Radio and infrared interferometry of low-mass stars and exoplanets

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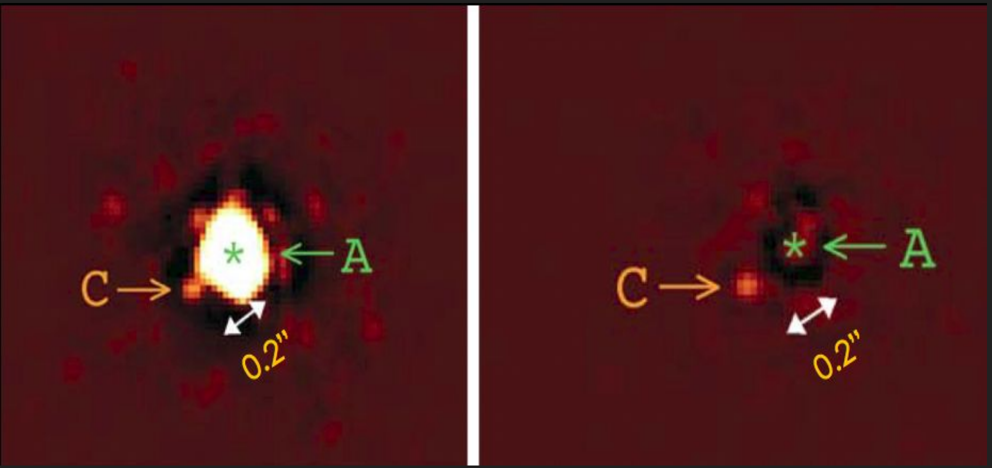
Abstract

The technique of interferometry combines the light from various telescopes achieving an angular resolution equivalent to that of a virtual telescope with a diameter of the maximum separation between the real telescopes. We apply this technique at infrared and radio wavelengths exploring phenomena that may have gone unnoticed or is inaccessible otherwise.

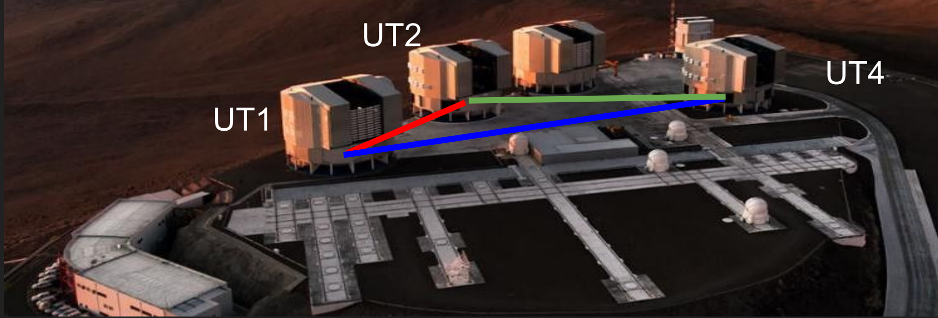
We present here the interferometric study of the brown dwarf AB Dor C at 2.0-2.5 μm. Our observations reveal that this object may be a binary with masses 0.072 $M_\odot$ and 0.013 $M_\odot$. We study whether this binary would be stable in the presence of the more massive AB Dor A and also how it would affect the current discrepancy between the observed magnitudes and theoretical mass-luminosity relationships. Additionally, we will also detail here our future work on radio interferometry of low-mass stars and exoplanets.



- AB Dor is a quadruple system formed by two pairs of stars separated by 9'', AB Dor A/C and AB Dor Ba/Bb.
- We will focus on the pair AB Dor A/C in the work presented here.
- The low-mass companion AB Dor C is an ultracool dwarf with spectral type M8 and a dynamical mass of 0.090 $M_{\odot}$.
- This figure shows the discovery image of AB Dor C with the NACO SDI high contrast camera at 1.625 μm on 2 February 2004.

Stellar evolutionary models show an increasing difficulty in accurately reproducing some of the characteristics of stars with masses below 1.2 $M_{\odot}$. Only stellar systems with dynamically determined masses can effectively be used to test and check them. AB Doradus (AB Dor) is one of such systems. However, previous works have found a discrepancy between observed magnitudes of AB Dor C and theoretical mass-luminosity relationships. One possible explanation for such discrepancy is that AB Dor C is a binary object. This is the hypothesis we have explored with infrared interferometry.

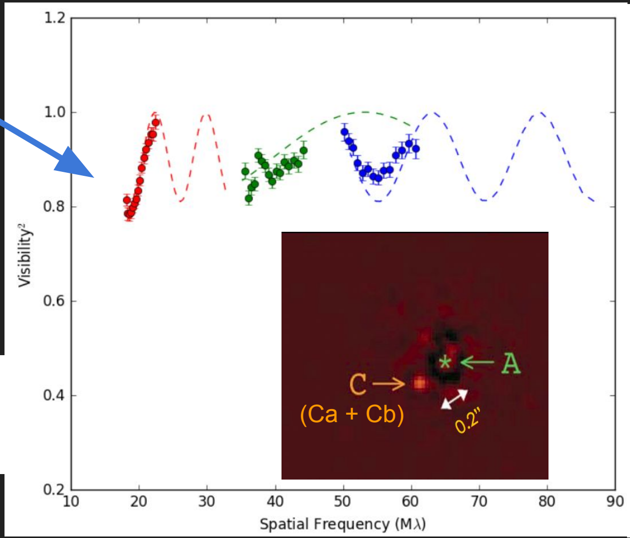
- We used 3 Unit Telescopes (UT) at the Very Large Telescope: UT1, UT2 and UT4 (baselines colored in figure).

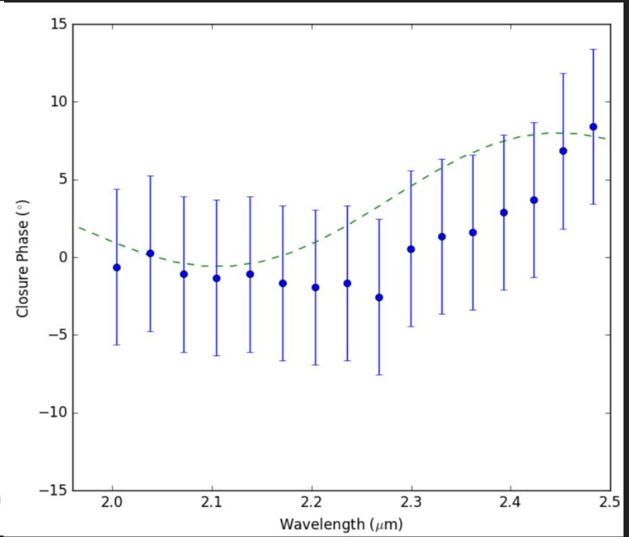


- We used the low resolution mode of AMBER at J, H and K bands (programme 090.C-0559(A)). However, only K band (2.0-2.5 μm) could be used for the analysis due to technical problems.

- We found the fringes using AB Dor A and then, knowing with high precision its expected position, we found fringes for AB Dor C.

Different color = different baseline
Dots = observational data
Dashed line = best fit model





The best model is a binary!
Characteristics for AB Dor Ca/Cb:

Flux ratio	Separation (mas)	P.A (°)
0.054 ± 0.004	38.1 ± 0.2	178 ± 1

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→

Knowing the K-magnitude of AB Dor C (Boccaletti et al. 2008) we estimate K-magnitudes for AB Dor Ca and AB Dor Cb: 8.43 +- 0.16 y 11.7 +- 0.3, respectively.

↓

Using the evolutionary models of Tognelli et al. 2018, Chabrier et al. 2000, and Baraffe et al. 2015 we estimate the masses of each component

↓

$0.072 \pm 0.013\ M_{\odot}$ and $0.013 \pm 0.001\ M_{\odot}$

near the hydrogen-burning limit

near the deuterium-burning limit

The binarity partially alleviates the disagreement between observed magnitudes and theoretical mass-luminosity relationships.

To be confirmed by GRAVITY

Climent et al. (2019)

Stability of the orbit of AB Dor Ca/Cb

At 0.2'' average angular distance from AB Dor C, the more massive AB Dor A could clearly affect the orbit stability of the tentative binary AB Dor Ca/Cb.
However, an analysis of this "triple system" (A, Ca, Cb) using the estimated masses and the well-known orbit reveals that our measured separation would correspond to a stable binary system.

Radio emission from Ultracool dwarfs and M-dwarfs with exoplanets

- Very Large Array (VLA) observations at 8.4 GHz of 5 low-mass binary systems in the AB Doradus Moving Group. Three clear new detections to be analyzed!
- European VLBI Network observations (EVN) at 5 GHz of 4 ultracool dwarfs with radio emission already detected but never observed at such high angular resolutions (1 clear detection + 1 tentative).
- VLA observations at 1.4 GHz of 5 M-dwarfs with known exoplanets around them in order to better understand the emission mechanisms in these objects and also search for radio emission associated with the exoplanet(s) around them (Turnpenney et al. 2018).

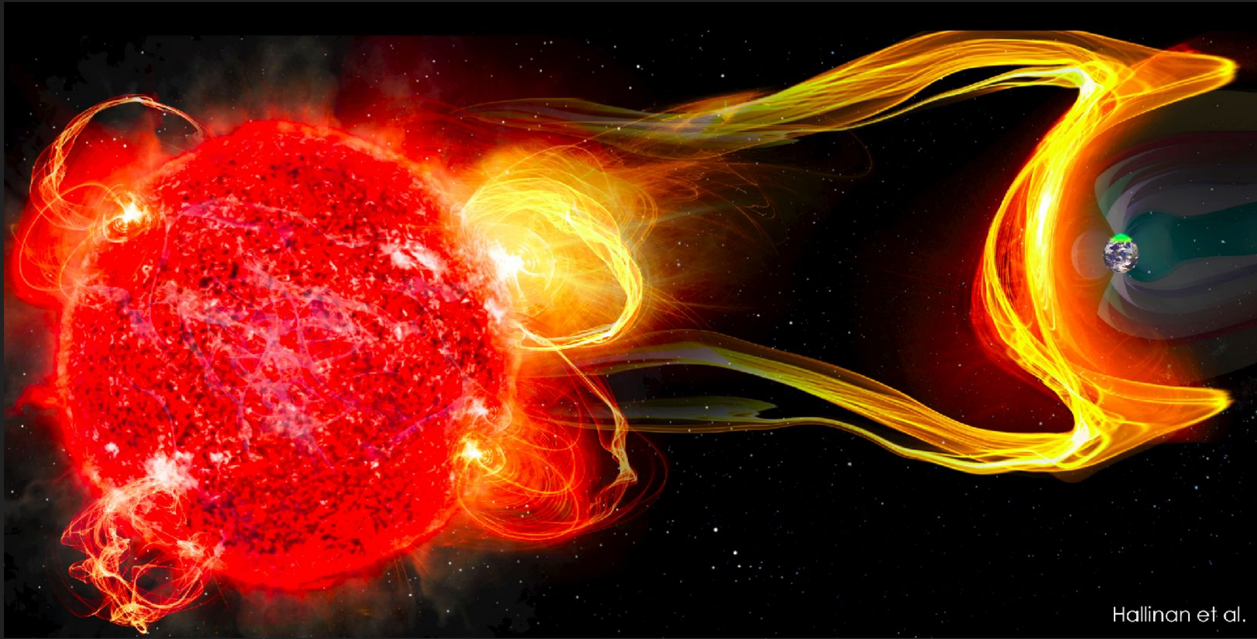
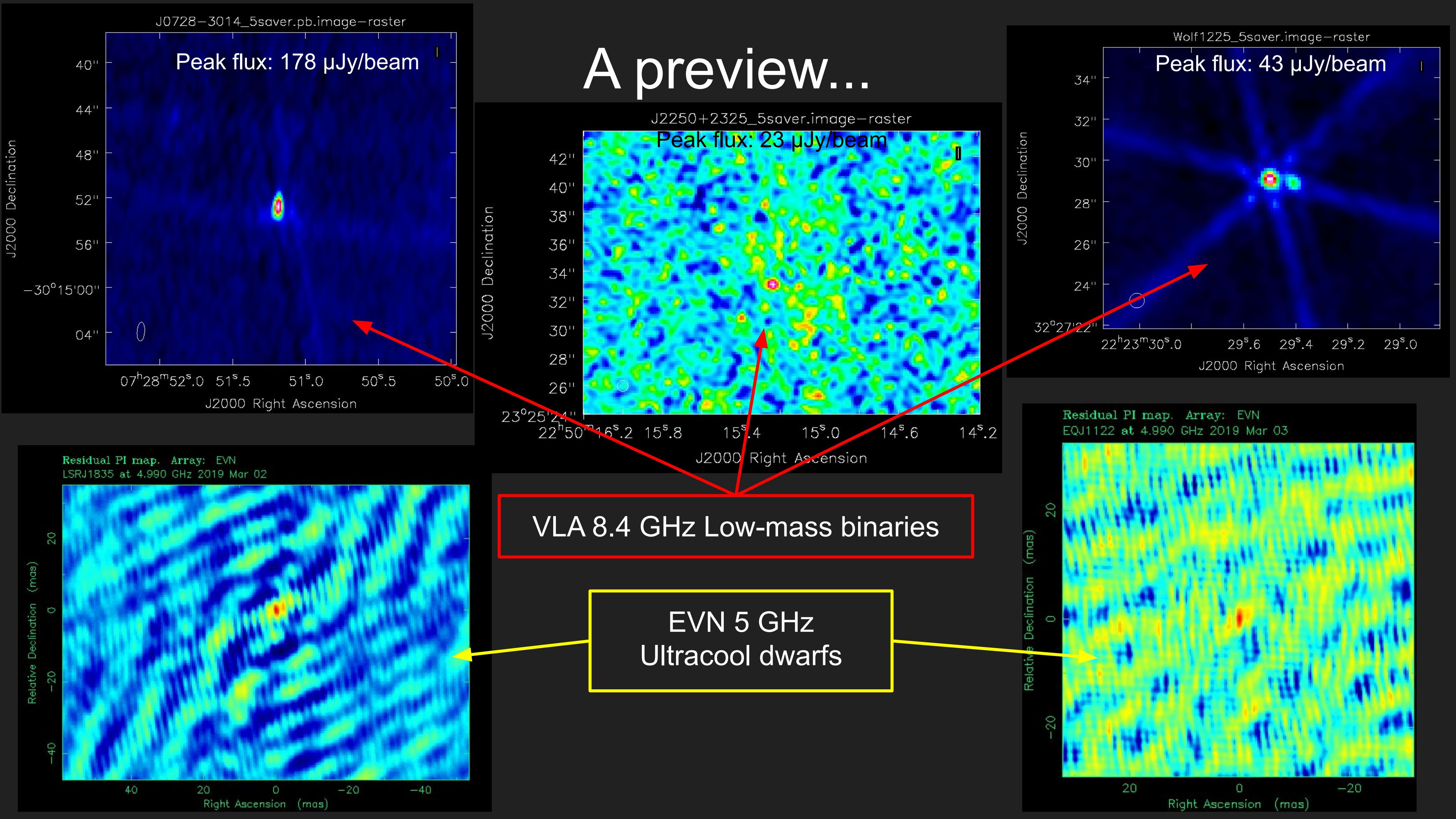


Illustration of the interaction between M-dwarf and exoplanet magnetosphere

A preview...


J0728−3014_5saver.pb.image−raster
Peak flux: 178 μJy/beam
J2000 Declination
J2000 Right Ascension
J2250+2325_5saver.image−raster
Peak flux: 23 μJy/beam
J2000 Declination
J2000 Right Ascension
Wolf1225_5saver.image−raster
Peak flux: 43 μJy/beam
J2000 Declination
J2000 Right Ascension
Residual PI map. Array: EVN
LSRJ1835 at 4.990 GHz 2019 Mar 02
Relative Declination (mas)
Right Ascension (mas)
Residual PI map. Array: EVN
EQJ1122 at 4.990 GHz 2019 Mar 03
Relative Declination (mas)
Right Ascension (mas)
VLA 8.4 GHz Low-mass binaries
EVN 5 GHz
Ultracool dwarfs