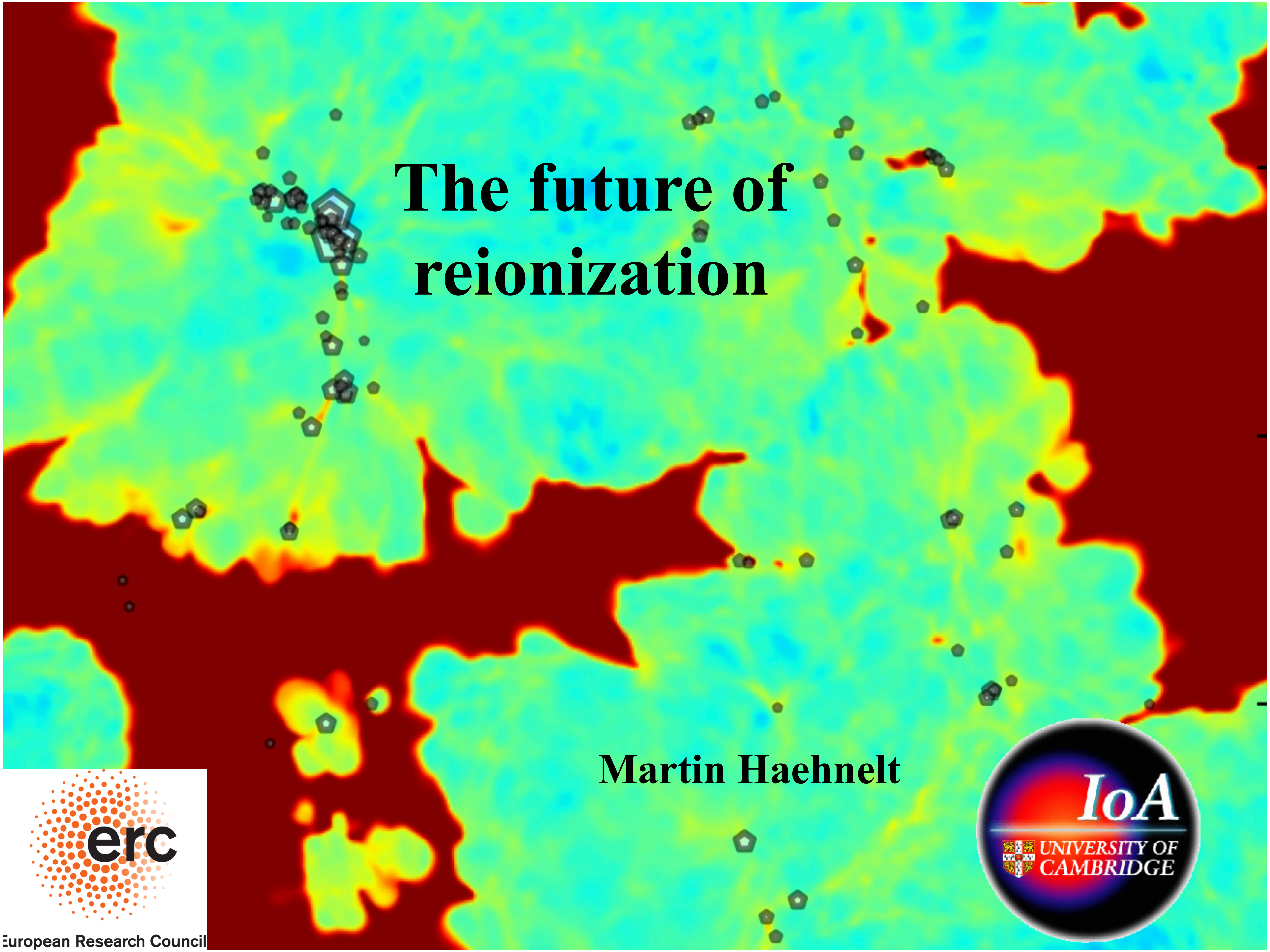


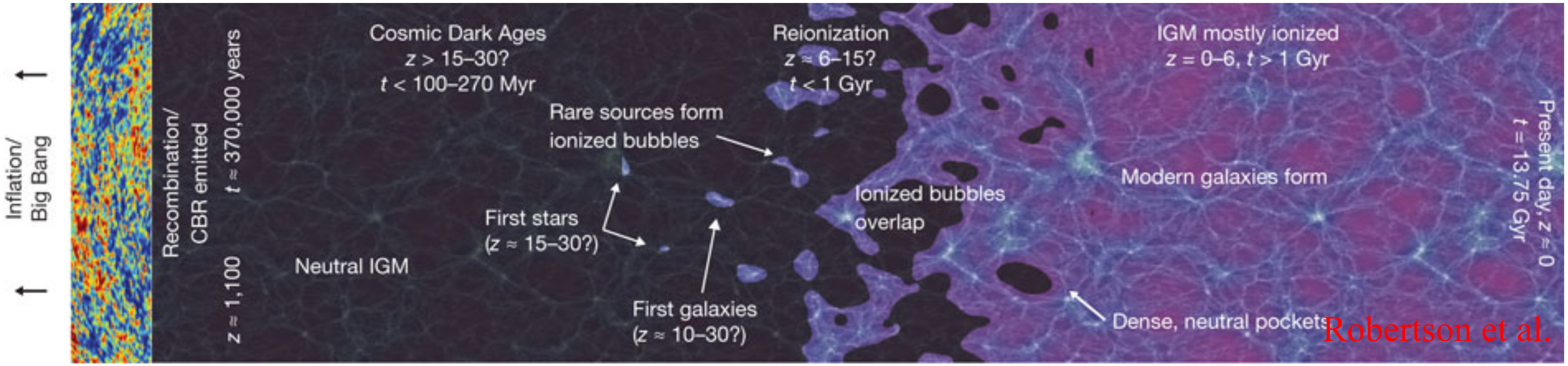
The future of reionization

Martin Haehnelt

European Research Council

IoA UNIVERSITY OF CAMBRIDGE

Probing the Epoch of Reionization

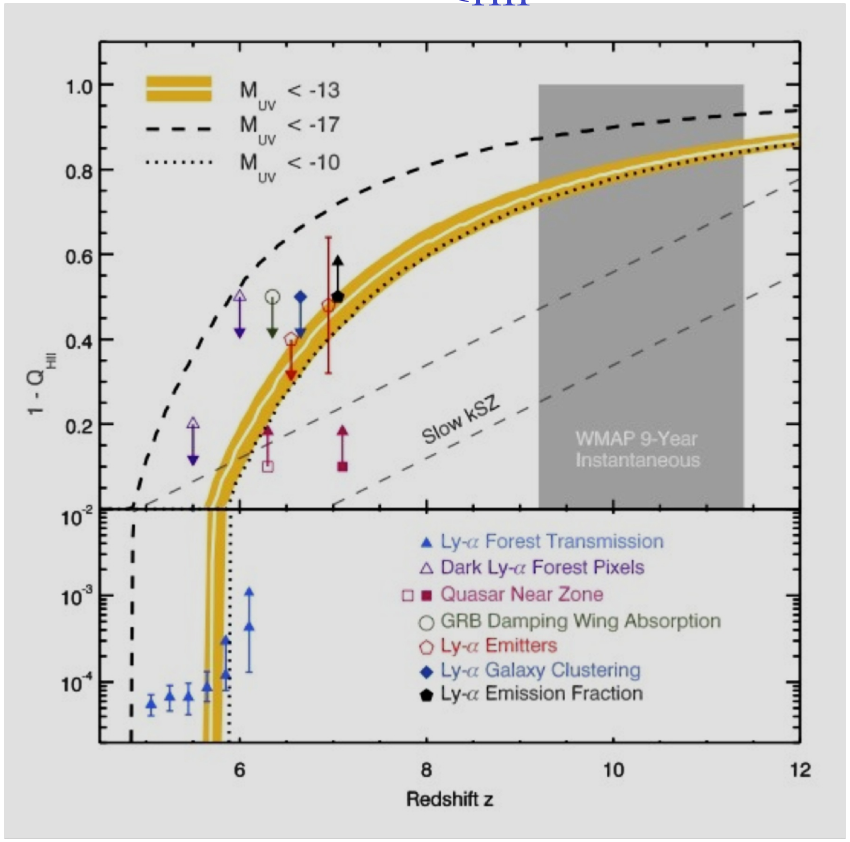


Robertson et al.

- CMB
- Lyman-alpha absorption
- Lyman-alpha emitters/high redshift galaxies
- 21cm emission/absorption

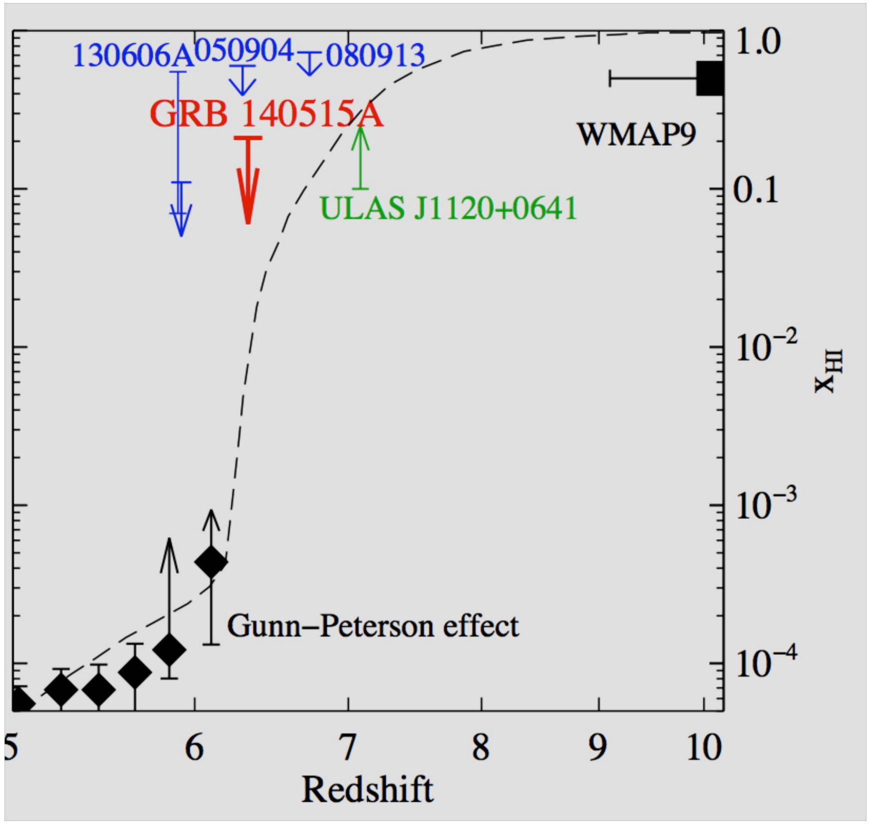
Homing in on the reionization history

$1\text{-}Q_{HII}$



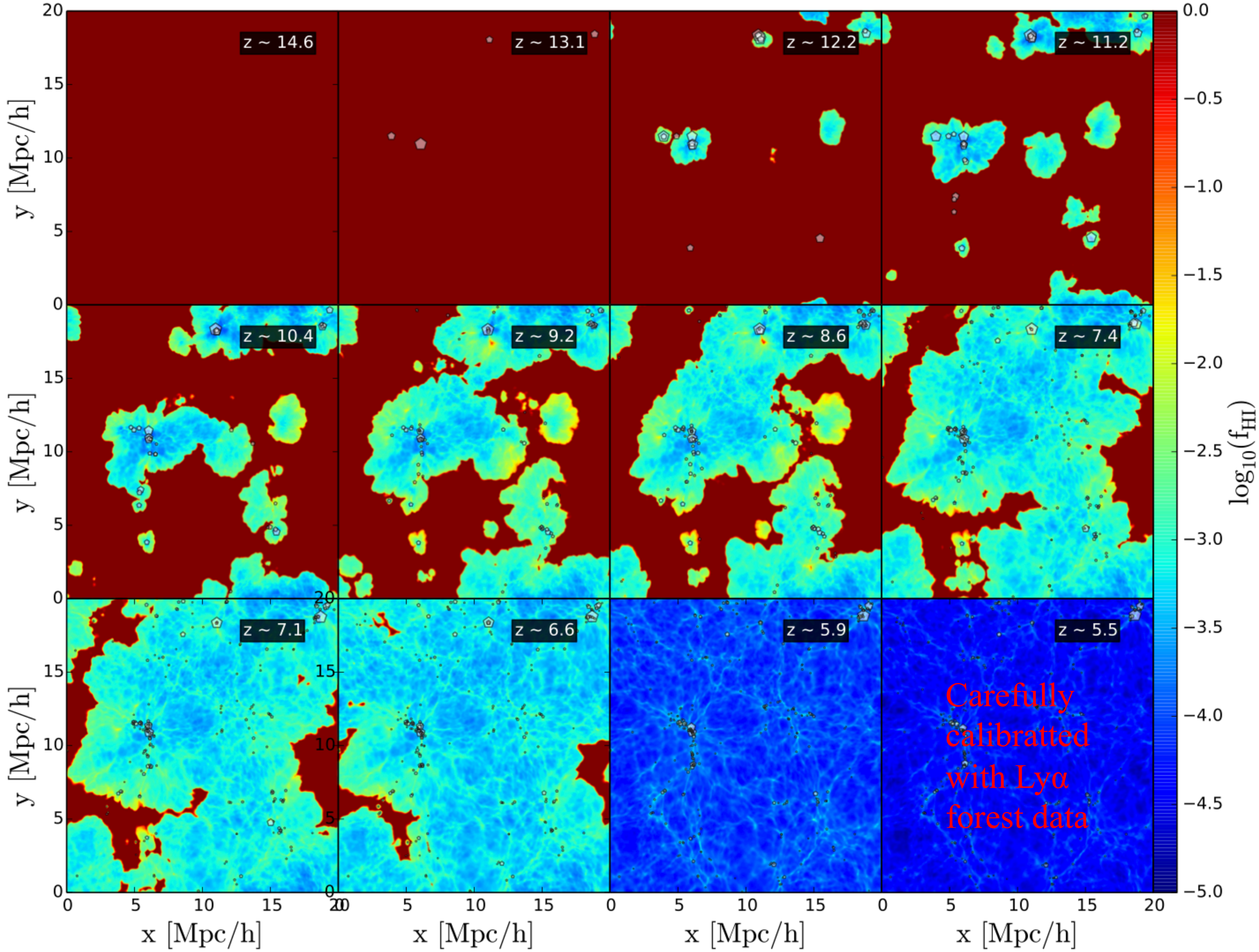
Robertson et al. 2013, Ellis 2014

f_{HI}



Chornock et al. 2014

But how early does it start, how late does it finish?



Chardin, Haehnelt, Aubert & Puchwein 2015

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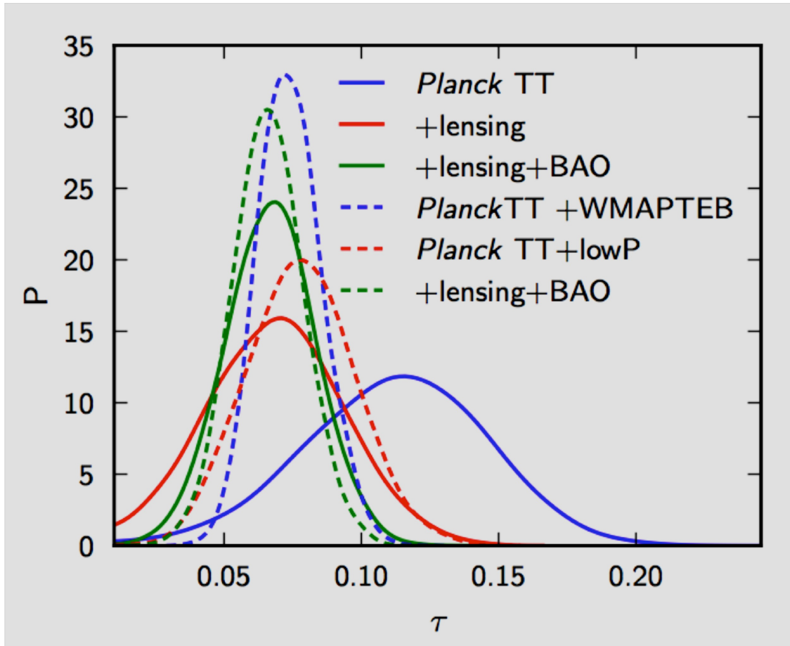
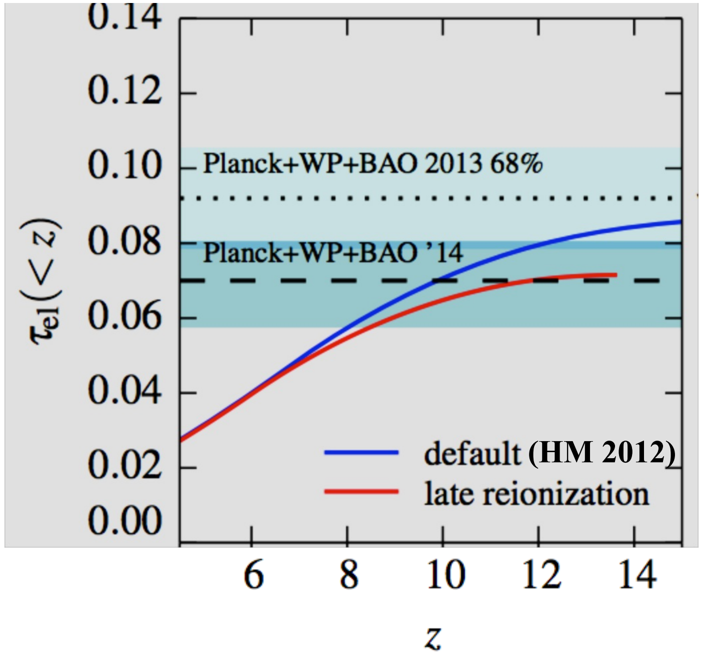
CMB

The (still preliminary) Planck 2014 results for τ



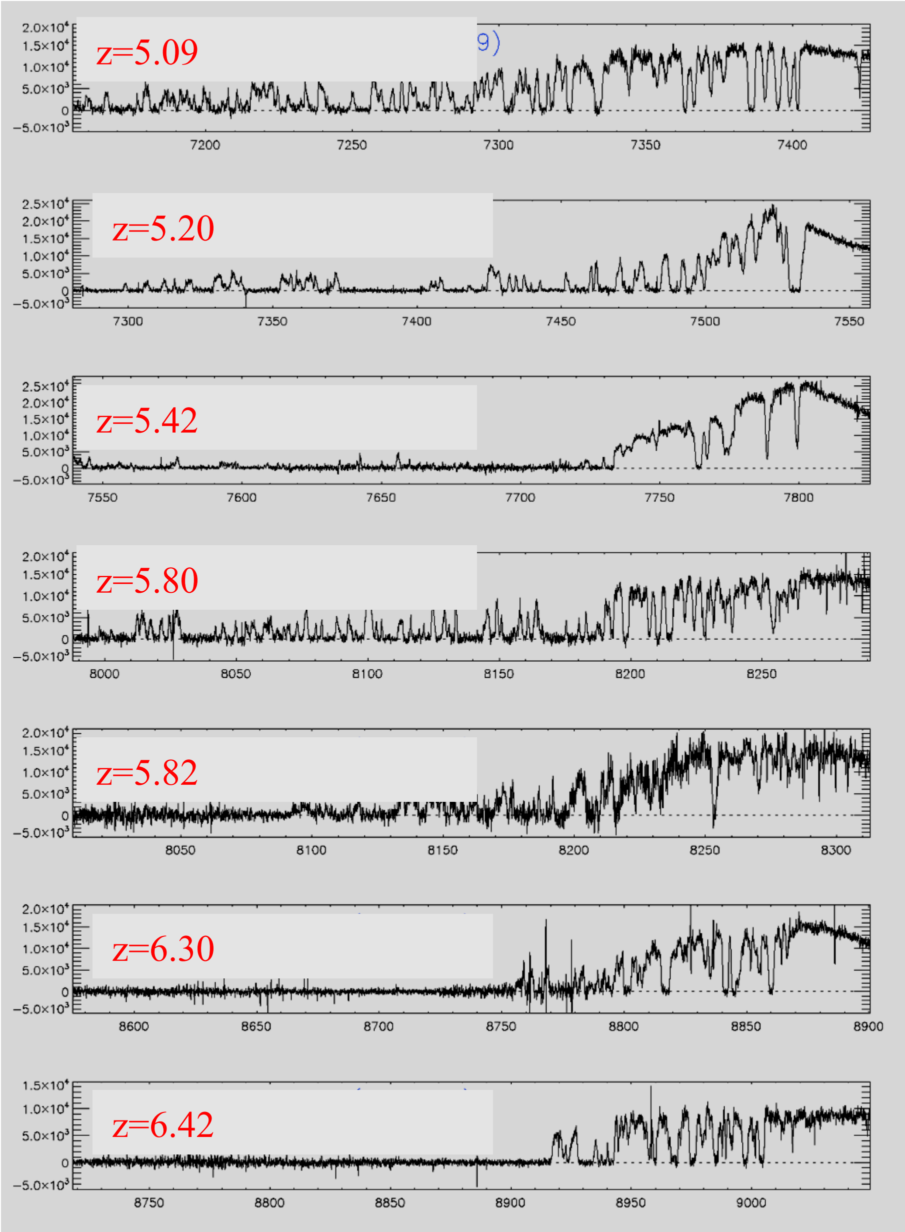


- ➢ constraints from CMB have become very weak.
- ➢ joint constraint with BAO appears to come down

Lyman-α (and OI) absorption

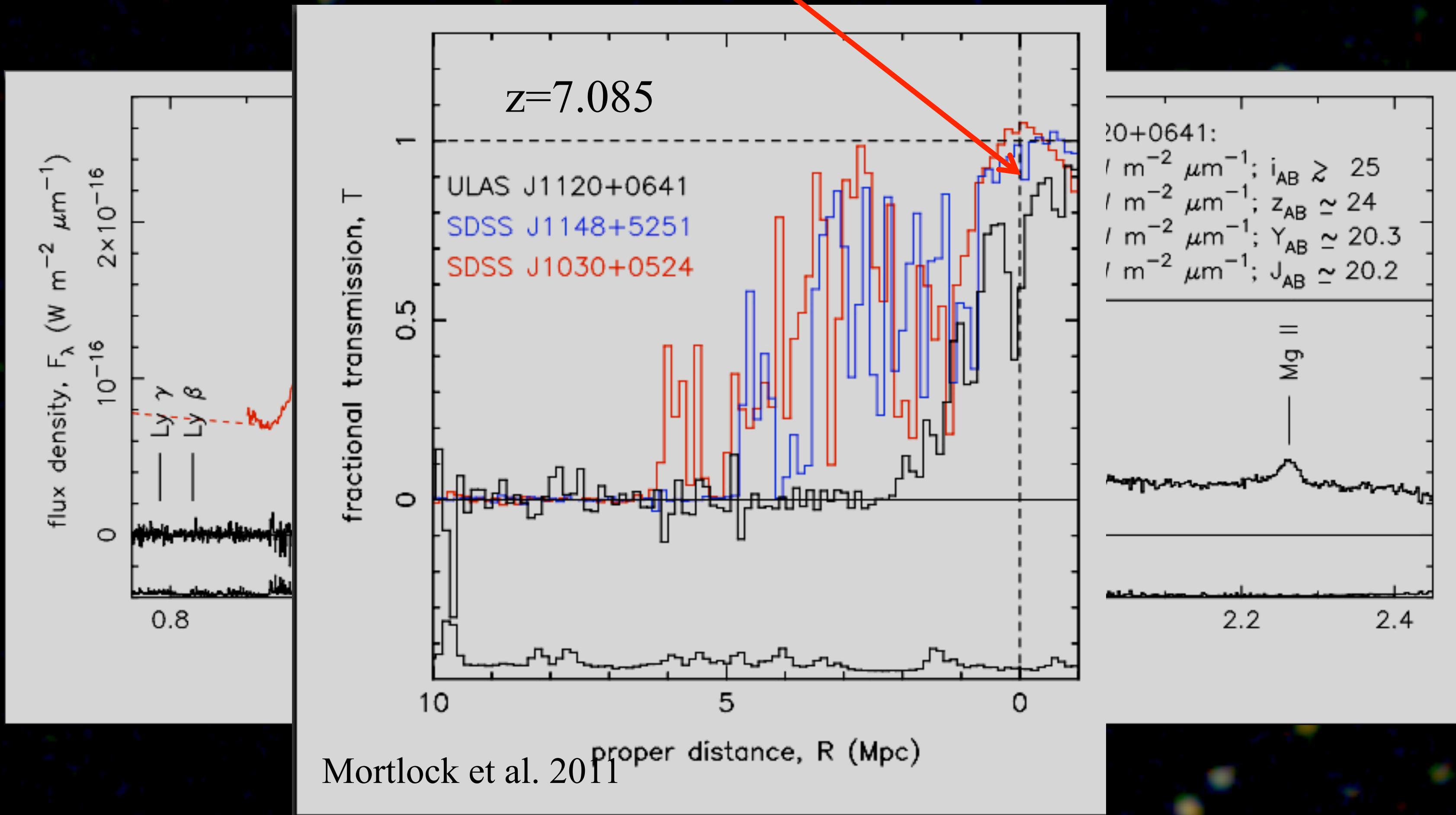
Searching for a Gunn-Peterson trough in QSO absorption spectra

$$\tau_{GP} \approx 10^5 \left(\frac{n_{HI}}{n_H} \right)$$



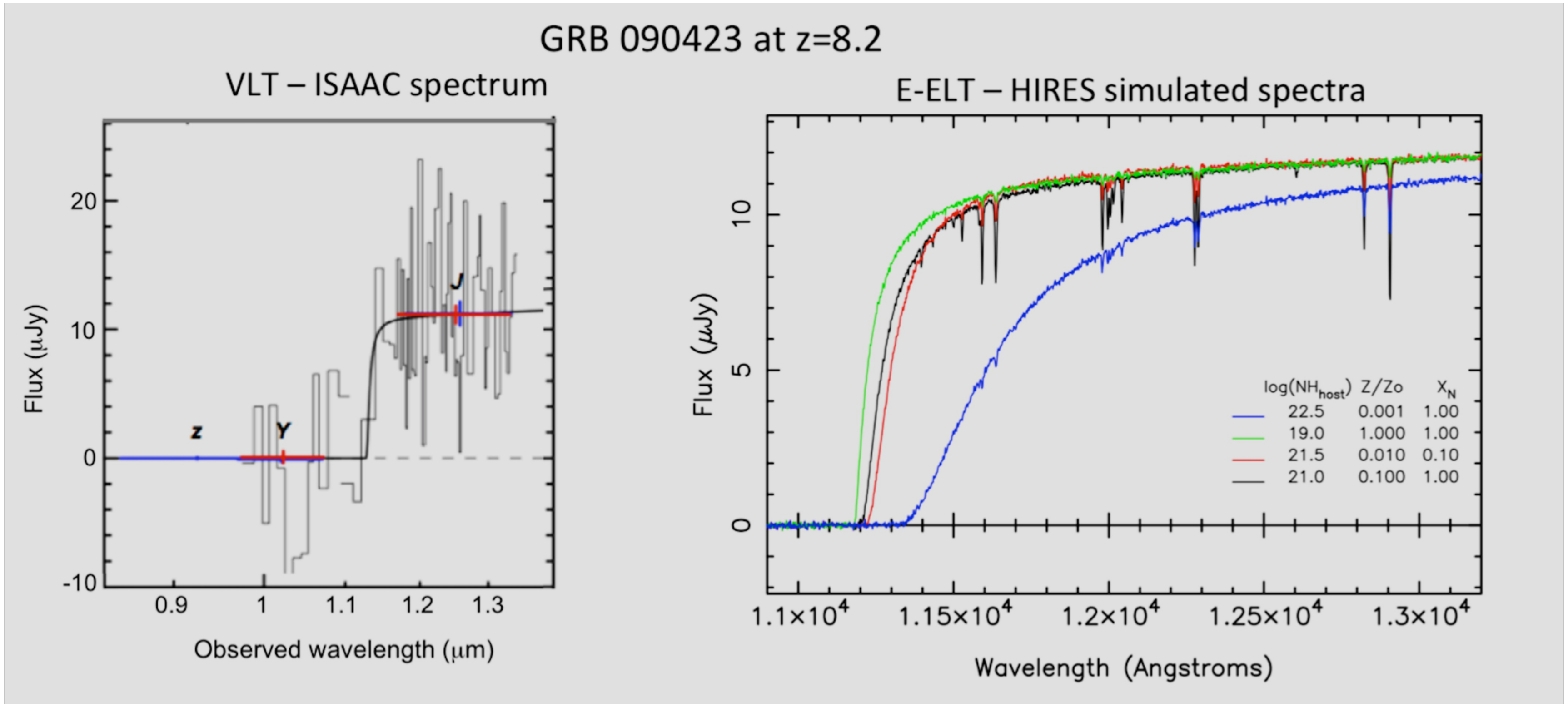
Fan et al., Becker et al.

A red damping wing?



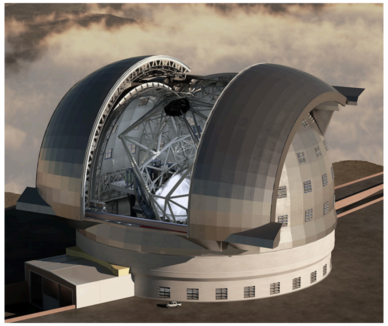
Mortlock et al. 2011

Red damping wings in QSO/GRB spectra with E-ELT



Maiolino, Haehnelt et al.

- should break degeneracy with N_{HI} in host galaxy
- proposed M4 mission THESEUS aims to detect 100 GRBs with z>6



ESO 2020, 21 February 2015

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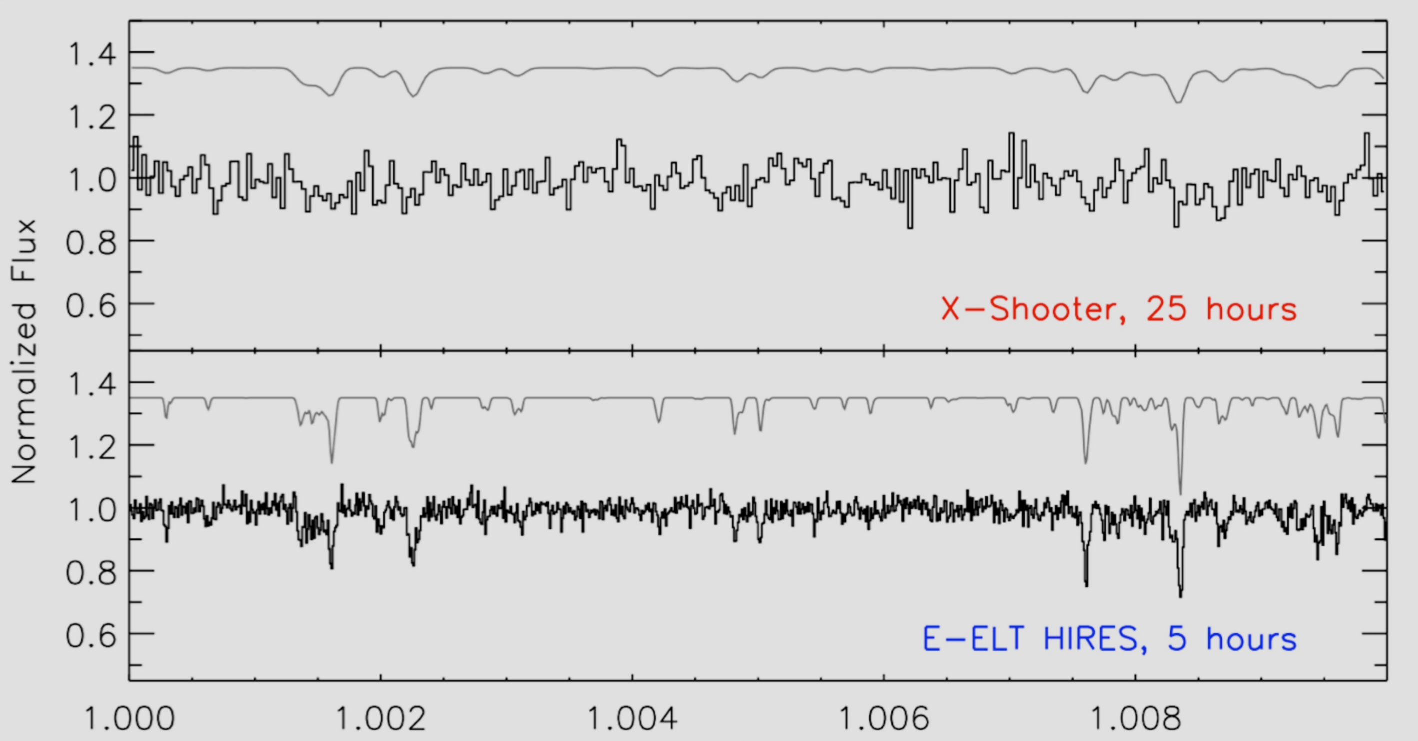
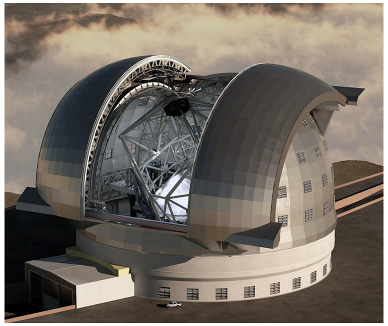
Harvesting the OI forest E-ELT

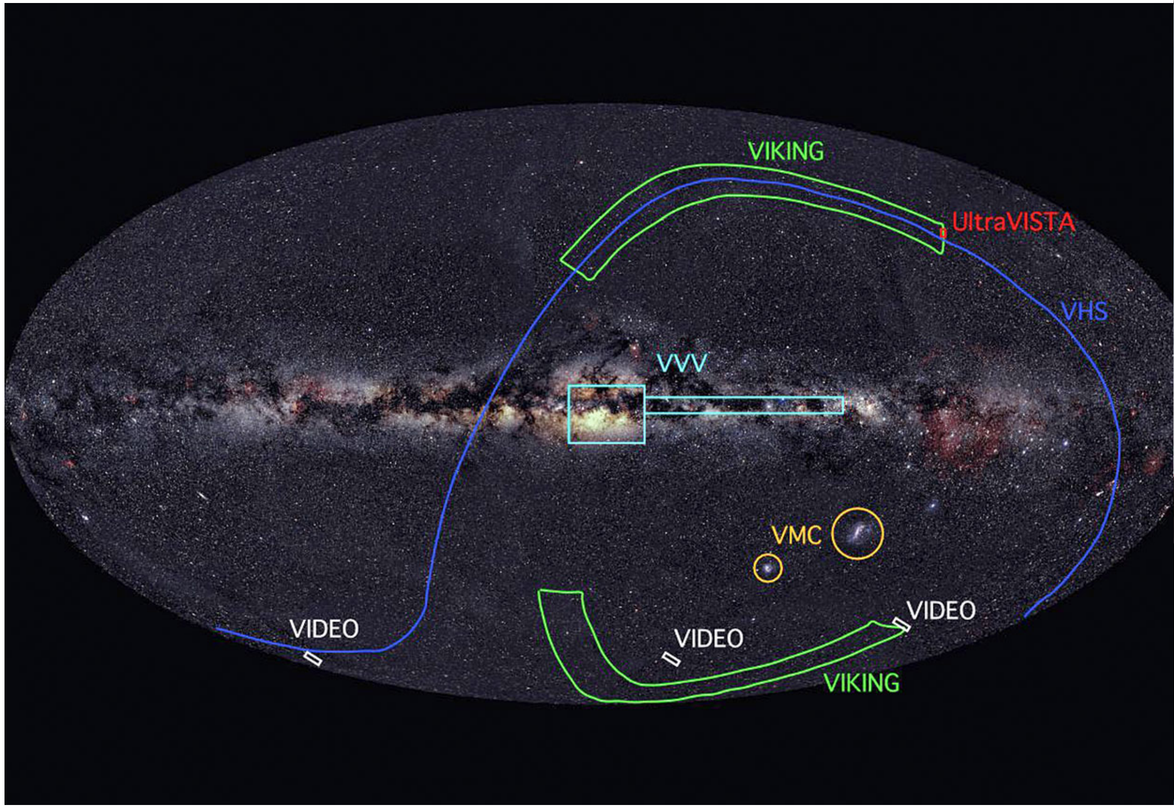


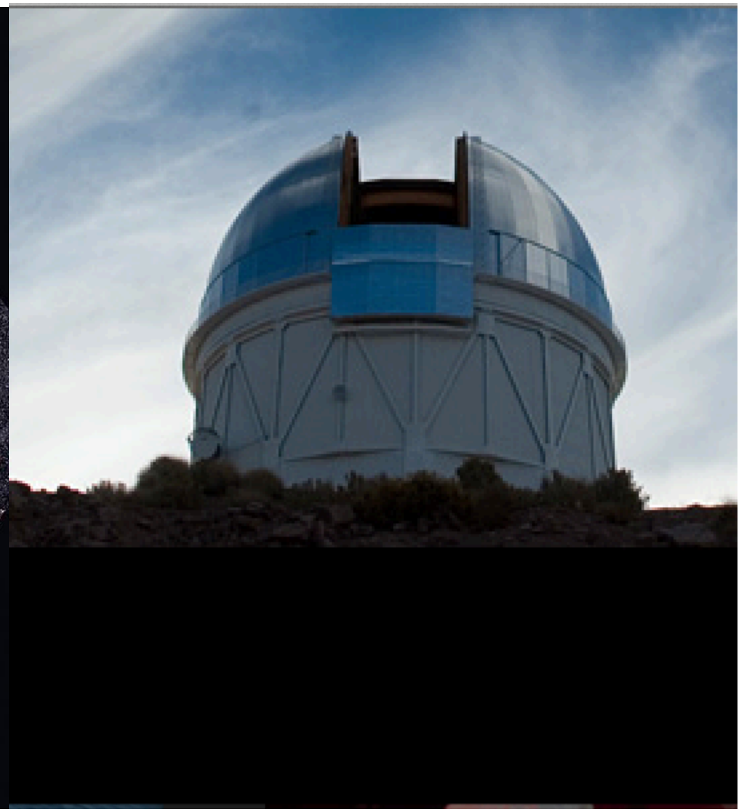
Maiolino, Haehnelt et al. 2014

- OI good tracer of HI at z>6 when Lyα is highly saturated



High-redshift QSOs from VHS/DES





- DES has officially started to take (optical) data 31 August 2014 and will complement the IR data from VISTA
- New z>7 QSOs will hopefully be rolling in soon.

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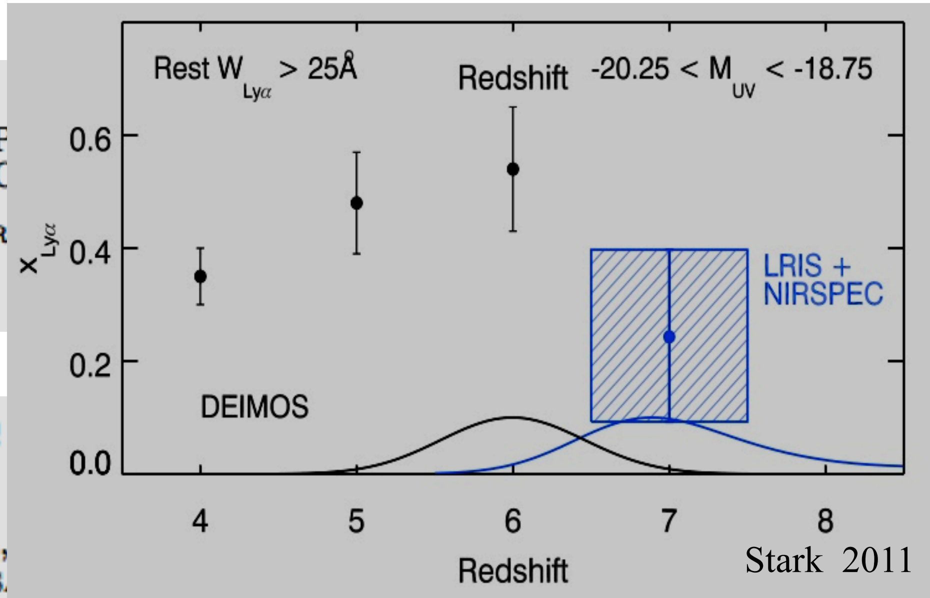
Lyman-α emission
High-redshift galaxies

KECK SPECTROSCOP … IDENCE FOR A DECLINING
FRACTIC … ANGE 6 < Z < 8

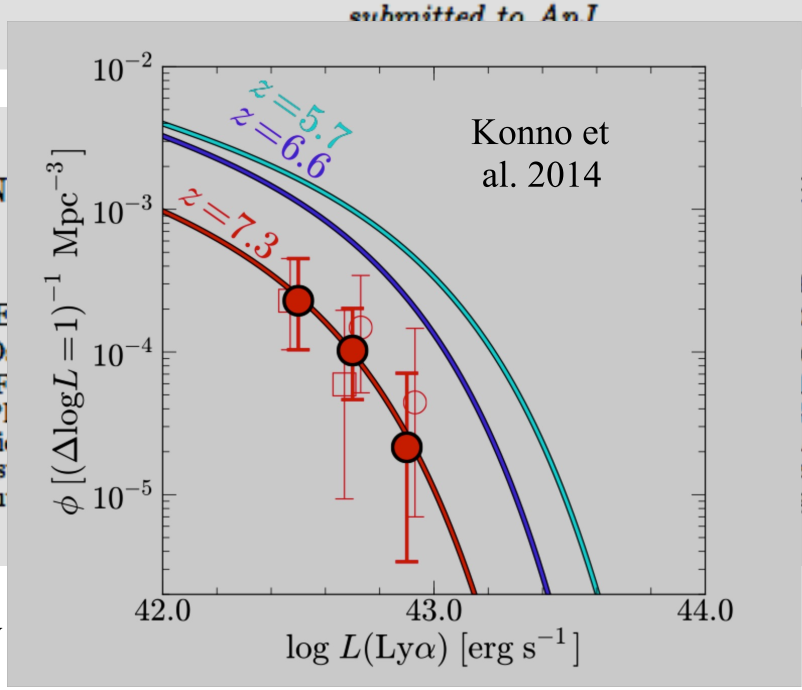
MATTHEW A. SCHENKER … N[1], JAMES S. DUNLOP[3], ROSS J.



SPECTROSCOPIC … XIES AT $z = 6.844 - 7.213$:
XIES[‡]

YOSHIAKI ONO [1], … NSON [5], KYLE PENNER [6],
KAZUHIRO SHIMAS… [5], KIMIHIKO NAKAJIMA [1],
HOOSHANG NAYYERI [4], DANIEL STERN [9], NOBUNARI KASHIKAWA [10], AND HYRON SPINRAD [11]

submitted to ApJ



SPECTROSCOPIC CON … RLIEST GALAXIES AND THE

L.PENTERICCI[1] A. FONTANA [1] … KSTRA [3] K. BOUTSIA [1] S. CRISTIANI [2]
M. DICKINSON[4] E… ORWOOD[6*] P. SANTINI [1]
[1] INAF O… eporzio (RM), Italy
[2] INAF … 31 Trieste, Italy
[3] Max-Pl… arching, Germany
[4] Nati… AZ 85726, USA
[5] Department of As… eet, Amherst, MA 01003 and
[6] European Sou… bei Munchen, German

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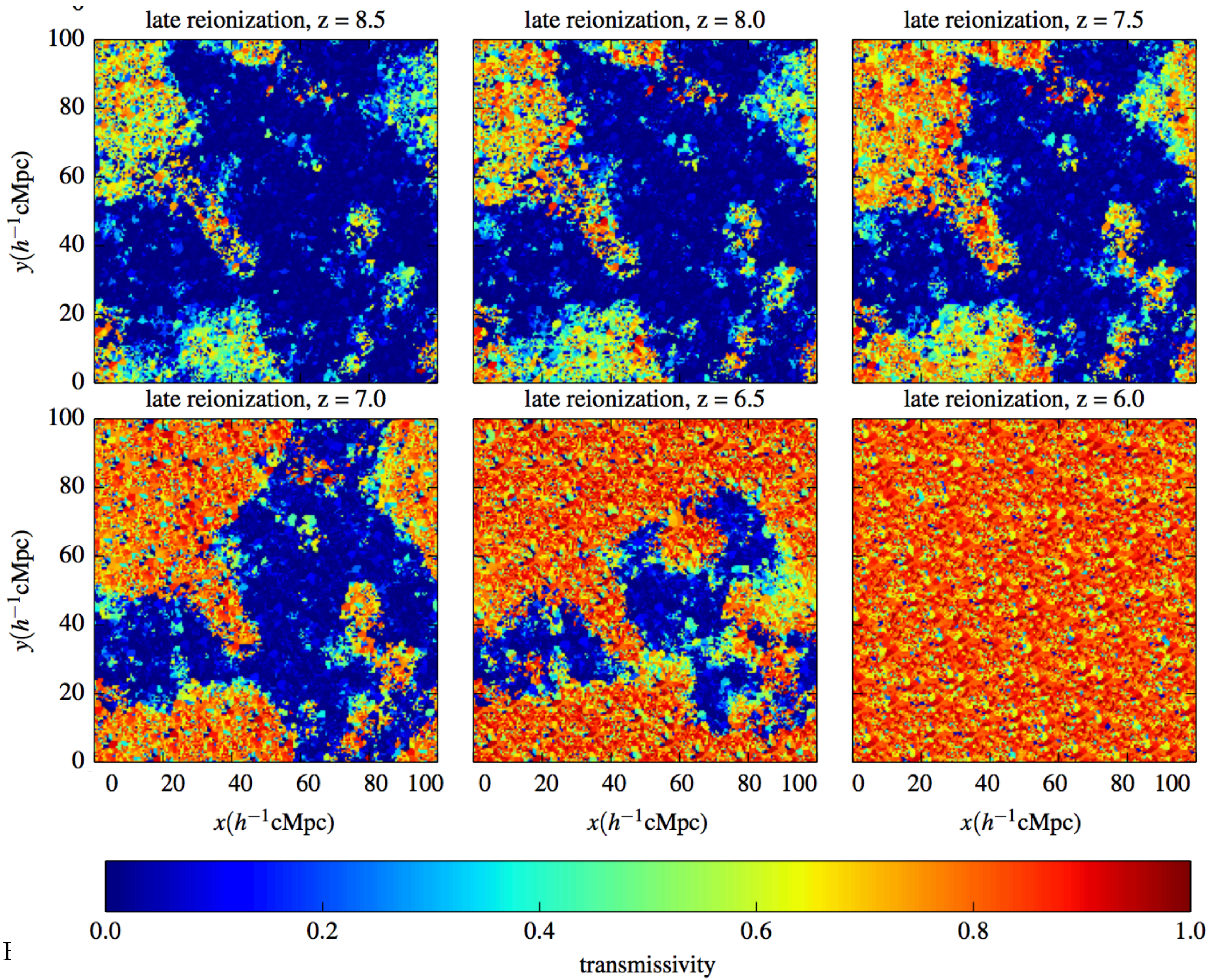
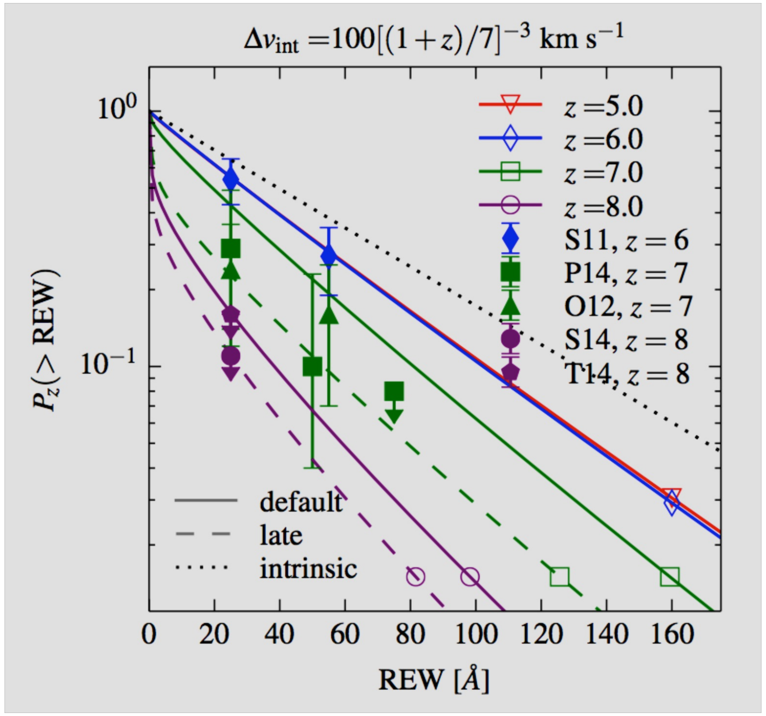
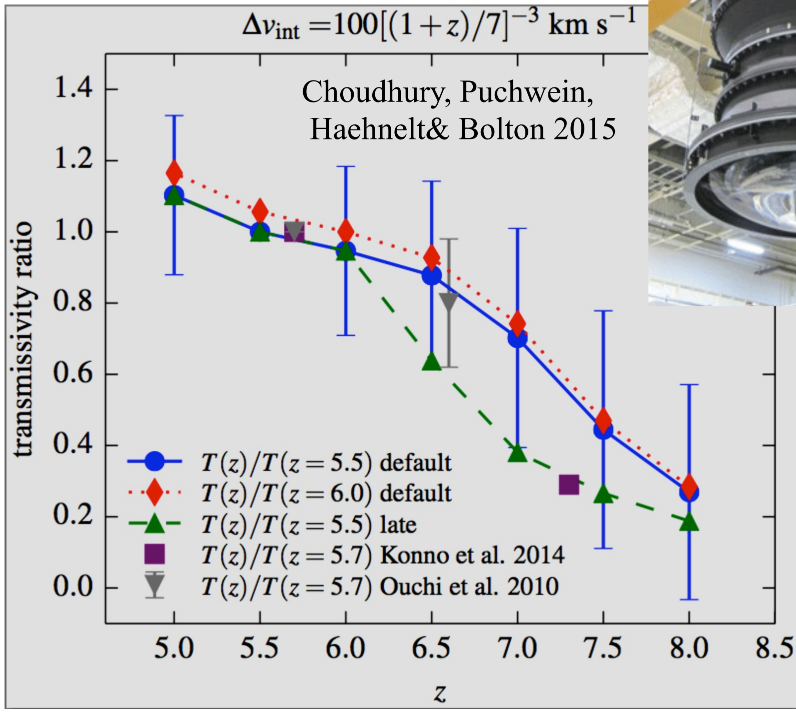


Choudhury, Puchwein, Haehnelt& Bolton 2015

The rapid demise of Lyα emission at z>6





- The rapid decline of Lyα emission at at z>6 is reproduced for by a modest decline of the volume-weighted ionized fraction perhaps aided by an evolution of the intrinsic red offset
- Reionization appears to finish somewhat later than predicted by HM2012
- Should be possible to probe bubble size and topology of reionization with Hyper Suprime Cam

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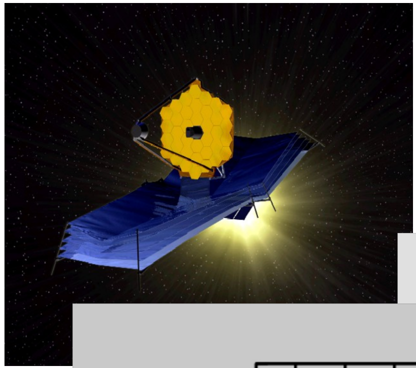
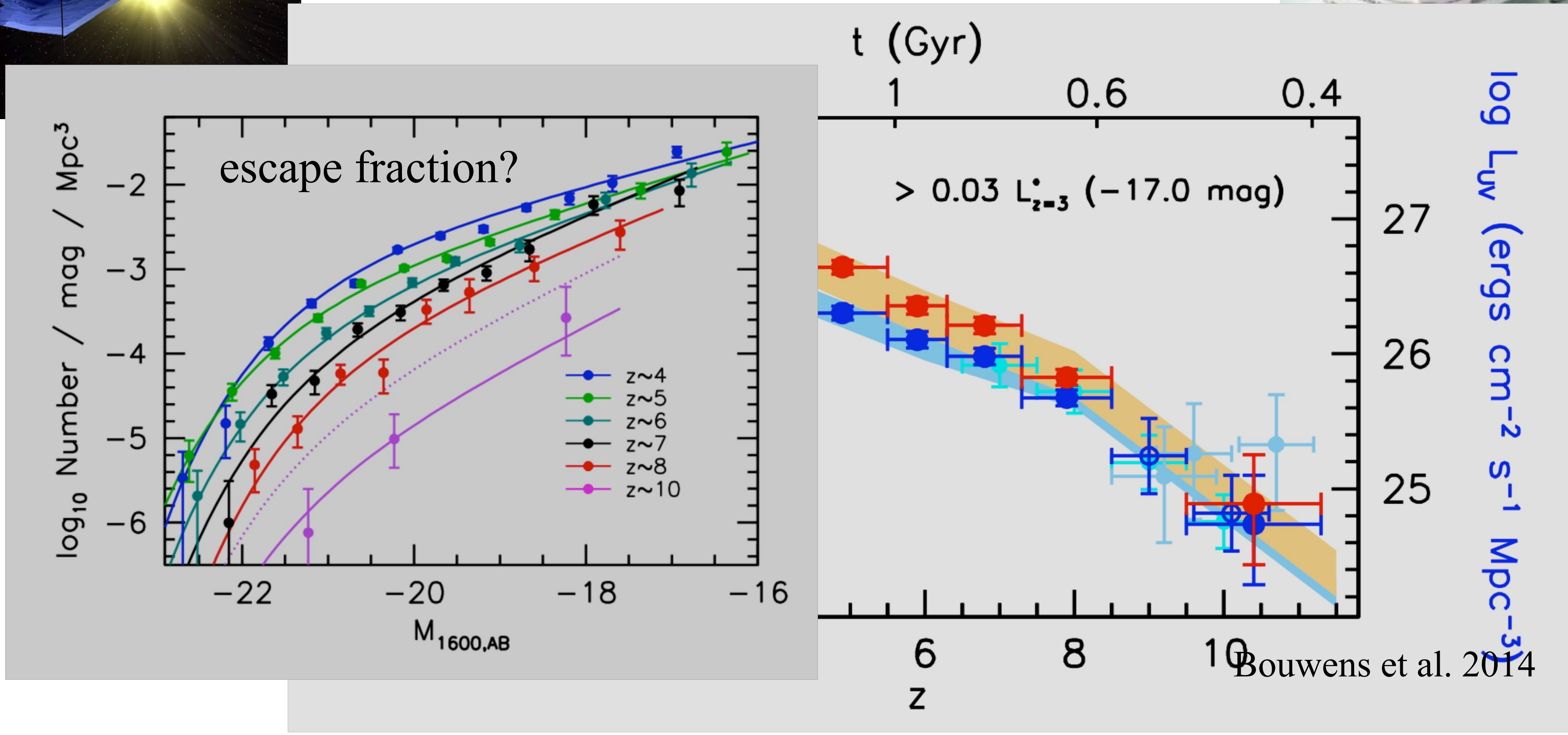


High-redshift galaxies



- JWST will reach about four magnitudes deeper and reach to z=20
- characterisation of physical properties with help of good spectra
- hopefully/possible escape fractions from Hα vs Lyα

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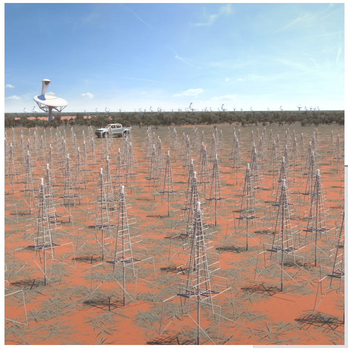
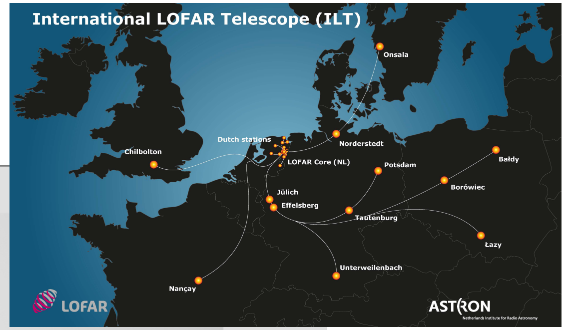
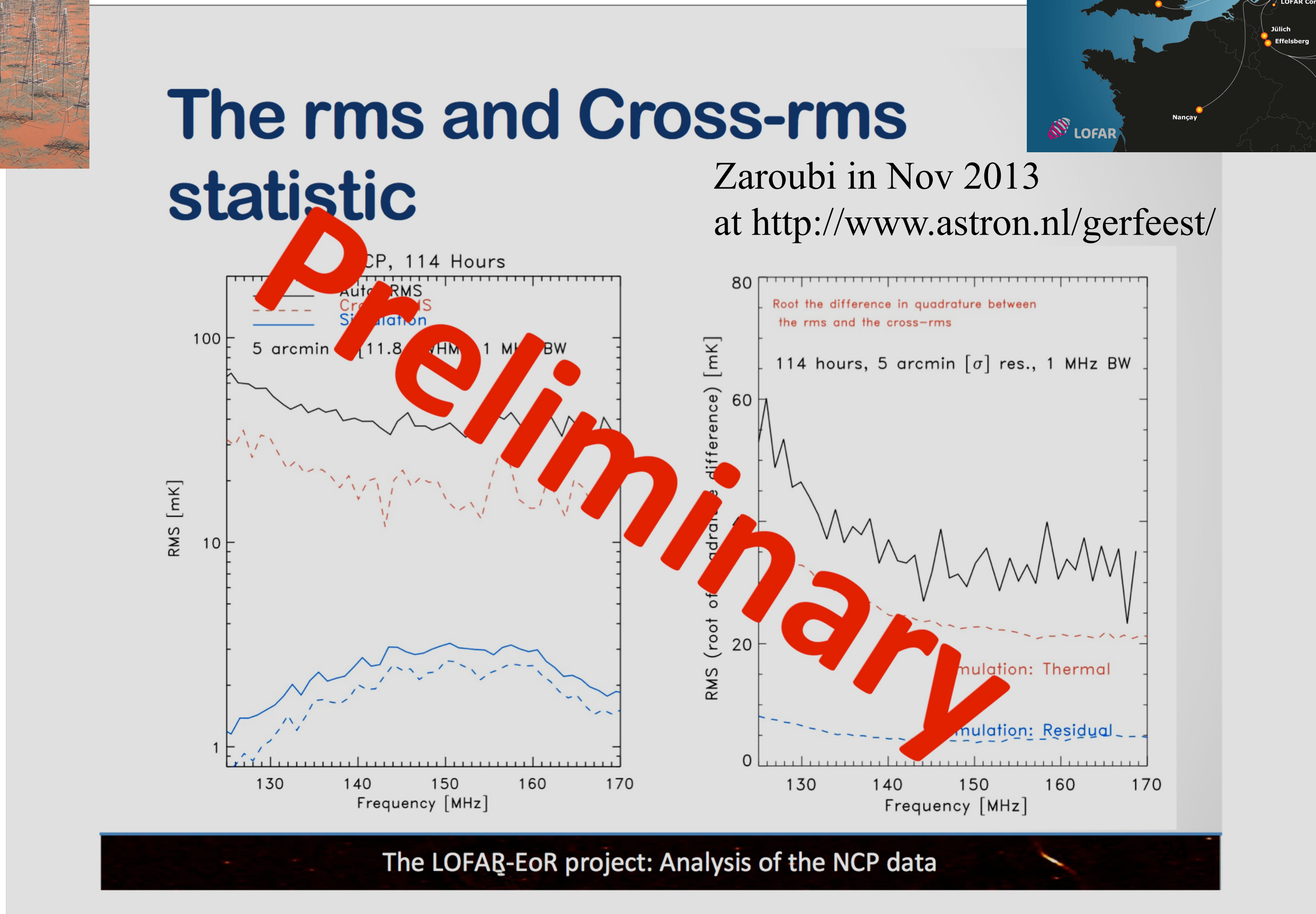
21cm



21 cm emission





Zaroubi in Nov 2013
at http://www.astron.nl/gerfeest/

- ➢ LOFAR (and PAPER) appear to be proceeding well
- ➢ SKA is gaining momentum

Summary

- evidence is building for a rather late reionization from
  - rapide demise of Lya emitters
  - QSO absorption spectra/near zones
  - ionizing emissivity
  - reduction of Thomson optical depth (CMB)

- lots of new data expected

  5 years: LOFAR, VISTA/DES and follow up

  10 years: JWST and follow up

  15 Years: E-ELT, SKA