

## **LOFAR observations of a $z \sim 6$ QSO at 180-220 MHz**

**Edwin Retana-Montenegro, Leiden Observatory.**



# Outline

## Introduction

- 21cm Absorption line studies
- Prospects with LOFAR

## LOFAR Observations

- Data reduction
- Results

## Summary/Conclusions



## 21cm absorption line

- Caused by spin-flips in neutral H (Hyperfine levels).
- Freq.: 1420 MHz or waveleng.: 21cm
- Located at radio-wavelengths
- First Predicted by a dutch astronomer: H. C. van de Hulst in 1944.
- Detected by Ewen and Purcell in 1952.
- A background powerful radio source is required.



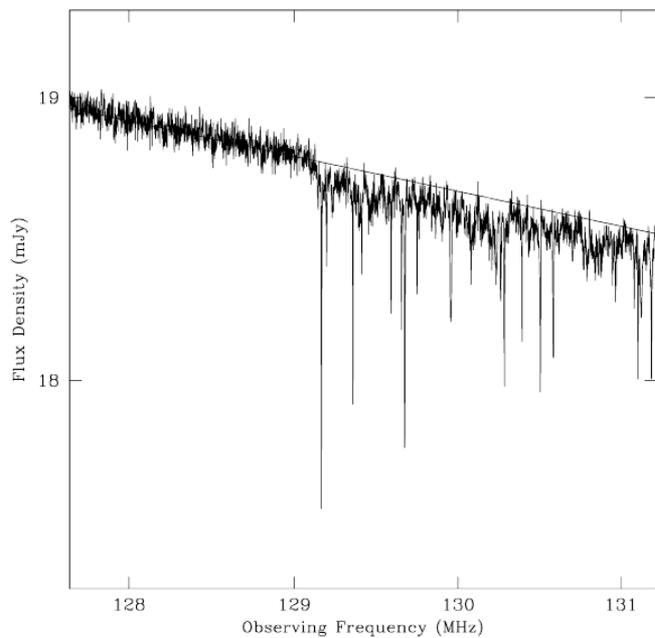


## Why is the 21cm absorp. line important?

- **Study the immediate environment of the AGN and host galaxy ISM.** (e.g. jet-cloud interactions, outflows)
- **Evolution of neutral gas content.**
- **Study possible homogeneity of the last neutral regions from cosmic reionization** (e.g. mini-haloes, protogalaxies).



## On SKA simulations...



$S_{120}=20$  mJy

$z=10$

Integration time: 10 days

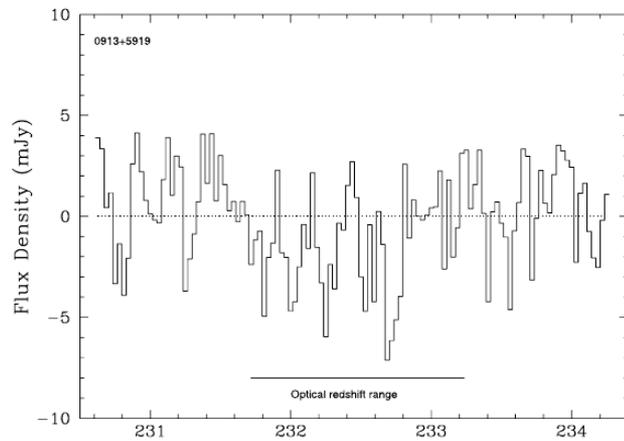
RMS per channel: 64/ $\mu$ mJy

1 kHz wide-channel

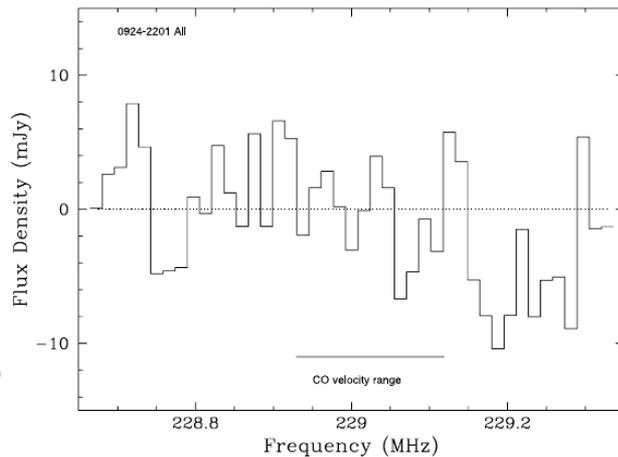
Carilli et al. 2002



## Previous works on 21cm absorp. line towards high-z radio sources.

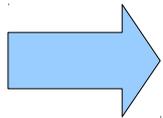


J0913+5919  
 $S_{230}=30\text{mJy}$   
 $z=5.1$

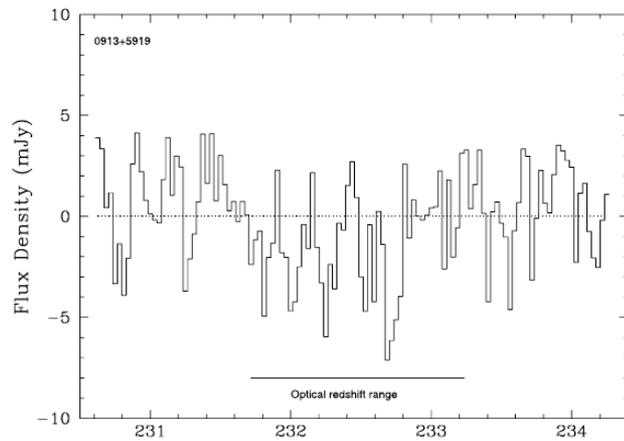


J0924-2201  
 $S_{230}=0.05\text{Jy}$   
 $z=5.2$

Carilli et al. 2007  
GMRT

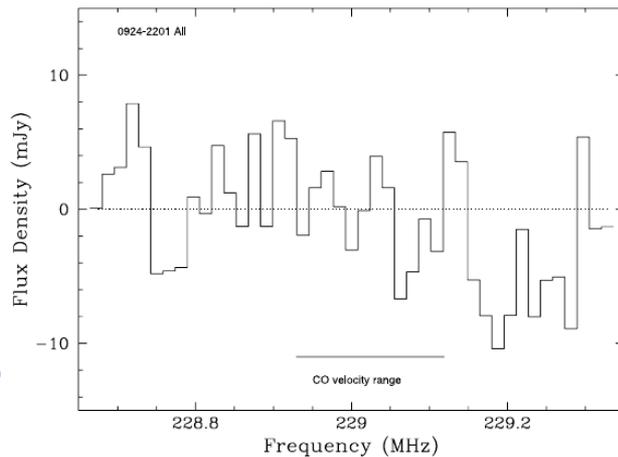


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No detections!

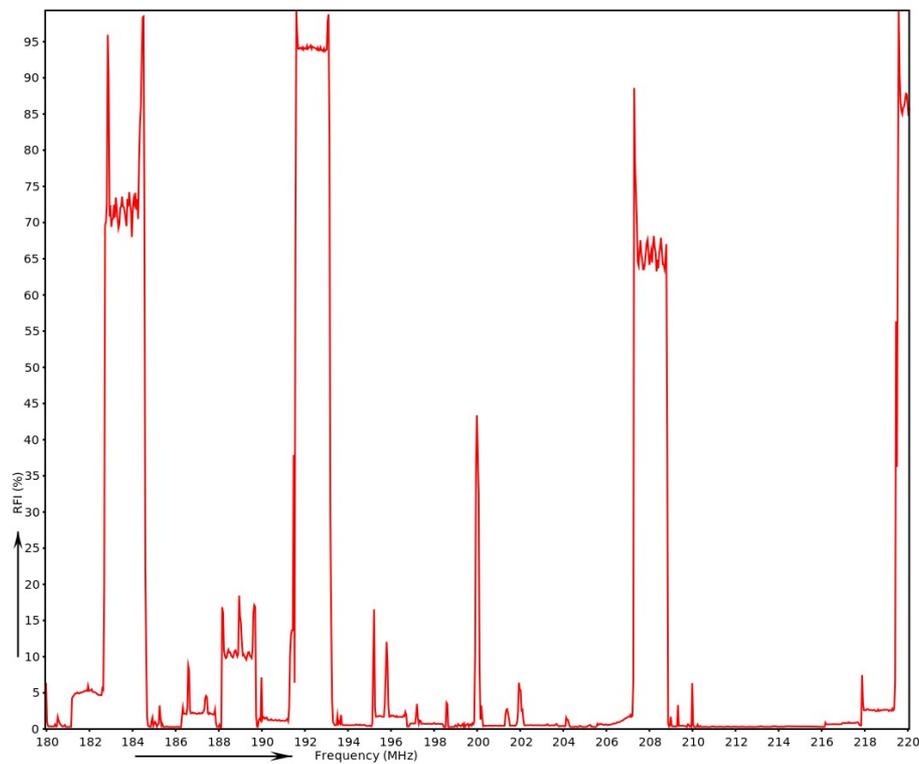


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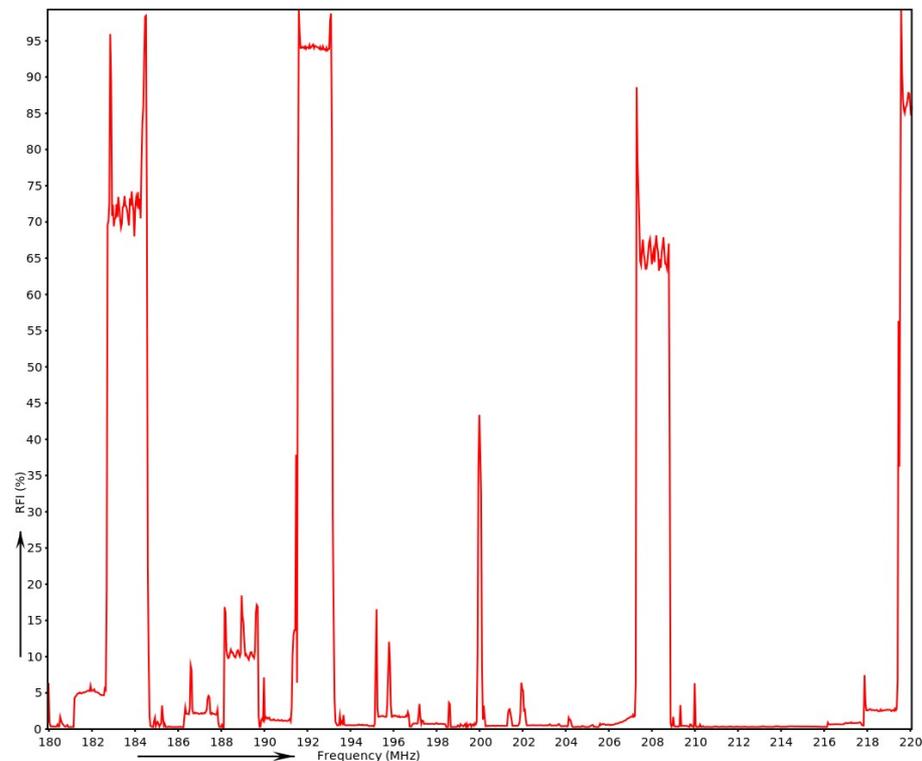
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- Need a bright radio source with spectroscopic redshift.
- 21cm line must fall into one freq. window with low RFI.



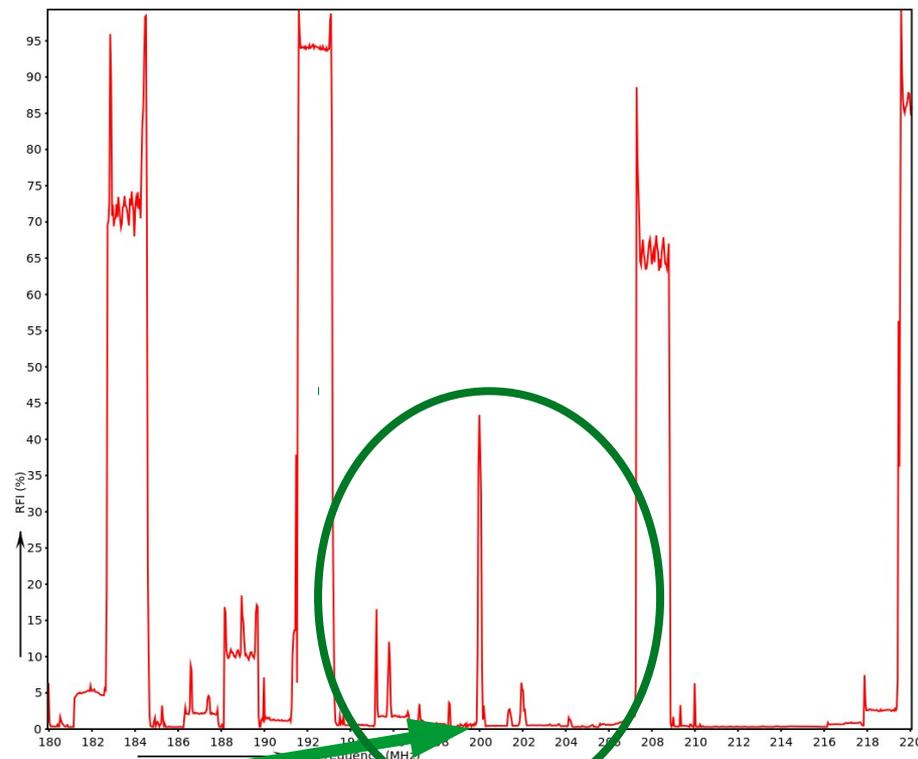
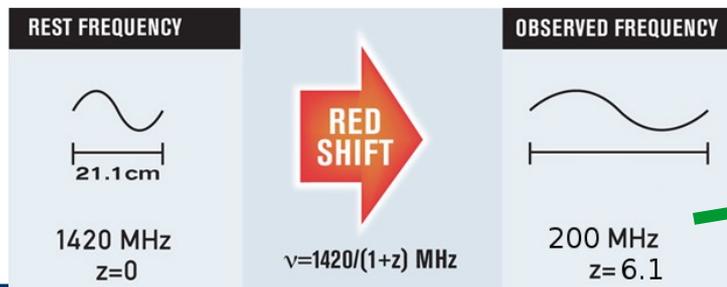
# Can we use LOFAR for 21cm absop. line studies for z radio sources in the EOR?

- Need a bright radio source with spectroscopic redshift.
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- Only a few objects.
- Radio-loud quasar J1427385+331241



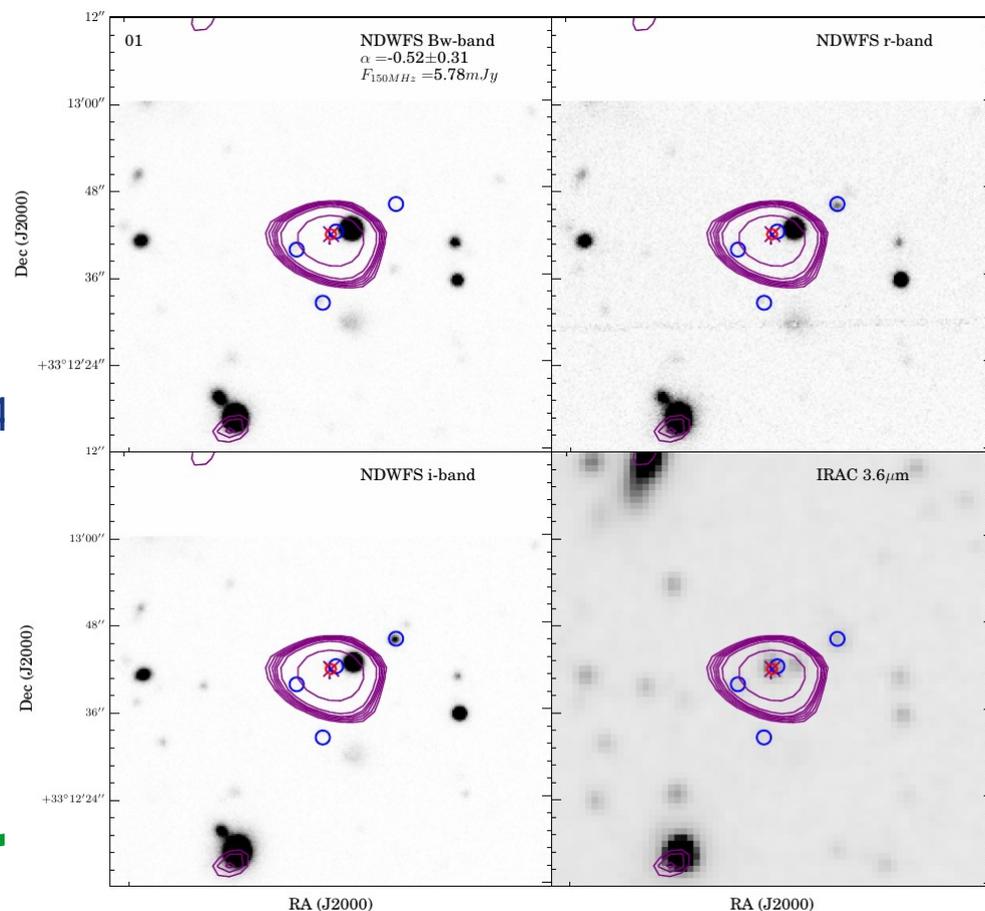
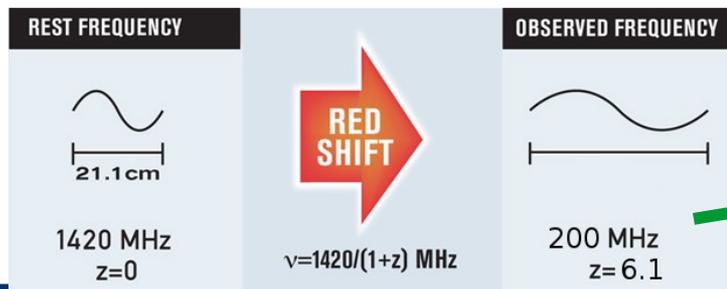
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- $S_{150}=6\text{mJy}$



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# LOFAR observations: Data reduction

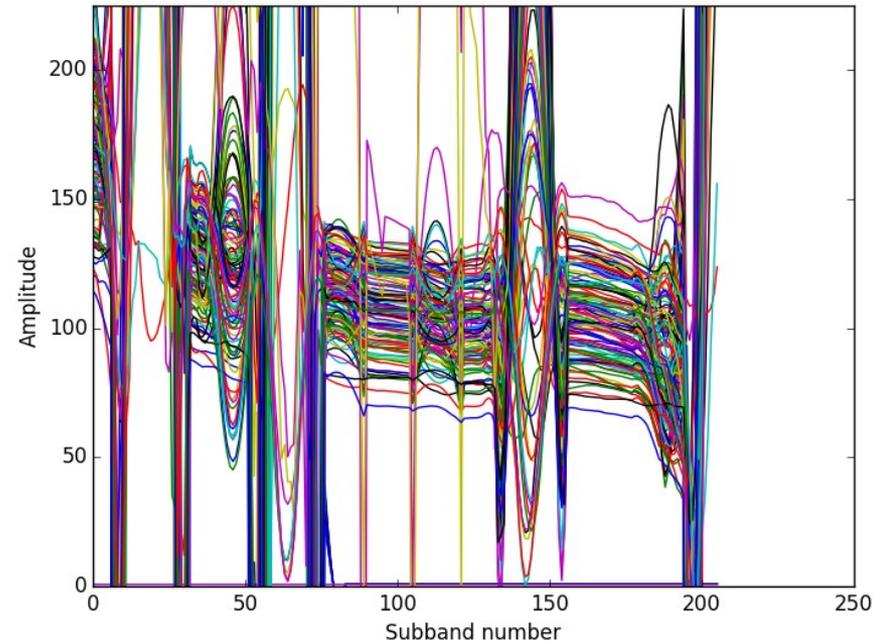
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- everything.
- PreFactor crashes.
- Calibrator: 3C196
- Transfer amp.+ phase calibration using skymodel Bootes Tier-2 analysis.

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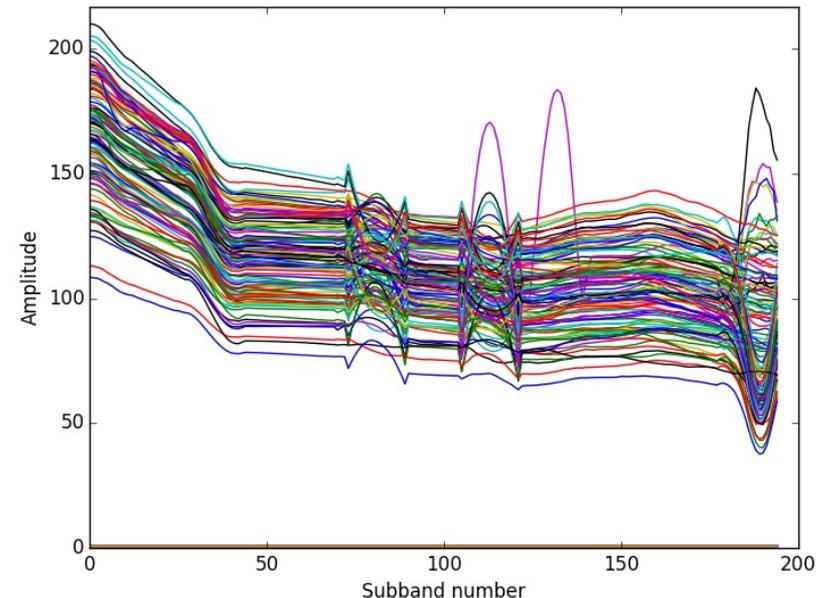
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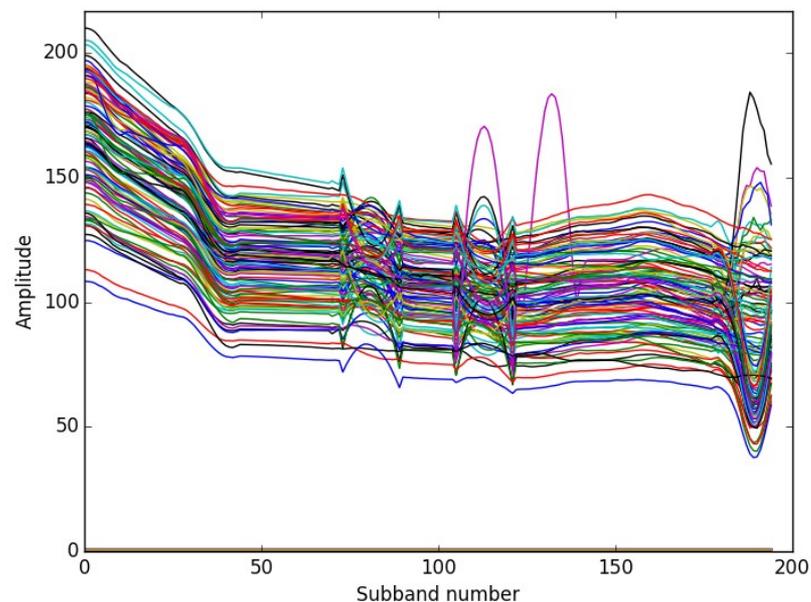
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- Freq. Cov: 180-220MHz
- Two simultaneous beams were used.
- 2x4h observations.
- More than 50% were discarded due to RFI.



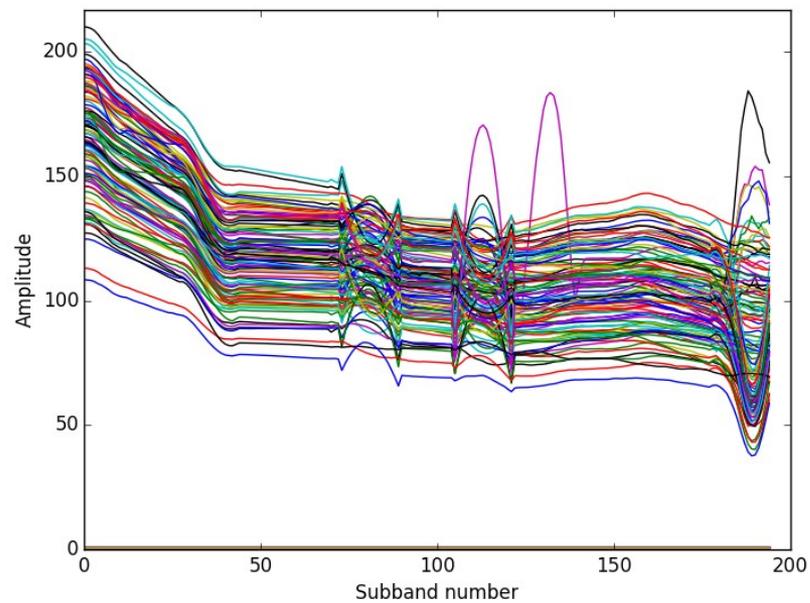
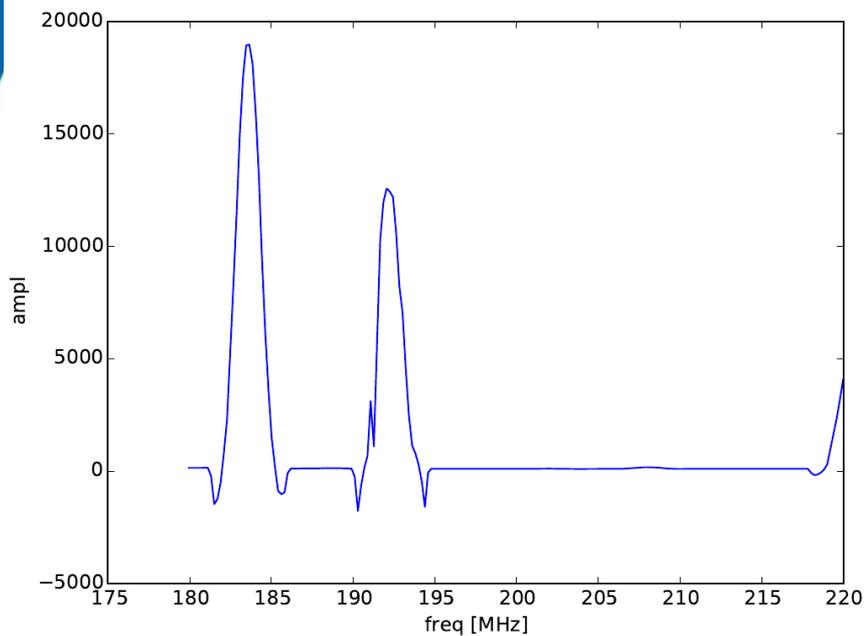
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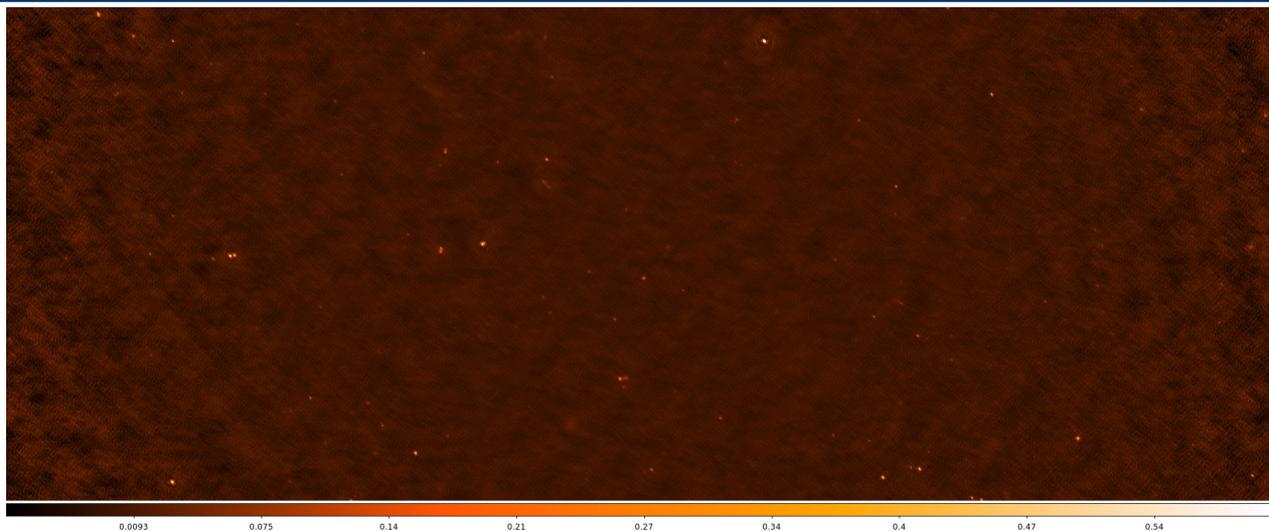


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## LOFAR observations: Results

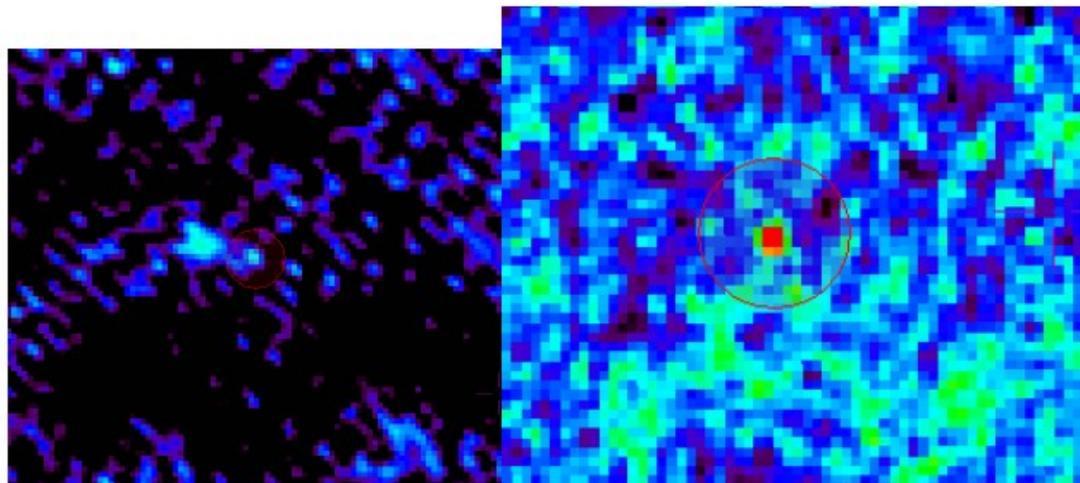


- Combined 8hr for one subband centered at 200MHz.
- Fluxes and astrometry looks ok.
- Noise~ 4.5 mJy.



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LOFAR  
@200MHz



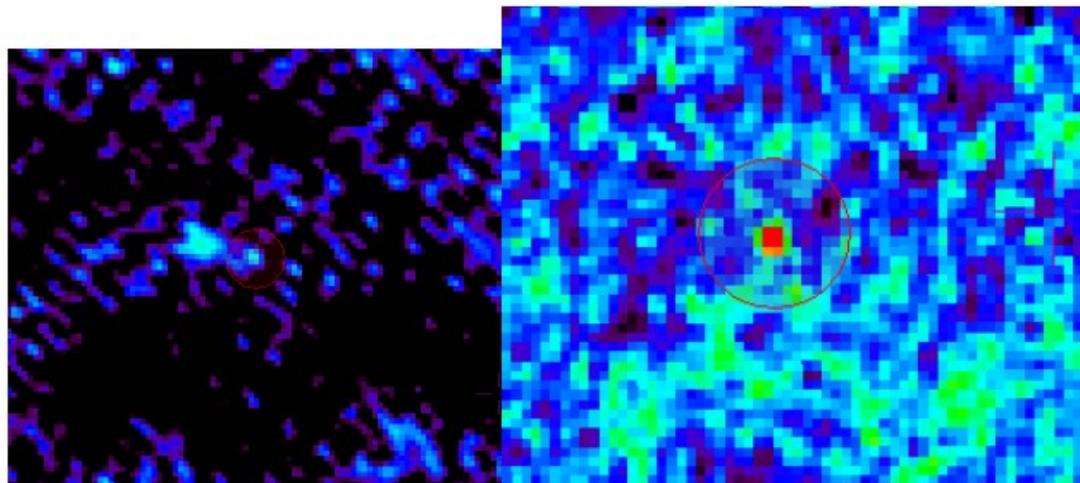
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FIRST

- Combined 8hr for one subband centered at 200MHz.
- Fluxes and astrometry looks ok.
- Noise~ 4.5 mJy.
- Sensitivity per channel is **insufficient** for detecting the 21cm line in only 8hr.



## Conclusions/Summary

- LOFAR works at 200MHz.
- No 21cm absorp. line is detected only in 8h of integration time.
- You need a bright object for which the 21cm line falls into a good freq. window with a long integration time.





Thanks!





## Why is important to study high-z quasars in radio?

- Understanding BH growth and accretion physics through cosmic time.
- Radio selection eliminates contamination from cool stars (Mcgreer et al. 2009; Bannados et al. 2015).
- Excellent tracers of large-scale structures at high-z.

