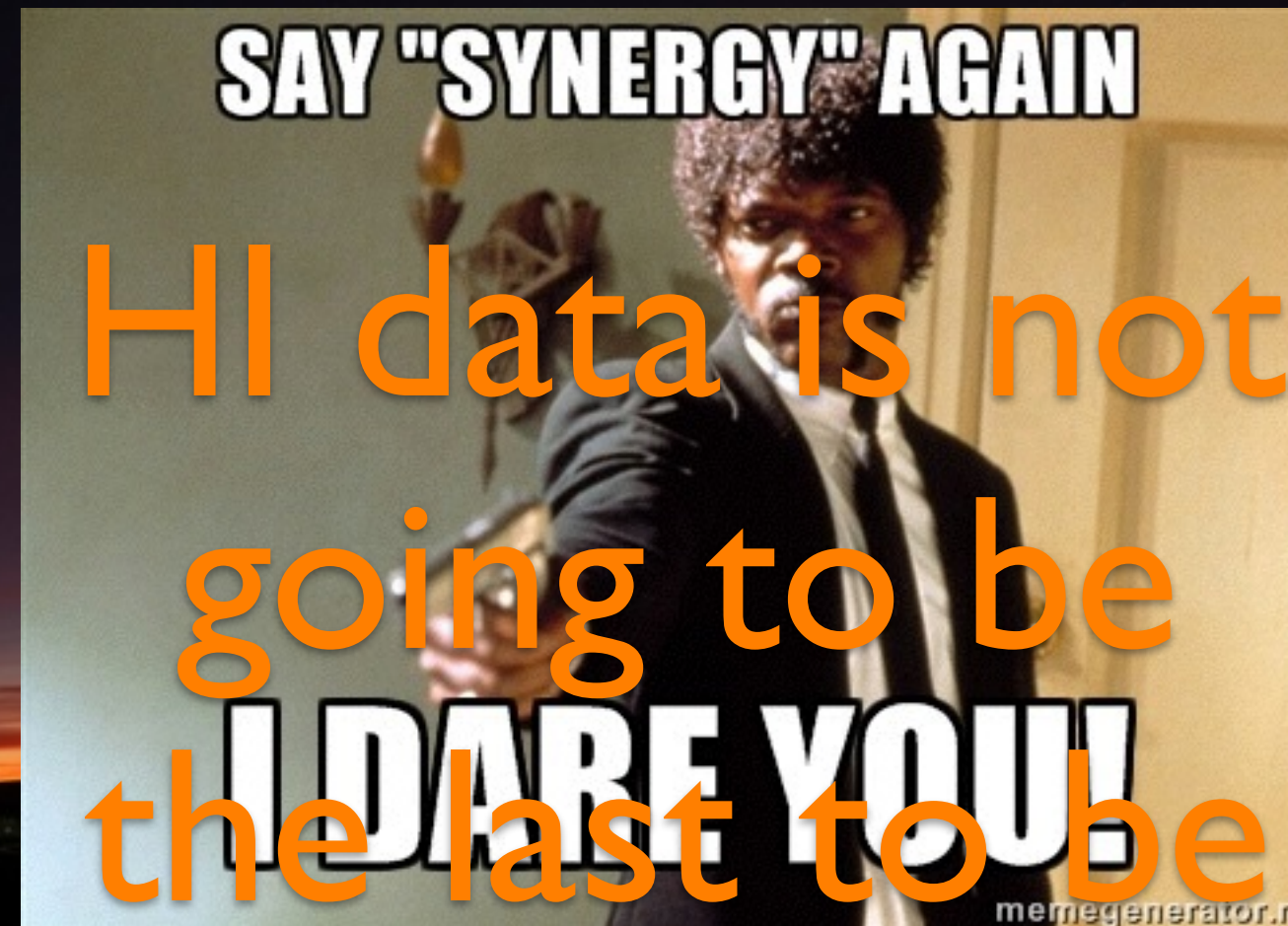


How many redshifts do we need?



Synergies

- LSST - deep Tully-Fischer
- HST/WFIRST/EUCLID - morphologies
- 4MOST - anything that requires stacking HI
- VLT/MUSE - environment
- SALT - SF characteristics
- JWST - SF/M*
- ALMA - full ISM tally



observed!

Our Ancillary Data

The LADUMA team has submitted 6 survey proposals (spectroscopic, imaging).

- **NOAO** proposal for deep U-band imaging over 2 deg².
- **SALT** commissioning proposal of 20 hours (8 x 30min exposures) on GOODS-S.
- **AAT** already targeted CDFS for several programs. Dedicated NASA time for LADUMA spectroscopic redshifts (2 successful programs).
 - Props to GAMA team for technical help!!
 - See Andrew Baker's talk on Wednesday.

ENTER THE WAVE(S)

- 4MOST wide and deep spectroscopic surveys.
- Led by the (former) GAMA team.
- Gets us all the redshifts we can eat in ~5 nights of observing.

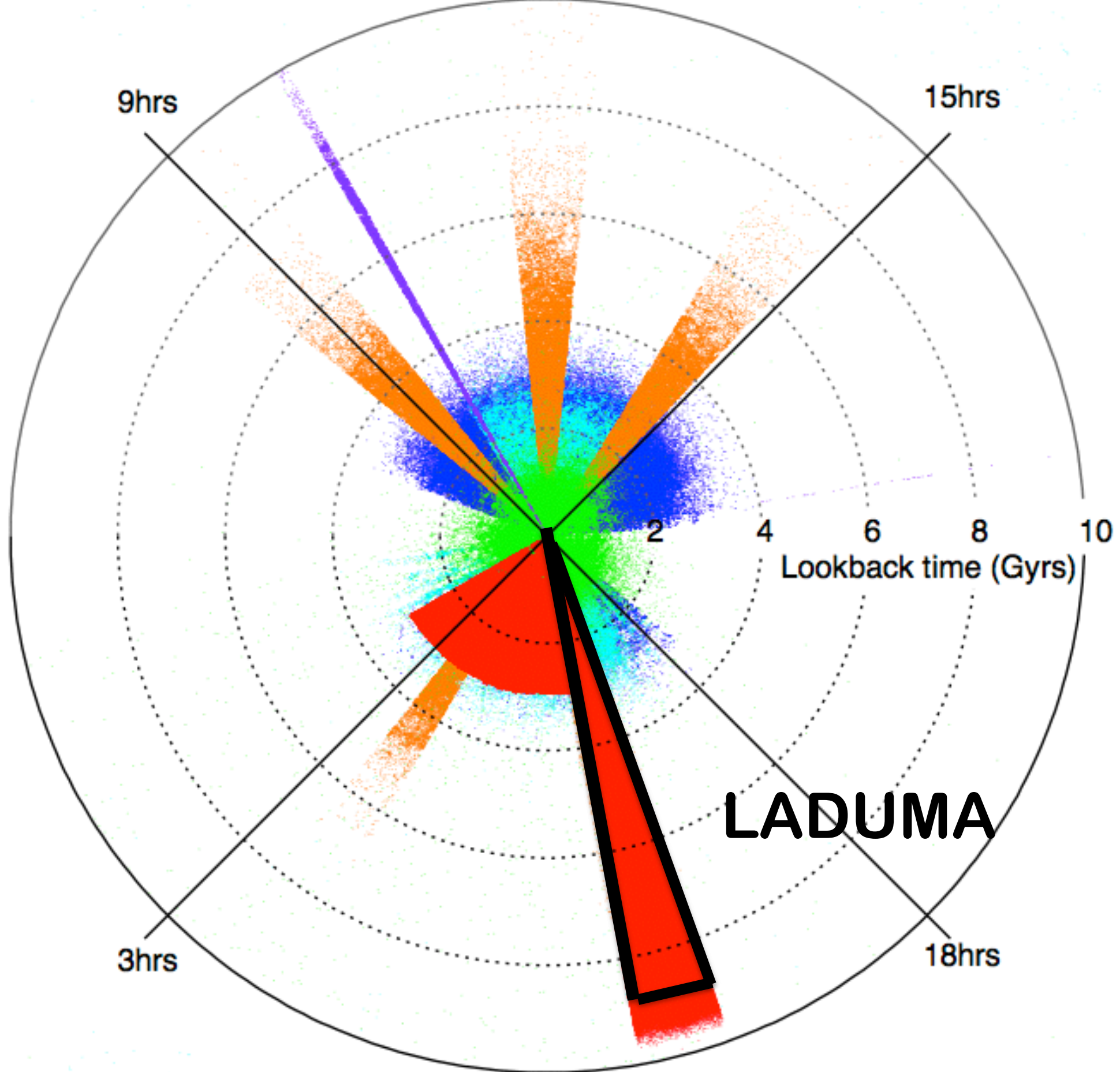




4
MOST

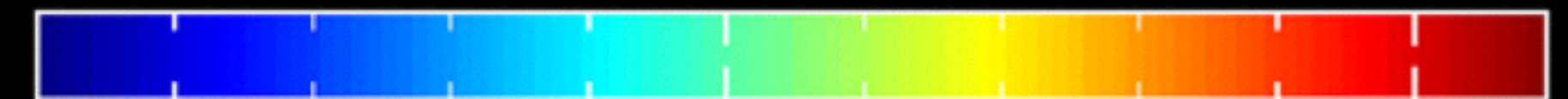
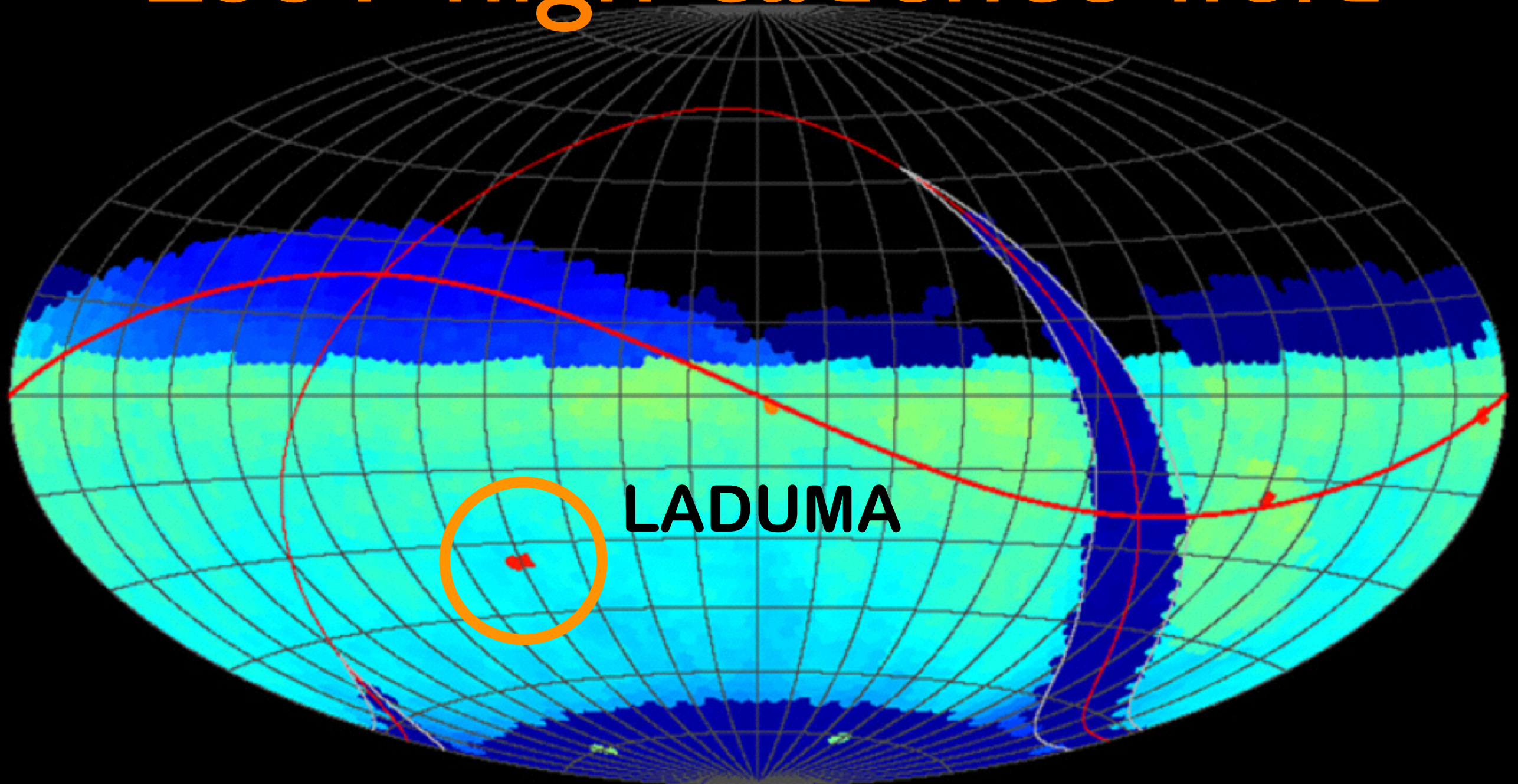


WAVES
wide area vista extragalactic survey



| 6dfGRS | SDSS DR9 | 2dFGRS | GAMA | zCOSMOS | WAVES |

LSST high cadence field

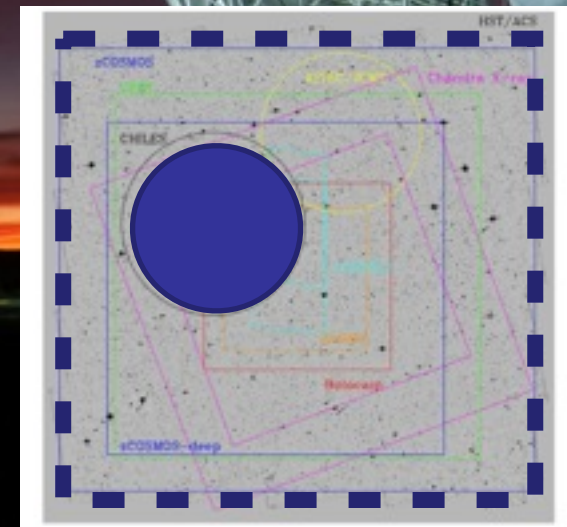
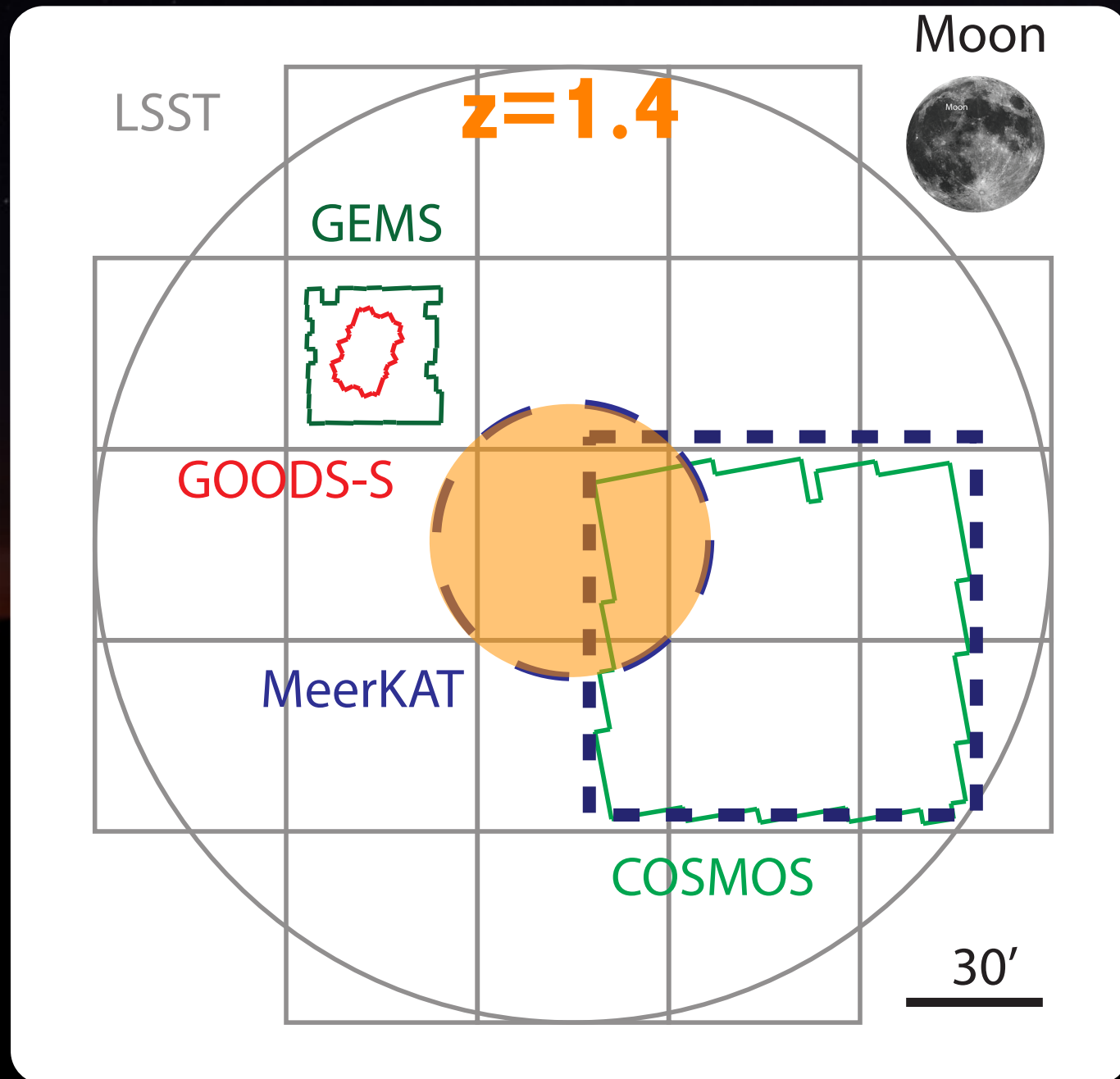


Shallow

Deep

Depth

CDF-S / COSMOS



Category	Chandra Deep Field	COSMOS
Spectral coverage	30% in the medium deep field VVDS	70% zCOSMOS, G10 area of GAMA 
Spectral Resolution	4MOST deep field	R=600
Deep	MUSE	10-12k redshifts over 1.0 sq. deg., I
HST	WFIRST/EUCLID	F814W (I) only
GALEX	deepest available 	< 26 M
X-ray	second deepest anywhere with Chandra, deepest in southern hemisphere (940 ks) 	XMM - 1.4 megaseconds Chandra - 200 ksec, mosaiced
Radio	Some continuum with ATCA, 20 cm with VLA	Continuum with VLA, some line observations with GMRT, CHILES
Optical	LSST deep field SpARCS z-band to 24.2 (AB)	Subaru B (27.4), V (27.2), r+ (26.9), i+ (26.9), z+ (25.6) CFHT-LS u*,g*,r*,i*,z*
NIR	VIDEO Z,Y,J,H,K to 25.7,24.6,24.5,24.0,23.5 (AB) JHK (ISAAC & SOFI) 	JH (CFHT-LS)
Spitzer	very deep IRAC & MIPS SWIRE fields 	sCOSMOS, uniform coverage
Herschel	deepest available,SERVS 	HERSCHEL-HERMES field

Cosmic Variance

- Two separate fields > 1 big one
- CHILES on COSMOS, LADUMA on CDFS

Two shots much better than one.

Out of Effort

This Friday Encore!

B. W. Holwerda (Sterrewacht Leiden) - PHISCC - 2016

Thank you!



- www.ska.ac.za
- www.ska.ac.za/meerkat
- <http://www.ast.uct.ac.za/LADUMA/>
- <https://www.facebook.com/MeerKATLaduma>