# High-resolution échelle at Skalnaté Pleso: future plans and development

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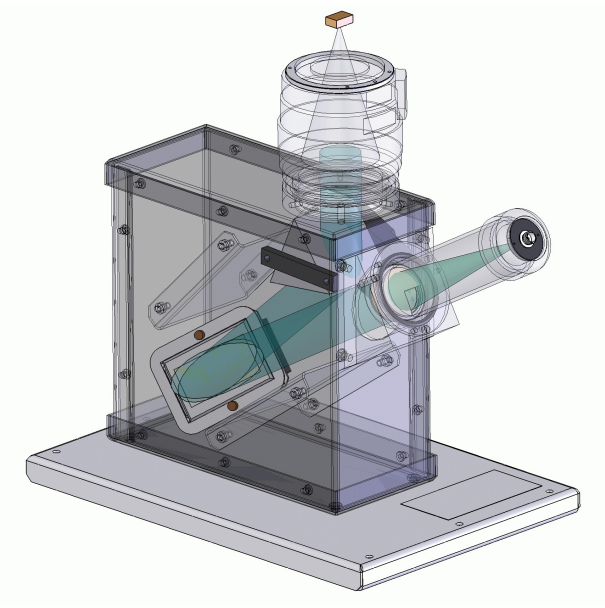
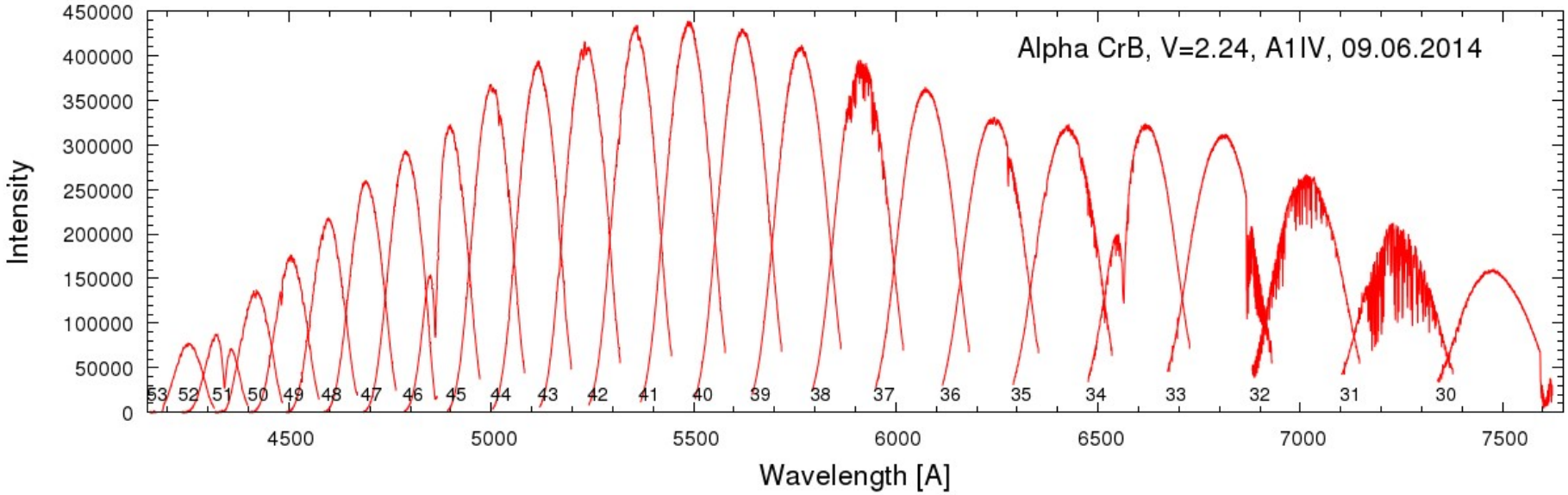
# Stará Lesná observatory

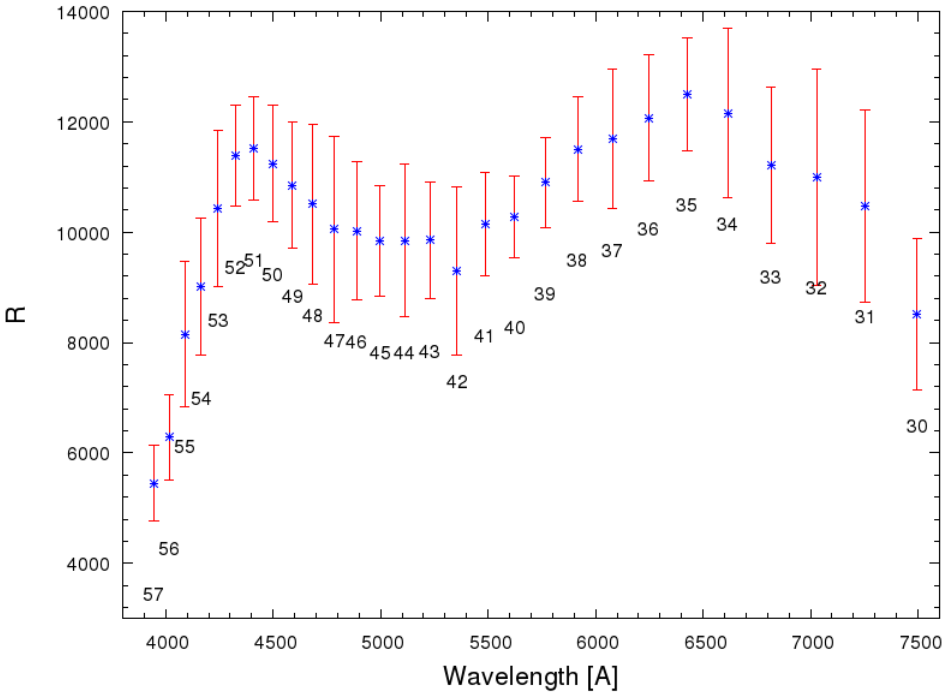
# Fiber-fed eShel @ 60cm

- focal reduction from f/12.5 to f/6 + f-ratio degradation
- Littrow design with f/5, prism cross-disperser, 125mm collimator
- useful spectral range: 28 orders covering 3920-7100 Å
- calibration lamps: ThAr, Tungsten, blue LED
- CCD detector: ATIK 460EX camera, ron = 5.1 e-, gain 0.26, 2749 x 2199 pixels, 4.54 um pixel
- f/6 FIGU, WATEC 120n guiding camera



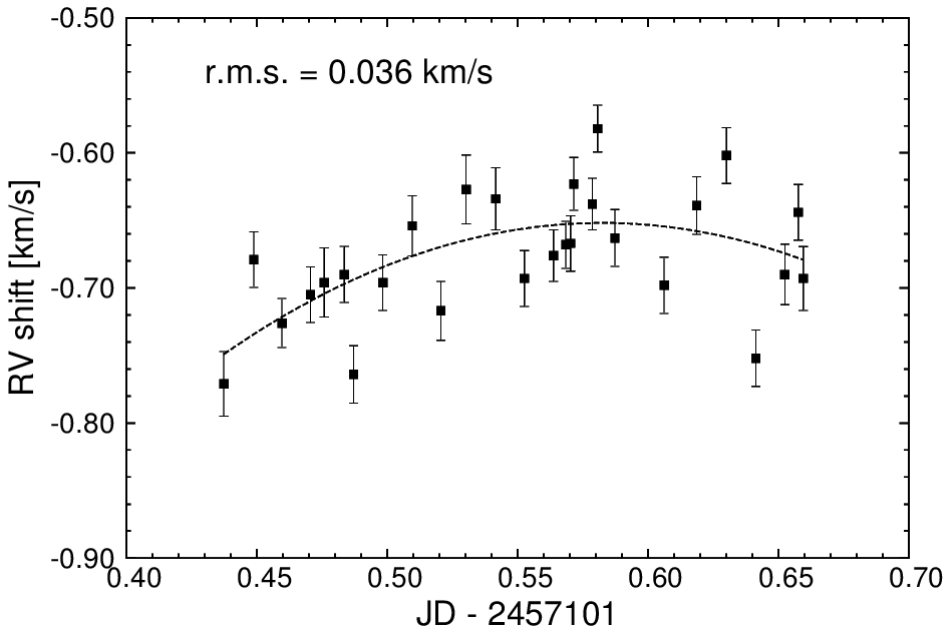


# eShel performance




Resolution measured on non-blended ThAr lines, depends on focusing the Canon lens

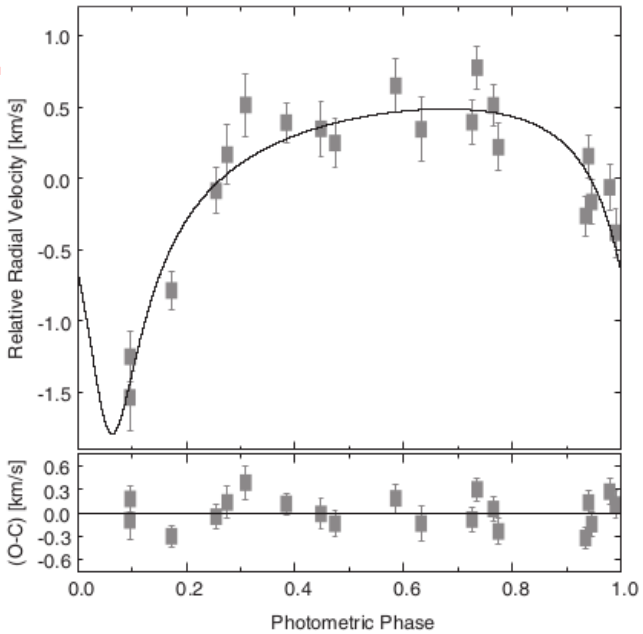
R> 10000 for 4300 Å < λ < 7200 Å, from July 2018 (with UV-optimized collimator)



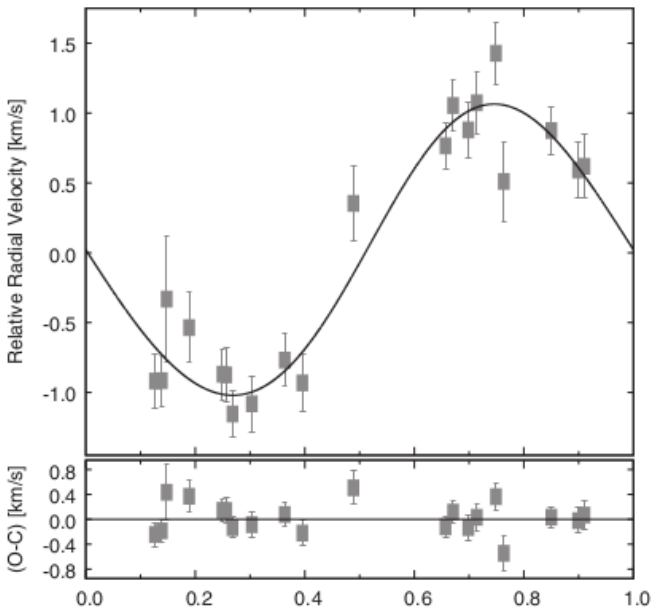

ThAr solution zero-point shifts over one night - limit on the RV accuracy

Magnitude limit: for V=11 star S/N = 15 at 5500 Å for 900-sec exposure

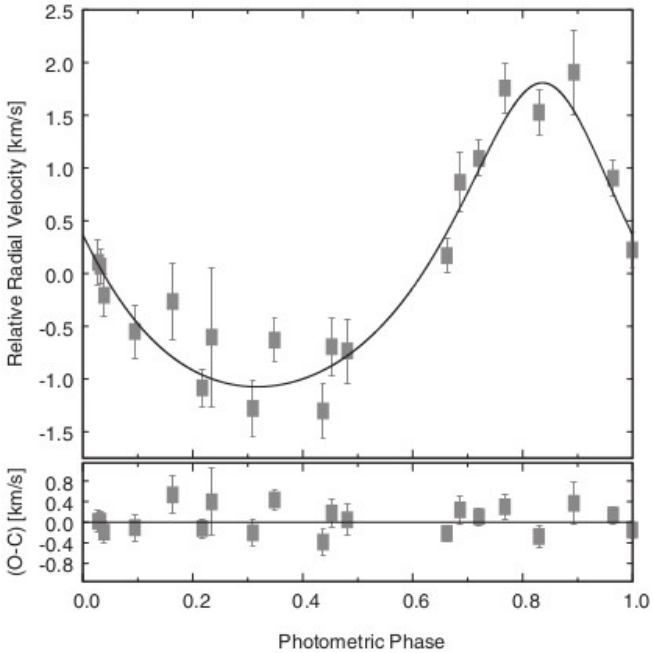
**HAT-P-2**




**WASP-14**

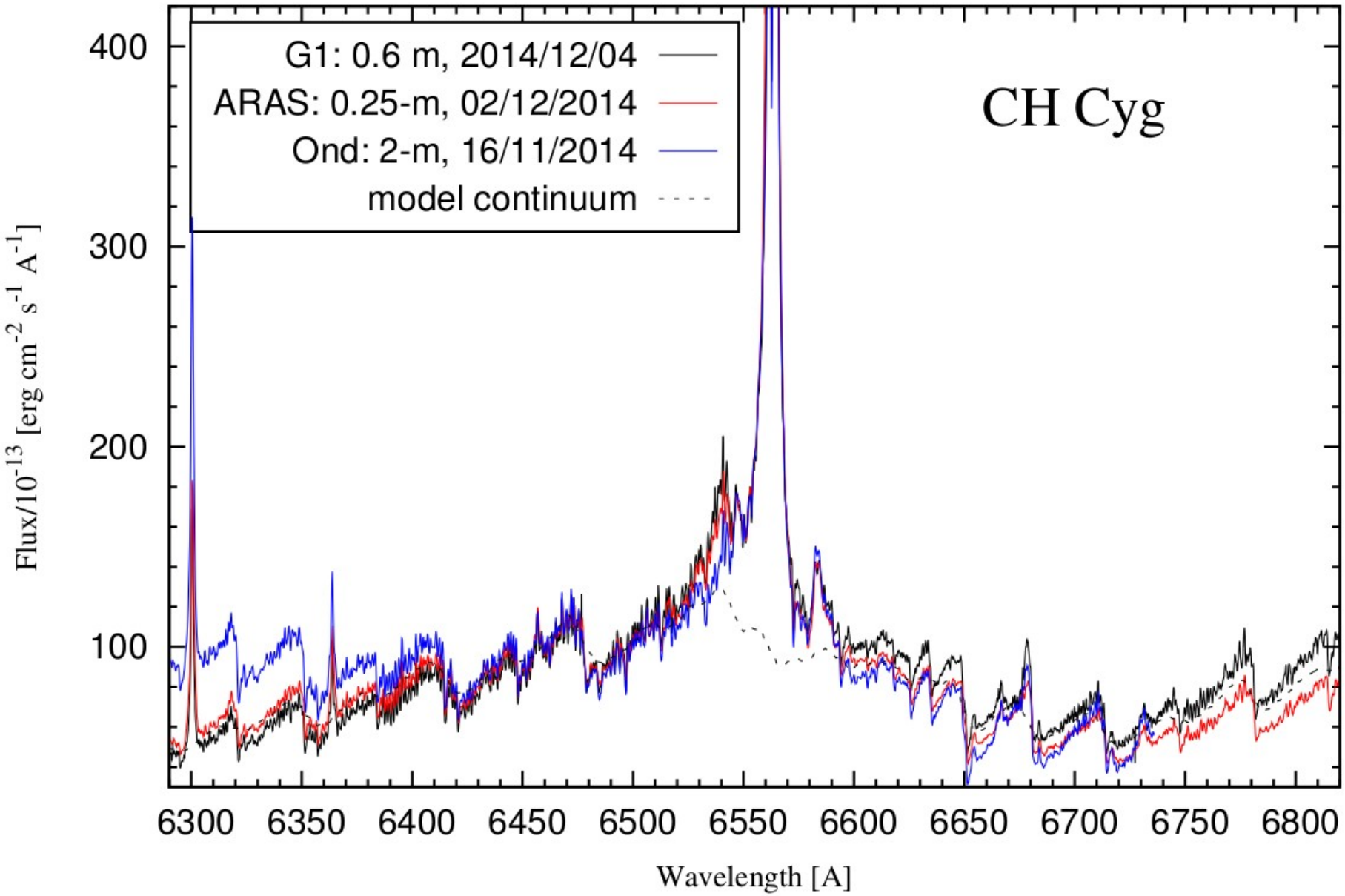



**XO-3**




- RV orbits of three well-known exoplanets with eShel at 60cm telescope at G1 (Stará Lesná)
- RV scatter: 170m/s (HAT-P-2), 220m/s (WASP-14) and 260 m/s
- RV scatter is brightness-limited on 60cm telescope
- Garai et al., 2017, AN, 338, 35

# CH Cyg


G1: 0.6 m, 2014/12/04
ARAS: 0.25-m, 02/12/2014
Ond: 2-m, 16/11/2014
model continuum
CH Cyg
400
300
200
100
Flux/10^-13 [erg cm^-2 s^-1 A^-1]
6300
6350
6400
6450
6500
6550
6600
6650
6700
6750
6800
Wavelength [A]

# Skalnaté Pleso observatory

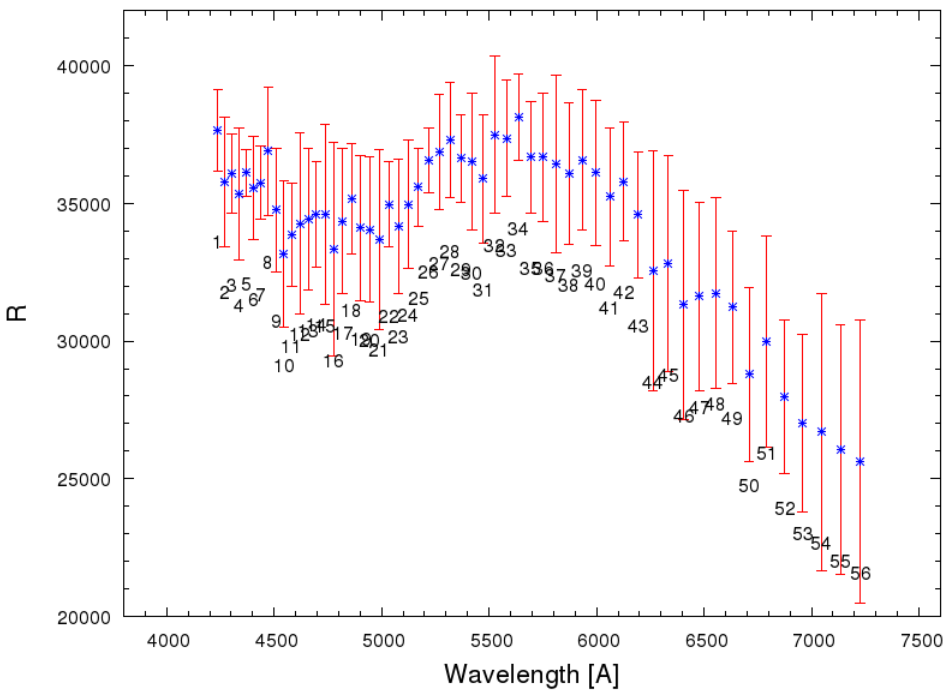
# 1.3m telescope at SP

- Astelco systems (2014)
- f/8 alt-az Nasmyth-Cassegrain with thin primary mirror
- active optics control: 9 actuators/benders with a Shack-Hartmann unit
- fast telescope slewing, near-Earth objects, 20 deg/sec, 2 deg/sec/sec
- pointing accuracy ±3 arcsec with pointing model
- full remote control of telescope and dome ==> easy to make robotic
- 2 Nasmyth foci available...

# MUSICOS @ 1.3m telescope

- MUSICOS = Multi-SIte COntinuous Spectroscopy
- fiber-fed and optical bench-mounted
- FIGU, fibers & calibration lamps from Shelyak
- 200µm calibration fiber, 50µm object fiber - both multimode
- collimator: f/4 on-axis parabolic mirror
- grating: 31.6 lines/mm, R2 échelle, 128x254mm
- crossdisperser: SF5 glass prism with 57° apex angle
- camera: Canon FD 2.8/400L
- detector: Andor iKon DZ-936 (ron 2.9$e^-$), with water circulation -100 C
- resolution: R=25000-40000 (FWHM)
- spectral range: 56 orders covering 4190-7200 Å (limited by the chip size)

# MUSICOS performance

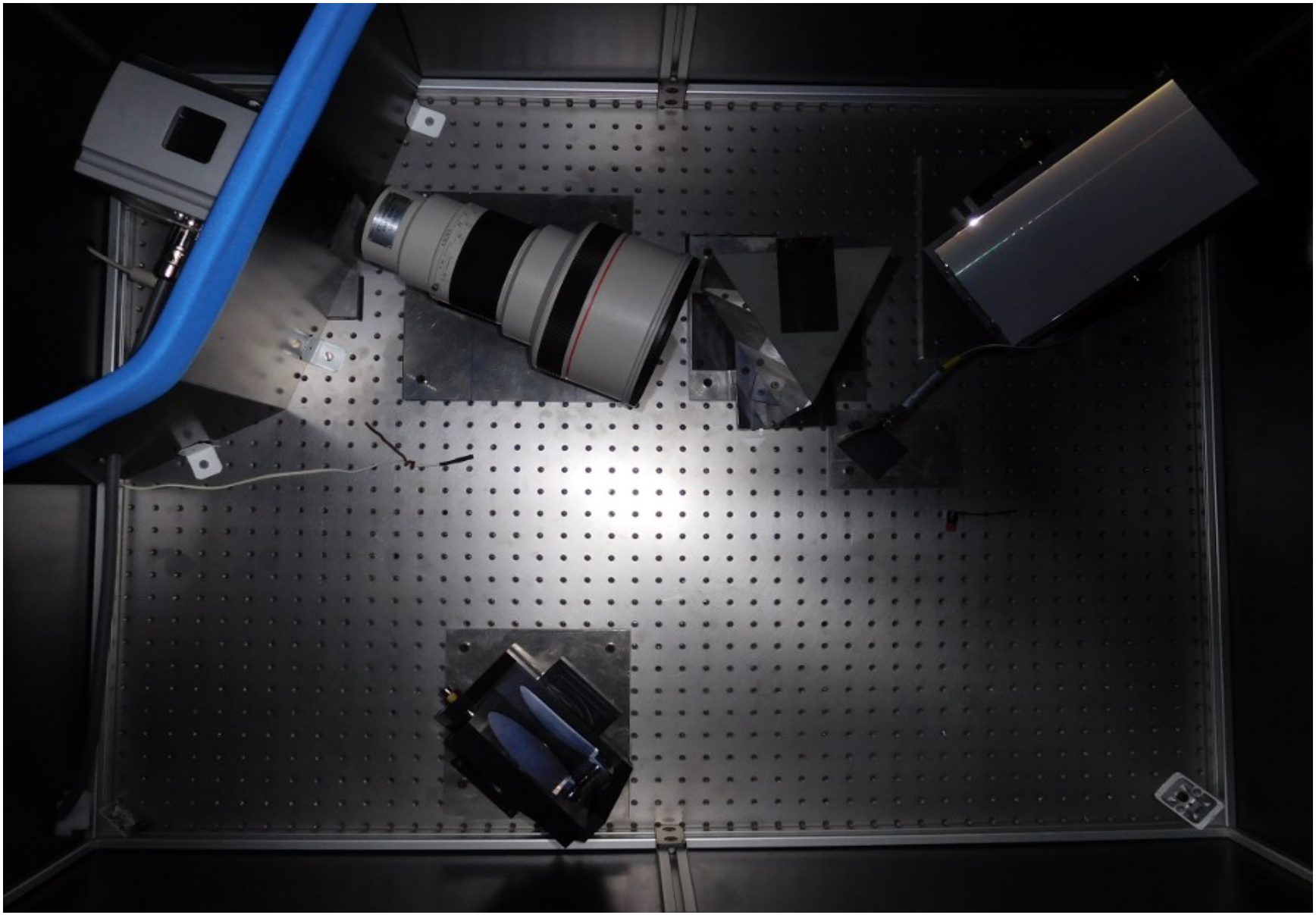



Resolution measured on non-blended ThAr lines, depends on focusing the Canon lens

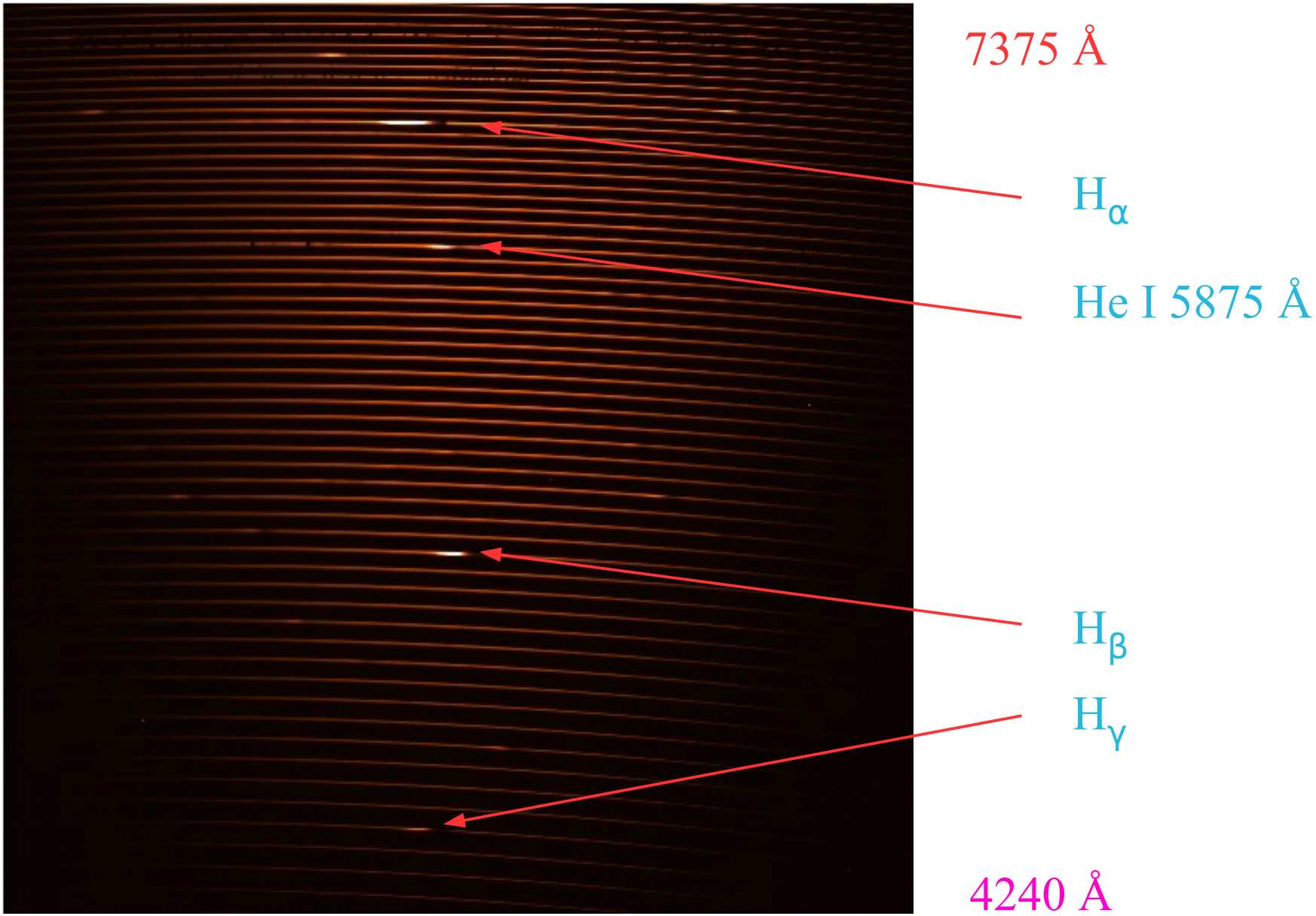
R> 30000 for λ < 6000 Å

ThAr solution zero-point shifts show about 100 m/s scatter

Magnitude limit: for V=11 star S/N = 15 at 5500 Å for 900-sec exposure



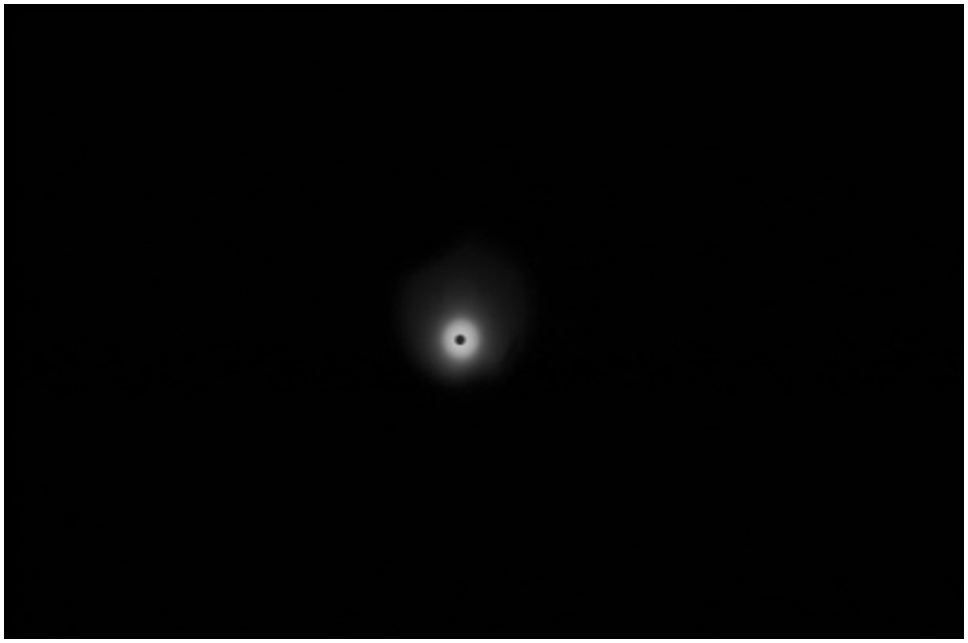
MUSICOS on the optical bench




Format of echelle spectrum on the Andor 2k x 2k CCD (P Cygni, 90-sec exposure)

# FIGU - Fiber Injection and Guiding Unit

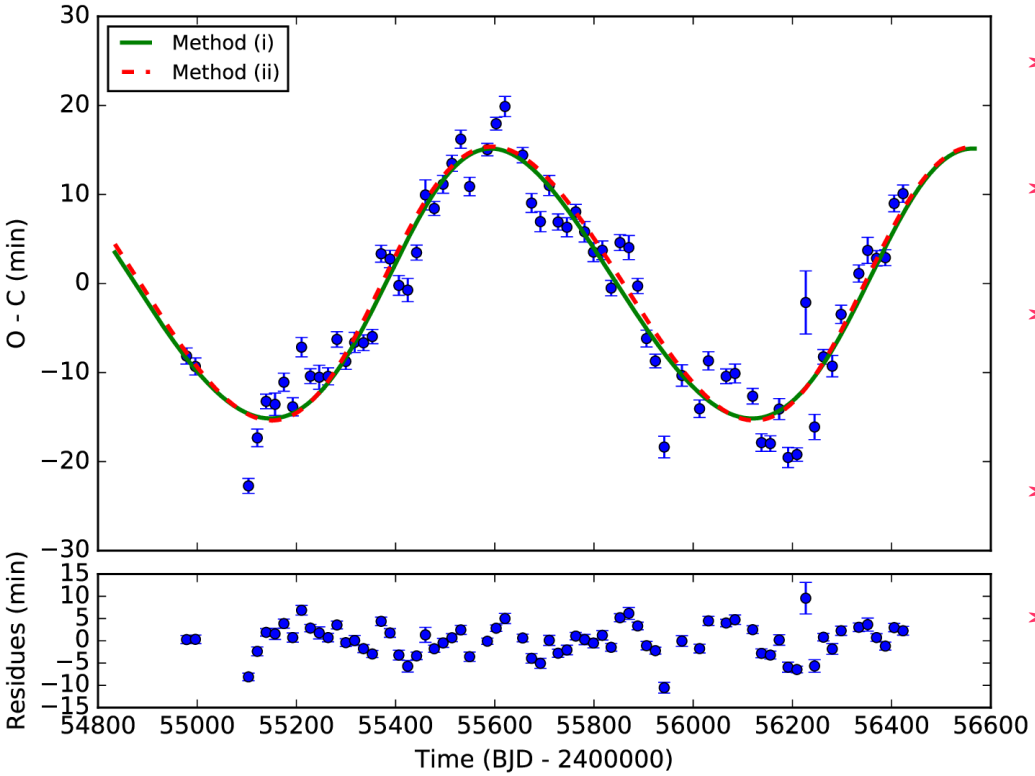
- FIGU optimized for f/6 but run at f/4
- focal reducer from f/8 to f/4
- inclined mirror reflects telescope image to a video camera , WATEC 120N
- no image slicer used at the fiber end



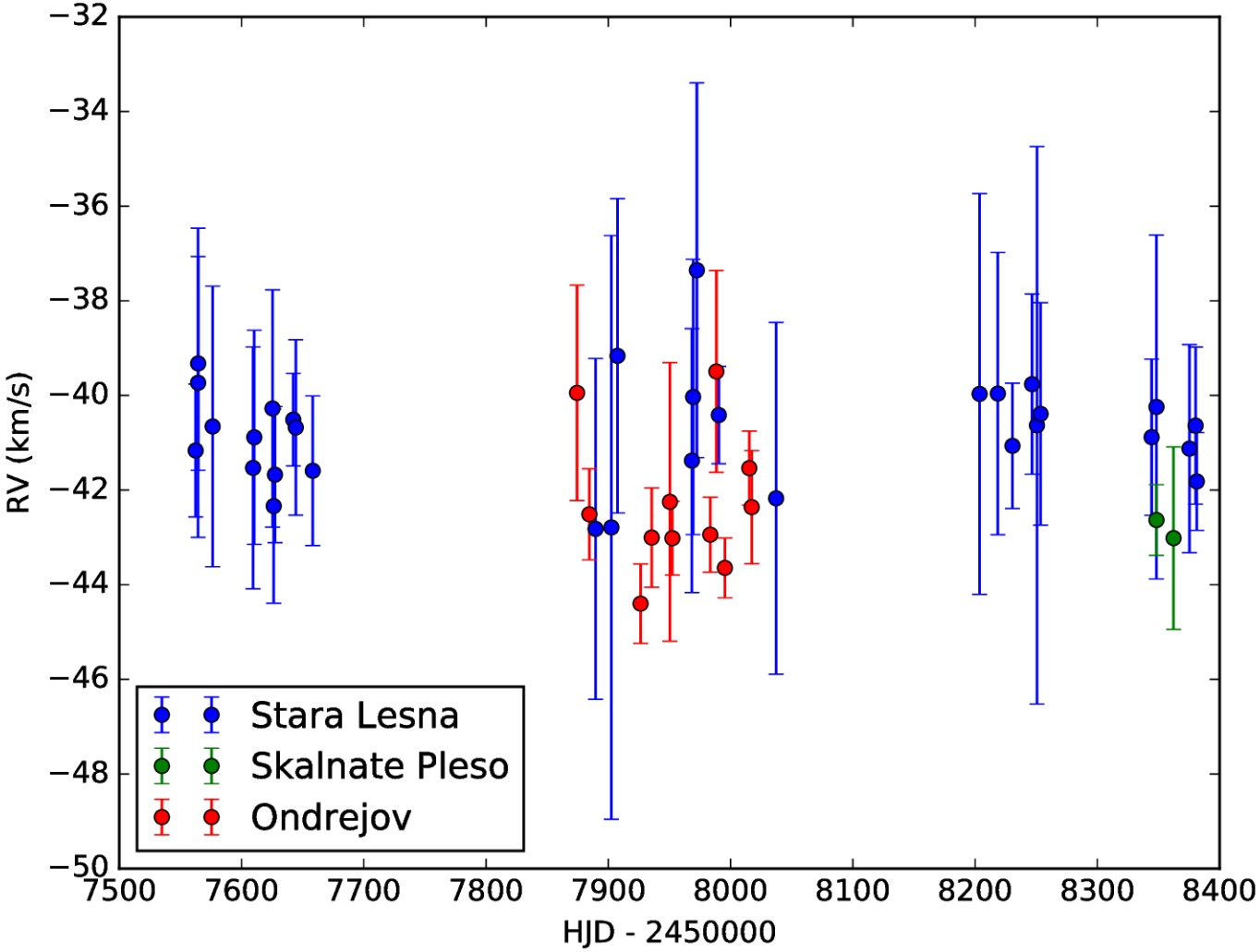
# Observing projects

- symbiotic stars and novae
- close binaries, multiple systems of stars
- T Tauri objects
- CP stars
- exoplanet host stars
- follow-up observations for BRITE satellite objects

# Kepler-410Ab



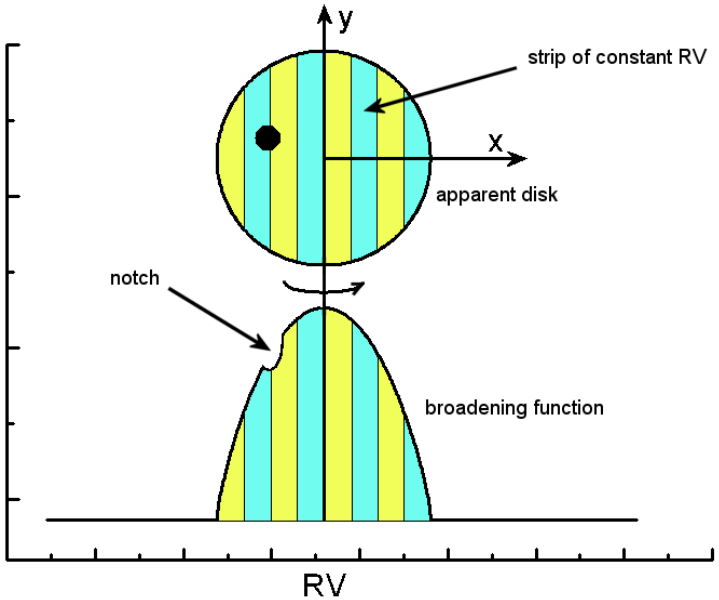

- Kepler-410Ab = HD175289, F6IV parent star
- Neptune-sized planet on a 17.8336 d orbit
- TTV variability observed with about 15-minute amplitude and 970-day orbit seen in the Kepler data
- The perturber must be a star with M > 0.9 Msun
- Expected RV amplitude K ~ 30 km/s (Gajdoš et al., 2017, MNRAS 469, 2907)



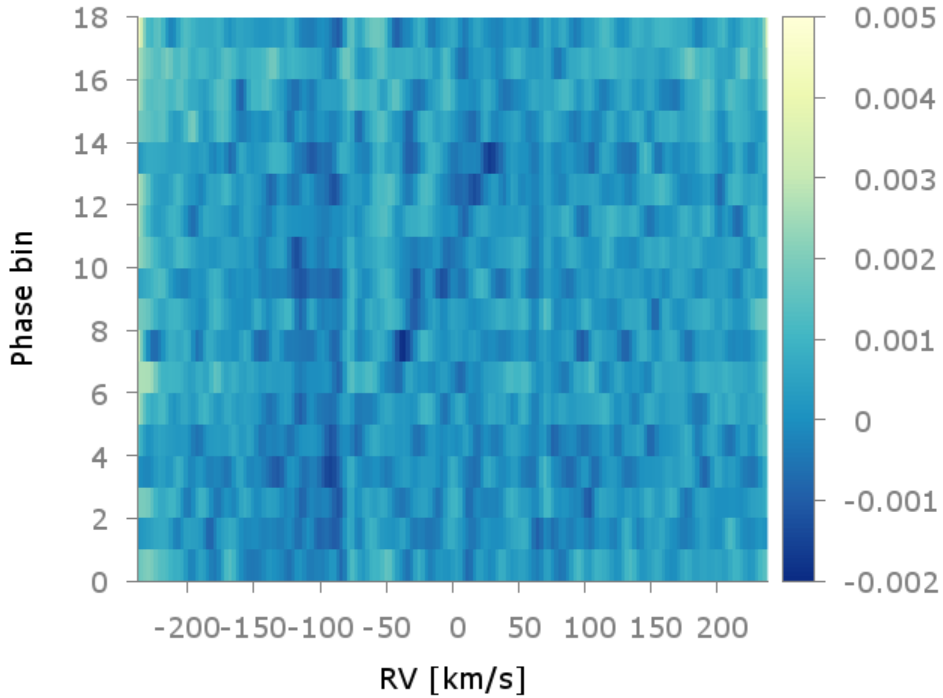

Now almost one cycle covered, observed RV variability < 3 km/s...

Possible explanation of TTV: resonance with a low mass planet

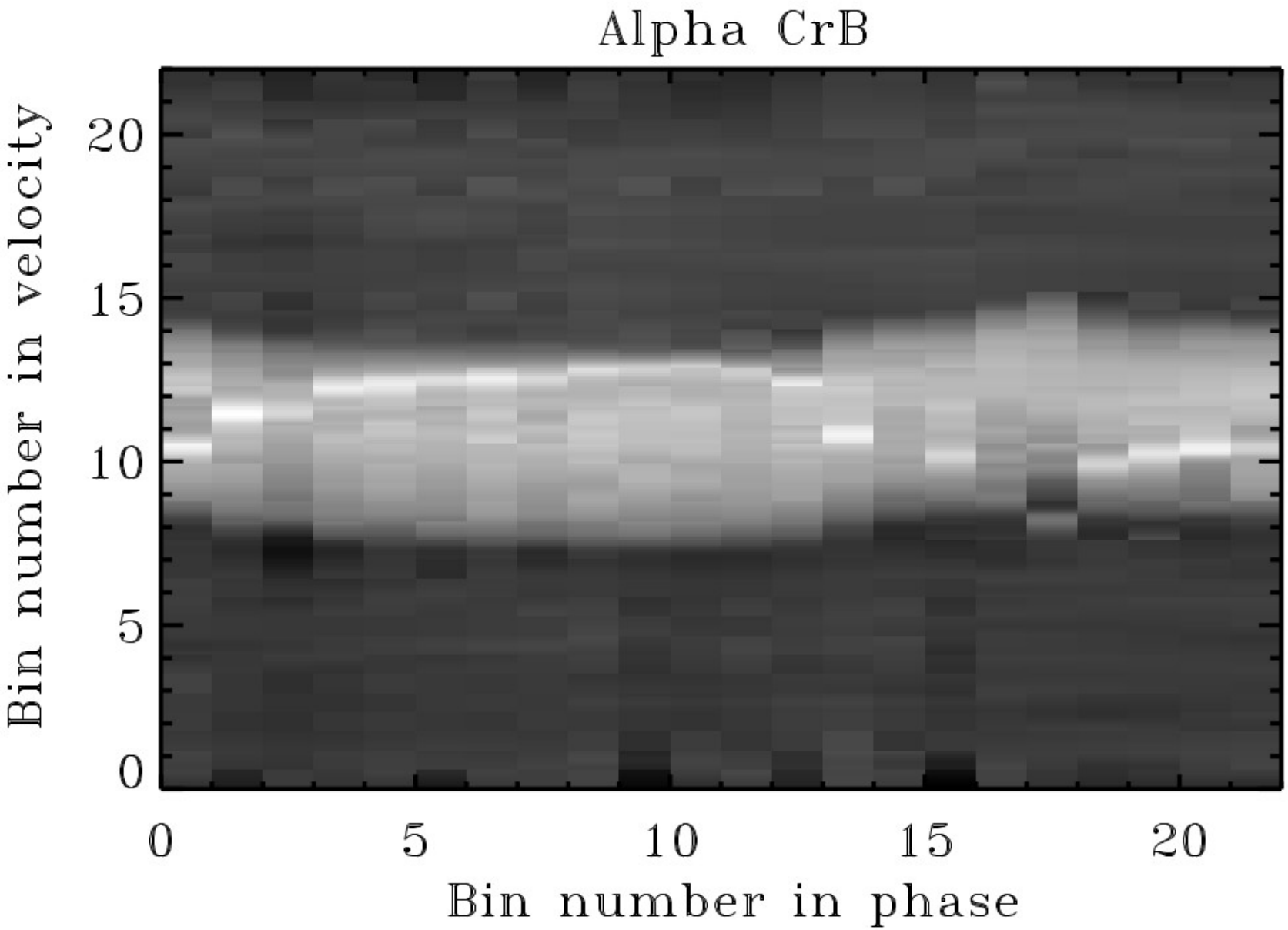
# Doppler tomography of exoplanet transits



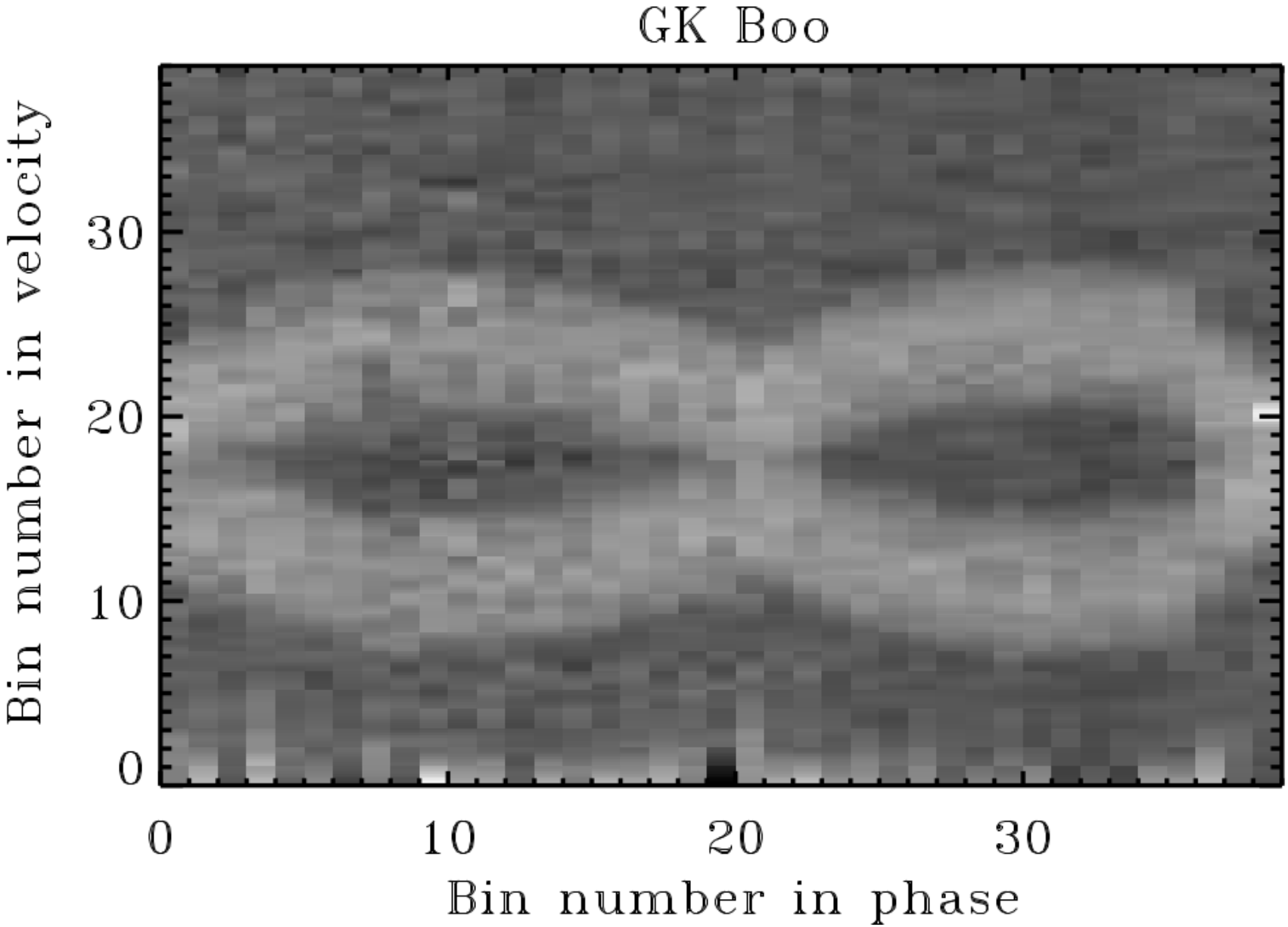

- Measuring spin-orbit misalignment
- requires v sin i » c/R
- Line profile modeled by limb-darkened rotational profile




- Kelt-7b = HD 33643, V=8.54
- F2V fast rotating parent star, v sin i = 74 km/s
- Transiting hot Jupiter P = 2.7347785 d, duration 210.7 minutes
- Spectroscopy with 15-min exposures, typical SNR = 40, 1.3m telescope
- BF = LSD profiles using HD102870 as a template and 4900-5600 Å range




- Vmax=2.24, A1IV+G5, P = 17.3599 days eclipsing binary, cold secondary easily detected in BFs




* Vmax=10.93, K3+K3V, P=0.4777 days, eclipsing binary, difficult object, short period and low brightness

# Future plans

# Spectrograph throughput (matters...)

- Telescope losses: 3 mirrors + focal reducer <70% efficiency ⇒ fiber to the primary focus ?, but then f/2.8 to f/5, silver coating
- Guiding losses: negligible - the alt-az mount shows ±3 arcsec pointing accuracy ⇒ not much can be done
- FIGU and seeing losses: fiber + FIGU: 42 % efficiency (measured by Shelyak) ⇒ possibly fiber reformaters ?
- collimator: now on axis + Al-coated, ⇒ off-axis collimator and dielectric coated or silver-coated
- grating: ~10% losses by overfilling (+extra modal noise) ⇒ changing f/4 to f/5
- camera: unknown throughput, too long focal ratio for the CCD ⇒ too expensive to have custom-made
- detector: BB version, QE ~ 90% ⇒ cannot be improved much

# Spectrograph stability

- The RV precision is now stability -limited even for V=9 objects
- Thermal stability of the room is $\Delta T \approx 1$ K within in one night $\Rightarrow$ tempertaure regulation and thermal insulation
- Modal noise and aperture obscuration: $\Rightarrow$ additional image scrambling + decreasing numerical aperture
- Simultaneous ThAr calibration $\Rightarrow$ using bifurcated fiber input

**Thanks for your attention !**