The search for radio emission from exoplanets using LOFAR low-frequency beamformed observations

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The Broad Impact of Low Frequency Observing

June 19, 2017

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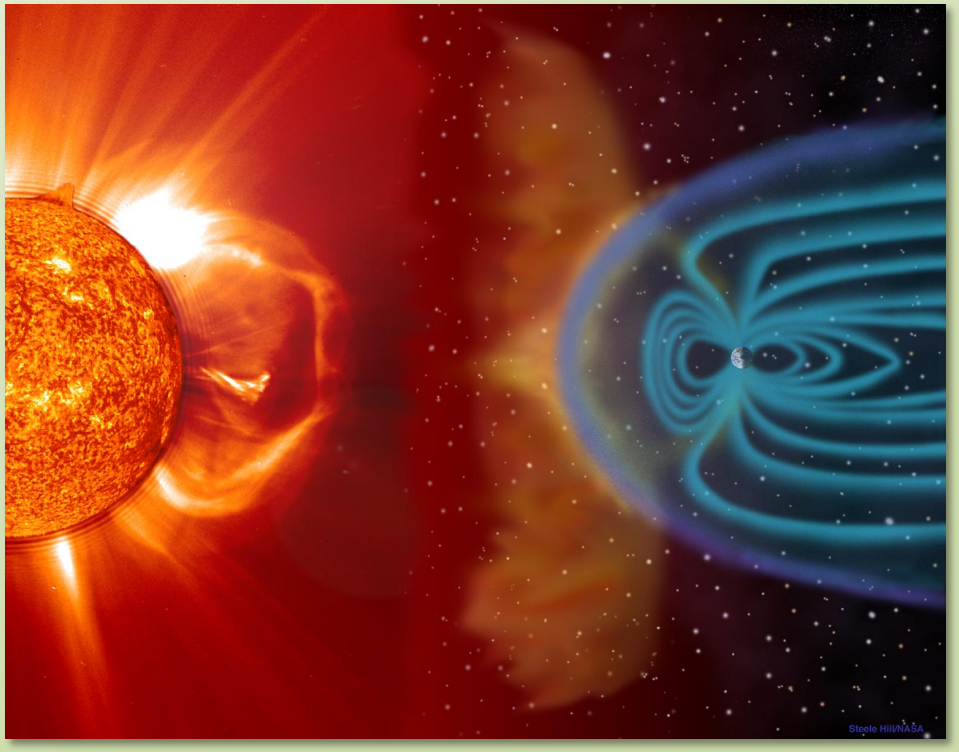
Overview

- Exoplanet Magnetic Fields
- Radio Observations of Exoplanets
- Our LOFAR Observing Campaign
  - Data Pipeline (Turner+ 2017, submitted)
  - Jupiter Observations
    - Jupiter as an exoplanet (Turner+ 2017, in prep)
  - Preliminary results on 55 Cnc (Turner+ 2017, submitted)

Exoplanet Magnetic Fields

Motivation

- Formation and evolution
- Interior structure
- Rotation period
- Atmospheric evolution and escape
- Ohmic heating
- Star-planet Interactions
- Moons
- Solar System comparison
- Habitability



Lazio+ 2010, Grießmeier+ 2005, Rauscher+ 2010, Hess & Zarka 2011, Grießmeier 2015, Zarka+2015

Radio Observations

- Electron cyclotron emission in radio
- Best method to study planetary magnetic fields (Grießmeier 2015)

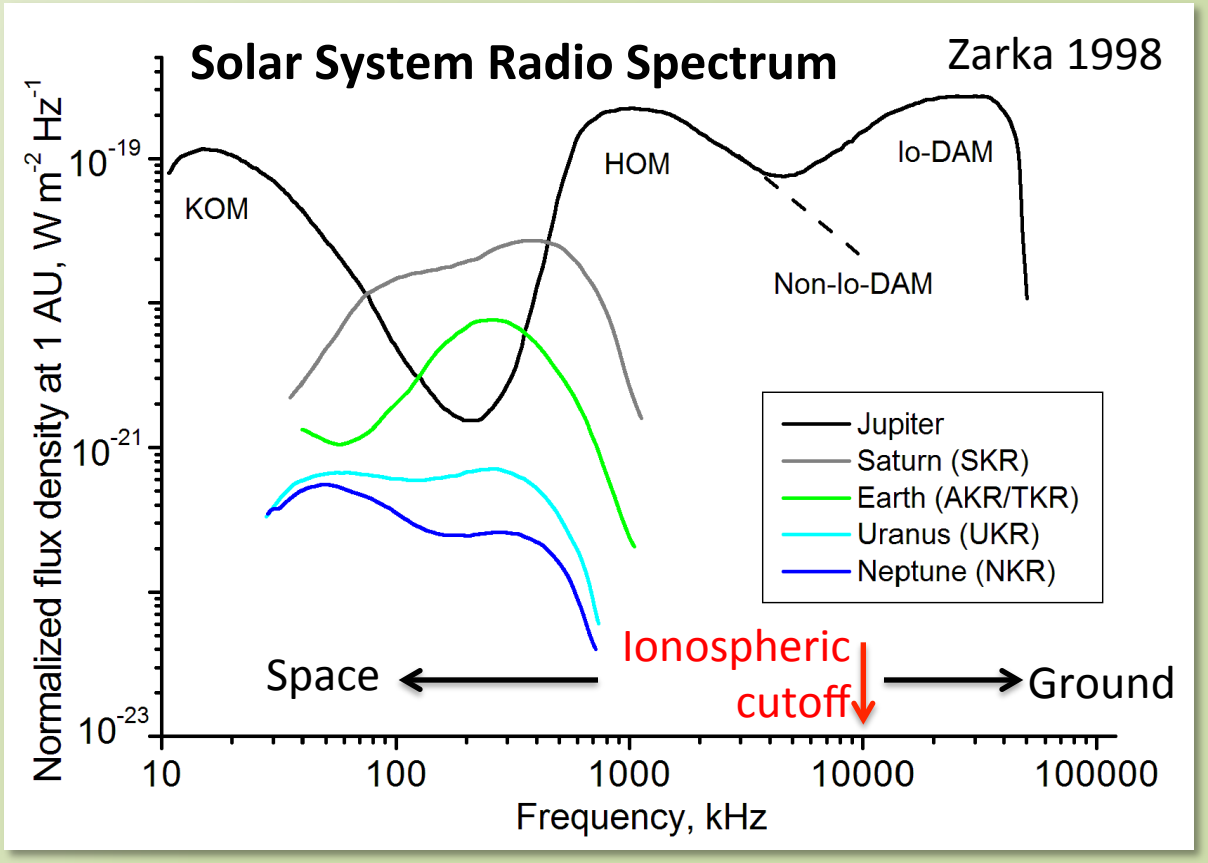
<u>Peak of Emission</u>

$f_g = 2.8\ (B_p/G)$ MHz

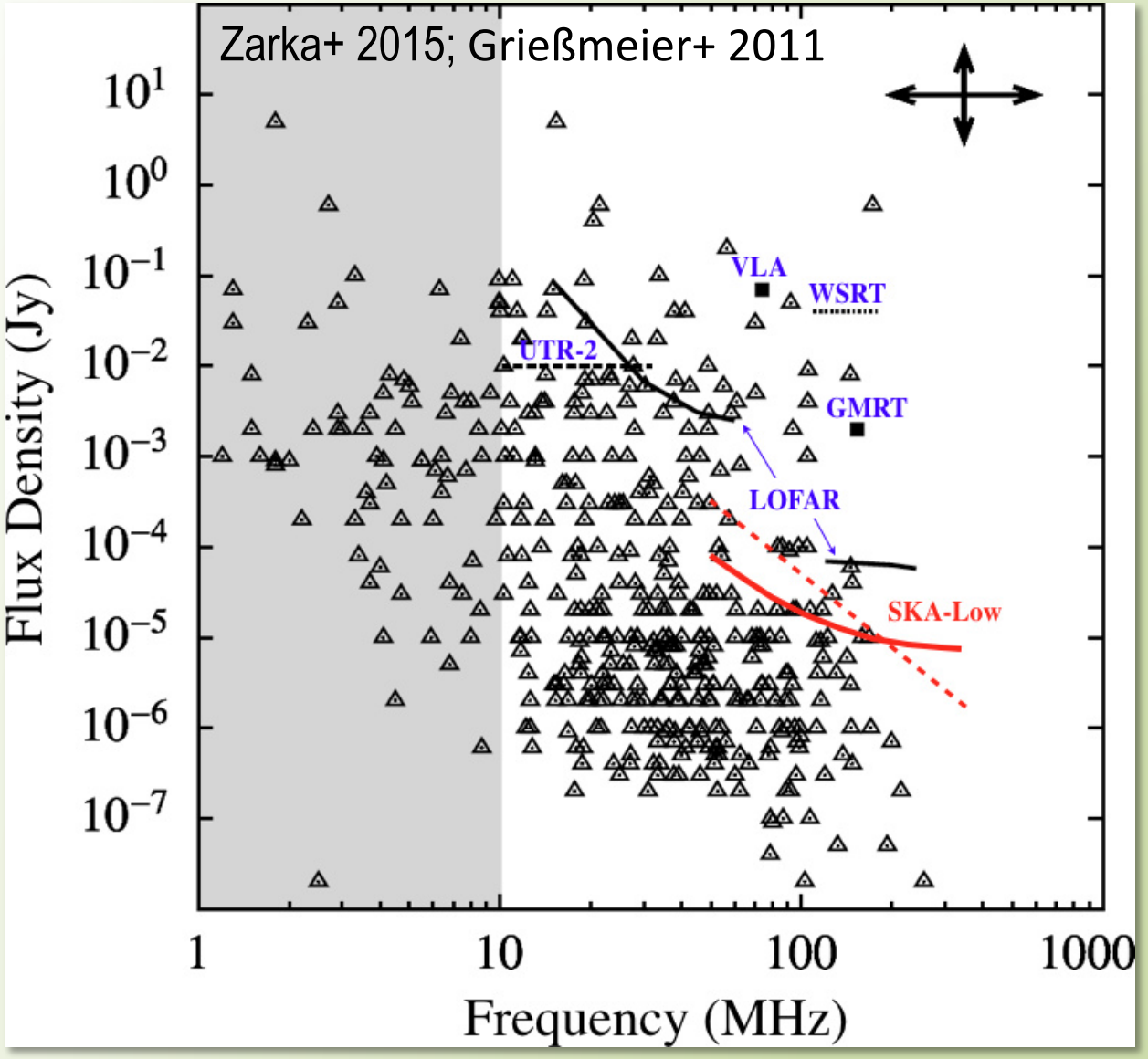
B_p: Planetary B-field

100% circularly polarized

Flux (Planet) ≥ Flux (star)



Radio Flux & Frequency Predictions



- Predicted maximum emission frequency for rotation-independent planetary magnetic field and expected radio flux for known planets

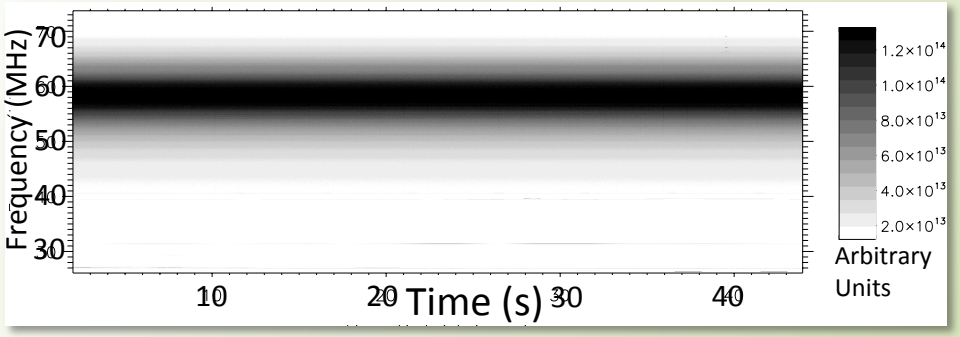
LOFAR Observations

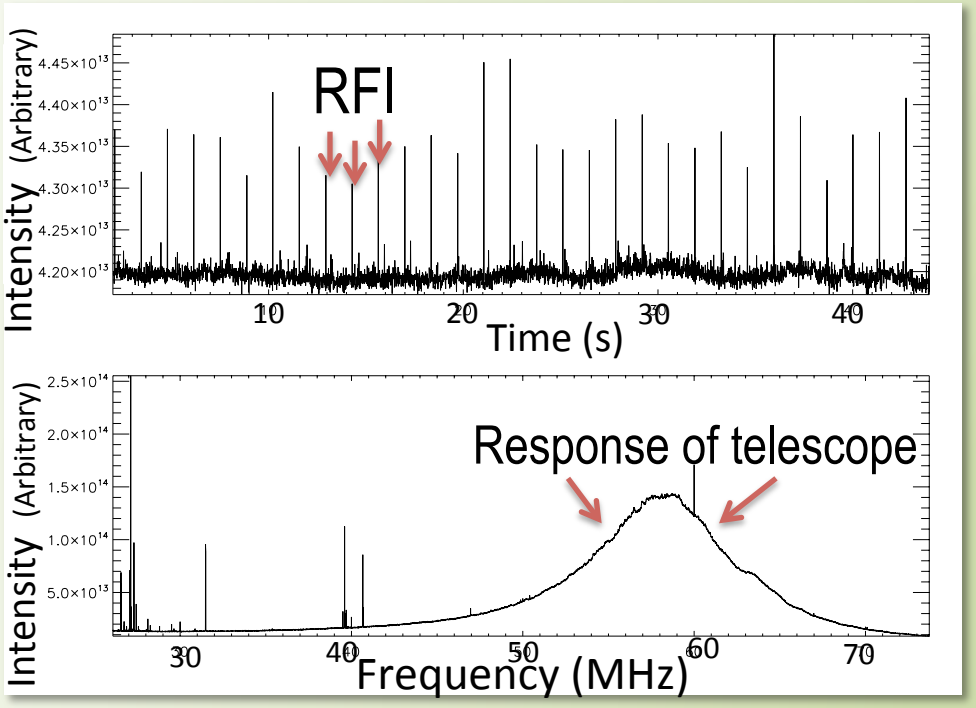
- ν: 26-73 MHz
- IQUV Polarization
- Raw Res: 10 msec & 3 kHz
- 9 arcmin resolution
- 16 mJy sensitivity: 2 mins over full band
- Observational Campaign:
  - 4 exoplanets so far
  - 3 Beams
  - Over full orbital phase

Turner+ 2017 (submitted)

LOFAR Pipeline

Raw





Turner+ 2017 (submitted)

LOFAR Pipeline

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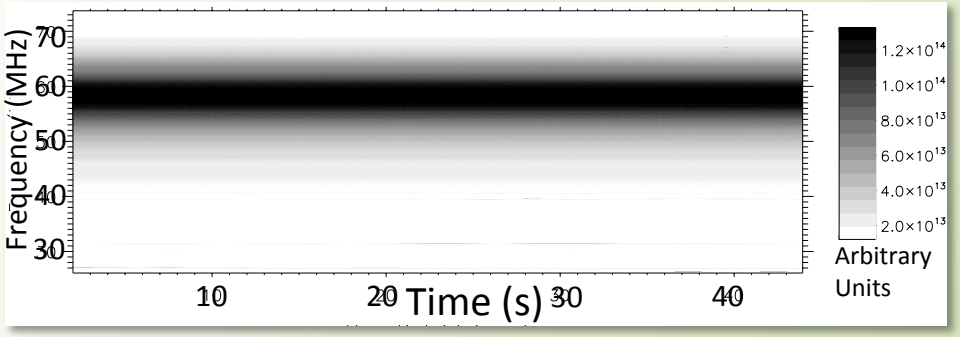
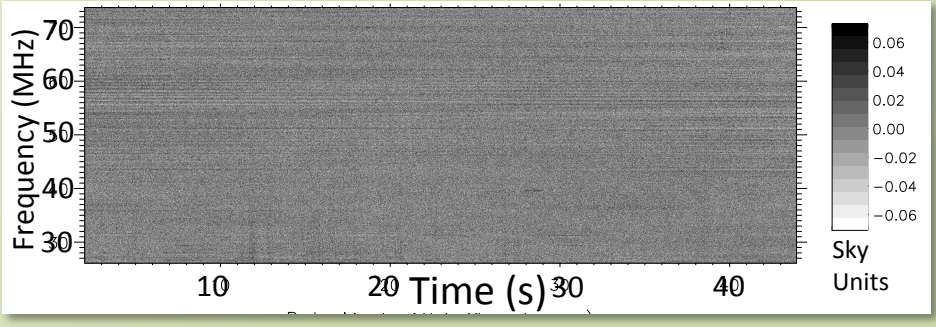
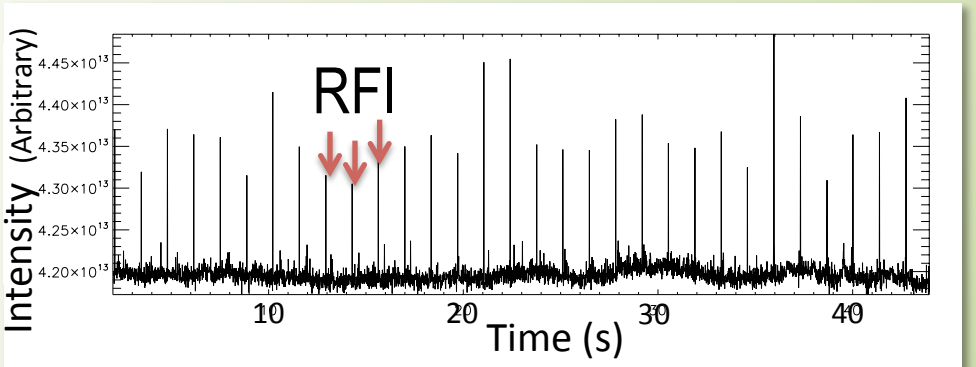
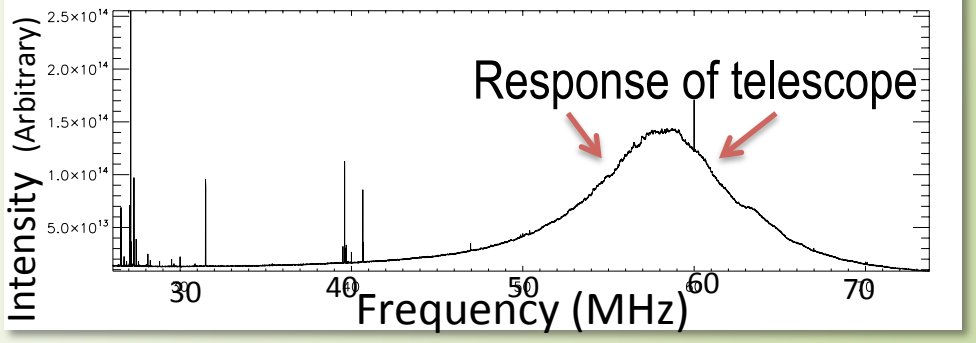
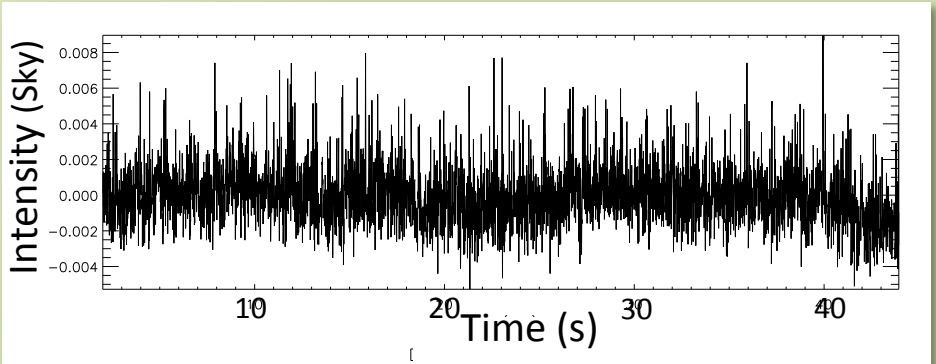


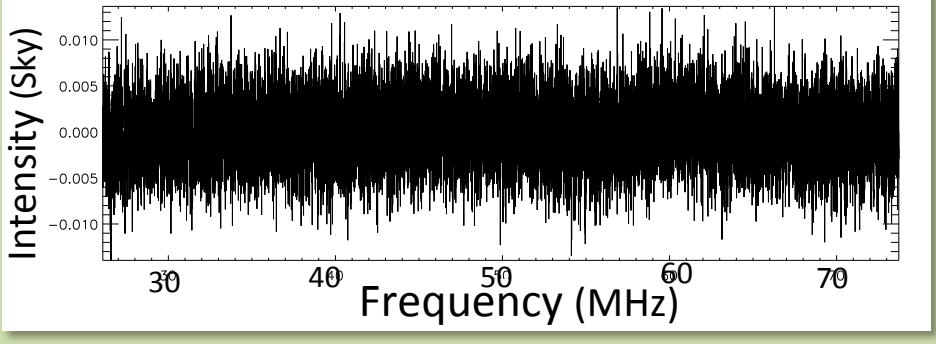
Normalized+ RFI mitigation





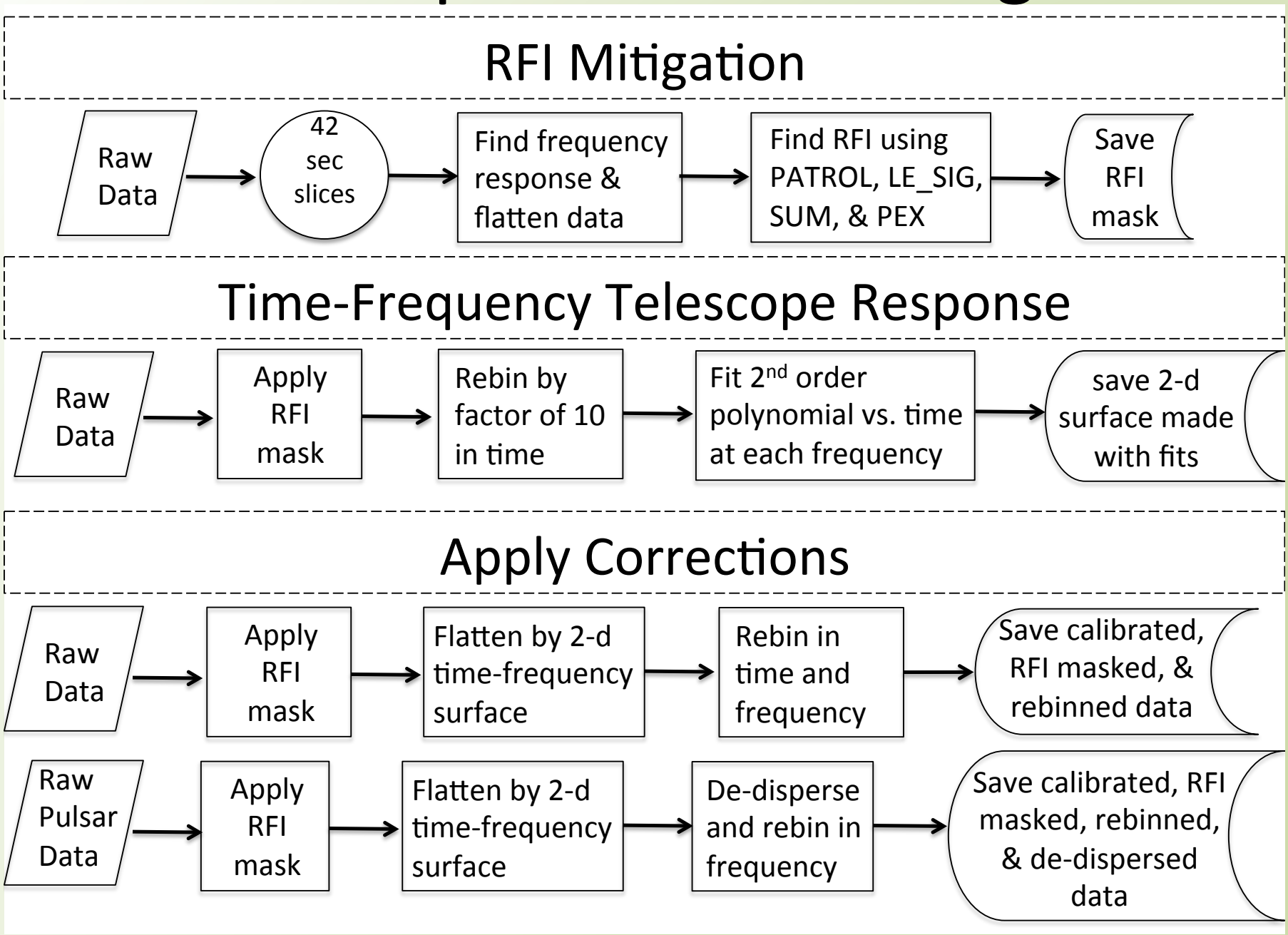




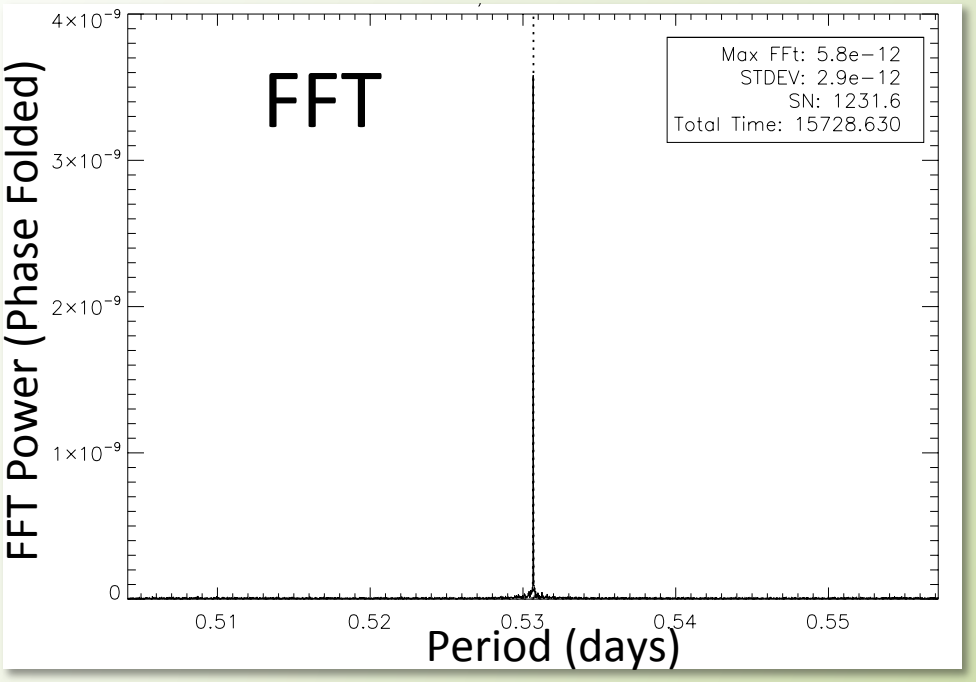


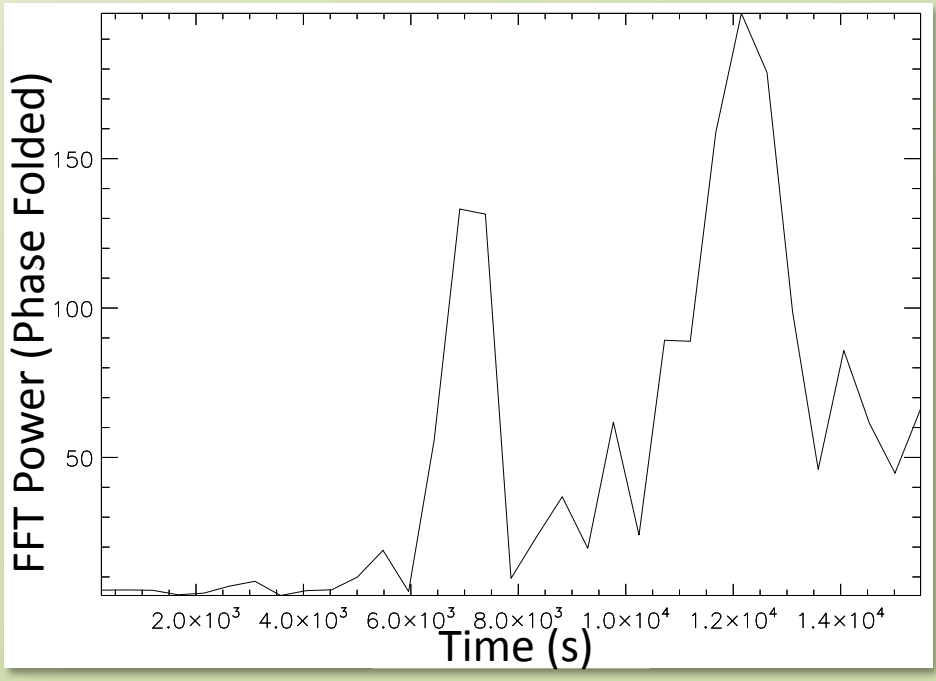
Turner+ 2017 (submitted)

LOFAR Pipeline: Block Diagram



Preliminary Results: Pulsar



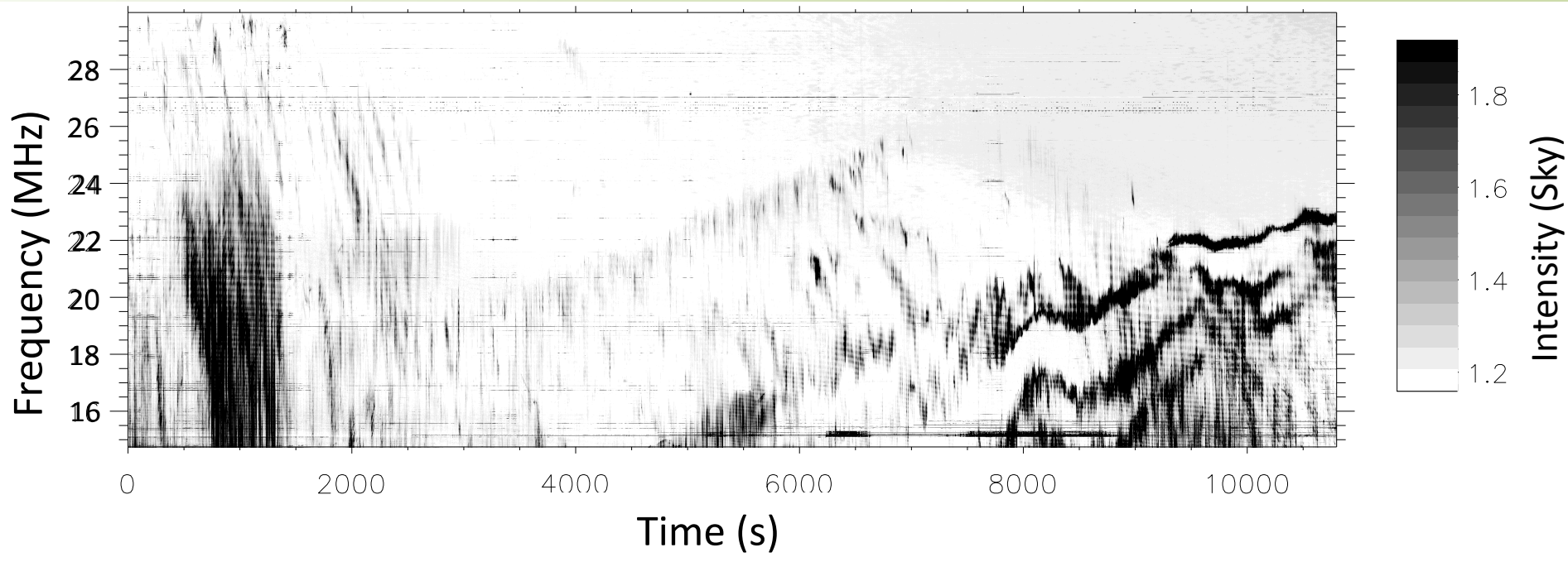


- Pulsar B0823+26 is detected at high S/N at known period
- Brightness of pulsar changes with time (known previously).

Turner+ 2017 (submitted)

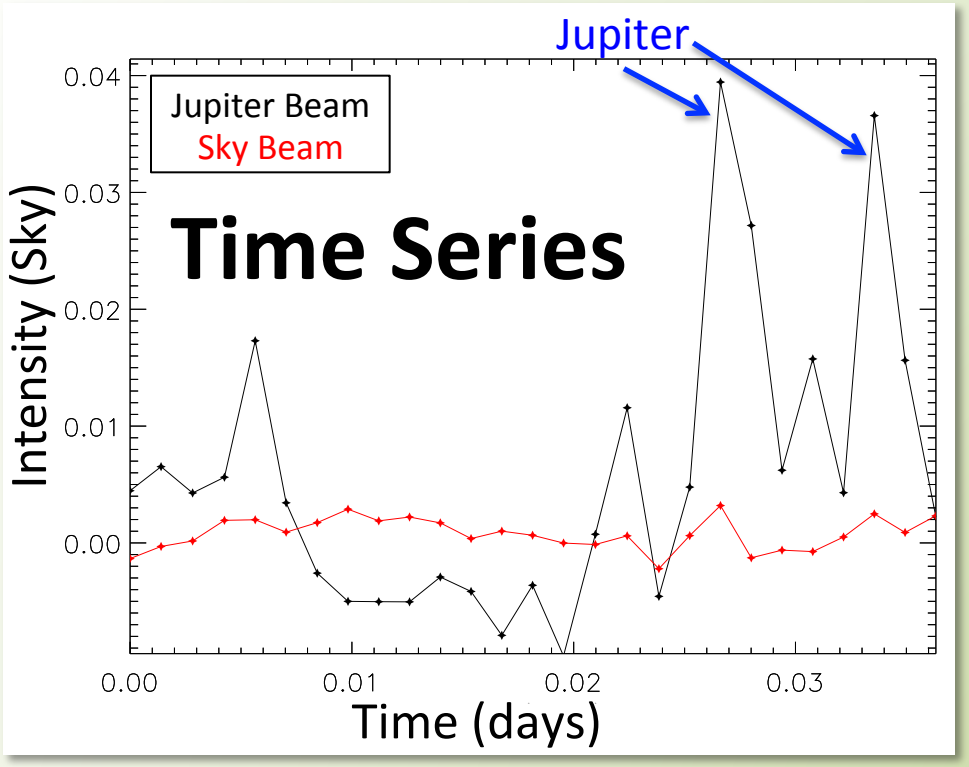
Jupiter Observations

- Scale Jupiter radio emission from LOFAR as if it was an exoplanet (reduce flux by 10^{-3} – 10^{-6}).
- Produce a set of observables that can be used as a guideline in the search exoplanetary radio emission

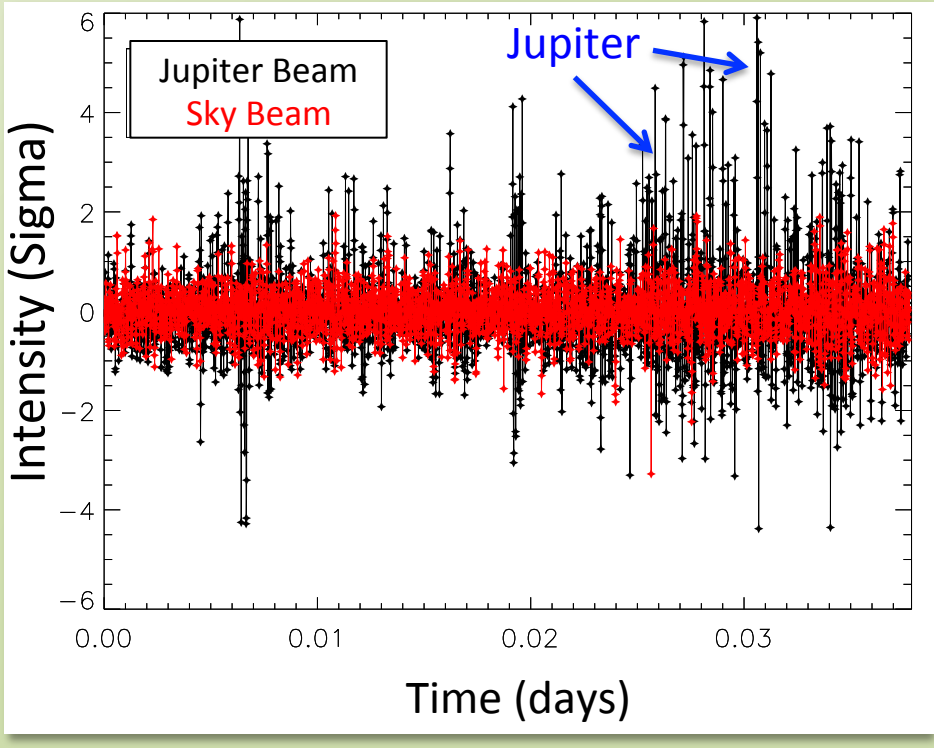


Turner+ 2017 (in prep)

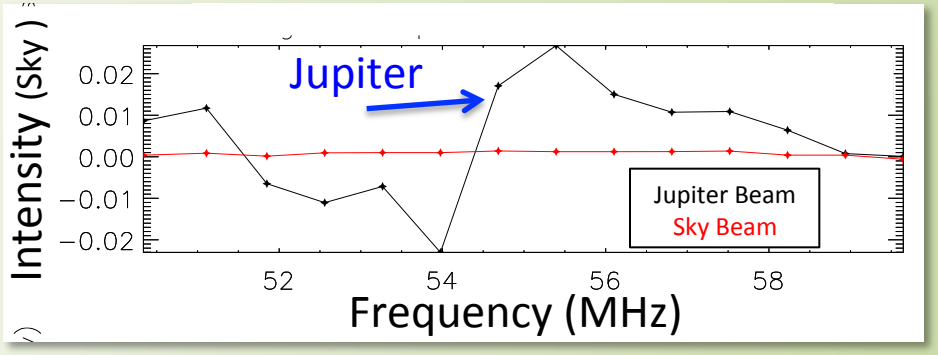
Observables



High-pass filtered time series

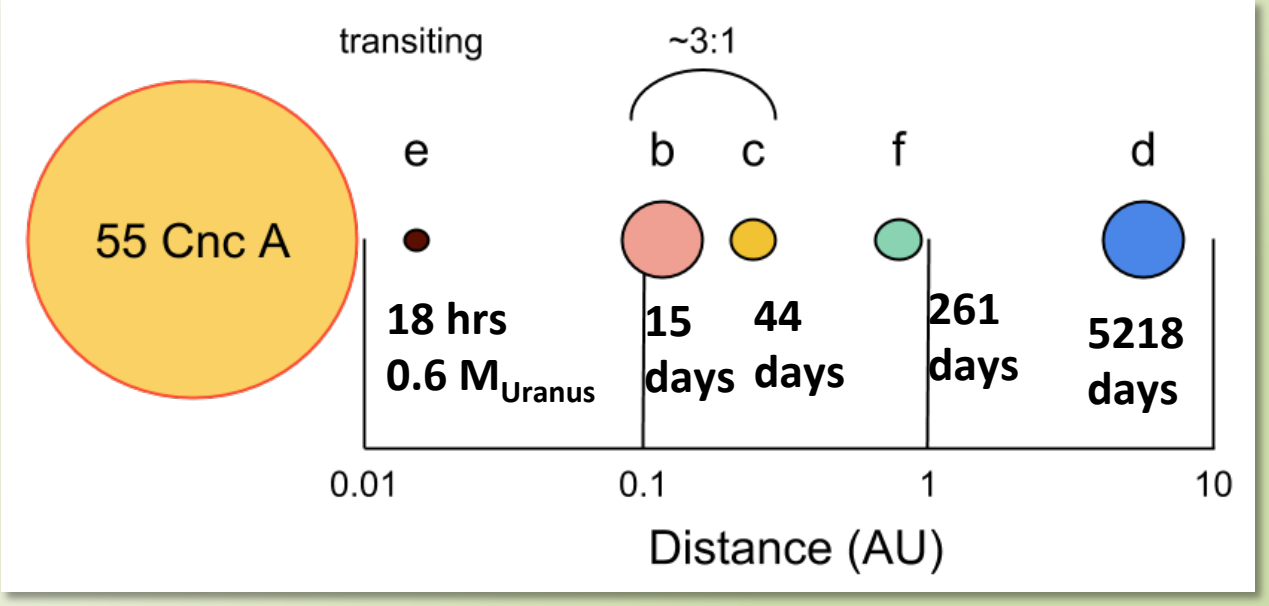


Integrated Spectrum



Turner+ 2017 (in prep)

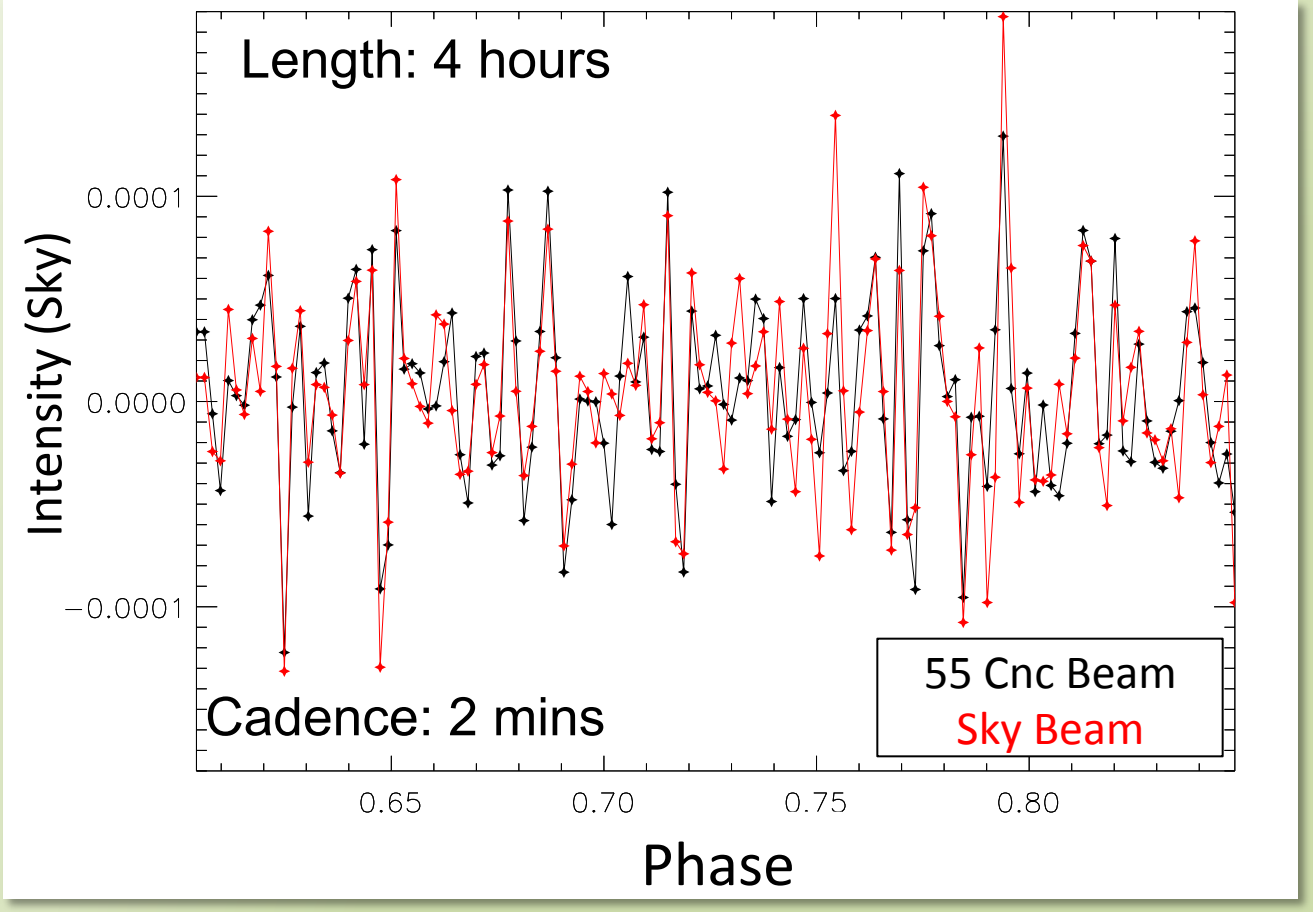
55 Cnc Planetary System



- One of best targets for radio observations due small orbital distance, proximity (12.3 pc), and multiplicity (Grießmeier+ 2007).
- Emission from 55 Cnc e possible: tens of MHz with flux densities up to hundreds of mJy (Grießmeier+ 2007, Jardine+ 2008).

55 Cnc Preliminary Results:

- Do not observe broadband emission from 55 Cnc
- Full dataset needs to be analyzed
  - Total of 18 hours



Turner+ 2017 (submitted)

Conclusions

- Radio observations are the best way to study exoplanet magnetic fields
- LOFAR data is stable and sensitive enough to detect astrophysical signals from the pulsar
- We observed Jupiter as if it was an exoplanet and developed a set of observables as guides
- Initial analysis of 4 hours of LOFAR 55 Cnc e data do no show an exoplanet signal
- The rest of the observational campaign is undergoing analysis