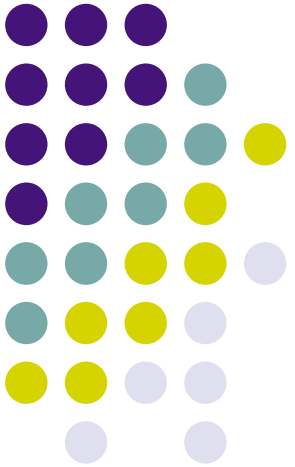
# LOFAR Long Baseline Status

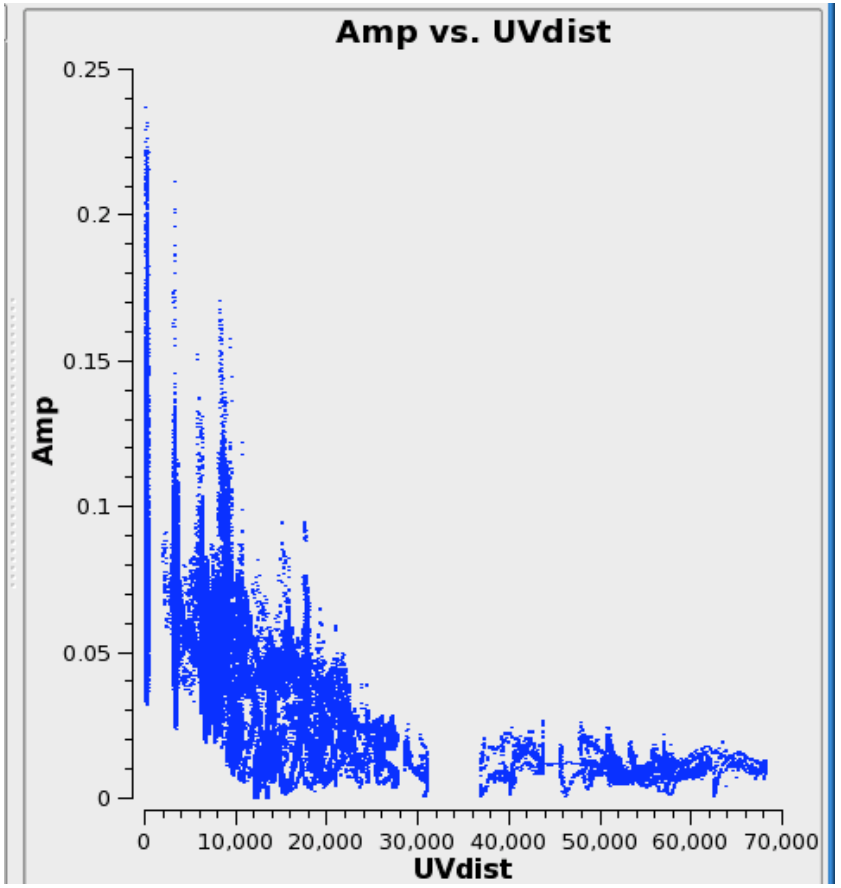
Adam Deller

on behalf of the Long Baseline Working Group

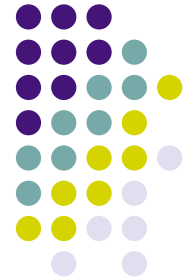


# Intl.LOFAR specific challenges

- Calibration: Fewer, weaker sources
  - Max flux ~few Jy on longest baselines; then typically a **very** complicated source



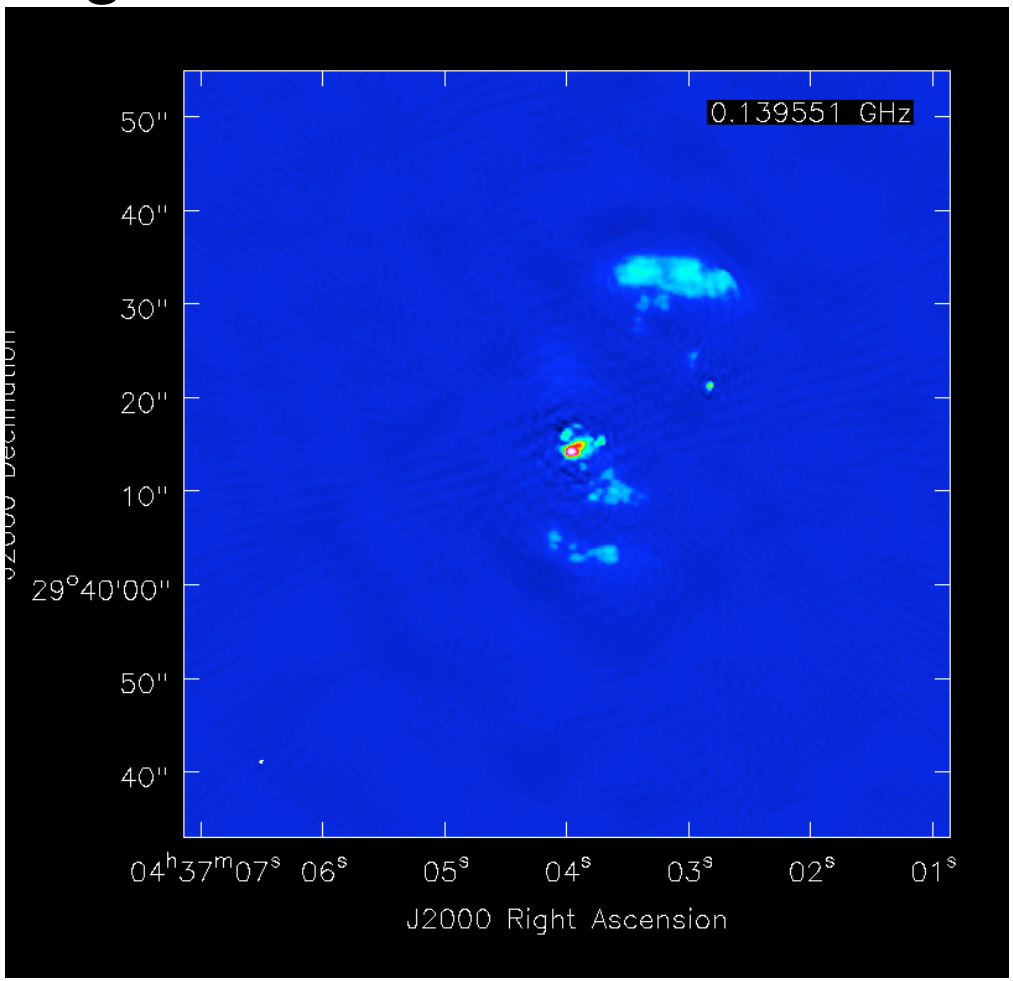
# Intl.LOFAR specific challenges



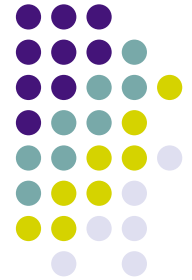
- Calibration: Differential ionospheric effects
  - Dispersive delays: up to 1 microsecond (high band), expect 10 microseconds in low band!
    - MUST be corrected before averaging, but sources are faint -> fringe fitting required
  - Faraday rotation: signal can be completely rotated out of XX, YY correlation products
    - Conversion to circular polarisation returns the signal (exc. leakage) into RR, LL - phase change becomes a delay offset between R and L (reduce search space, use standard tools)

# Intl.LOFAR specific challenges

- Imaging: Baseline range
  - Baselines from 10^2 to 10^6 metres; must either limit, or face huge challenges imaging various structure scales simultaneously

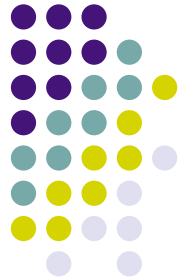


# Intl.LOFAR specific challenges



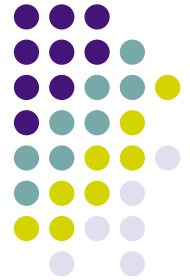
- Currently, there is $1^{+0}_{-1}$ known sources in the sky for which the “normal” BBS calibration path would work for observations with the long baselines
- Task of the Long Baseline Working Group: Develop a usable pipeline to reduce long baseline LOFAR data

# 1st Long Baseline Busy Week



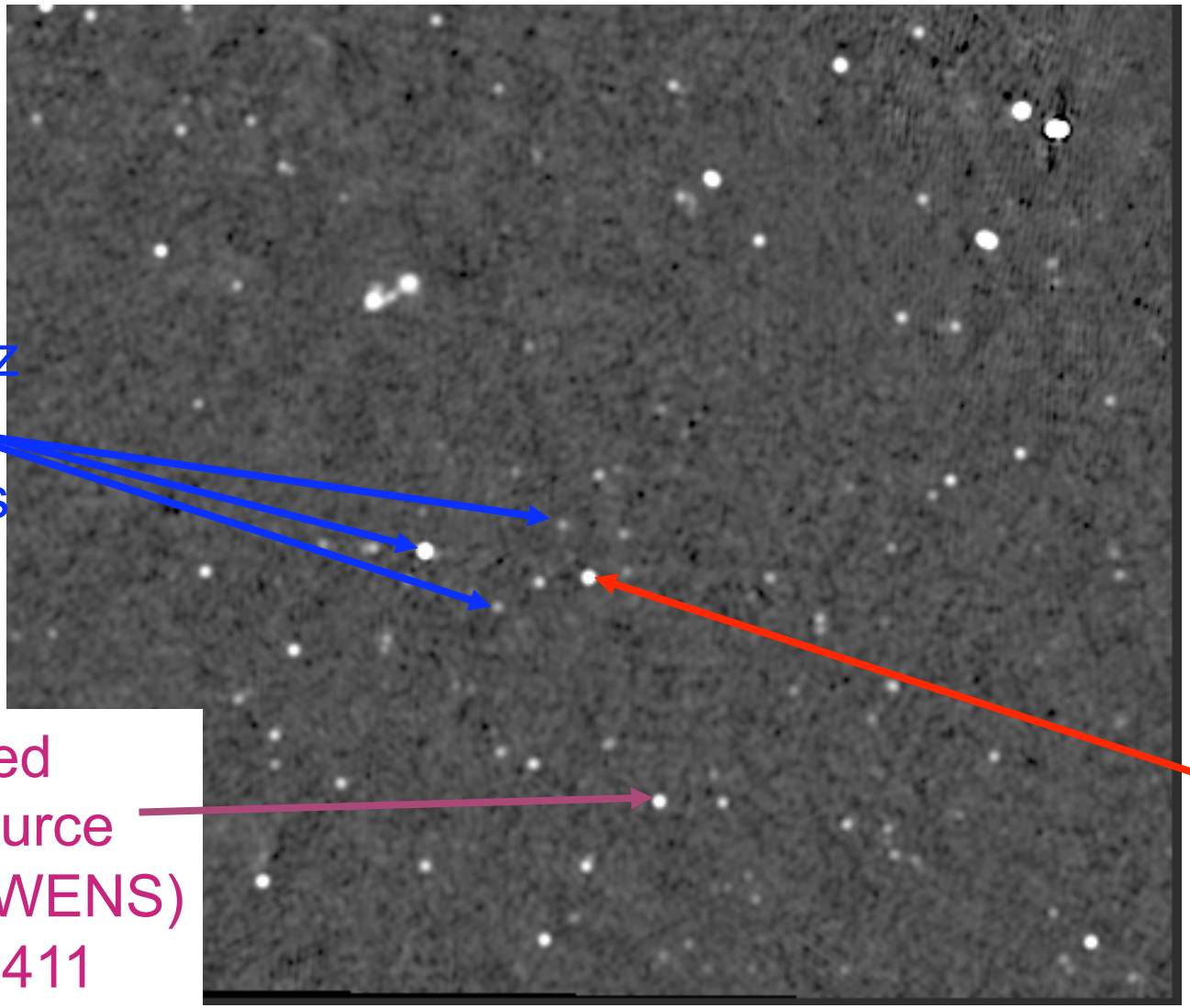
- MPIfR, Bonn, May 21-25
- 17 participants from 9 institutes
- Outcomes:
  - Basic pipeline (usable by someone who knows python and AIPS) developed
  - Four different sources now imaged (3 HBA, 1 LBA) - could have been more, but observing freeze held back some commissioning obs.
  - First calibration transfer between sources (1 field)

# LBBW#1 pipeline components



- Use NDPPP for flagging, [shifting,] averaging
- The following innovations have been developed and tested:
  - Phasing the superterp stations into 1 virtual station, including determination of phase offsets
  - Conversion to circular pol using simple beam model
  - Arranging the data into spectral windows of width ~ few MHz (for piecewise linear delay approximation)
  - Calibration and imaging (all in circular polarisation) in AIPS

# LBBW#1 Images: PSR B0329



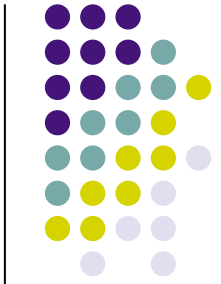
Known 1.6 GHz VLBI sources

Suspected bright source (NVSS+WENS) J0332+5411

PSR B0329+54

**2 degree x 2 degree NVSS field**

# LBBW#1 Images: PSR B0329



- 1.5 hour observation; cal/imaging time ~1.5 hours
- Calibration using PSR B0329+54 (~1 Jy perfect point source) using uv range >15 kλ
  - 4 groups of 16 subbands, so 12 MHz ~= 1/4 total bandwidth; theoretical noise ~0.2 mJy (nominal Tsys)
  - Data was averaged to 4 seconds and 48 kHz, gives smearing-limited FOV of ~10 arcminutes (so really should go back to raw data and uv shift: not done here)
  - Distance between fields is 6 - 24 arcmin ~= 4000 - 16000 pixels

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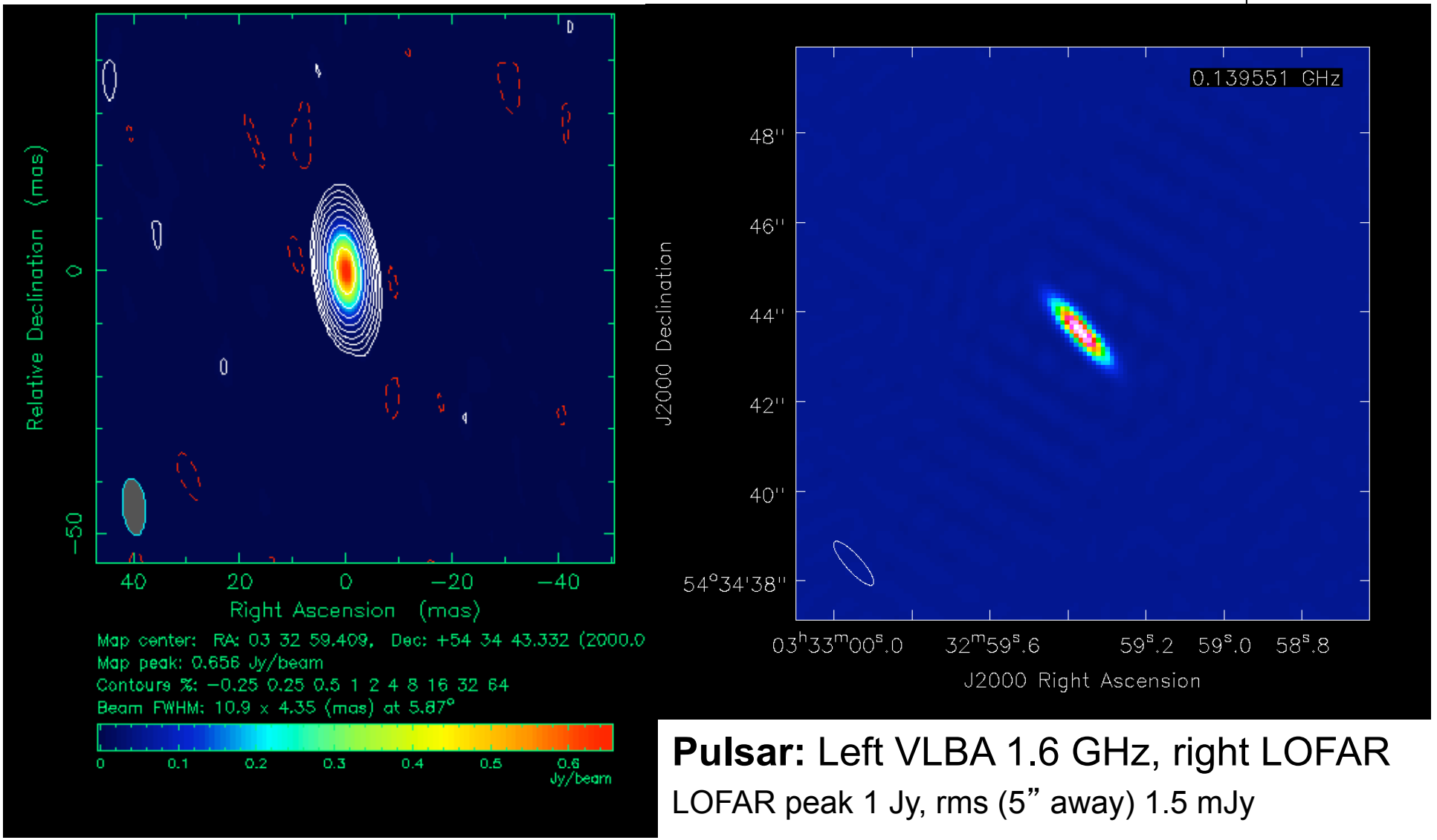
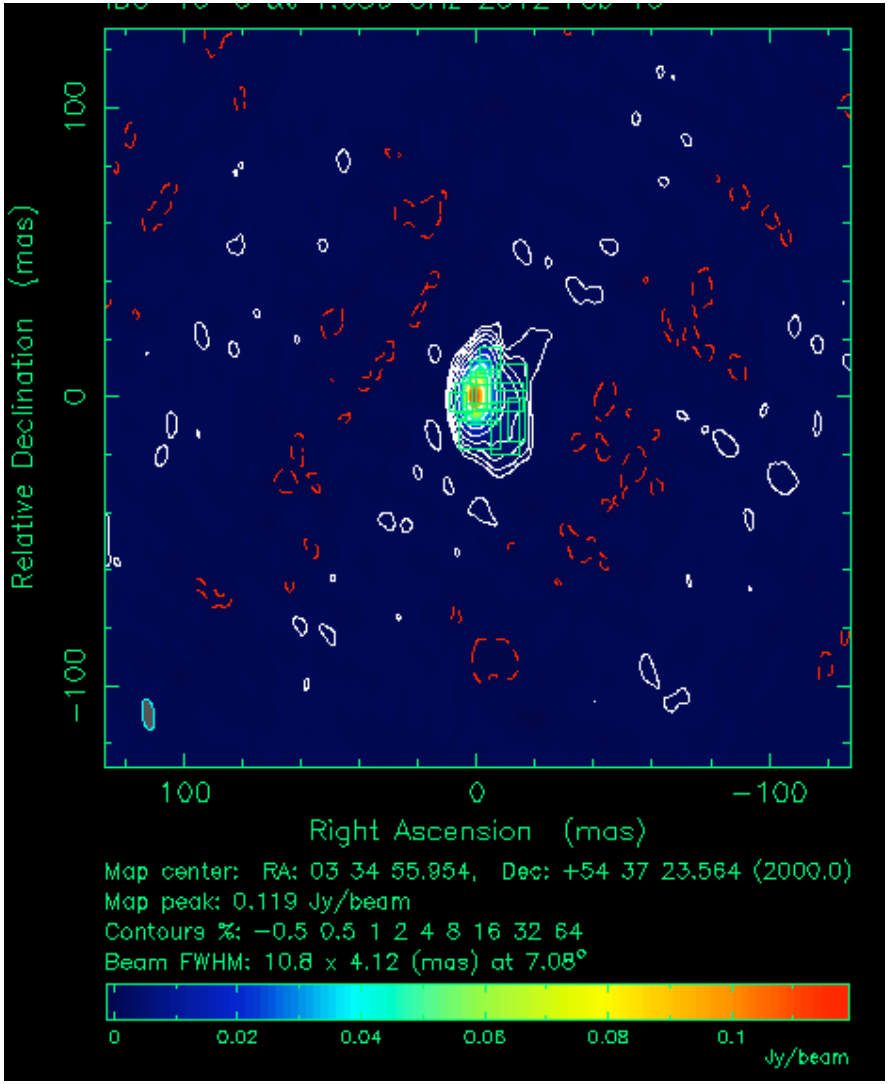
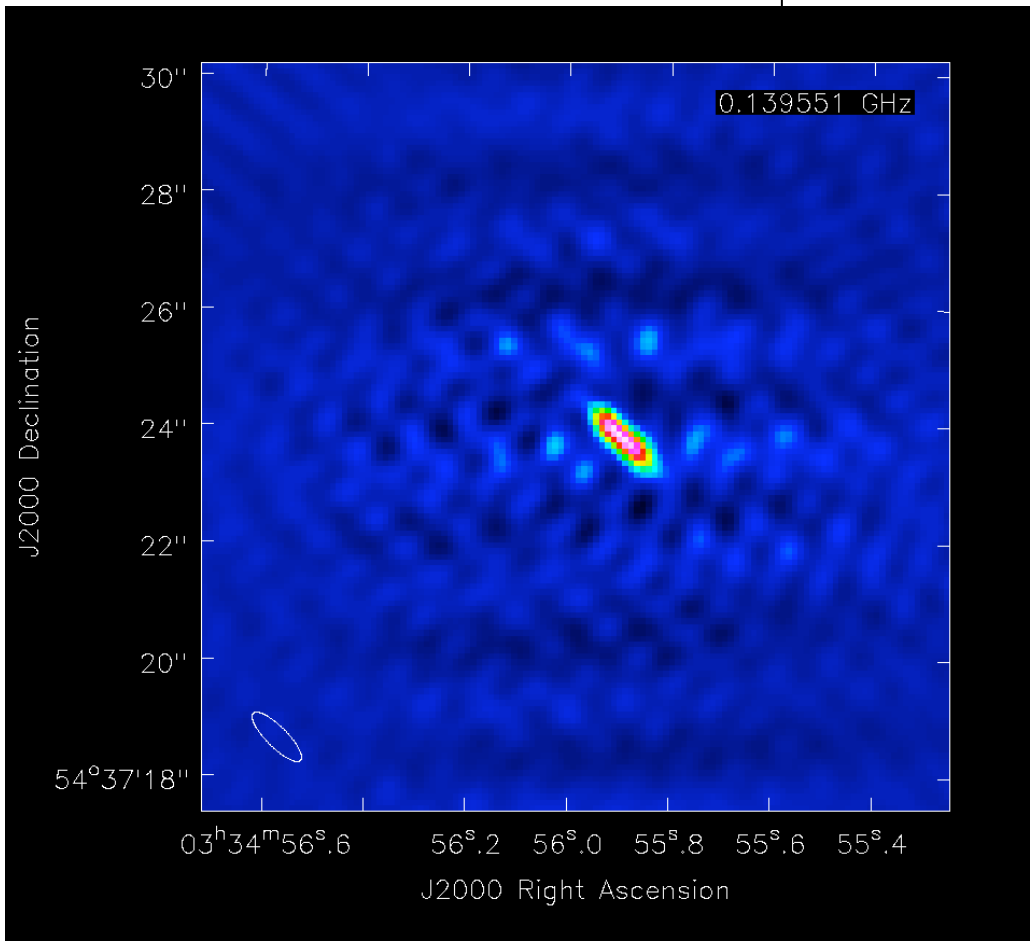



**Pulsar:** Left VLBA 1.6 GHz, right LOFAR

LOFAR peak 1 Jy, rms (5” away) 1.5 mJy

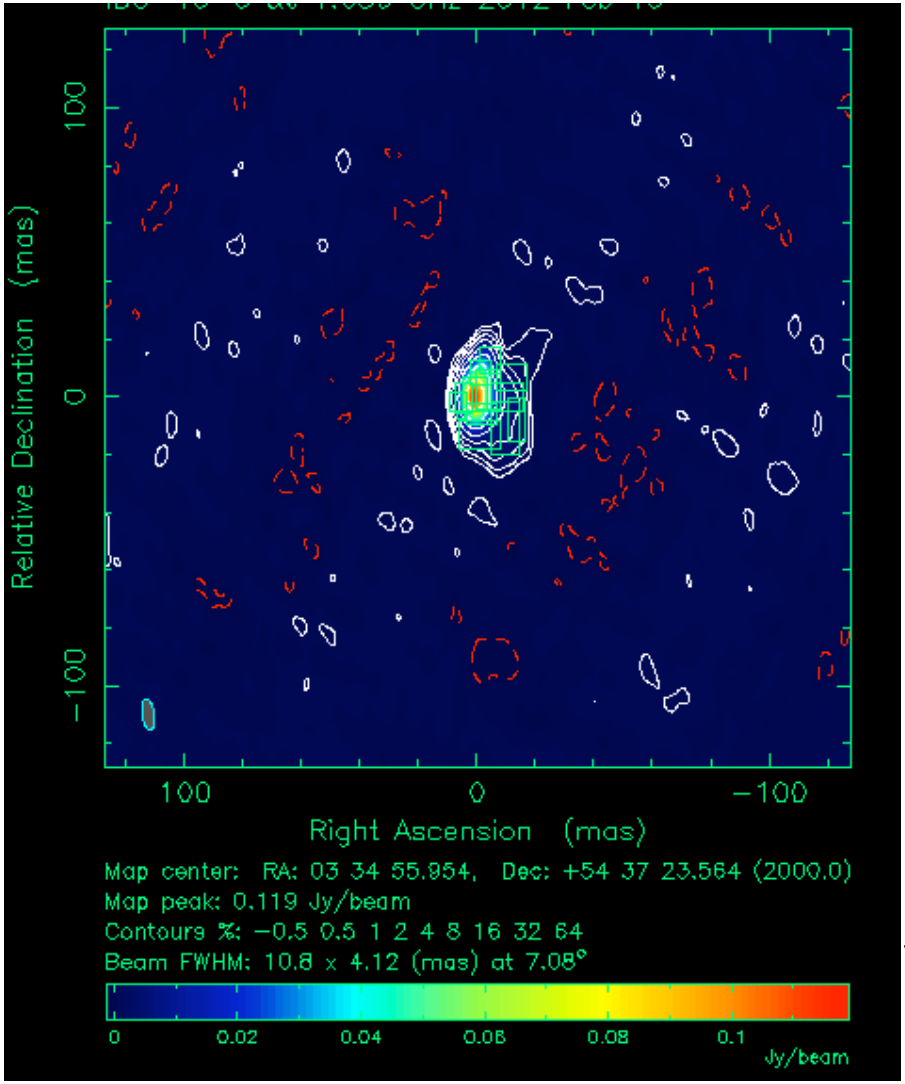
# LBBW#1 Images: PSR B0329

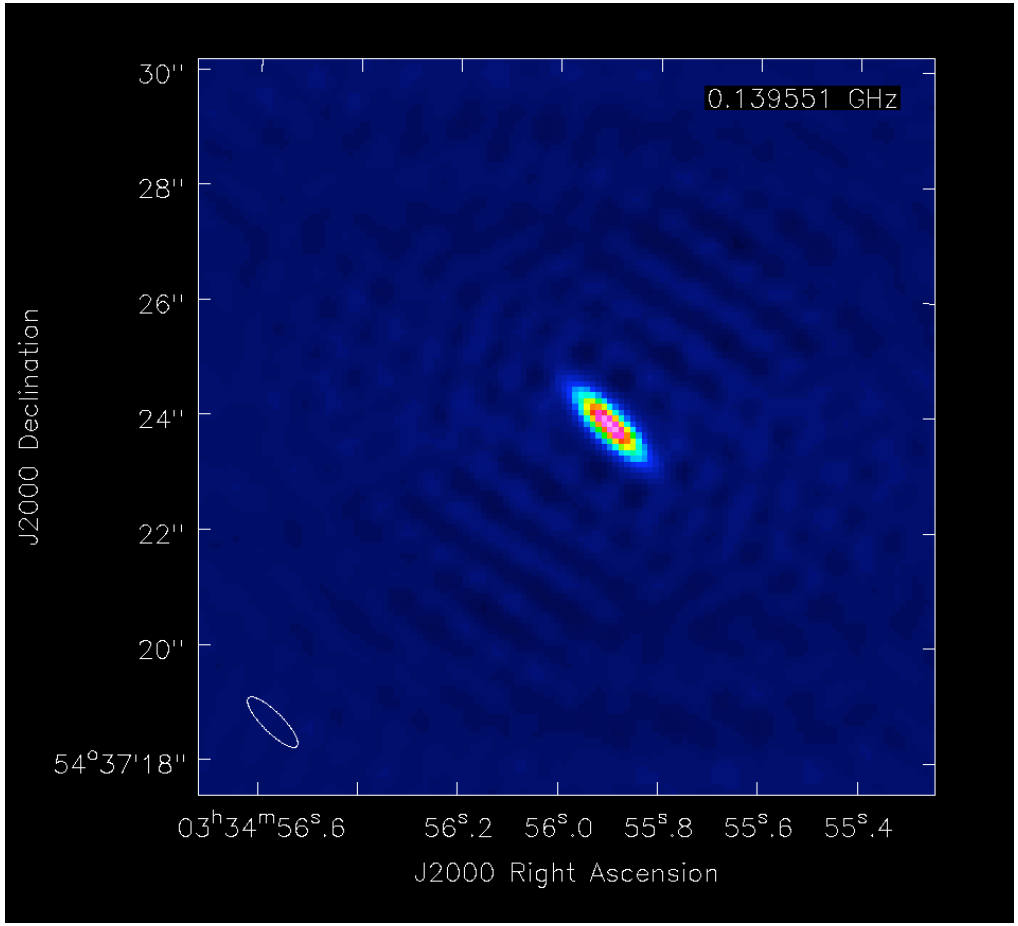



**VLBA1:** Left VLBA 1.6 GHz, right LOFAR
LOFAR peak 142 mJy, rms (10” away) 1 mJy

# LBBW#1 Images: PSR B0329

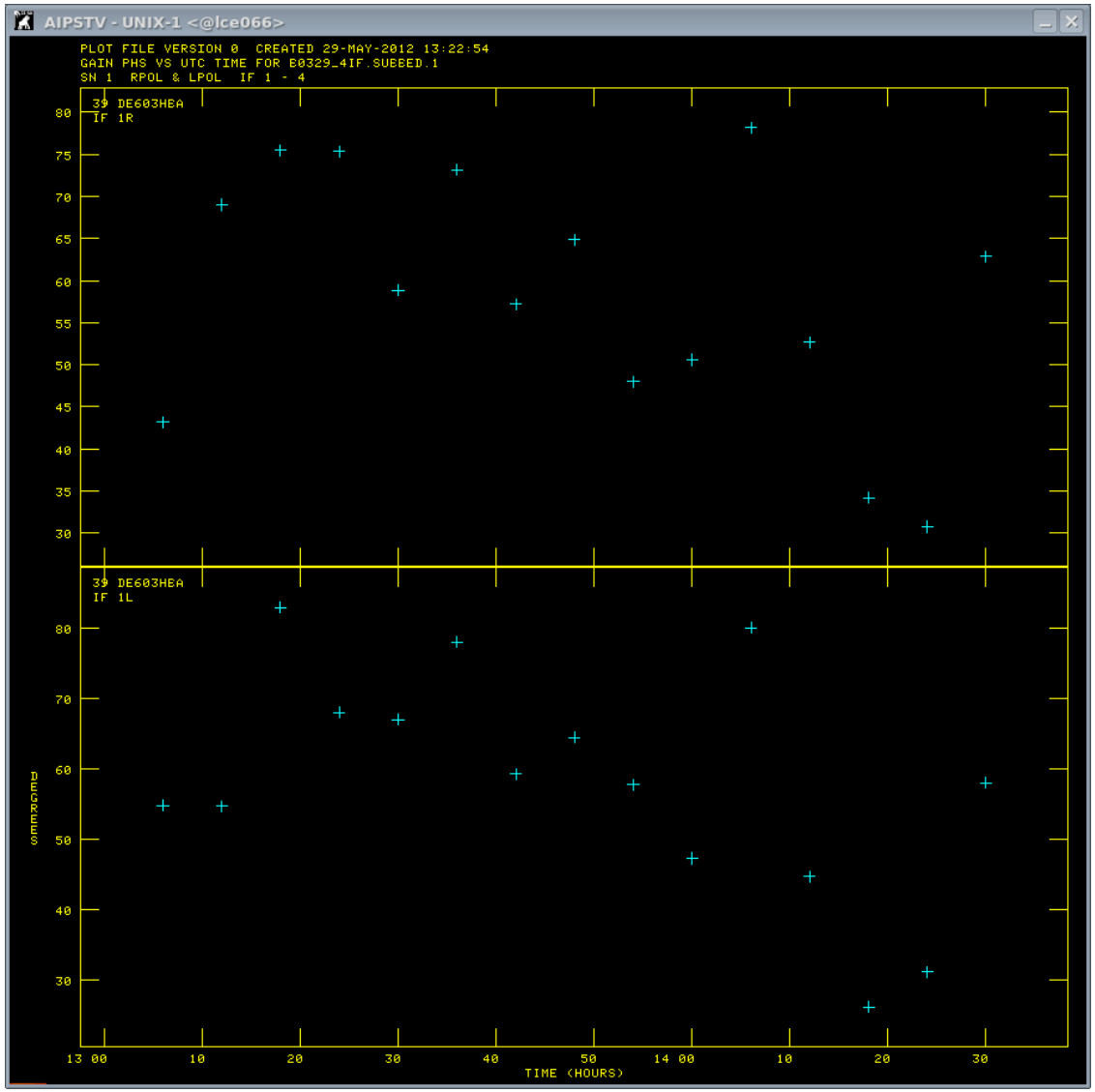



**VLBA1 (selfcal):** Left VLBA, right LOFAR

LOFAR peak 180 mJy, rms (10” away) 0.6 mJy

# LBBW#1 Images: PSR B0329



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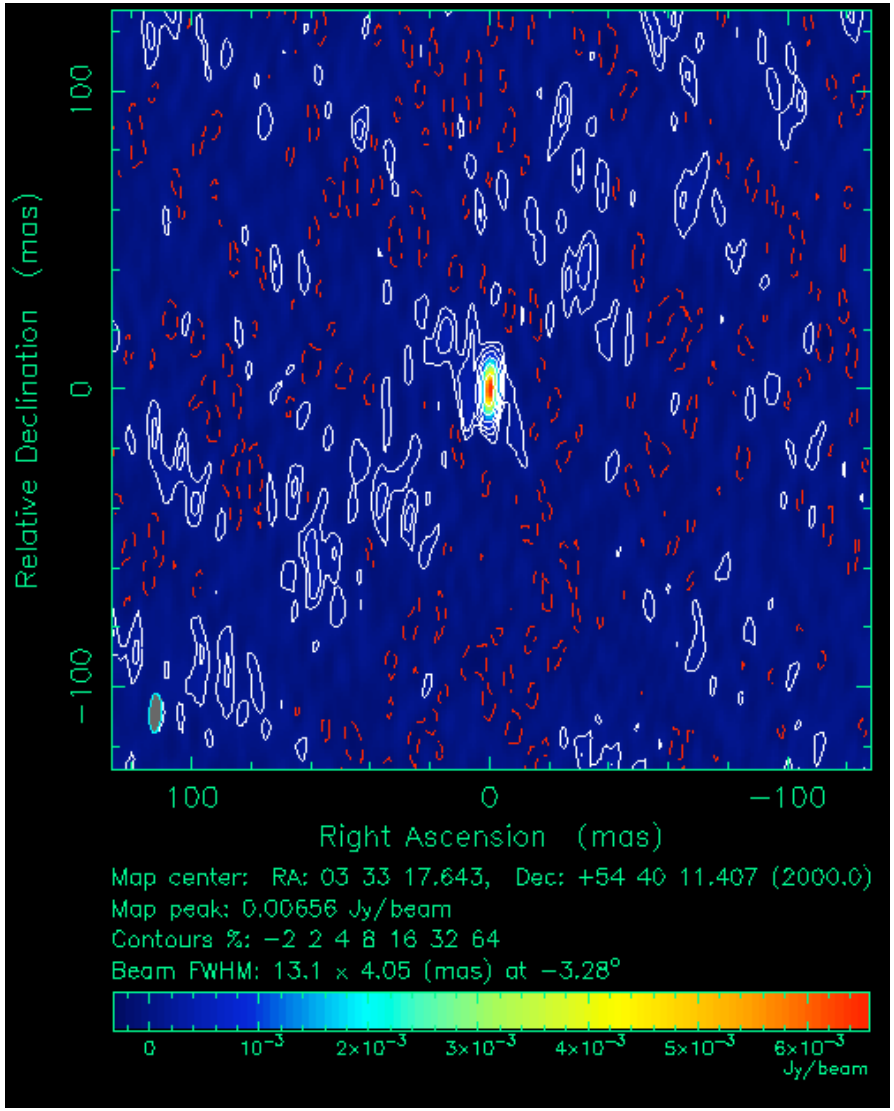
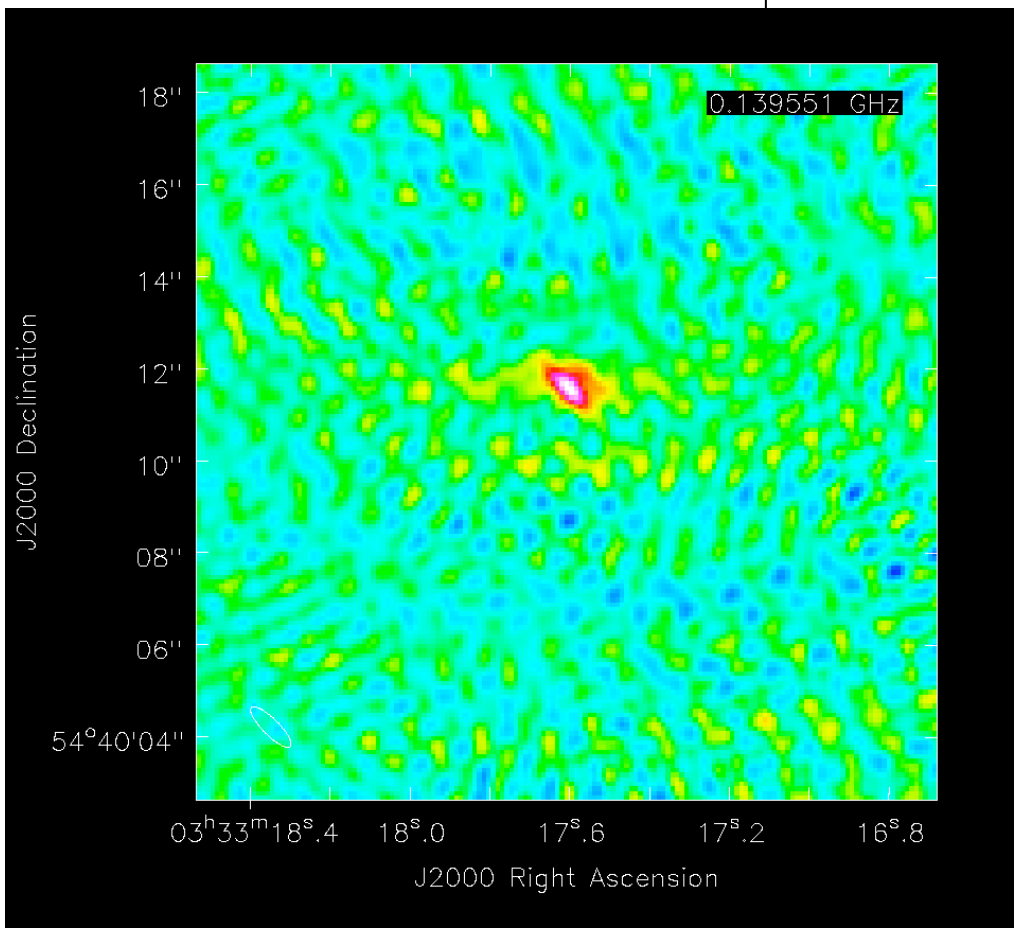
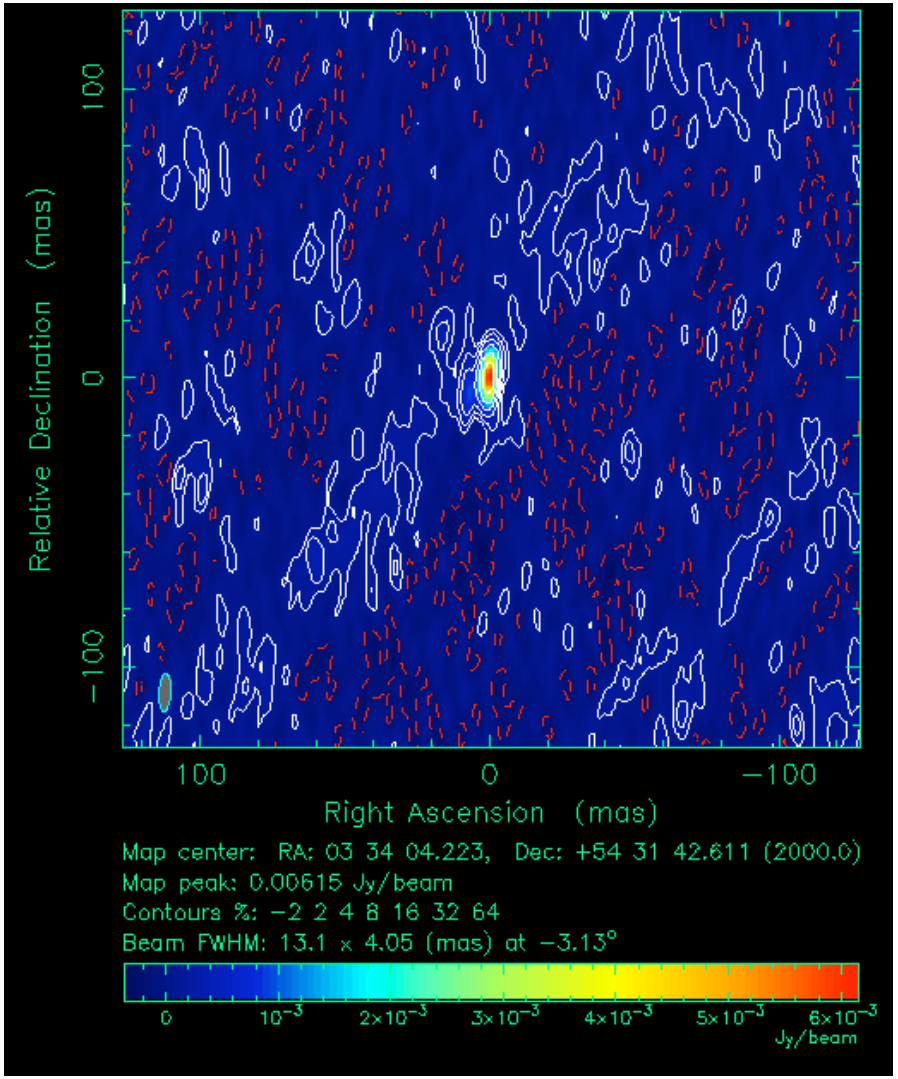


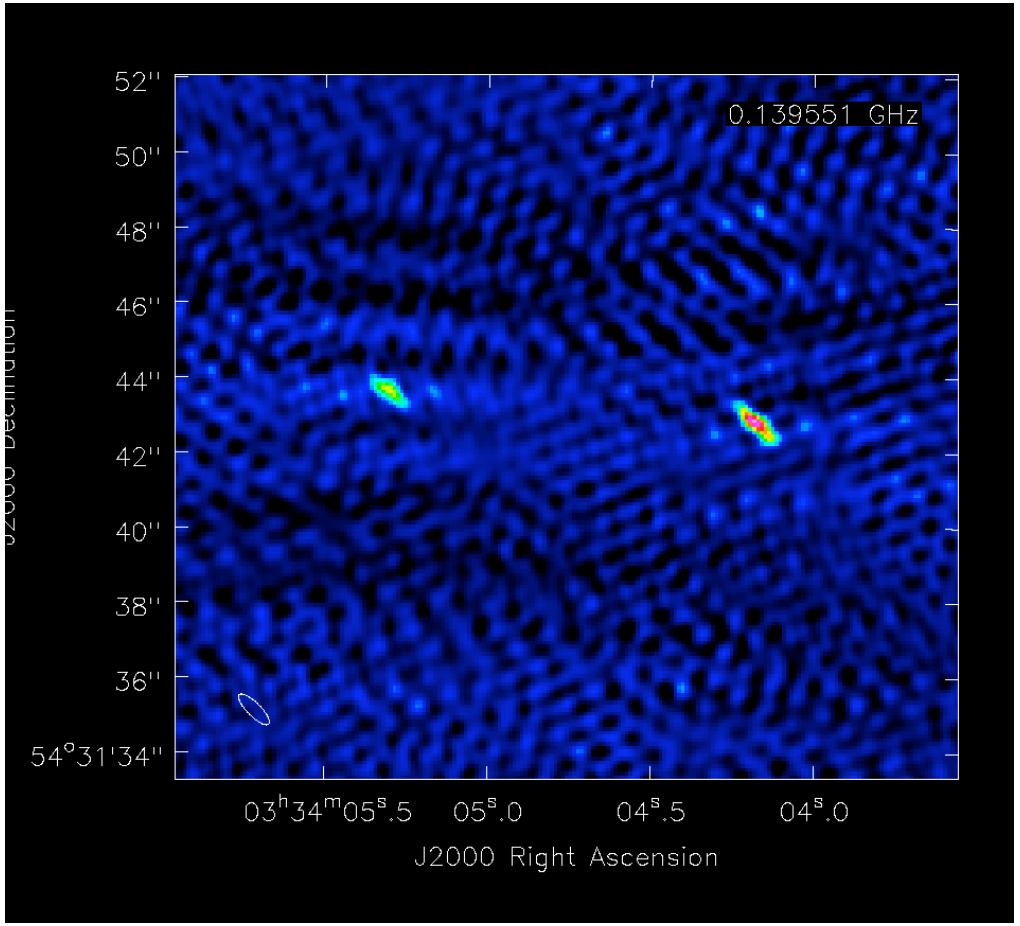




**VLBA2:** Left VLBA 1.6 GHz, right LOFAR

LOFAR peak 4.5 mJy, rms (10” away) 0.3 mJy

# LBBW#1 Images: PSR B0329



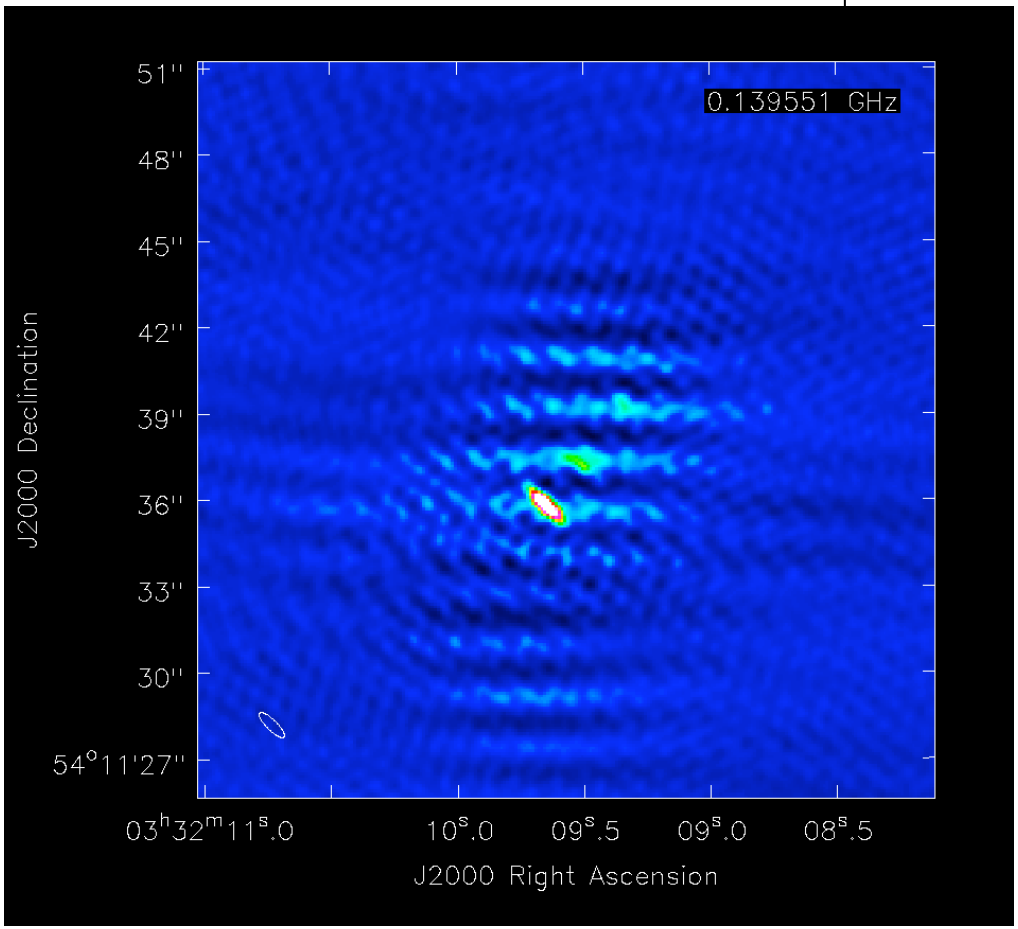




**VLBA3:** Left VLBA 1.6 GHz, right LOFAR

LOFAR peak 4.5 mJy, rms (10” away) 0.3 mJy

# LBBW#1 Images: PSR B0329

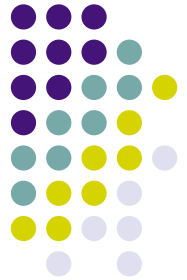
**No VLBA data for this source (NVSS flux 90 mJy)**




**0332+5411:** LOFAR

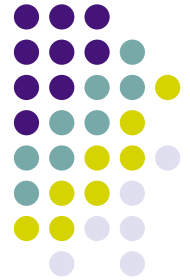
LOFAR peak 33 mJy, rms (10” away) 0.4 mJy

# Current state and future plans



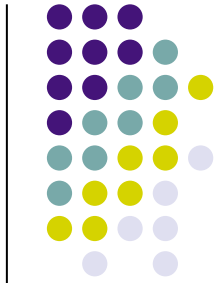
- Status:
  - Conversion to circular polarisation required to beat differential faraday rotation
  - Creating “subbands” of ~few MHz allows piecewise linear correction of delays - can then immediately go in to image in circular
  - Poor a priori amplitude calibration makes it really hard when the source structure is unknown!
  - Python scripts for circular conversion and superterp phasing are available

# Current state and future plans



- Status:
  - Multiple sources can be imaged within a HBA beam. Contemporaneous calibration works (dual beam, time interpolation / “slewing” not yet tried)
  - Raw data (1s, 64 ch/sb) allows 2x2 degree FOV
  - A single facet can be ~10 arcmin x 10 arcmin, proper imaging of larger fields requires shift/ average in NDPPP from raw data
  - HBA calibrator requirement: source with compact flux density > few hundred mJy **and known structure** (LBA higher due to higher Tsys)

# Current state and future plans



- Future plans:
  - Incorporation of superterp phasing into NDPPP (ease of use, supportability)
  - What about conversion to circular?
  - Fit for clock, ionosphere and Faraday rotation in circular pol solutions, write a BBS parmdb and use BBS to correct in linear pols
    - Can then use average and use standard LOFAR tools
    - Better beam model, better subsequent polarisation calibration, hopefully better imaging