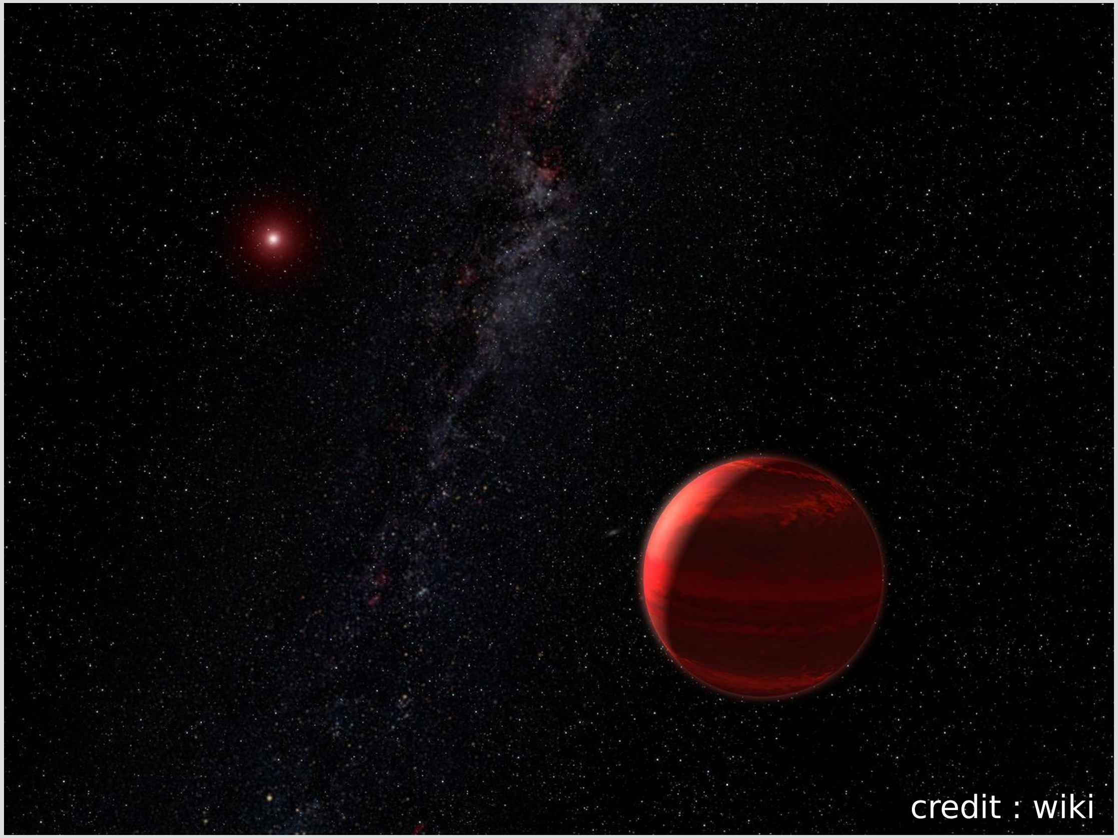
Project RISARD

- the story so far



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(Toruń Centre for Astronomy)

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K. Goździewski, K. Katarzyński, G. Rycyk
(TCfA)

Overview

- RISARD motivation and current status
- first results – TVLM 513-46546
- impact of flux variability on VLBI astrometry
- HOM emission from massive jovian planets

Radio ***I***nterferometry ***S***urvey of ***A***ctive ***R***ed ***D***warfs (RISARD)

Why red dwarfs (M-dwarfs)?

- most numerous in our Galaxy (and Universe) at present epoch
- mass range 0.08-0.6 $M_{\odot}$
- dominant population in the Solar neighbourhood
- in numbers >70% stars, total mass >40% (Henry 1998)
- Mass-Luminosity Relation is poorly constrained
- young (<1Gyr) M-dwarfs are sources of variable cm radio emission ($\lesssim$1mJy, Güdel 1993) due to magnetic activity
- radial velocity (RV) surveys are possible only in the case of old inactive M-dwarfs

Radio ***I***nterferometry ***S***urvey of ***A***ctive ***R***ed ***D***warfs (RISARD)

Red dwarfs planetary systems

- due to their high planet–star mass ratios, red dwarfs are the easiest targets for detection of low-mass planets
- first exoplanet orbiting their parent star inside the habitable zone was found around nearby M-dwarf, Gl 581 (Udry & Santos 2007)
- remarkable multi-planet resonant system was found around Gl 876, hosting two Jupiters (Marcy+ 1998)
- due to magnetic activity little is known about planetary systems around young red dwarfs

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Red dwarfs planetary systems

- the occurrence rate for Earth-sized with radii $0.5R_{\oplus} < r_{p} < 5R_{\oplus}$ and orbital period <50 days is 0.90±0.04 planets per star (KEPLER mission data, Dressing & Charbonneau 2013)

- the occurrence rates for planets within mass range 3-10$M_{\oplus}$ is 0.21±0.05 per star (RV surveys, Tuomi+ 2014)

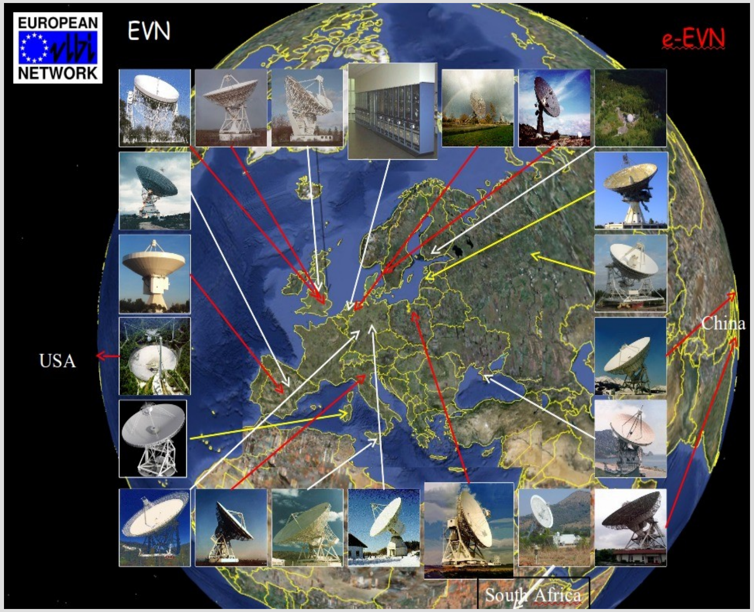
- the occurrence rate for planets in the mass range $10M_{\oplus} \lesssim m_{p} \sin i \lesssim 3000M_{\oplus}$ and period 10-3000 days is 0.36±0.05 per star (microlensing observations, Gould+ 2010)

- occurrence rate for giant planets based microlensing data is one order of magnitude higher than in the case of RV surveys (e.g. Bonfils+ 2013)

Radio ***I***nterferometry ***S***urvey of ***A***ctive ***R***ed ***D***warfs (RISARD)

Main targets

- astrometric survey of nearby (10<d<15 pc) active young RDs with the e-VLBI at 6cm (RIPL, Gower+ 2009,2011; 29 RDs, d<10 pc)
- searching for sub-stellar companions
- non-bias estimation of planetary system statistic (gas giants)
- precise estimations of proper motion and parallaxes (complementary to GAIA mission)
- study radio emission properties of RDs



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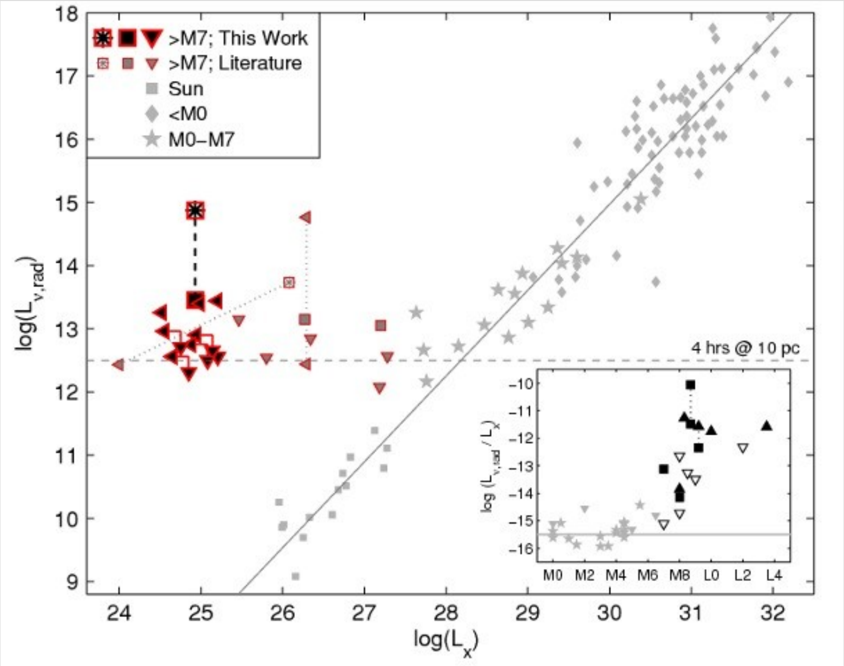

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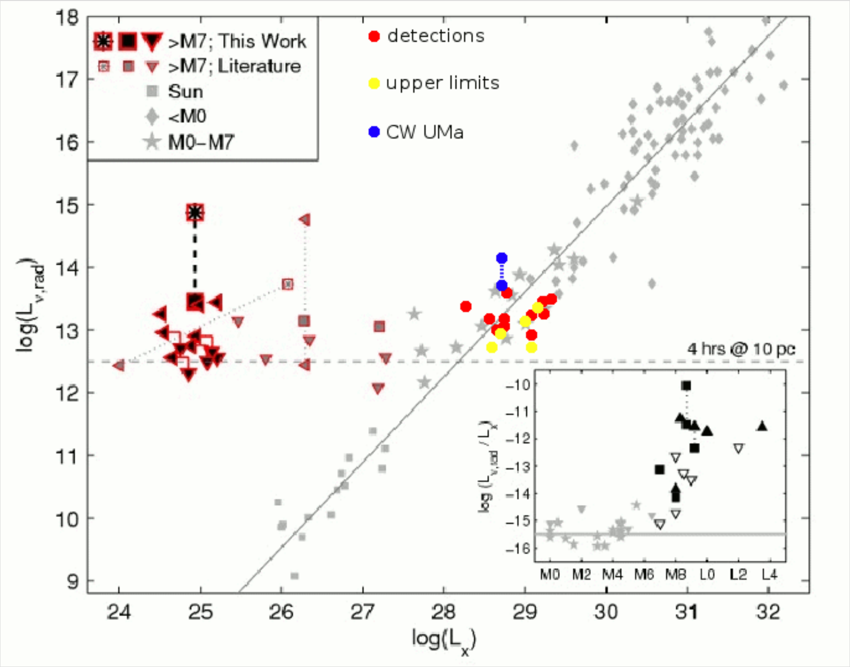

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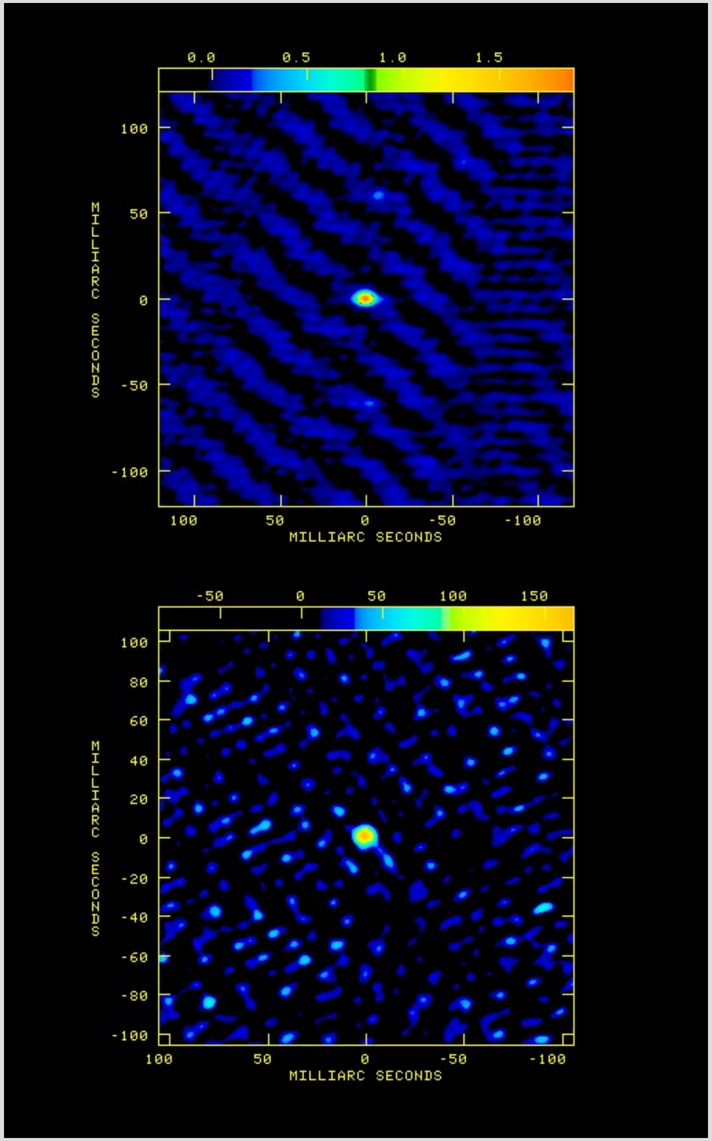

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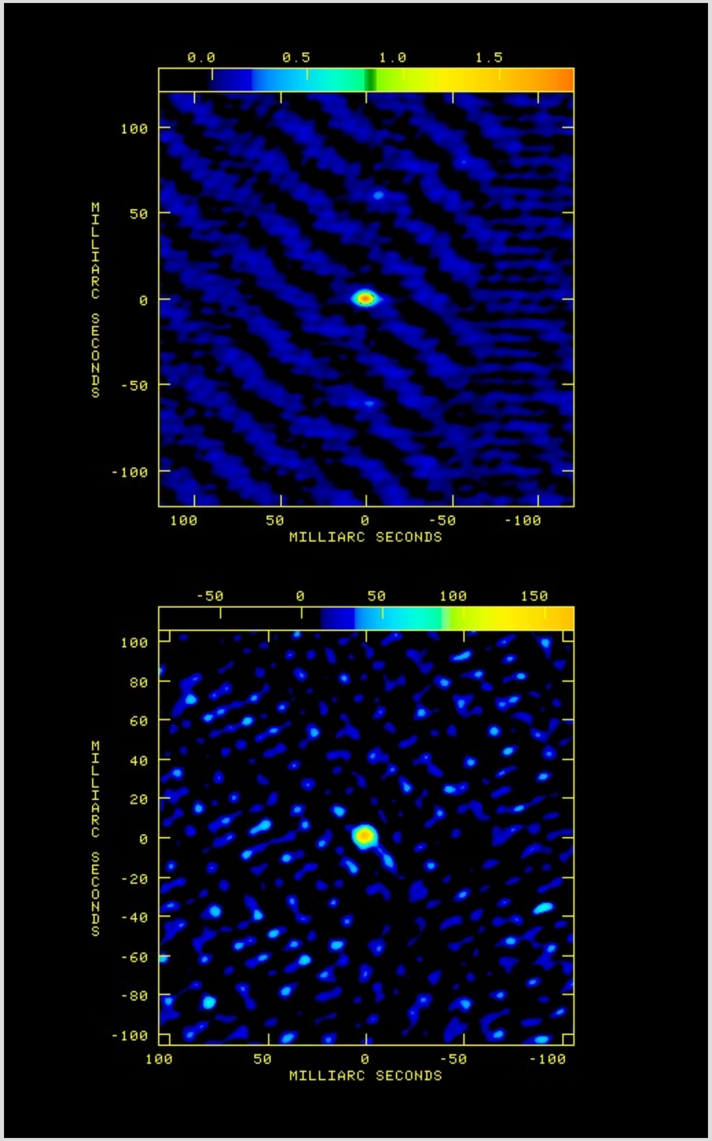
- 3rd step: regular astrometry observations of 6 RDs, 6 epochs for each target (2013-2015), only stars detected in each epoch during 2nd part of RISARD



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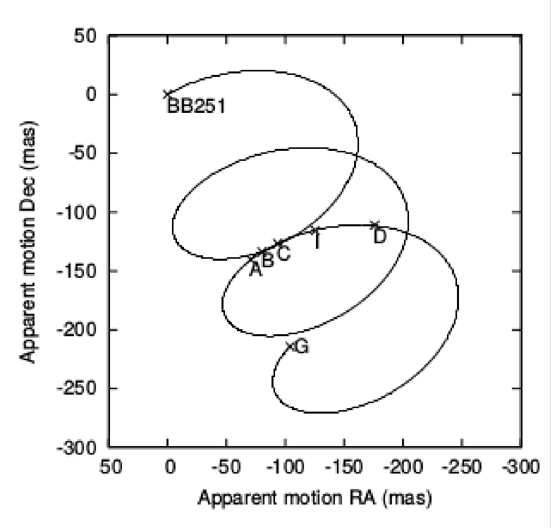
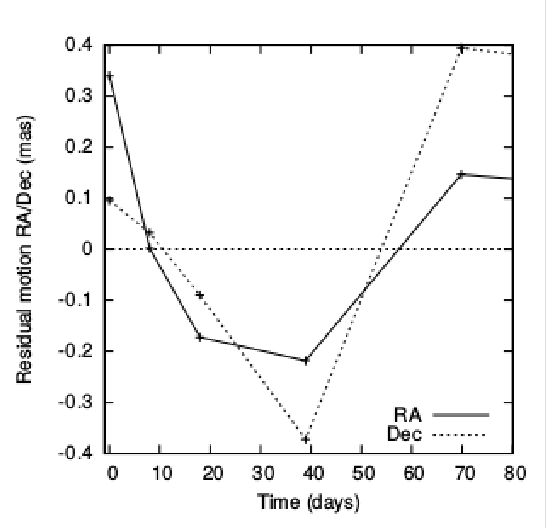
First results - TVLM 513-46546

- M8.5 dwarf at distance 10.7pc
- target for dedicated astrometric project with VLBA at 8.4GHz (7 epochs in 2010-2011; Forbrich+ 2013)
- low significance pattern in the residuals suggests ~2.6M_J with orbital period ~70 days)





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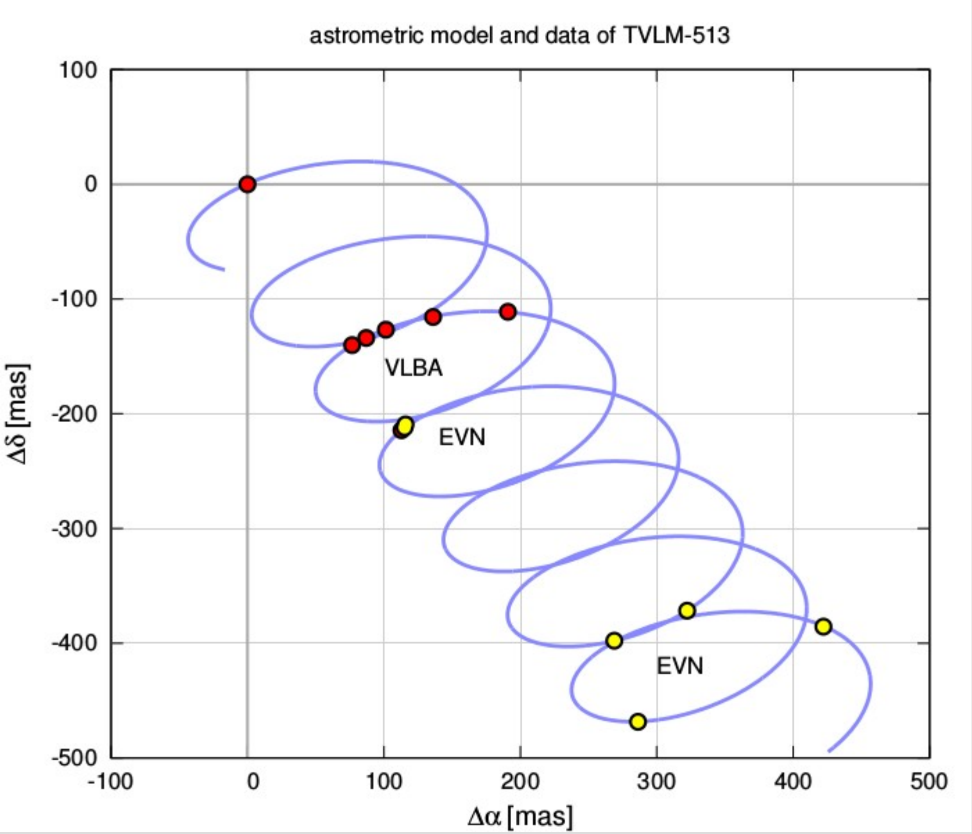
- six additional epochs from RISARD (2011-2014)
- new astrometric model based on VLBA+RISARD measurements



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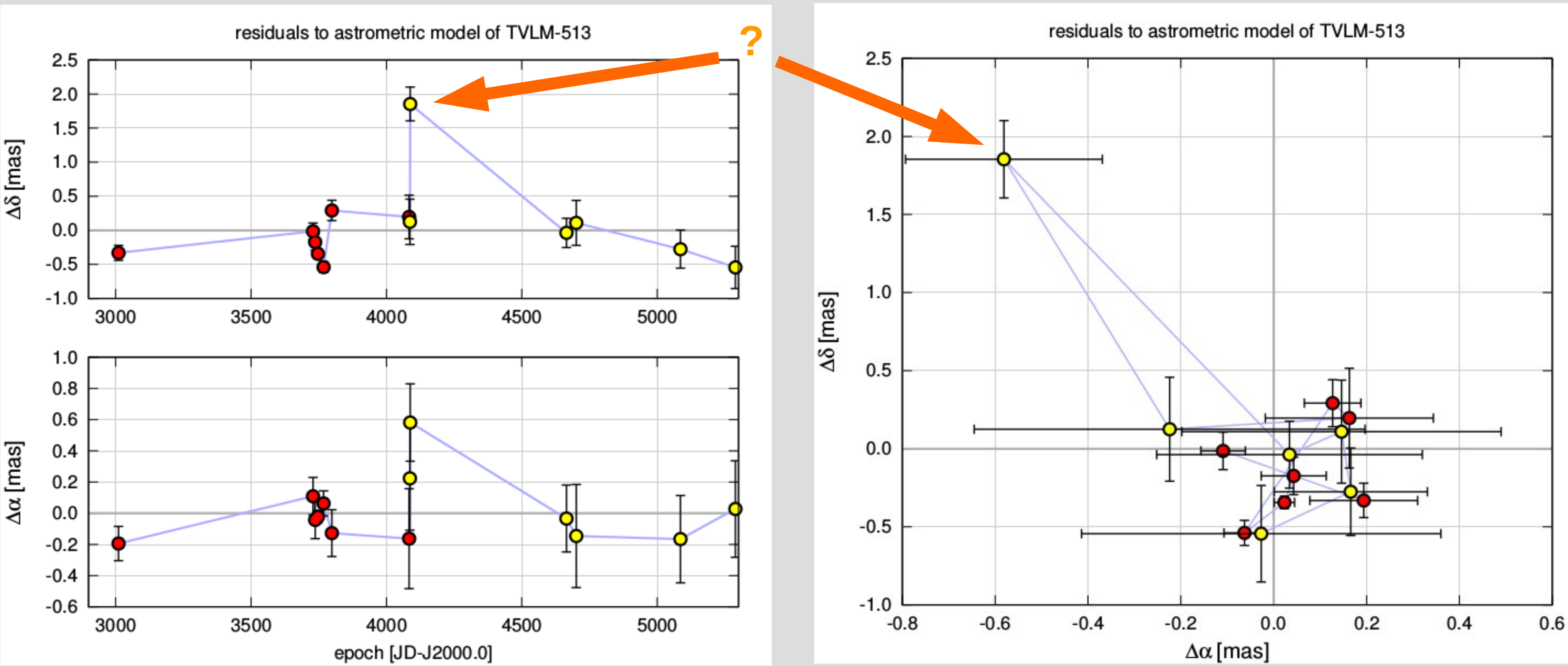

Residuals to astrometric model of TVLM-513

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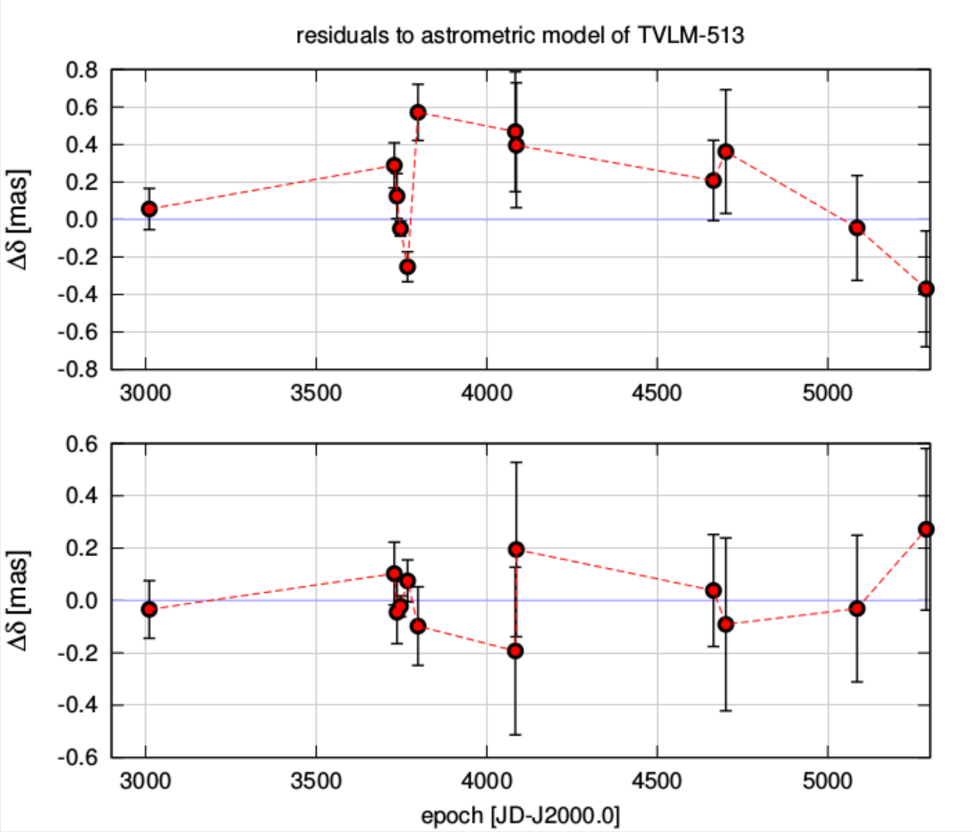
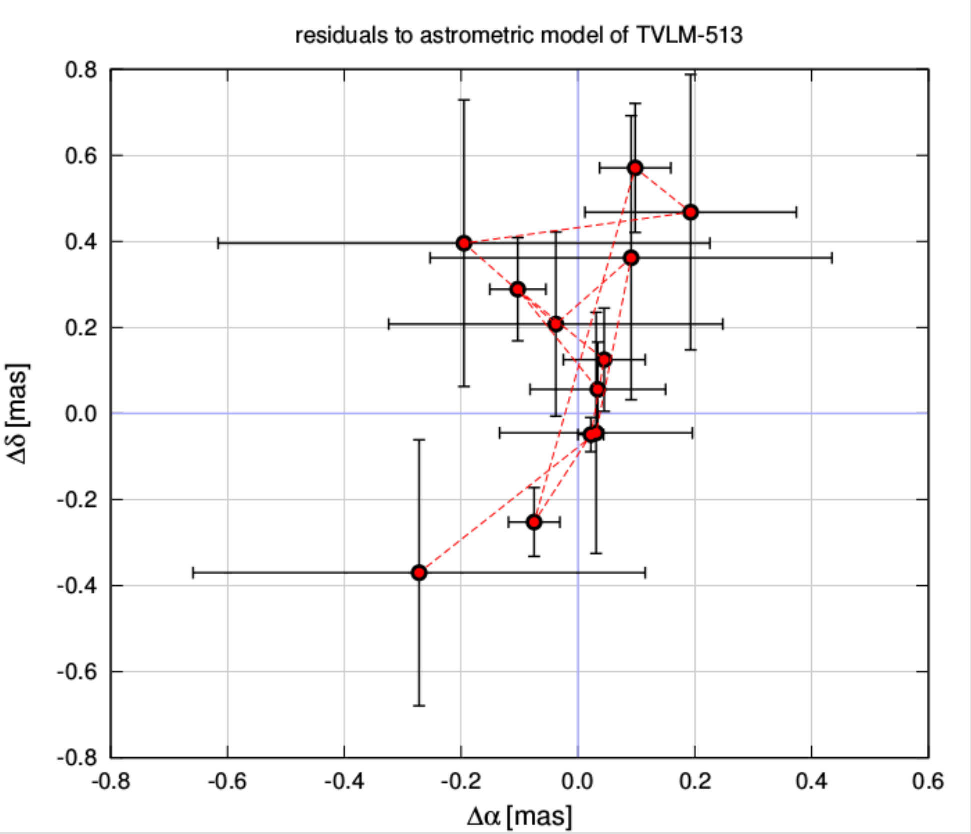




New astrometric model do not support trend in residuals suggested by Forbrich+ (2013)

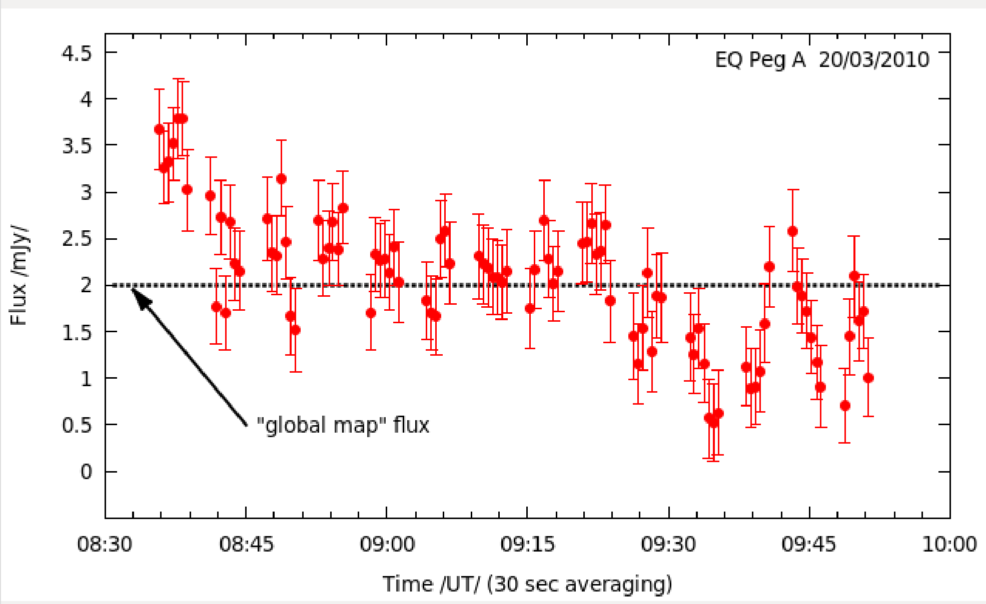
Stile 3 more epochs scheduled for TVL-513 in RISARD.

Radio ***I***nterferometry ***S***urvey of ***A***ctive ***R***ed ***D***warfs (RISARD)

Flux variability impact on the VLBI astrometry

- using EVN data it is possible to track radio flux variability on time scales ~1 min

- flux obtained from “global” map ≈ averaged value from flux measurements



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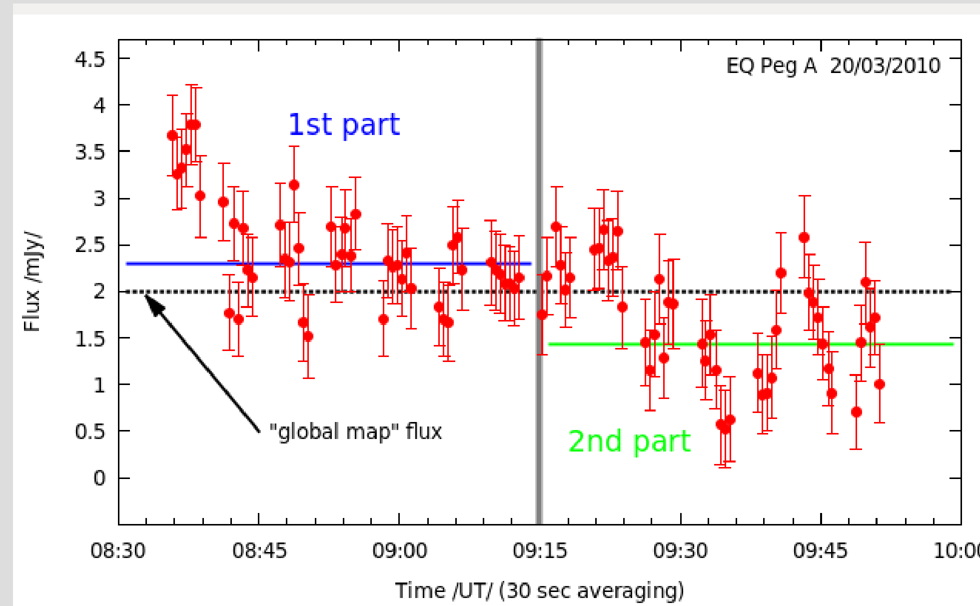
- two equal parts of data lead to different astrometry precision (different S/N ratio)



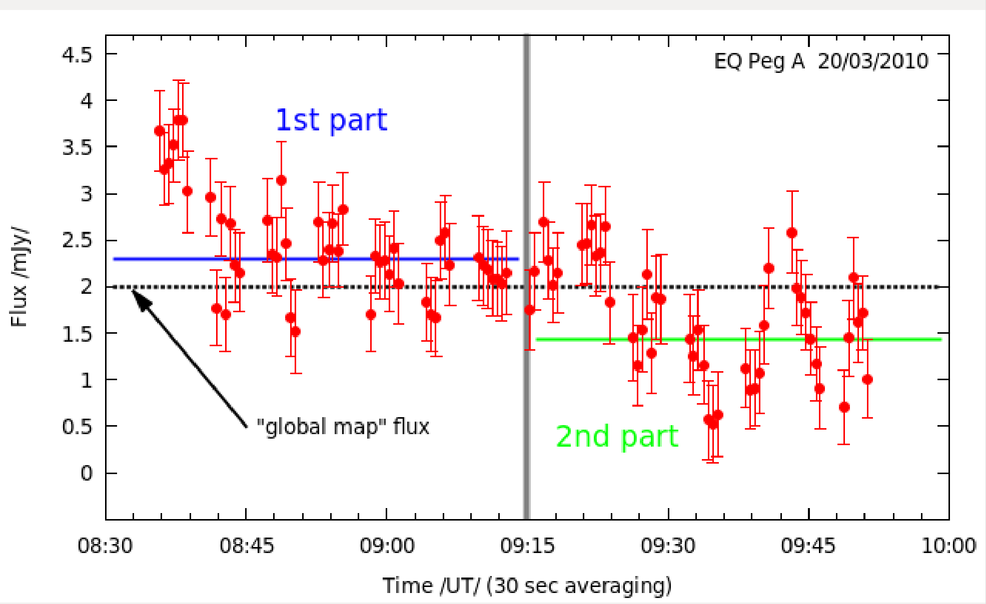
Star	Epoch (JD-2455000)	RA (J2000)	ΔRA (mas)	Dec (J2000)	ΔDec (mas)	S_{5GHz} μJy
EQ Peg A	275.88455	23 31 52.594757	0.09	19 56 13.466049	0.06	2005±103
EQ Peg A[1)]	275.87083	23 31 52.594760	0.10	19 56 13.466002	0.06	2299±97
EQ Peg A[2)]	275.89826	23 31 52.594742	0.12	19 56 13.466135	0.08	1422±80

Radio ***I***nterferometry ***S***urvey of ***A***ctive ***R***ed ***D***warfs (RISARD)

Flux variability impact on the VLBI astrometry

The most extreme cases:

- RD could be detected in part of data but not in the whole dataset
- longer integration ≠ improved SNR & improved astrometry precision
- better astrometry precision could be achieved by selecting subsample(s) of dataset



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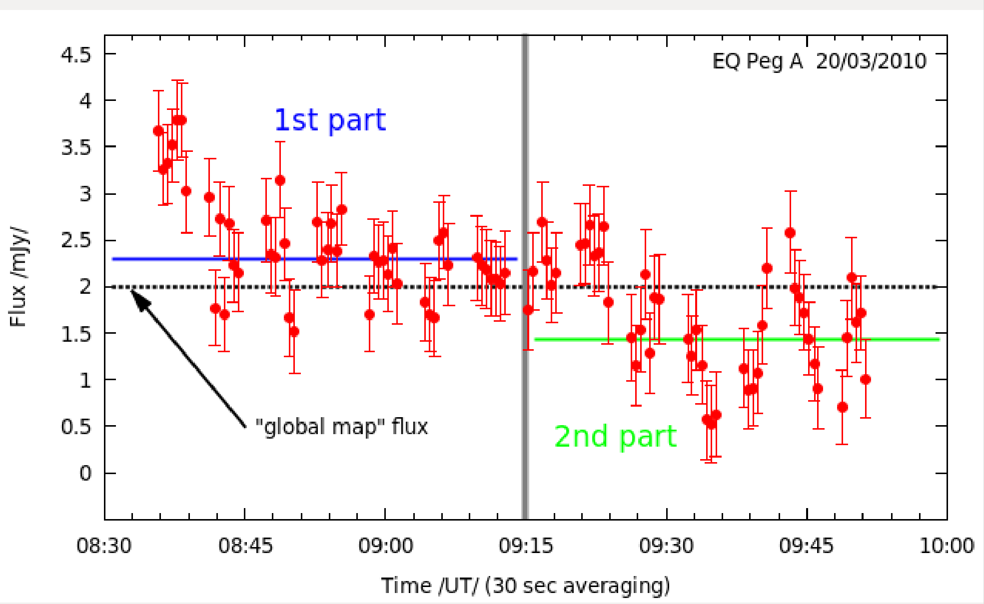
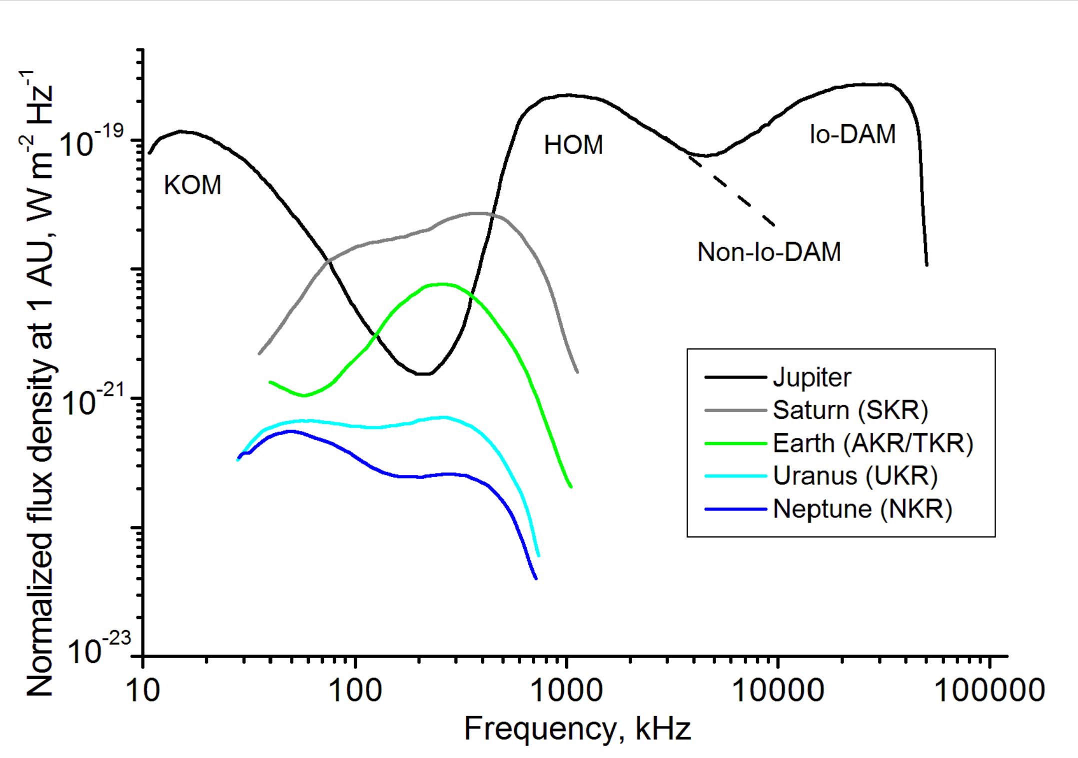


Removing flux variability impact on the VLBI astrometry could increase detection rate and astrometry precision – reduction of the interferometric data with non-stationary signals present (Gawroński+, submitted)**.**

HOM emission from giant exoplanets

Solar system planets are sources of radio emission.



KOM - kilometric radiation

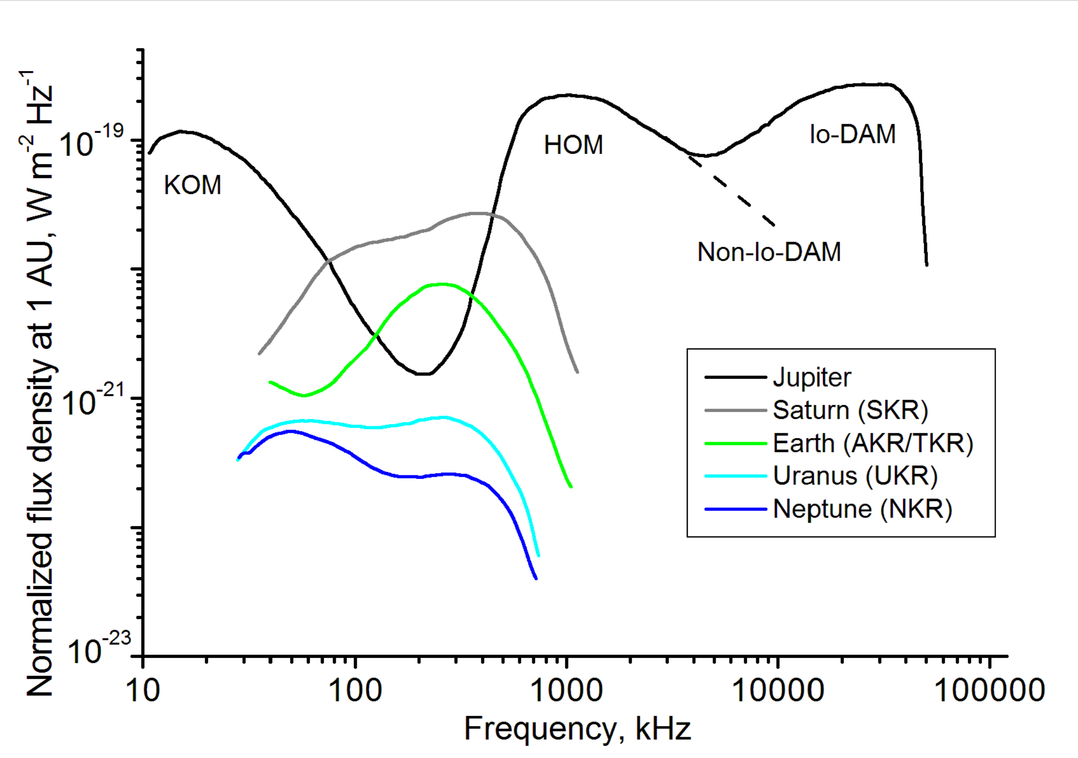
HOM – hectometric radiation

DAM – decametric radiation

It is assumed that DAM emission is mainly produced by cyclotron maser instability in regions close to the magnetic poles (interaction between solar wind and planet magnetosphere) .

HOM emission from giant exoplanets

Exoplanets as sources of radio emission.



- In principle it was demonstrated that it should be possible to detect HOM emission at least from a few discovered exoplanets: τ Boo b, ε Eri b, Gl 876 b,... (e.g. Nichols 2011, Grießmeier+ 2007)

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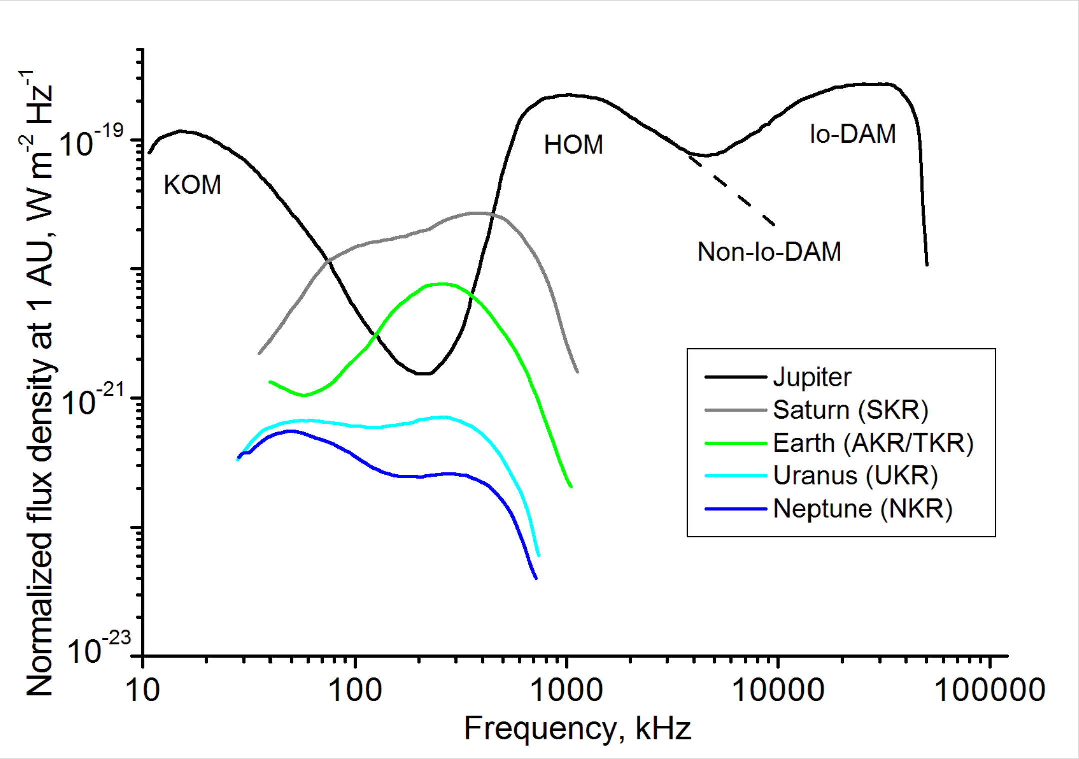

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- many observational tries but there is no confirmed detection of radio emission of exoplanet (e.g., Bastian+ 2000, George & Stevens 2007, Lazio & Farell 2007)

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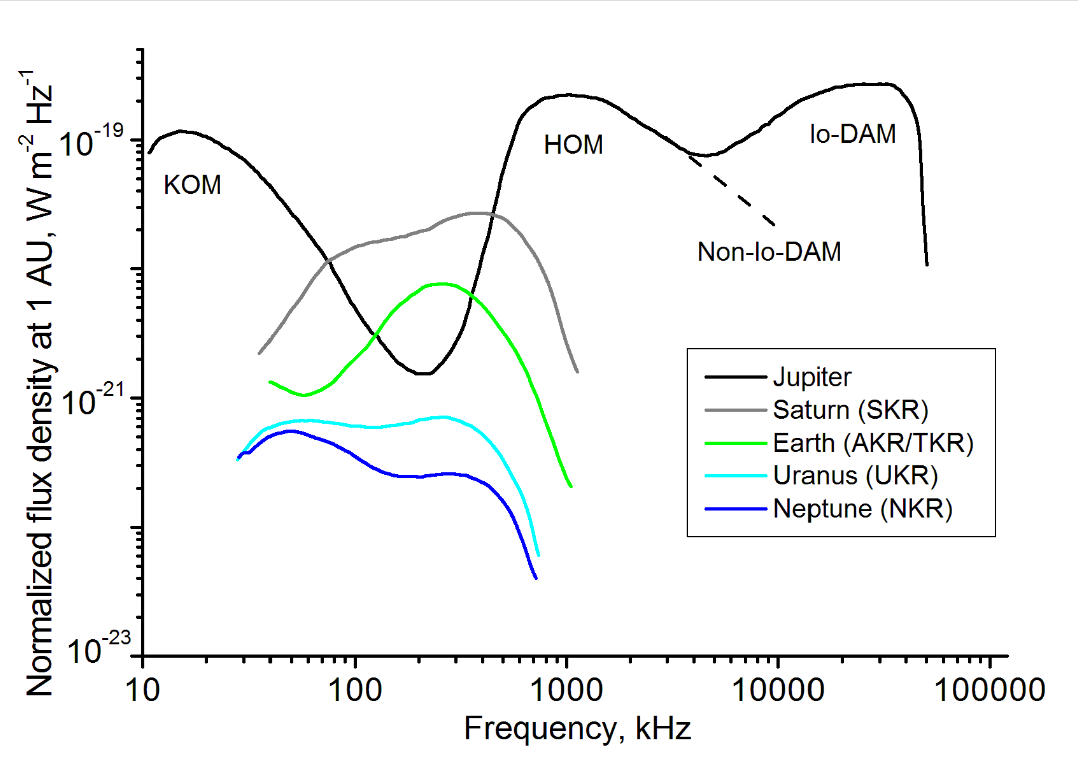

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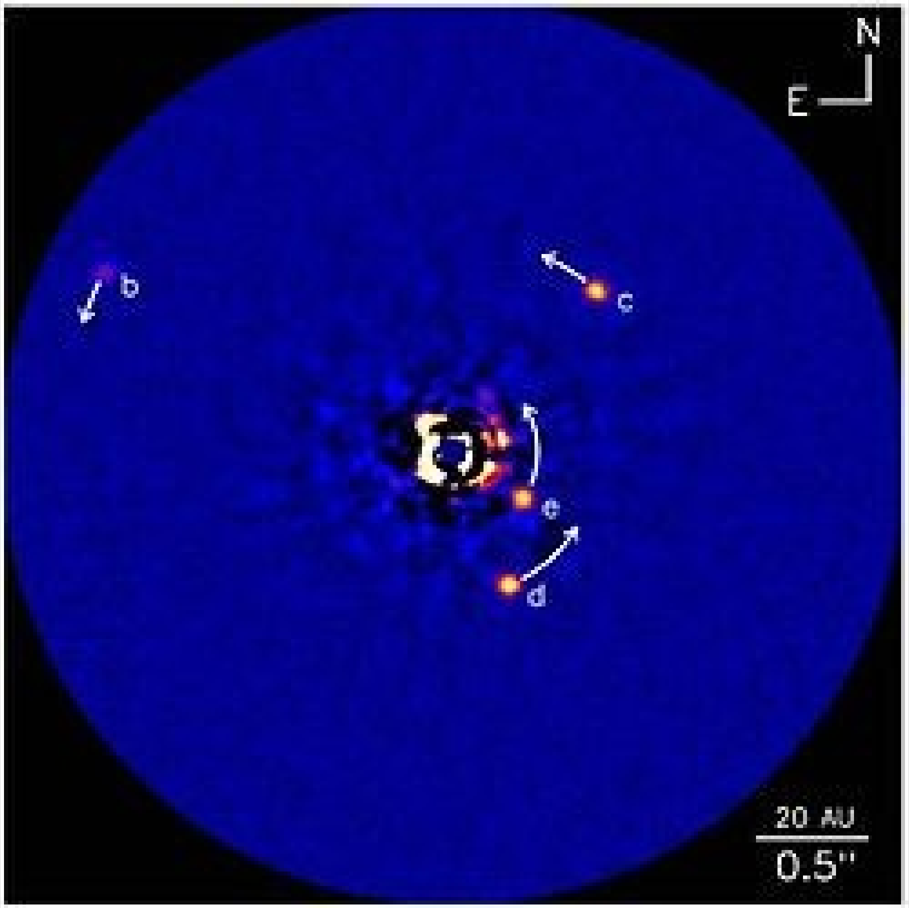
- many observational tries but there is no confirmed detection of radio emission of exoplanet (e.g., Bastian+ 2000, George & Stevens 2007, Lazio & Farell 2007)
- Sirothia+ 2014 using GMRT found sources of radio emission towards four planetary systems (survey of 175 know exoplanetary systems)

HOM emission from giant exoplanets

Could HOM emission be produced at GHz frequencies?



HR 8799 Marois+ (2008)

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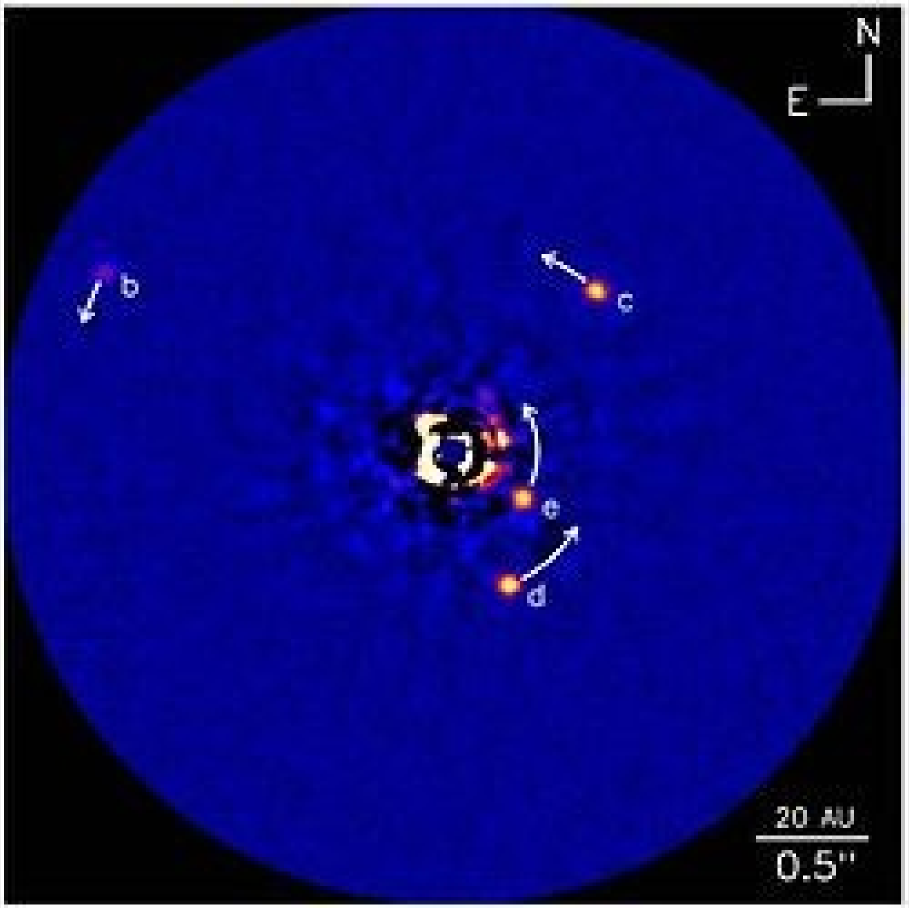

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Could we do an image of exoplanetary system using

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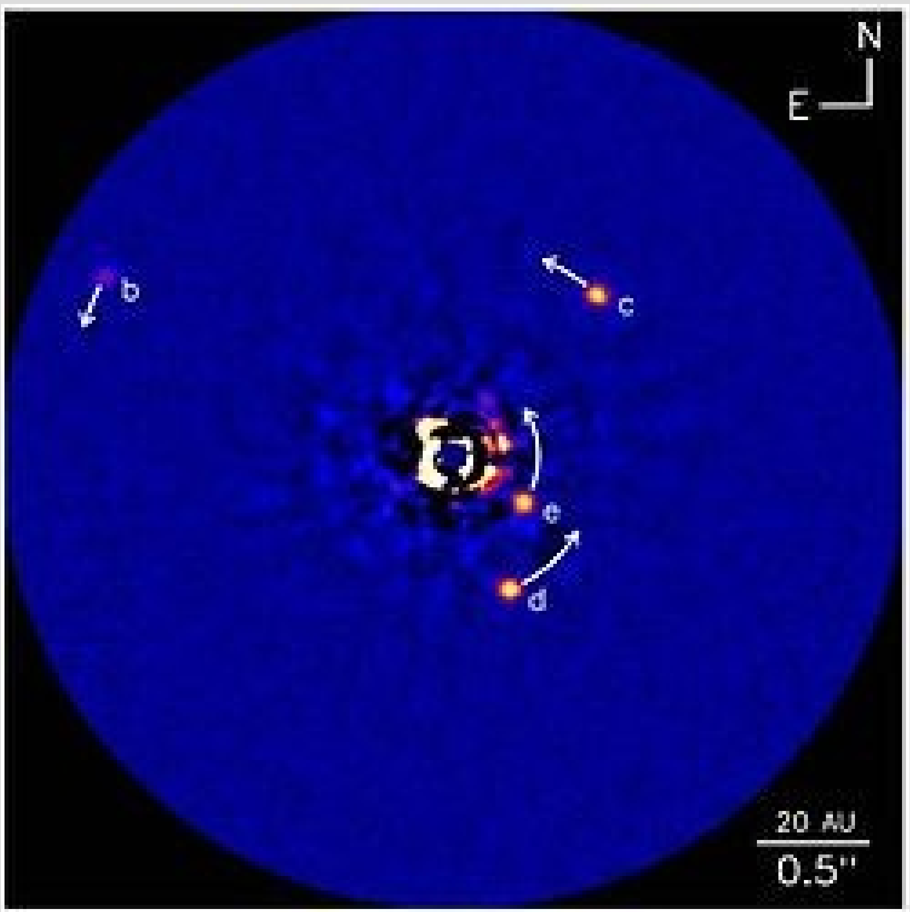

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Could we do an image of exoplanetary system using

The main motivation:

Reiners & Christensen (2010) showed that in young (<1Gyr) and massive sub-stellar objects (10-80 M_{jup}) magnetic field could excess 1kGs.

HOM emission from giant exoplanets

Main model assumptions

- dynamo magnetic field strength at the surface of the planet (Reiniers & Christiansen 2010)

$$B_{\rm dyn} = 4.8 \times 10^3 \left(\frac{ML^2}{R^7} \right)^{1/6} \ [{\rm G}]$$

- the polar dipole magnetic field strength

$$B_{\rm dip}^{\rm pol} = \frac{B_{\rm dyn}}{\sqrt{2}} \left(1 - \frac{0.17}{M/M_{\rm J}} \right)^3$$

- the magnetic momentum

$$\mathcal{M} = 4\pi \frac{B_{\rm dip}^{\rm pol} R^3}{2\mu_0}$$

- the total radiated power (Grießmeier+ 2005)

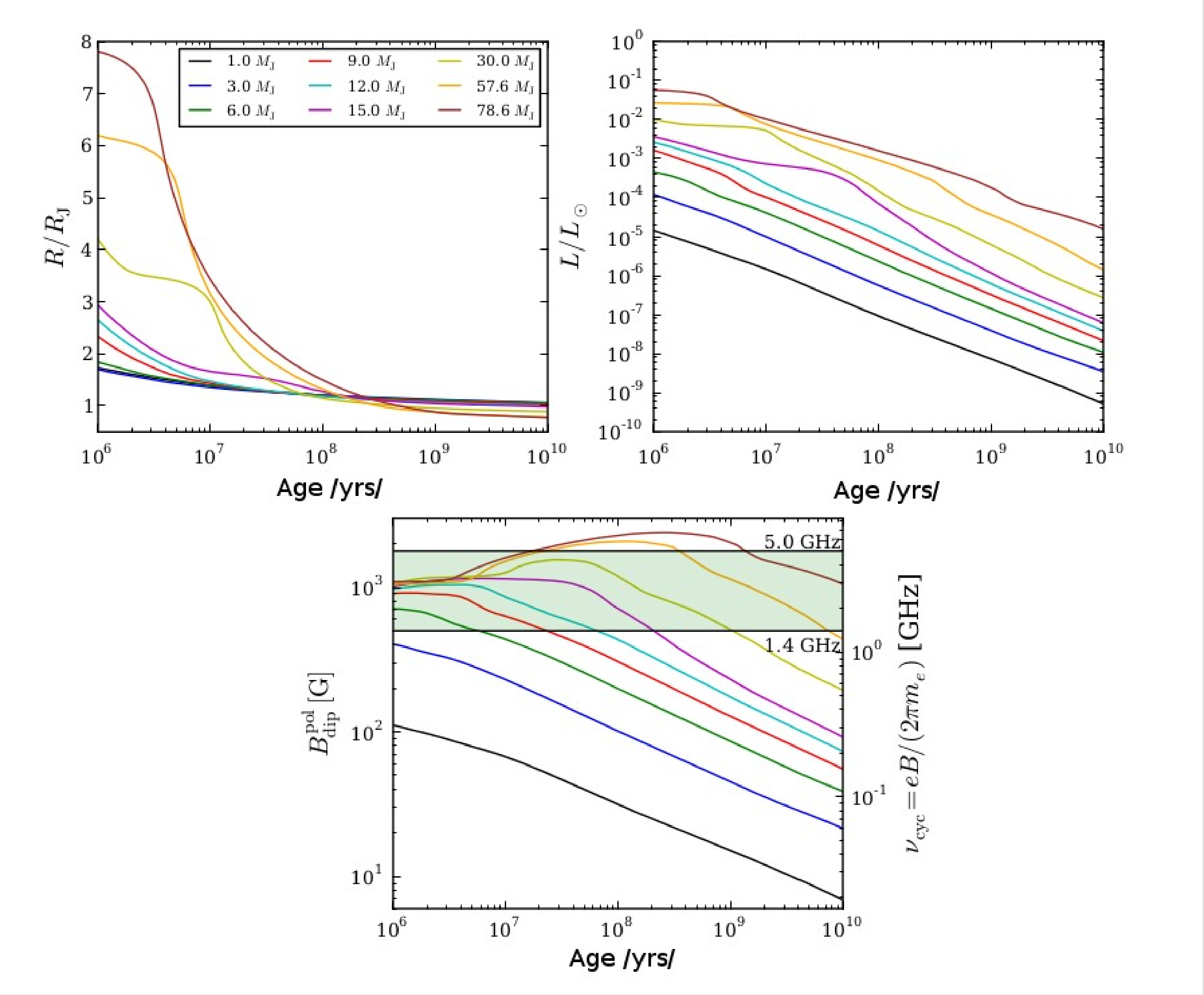
$$P_1 = \left(\frac{\mathcal{M}}{\mathcal{M}_{\rm J}} \right)^{2/3} \left(\frac{n}{n_{\rm J}} \right)^{2/3} \left(\frac{v}{v_{\rm J}} \right)^{7/3} \left(\frac{d}{d_{\rm J}} \right)^{-4/3} P_{\rm J}$$

Where:

- M-mass, L-Luminosity, R-radius in solar units
- M_J – Jupiter mass
- $\mathcal{M}_J$ – Jupiter magnetic momentum
- P_J – emission power in Jupiter system (high activity periods) $P_J = 2\times10^{11}$ W
- n_J- wind particle number density, v_J – wind velocity, p_J – planet distance (normalized to Jupiter values)
- Evolution of L & R for gas giants based on Burrows+ (1993,1997)

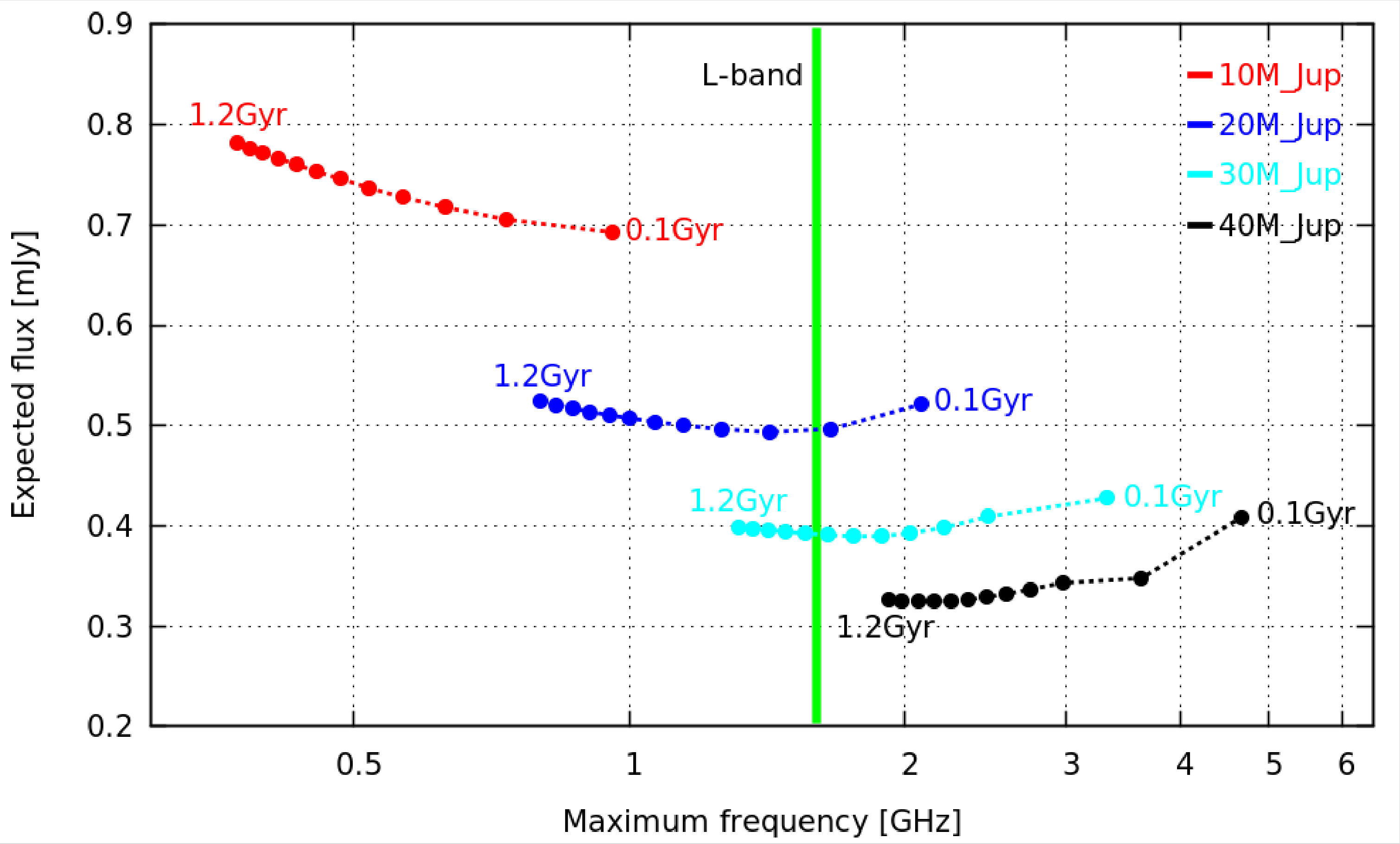
HOM emission from giant exoplanets

Gas giants evolution



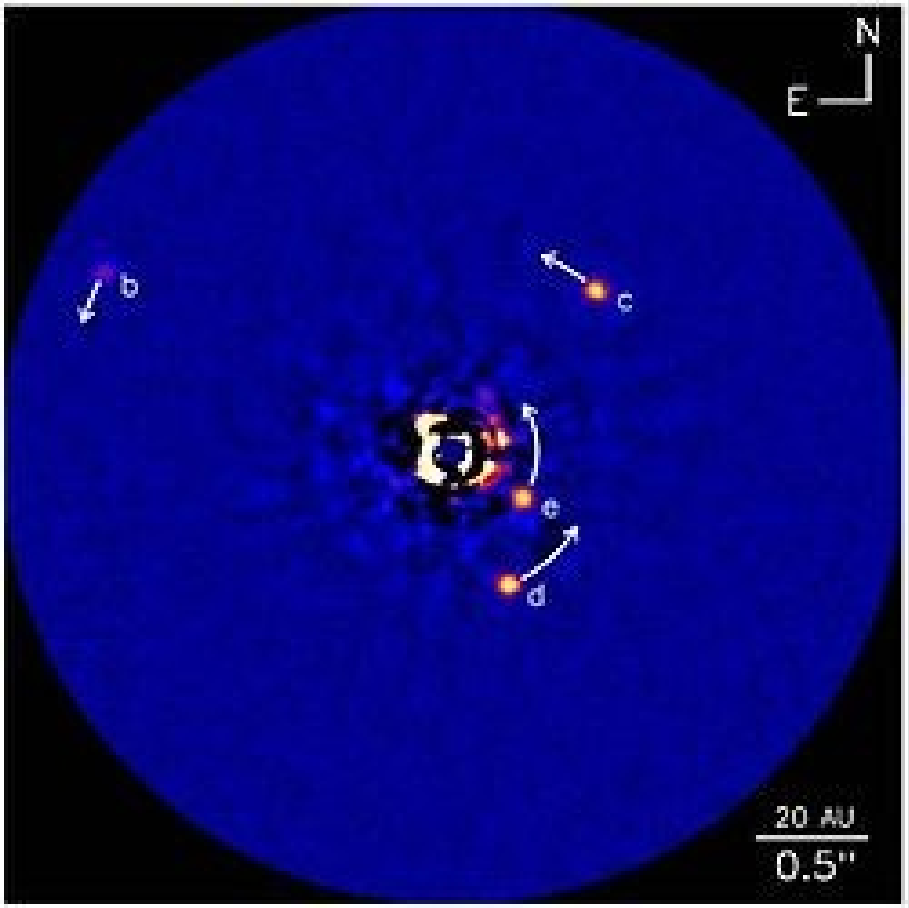
HOM emission from giant exoplanets

Gas giant in a system at a distance of 20pc and orbit 1AU
(wind particle density=5n_J and wind velocity=5v_J)



HOM emission from giant exoplanets

Where we could find young gas giants?



HR 8799 Marois+ (2008)

- fundamental theoretical scaling relation between stellar host mass and protoplanetary disc mass (e.g. Kornet+ 2006)
- correlation between the giant planet frequency and stellar host mass (Johnson 2007)

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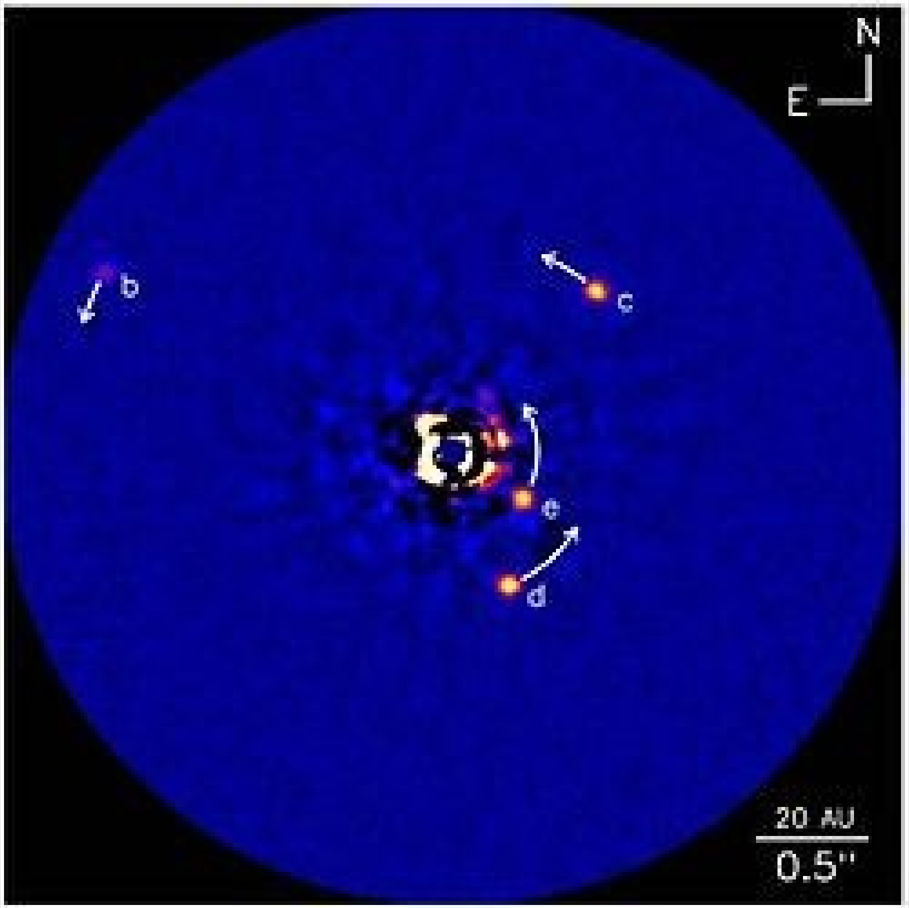

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- A-type main-sequence stars are young (<1Gyr) massive stars (1.4-2.1 $M_{\odot}$)
- A-type stars are fast rotators → featureless optical spectra
- A-type stars are rare → transit statistic very limited
- HR 8799 is A5-type main-sequence object (~30Myr old)

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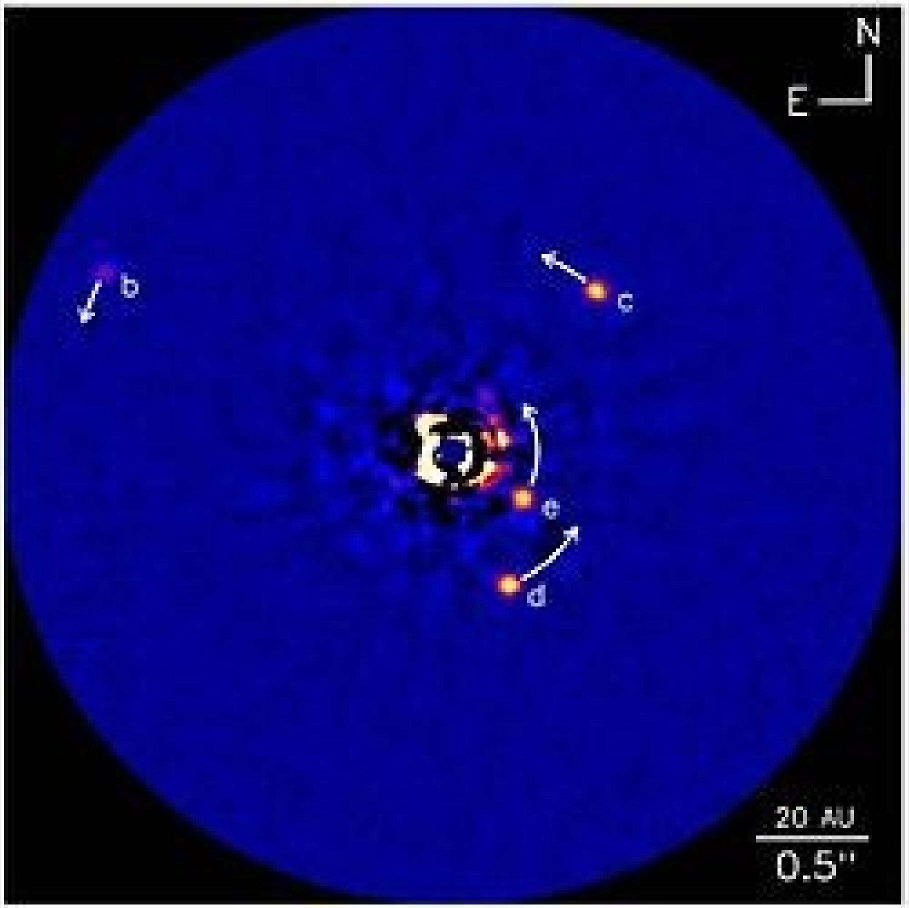

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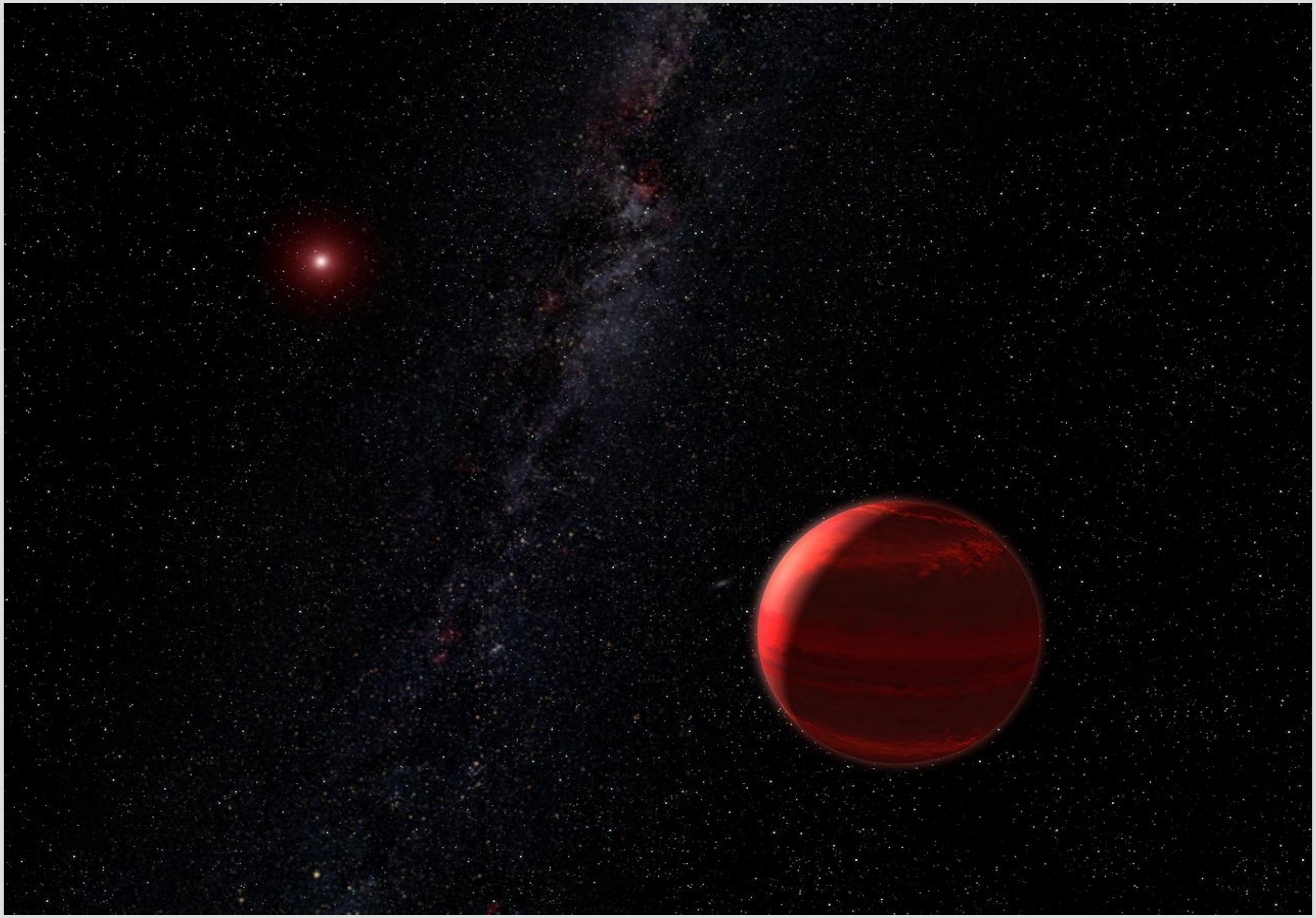
VLBI could be a perfect tool to study planetary systems of A-type main-sequence stars!



Thank you for your atention!