Spektroskopija:

preučevanje intenzitete svetlobe v odvisnosti od valovne dolžine

Tomaž Zwitter

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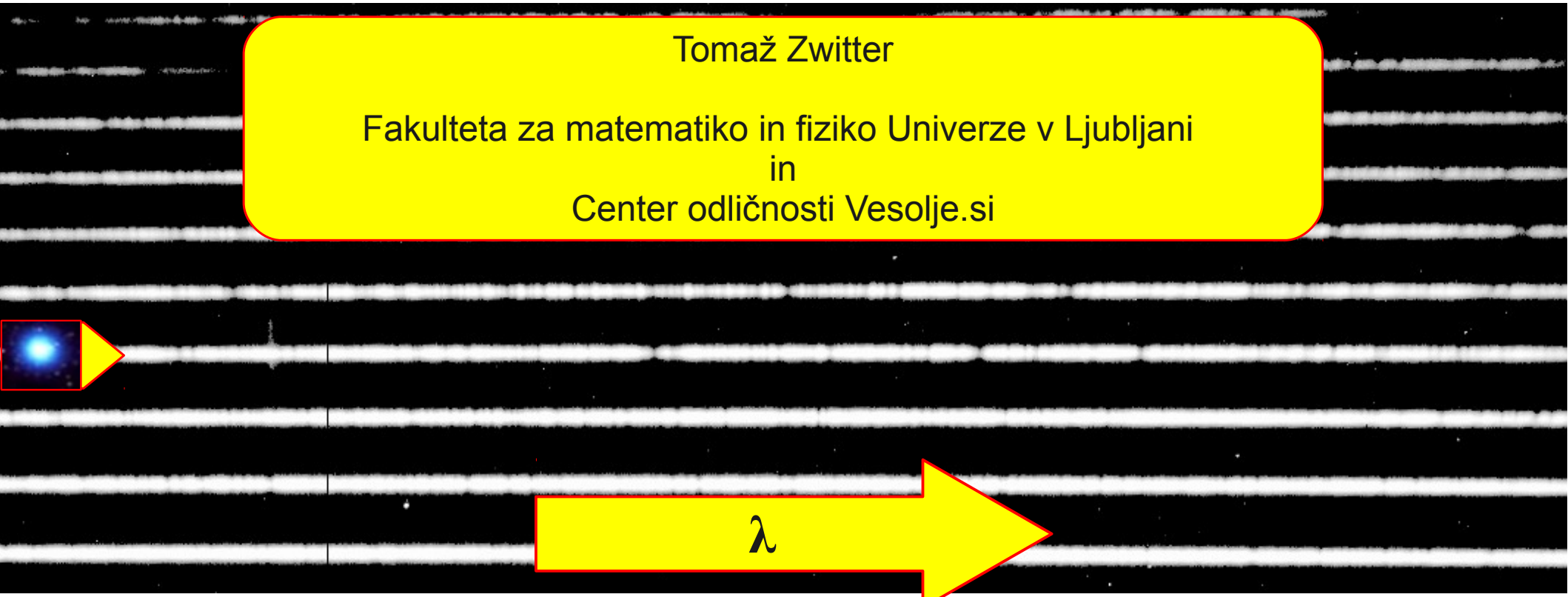
in
Center odličnosti Vesolje.si



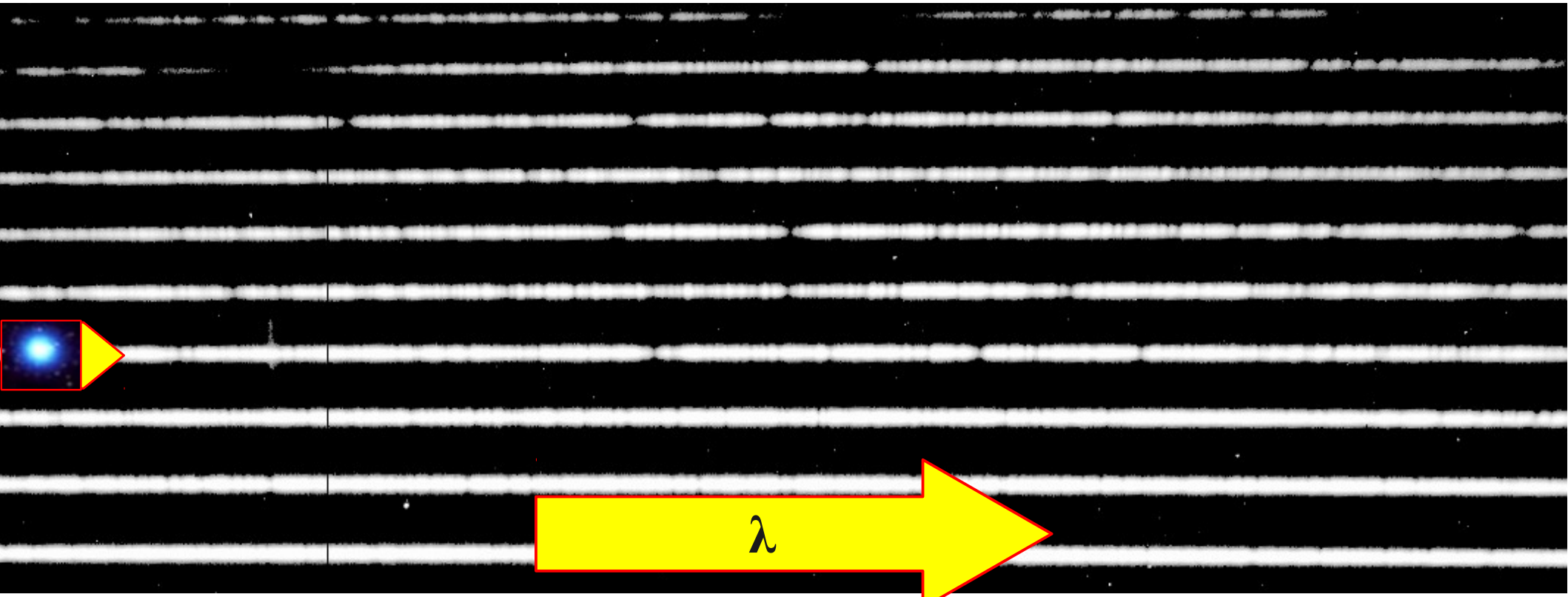
λ

informacija podobna kot pri črtni kodi

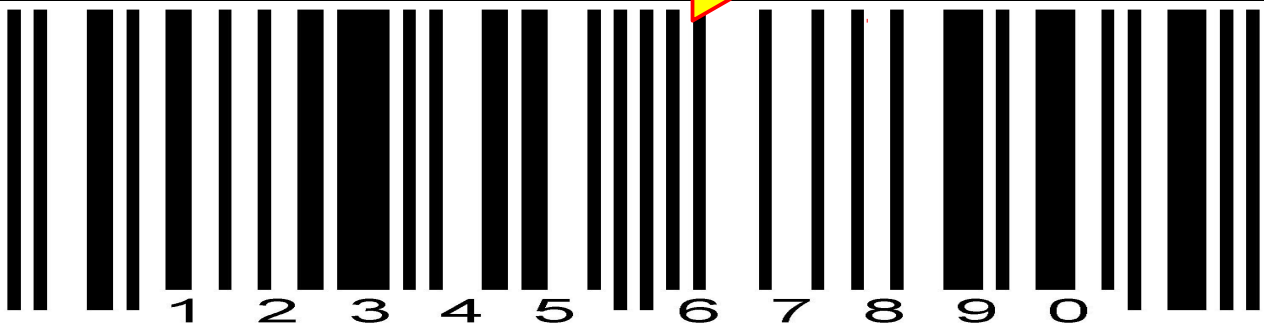
Barve in temperature zvezd

Spektroskopija:

preučevanje intenzitete svetlobe v odvisnosti od valovne dolžine

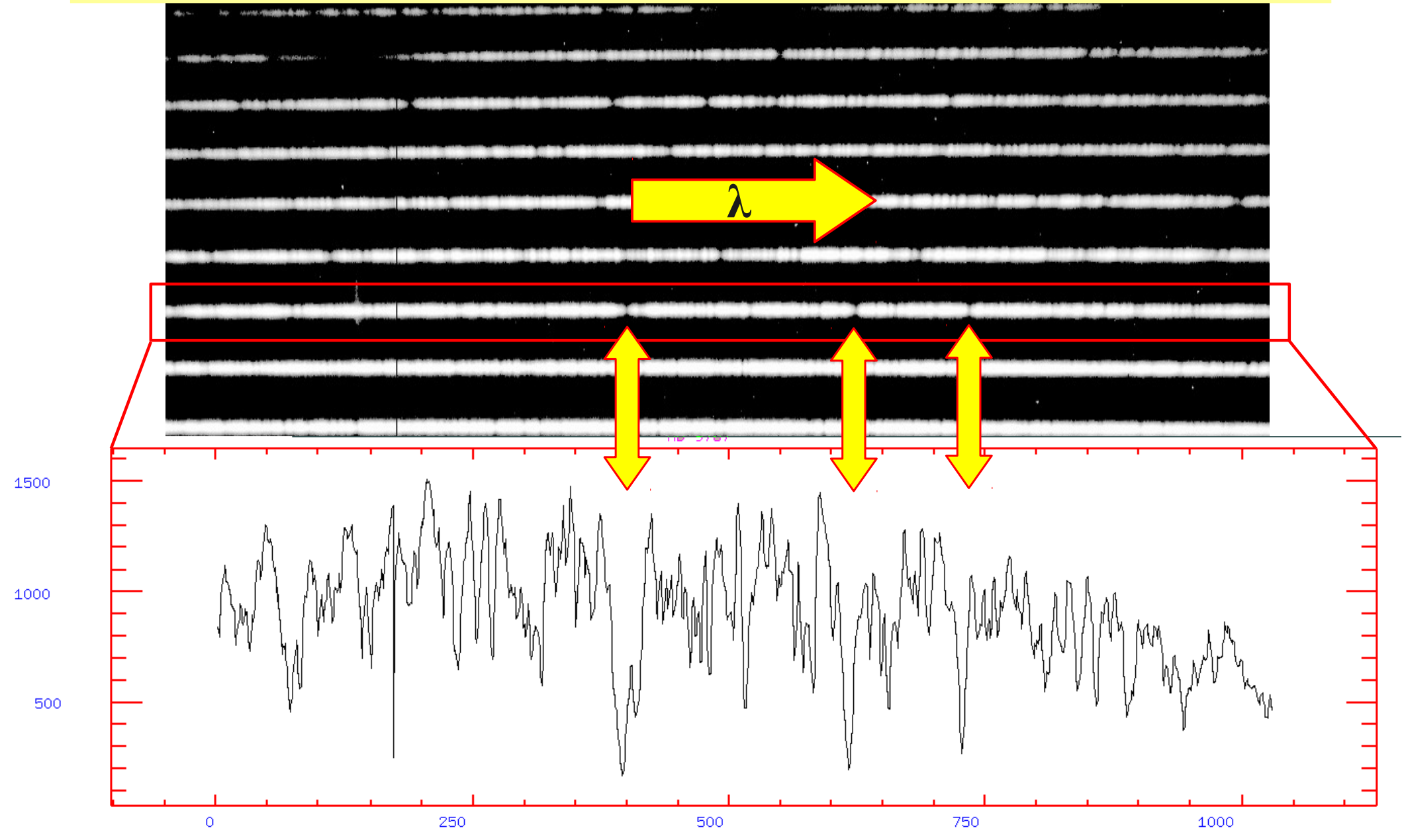


informacija podobna kot pri črtni kodi



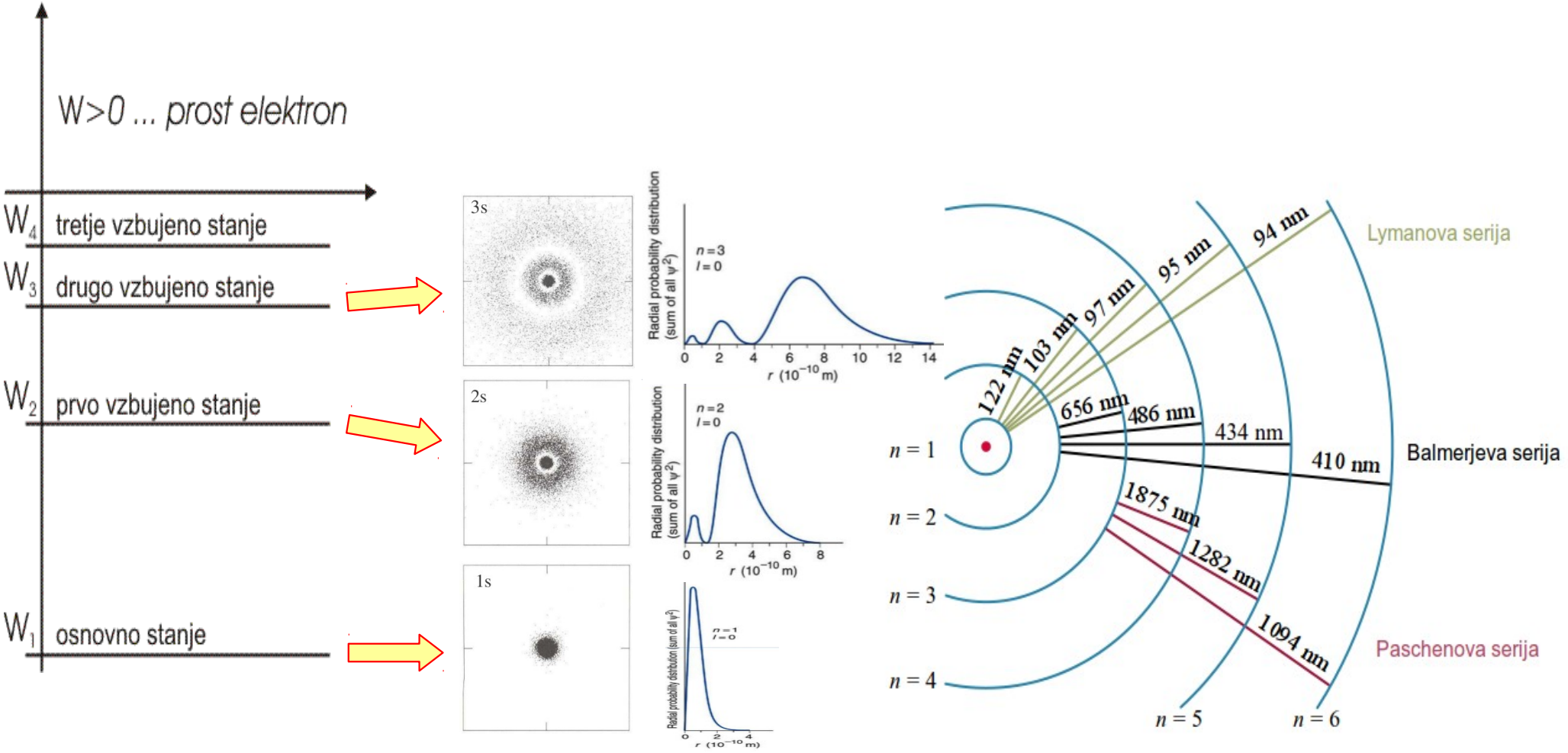
Predstavitev spektra:

sled ali graf

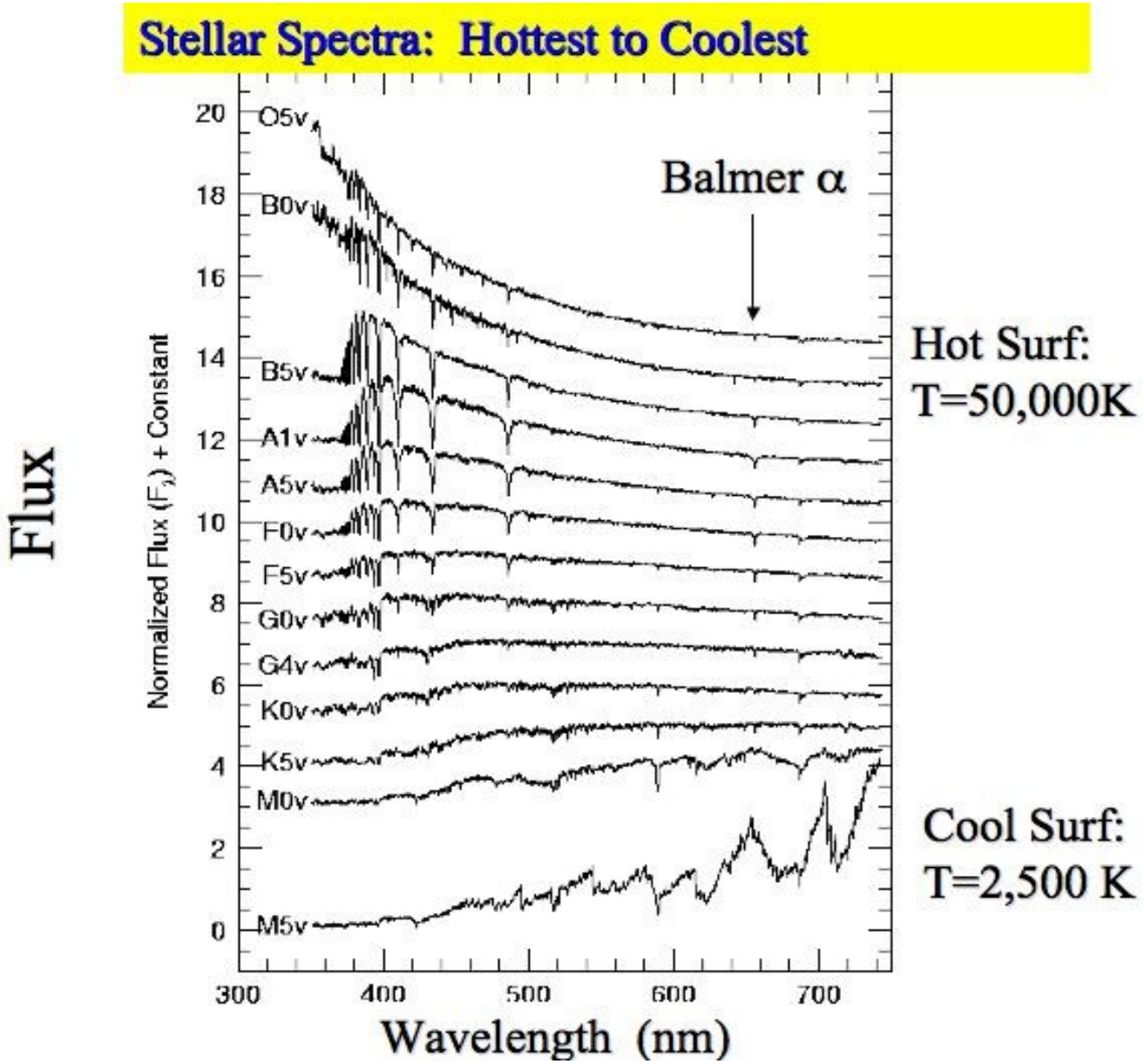


Iz take smo snovi kot zvezde. ⟺ Zvezde so iz take snovi kot mi.

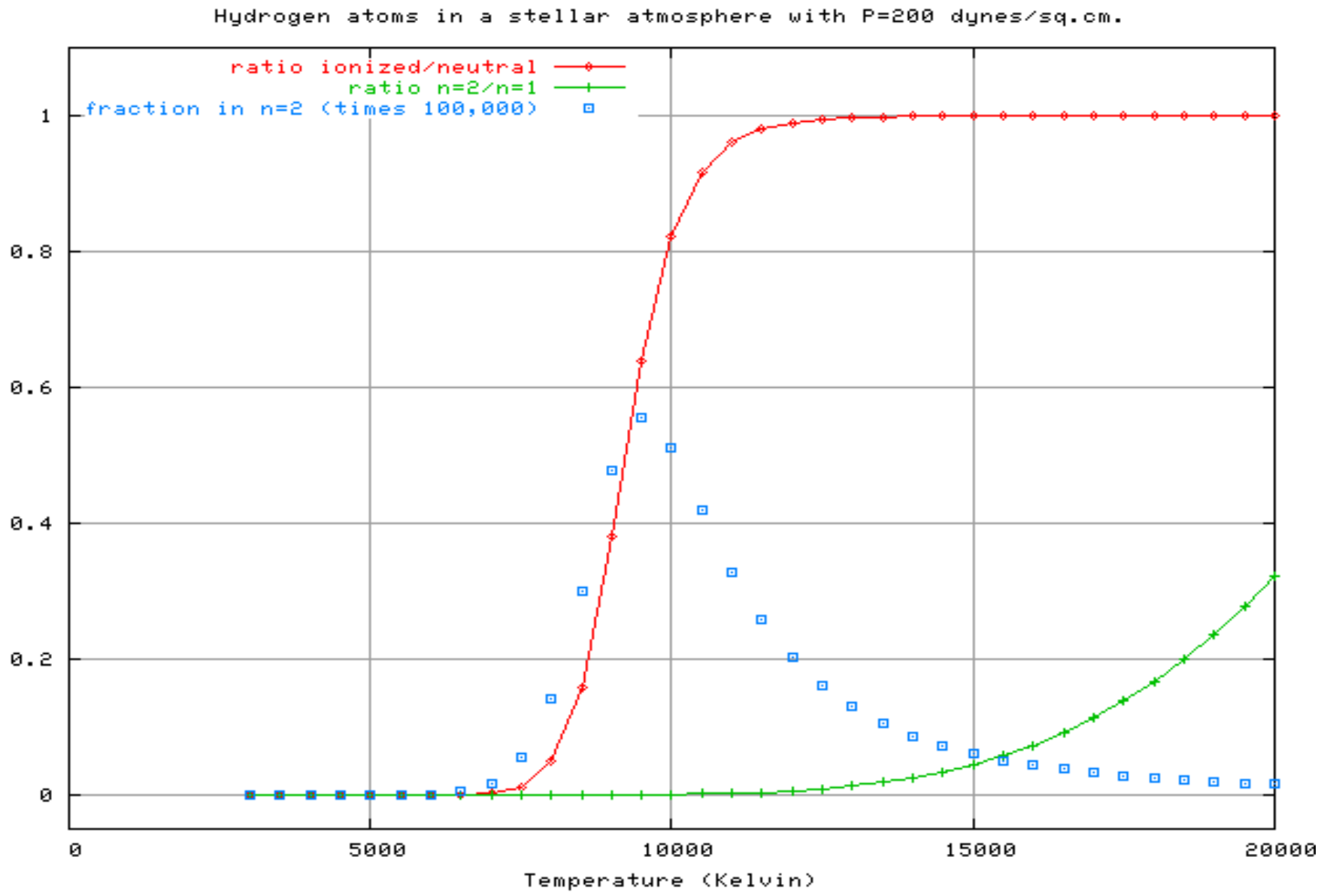
Primer **vodika** kot najpreprostejšega in obenem najbolj pogostega elementa v vesolju.



Spektri zvezd



Odvisnost moči spektralne črte od temperature



Spektri zvezd: temperatura

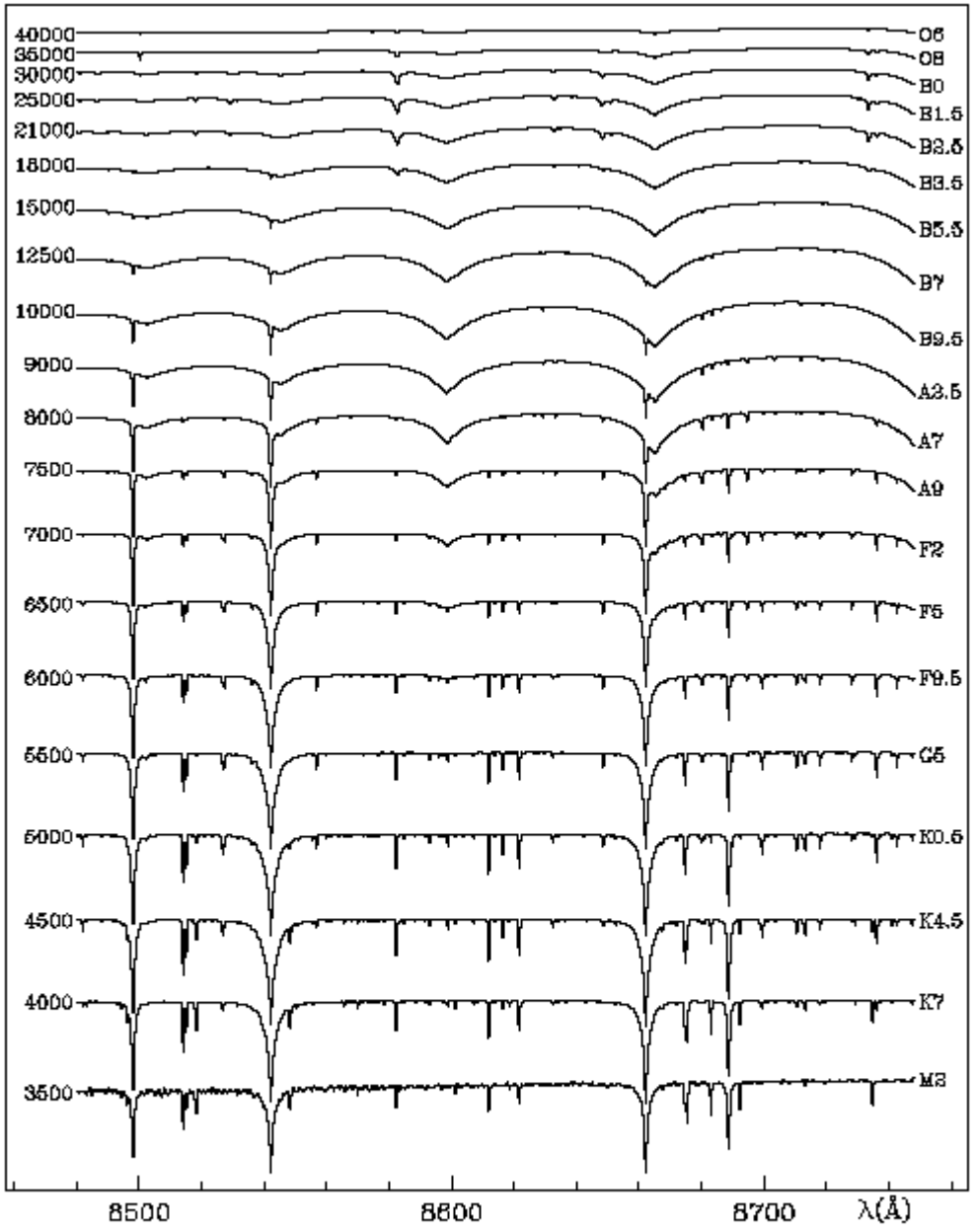
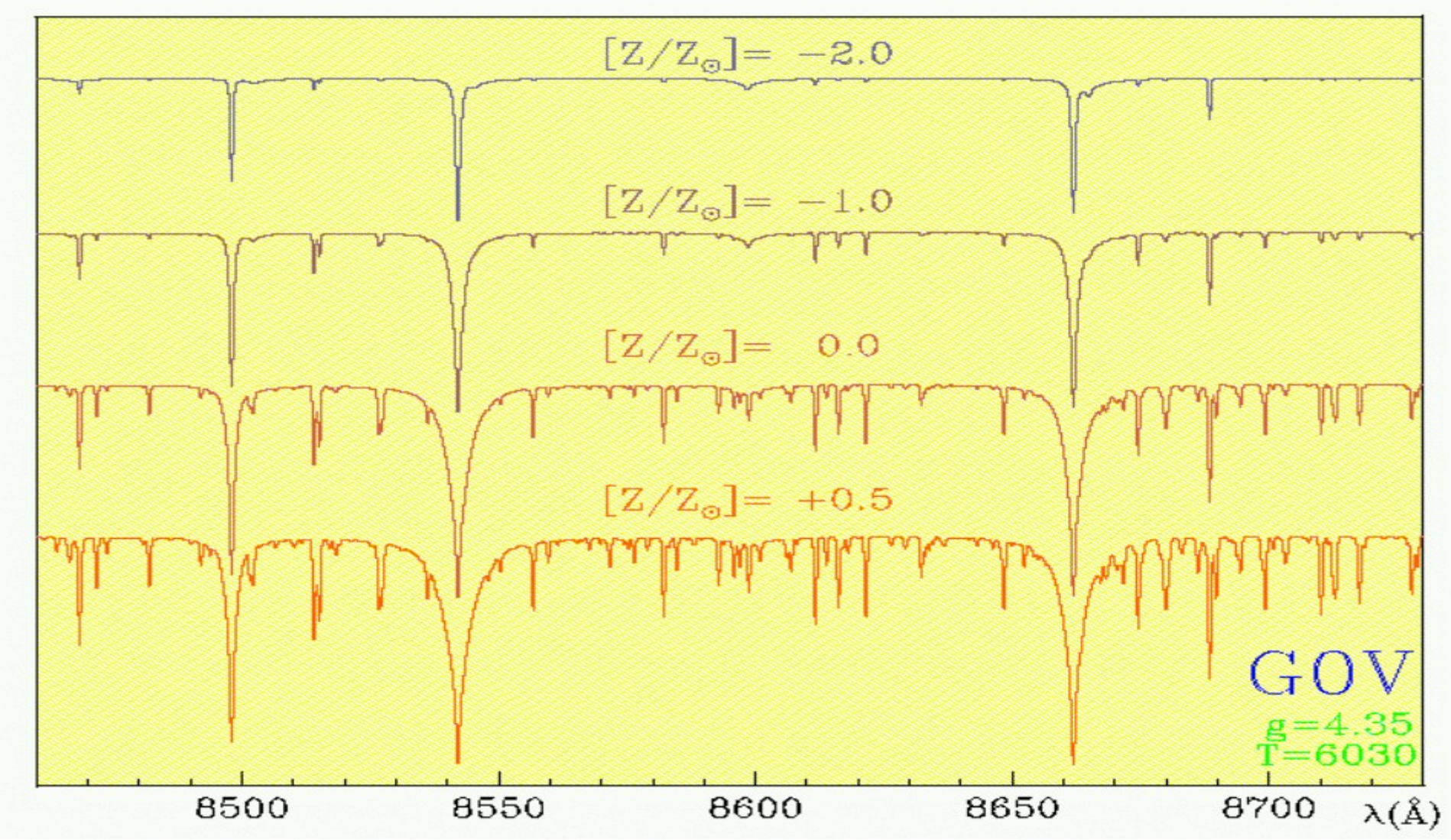
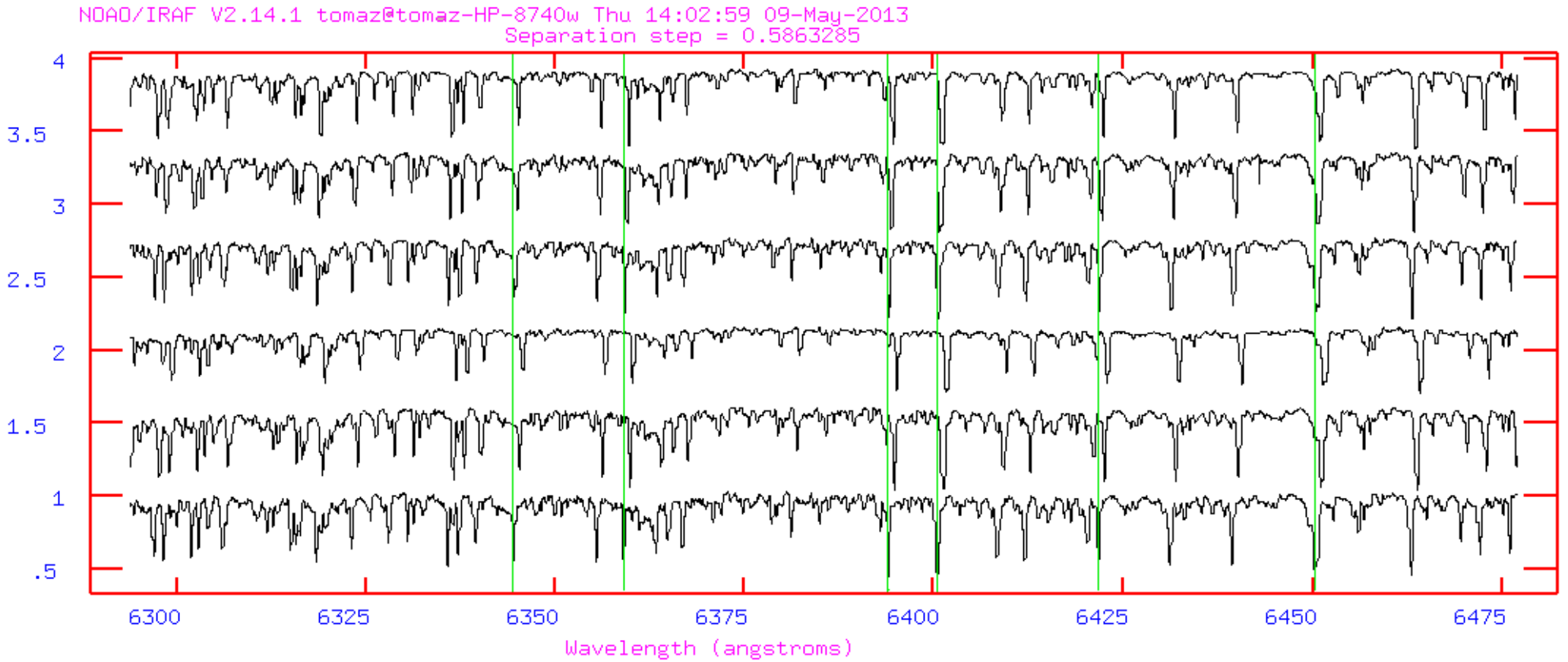


Fig. 2. Sequence of synthetic spectra (from Munari & Castelli 2000, Castelli & Munari 2001) illustrating the variations along the main sequence (T_{eff} in K on the left and corresponding spectral type for luminosity class V on the right) for moderately metal poor stars ($[Z/Z_{\odot}]=-0.5$). All spectra are on the same ordinate scale, only displaced in their zero-points.

Spektri zvezd: kemična sestava



Spektri zvezd: radialna hitrost



Dopplerjev pojav
za majhne hitrosti

$$\frac{v_{\mathrm{rad}}}{c} = \frac{\lambda_{\mathrm{shift}} - \lambda_{\mathrm{rest}}}{\lambda_{\mathrm{rest}}}$$

Spektri galaksij: rdeči premik

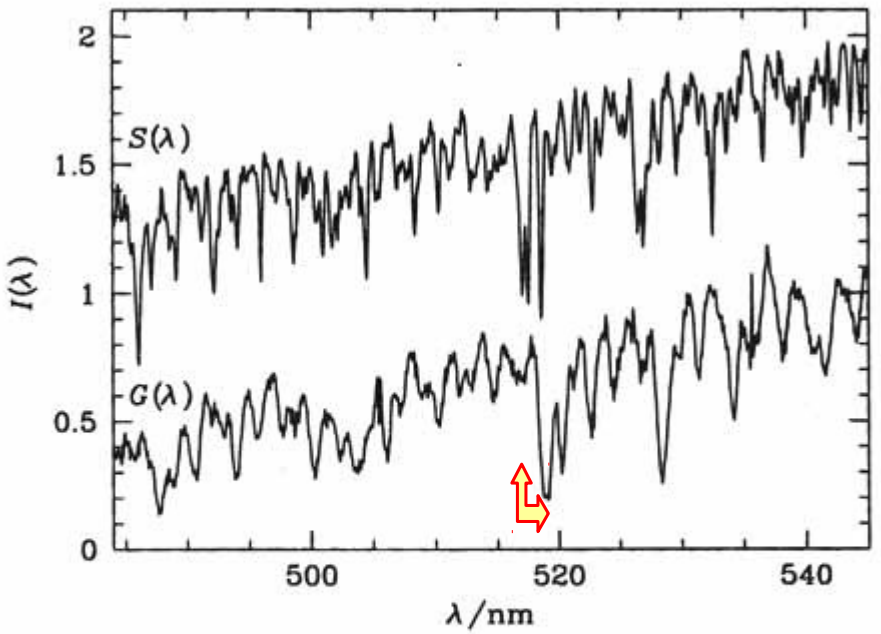


Figure 11.1 Spectra of a K0 giant star (S) and the center of the lenticular galaxy NGC 2549 (G). These data cover a small part of the optical spectrum around the strong Mg b absorption feature at 518 nm.

Rdeči premik (z)

$$z = \frac{\lambda_{shift} - \lambda_{rest}}{\lambda_{rest}}$$

Spektri zvezd: projecirana hitrost vrtenja

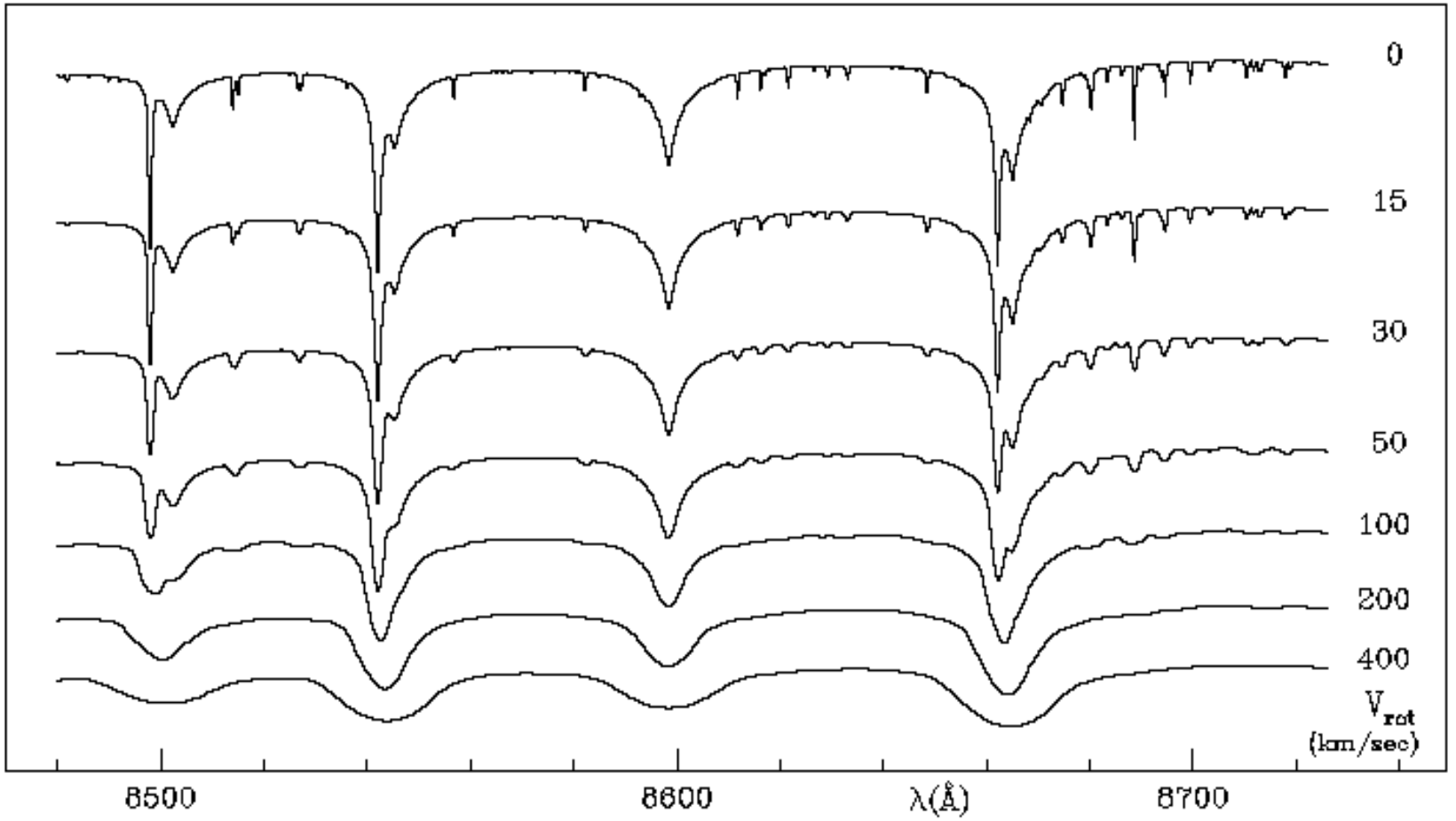


Fig. 7. Rotational velocity sequence for F0 III giants (spectra from Zwitter et al. 2001).

Spektri zvezd

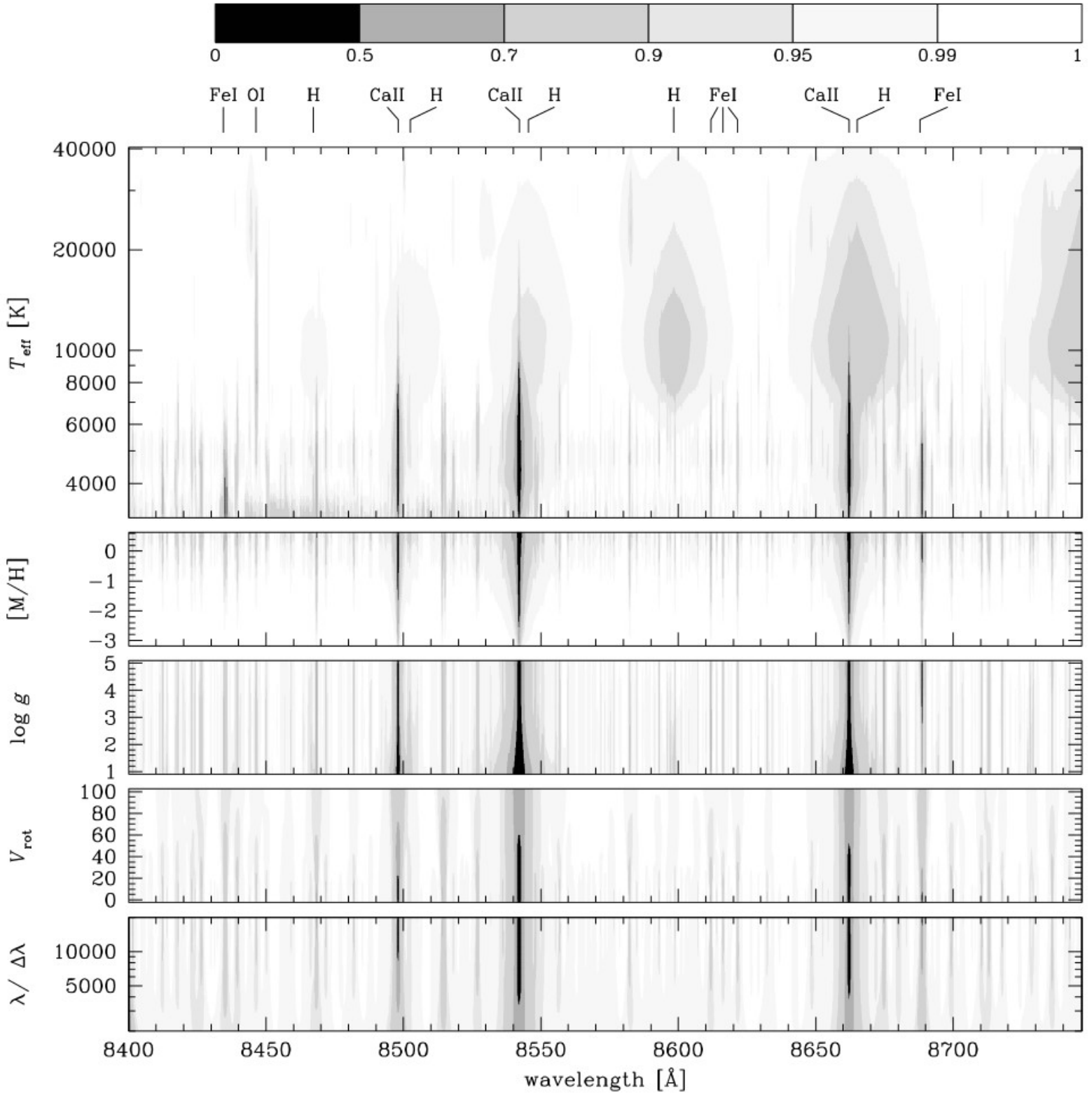
temperatura

kemična sestava

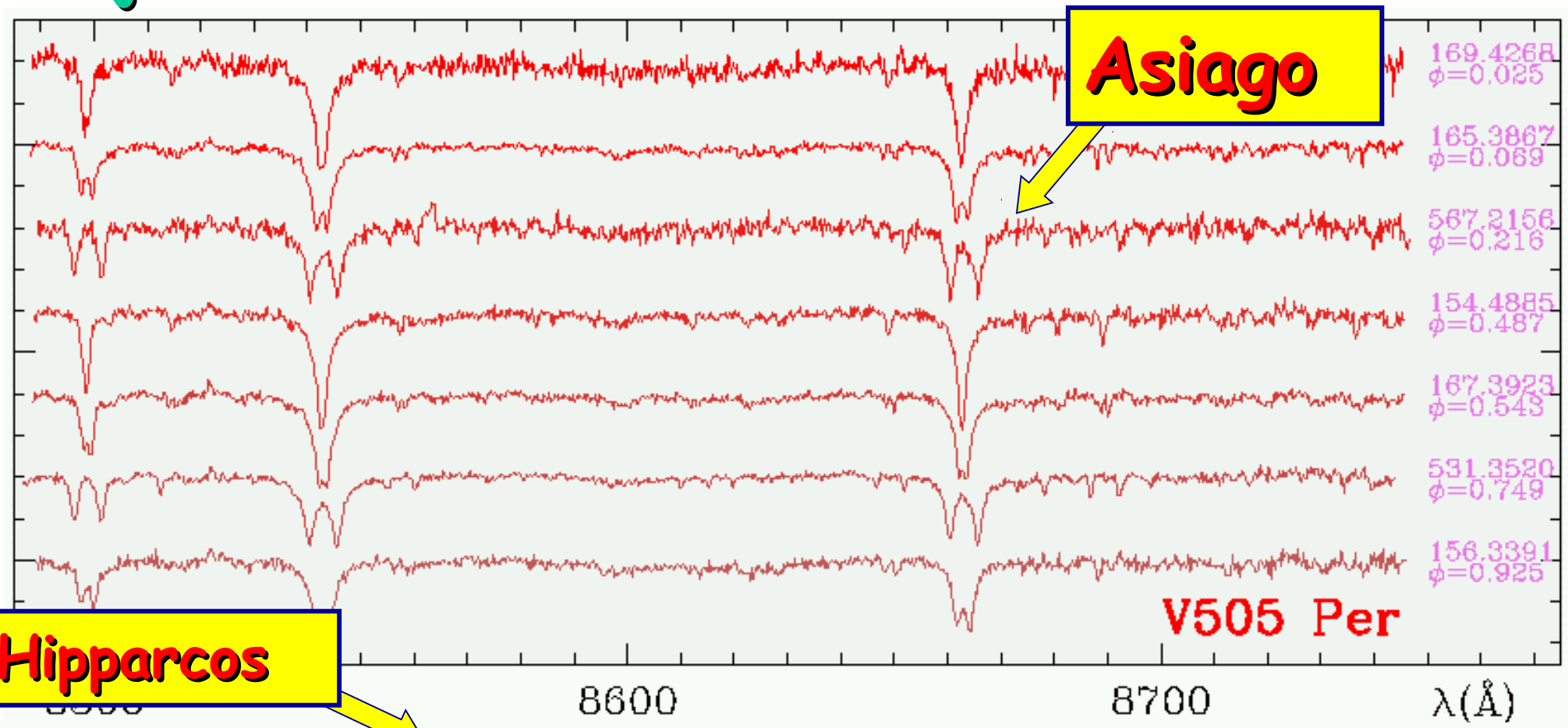
gravitacijski pospešek

projekcija hitrosti rotacije

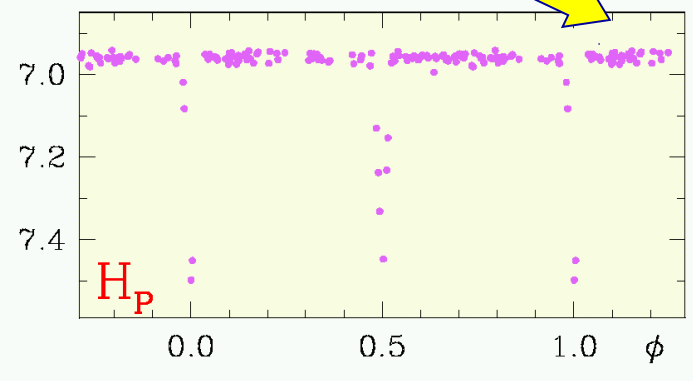
resolucijska moč

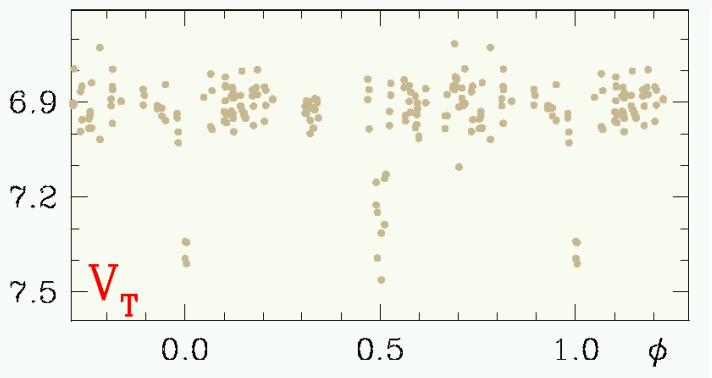


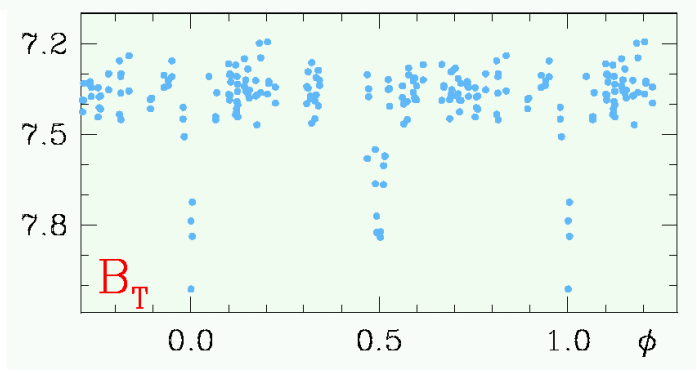
Dvojne zvezde



Hipparcos

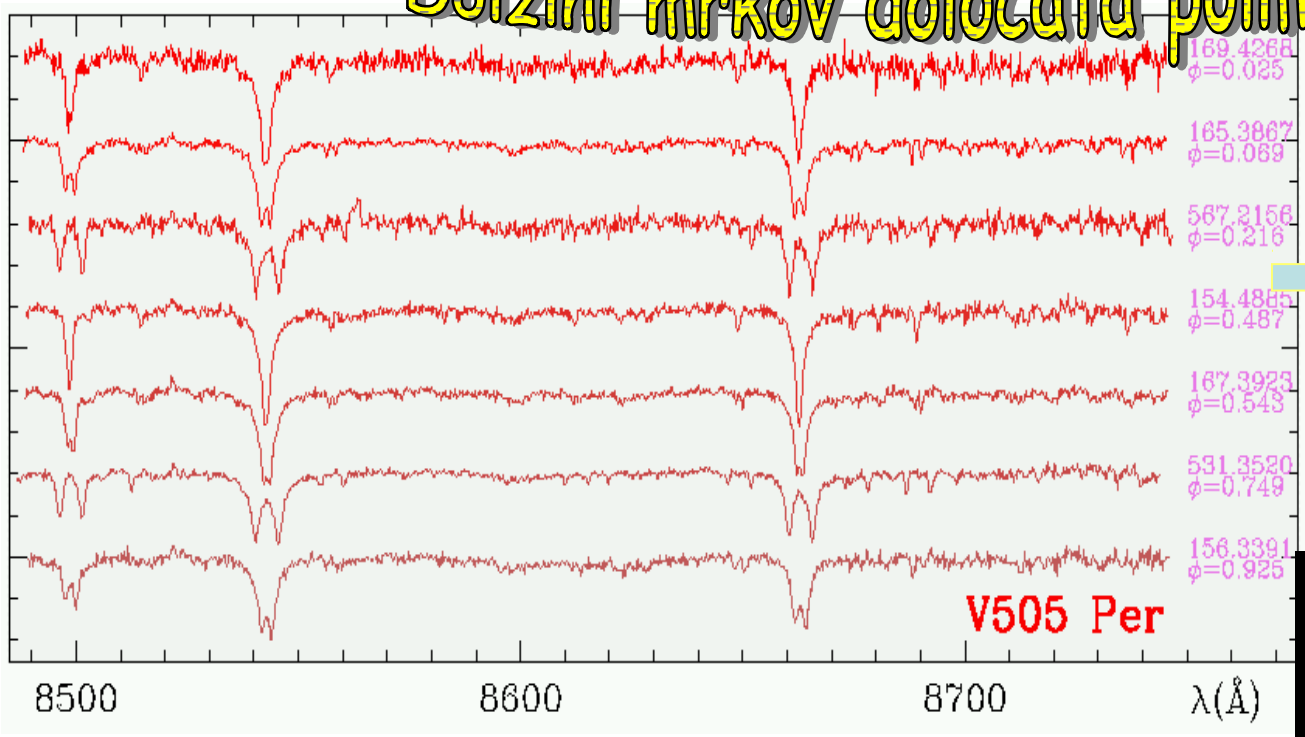


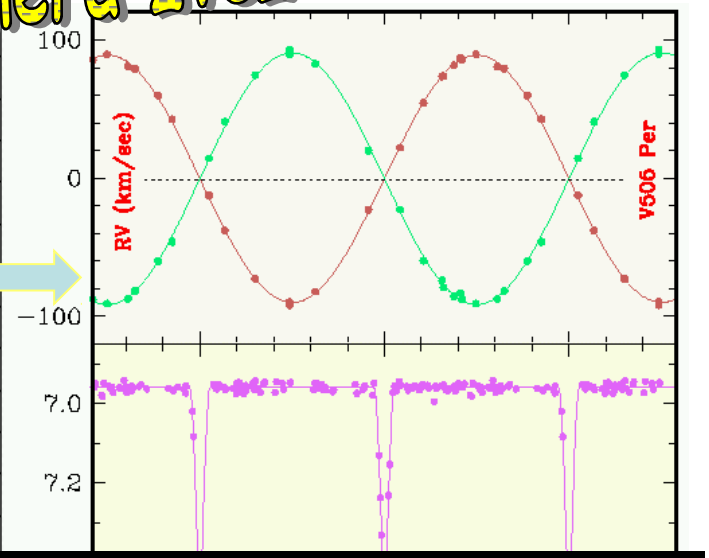


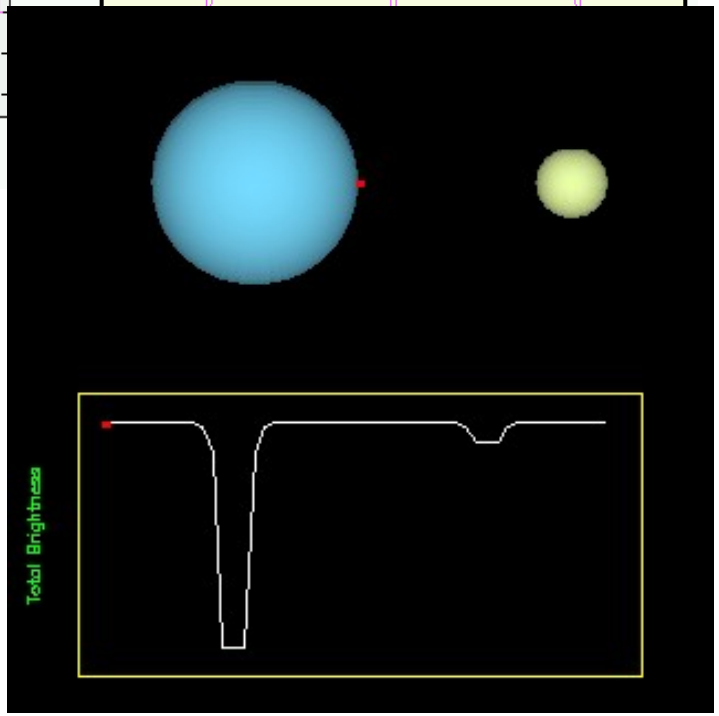


Prekrivalne dvojne zvezde

Dolžini mrkov določata polmera zvezd







a = 15.06 +/- 0.08 R_o

M_1 = 1.30 +/- 0.02 M_o
M_2 = 1.28 +/- 0.02 M_o

R_1 = 1.40 +/- 0.02 Ro
R_2 = 1.14 +/- 0.03 Ro

T_1 = 6460 +/- 50 K
T_2 = 6415 +/- 50 K

razdalja: 60 +/- 3 pc Asiago/GAIA
66 +/- 4 pc Hipparcos

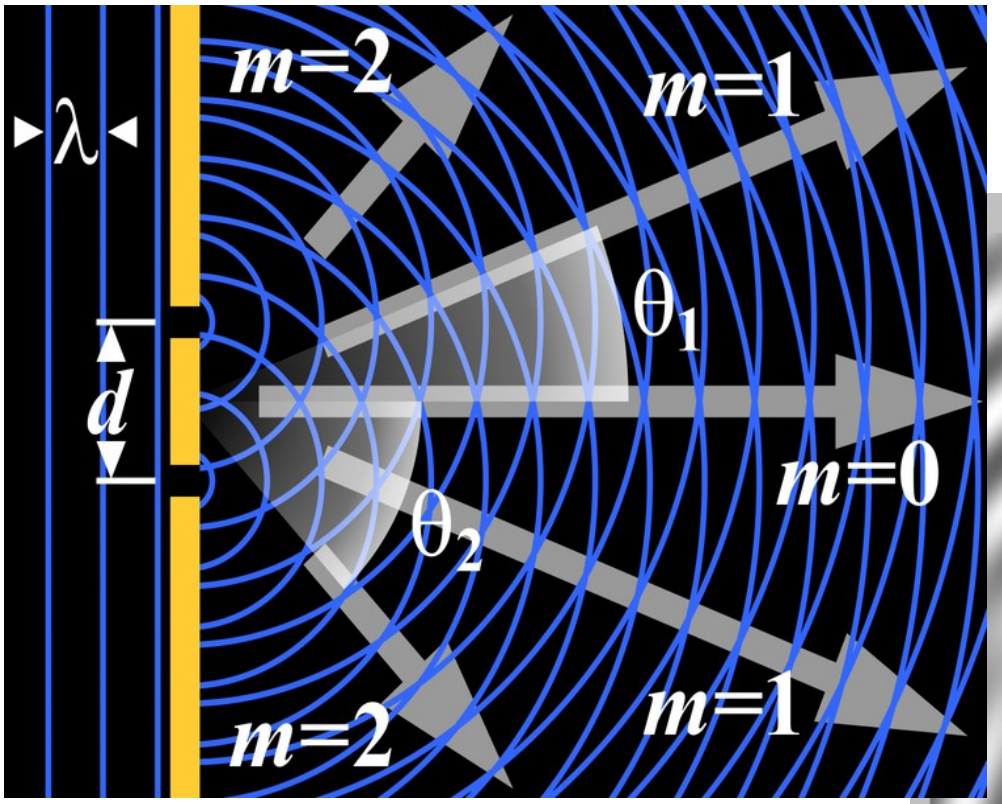
Spektrograf: smer žarka postane odvisna od valovne dolžine svetlobe

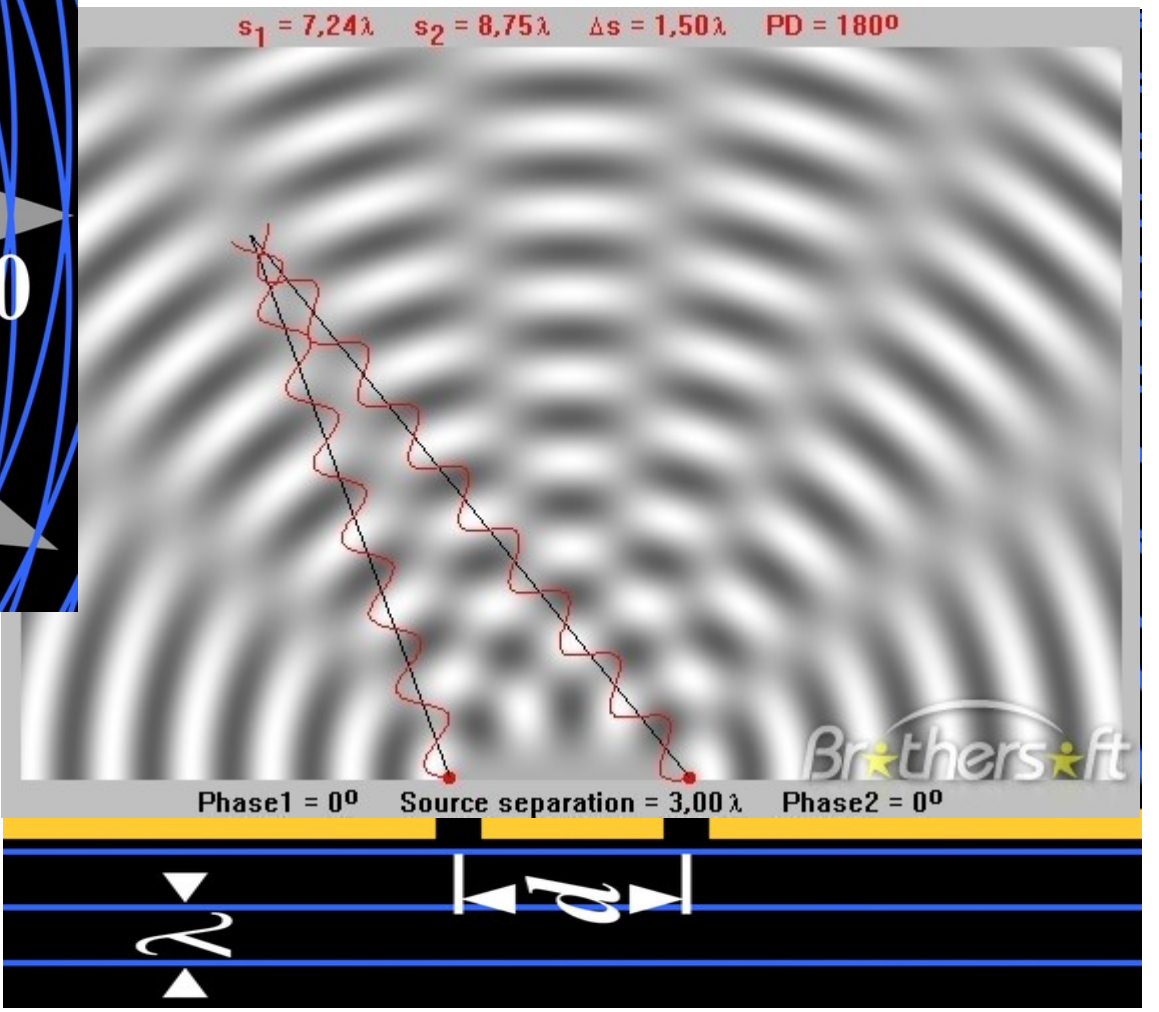
Če primerjamo spremembo smeri žarkov pri valovnih dolžinah 480 in 650 nm,
potem ko gredo skozi razklonilni element:

pri **prizmi** sta smeri tipično razmaknjeni za 0,6 stopinje.

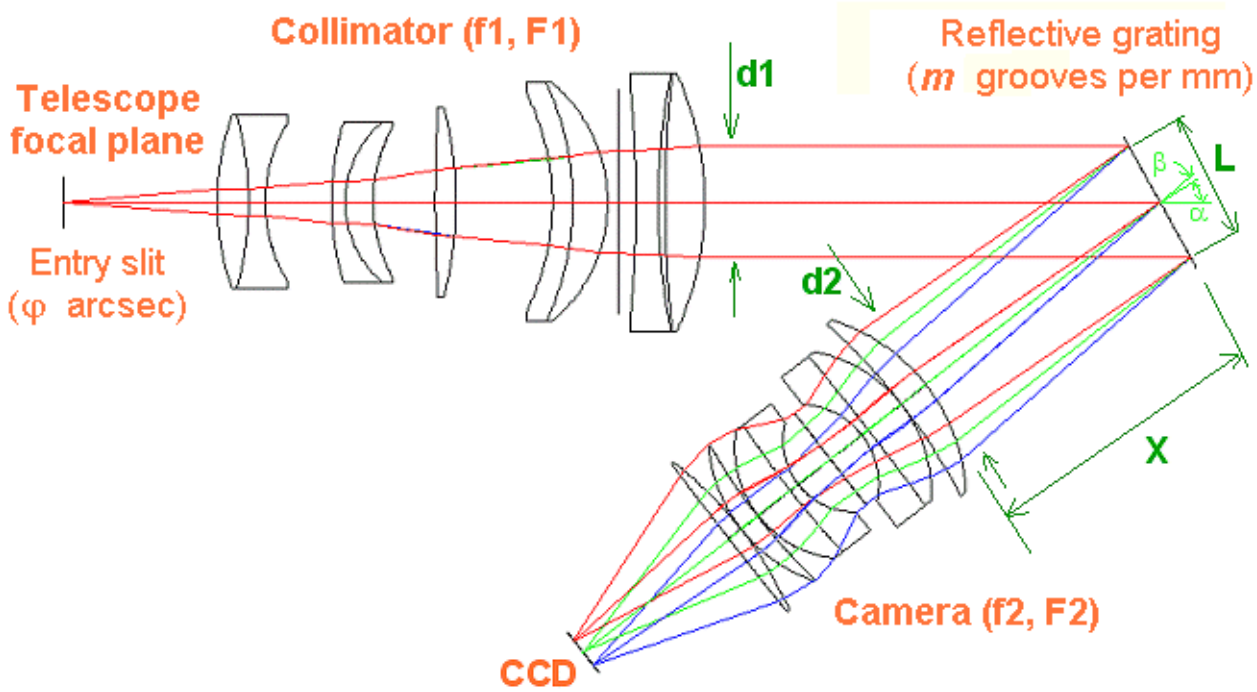
pri **uklonski mrežici** s 1800 režami na milimeter sta smeri tipično razmaknjeni za 20 stopinj.

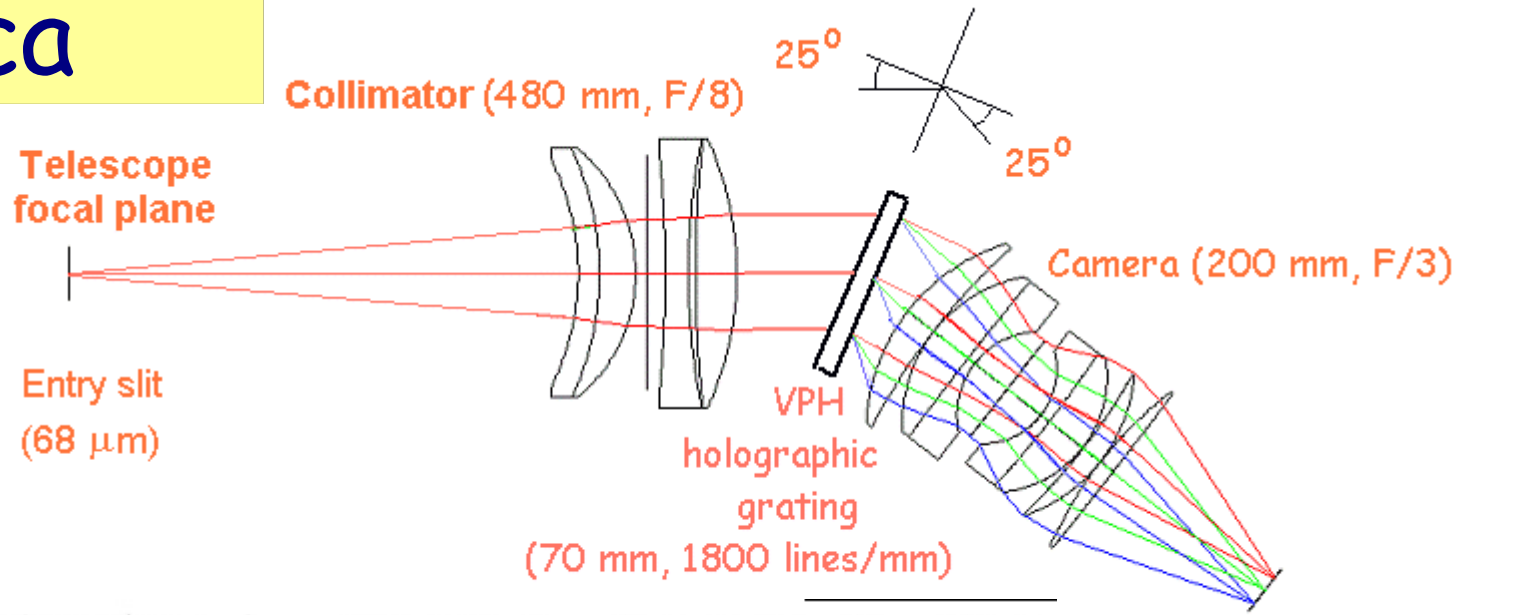
Interferenca na dveh režah





Odbojna in transmisijska uklonska mrežica

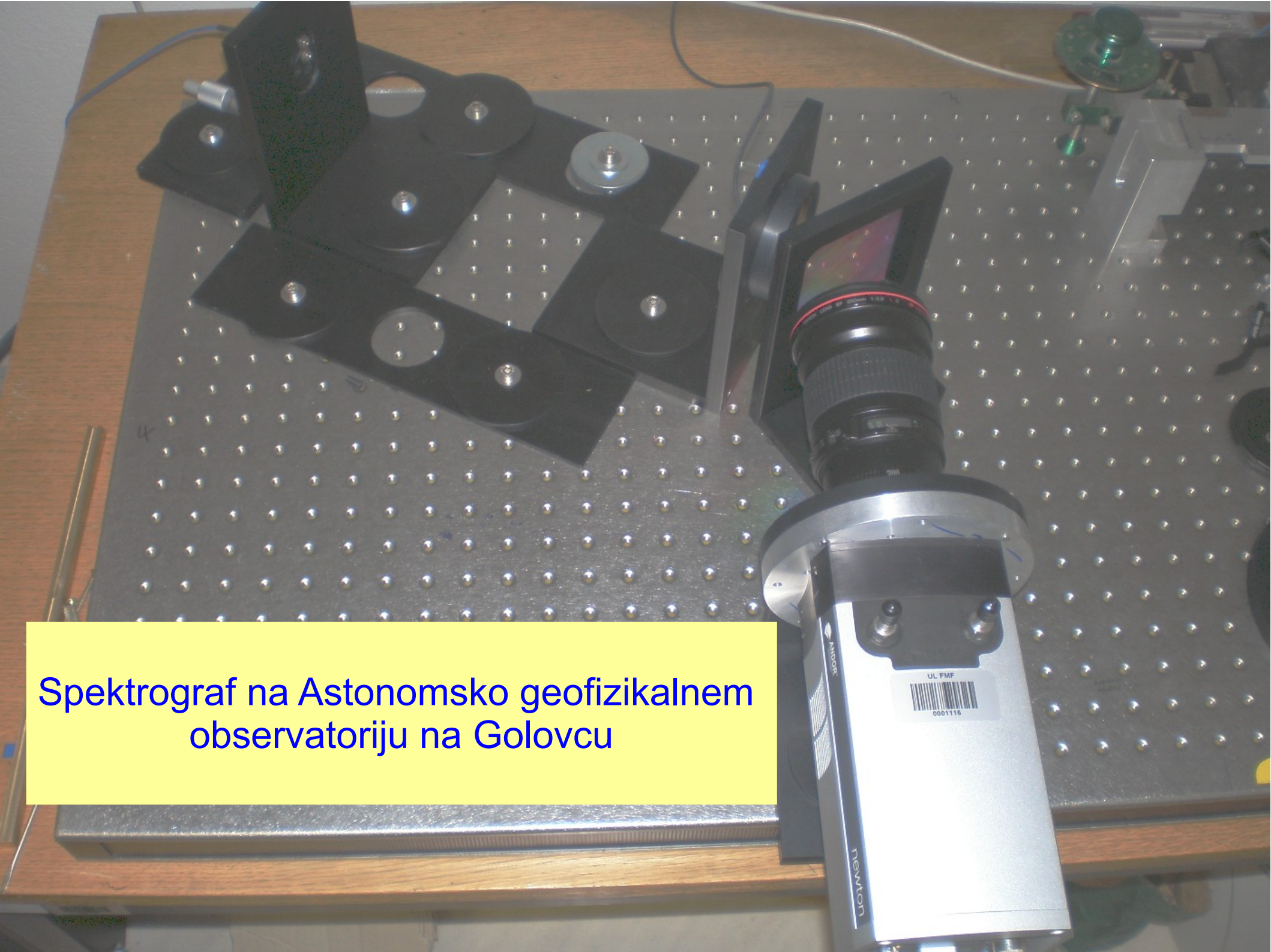




$$R \lesssim \frac{Lm\lambda_o}{\varphi D}$$

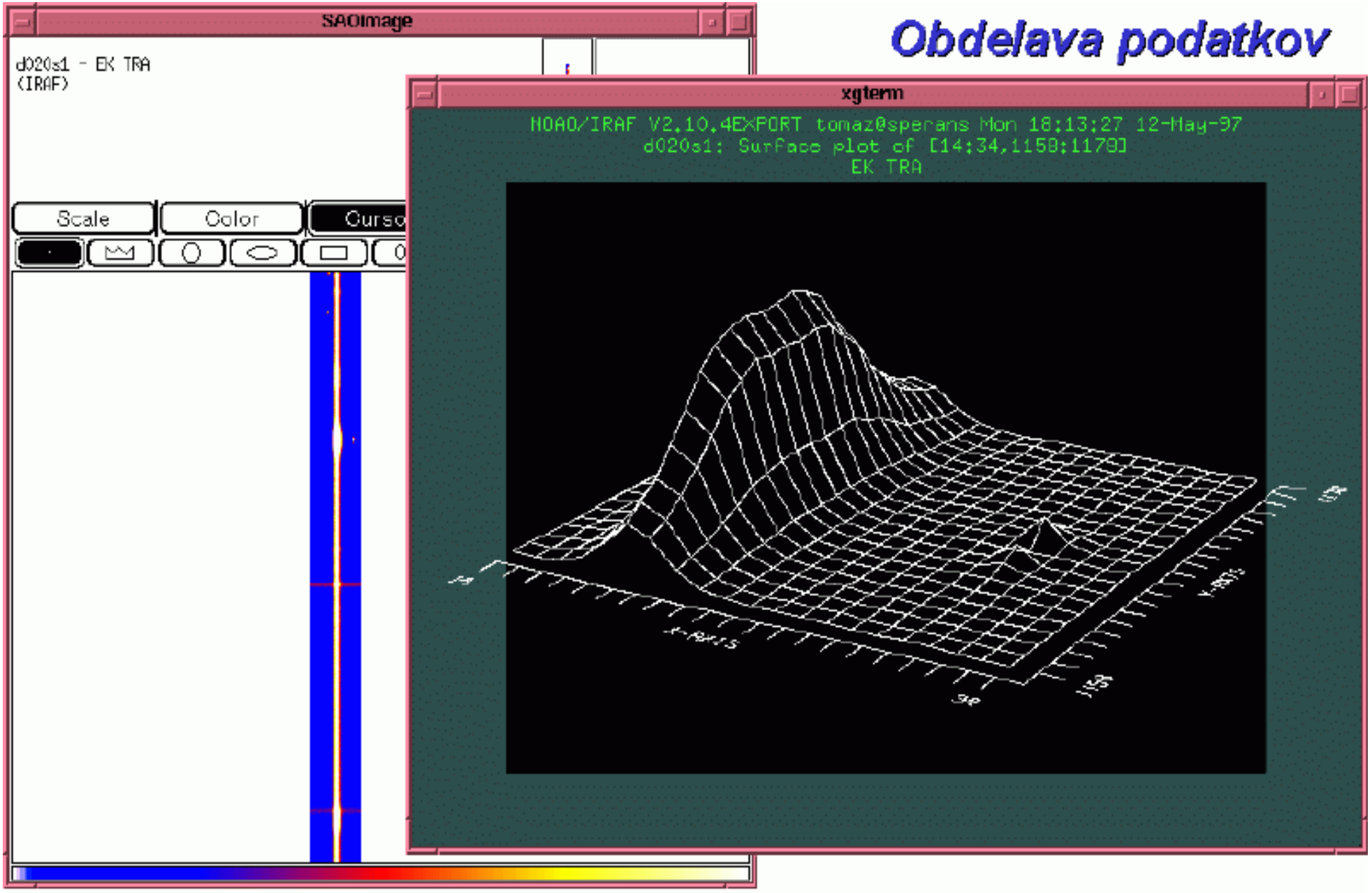
$L = 80$ mm, $m = 1800$ lines/mm, $\lambda_o = 550$ nm, $\varphi = 2.5$ arcsec, $D = 0.7$ m

$\Rightarrow R \lesssim 9280.$



Spektrograf na Astonomsko geofizikalnem observatoriju na Golovcu

Obdelava podatkov



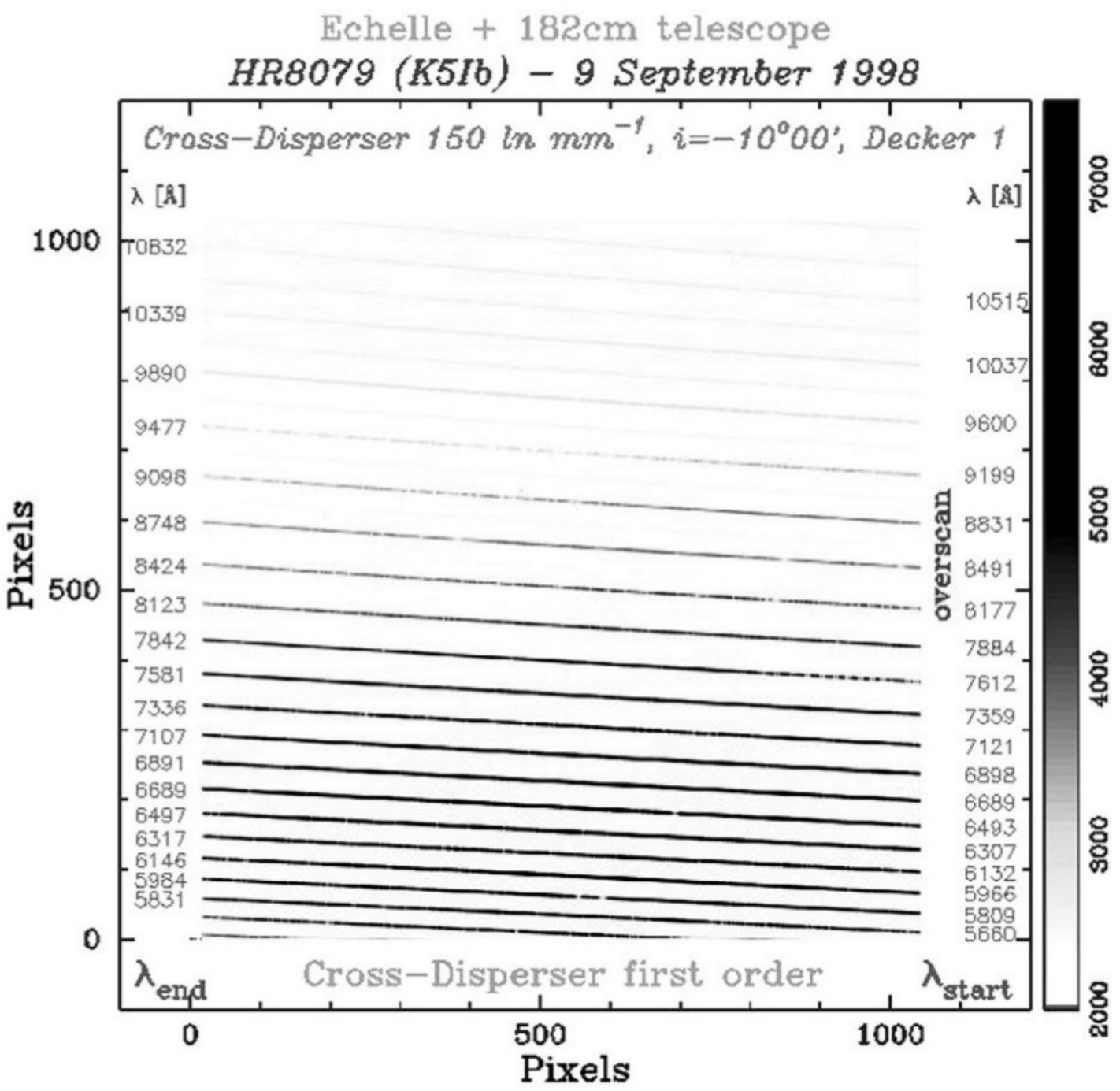
Problemi klasičnega spektrografa

- spekter je relativno kratek (~2000 točk) in zato pokriva majhno območje valovnih dolžin,
- naenkrat opazujemo le en objekt (zvezdo).

Možno je rešiti eno ali drugo težavo:

- rešitev za prvo je stopničasti spektrograf,
- rešitev za drugo pa optična vlakna in velik / širokokoten teleskop.

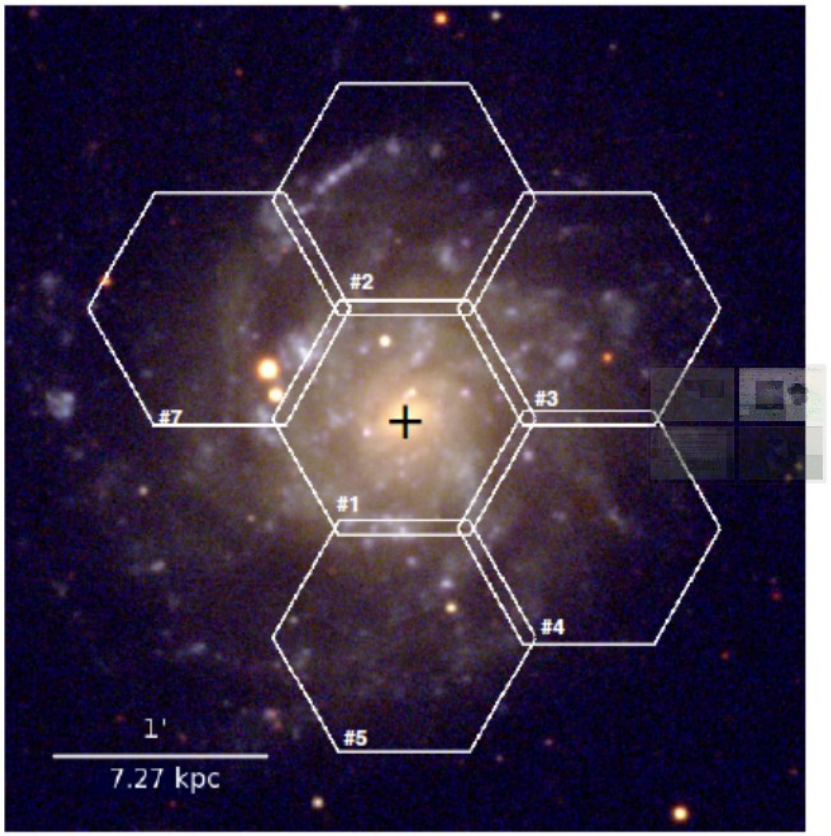
Stopničasti spektrograf

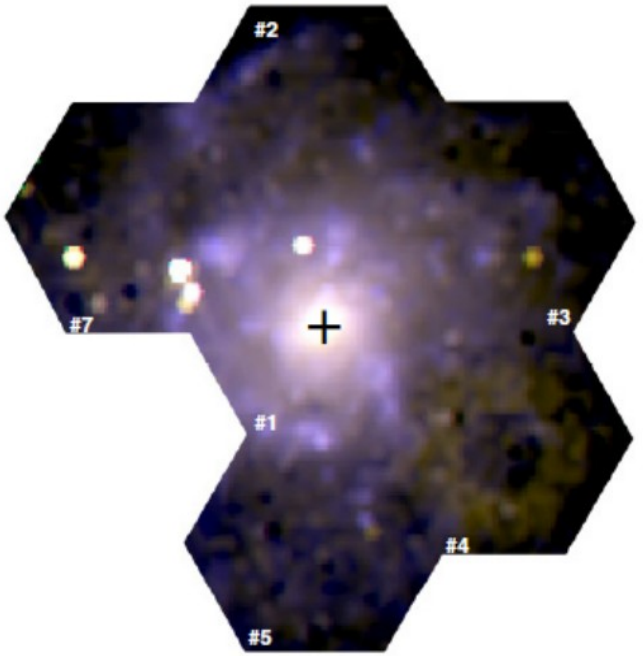


Spectrum of the cool star HR 8079 (K5Ib, V=3.7 mag, 600 sec expt) without second-order suppressing filter. The low flux at the blue wavelengths of the second order spectrum reduces contamination to minimal terms.

2-D spektroskopija kotno majhnih objektov

PPAK Integral Field Unit
the Calar Alto (CAHA) observatory 3.5 m telescope





Marino et al. 2013

Figure 1: *Left panel:* False-color SDSS Optical image of NGC 5668. Plate scale is 0.396 arcsec/pix. *Right panel:* Synthetic false-color image obtained from the PPAK data cube and the response curves of the SDSS u, g and r filters. Plate scale is 1 arcsec/pix in this case. North is up and East is to the left in both cases.

2-D spektroskopija kotno majhnih objektov

Marino et al. 2013

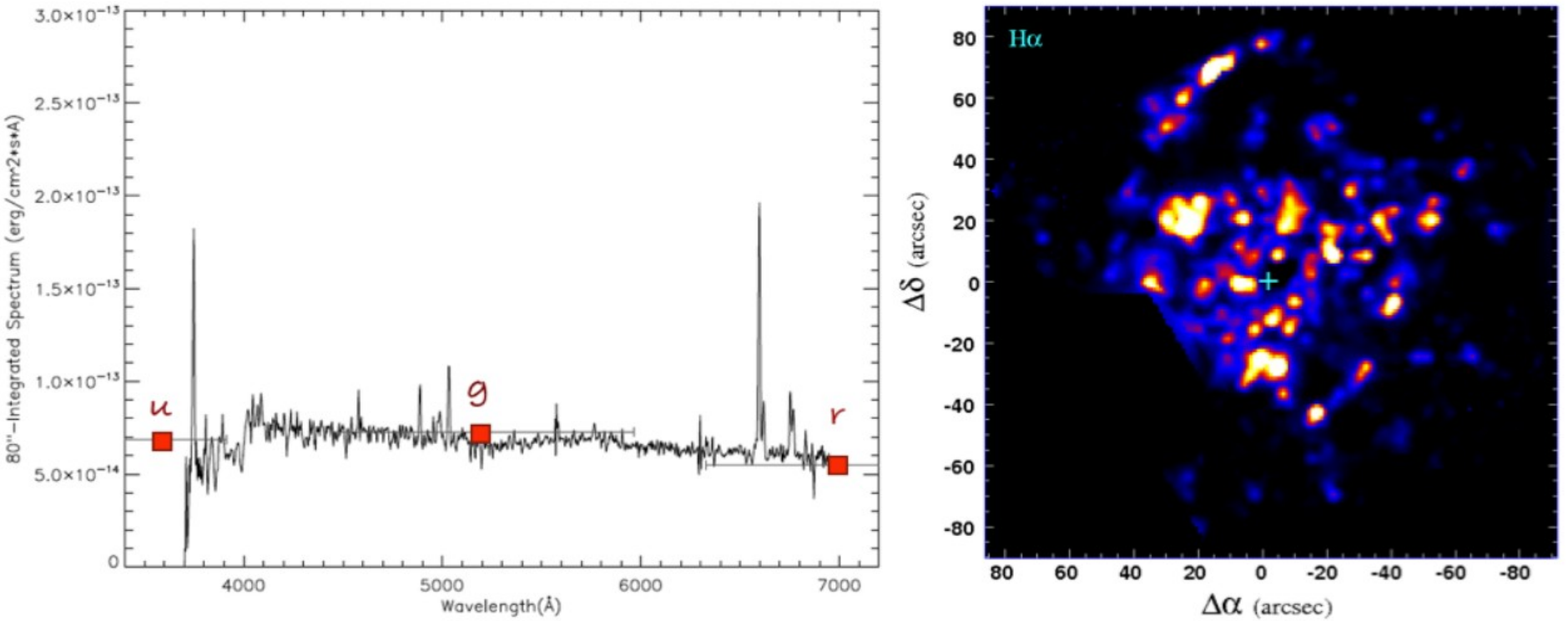
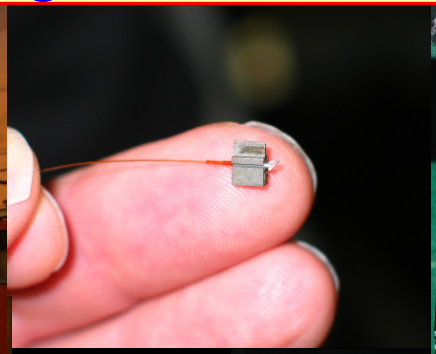
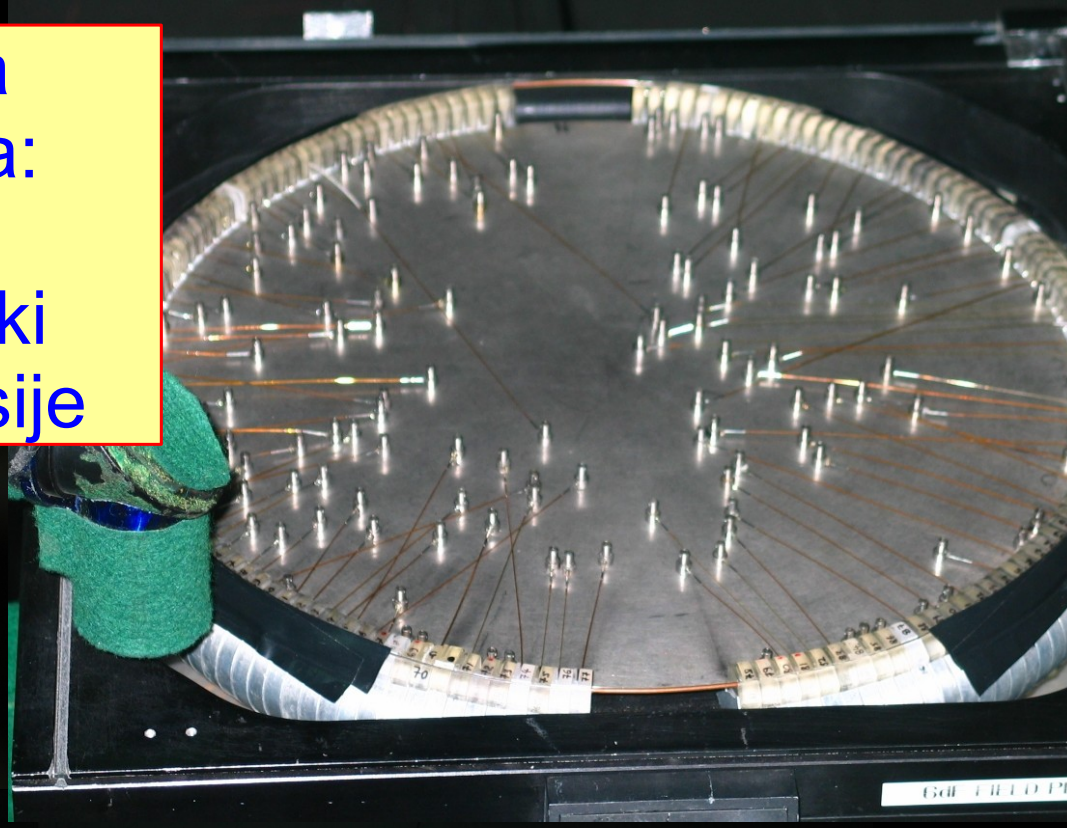


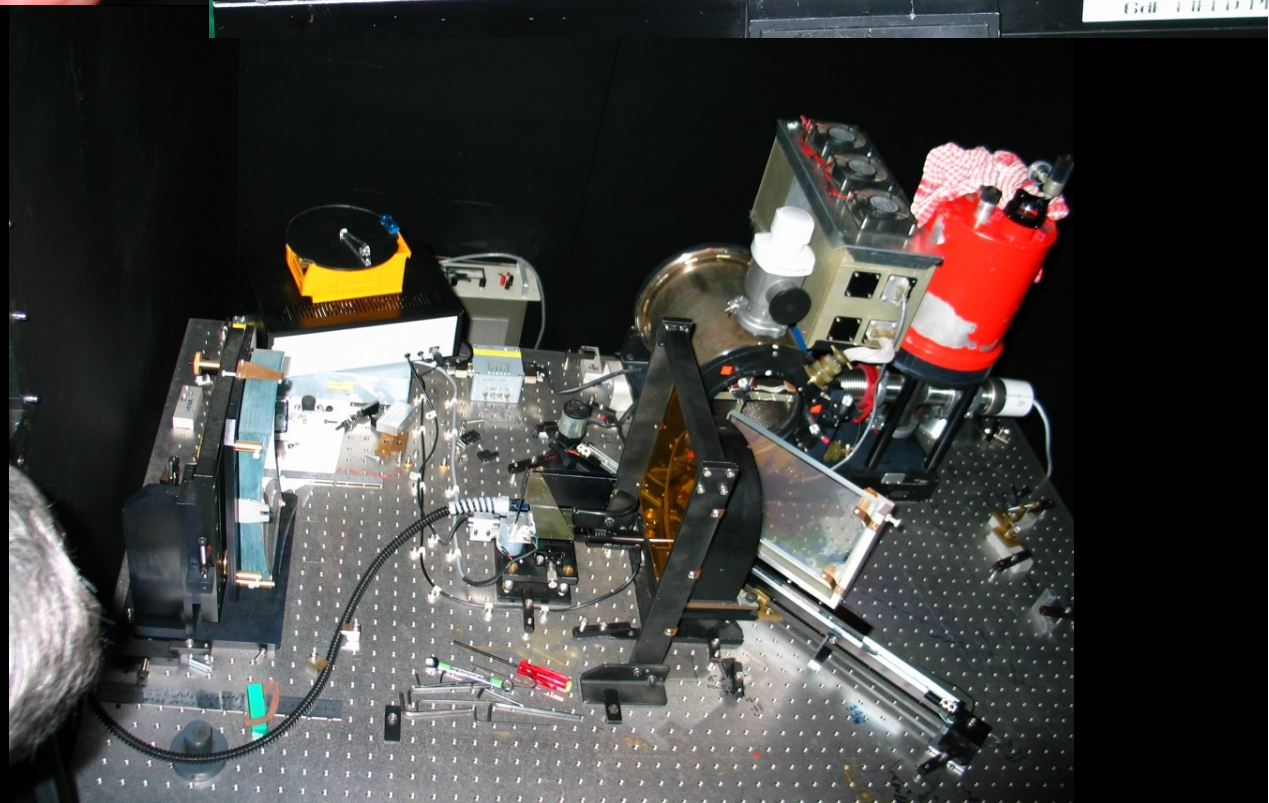
Figure 2: *Left panel:* The integrated spectrum of NGC 5668 is shown as a black line. The SDSS *g'* and *r'* band photometry data are shown as red squares. Horizontal error bars represent the FWHM of each filter. *Right panel:* Hα emission lines map. The mosaic center is marked with a cyan cross. North is up and East is to the left.

Multiobjektna spektroskopija:

spektroskopski pregledi Galaksije







Multifiber spectra: arc, flat & object

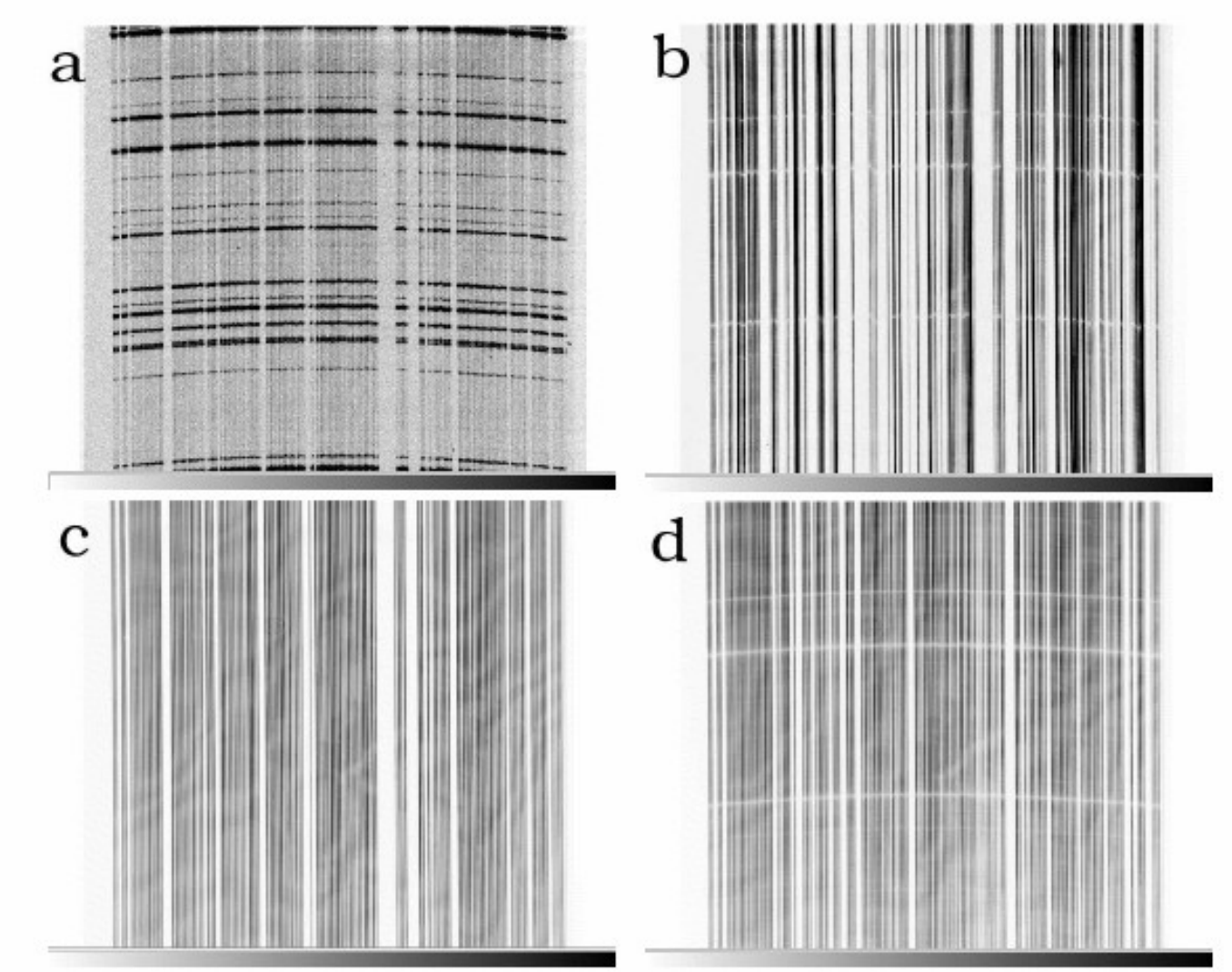
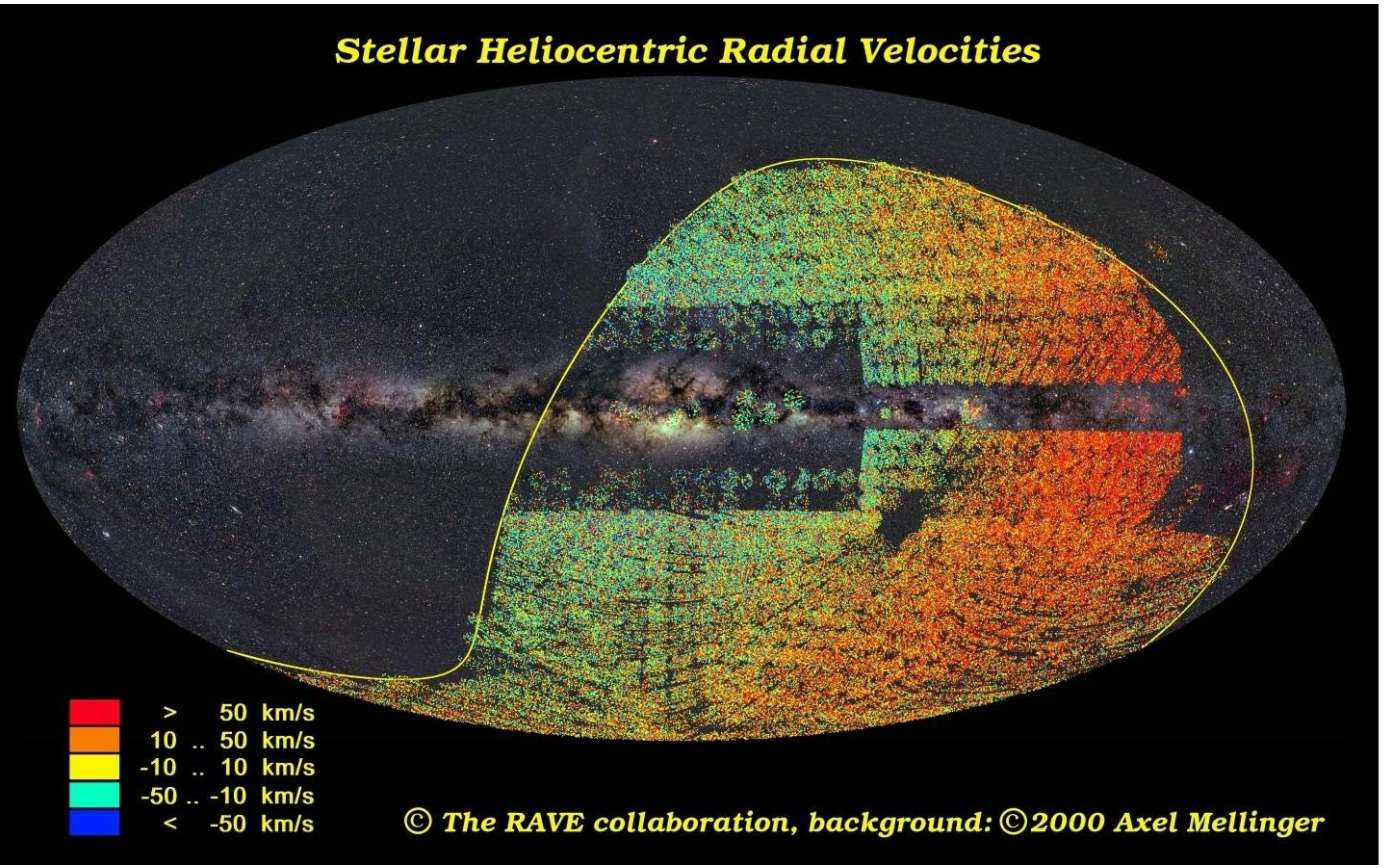
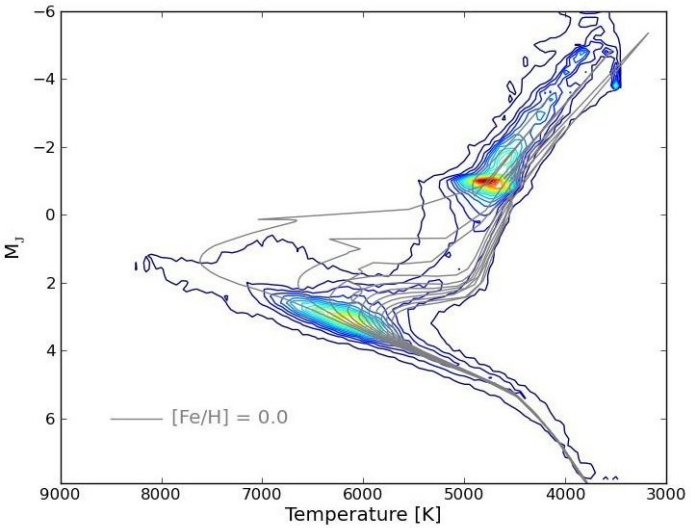


Figure 1: Identification of different kinds of files by visual inspection with the IRAF's *display* command: (a) an arc exposure, (b) a scientific exposure, (c) a useful flat-field, (d) a bad flat-field. The latter should not be used because the Ca II absorption lines of unknown (but local) origin would jeopardize flux calibration. In the text we refer to the horizontal or x-direction as across-dispersion, vertical or y-direction is along-dispersion.

RAdialnohitrostni Vesoljski Eksperiment (RAVE)





www.rave-survey.org

- 574,630 spektrov 483,330 različnih zvezd,
- že blizu 30 znanstvenih člankov,
- med rezultati: ubežna hitrost in masa Galaksije, razlaga nastanka debelega diska Galaksije, kinematika diska, odkritje razpadlih pritlikavih galaksij in velikega števila posebnih zvezd...

Položaj RAVEovih zvezd v Galaksiji

modro: pritlikavke (log g>3.5)
rdeče: orjakinje (log g<3.5)

Podatki: Zwitter idr. 2010, animacija: G. Matijevič

RAVEove zvezde pred 220 milijoni let

modro: pritlikavke (log g>3.5)
rdeče: orjakinje (log g<3.5)

Podatki: Breddels idr. 2009, animacija G. Matijevič & M. Vodopivec

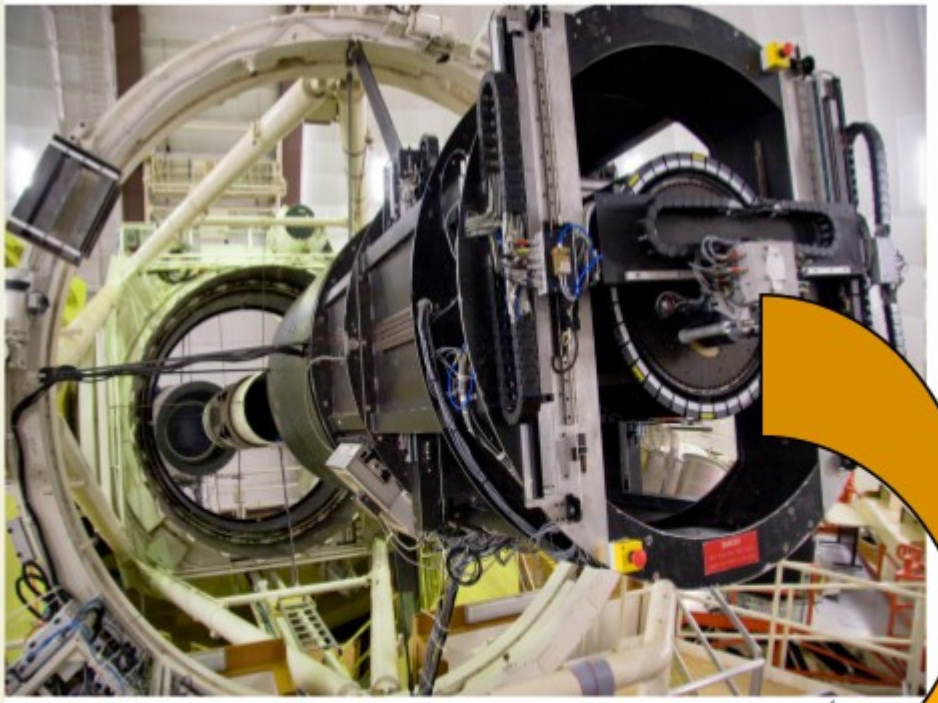
Galactic archaeology

- Major goal of GA is to unravel the formation of the Galactic Disk
  - look for fossil substructure via chemical signatures
  - Chemical Tagging (Freeman & Bland-Hawthorn 2002)
  - stars from a common star-forming event
  - stars from accreted satellites

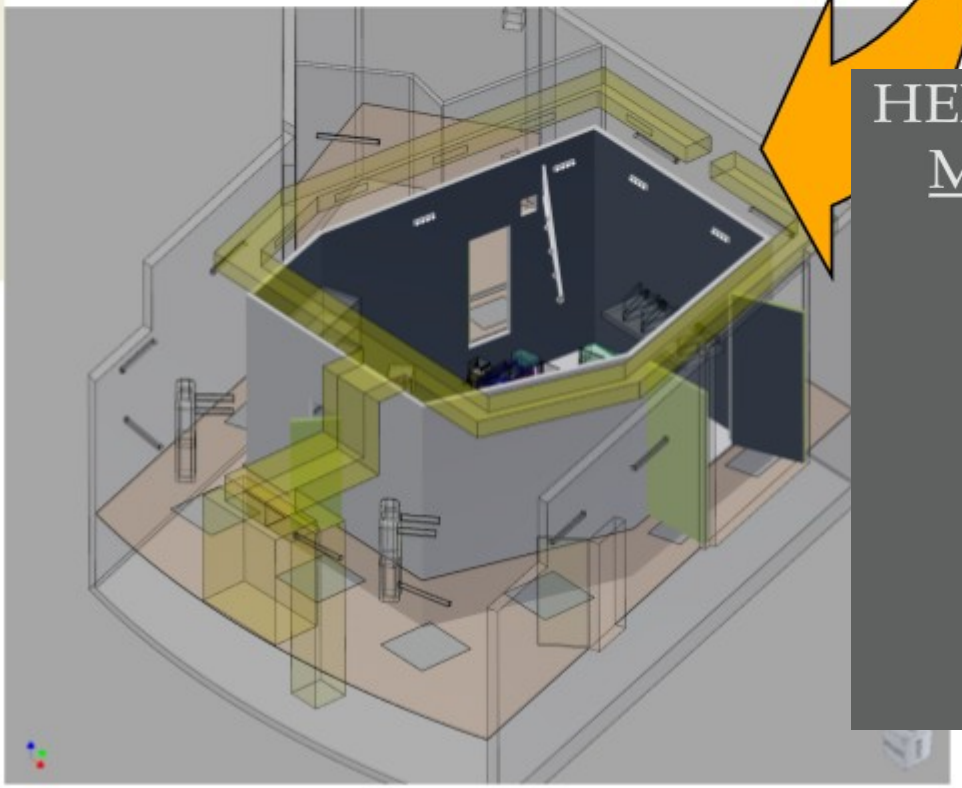
Abundance accuracy

- To distinguish different star-forming sites we require high abundance accuracy
  - observed scatter in solar neighbourhood ~ 0.25 dex (Eg. Reddy et al, Bensby et al.; varies for different elements)
  - cluster star-to-star abundance variation < 0.05 dex
  - target 4-5 abundance 'bins' per element
  - require measurement accuracy 0.05 – 0.1 dex
  - drives requirement for spectral resolution and efficiency

Basic design of HERMES



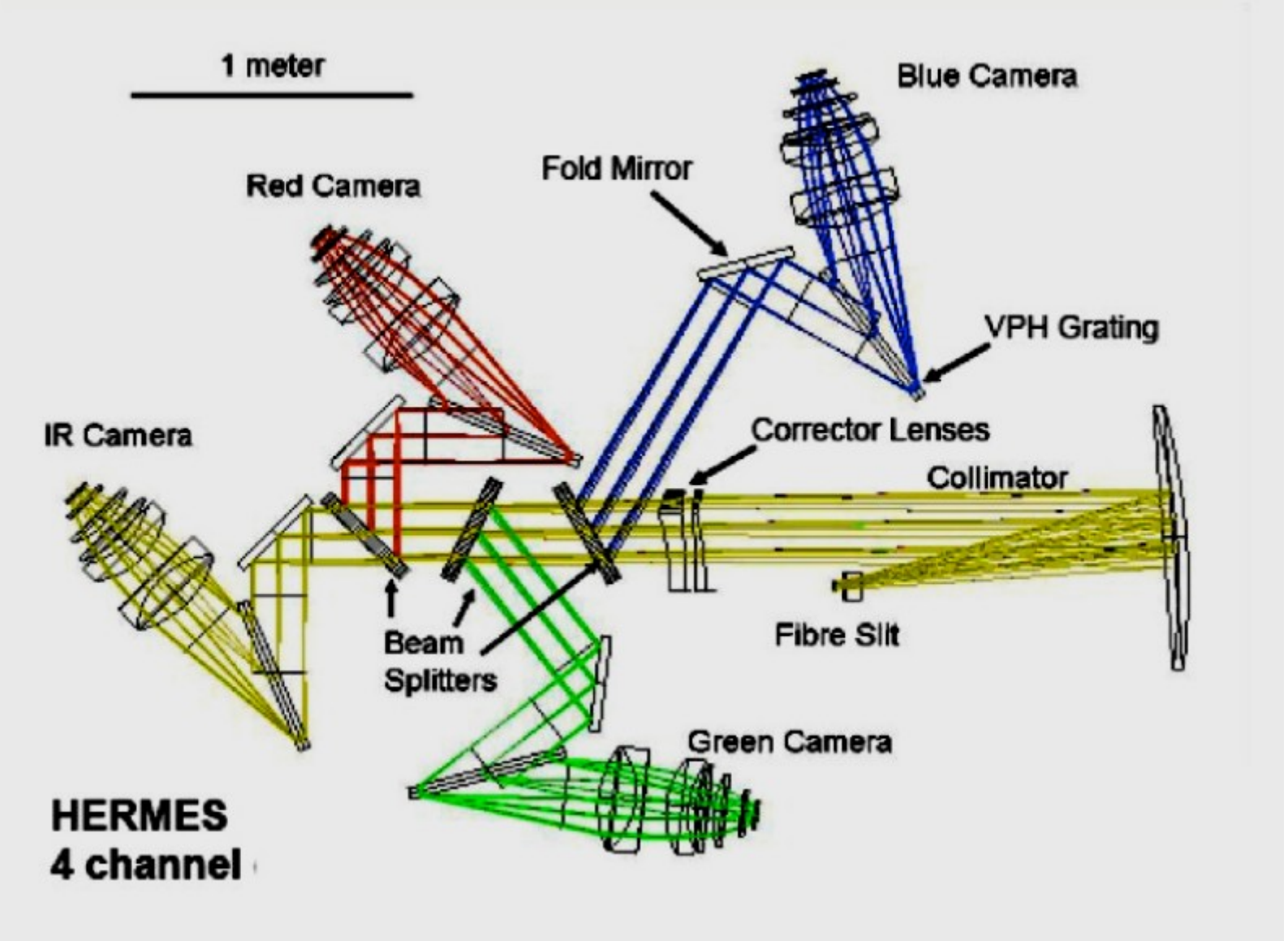
Fiber Feed



HERMES is a High Efficiency and Resolution Multi-Element Spectrograph

- 392 fibers, each 2 arcsec in diameter
- deployable over a 2 degree field of view, using the 2dF positioning facility
- four channel design with similar spectral resolution
- minimum separation of 200Å between adjacent wavelength bands

Basic design of HERMES



Observational parameters

- Spectral Resolution:
  - Spectral resolution ~30,000 (> 25,000 at minimum)
  - Sufficient to resolve lines of interest
  - Spectral resolution ~ 50,000 needed for accuracy < 0.05 dex
  - Achievable using a slit mask
- Signal-to-noise ratio:
  - ~ 100 per resolution element
  - esp. important for the weak lines (most n-capture elements)
  - SNR = 100 @ V = 14 in 1 hour (for timely completion of survey)
  - overall 10% instrument efficiency

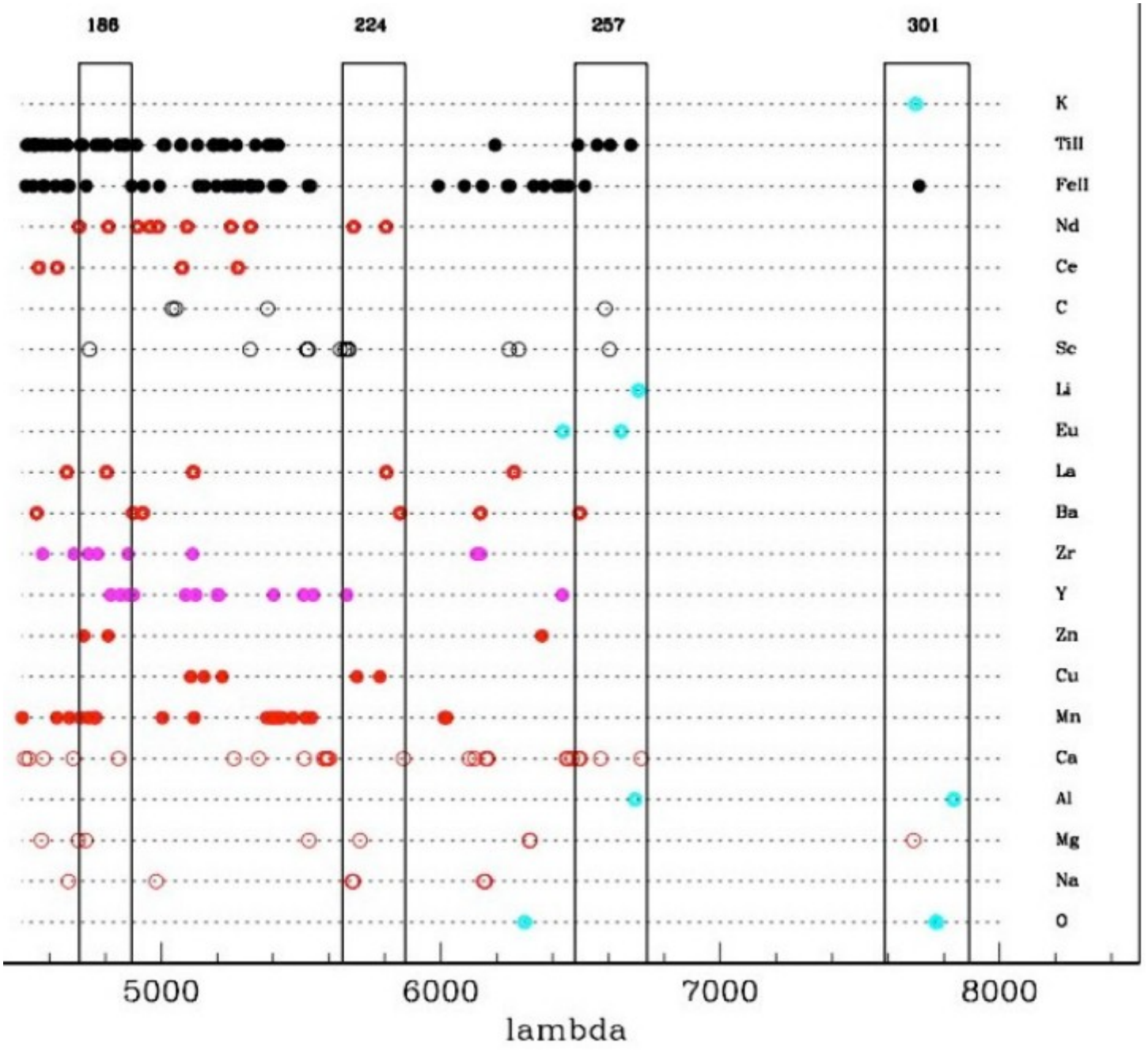
Element	Measurement Error
Light Elements	
Li	0.06
Alpha elements:	
O	0.07
Mg	0.05
Si	0.05
Ca	0.04
Ti	0.06
Odd-Z elements:	
Na	0.09
Al	0.04
Fe-peak elements:	
Cr	0.06
Mn	0.05
Fe	0.03
Co	0.05
Ni	0.03
Light s-process:	
Zr	0.12
Heavy s-process:	
Ba	0.08
La	0.08
r-process elements:	
Eu	0.06

- Abundance accuracy from literature studies using R ~25,000 – 30,000 and SNR ~ 100
- Measured via 'Equivalent Widths' and/or Spectral synthesis techniques (planned GA survey abundance analysis pipeline – talk by E.Wylie)

Chemical elements tbd

Ref: Pancino et al, 2010; Jacobson et al., 2009; Carney et al, 2005; Yong, et al., 2005; Friel et al., 2003

Chemical elements to be done



Spektroskopski pregledi zvezd

ime pregleda	obdobje	število zvezd	teleskop	resolucija	S/N	naše sodelovanje
RAVE www.rave-survey.org	2003-2013	483,330	1,2-m UKSchmidt	7500	~40	operativno vodenje, posebne zvezde, razdalje.
Gaia-ESO surveys.roe.ac.uk /ges/	2012-2017	125,000	8-m VLT	~17500	~30	medzvezdni prostor, posebne zvezde,
Gaia gaia.esa.int	2013-2019	20 M	Gaia-RVS	10500 & 5500	~4	RVS: RVMask modul, šum,kataloška podpora
Hermes-Galah www.aao.gov.au/HERMES/GALAH/	2013-2019	1 M	4-m AAO	25000 & 50000	100	medzvezdni prostor, dvojne zvezde, posebne zvezde, izbor zvezd

Pregled neba Sloan-SDSS je posnel manjše število zvezd v nižji resoluciji.