IDENTIFICATION OF POSSIBLE STELLAR COMPANIONS VIA SPECKLE INTERFEROMETRY IN A SAMPLE OF BE STARS

Physics of Extreme Massive Stars

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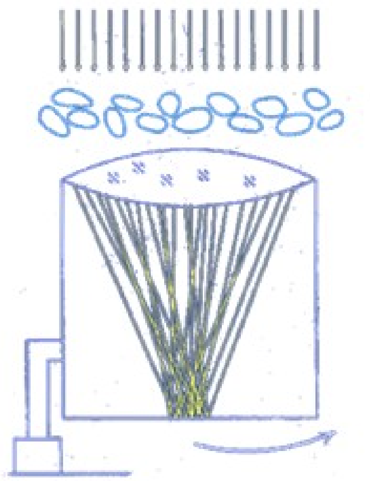
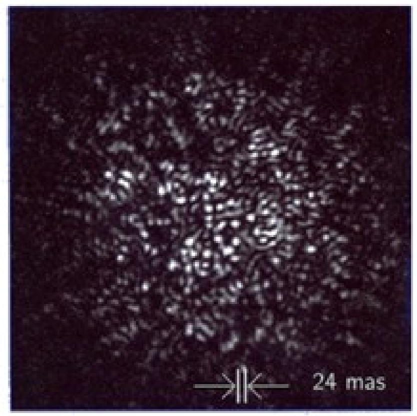
INTRODUCTION

- The real limitation on angular resolution for ground-based telescopes is the atmosphere
- By analyzing interference effects in short exposure images, we can achieve observations limited by diffraction
- Speckle interferometry
- Binary stars

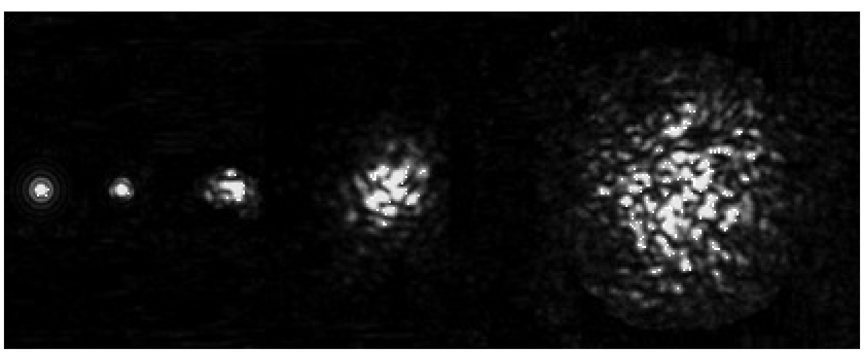
IMAGES DISTORTED BY ATMOSPHERIC TURBULENCE





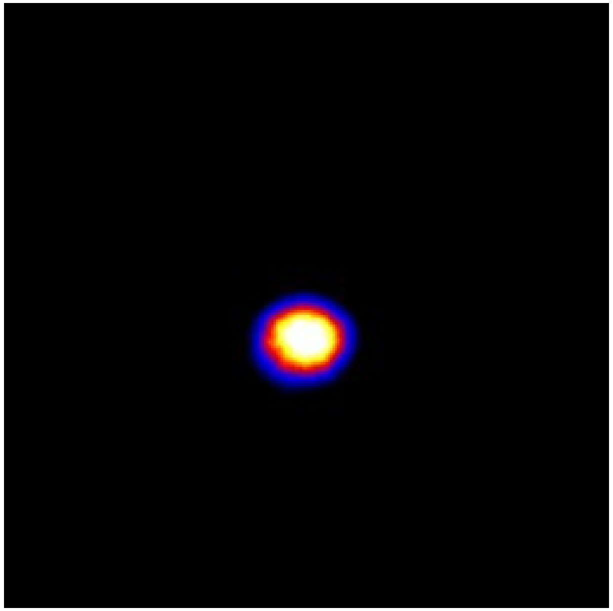
$$N \propto \left(\frac{D}{r_0}\right)^2$$

- The seeing parameter , is cm at visible wavelengths, at best

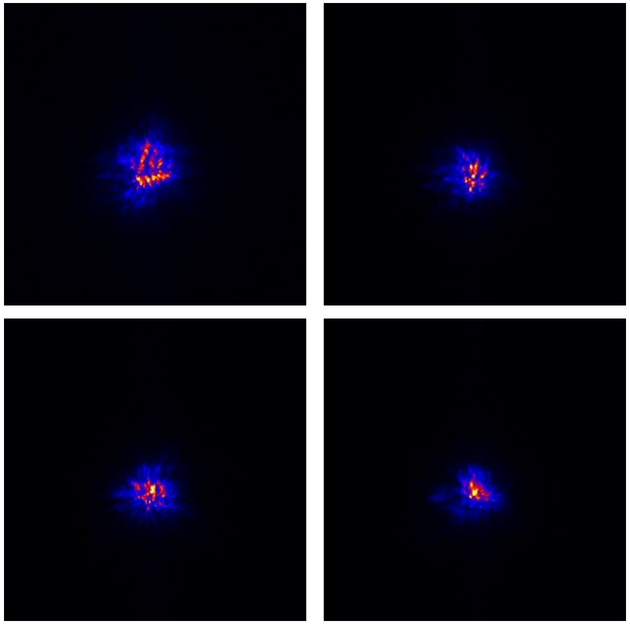


- Images taken bellow the coherence time , typically,

LONG EXPOSURE IMAGE

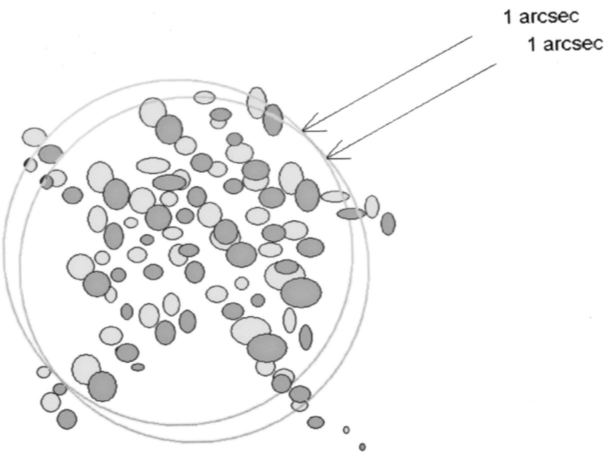


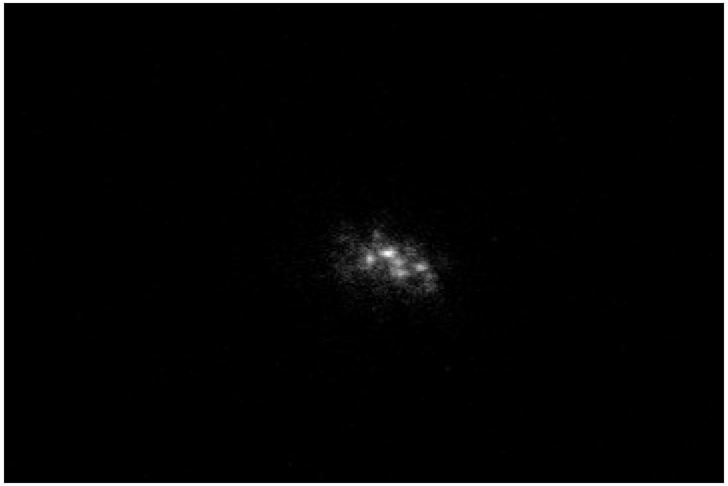
exposure
WDS +234 00 279



Four consecutive
WDS +234 00 279

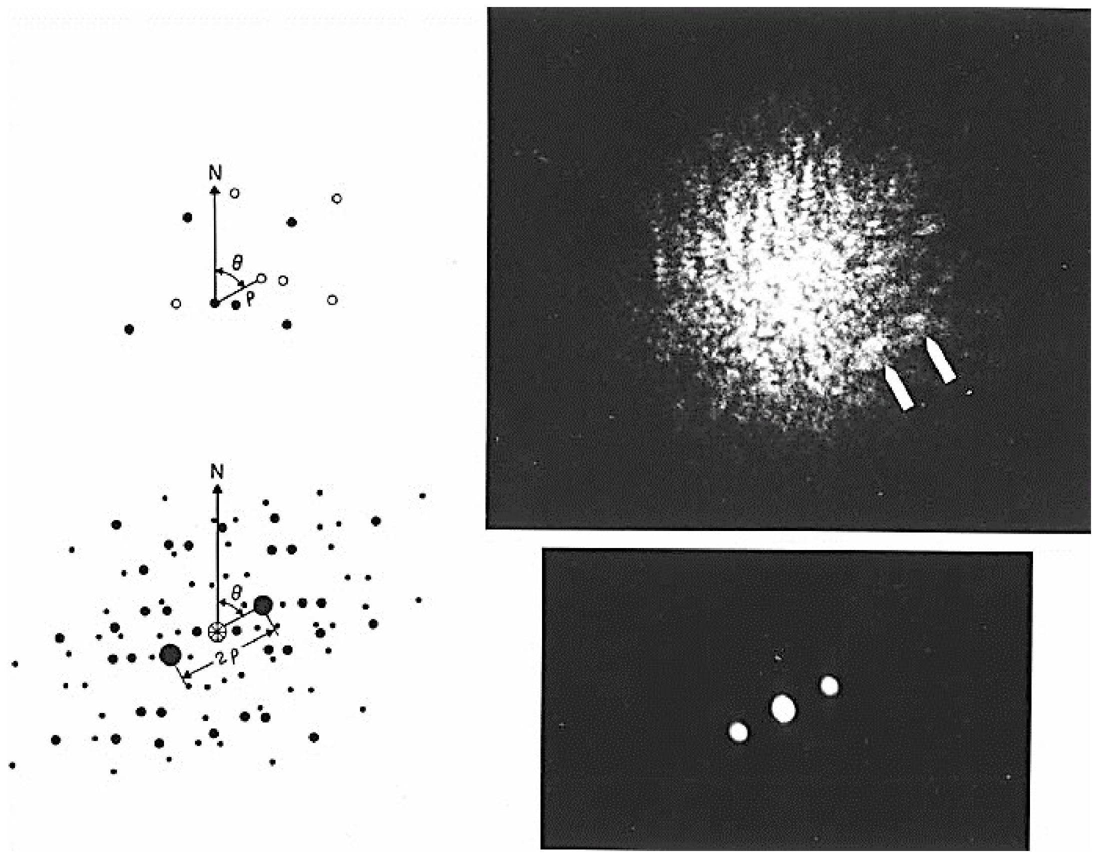
SPECKLE PATTERN OF A BINARY STAR





WDS 00279+2340

SPECKLE PATTERN OF A BINARY STAR



SPECKLE INTERFEROMETRY

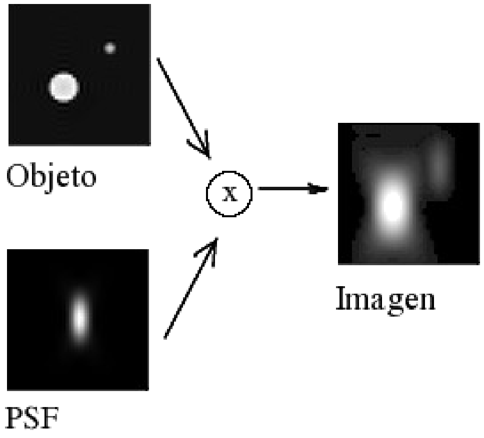
- Labeyrie (1970) introduced the principle of speckle interferometry in astronomy

- Speckle pattern: is an interference effect in an image caused by random amplitude and phase perturbations induced in the wavefront of incident light due to atmospheric turbulence and telescope diffraction

SPECKLE INTERFEROMETRY

- The image of a source is the convolution between its brightness distribution and the atmospheric dispersion function

- By the convolution theorem:



POWER SPECTRUM

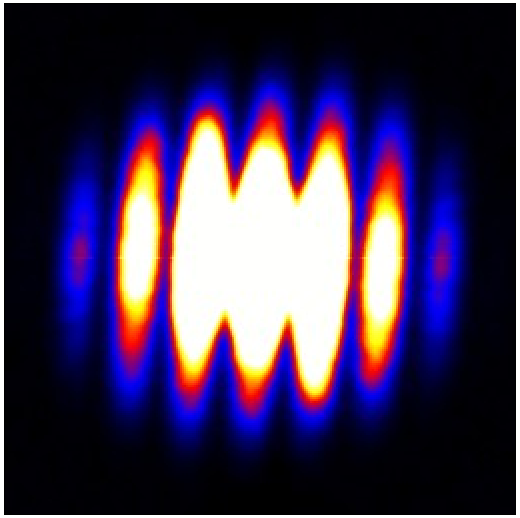
- Typically, an image cube contains frames

- The power spectrum of each cube is obtained by adding the squared modulus of the Fourier transform of each image:

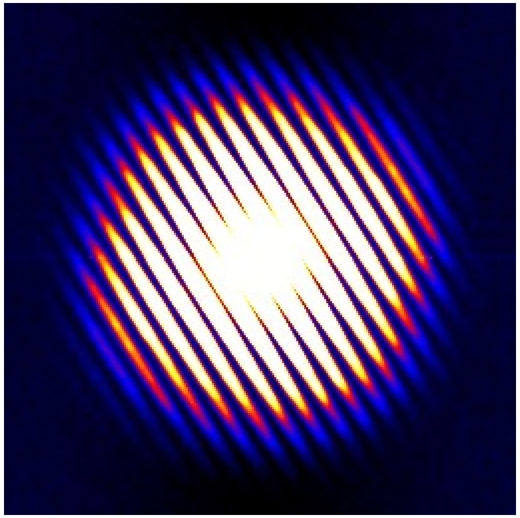
POWER SPECTRUM

- For a binary star, the spatial frequency most likely to occur in the individual speckles is the separation between the two stars
- The power spectrum will show light and dark bands
- The distance between maxima of the bands is associated with the separation of the two stars, while the axis perpendicular to the bands represents the position angle
- The contrast is associated to the magnitude difference between the stars of the system

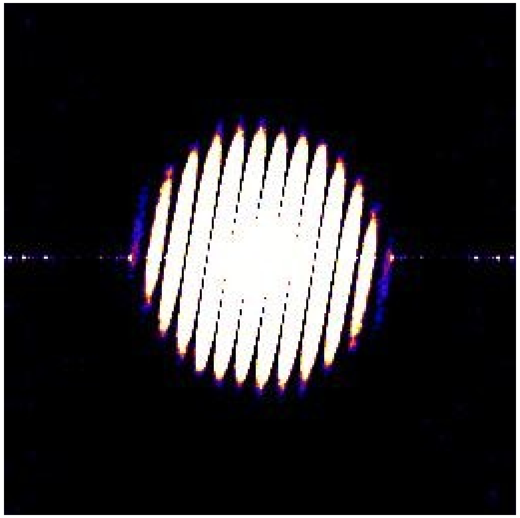
POWER SPECTRUM



WDS +2340 0279

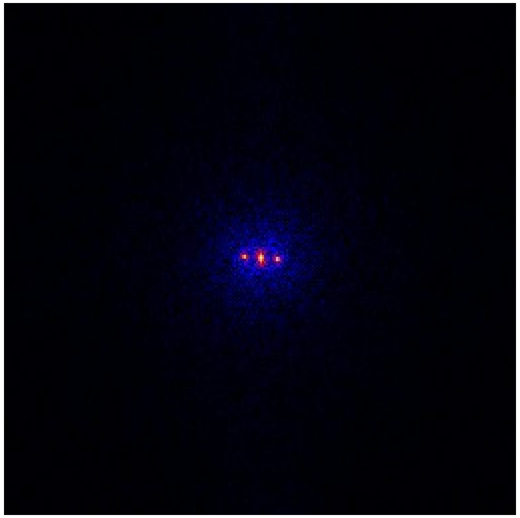


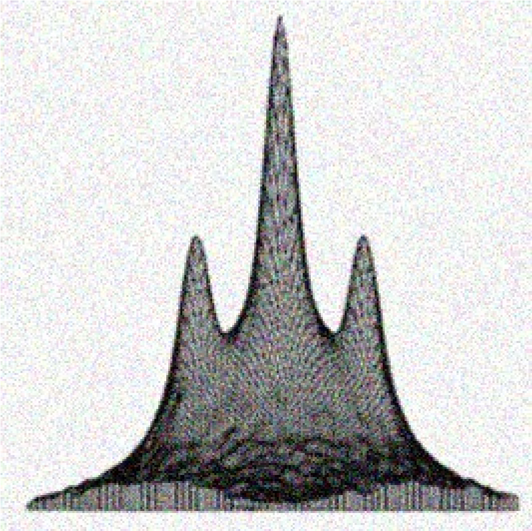
WDS +15350 1478



WDS +01547 3235

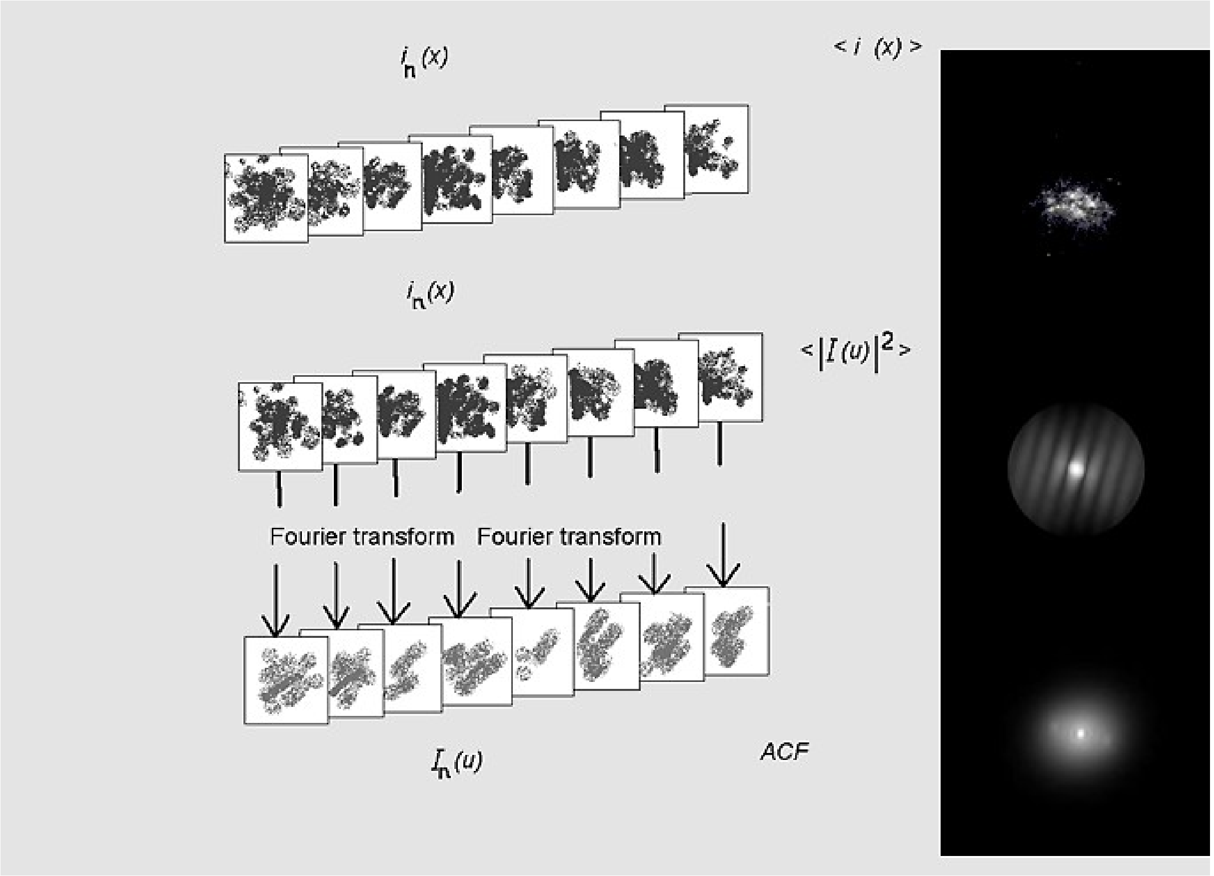
AUTOCORRELATION FUNCTION





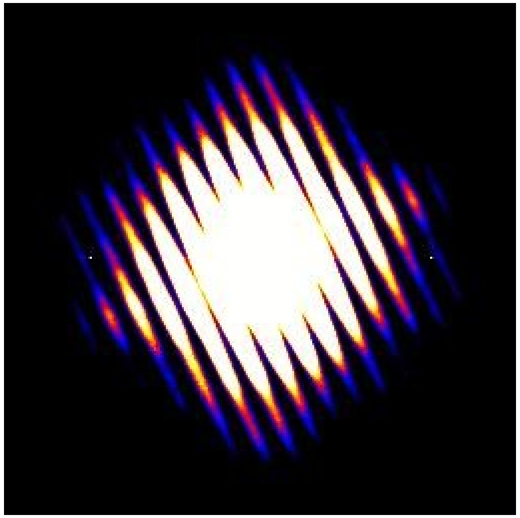
Autocorrelation
WDS 00 279+234

SPECKLE INTERFEROMETRY

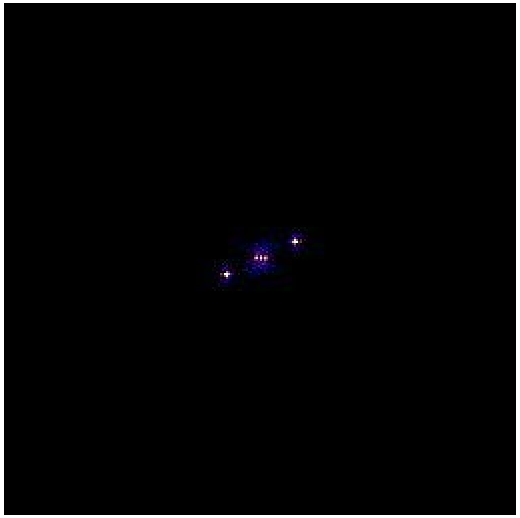


SPECKLE INTERFEROMETRY

- Physical parameters: Observation time , separation , position angle and magnitude difference

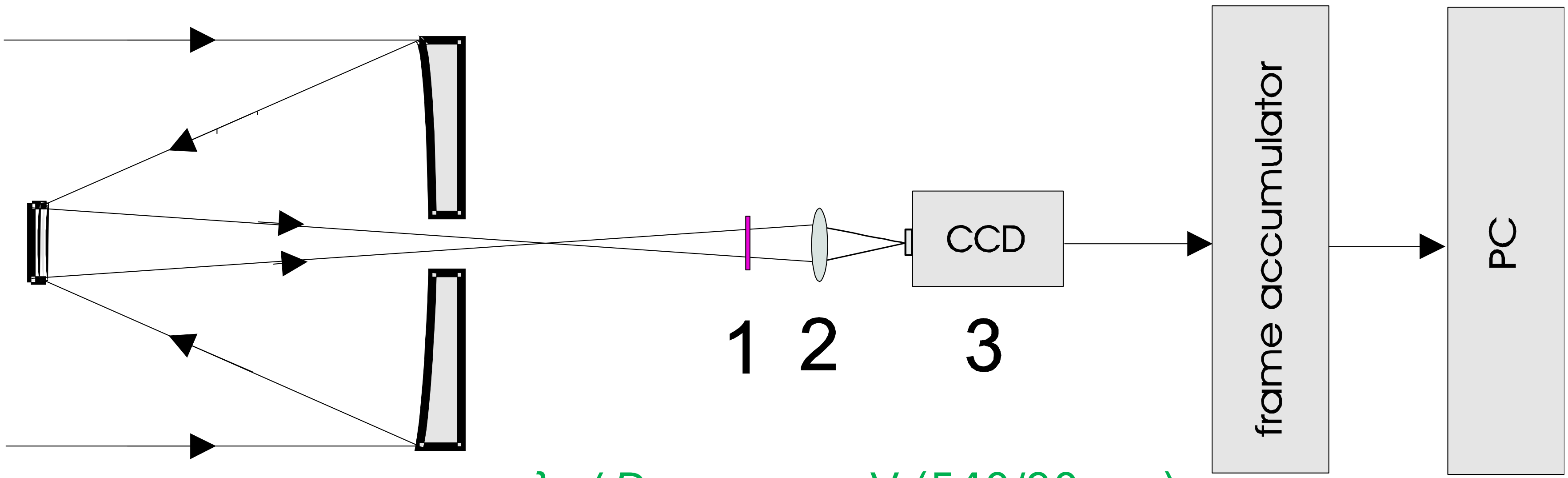


WDS +09285 0903



WDS +09285 0903

SPECKLE INTERFEROMETER



λ_V / D = 0.053”
λ_R / D = 0.067”
λ / D = 0.088”

V (540/90 nm)
R (640/130 nm)
I (800/160 nm)

1. Filter
2. Microscope
3. Camera
4. Image accumulator
5. Control computer

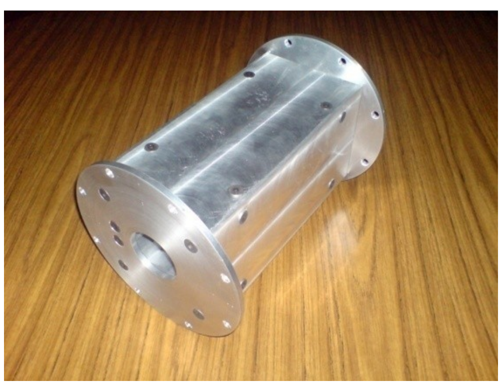
See Guerrero et al. 2018a, 2018b; Guerrero et al. 2020

SPECKLE INTERFEROMETER

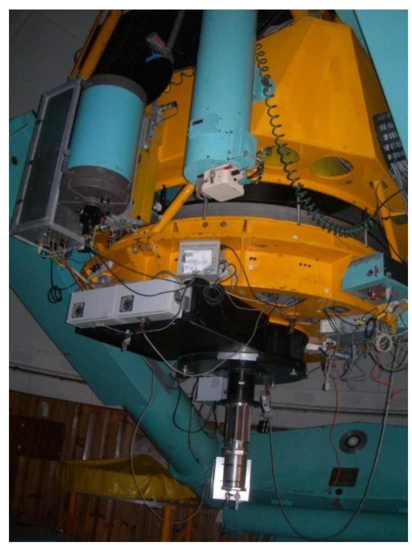
Filter

Microscope

Manufacture Diagrams



Ensamble



EMCCD

Telescope + Interferometer

IDENTIFICATION OF POSSIBLE STELLAR COMPANIONS VIA SPECKLE INTERFEROMETRY IN A SAMPLE OF BE STARS

THE ASTRONOMICAL JOURNAL, 159:132 (10pp), 2020 April
https://doi.org/10.3847/1538-3881/ab6dcd

CrossMark

Identification of Possible Stellar Companions via Speckle Interferometry in a Sample of Be Stars

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Souza, Guerrero & Borges Fernandes, 2020

IDENTIFICATION OF POSSIBLE STELLAR COMPANIONS VIA SPECKLE INTERFEROMETRY IN A SAMPLE OF BE STARS

- In prep. Guerrero, Souza & Borges Fernandes

SAMPLE SELECTION

- One significant advantage of speckle interferometry is that it allows high angular resolution to be achieved with small- and medium-sized telescopes
- Thus, we are interested in the observation of southern Be stars (from OPD-LNA, Brazil) and northern Be stars (from OAN-SPM and OAGH, Mexico)
- It is important to note that due to the limited time coverage of our observations, we can only identify companion candidates at this stage

SAMPLE SELECTION

- However, identifying candidate companions is still valuable, especially for modeling Be stars and their disks

- The potential for binarity can help to explain the complex morphologies observed in several studies (remember many of the talks of our meeting…)

- We selected a sample of Be stars (Souza, Guerrero & Borges Fernandes, 2020); and   Be Stars (Guerrero, Souza, Borges Fernandes, in prep.)   with

RESULTS

- We have positive binary detections for of the objects for the Southern sample, of which are new discoveries
- Table 4 presents the new resolved pairs that we found in previously suggested double or multiple stars and also the new possible double stars discovered by us

Table 4
Newly Resolved Pairs in Previously Known Multiple Systems, and New Possible Double Stars Discovered by Us

HD	WDS (2000)	New Components	Epoch +2000	θ (deg)	σ_θ (deg)	ρ (arcsec)	σ_ρ (arcsec)	Δm (mag)	λ (nm)
71510	08255−5144	Aa,Ab	17.2357	23.6	1.6	0.28	0.02	0.93	538
			17.2357	23.3	1.6	0.26	0.03	1.04	630
			17.2357	23.9	0.9	0.28	0.01	1.20	894
76838	08571−4315	Ba,Bb	17.2357	35.1	1.5	0.18	0.01	1.29	538
			17.2357	34.9	1.5	0.18	0.01	0.98	630
			17.2357	35.0	1.5	0.17	0.01	0.99	894
			18.2651	65.3	1.5	0.11	0.02	1.30	538
			18.2651	65.2	1.6	0.10	0.01	0.97	630
			18.2651	64.9	1.5	0.11	0.01	0.98	894

RESULTS

- We identified double stars amongst the 47 objects for the Northern sample, of which are new discoveries

Table 4: New possible double stars discovered in this work.

HD	New Components	Epoch +2018	θ (deg)	σ_θ (deg)	ρ (arcsec)	σ_ρ (arcsec)	Δm (mag)	λ (nm)
35079	AB	0.1735	202.7	1.5	0.09	0.01	0.54	538
		0.1735	202.6	1.7	0.09	0.01	0.79	630
		0.1735	203.0	2.1	0.10	0.01	2.09	894
51893	AB	0.1654	180.1	0.3	0.09	0.01	2.22	538
		0.1654	179.8	1.1	0.09	0.01	2.20	630
		0.1654	179.9	0.7	0.10	0.02	2.15	894
55606	AB	0.1789	155.8	1.6	0.09	0.01	0.58	538
		0.1789	155.9	1.9	0.08	0.01	0.66	630
		0.1789	155.7	1.4	0.09	0.01	0.68	894

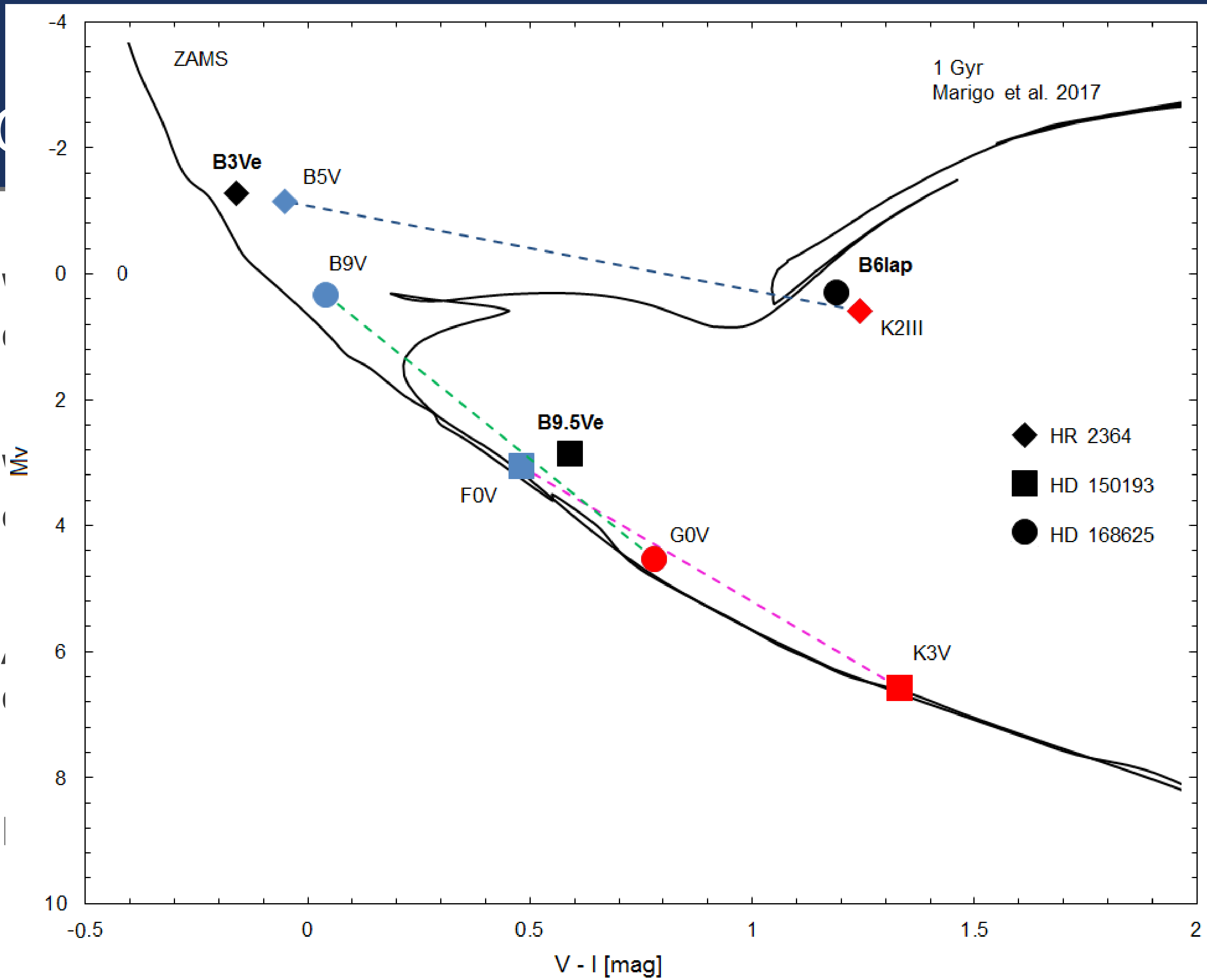
DISCUSSION

- We found a **multiplicity** fraction amongst Be stars of
- of the double systems have angular separation , meaning they are most likely to be gravitationally bound
- Separations ranging from tens to hundreds of AU
- Follow up observations are needed

NULL DETECTIONS

- Between the two samples, we observed Be stars
- Of these, turned out to be single stars
- Possible reasons:
  - The angular separation of the companion is larger than the FOV or smaller than our resolving power
  - The companion is fainter than the sensitivity of our observations ()
  - A combination of both scenarios
  - **There is no companion at all**

C


ZAMS
1 Gyr
Marigo et al. 2017
B3Ve
B5V
B9V
B6Iap
K2III
B9.5Ve
F0V
G0V
K3V
HR 2364
HD 150193
HD 168625
Mv
V - I [mag]
-4
-2
0
2
4
6
8
10
-0.5
0
0.5
1
1.5
2

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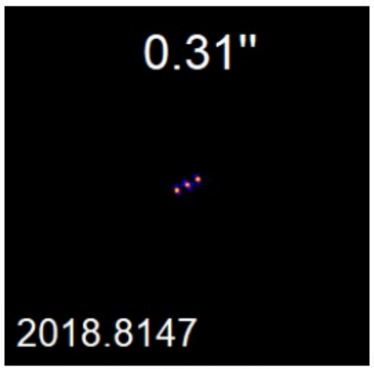
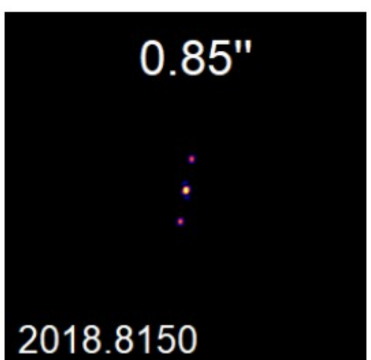
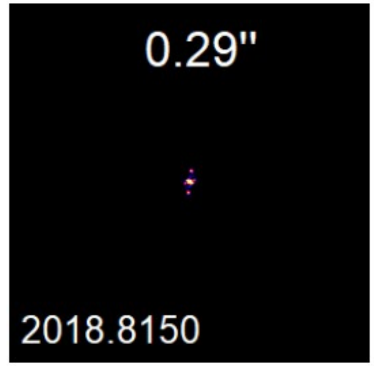
Thank you!



(a) HD 17520

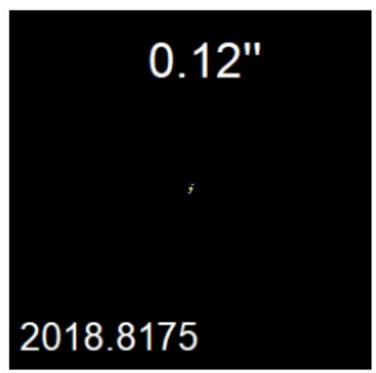


(b) HD 37115

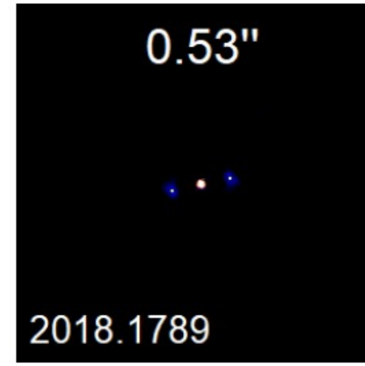


(c) HD 37330

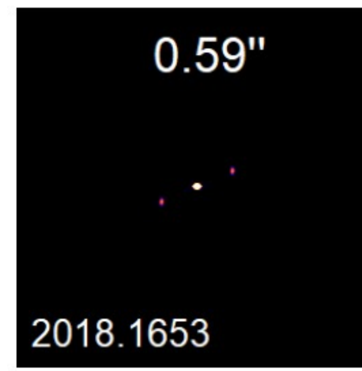
Obrigado!



(d) HD 41600



(e) HD 41335



(f) HD 45828

¡Gracias!

Guerrero et al. In prep.

PHYSICAL PARAMETERS

Parameter	HR 2364	HD 150193	HD 168625
Spectral characteristic	Be star	HAeBe	LBV Candidate
ρ [arcsec]	1.11 ± 0.01	0.93 ± 0.01	1.10 ± 0.03
θ [°]	45.1 ± 1.2	227.3 ± 1.1	21.8 ± 1.5
π_{Hip} [mas]	3.96	6.66	2.43
V_{Tot}	5.74	8.79	8.63
$(V-I)_{Tot}$	−0.16	0.59	8.36
ΔV	1.79	3.47	4.2
m_1	5.86	8.94	8.4
m_2	7.6	12.45	12.6
MK_{Tot}	B3Ve	B9.5Ve	B6Iap
MK1	B5V	F0V	B9V
MK2	K2III	K3V	G0V
a [AU]	280.29	144.09	452.52