False-positives in transit-search programs

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Alonso, R., Carpano, S., Deeg, H. J., Deleuil, M., Dreizler, St., Endl, M., Fridlund, M., Gandolfi, D.,Gillon, M., Guillot T., Jehin, E., Léger, A., Moutou, C., Nortmann, L., Rouan, D., Samuel, B., Schneider, J., Tingley , B.

Why is it important to remove false-positives?

- Removing false-positives before starting with RV-measurements is important because RV-measurements require a large amount of observing time.

- If we would know that a large fraction of the candidates are really planets, we would be able to do “planet-statistics” just with the candidates.

A short look at Kepler - results

- 2011: based on stellar statistics Morton & Johnson estimate the FP-art to be ≤ 10%.

- 2012: Santerne et al. obtain RV-measurements of 46 candidates with transit depth >0.4% and periods of less than 26d, from which they derive a FP-rate of 46%.

- 2012: Colón et al. obtain multicolour transit photometry 4 candidates with $R \leq 6\ R_{Earth}$, two candidates are FP. The probability of identifying two false positives out of a sample of four targets is less than 1 per cent, assuming an overall false positive rate for Kepler planet candidates of 10 per cent.

- 2012: Lillo-Box et al. observes 98 candidates using lucky imaging. In 41.8% of the candidates, they find at least one additional star within 6 arcsec. In 17% there is at least one star within 2 arcsec. Of these, 42% of the same i-z colour as a physical companion.

Excluding false-positives

- Detailed modelling of the LCs (talk by Pascal Bordé).
- Seeing-limited observation in and out of transit (talk by Hans Deeg).
- Photometry/low-resolution spectroscopy to exclude giant stars (talk by Cilia Damiani and poster by Matthias Ammler-von Eif)

---> AO-imaging

---> NIR spectroscopy

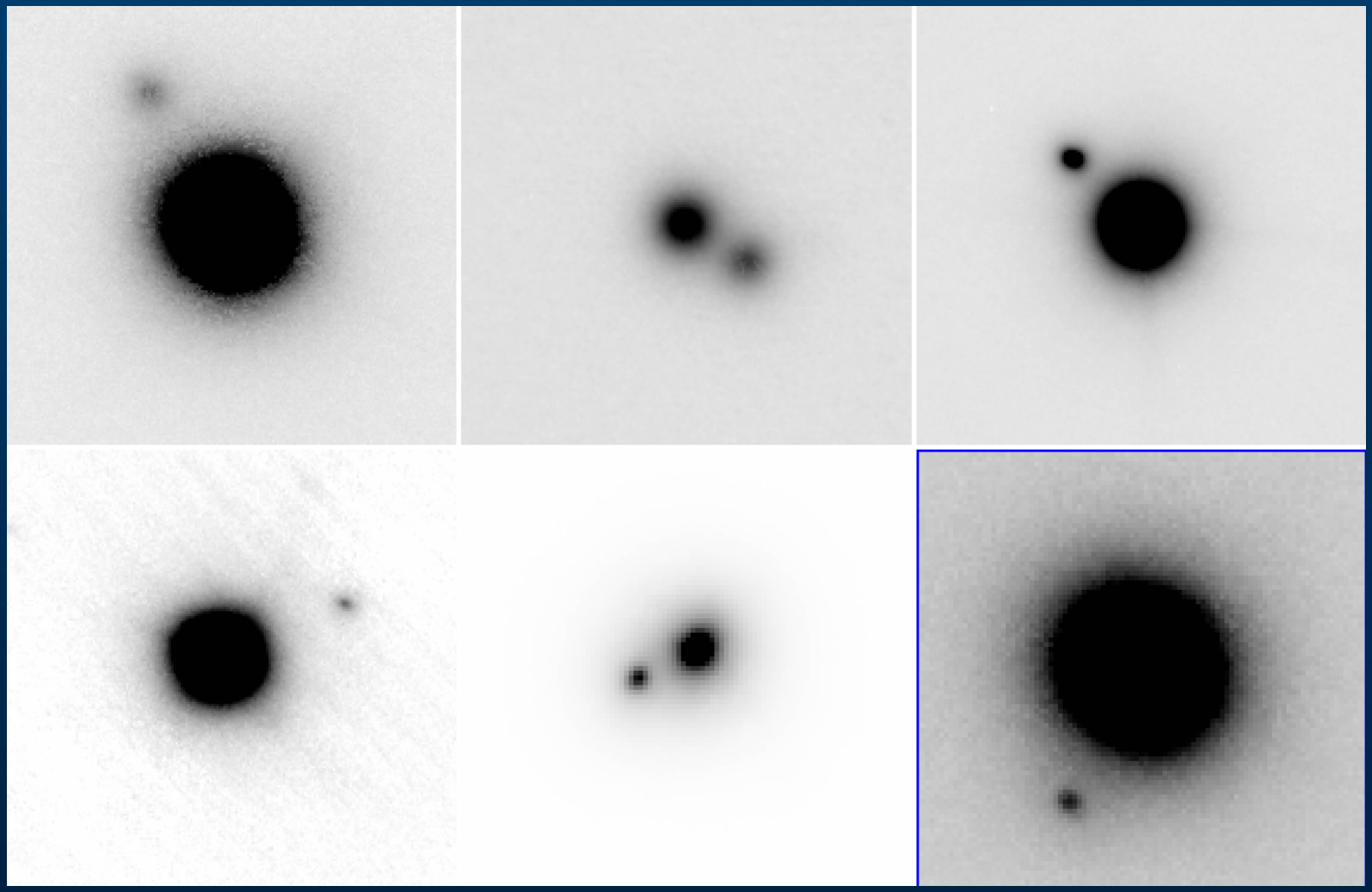
- RV-observations (talk by Francois Bouchy)

AO-imaging with NaCo

From the brightness of the star and the depth of the transit, we can calculate from the depth of the transit and the brightenesof the stars that a potential FP has to be brighter than X mag. X is typically in the range between V=19.9 to 23.0 mag.

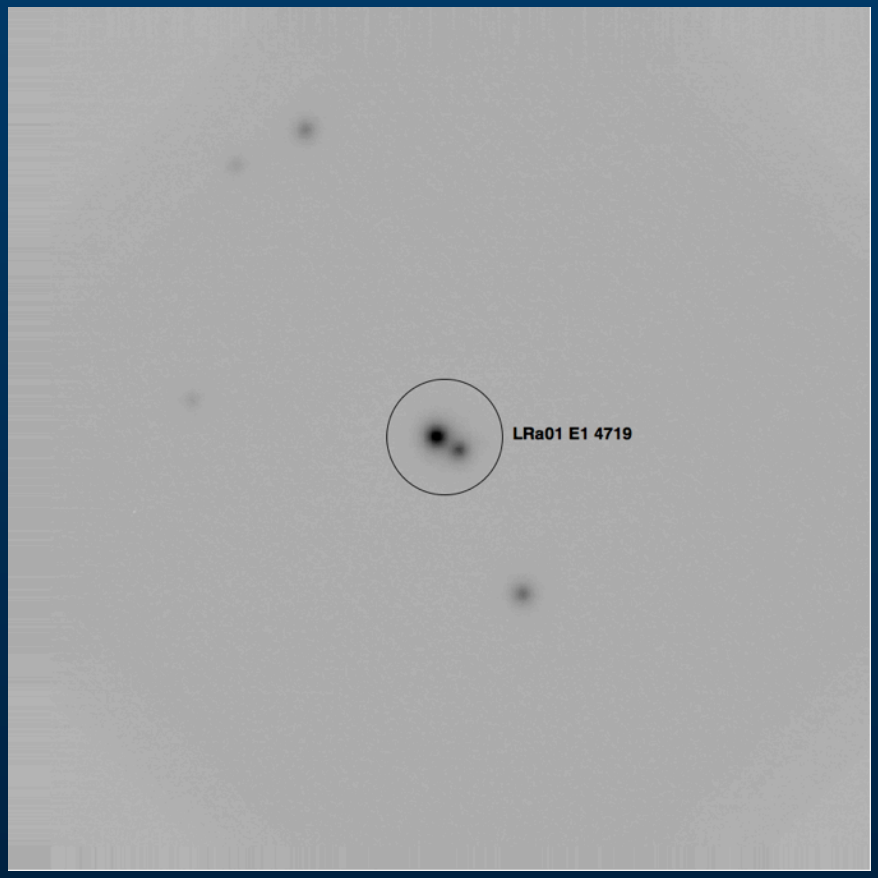
- 17 CoRoT candidates
- Observation in J(K)-band
- Challenge: CoRoT observes in the wavelength-region from 370-950 nm (peak sensitivity 600-700nm) but NaCo observations are at 1250nm--> Bright would the FP be in the J-band?
- $V_{579\text{-}642nm}$ - J = 1.6 to 2.0 mag for LRa-fields, and 3 mag for LRc-fields (FPs should be brighter than 18 to 21 mag)
- Limiting magnitude of the NaCo images: J=21.7 to 22.4

We found in 6 of the 17 stars that are bright enough to be FPs. They have separations between 0.8 and 1.8 arcsec and are between J=14.5 and J=18.8.



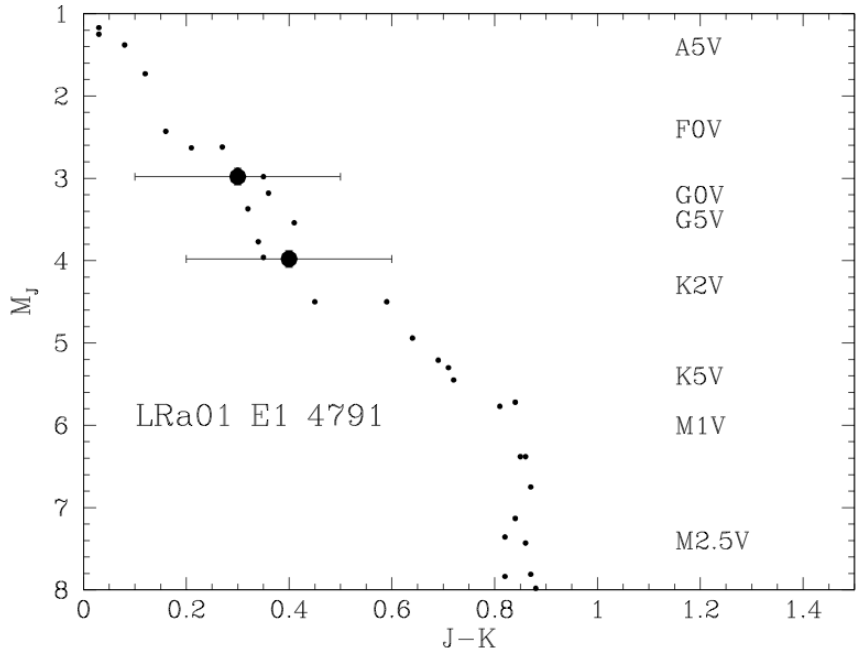
When possible, we obtained J and K-and images in order to constrain the spectral type of the companion candidates. Example: LRa01-E1-4719

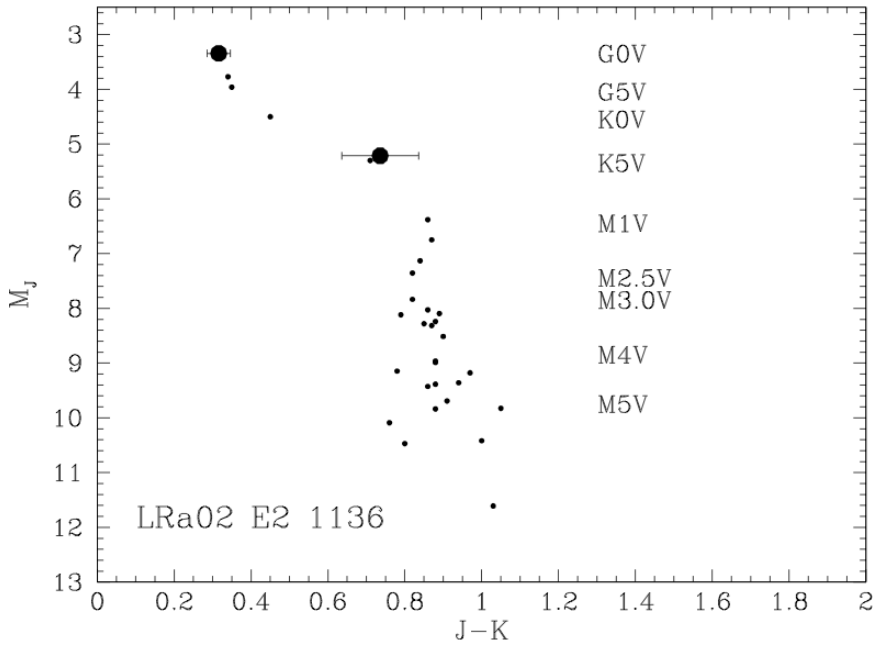
J-band

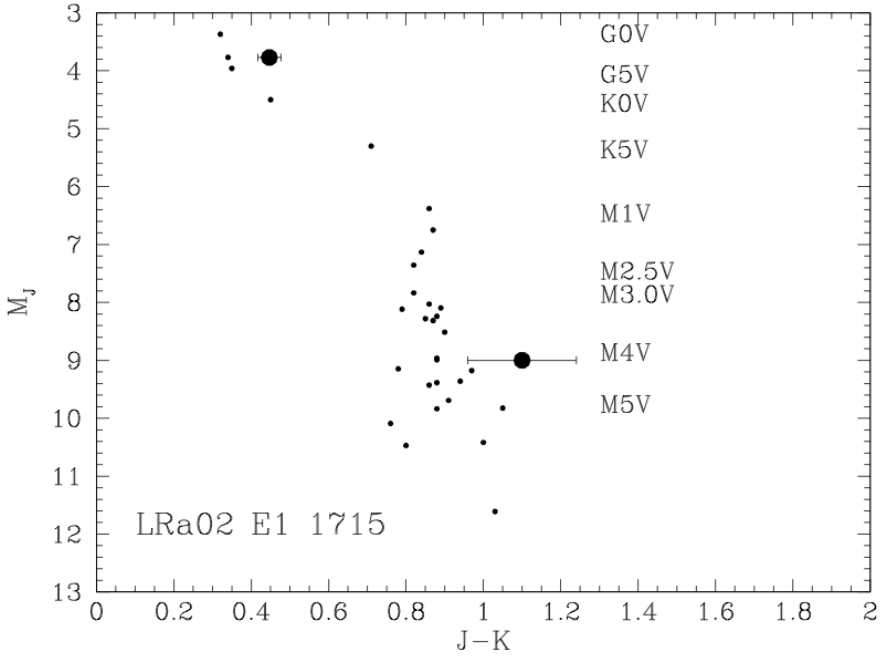


K-band

In all three cases in which we obtained J and K-band images, the J-K colours match very well those of physical companions. However, unrelated background stars have J-K=0.6 to 0.7, which is not that different!



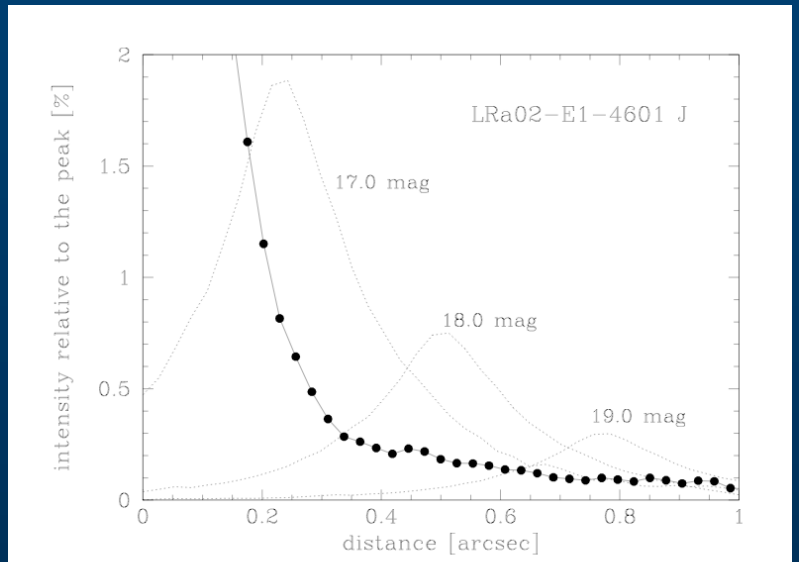


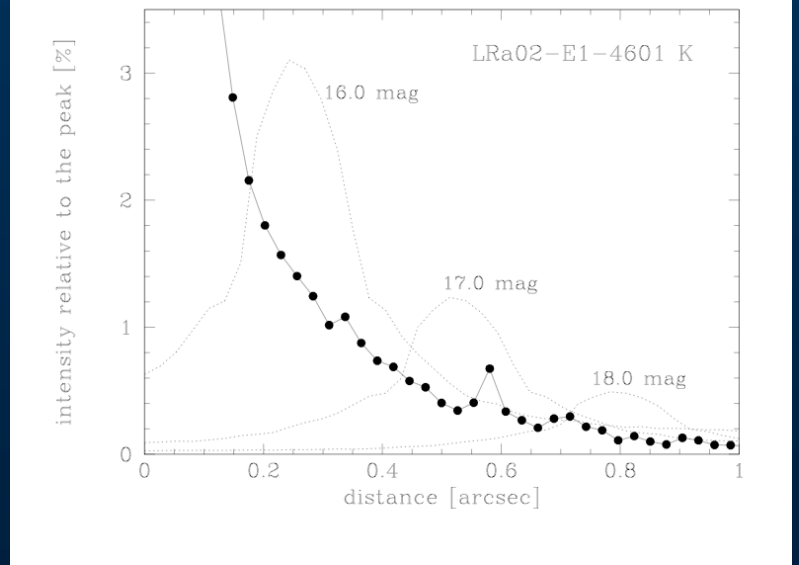


NIR spectroscopy with CRIRES

The NaCo images do not allow to exclude FP with separation of less than, say, 0.5 arcsec.

--> Use IR spectroscopy

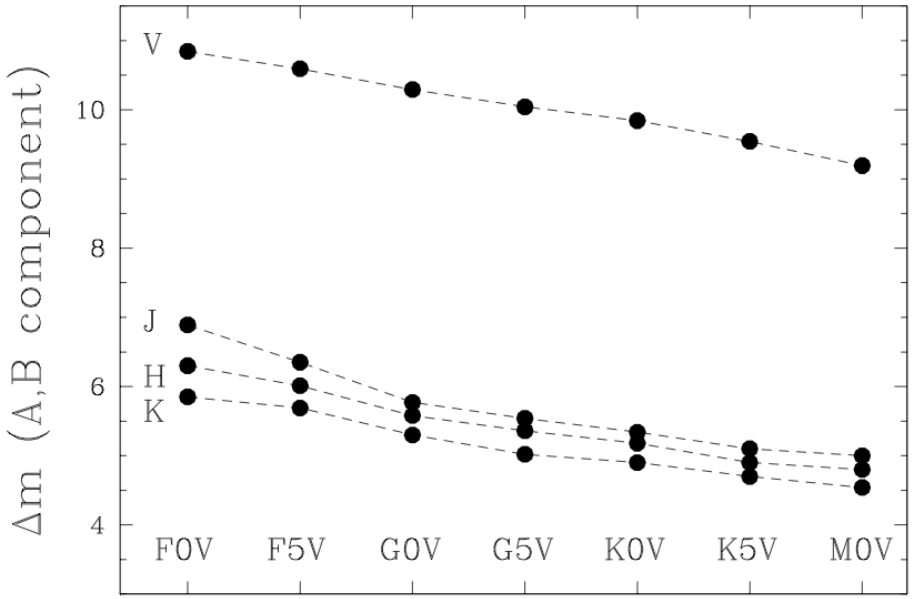


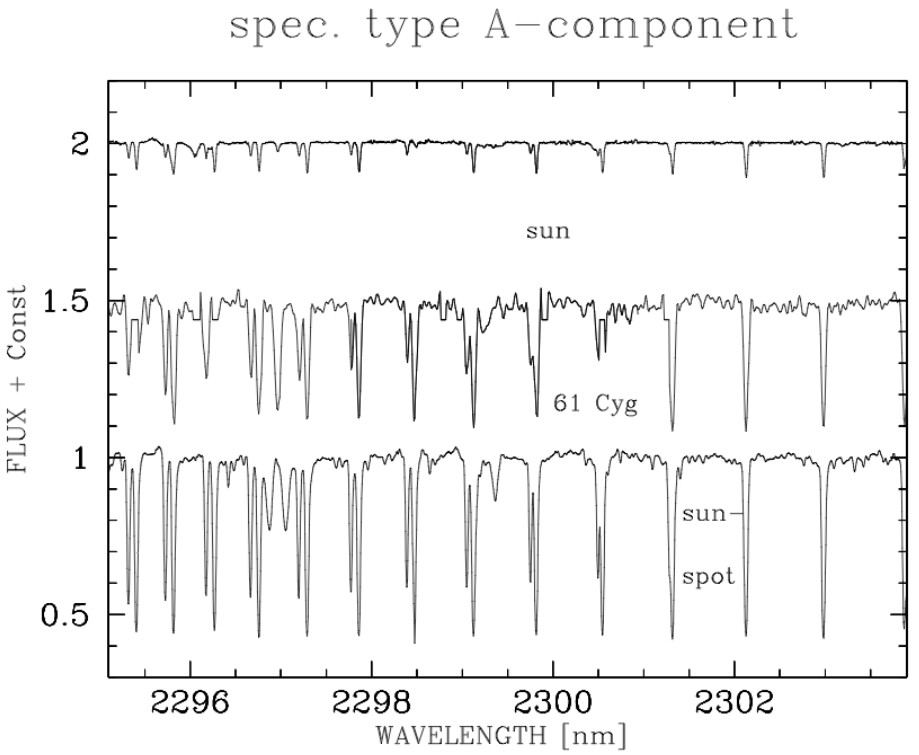


The basic idea:

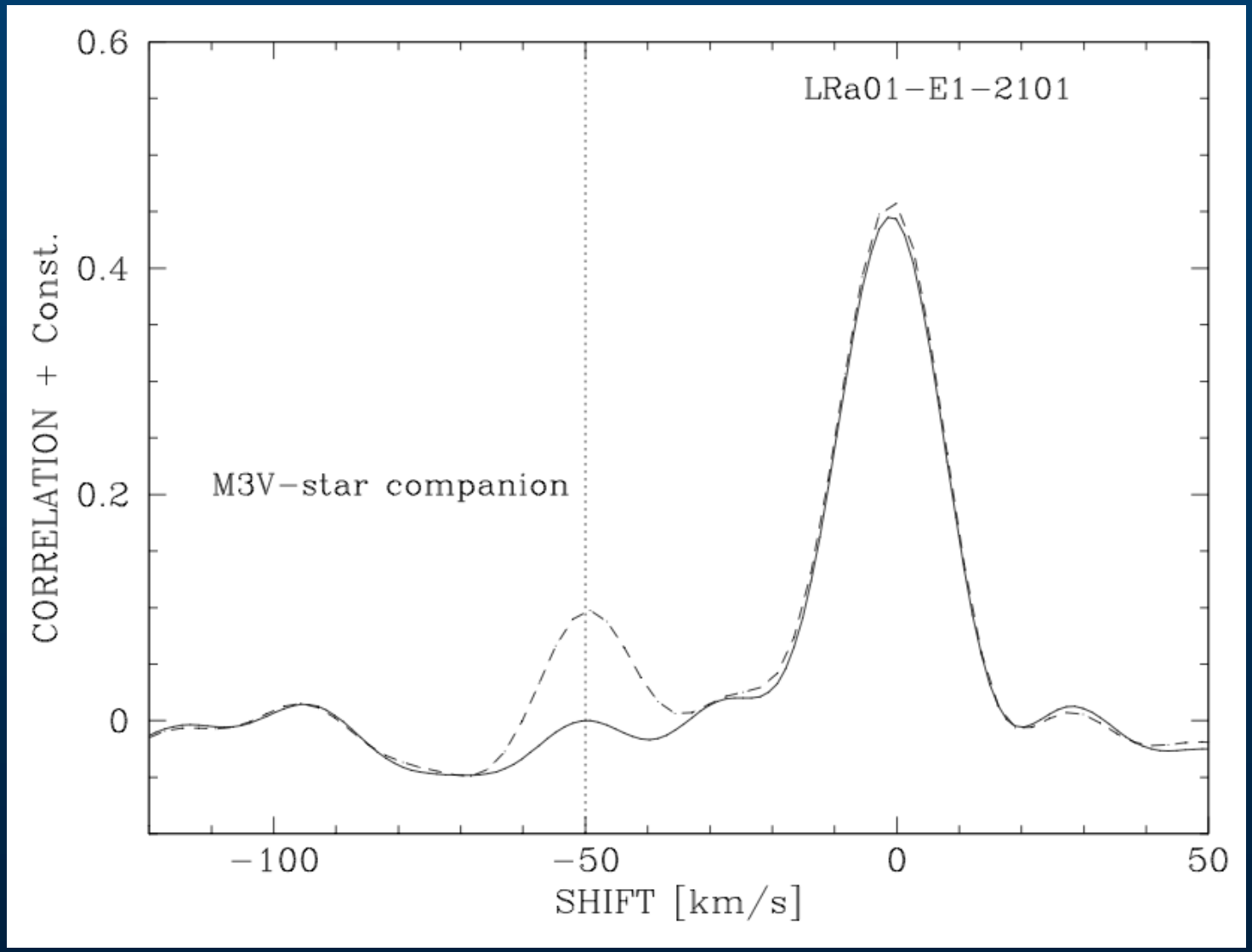
(article by Eike Guenther and Lev Tal-Or 2010)

- The brightness difference between a G-star and a potential FP is much smaller in the IR than in the optical (upper Fig.: brightness difference between a primary and a secondary that mimics a transiting Jupiter-like planet).
- The CO-lines become stronger for cooler stars





Using the CC-technique even a very faint late-type companion can be detected



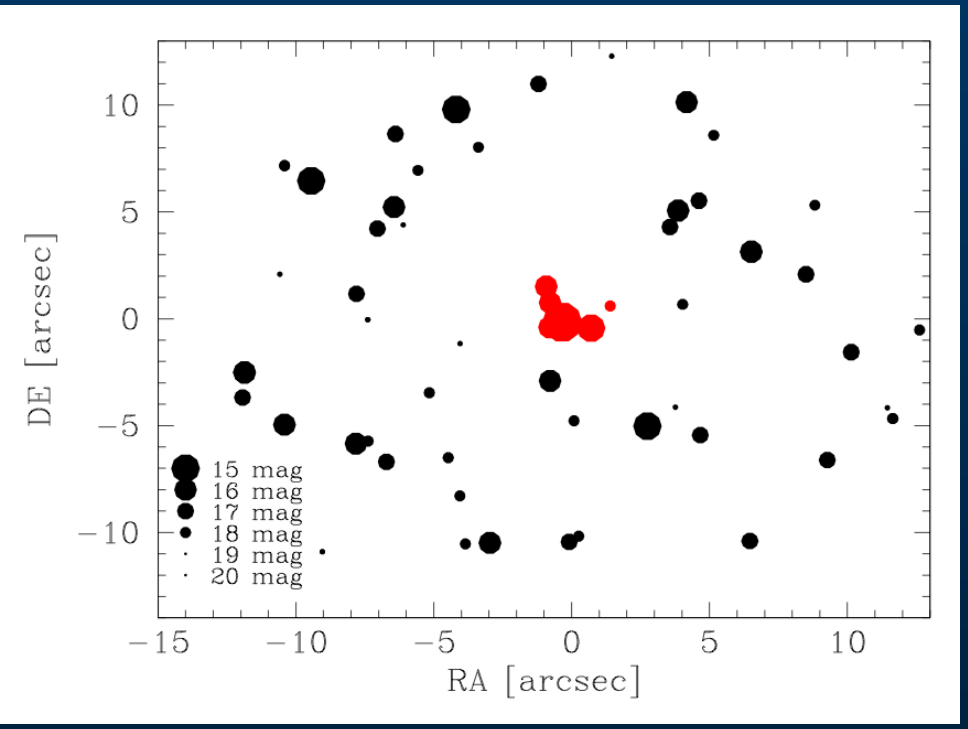
Results of the CRIRES observations

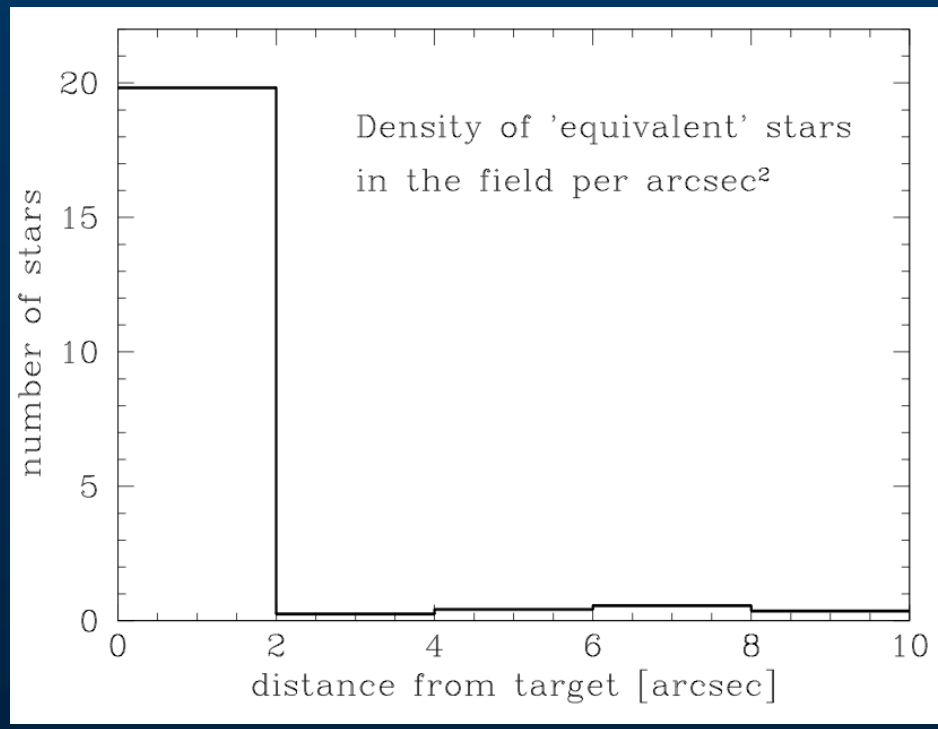
- Given that the size of the mask is typically 35x23 arcsec^2, and the seeing-limited NaCo observations allow to detect stars in 99.6% of the area of the mask--> unrelated background objects are unlikely.
- We have observed 17 candidates with CRIRES. For 16 we can exclude a FP.
- Spectral types of the primary is needed in order to judge whether CO-lines detected are from the primary, or and undetected late-type companion (TLS-NASMYTH spectrograph).
- On G and K-stars we can typically exclude M0V to M3V stars. This is not fully sufficient

  --> new instrument CRIRES+

Results and interpretations I

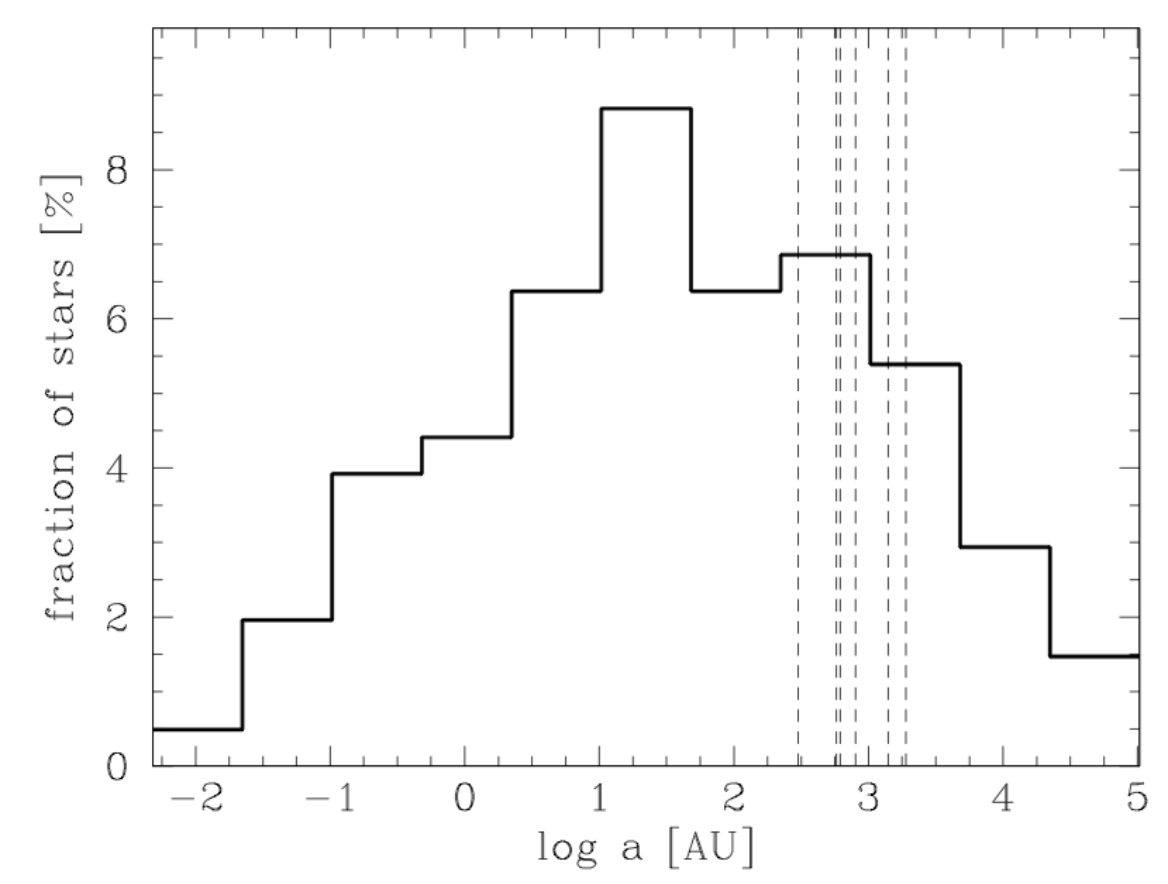
- NaCo: companion candidates found for 6/17 stars within 2 arcsec
- The density of stars is 14 times higher within 2 arcsec of the targets than in the general field (we would have expected to find one star instead of 6)
- If we take the brightness of the star into account (the number of star increase by a factor of 2.1 per mag), the excess is even 50 times.





Results and interpretations II

- NaCo: companion candidates found for 6/17 stars = 35+/-15%. If there were binaries they would be at projected distances between 300 and 1900 AU.
- Expected is that only ~6% of the stars are binaries of this kind.




...life is full of
surprises
(Tagana, Tenerife 18.03.21013)