Latest developments and results in lunar and asteroidal occultations at “professional” observatories

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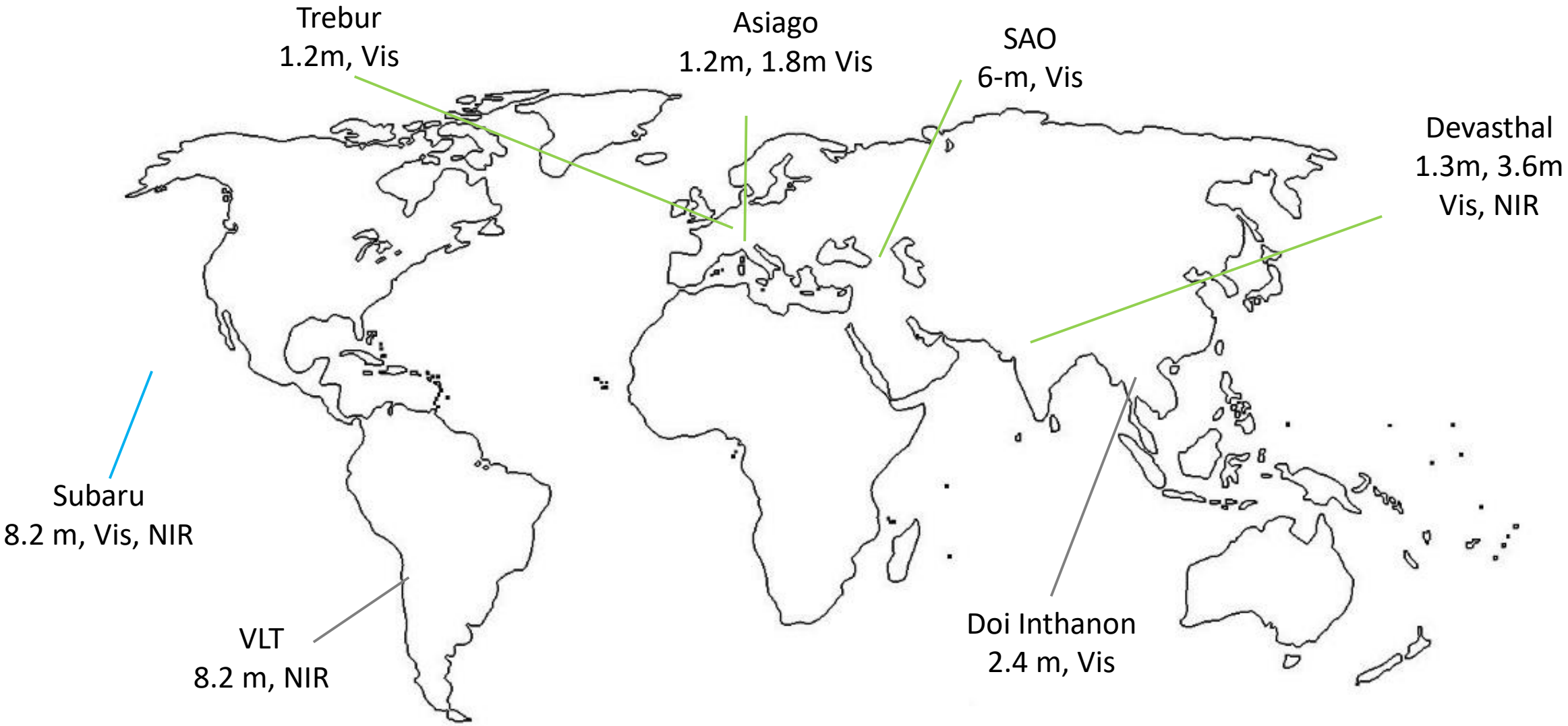
Some observatories with facilities for occultation observations



High angular resolution with Lunar Occultations

Milli-arcsecond (mas) resolution achieved from modeling (dependent or independent) of diffraction pattern generated at the lunar limb (telescope being only a photon collector). Hence, largely independent of seeing, clouds, and telescope size. Diffraction fringes move with speed > m/ms, hence time resolution ~ms is needed.

Main scientific drivers typically are:

- stellar angular diameters (effective temperatures, esp. needed for cool giant variable stars)
- binary stars (orbits, dynamical masses, colors, multiplicity, binary star formation rates, etc)
- spatial distribution of circumstellar matter, dust, molecules, but also photospheres and asymmetries

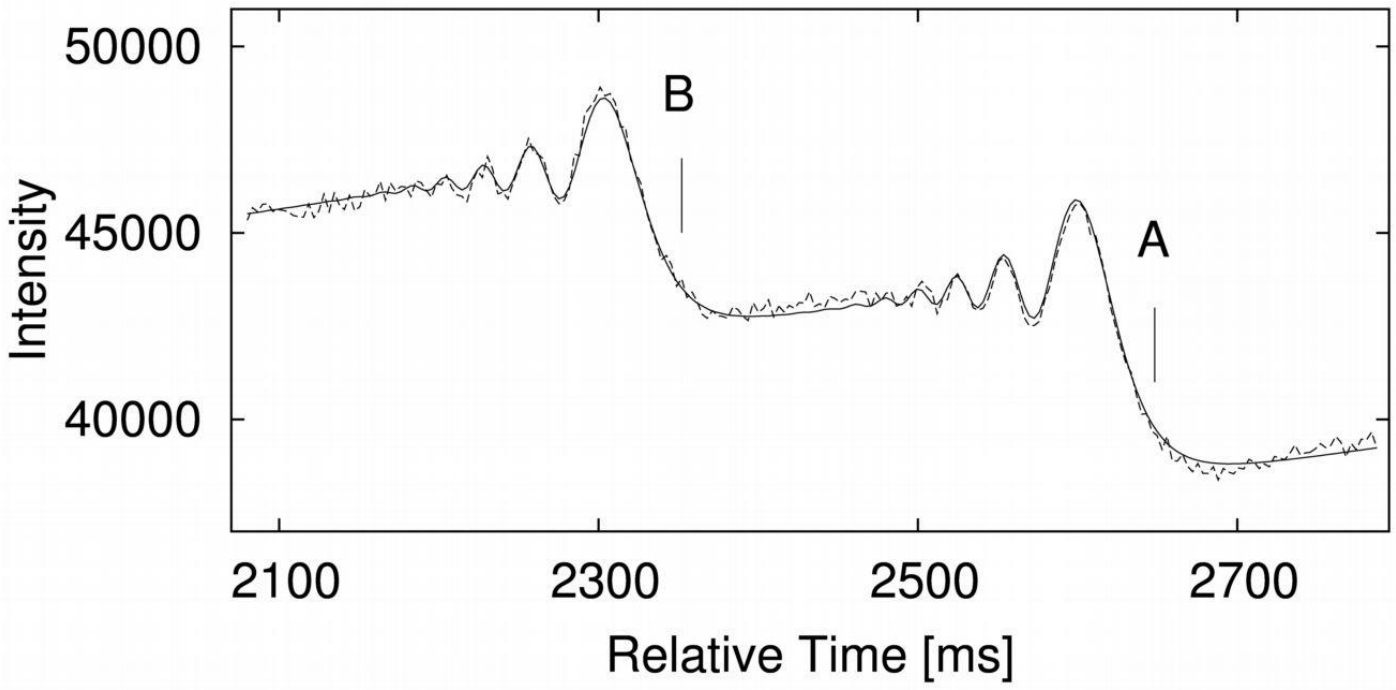
Competition/Complementarity with other high angular resolution methods:

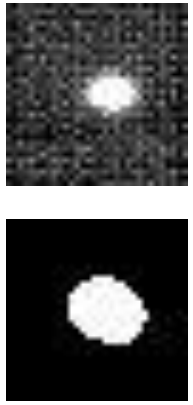
- Adaptive Optics (inferior resolution, higher sensitivity, targets, expensive infrastructure)
- Long Baseline Interferometry (comparable resolution, less sensitivity, targets, very expensive and time consuming)
- Radio arrays, Space missions, etc.

Example of a large separation binary

- HD 158122
- F5V, V=7.9, K=6.7
- known binary

- mask extraction required

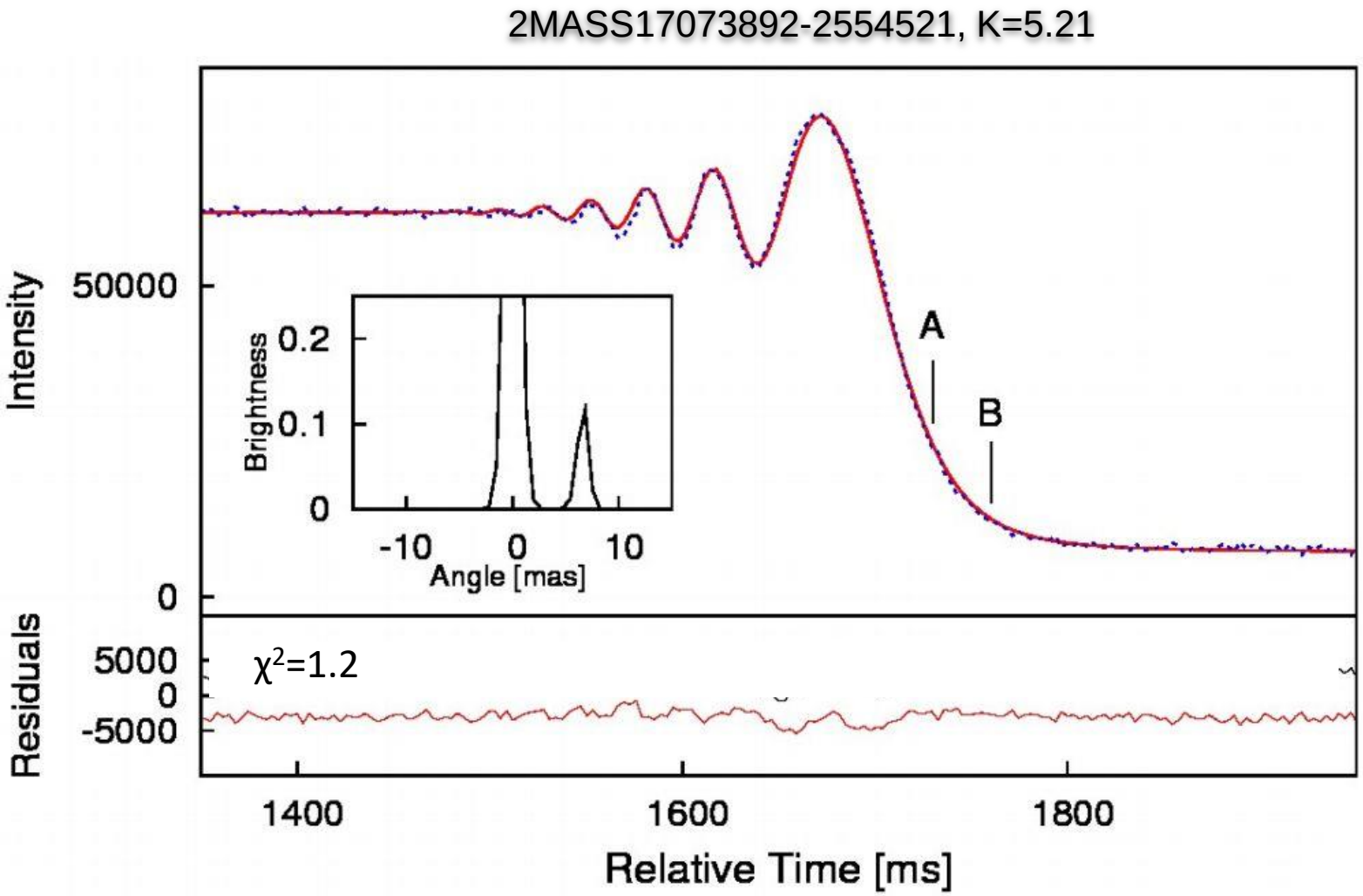




Proj. Sep.: 83mas
Br.Ratio: 1:1.2
SNR: 50

Richichi+ (2014) AJ, 147, 57

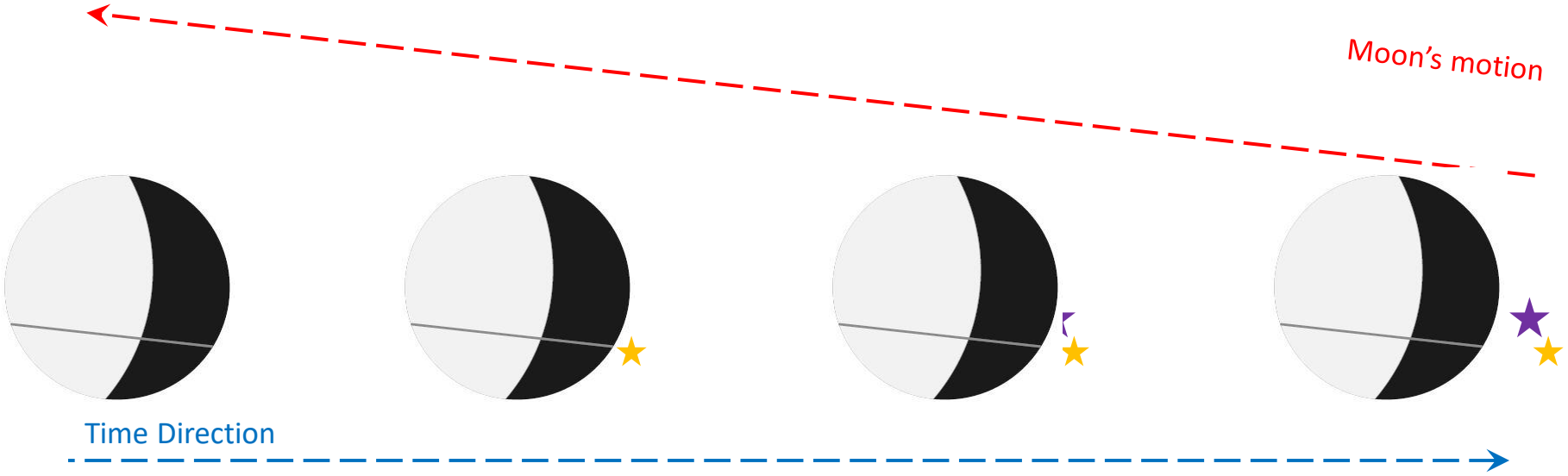
Example of a small separation binary

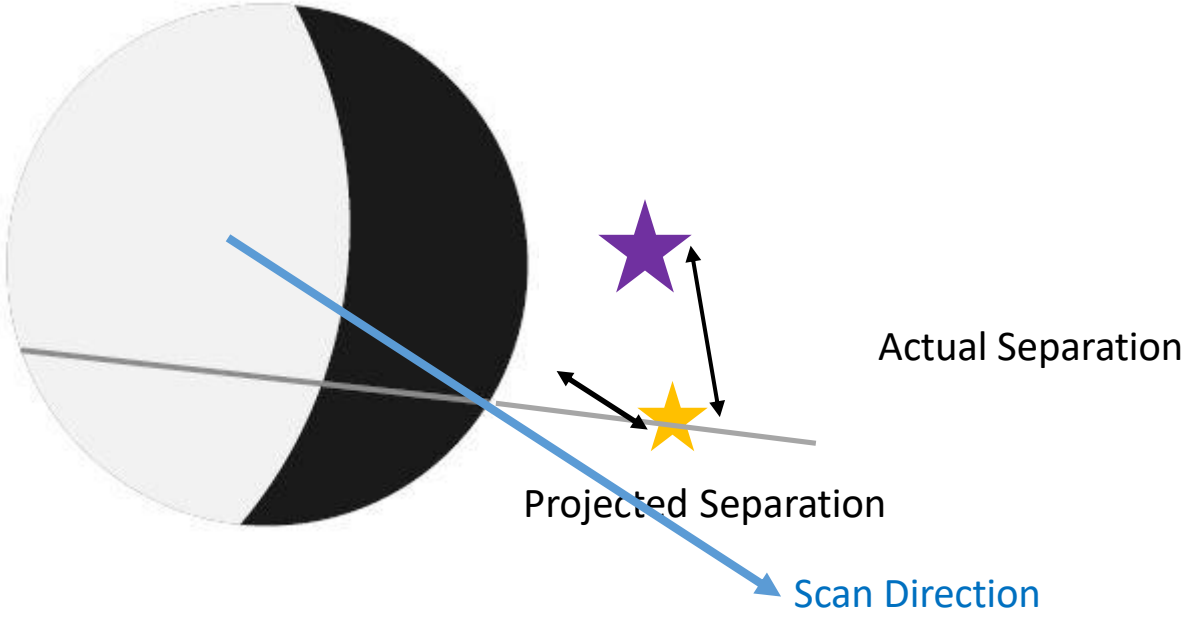


Sep=6.76±0.03 mas K_1=5.6, K_2=7.9

Richichi+ (2010), A&A 522, A65

Lunar Occultations measure projected separations





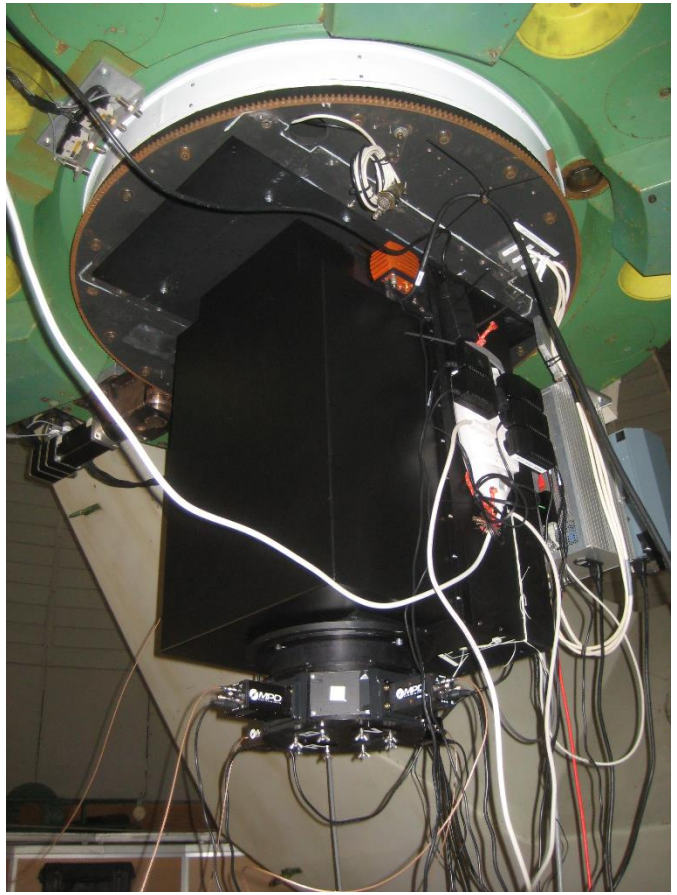
LO @ Asiago

National Institute for Astrophysics (INAF) & University of Padua

Aqueye (1.8m), Iqueye (1.2m)
4 SPAD detectors, < ns time res
R, I, Hα Filters

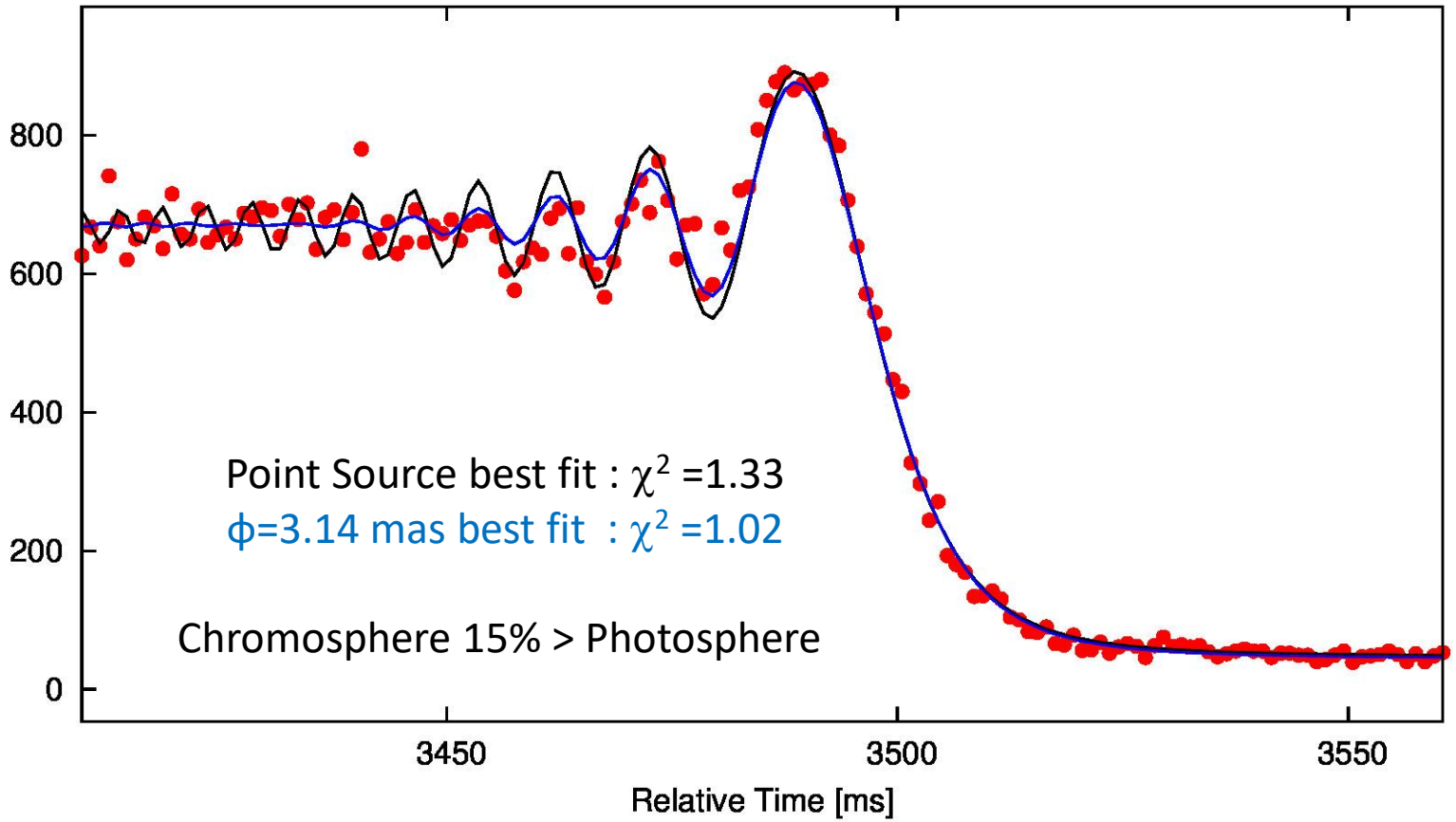
1.8-m

1.2-m



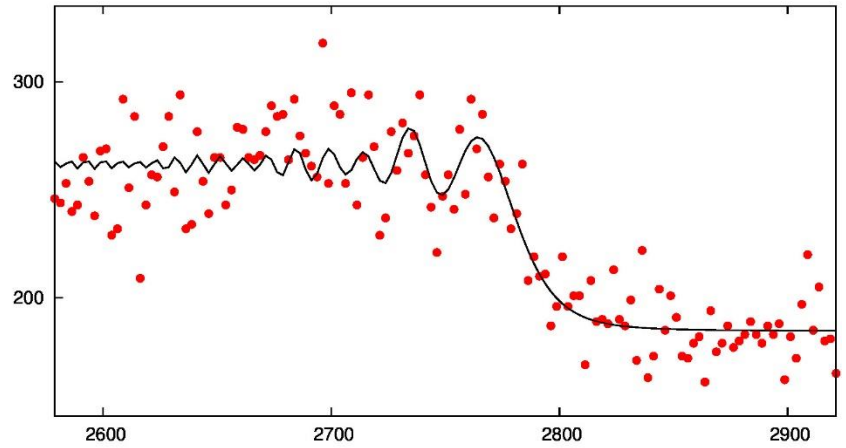
LO @ Asiago

μ Psc – K4III, V=5mag
16 Jan 2016 – 1 ms rebin - Hα filter

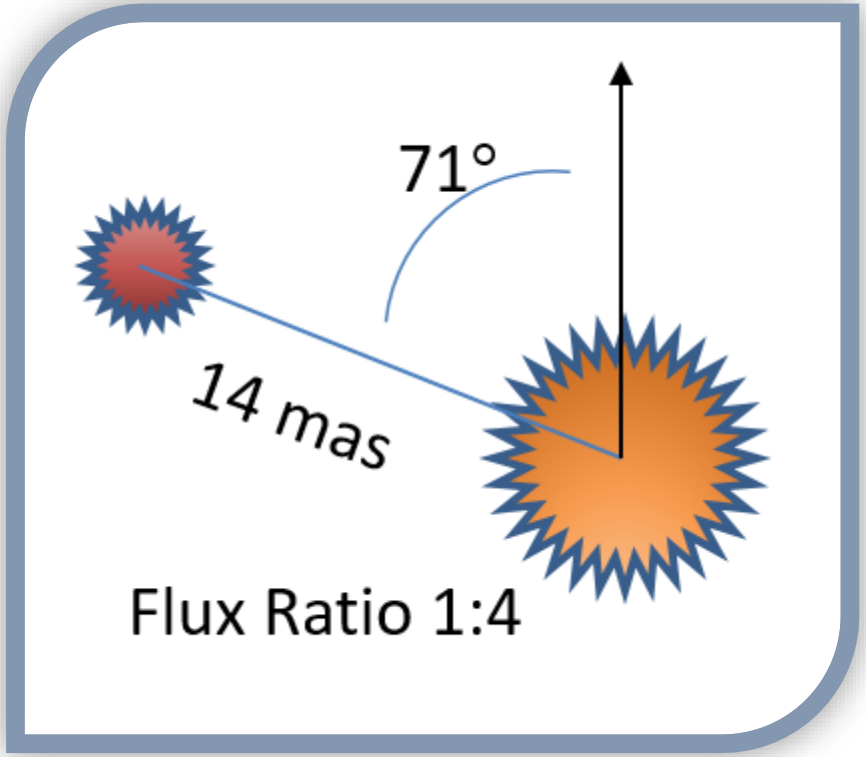


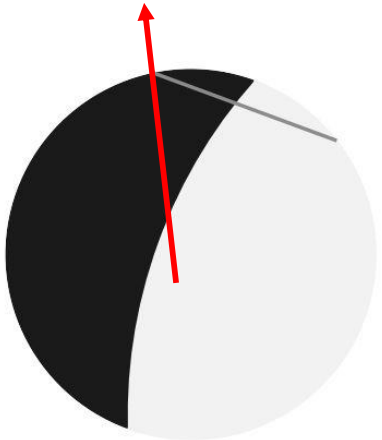
Zampieri+ (2019) AJ, 158, 176

LO @ Asiago

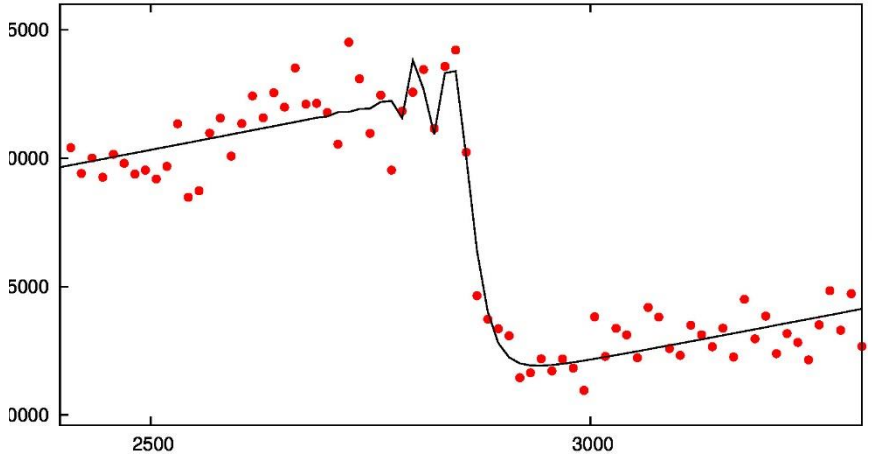


Marginally better fit for a binary model with 7 mas projected separation



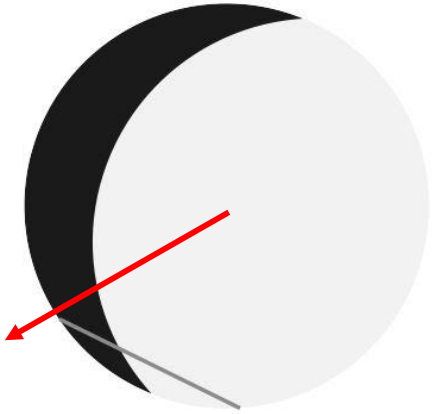


Asiago, 2016-01-16, PA=12°



Previous LO measured at TNO, also showing a binary with similar flux ratio

SAO 92922, K0, V=7mag



TNO, 2015-12-21, PA=124°

LO @ Devasthal

Aryabhatta Research Institute of Observational Sciences (ARIES)

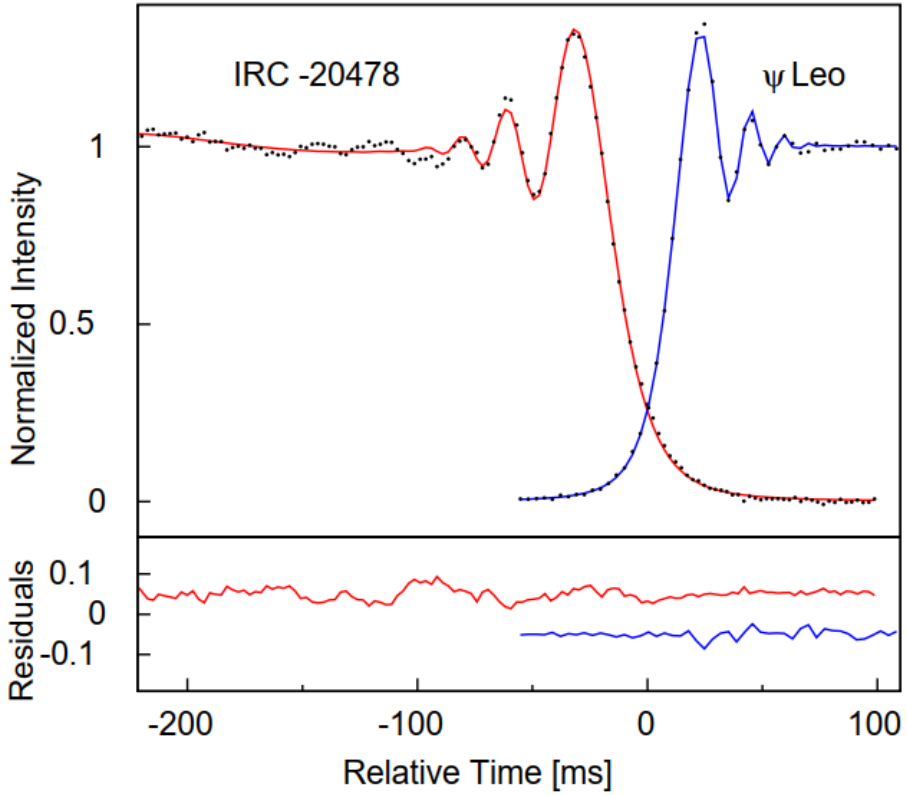
1.3-m RC Ritchey-Chretien F/4
frame transfer ANDOR iXon EMCCD

512 x512 16 µm pixels
Operated up to 500 fps
R,I filters

3.6-m Ritchey-Chretien F/2
TIRCAM2 (TIFR, Mumbai)

512×512 pixels InSb Aladdin III
Operated up to 60 fps
K filter

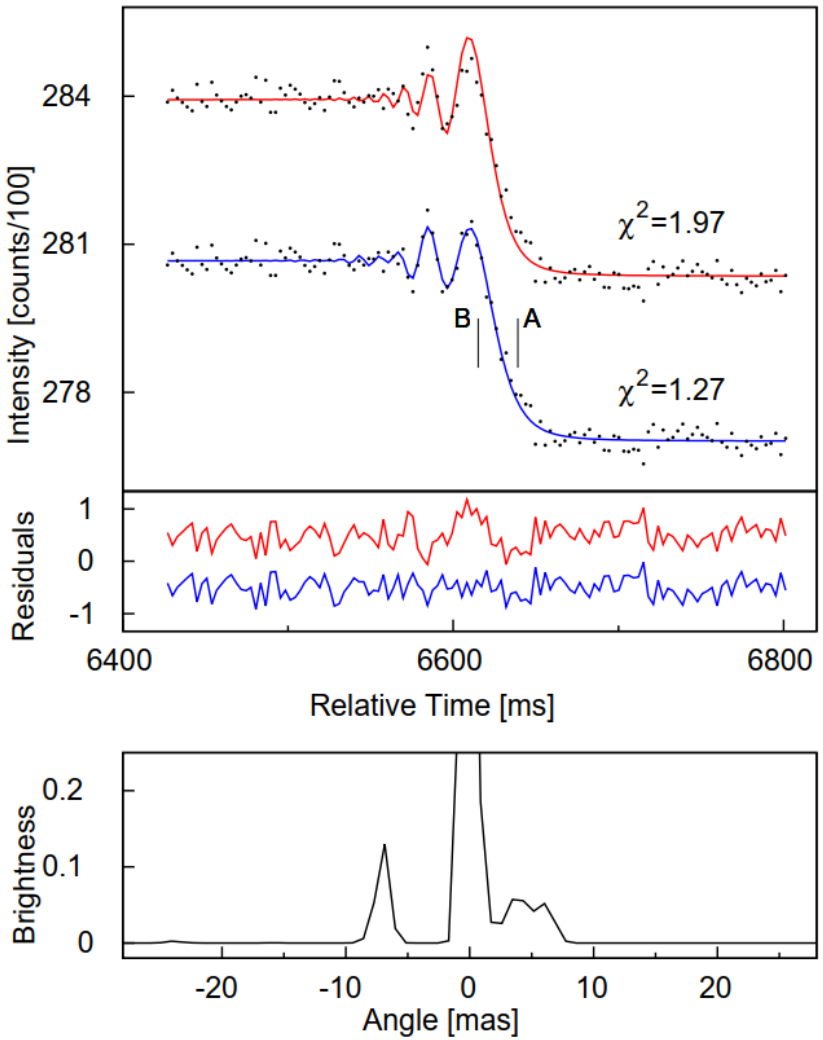
LO @ Devasthal



IRC -20478, V=4.9, K1, 25 Oct 2017
Diameter 2.57 ± 0.04 mas

Psi Leo, V=5.4, M2, 4 January 2018
Diameter 3.03 ± 0.03 mas

HR 1860, V=6.2, B6, 18 January 2019
Pr. Sep 6 mas, Ratio 1:4.6



Richichi, Sharma, et al, MNRAS, August 2020 (in press)

LO @ Trebur Observatory

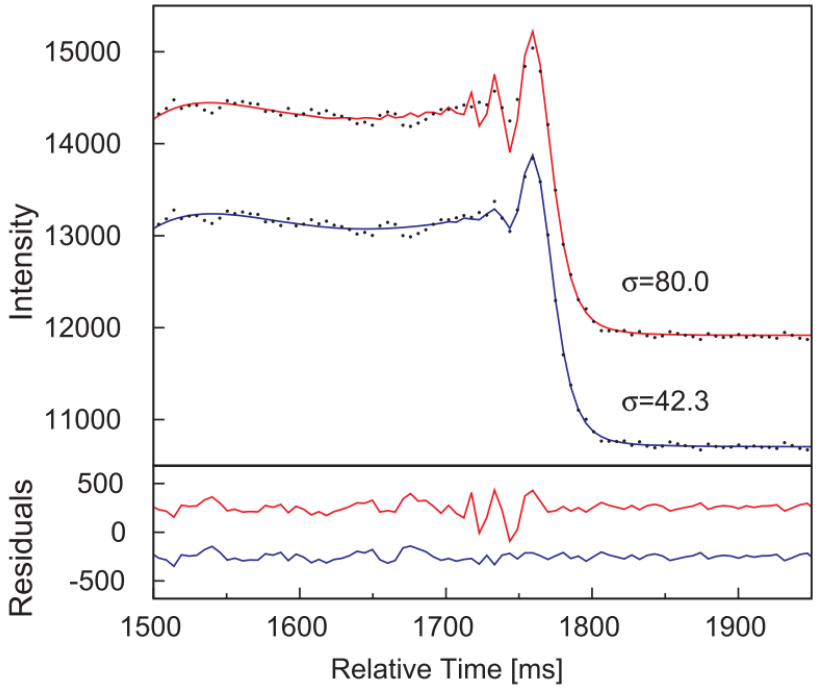
Astronomie Stiftung Trebur
Michael Adrian Observatorium

1.2-m Cassegrain telescope F/8
(Using focal reducer for LO)

QHY 5L-IIm CMOS camera
1280 × 960 3.75 µm pixels
Operated as 320x240 @ 200 fps
R,I filters

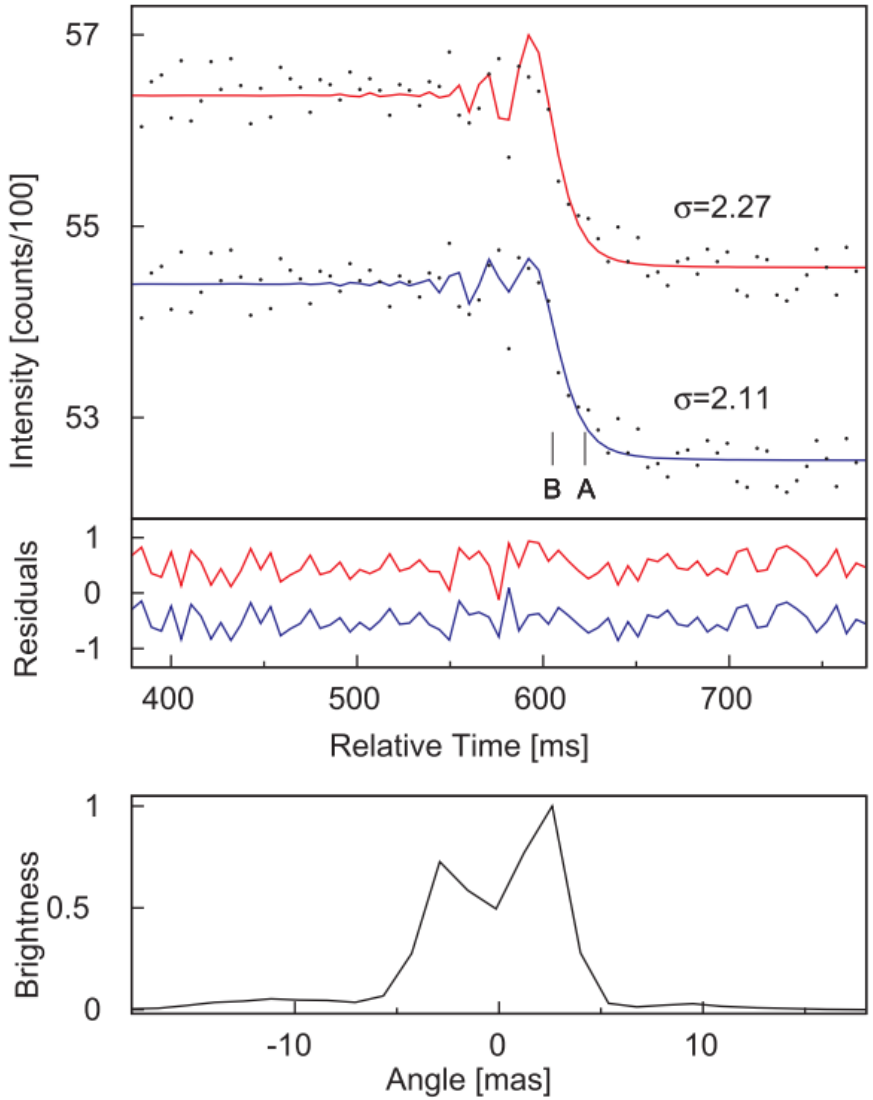
Observations by J.M. Ohlert

LO @ Trebur Observatory



T Cnc, V=7.6, C-N5, 30 April 2020
Diameter 5.94 ± 0.05 mas

SAO 119489, V=9.1, K2, 8 July 2019
Pr. Sep 5 mas, Ratio 1:2.4



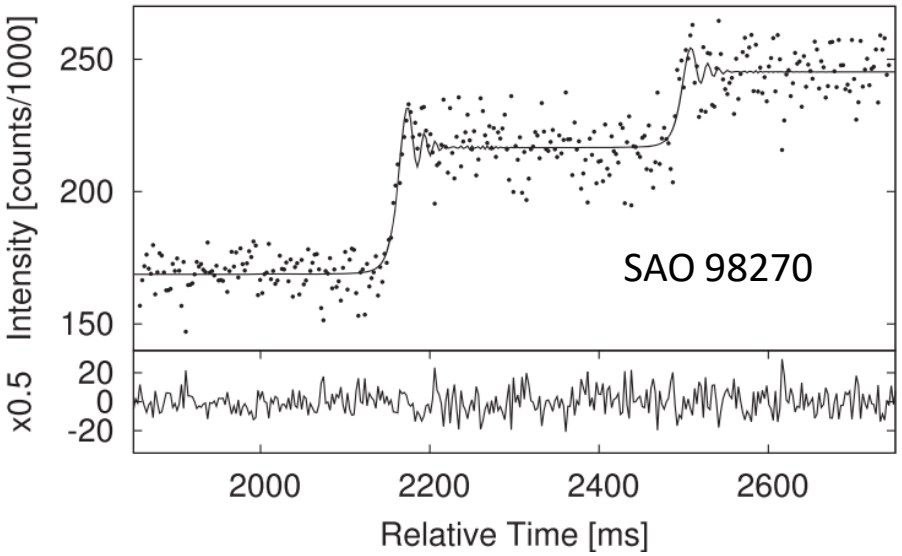
A. Richichi, J.M. Ohlert, New Astronomy, August 2020 (in press)

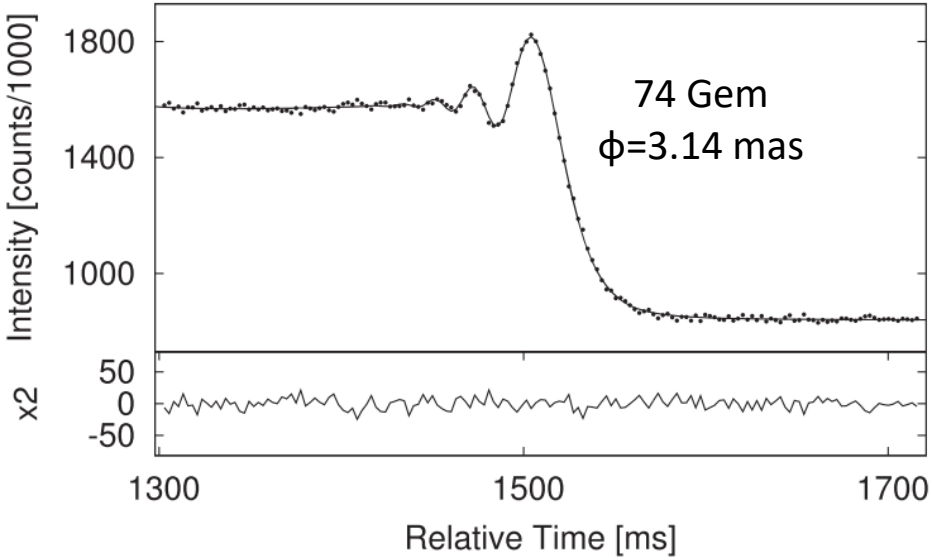
LO @ 6-m BAT

Special Astrophysical Observatory, Russian Academy of Science

6-m alt-az F/4

512 × 512 EMCCD
Andor iXon Ultra DU-897-CS0x512
for speckle interferometry
prime focus, with magnifiers
several broad/narrow band filters

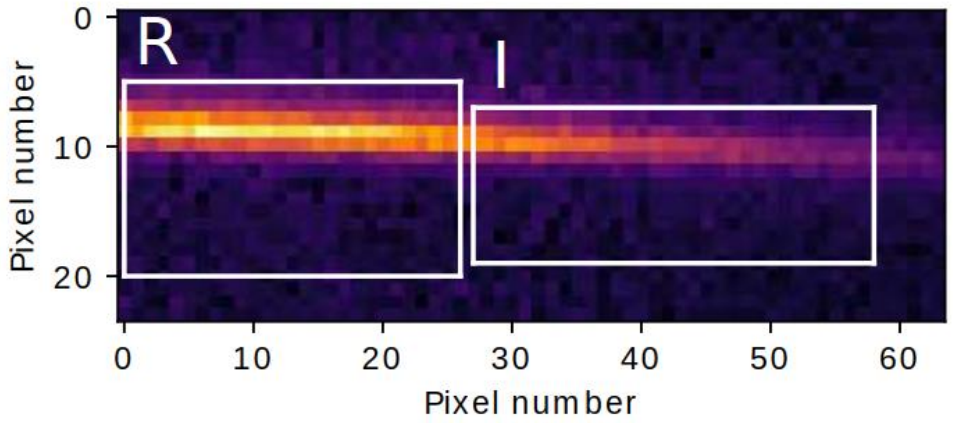


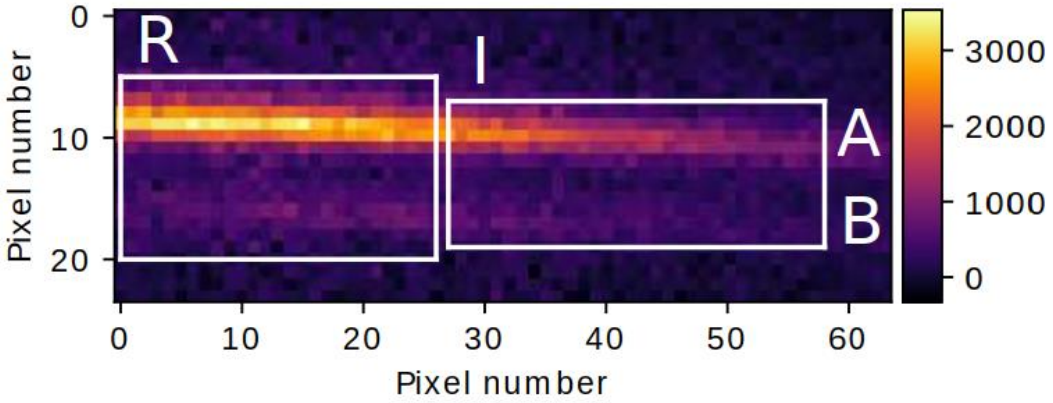


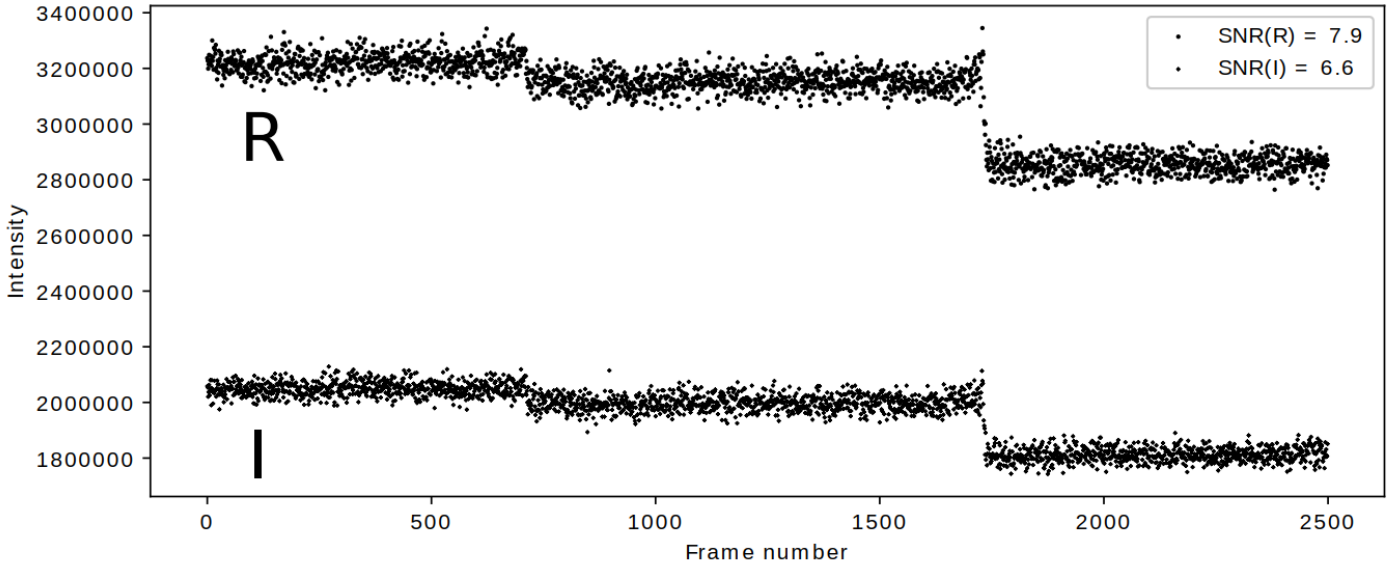
V. Dyachenko, A. Richichi, Yu. Balega et al. (2018) MNRAS, 478, 5683

Spectrally Dispersed LO @ 6-m BAT

First systematic, well characterized measurements of this kind.
64 or 128 channels from 600 to 900 nm at ms time resolution





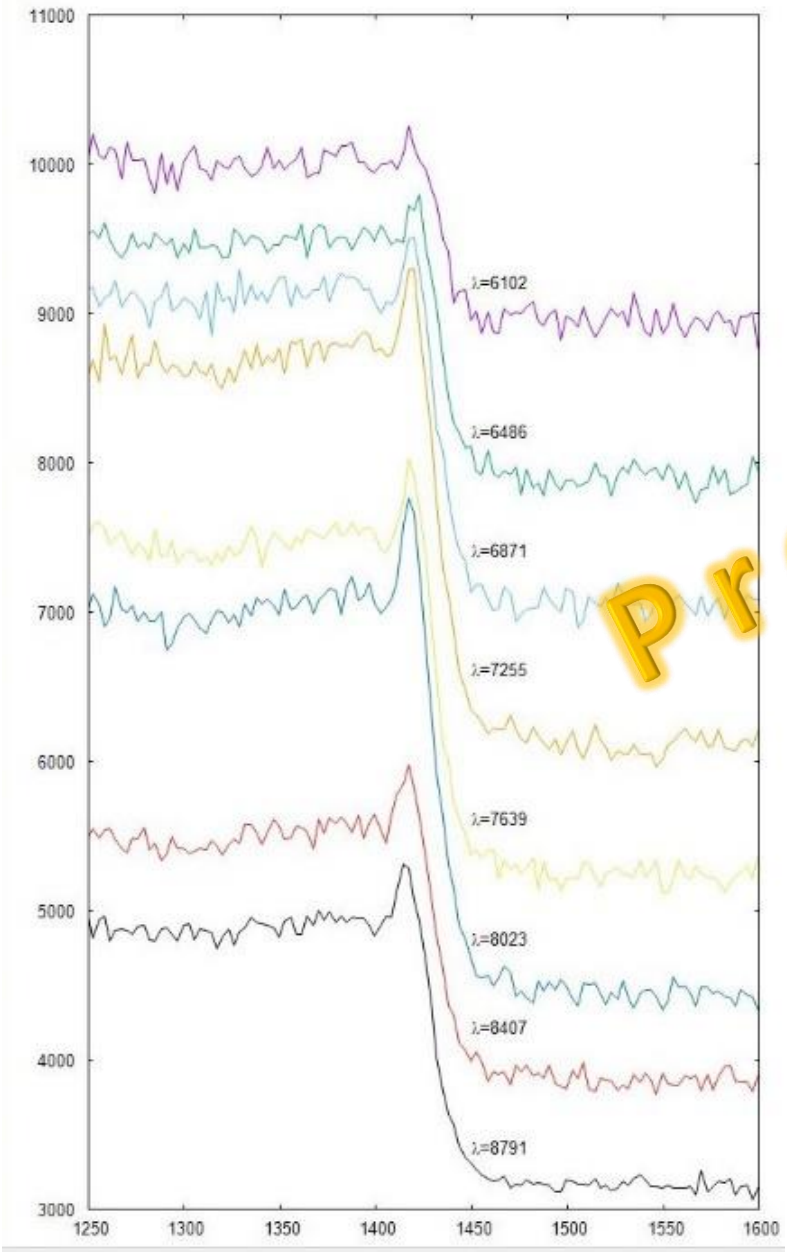


First test on the wide binary HD 36524, with wavelengths grouped to form R and I filters

	SNR	Intensity ratio	Measured Δm	Calculated Δm
R band	7.9	4.1 ± 1.1	1.53 ± 0.28	1.48 ± 0.05
I band	6.6	3.4 ± 1.0	1.34 ± 0.32	1.29 ± 0.05

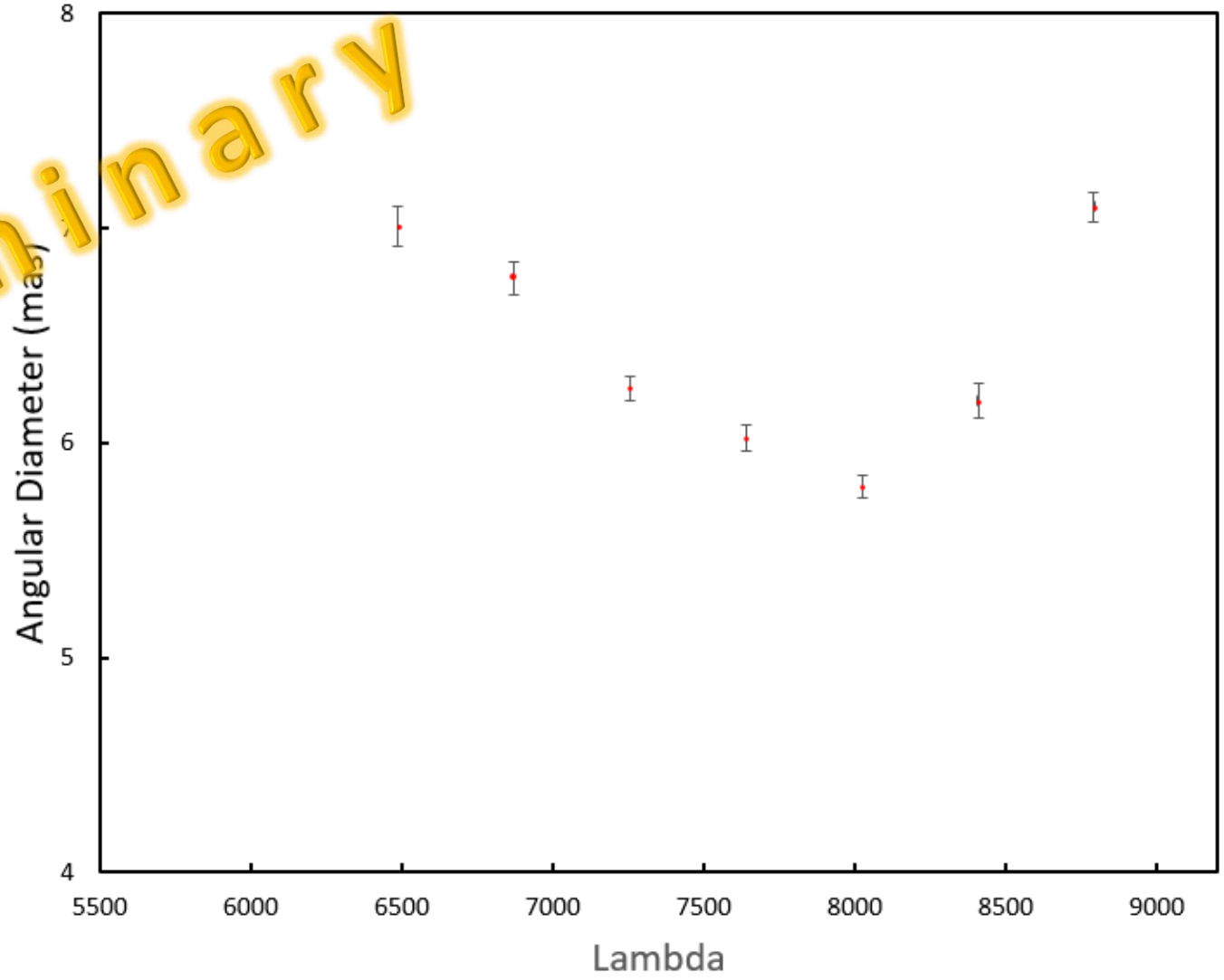
E. Shmaylova, V. Dyachenko, A. Richichi, (2020) RA&A, in press

Spectrally Dispersed LO @ 6-m BAT

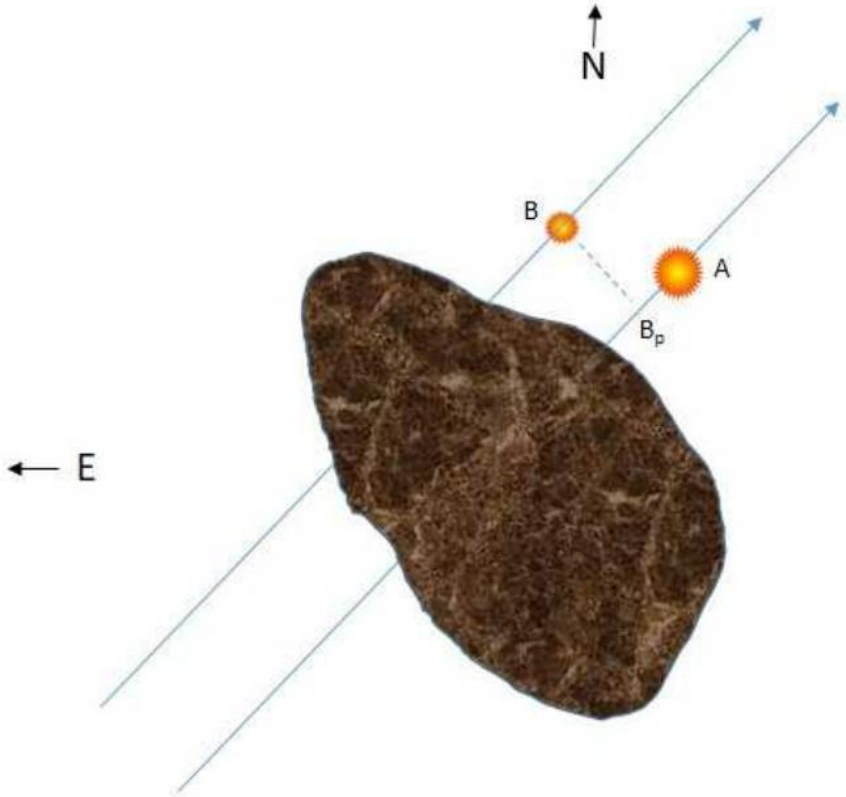


16 sources recorded so far

Y Tau, bright carbon star, 14 March 2019

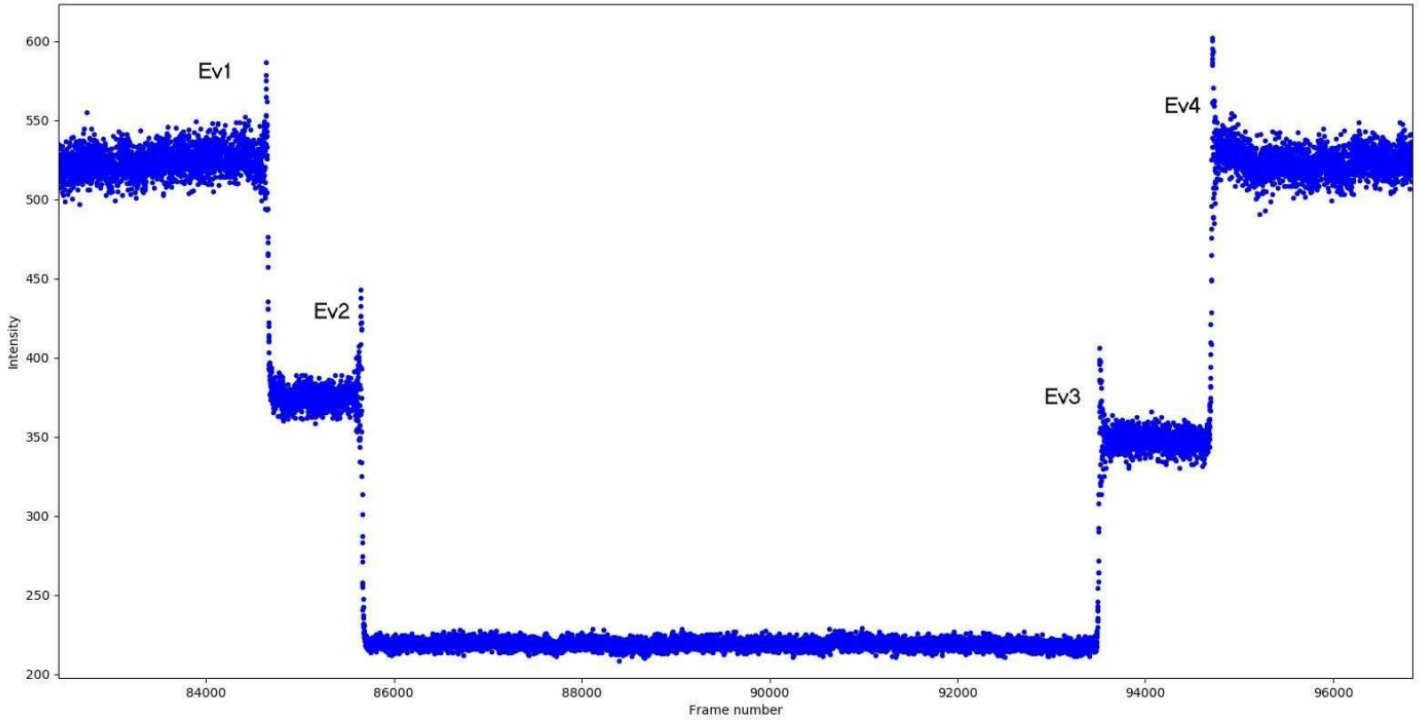


Asteroidal Occultation @ 6-m BAT



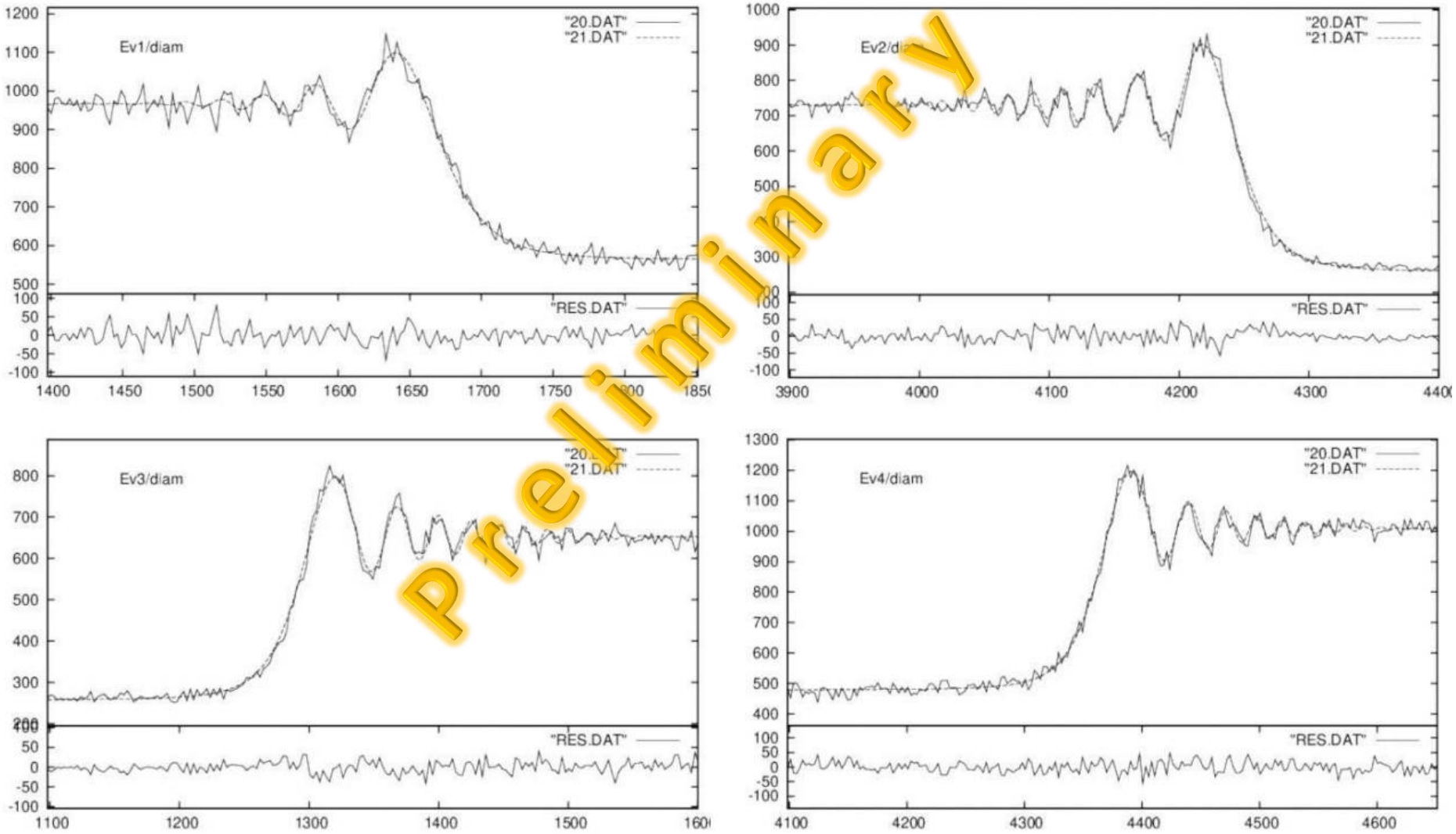
Scheme, not to scale
Event recorded Dec 12, 2019

Asteroid 87 Sylvia occulting TYC 1947-290-1 (V=10.9), revealed as binary with proj. separation about 10 mas



Asteroidal Occultation @ 6-m BAT

Four diffraction patterns well resolved in time, allowing us to measure
the angular diameters of both components (smallest direct measurement ever)



Conclusions

- A few “professional” observatories are still actively pursuing lunar (and asteroidal) occultations
- Results keep coming, often competitive with other high angular resolution techniques
- Occultations suffer from obvious limitations, but also have important advantages
- Required instrumentation is relatively cheap and occultations are well suited to fit any observatory budget

- Spectroscopically dispersed occultations are an innovative approach, with exciting astrophysical potential

- Asteroidal occultations are not only important to study asteroids, but with proper collecting power and time resolution can lead to unprecedented angular resolution on the occulted target

Some References

[1] Richichi, V. Dyachenko, A.K. Pandey, et al, 2017, Evidence of asymmetries in the Aldebaran photosphere from multi-wavelength lunar occultations, MNRAS 464, 231

[2] Richichi, O. Tasuya, P. Irawati, R.K. Yadav, 2017, Further Lunar Occultations from the 2.4-m Thai National Telescope, AJ, 154, 215

[3] Richichi, S. Sharma, A.K. Pandey, et al, 2018, Lunar occultations of Aldebaran and other late-type stars observed from Devasthal, New Astronomy 59, 28

[4] V. Dyachenko, A. Richichi, Yu. Balega, et al 2018, Lunar occultation observations at the SAO RAS 6-m telescope, MNRAS, 478, 5683

[5] L. Zampieri, A. Richichi, G. Naletto, 2019, Lunar Occultations with Aqueye+ and Iqueye, AJ, 158, 176

[6] E. Shmaylova, V. Dyachenko, A. Richichi et al, 2020, The first results of observations of lunar occultations in different spectral ranges at the 6-m telescope of the SAO RAS, Research in Astronomy and Astrophysics, in press

[7] Richichi, J.M. Ohlert, 2020, First Lunar Occultations Results from the Trebur Observatory, New Ast. in press

[8] Richichi, S. Sharma, T. Sinha, et al 2020, Further milliarcsecond resolution results on cool giants and binary stars from lunar occultations at Devashtal, MNRAS, in press