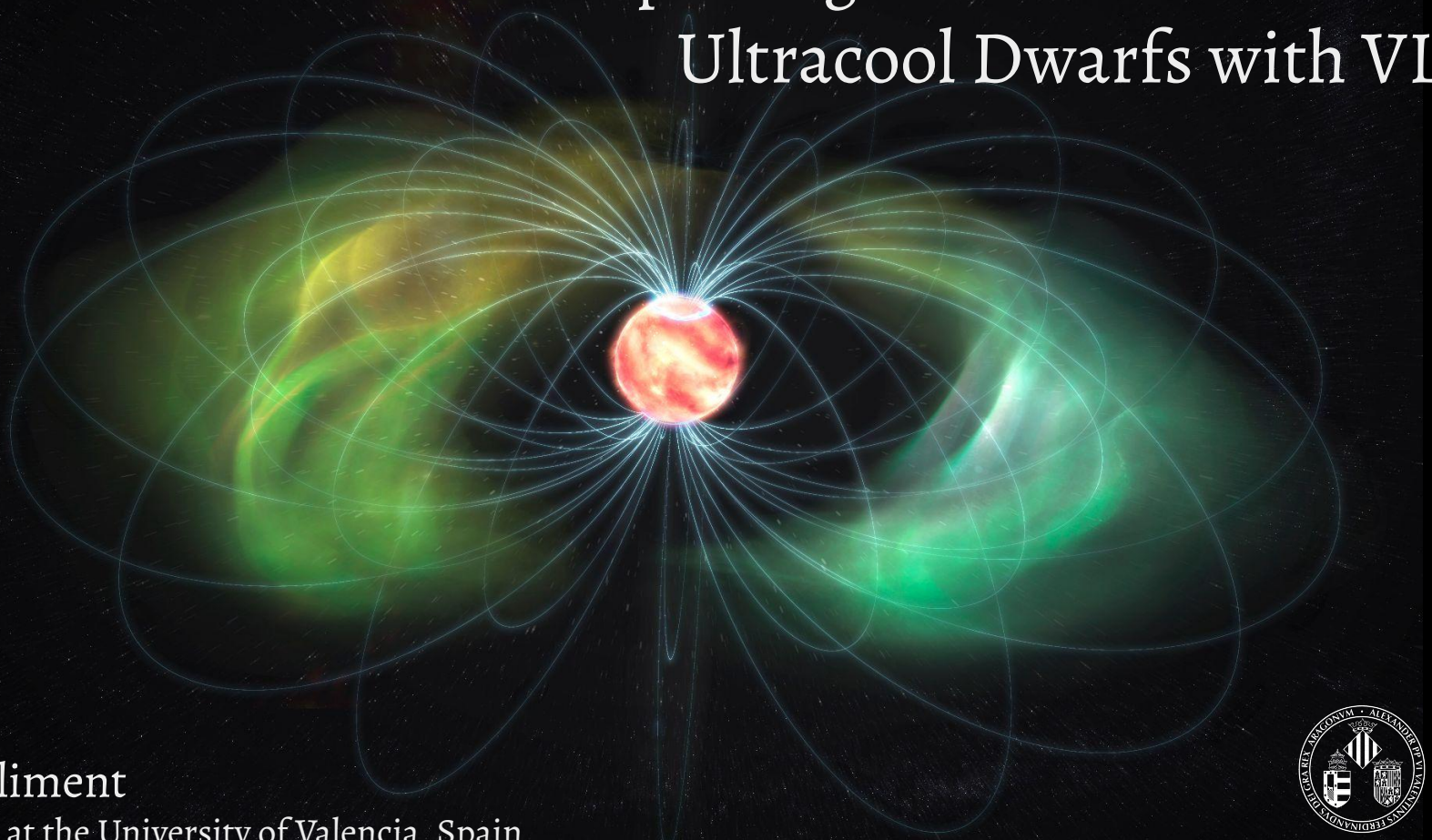
Radio Stars 2024
18 April

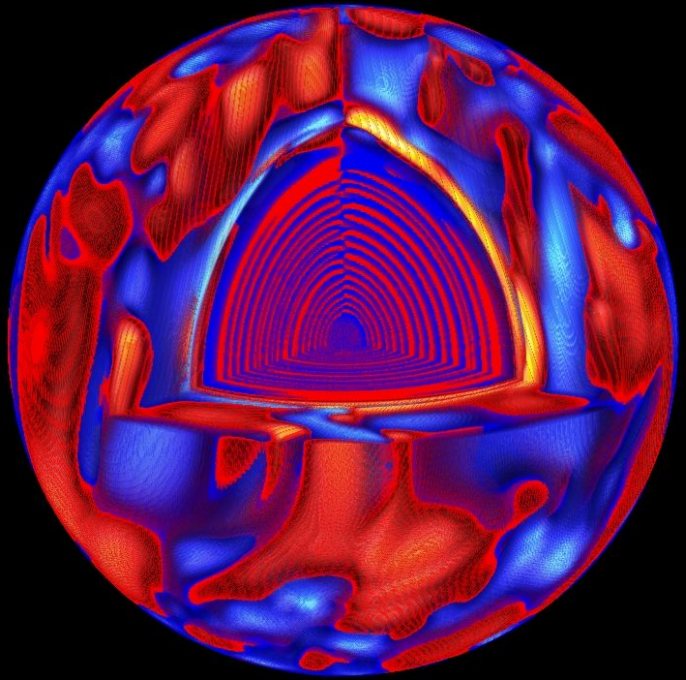
Exploring the radio emission of Ultracool Dwarfs with VLBI



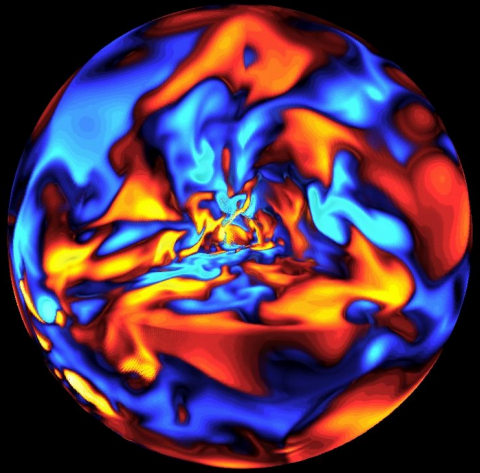
Joan Climent
Post-doc at the University of Valencia, Spain

VNIVERSITAT DE VALÈNCIA

Sun



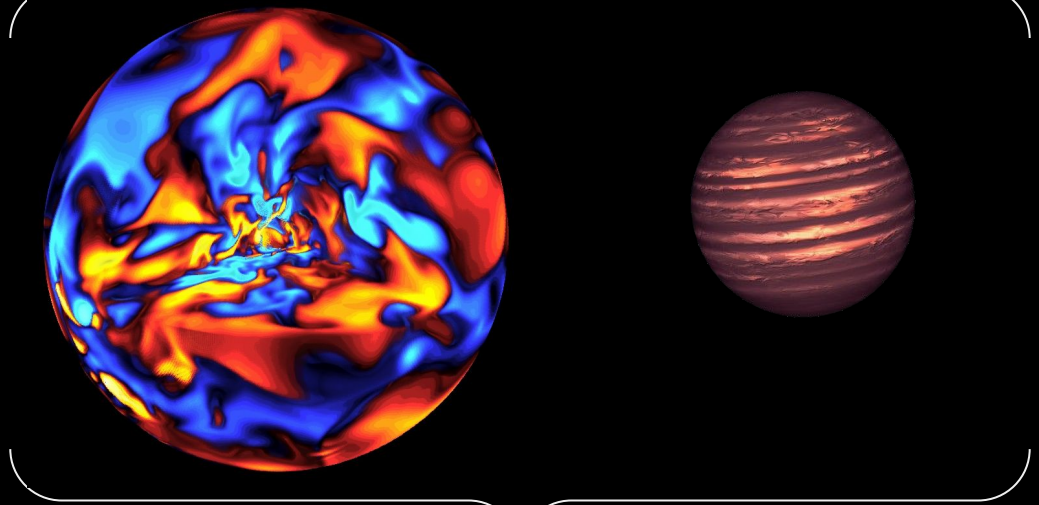
Low-mass star



Brown dwarf

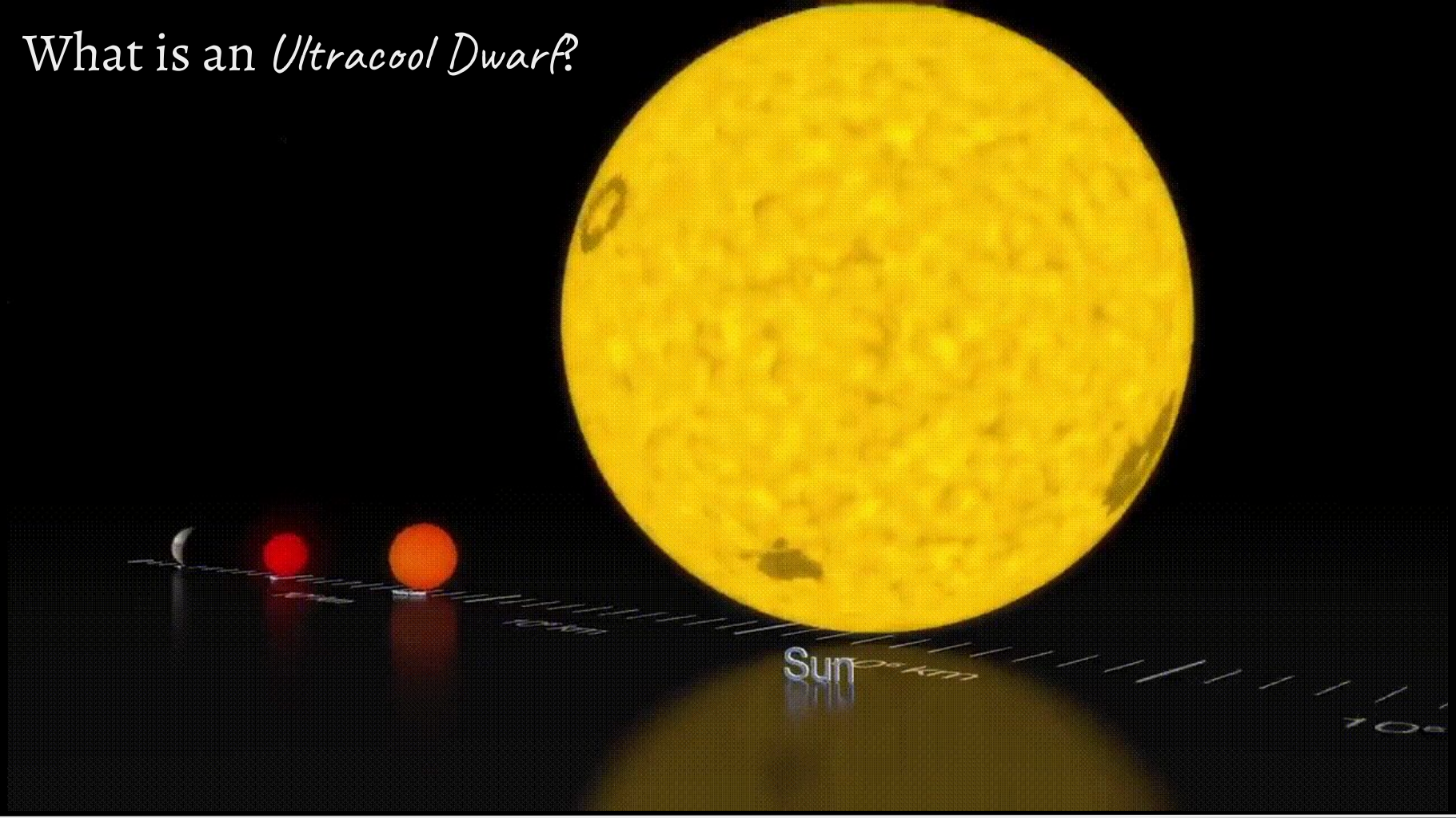
Credits: The Stars2 Project, NASA/JPL-Caltech.

Ultracool Dwarfs

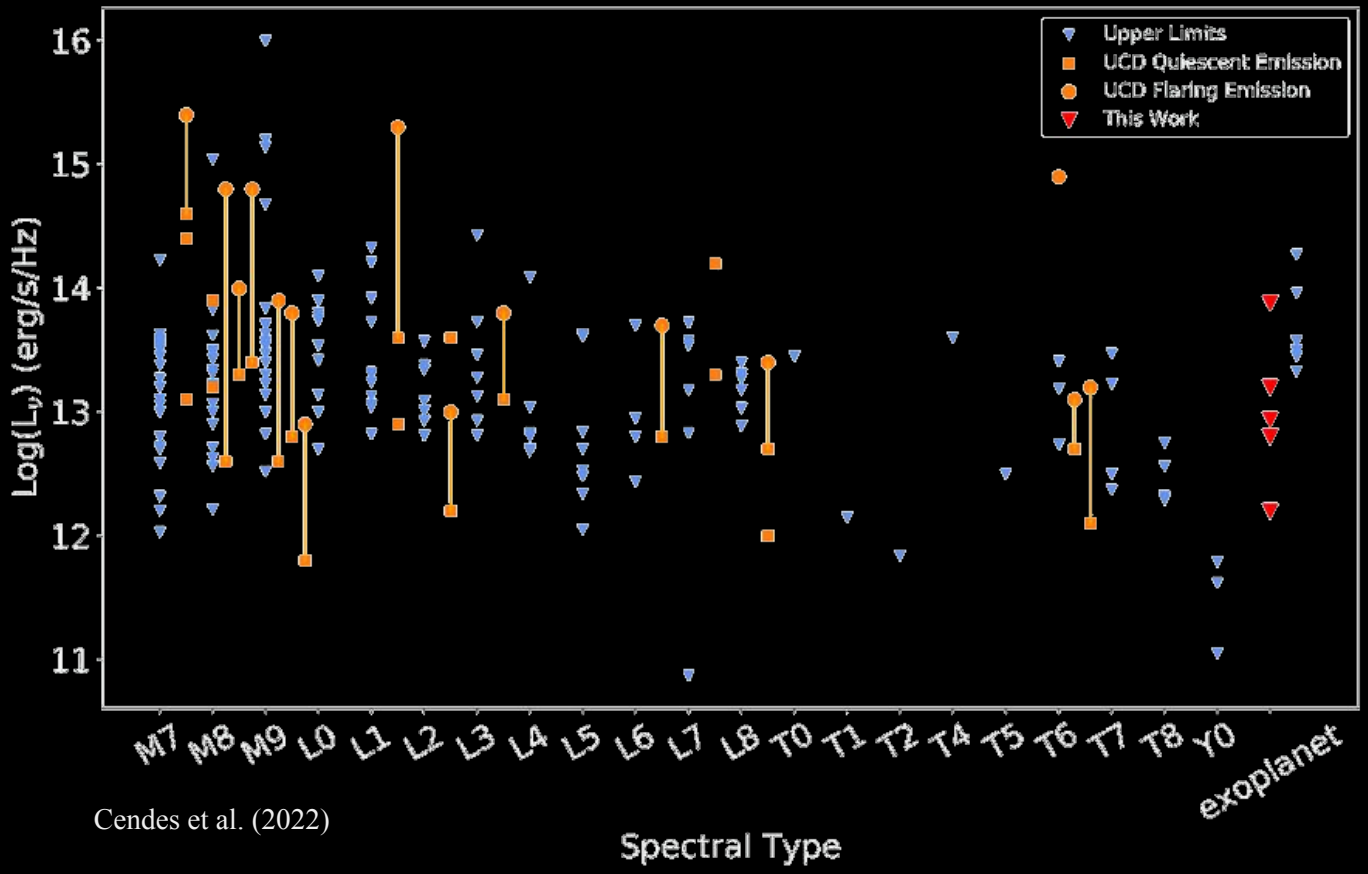


UCDs

What is an *Ultracool Dwarf*?



Past *detections* and *non-detections*

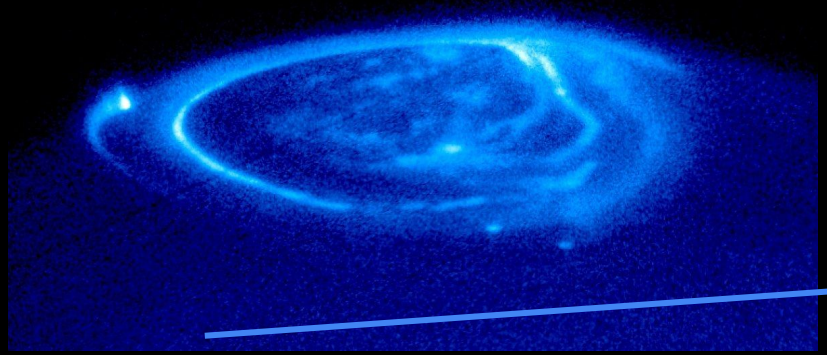


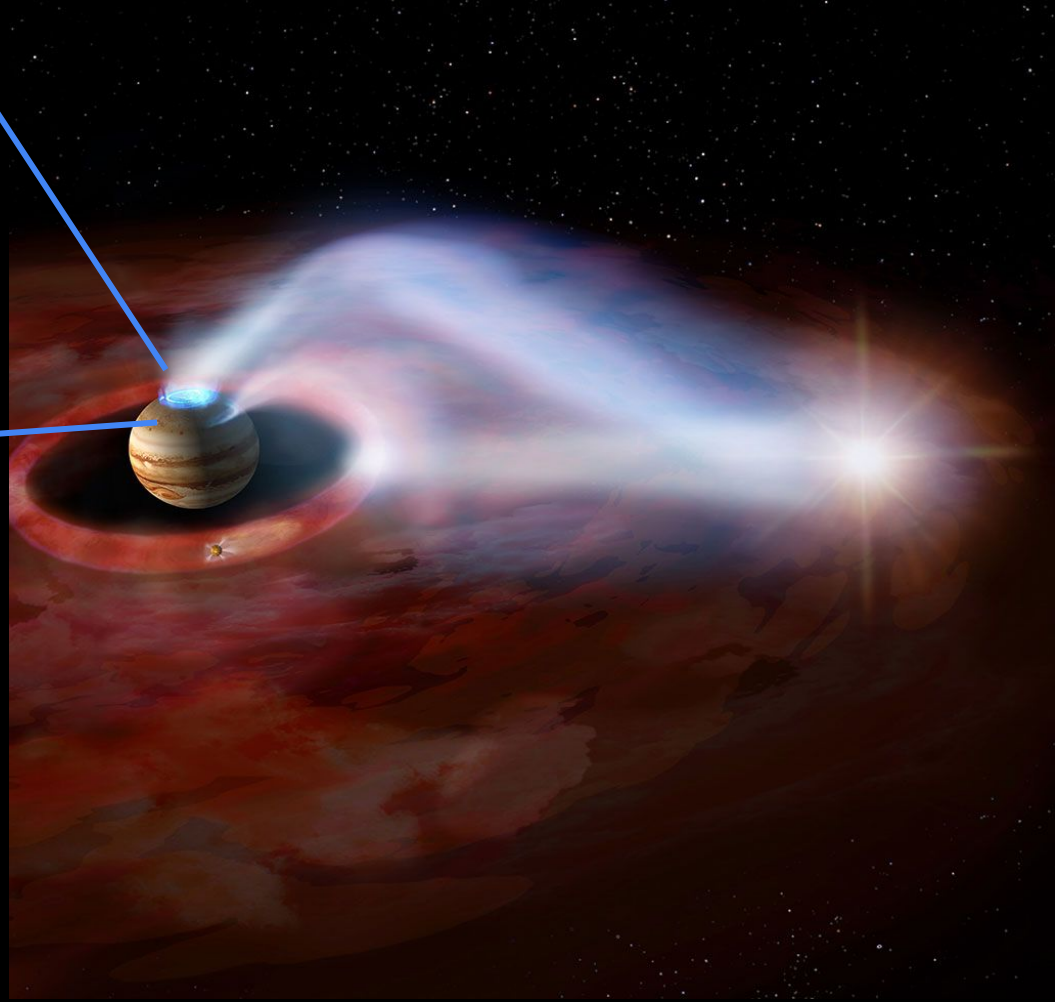
Cendes et al. (2022)

As of 2023:

30 at GHz (26: Tang et al. 2022 and references therein; 3: Kao & Pineda 2022; 1: Rose et al. 2023)

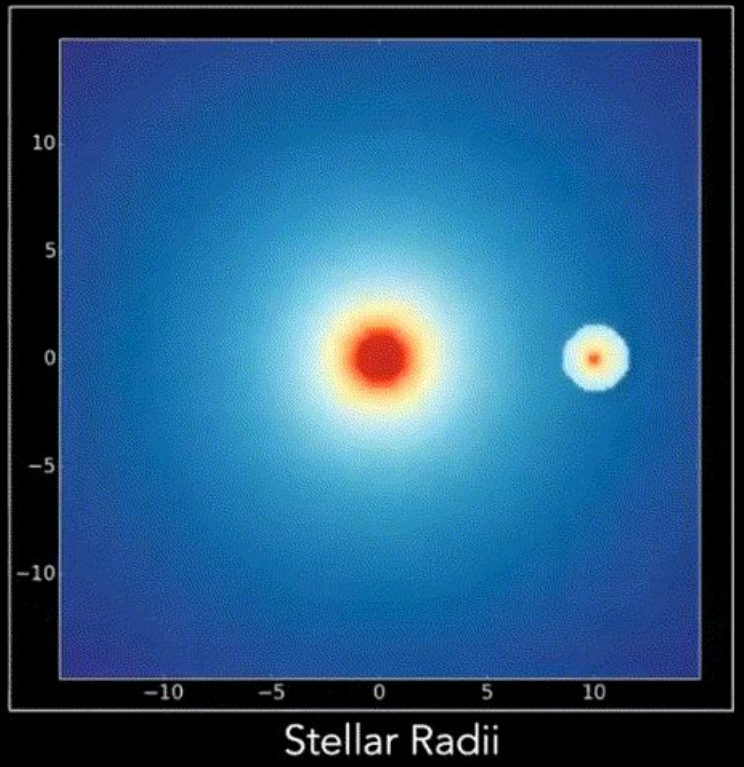
2 at MHz (Vedantham et al. 2020, 2023)





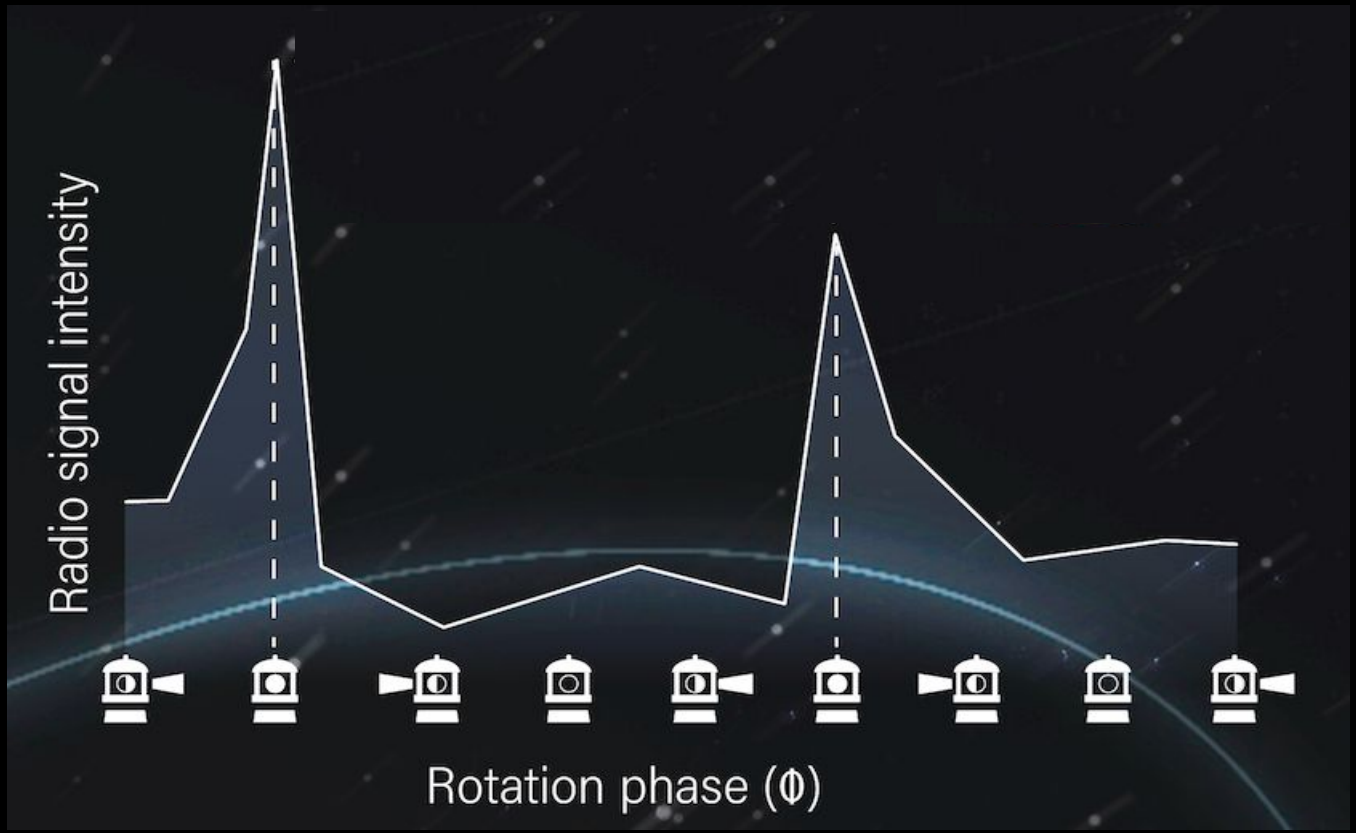
Credits: NASA, ESA & John T. Clarke (Univ. of Michigan)

Gerard et al. (2022)

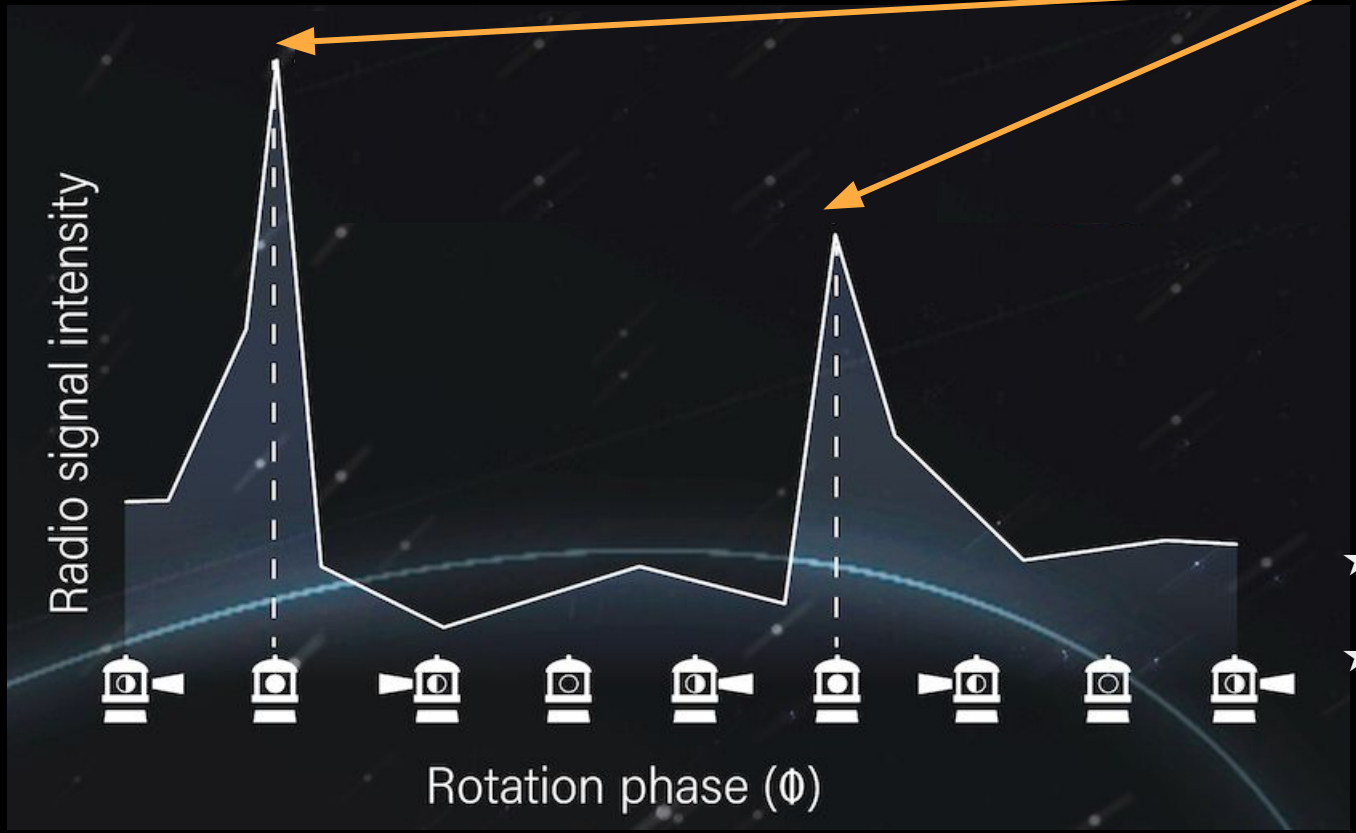


Masakos et al. (2015)

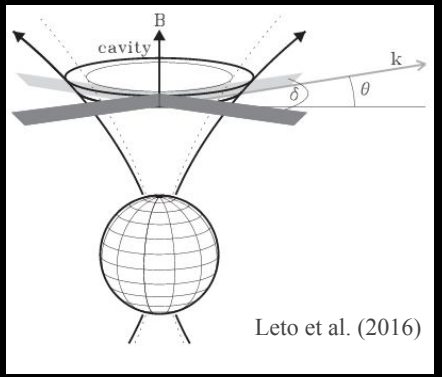
Your typical *UCD*



Your typical *UCD*



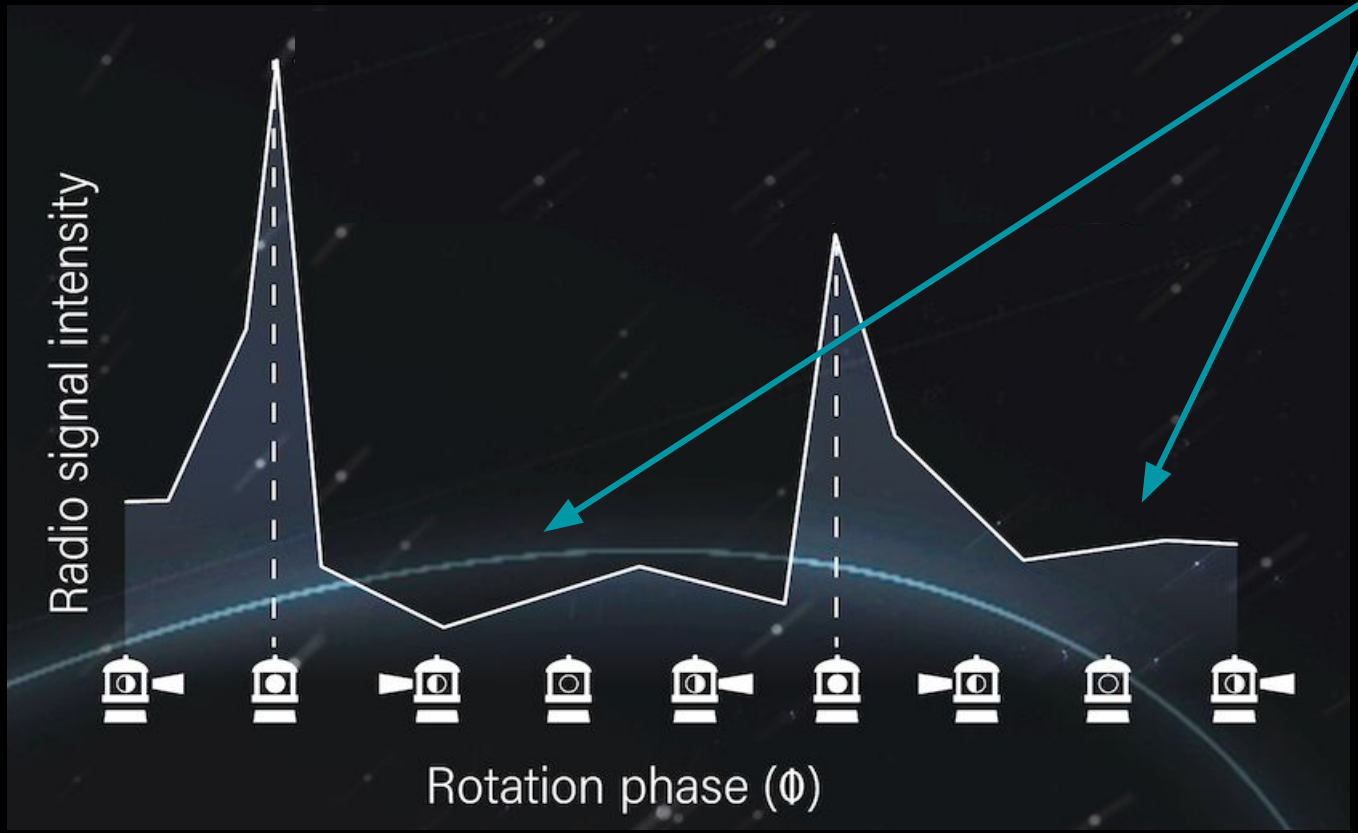
Auroral emission via Electron Cyclotron Maser Instability (ECMI)



★ Highly circularly polarised

★ Rotationally modulated

Your typical *UCD*



Quiescent emission via (gyro)synchrotron emission

- ★ Low degree of circular polarization
- ★ Slowly-varying
- ★ Origin
  - Coronal reconnections?
  - Radiation belt?

Your typical *UCD*

More on Melodie Kao's talk at 3:30

IX. Ultracool Dwarfs

Chair: Jose Carlos Guirado

3:30-4:00 Radio Emission as Tool for Studies of Ultracool Dwarfs and Star-Planet Interactions *(Invited)*

Melodie Kao

4:00-4:20 Stellar mass loss through a low-frequency lens

Sanne Bloot

4:20-4:40 Search for a spectral cut-off and periodic signal from a radio brown dwarf binary

Timothy Wing Hei Yiu

4:40-5:00 Investigating exoplanet magnetospheres through radio transit observations

Jake Turner

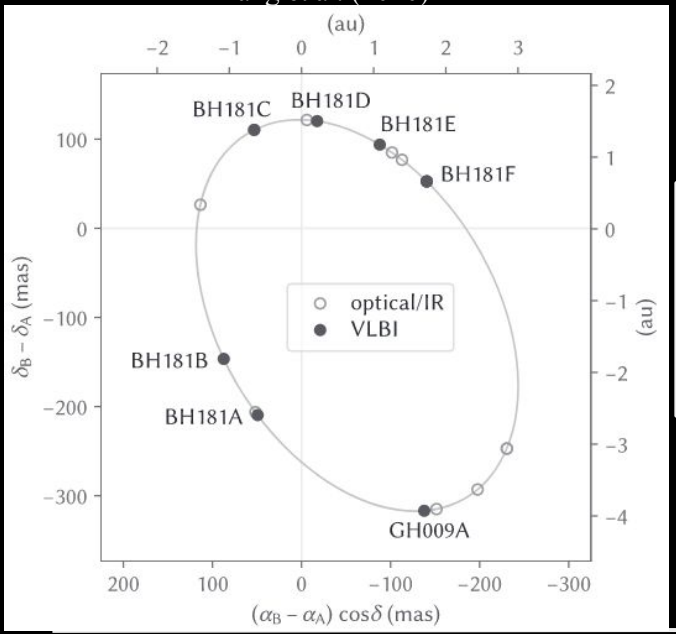
VLBI efforts

Until 2023, only three published detections (Forbrich & Berger 2009, Zhang et al. 2020, Forbrich et al. 2016) but extremely useful:

VLBI efforts

★ Both components of 2MASS J0746+2000AB (L0 + L1.5) emit at GHz.

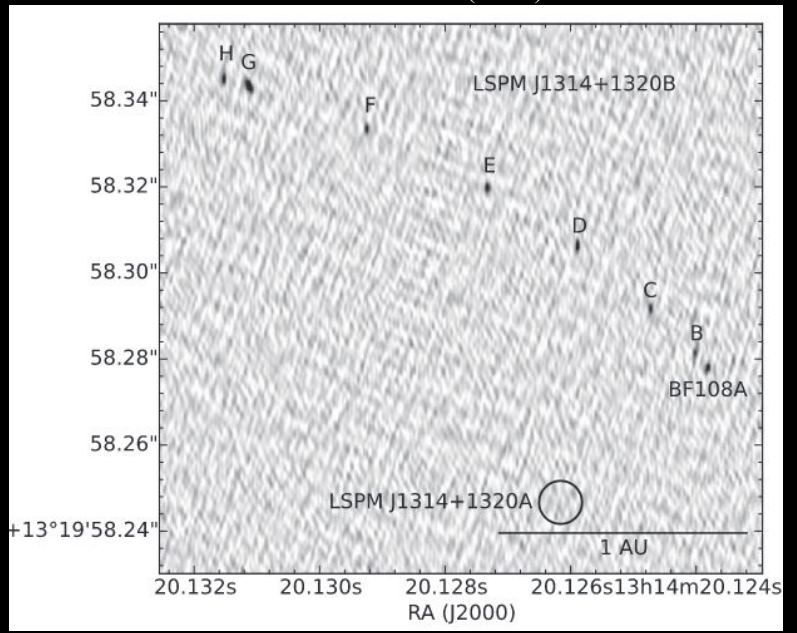
Zhang et al. (2020)



Dynamical masses, resolve components, parallax + proper motion, and exoplanets

★ Emission coming from only one component in LSPM J1314.

Forbrich et al. (2016)

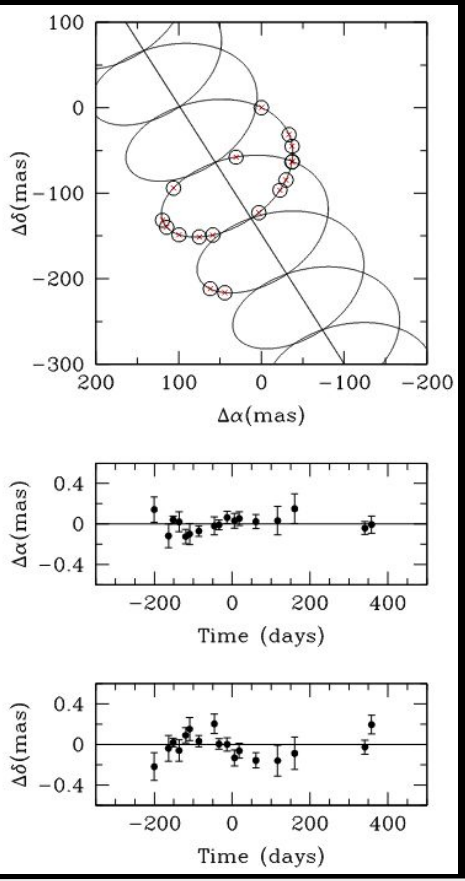


VLBI efforts

- ★ Curiel et al. (2020) presented the first astrometric evidence of a planetary companion to TVLM 513.
- ★ The residuals are compatible with a companion of:
  - 0.35–0.42M_{Jup}
  - with a circular orbit
  - a semi-major axis a = 0.28–0.31 AU
  - inclination angle i = 71–88°.

Date (2)
2010 Mar 18
2010 Mar 26
2010 Apr 5
2010 Apr 26
2010 May 27
2010 Jun 25
2010 Nov 3
2011 Mar 8
2011 Aug 3
2018 Jun 20
2018 Jul 26
2018 Aug 7
2018 Aug 22
2018 Sep 8
2018 Sep 18
2018 Oct 12
2018 Nov 5
2018 Nov 21
2018 Dec 3
2018 Dec 24
2019 Jan 12
2019 Jan 24
2019 Mar 8
2019 May 3
2019 Jun 16
2019 Dec 13
2019 Dec 30

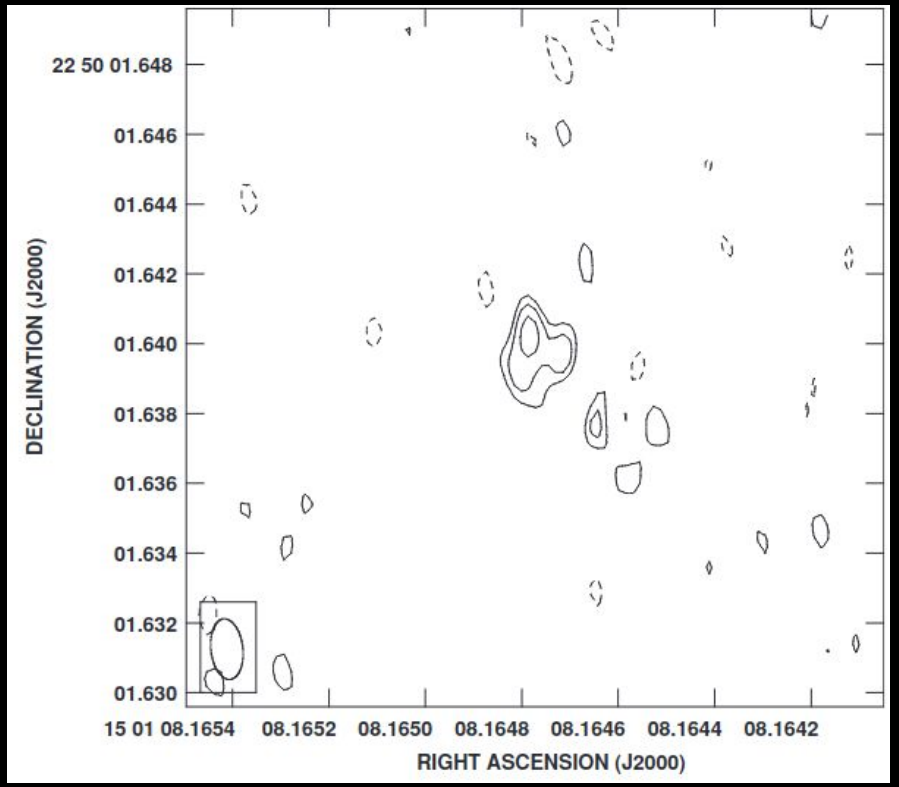
Curiel et al. (2020)



VLBI efforts

- ★ TVLM 513–46546 (M8.5) was the first detection (Forbrich & Berger 2009).
- ★ May be unresolved but noise comparable with the “extended” structure. Structure not confirmed.

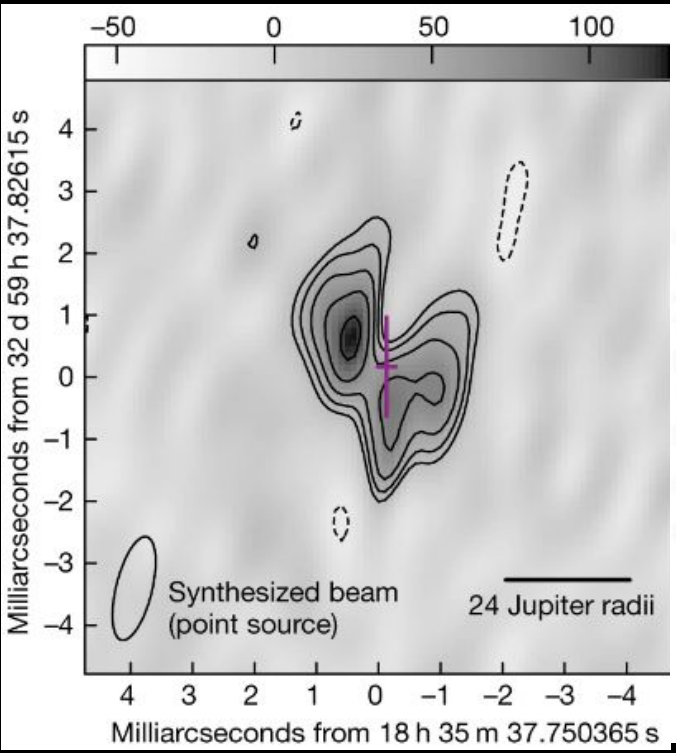
Forbrich & Berger (2009)



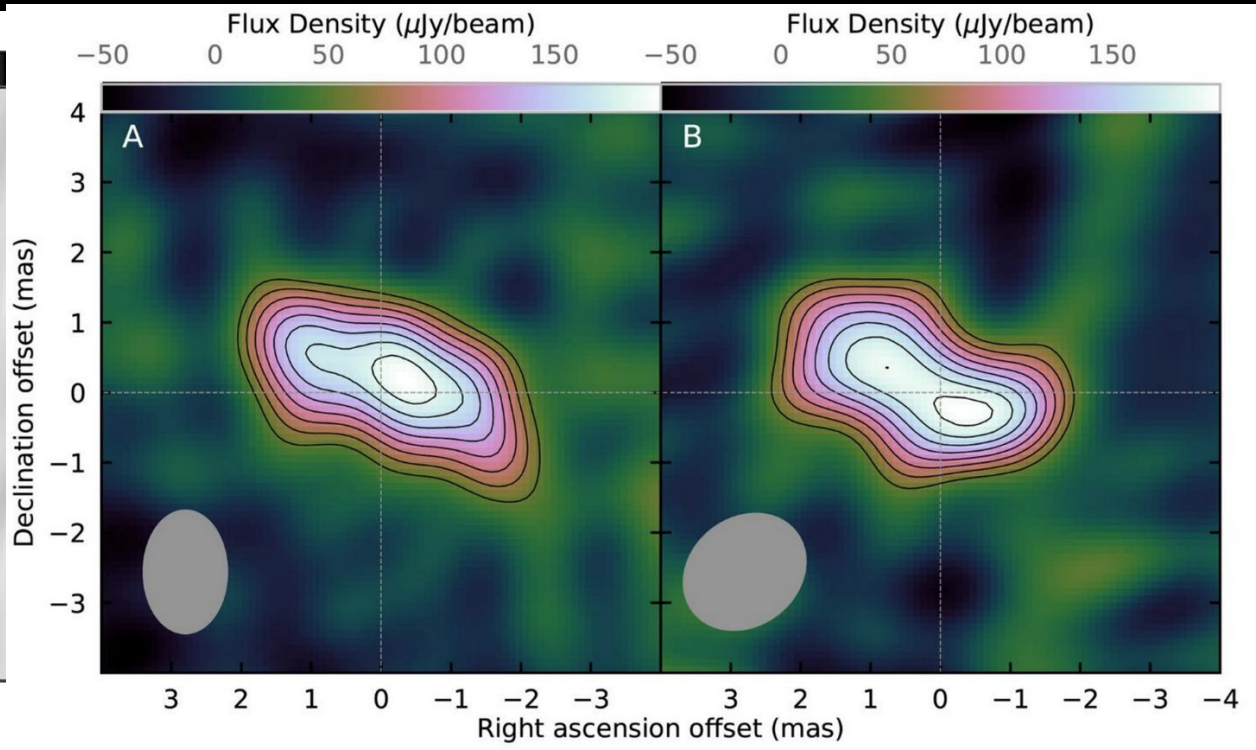
New results: LSR J1835+3259

M8.5 object at only 5.6885 pc (Gaia)

P_{rot} = 2.84140 ± 0.00039 hr (Miles-Páez et al. 2023)

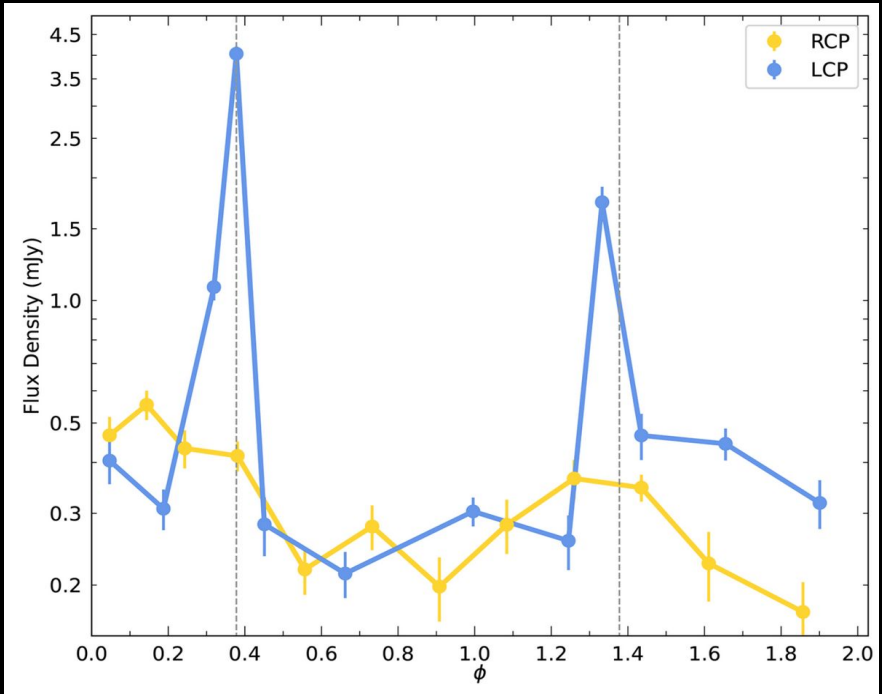


Kao, M. et al. (2023)

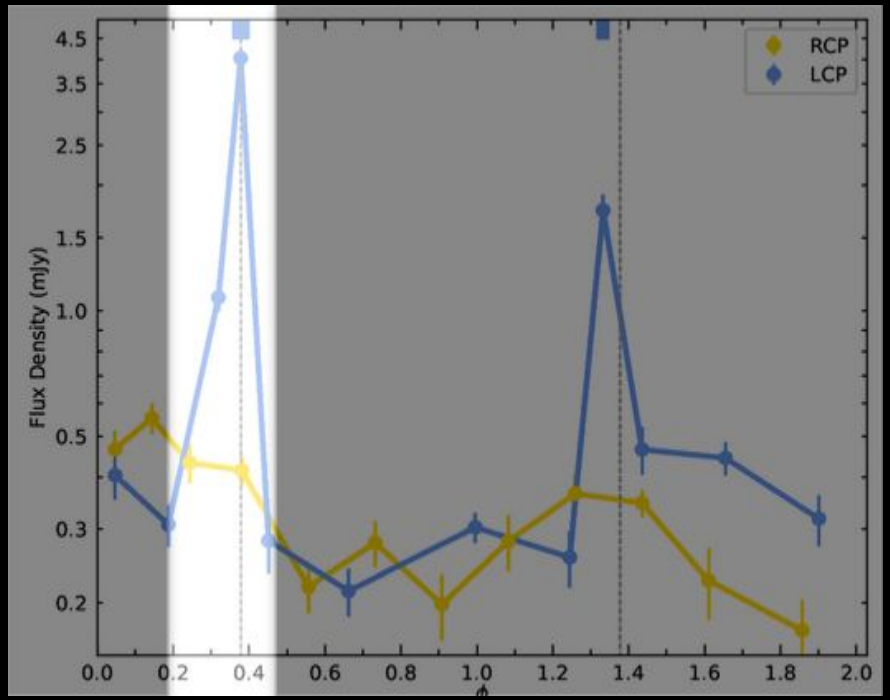


Climent et al. (2023)

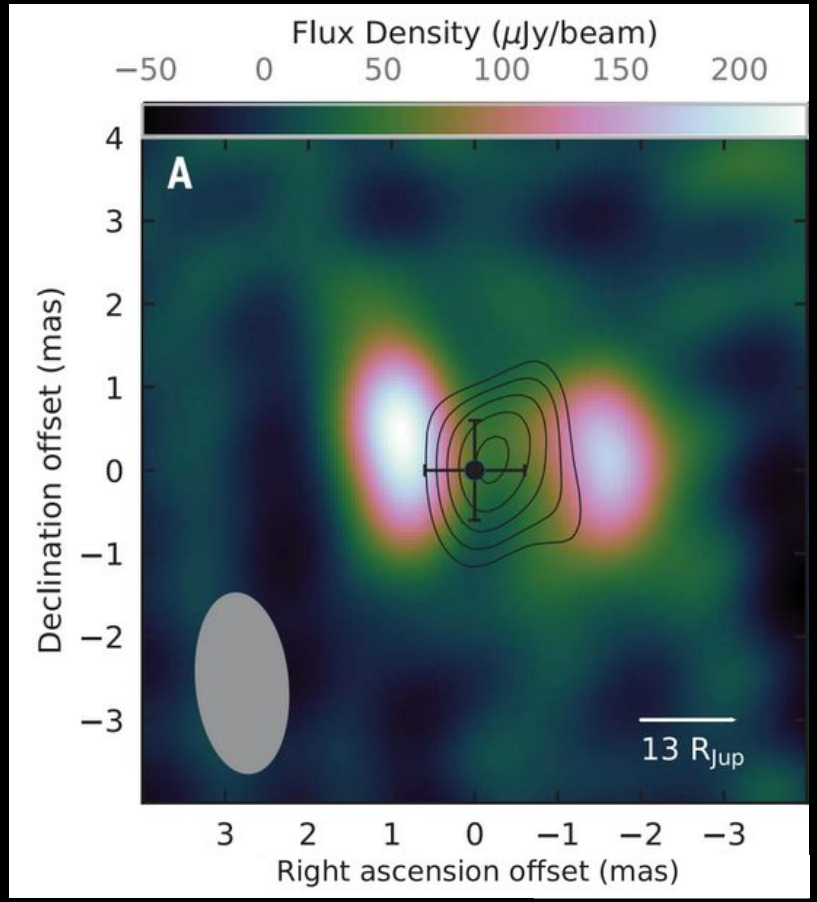
LSR J1835+3259



LSR J1835+3259

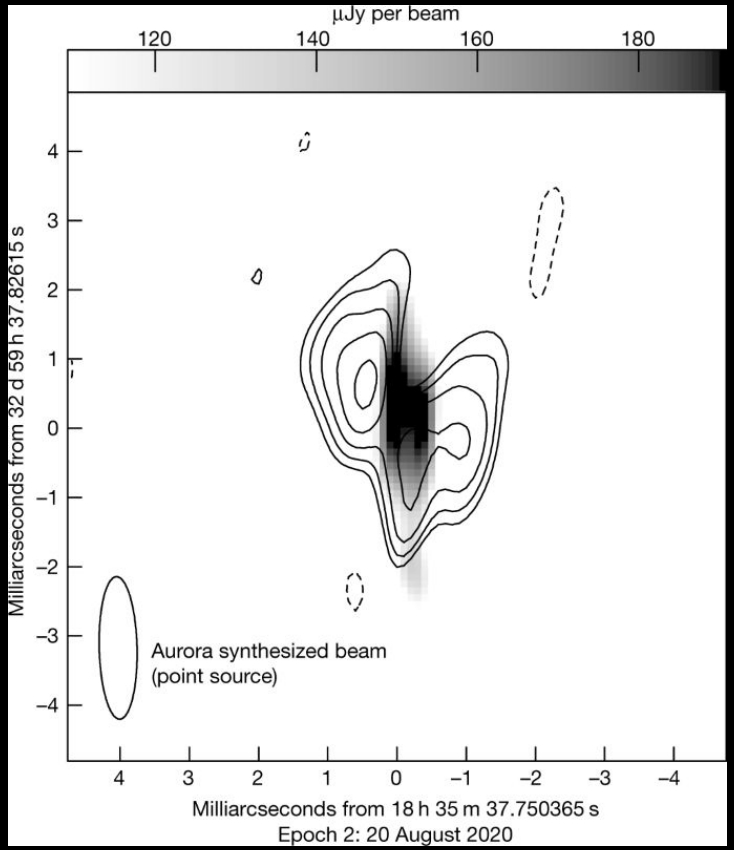


30 min

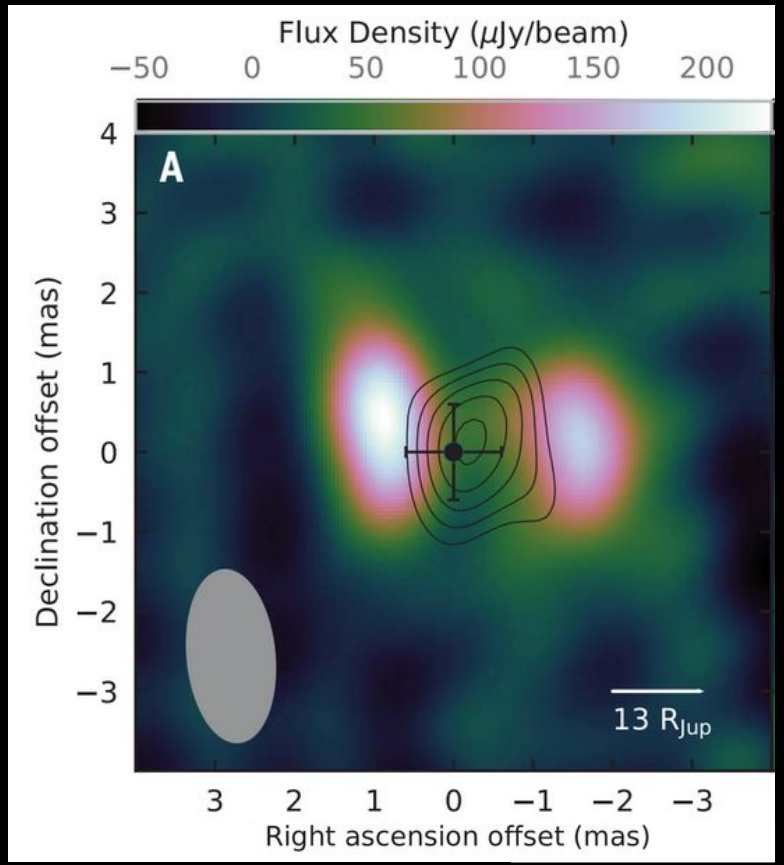


Climent et al. (2023)

Independent confirmation!



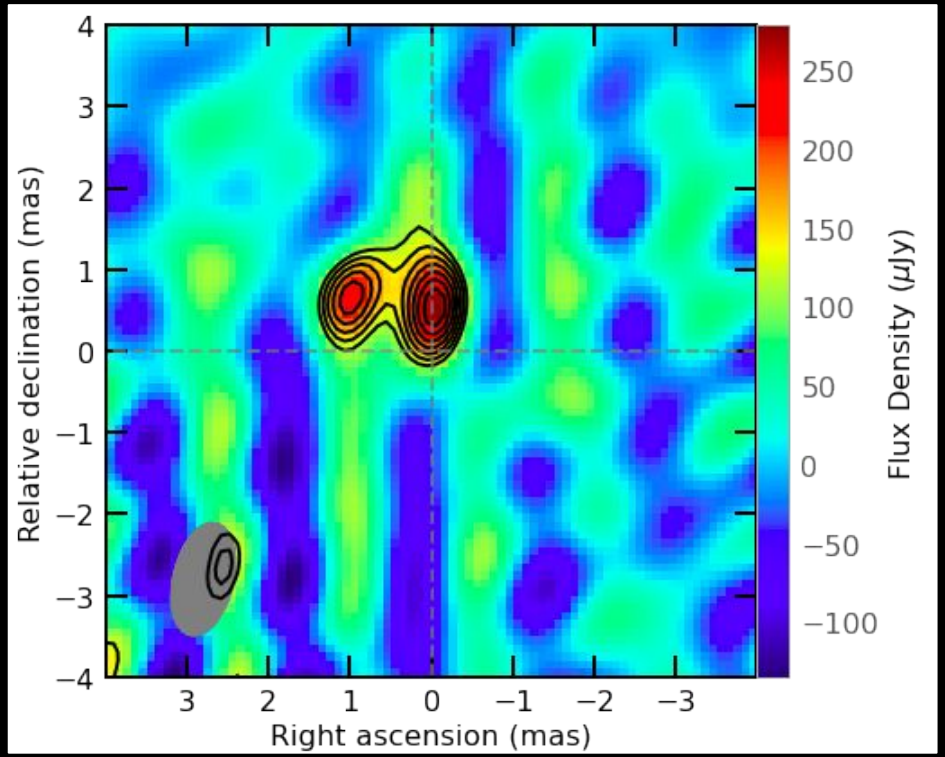
Kao, M. et al. (2023)



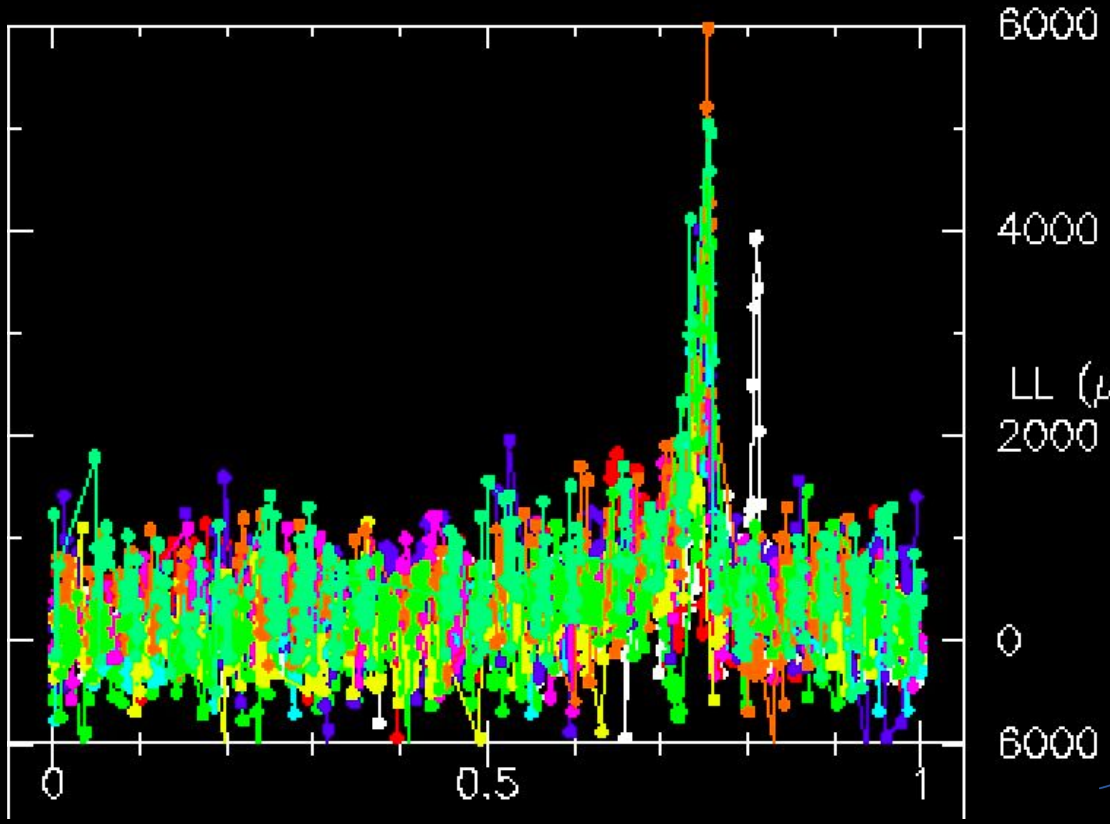
Climent et al. (2023)

Preliminary work on LSRJ's new *data*

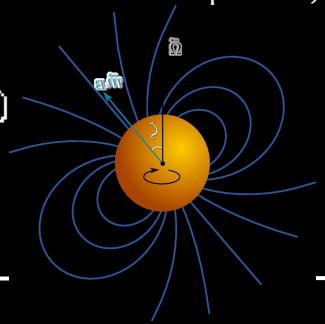
- ★ 4 consecutive nights
- ★ At first sight: some show extended structure, some don't
- ★ At odd with magnetic structure stable >1 year
- ★ Worse data than 2021! Need to double check



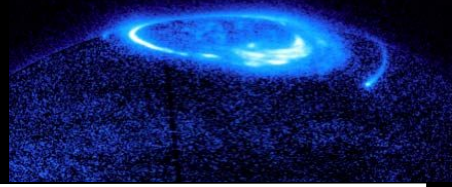
Preliminary work on LSRJ's new *data*



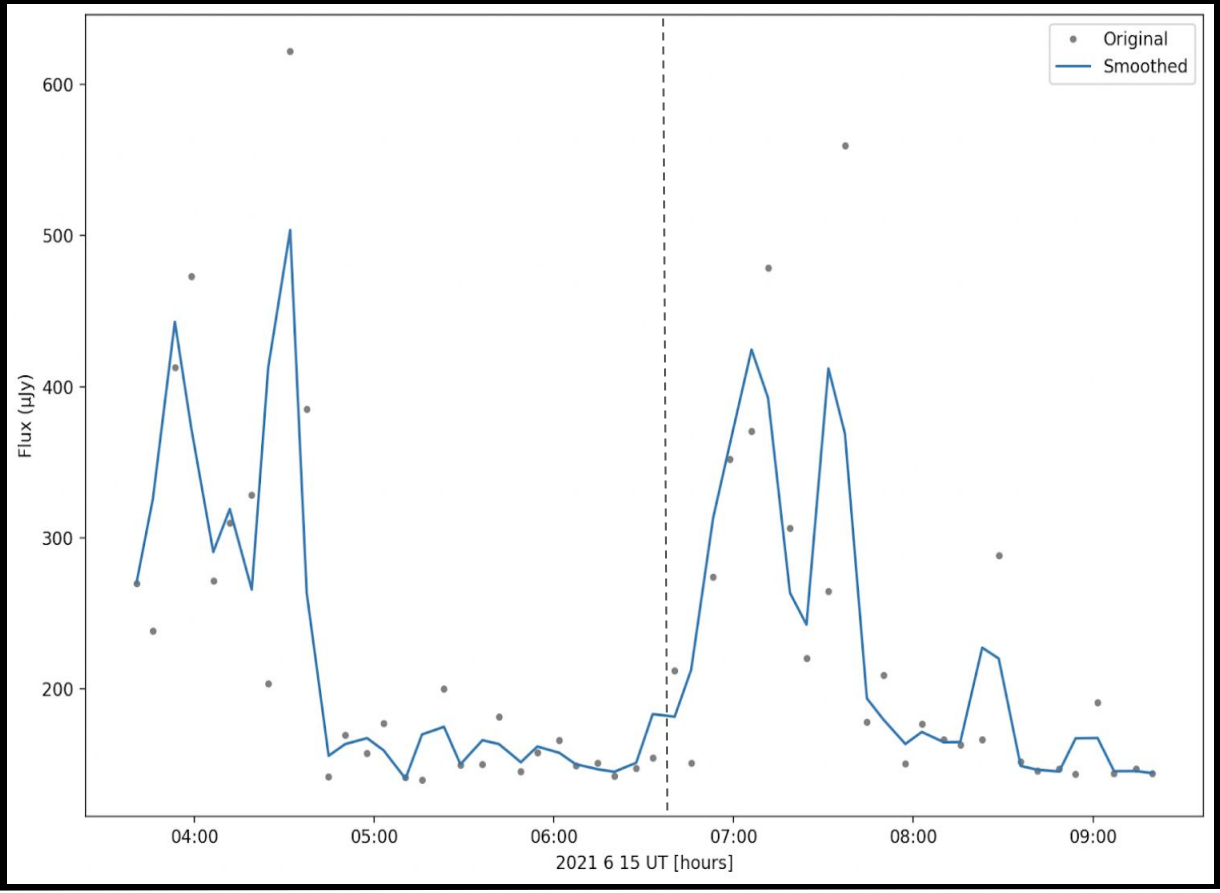
- ★ 8 2022 bursts + 2 2021 bursts
- ★ Folded at 2.84140 ± 0.00039 hours (Miles-Páez et al. 2023)
- ★ During consecutive nights, emission coming from same region
- ★ 2021 data might be an "outlier" or not…
- ★ Well reproduced by oblique rotator model + auroral ring (Kavanagh's poster)



+

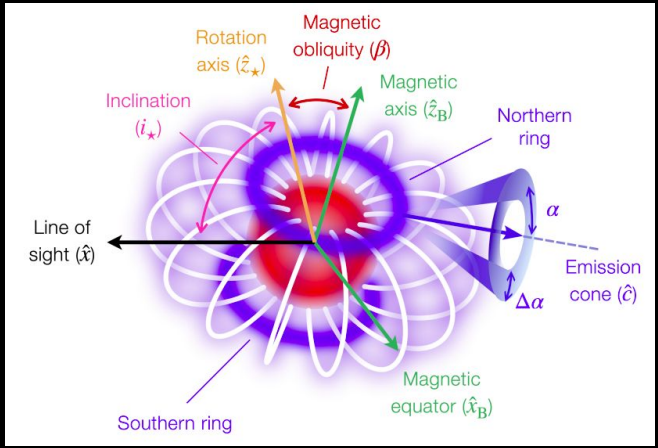


New work



L dwarf

New work

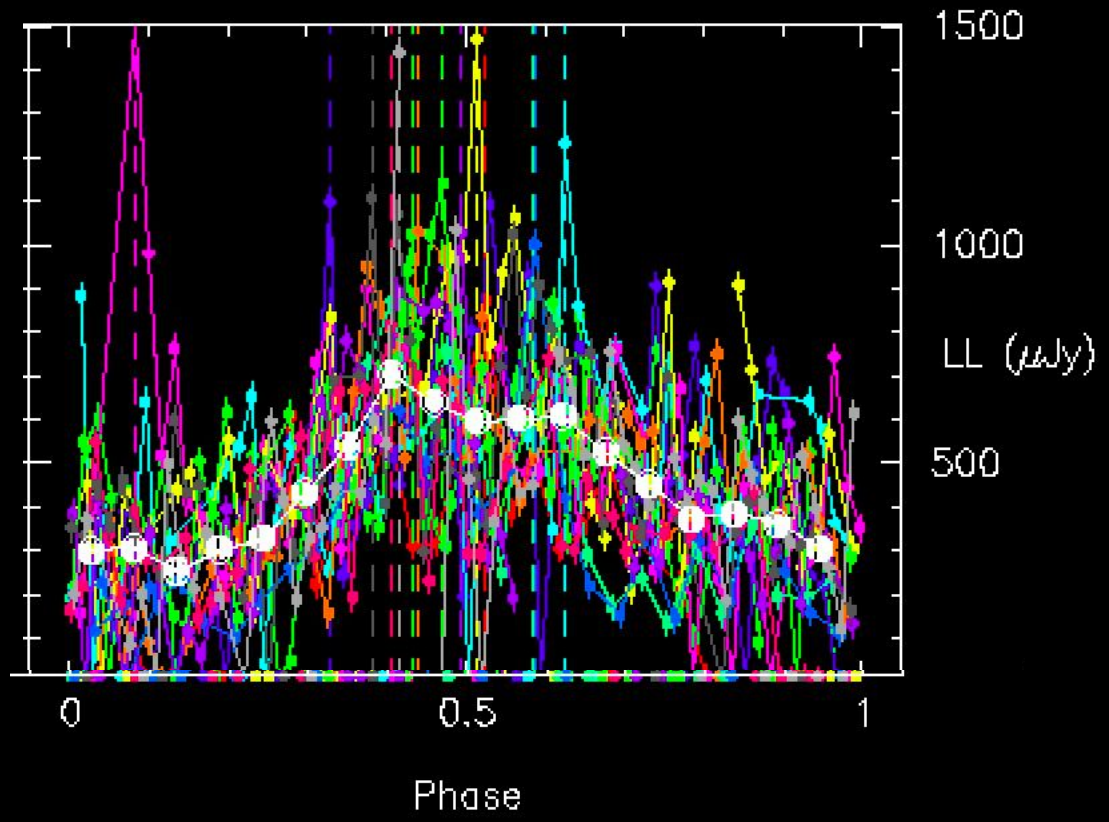


Sanne, B. et al. (2024)

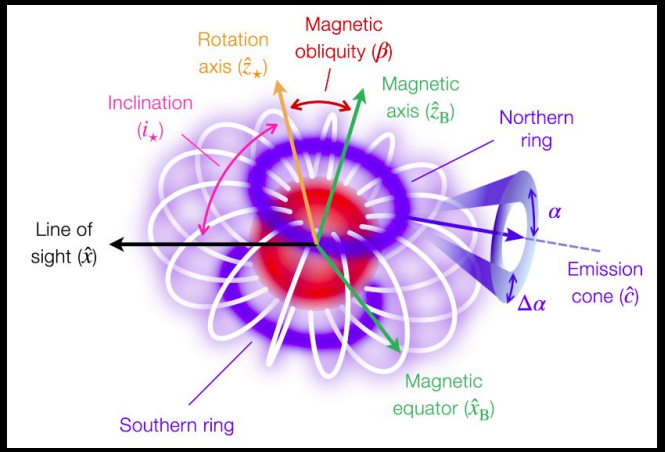
L dwarf

EVN and VLBA data folded at IR rotation period

White lines = average



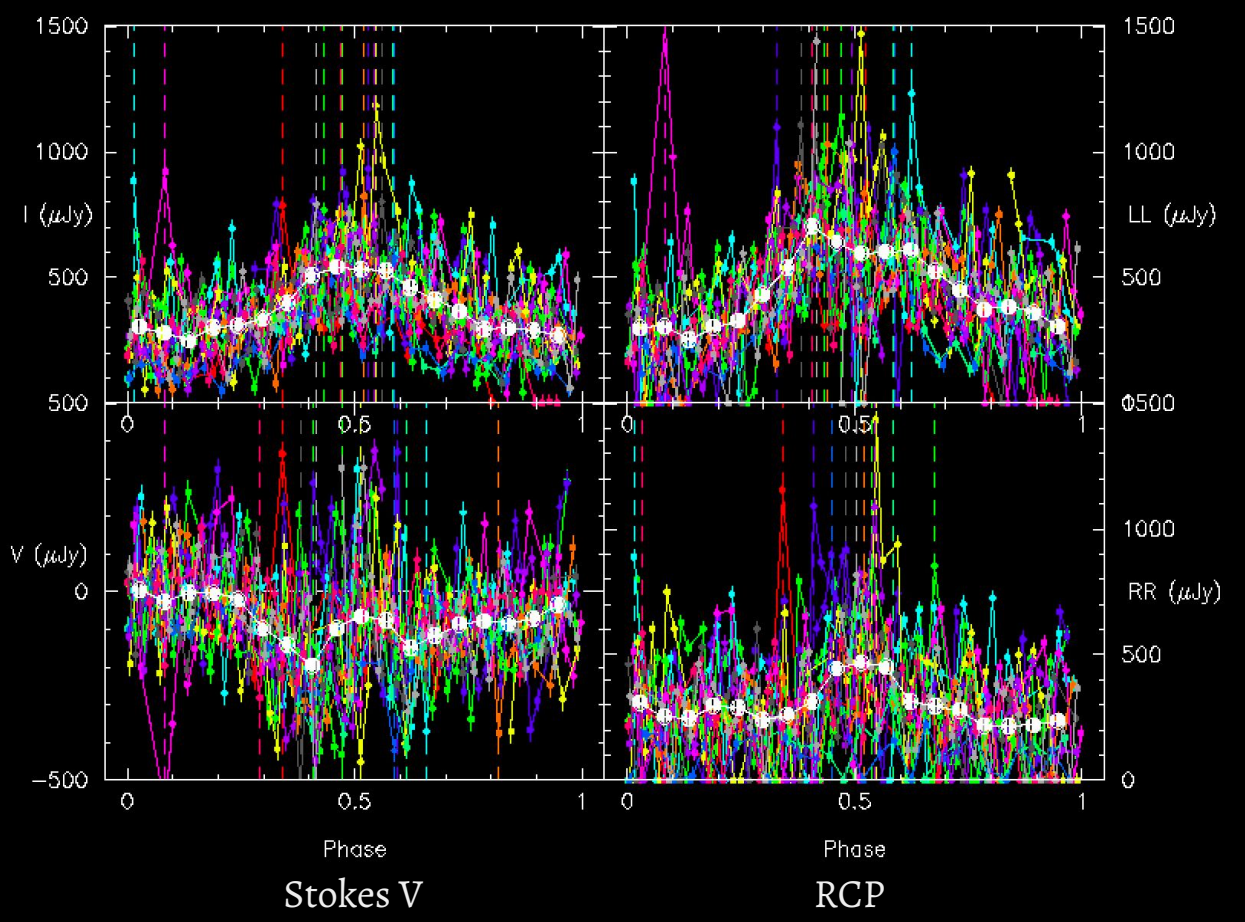
New work



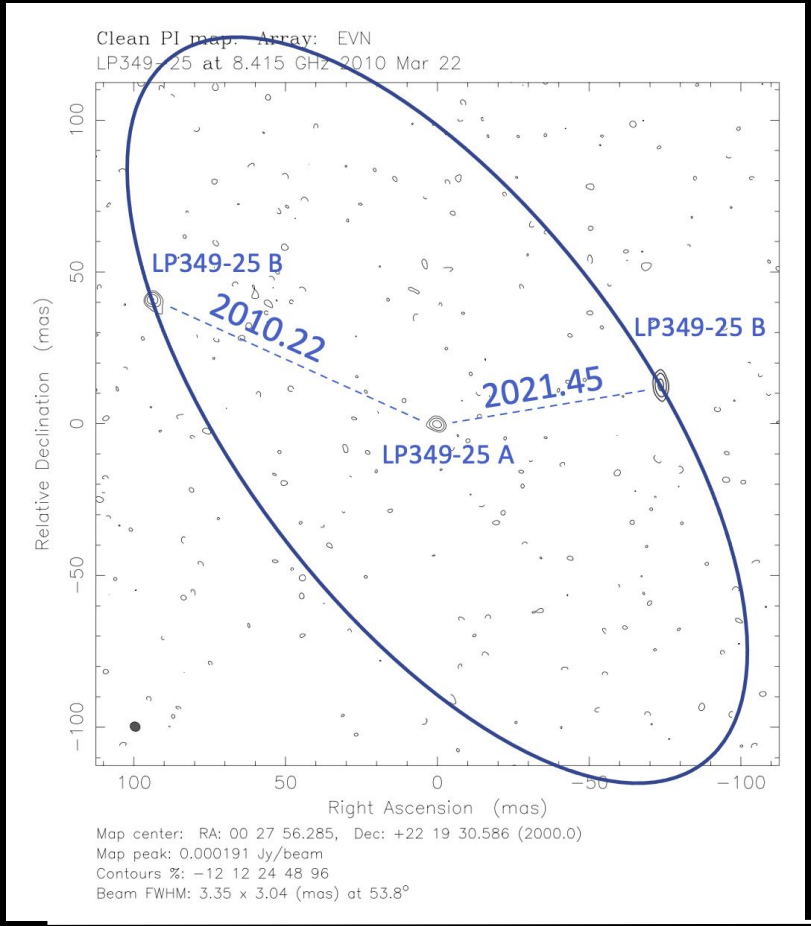
Sanne, B. et al. (2024)

Very sensible to rotation period

Allows for determination of magnetic obliquity in the model

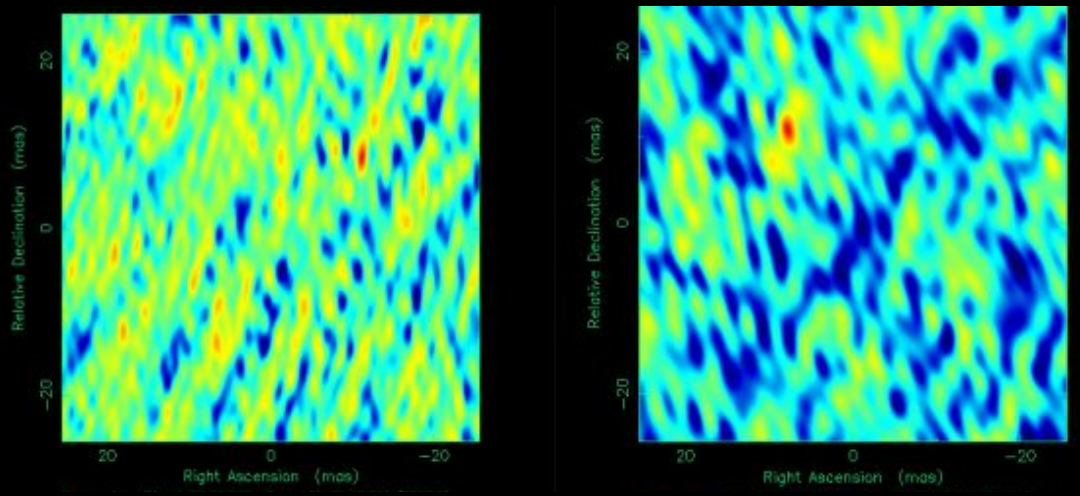


New work, new work



- ★ LP 349-25 is a binary M8+M9 with know radio emission from 1 GHz to 97.5 GHz with a total mass of 165 M_{Jup}.
- ★ Three different epochs: two with emission from both components (2010 and 2021) + one with emission from only LP 349-25A (2019).
- ★ Why this variability in LP349-25B? Is it related to the orbital position?
- ★ A full astrometric analysis is in progress/accepted for publication right now! (Ortiz-León, G. talk)
- ★ No significant circular polarization is detected.

New work, new work, new work

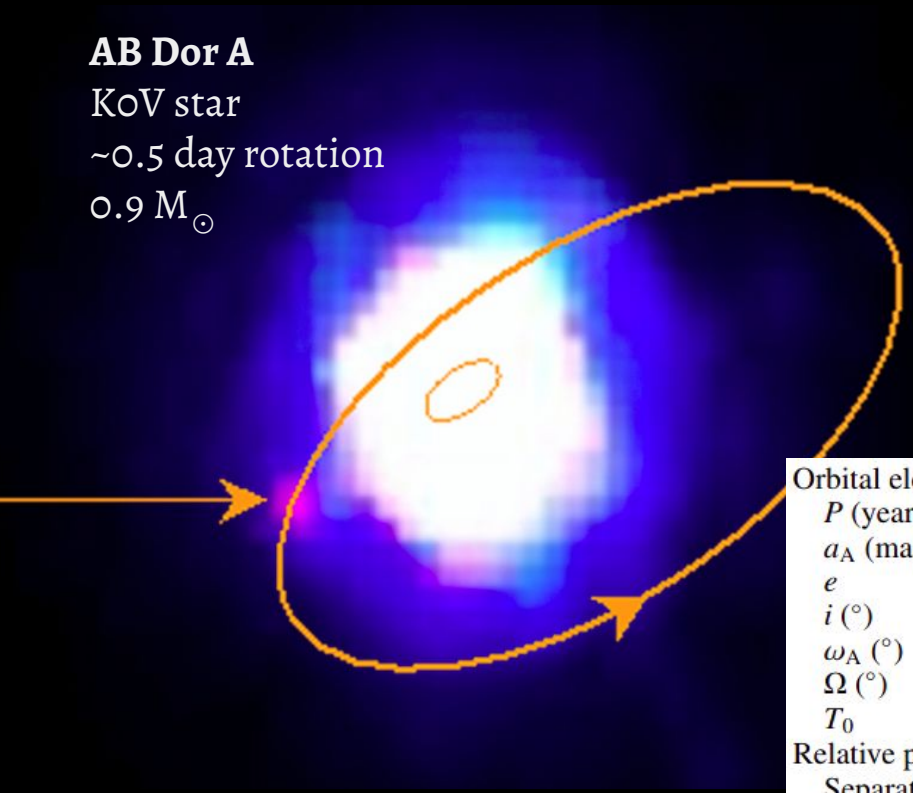


- ★ Spectral type T6 (really ultracool!) with (theoretical) mass well below the substellar limit: 30 M_{jup}
- ★ Fast rotation, but period under discussion (17-116 min; Williams 2017)
- ★ F~100 microJy, 100 % polarized (RCP)
- ★ Variable emission favoring P~ 110min.
- ★ Ongoing astrometric monitoring: 2xEVN + 5xVLBA epochs (sensible to Saturn-like planets).

Bonus

~15 pc away
30-150 Myr

AB Dor A
KoV star
~0.5 day rotation
0.9 $M_\odot$



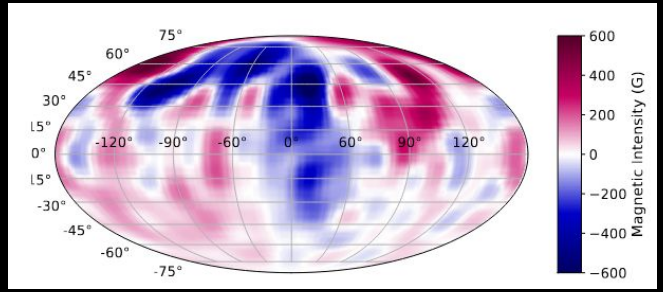
M8 object
0.090 $M_\odot$

Orbital elements AB Dor A [b]	
P (years)	11.78 ± 0.10
a_A (mas)	31 ± 1
e	0.59 ± 0.05
i (°)	65 ± 1
ω_A (°)	114 ± 5
Ω (°)	132 ± 2
T_0	1991.9 ± 0.2
Relative position AB Dor C [c]	
Separation (″)	0.156 ± 0.10
PA (°)	127 ± 1

Bonus

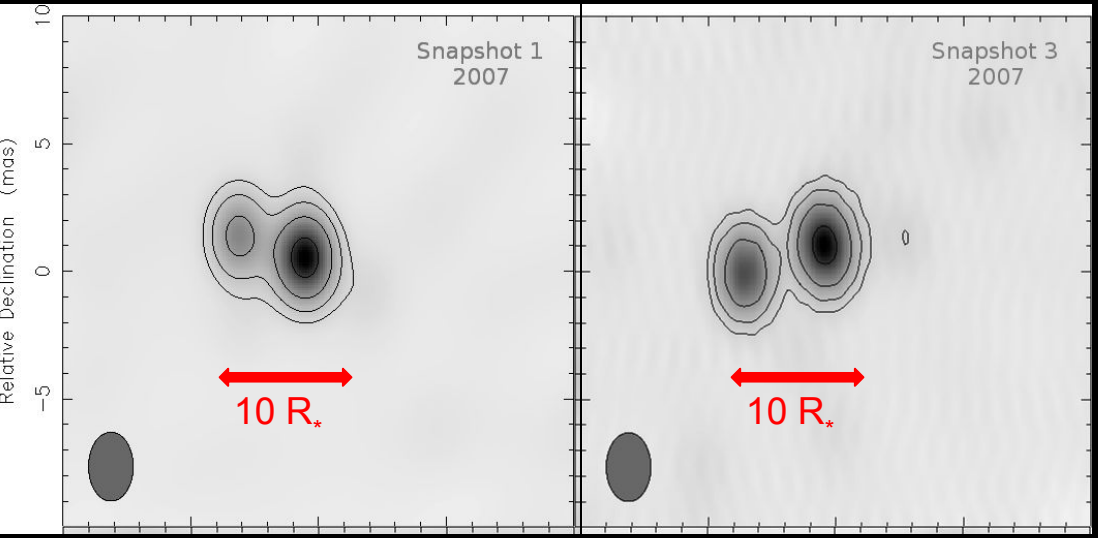
AB Dor A
K0V star
~0.5 day rotation
0.9 $M_\odot$

Cohen et al. (2010)



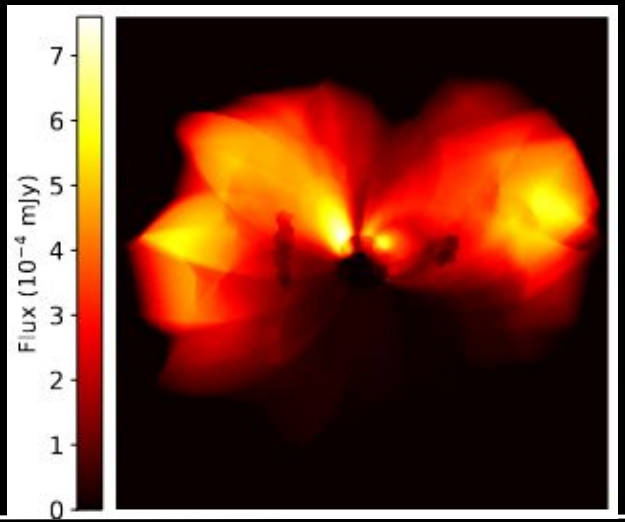
Property	Value
ZDI map year†	2007
Prominence temperature (T_{prom})‡	8, 500 K
Base pressure (p_0)	$10^{-5.5} \times B_0(\mathrm{G})^2$ Pa
Source surface radius (R_{ss})	$8.1 R_\odot$
Corona temperature (T_{cor})	2×10^6 K
Observation frequency	8.4 GHz
Resolution	$.01 R_*$/ px
Image size	$200x200$ px

Climent et al. (2020)



10:30 - 16:00 16:00 - 22:00

Synthetic images from Brasseur et al. (2024)




THANK YOU
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