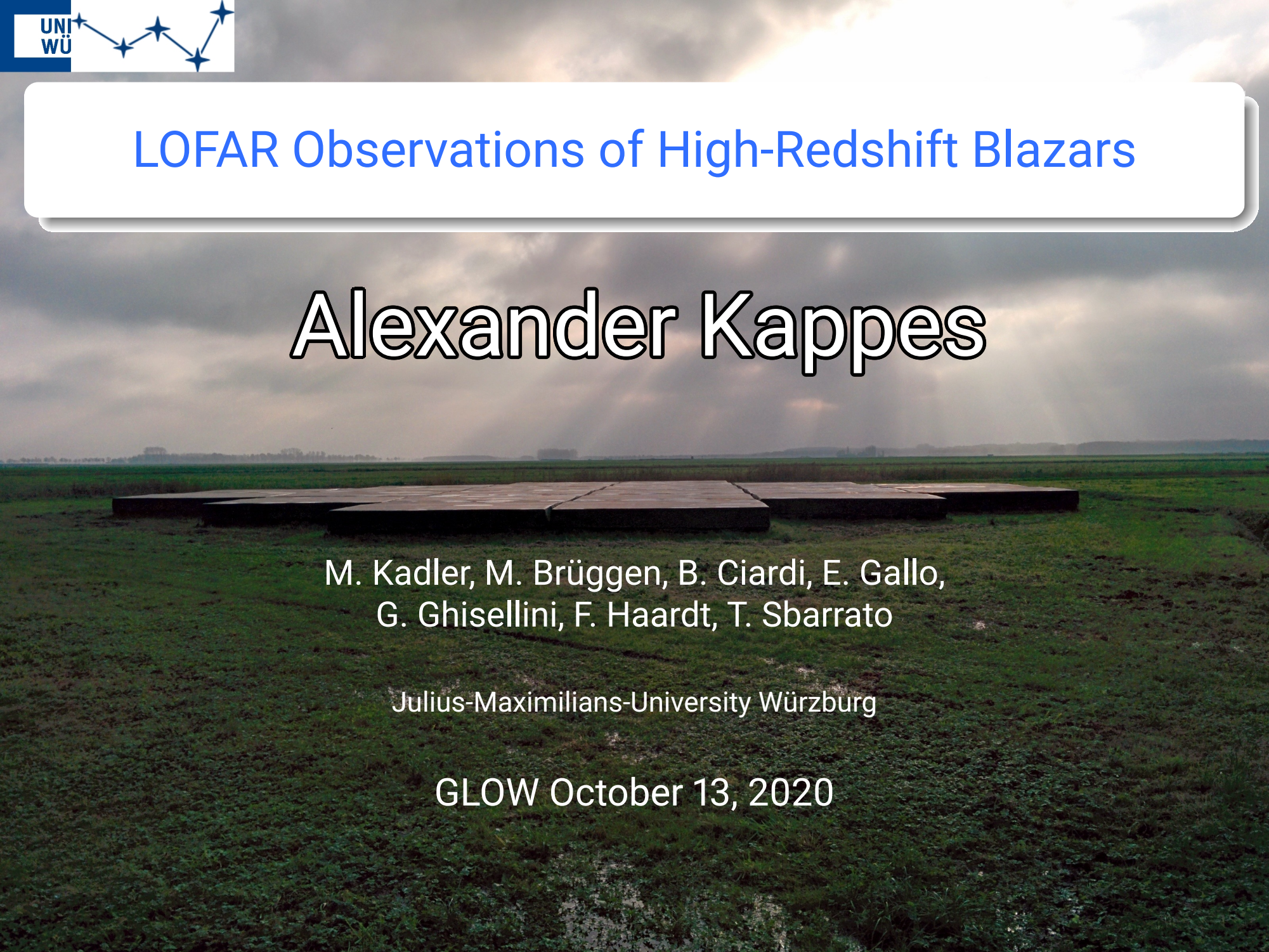
LOFAR Observations of High-Redshift Blazars



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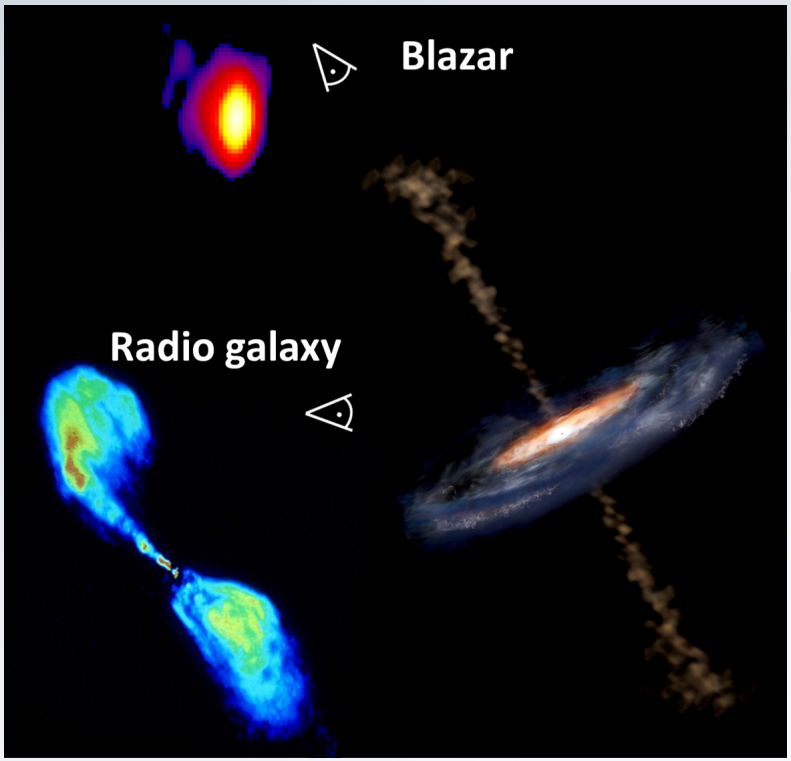
G. Ghisellini, F. Haardt, T. Sbarrato

Julius-Maximilians-University Würzburg

GLOW October 13, 2020

Where are the distant Radio Galaxies?



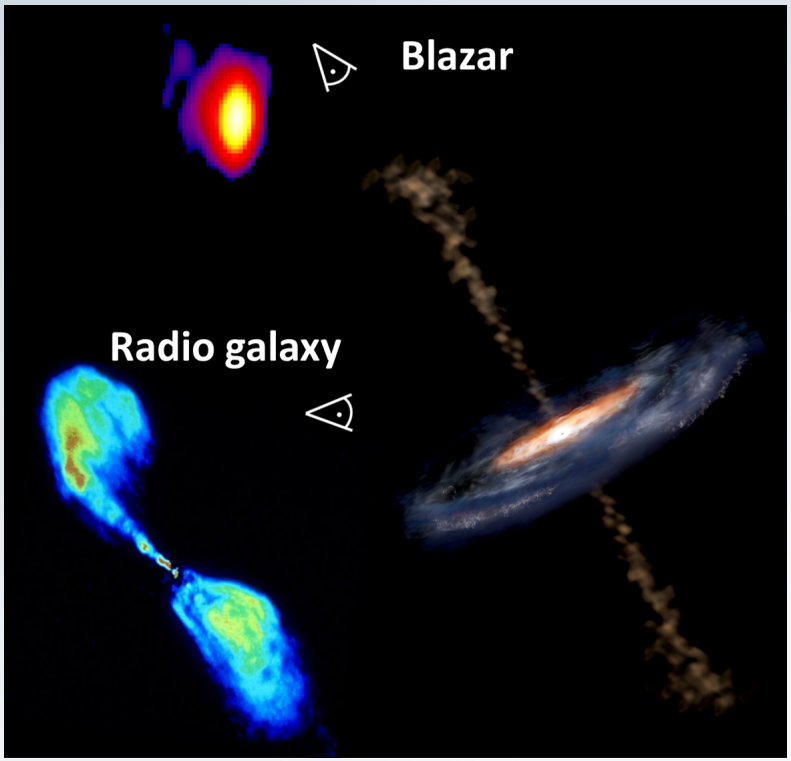
credit: adopted from Aurore Simonnet (Sonoma State University), MOJAVE program

Blazars and Radio Galaxies:

- two populations differ due to line of sight (unified model)
- intrinsically same properties
- ratio between populations should be roughly constant with distance

BUT: Observations find a lack of Radio Galaxies for high-z (Volonteri et al 2011)

Where are the distant Radio Galaxies?



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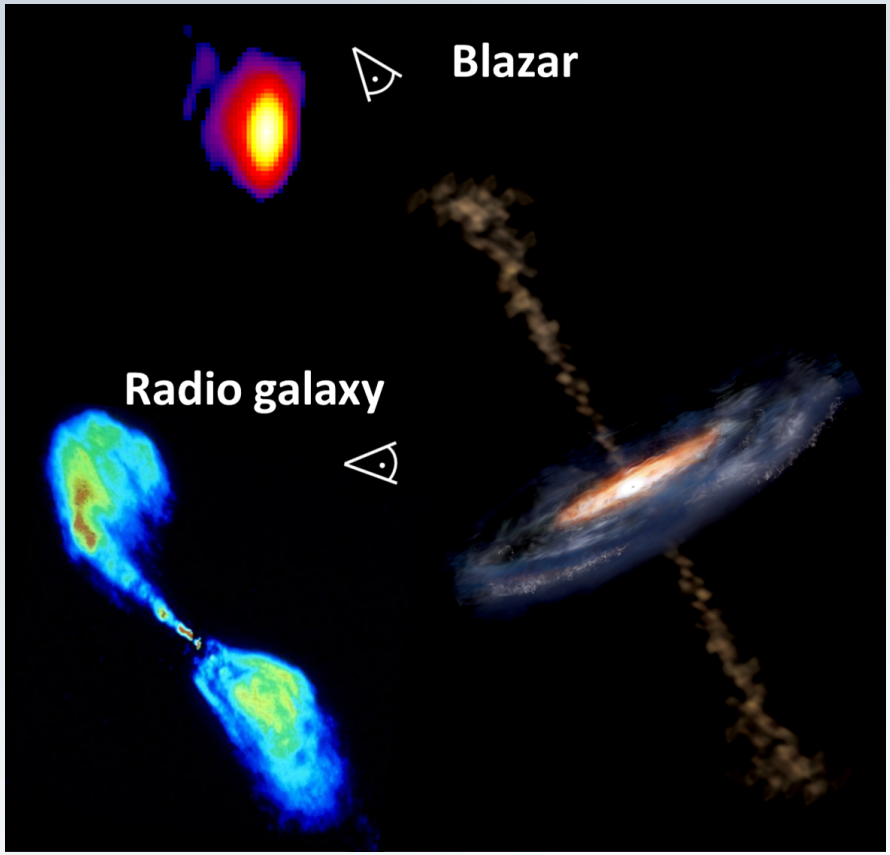
Why the difference?

- Radiation from different components is direction dependent
- Radio Galaxies dominated by isotropic radiation
- Blazars dominated by highly beamed radiation

Where are the distant Radio Galaxies?



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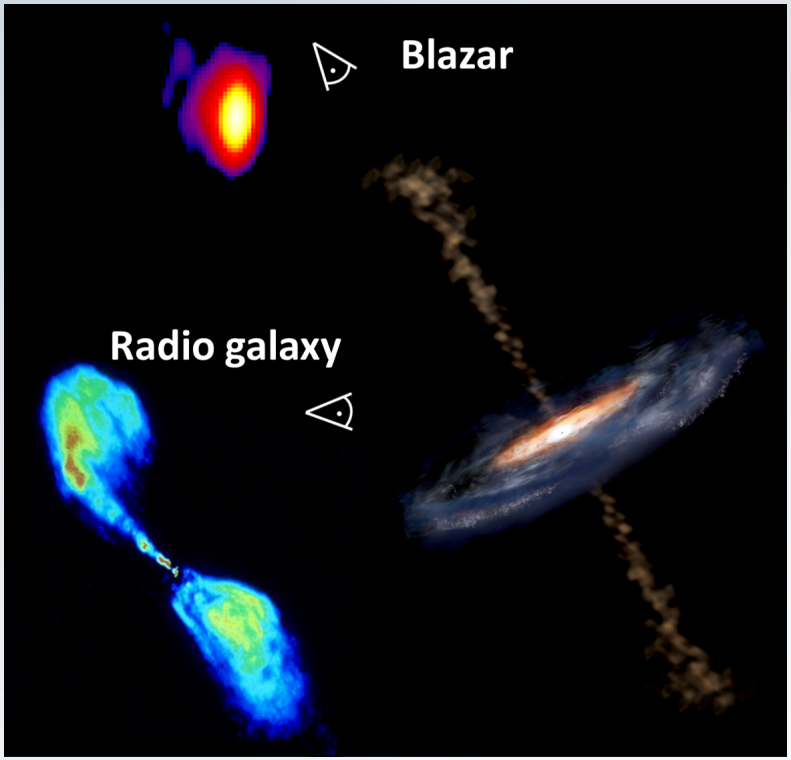
Possible reason CMB quenching

Ghisellini et al. 2014; J. Wu et al 2019

- CMB energy density $U_{\mathrm{CMB}} \propto (1+z)^4$
- for $z \gtrsim 4$: U_{CMB} can exceed U_{B}
- e^- cool preferentially off via IC scattering with CMB instead of synchrotron
- e^- close to the core: much higher U_{B}

$\Rightarrow$ Blazars remain visible

Where are the distant Radio Galaxies?



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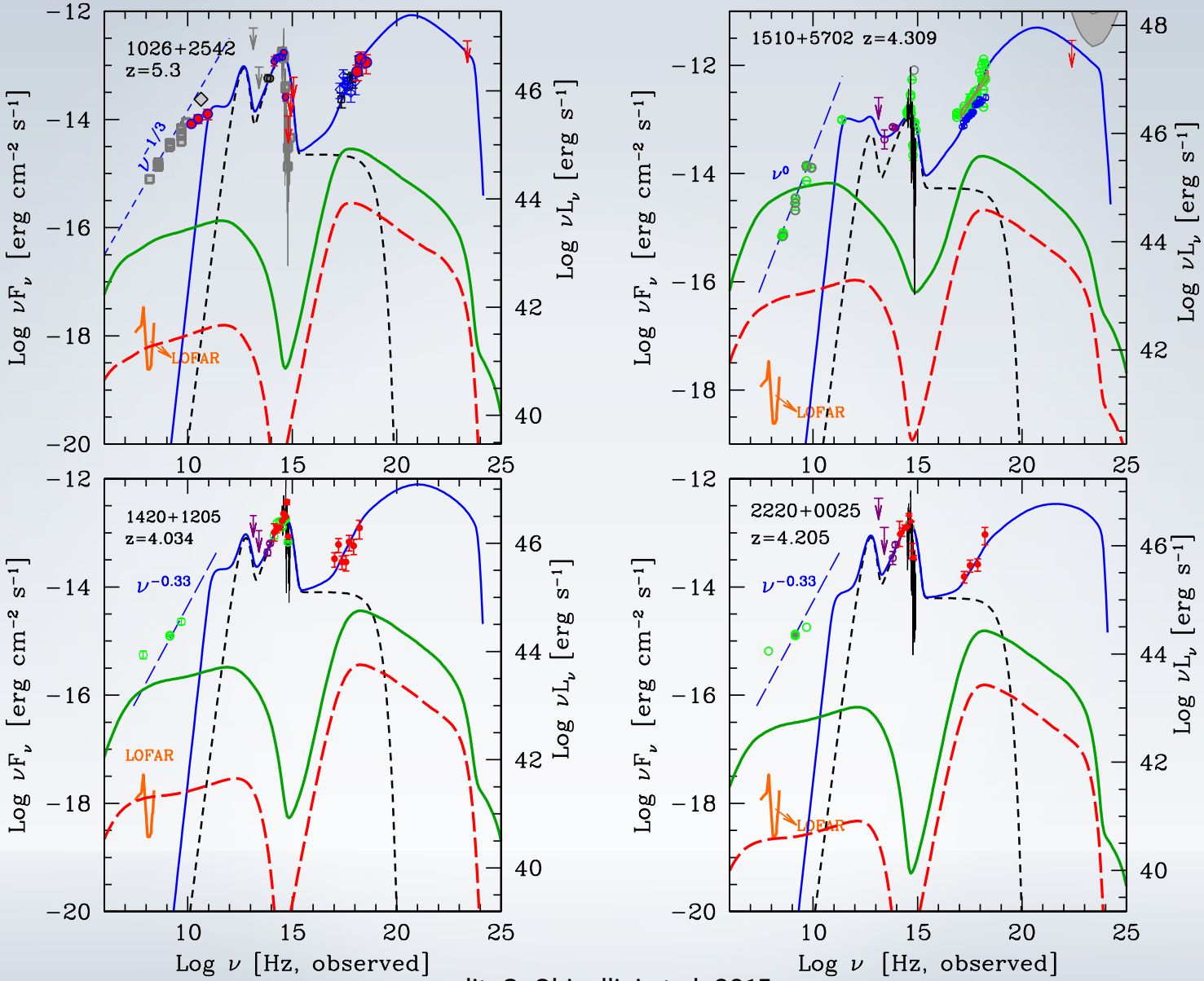
How can we test it?

- lower energy e^- have longer cooling time
  $\rightarrow$ long wavelengths less affected
- pick suitable Blazars
  - high-z
  - expected to be luminous in long wavelengths
  - visible by instrument

$\Rightarrow$ Search for extended structure with LOFAR (ILT)

The Chosen Ones!



credit: G. Ghisellini et al. 2015

Straightforward! ... Right?

Unfortunately no

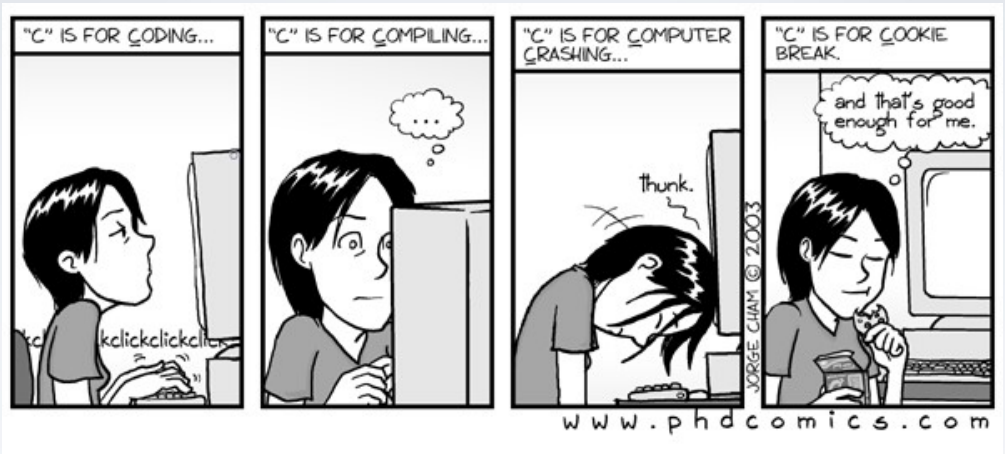
The Observation

- Took place in Q4/2015
- Frequency range: 120 - 160 MHz (LOFAR HBA)
- Integration time: 4 h each target
- With International Stations $\Rightarrow$ resolution $\lesssim$ 1 arcsec

Target	z
1026+2642	5.304
1420+1205	4.034
1510+5702	4.309
2220+0025	4.205

Big Data

Turns out dealing with it is pretty hard

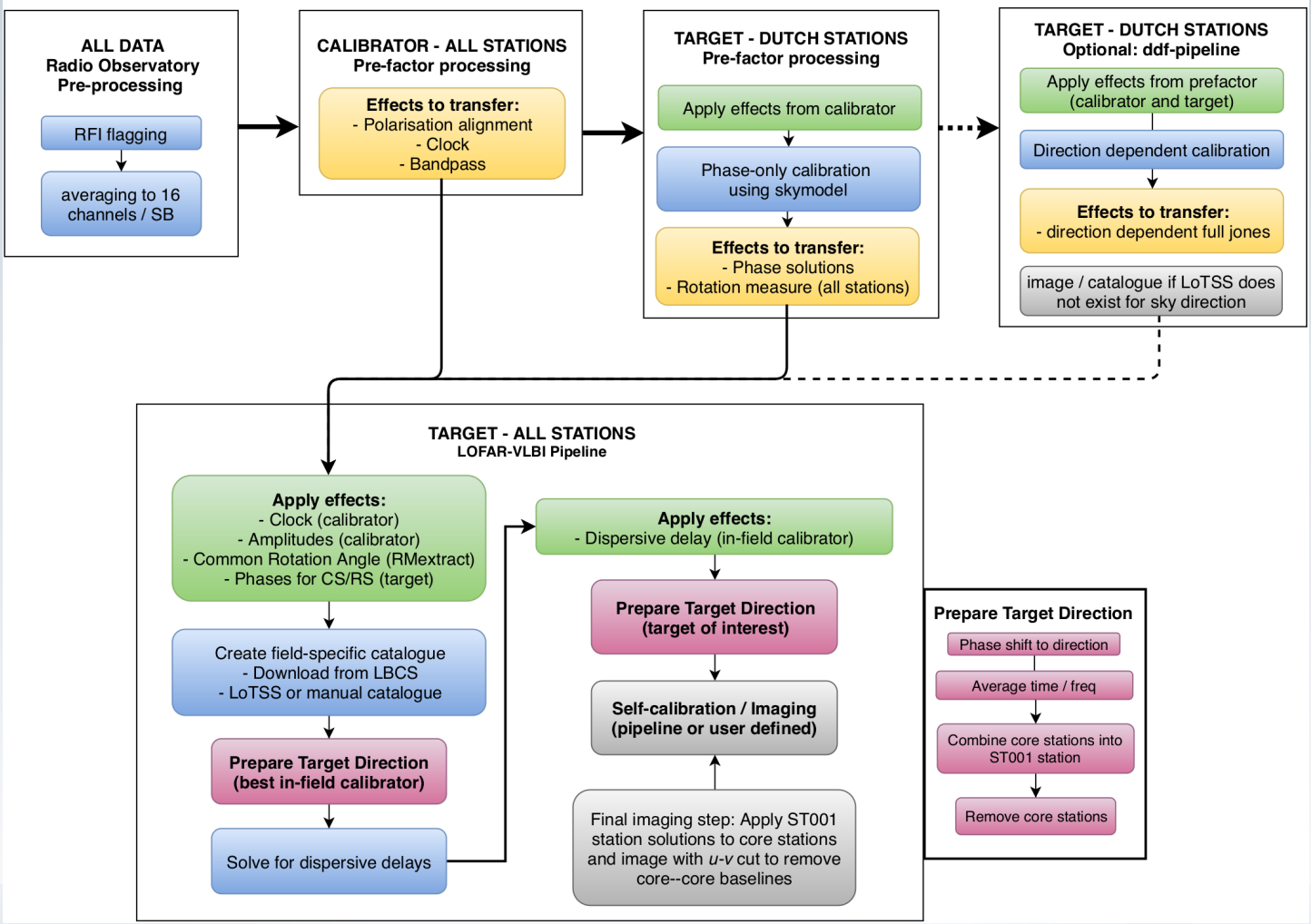


The Long Baseline Pipeline for LOFAR

- developed by Long-Baseline-Workgroup
- https://github.com/lmorabit/lofar-vlbi
- https://lofar-vlbi.readthedocs.io/en/latest
- currently being tested
- planned to be in an official final state at the end of 2020
- input is Prefactor processed LOFAR data
- https://github.com/lofar-astron/prefactor

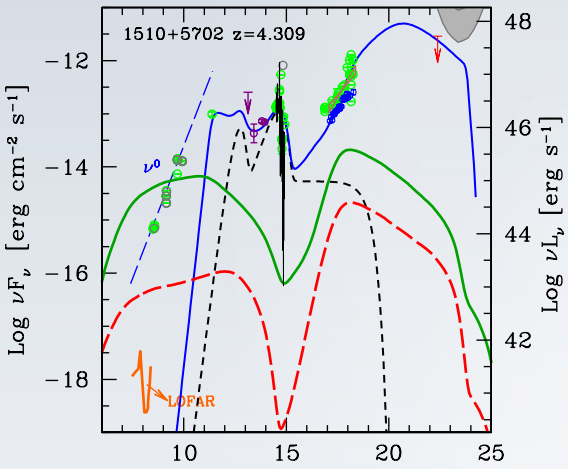
$\Rightarrow$ Fully automatic calibration and imaging pipeline (except for defining parset files)!

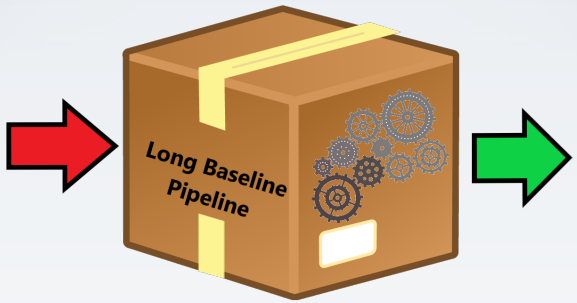
The Workflow



credit: L. Morabito/Documentation

LOFAR observation of 1510+5702





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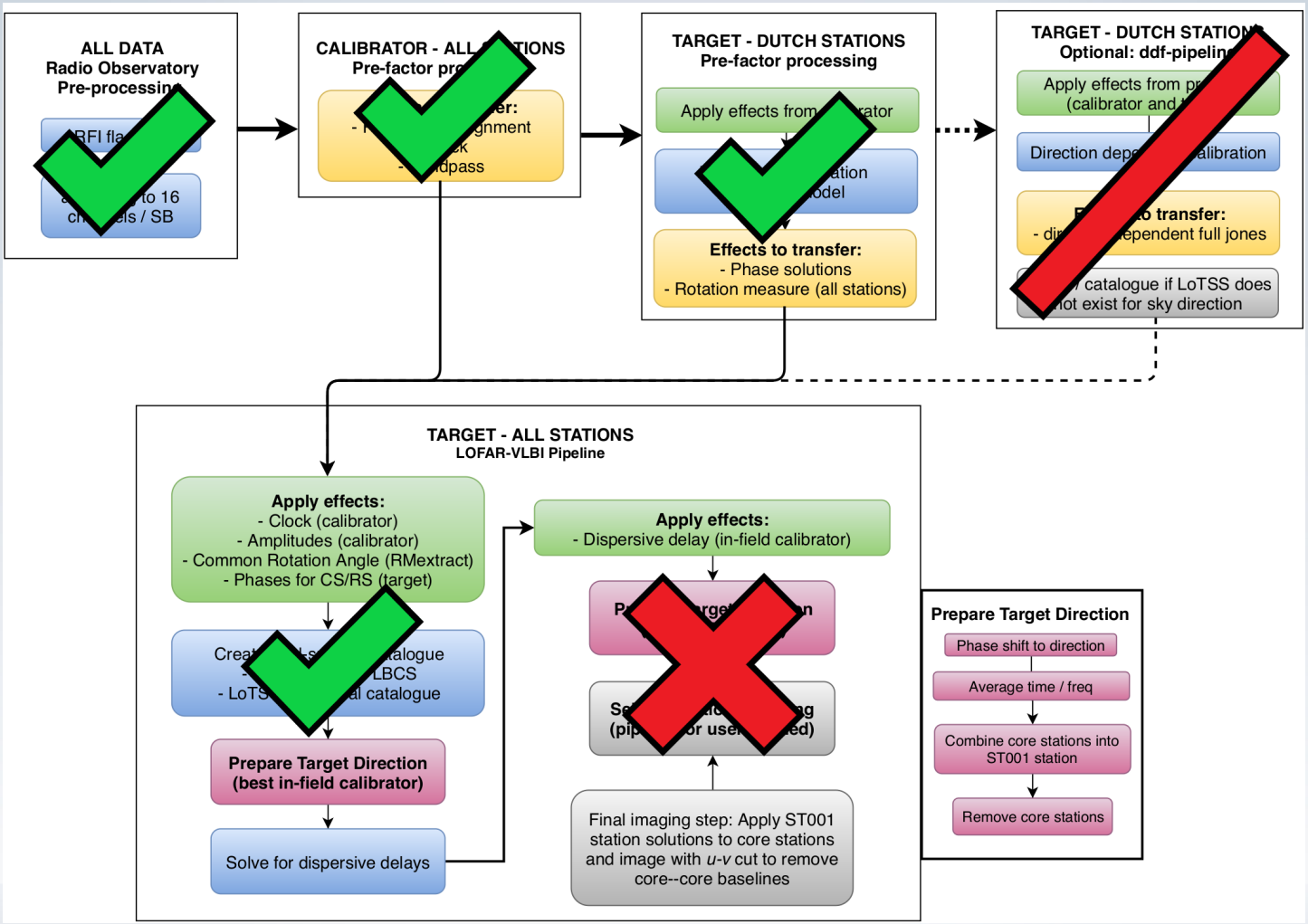
The Workflow - How far are we?



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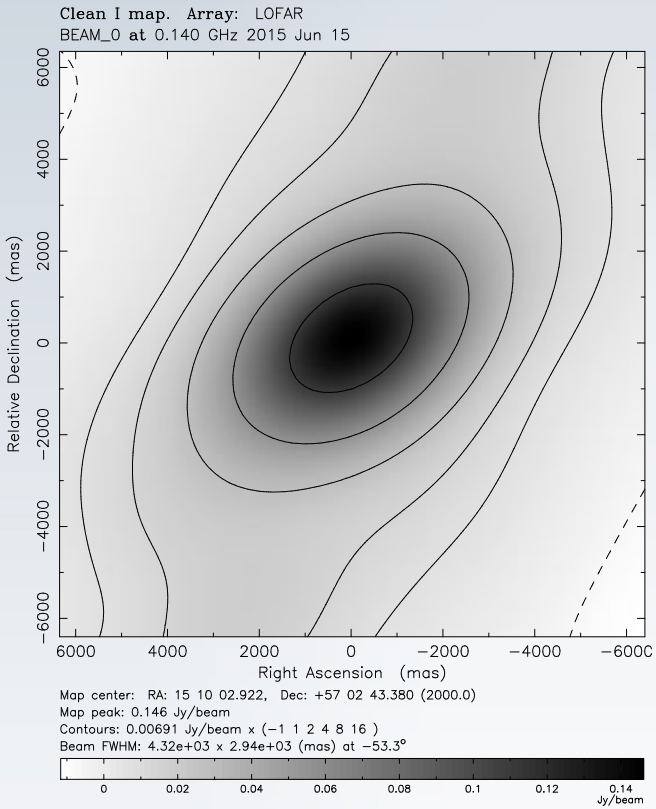

Preliminary image of 1510+5702

Current Project status:

- during most calibration steps observation seems fine
- we can detect the target, although its very faint
- in the last steps most int. stations show poor calibration
  $\rightarrow$ poor resolution
- wider field shows present issues in phases

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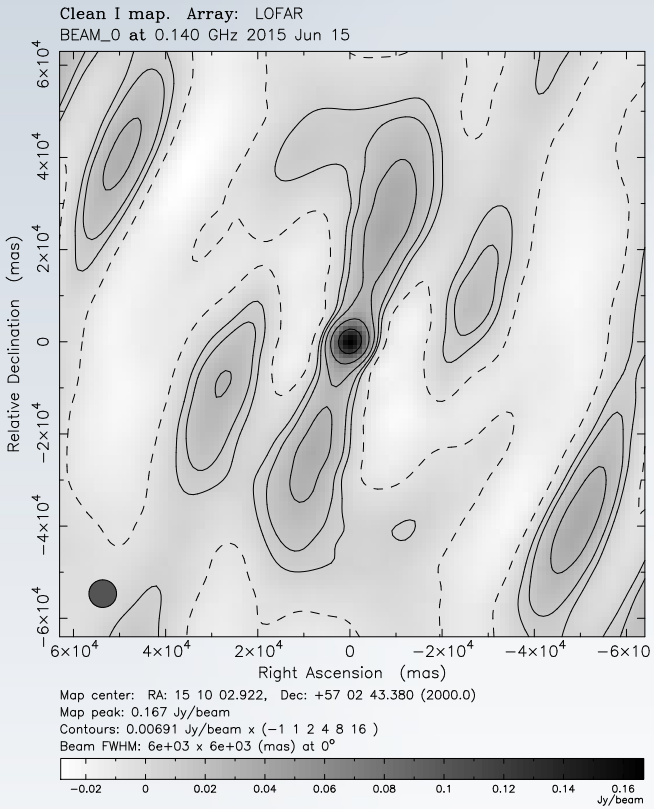

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- Problem: lack of detected radio galaxies at high-z
- Possible explanation: CMB quenching
- Can be tested with deep LOFAR observations

- Current status looks promising to deliver usable results
- Long Baseline Pipeline seems to work as expected mostly - though some bug fixing still needs to be done

- Replicate procedure on other sources

Literature I


G. Ghisellini et al.
CMB quenching of high-redshift radio-loud AGNs.
arXiv:1505.05512


G. Ghisellini et al.
Radio-loud AGNs at high redshifts and the cosmic microwave background.
arXiv:1311.7147


A. Kappes et al.
LOFAR Measures the Hotspot Advance Speed of the High-Redshift Blazar S5 0836+710.
arXiv:1909.02412


M. Volonteri et al.
Blazars in the early Universe.
arXiv:1103.5565


J. Wu et al.
CMB-induced radio quenching of high-redshift jetted AGNs with highly magnetic hotspots.
arXiv:1702.04725