Gaia spectroscopy overview and Comparative Spectrum Modelling for Cool Giants

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GREAT

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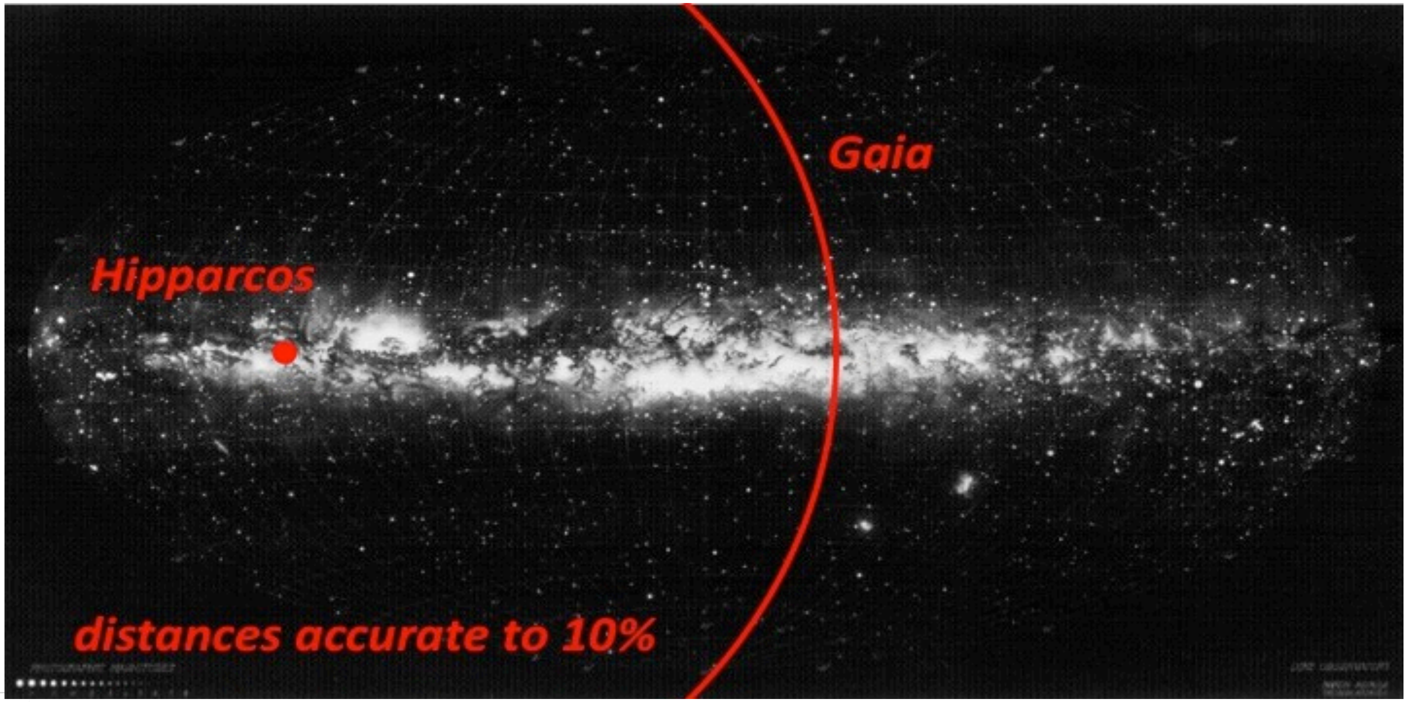
Outline

- Gaia overview – RVS and RP/BP instruments and simulated data
- Apsis – purpose and performance examples
- Synthetic spectra grid examples
- Comparative spectrum modelling experiment for two benchmark stars – cool giants

Gaia overview

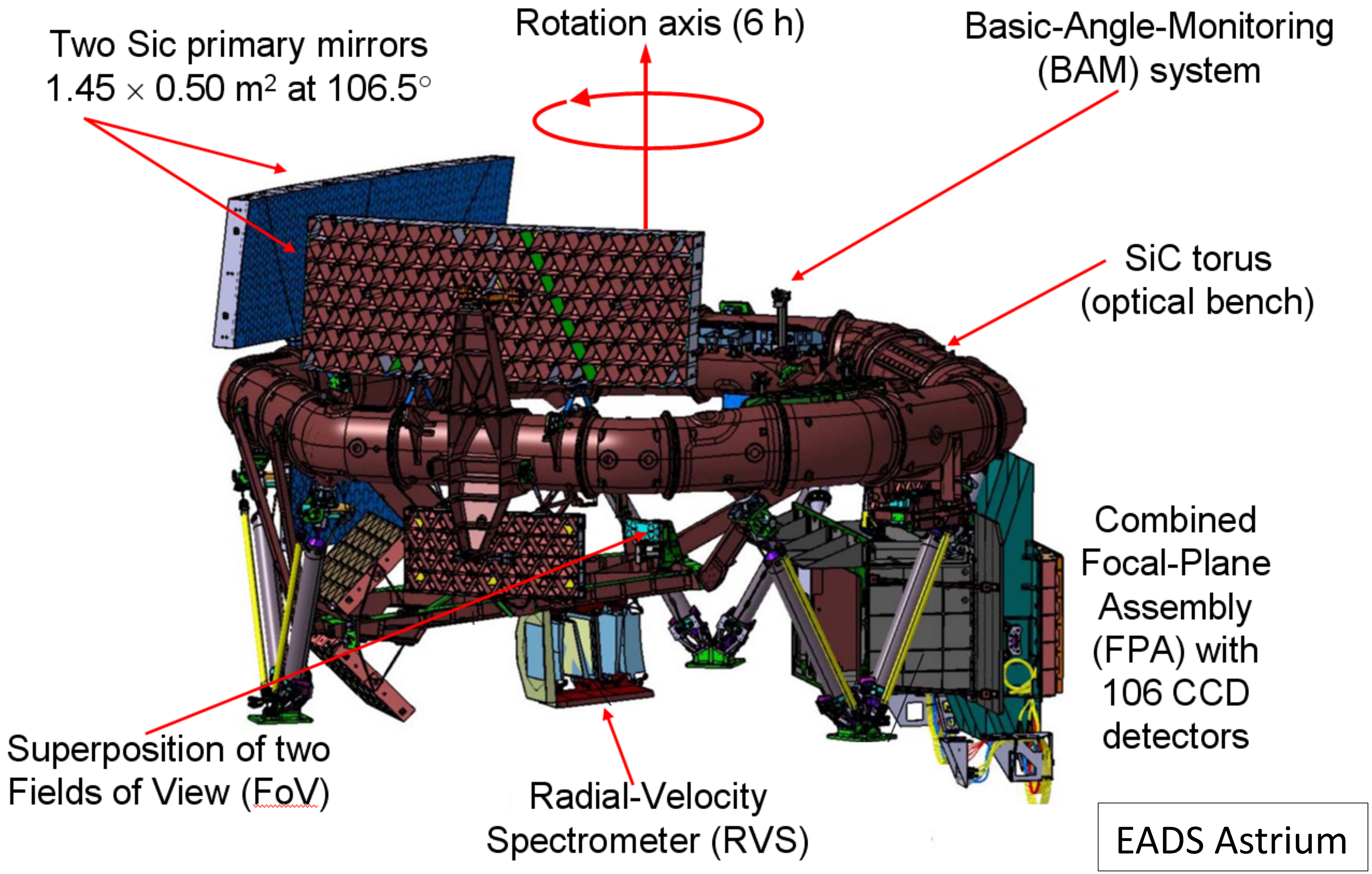
Gaia's astrometric field + radial velocity spectrometer + photometric instrument will obtain positions, space motions, and **physical parameters** for 1 billion stars



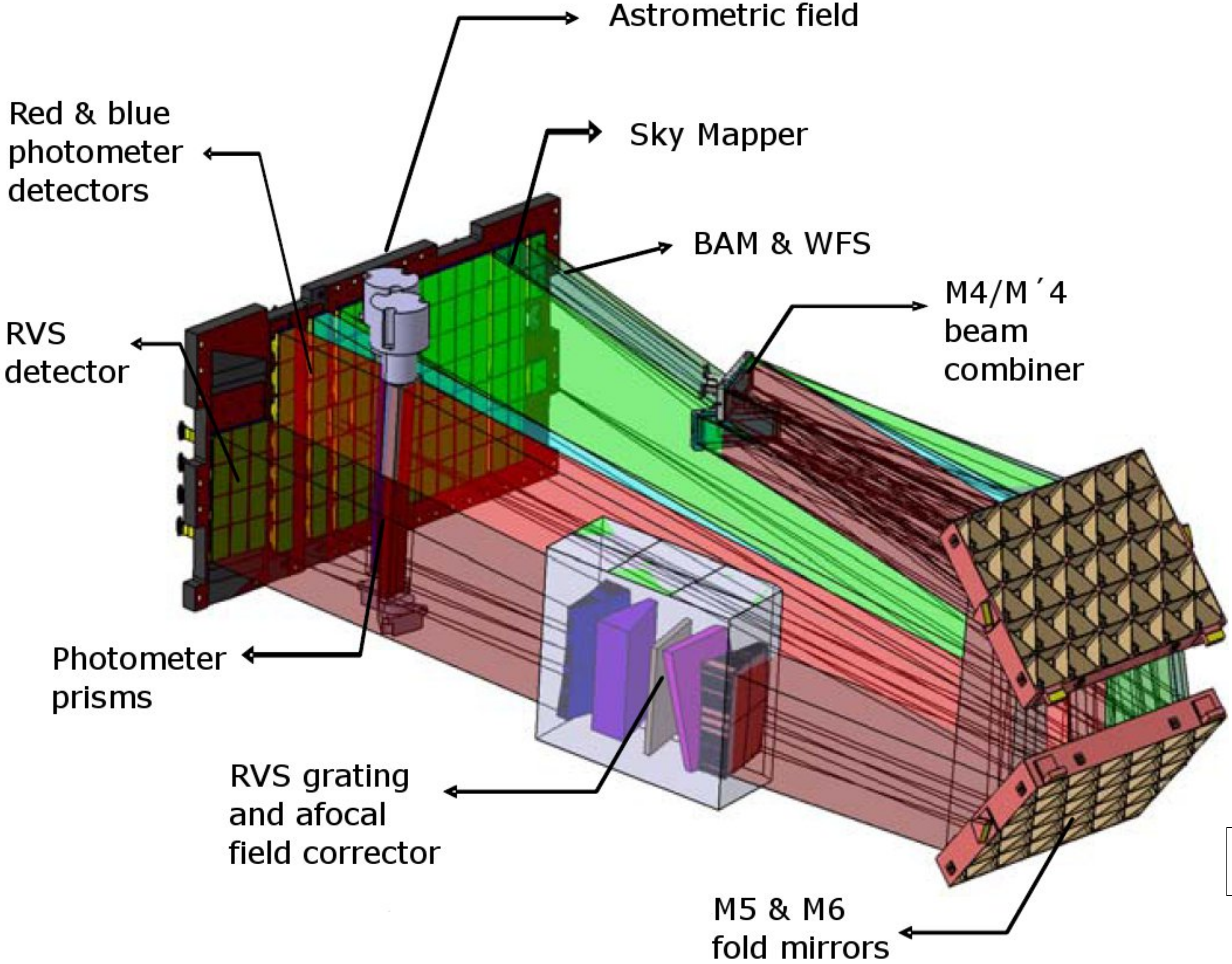
Gaia spectroscopic instruments

- Radial Velocity Spectrometer – RVS
  - wavelength range **847–874 nm** (CaII IR triplet and Paschen lines)
  - resolution ($R = \lambda/\Delta\lambda$) **11 500** for $V \leq 12$, **5 500** for $V \geq 12$
  - SNR >200, 100, 10 at V= 9, 12, 15
- Red and Blue Photometer – RP/BP
  - two prism spectra at low resolution (~4 – 30 nm/pixel)
  - wavelength range 330 – 680 nm and 640 – 1000 nm

Gaia instruments



Gaia instruments

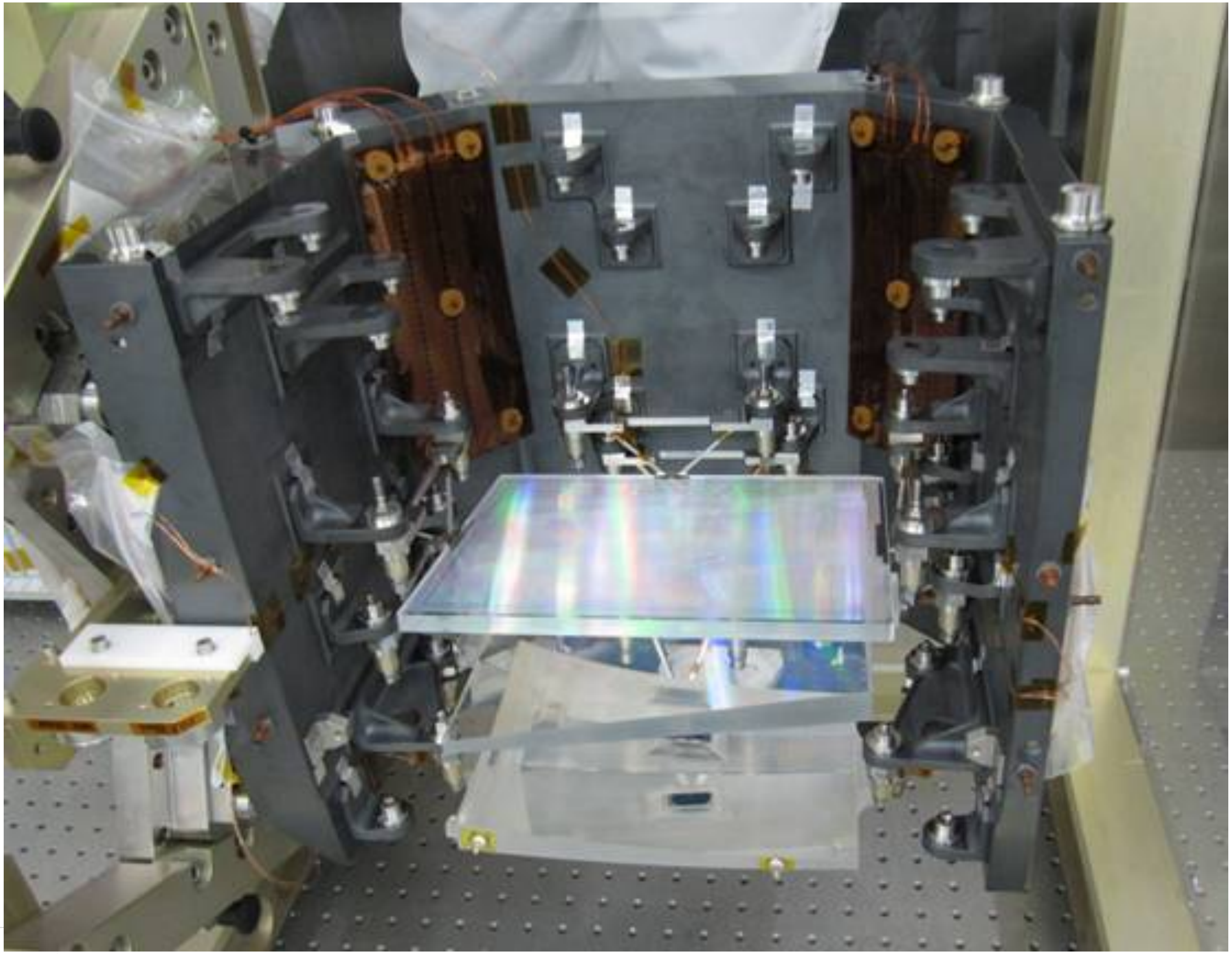


EADS Astrium

Gaia torus and "Folding-Optics Structure"

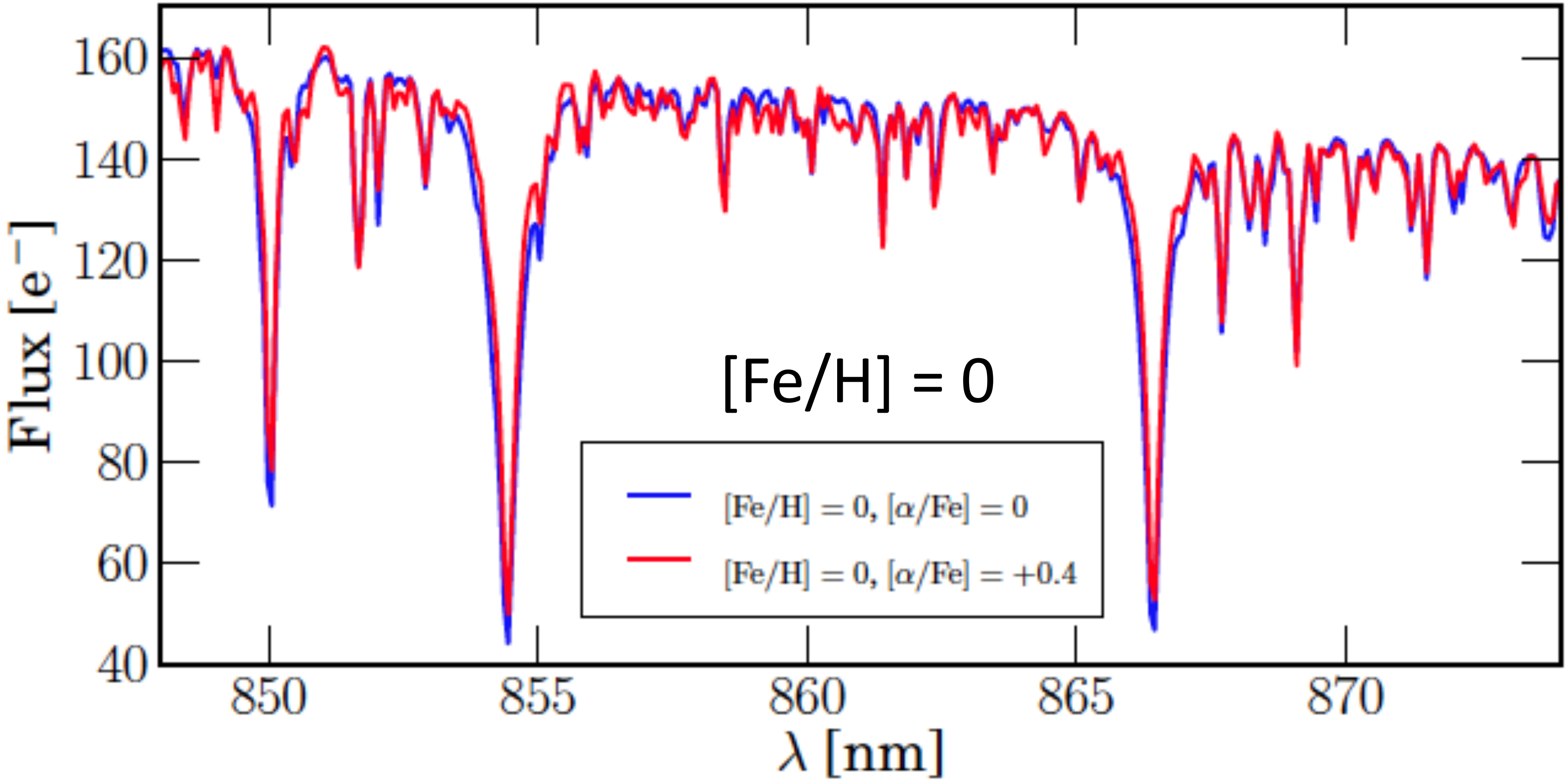
EADS
Astrium
SAS

RVS grating + prism + lens



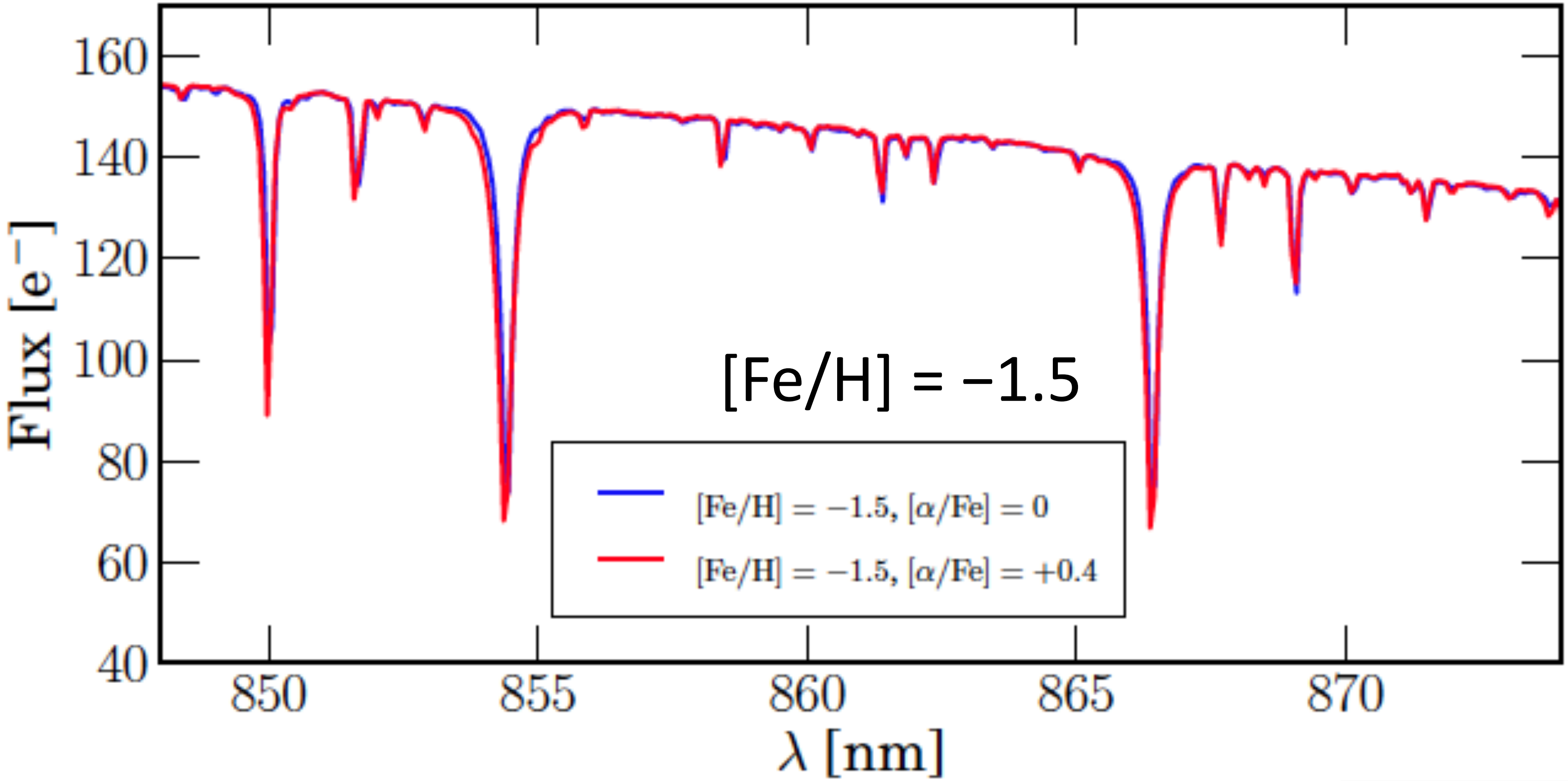
Astrium

Simulated data – RVS – for late-type stars



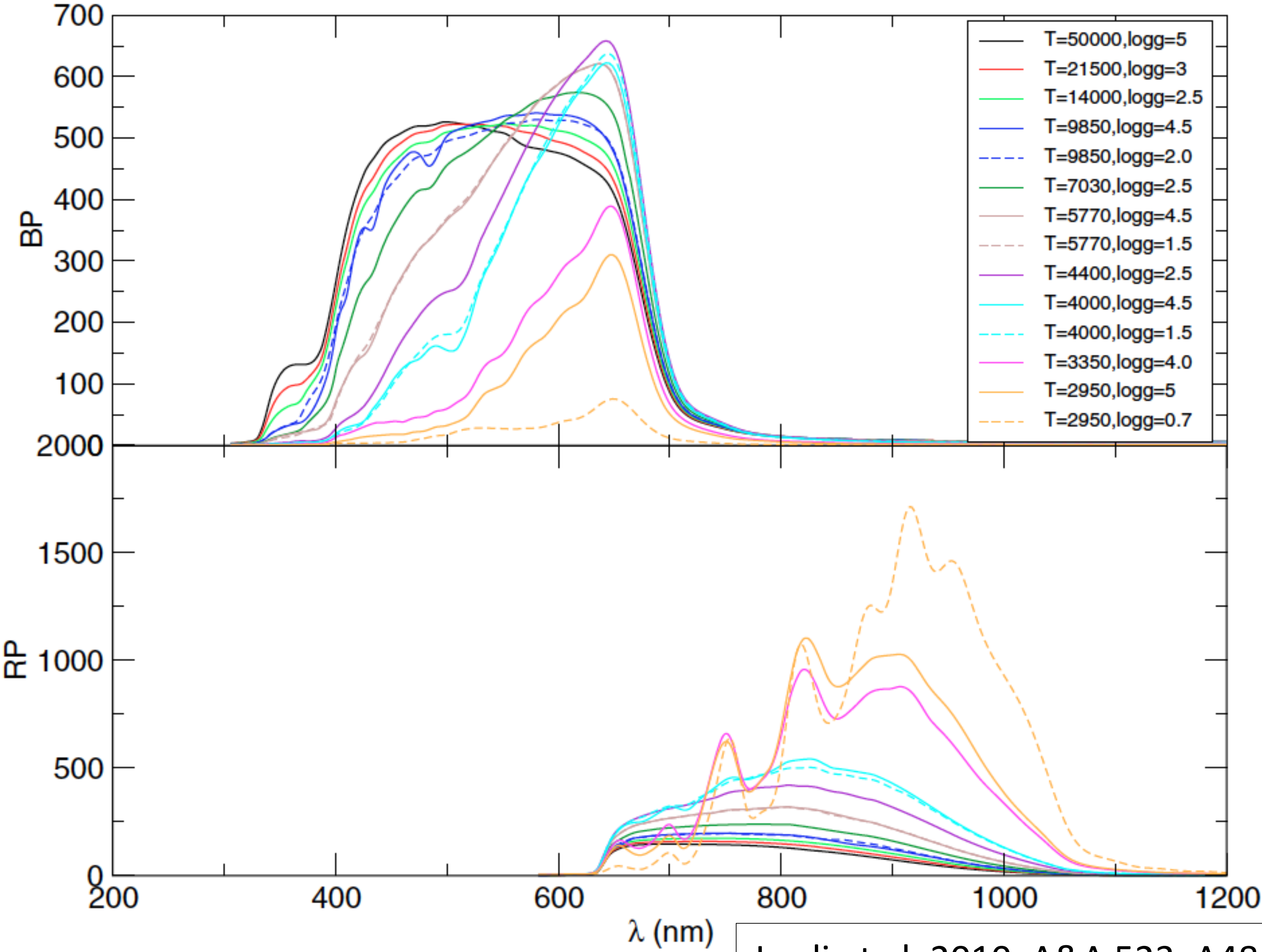
P. Sartoretti

Simulated data – RVS – for late-type stars



P. Sartoretti

Simulated data – RP/BP



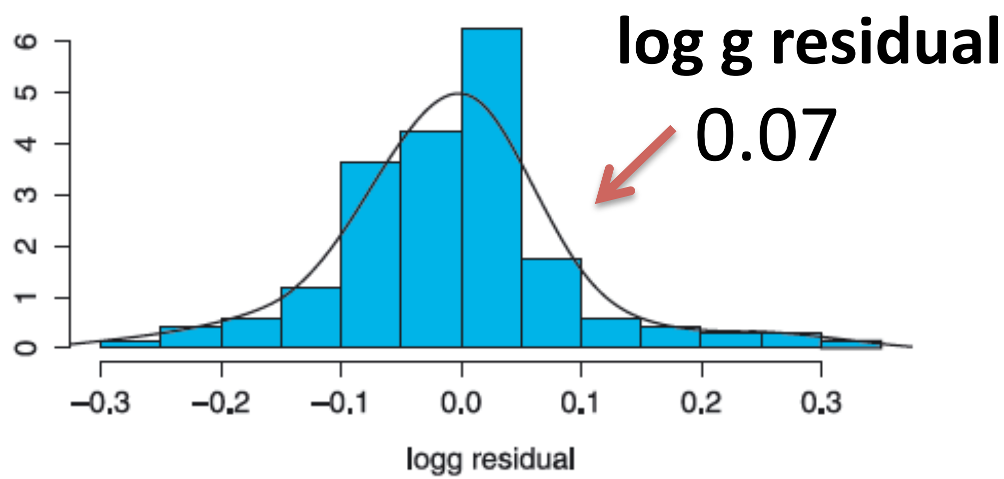
Jordi et al. 2010, A&A 523, A48

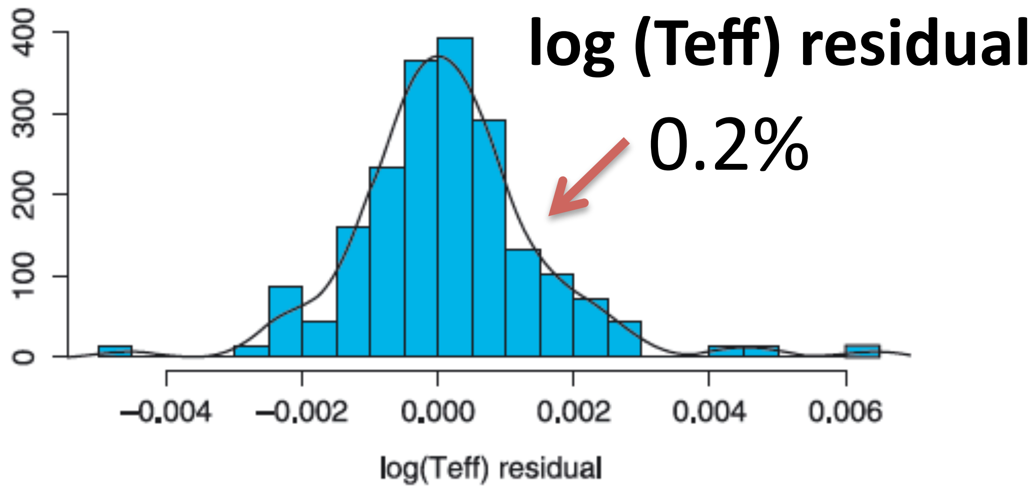
Gaia data processing – Apsis

- Astrophysical parameters inference system (Gaia DPAC CU8 software)
- Will **classify** all sources –> probabilities for being a star, galaxy, quasar, etc.
- Will **determine astrophysical parameters** for stars: T_{eff}, log *g*, metallicity, extinction, α elements, …
- General Stellar Parametrizer for **RP/BP** and **RVS**: **GSP-phot** and **GSP-spec**
- **Trained on model stellar spectra**

GSP-phot performance example

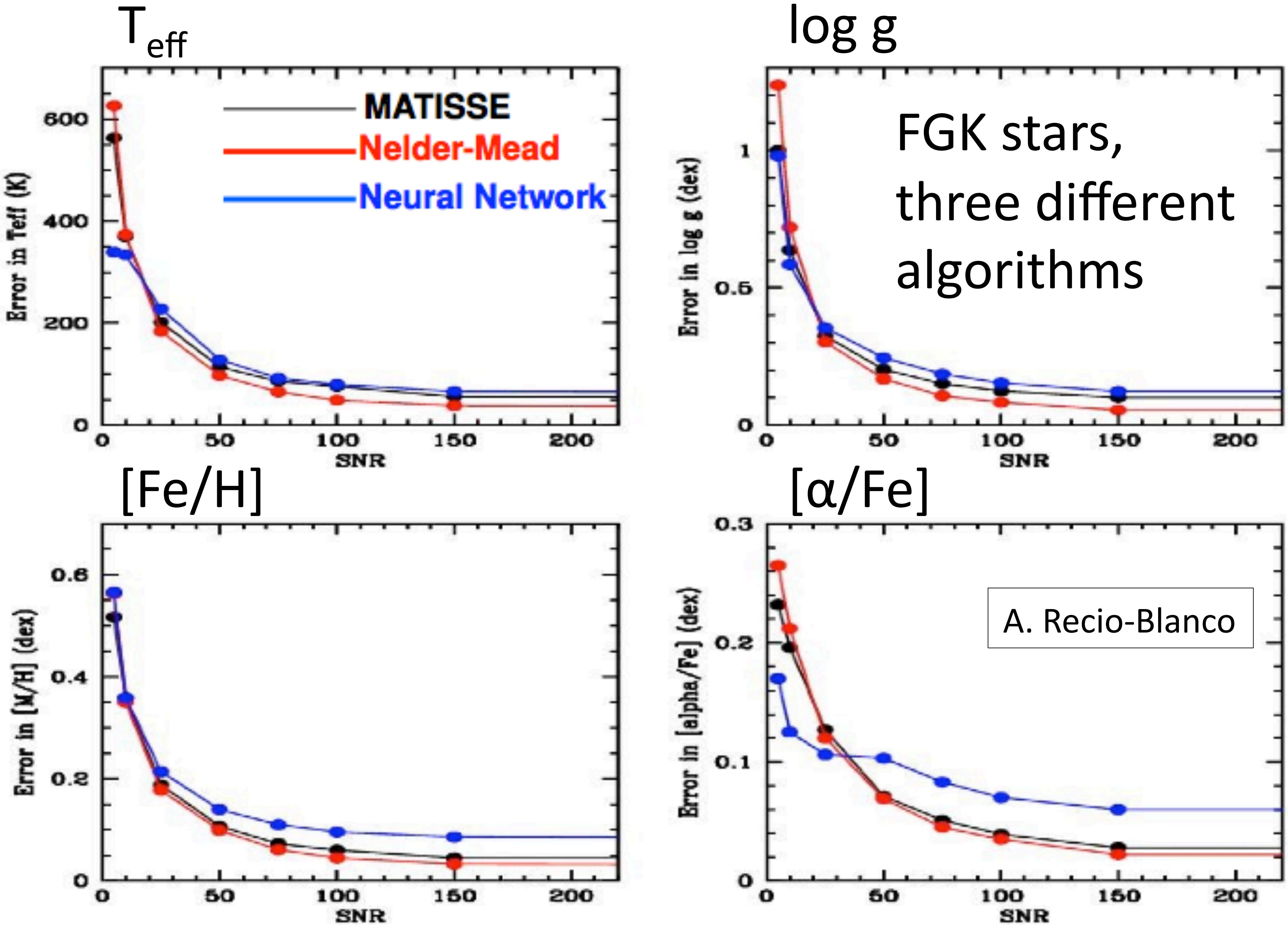
- ILIUM algorithm (Bailer-Jones 2010, MNRAS 403, 96)
- **Best case**, T_{eff} + log g: estimated minus true APs for 137 simulated stars at **G=15 without extinction**





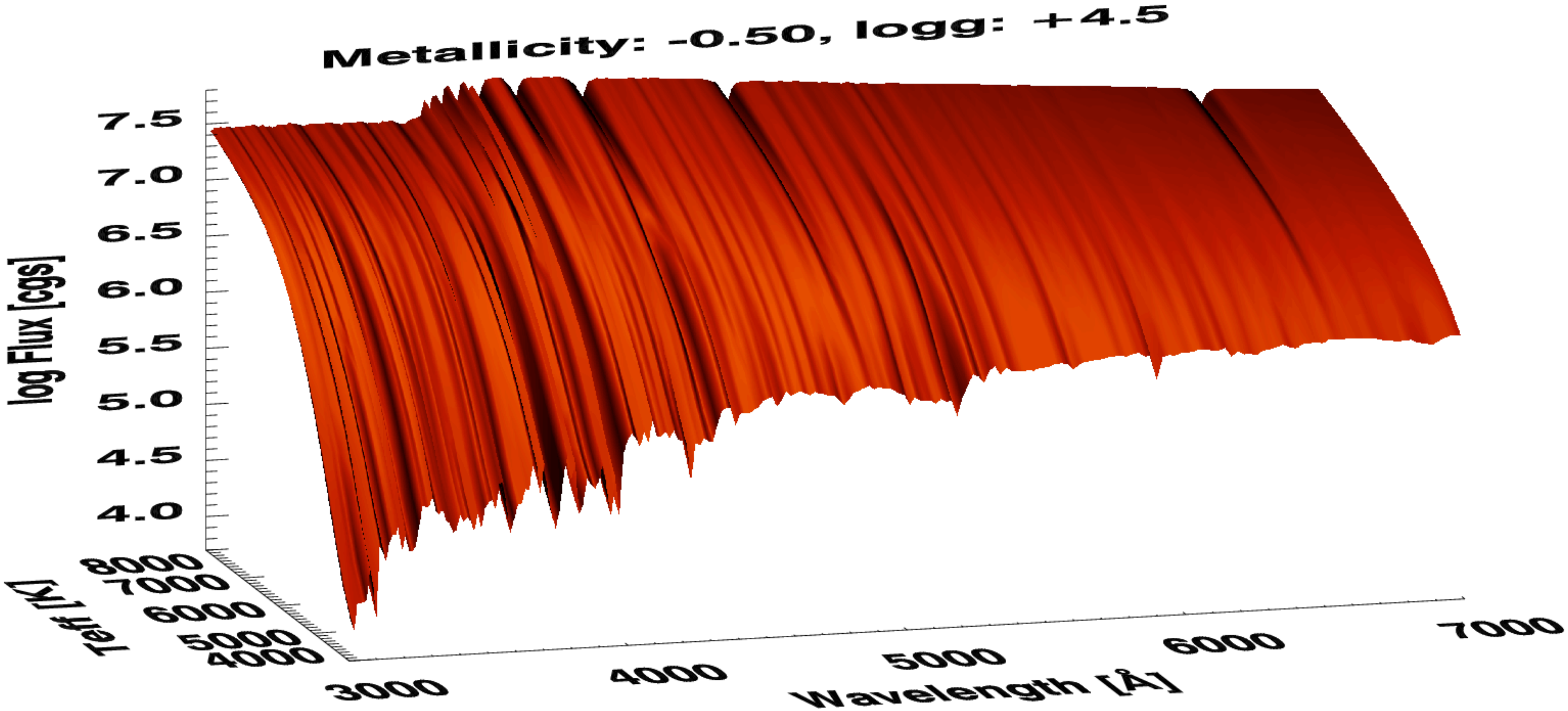
- **In general**, for variable extinction and G=15 and 18.5: T_{eff}: ±3 to 13%, log g: ±0.3 to 1.1, [Fe/H]: ±0.5 to 1.3

GSP-spec performance example – high *R*

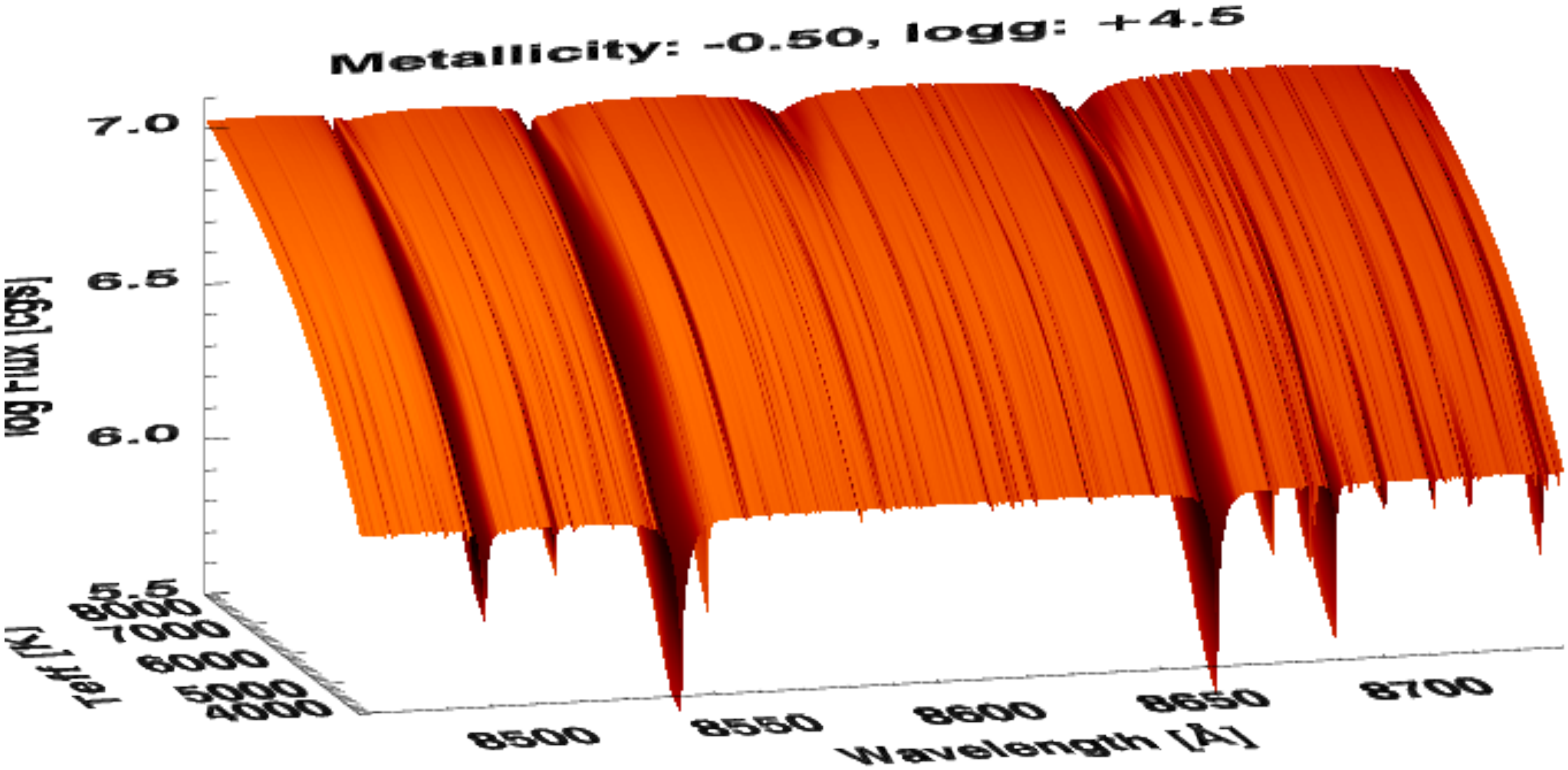


Apsis depends on synthetic spectra grids

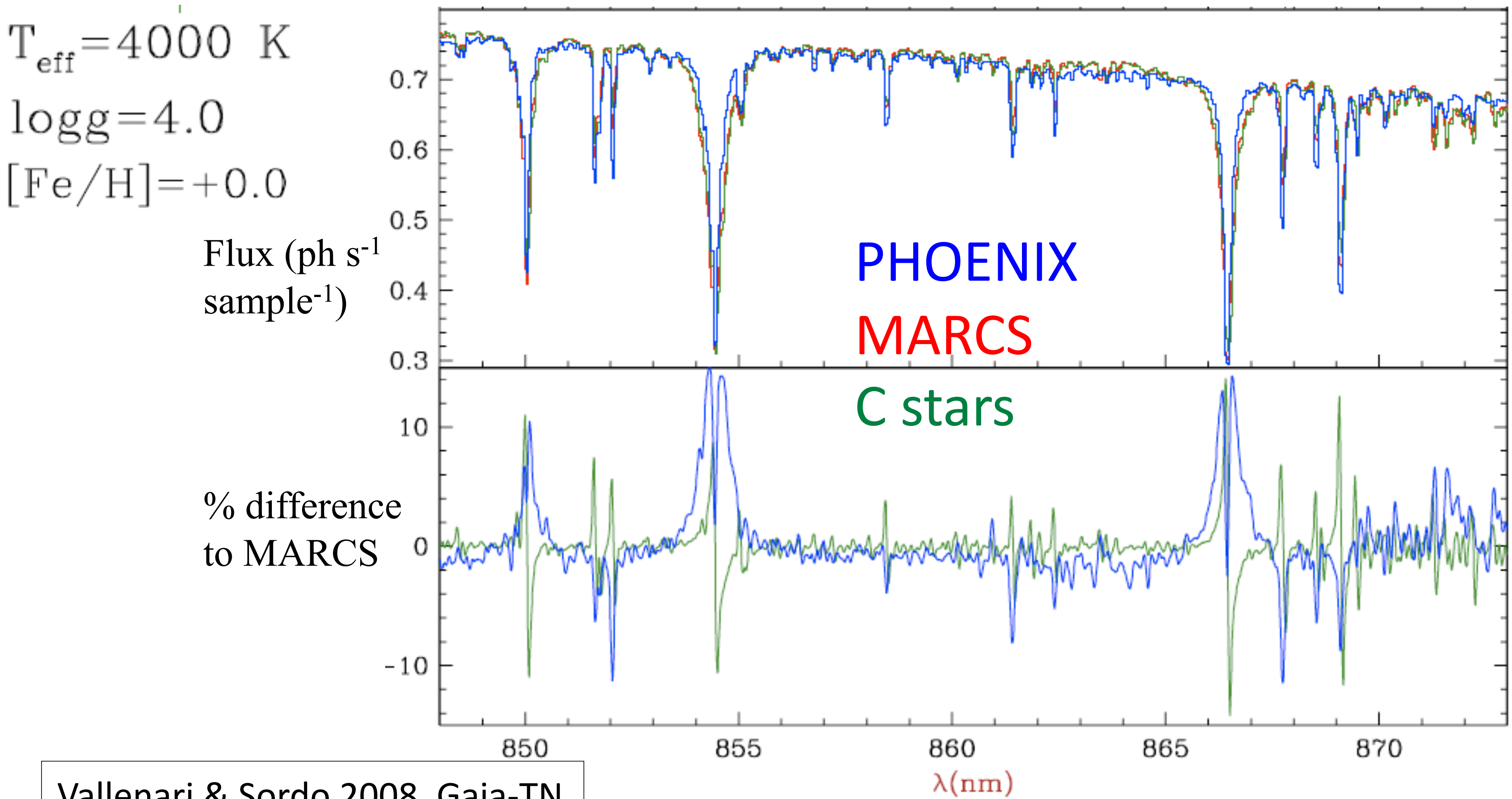
- e.g. MARCS, Gustafsson et al. (2008) http://marcs.astro.uu.se



MARCS grid in RVS region



Comparison of different grids – RVS



Vallenari & Sordo 2008, Gaia-TN

Exploring effect of spectrum modelling on stellar parameters for cool giants

- **GREAT-ESF Workshop** on ***Comparative Stellar Spectrum Modelling*** held Aug 2010 in Vienna
  Organizers: **Thomas Lebzelter**, Ulrike Heiter
- **Observed optical spectra of two benchmark stars** and **two simulated H-band spectra** were analysed by **14 groups** using different models and analysis approaches
- **Resulting parameters** T_{eff}, log g, [Fe/H] cluster around the "true" values within ~100 K, ~0.5 dex, ~0.4 dex

Stellar data and parameters

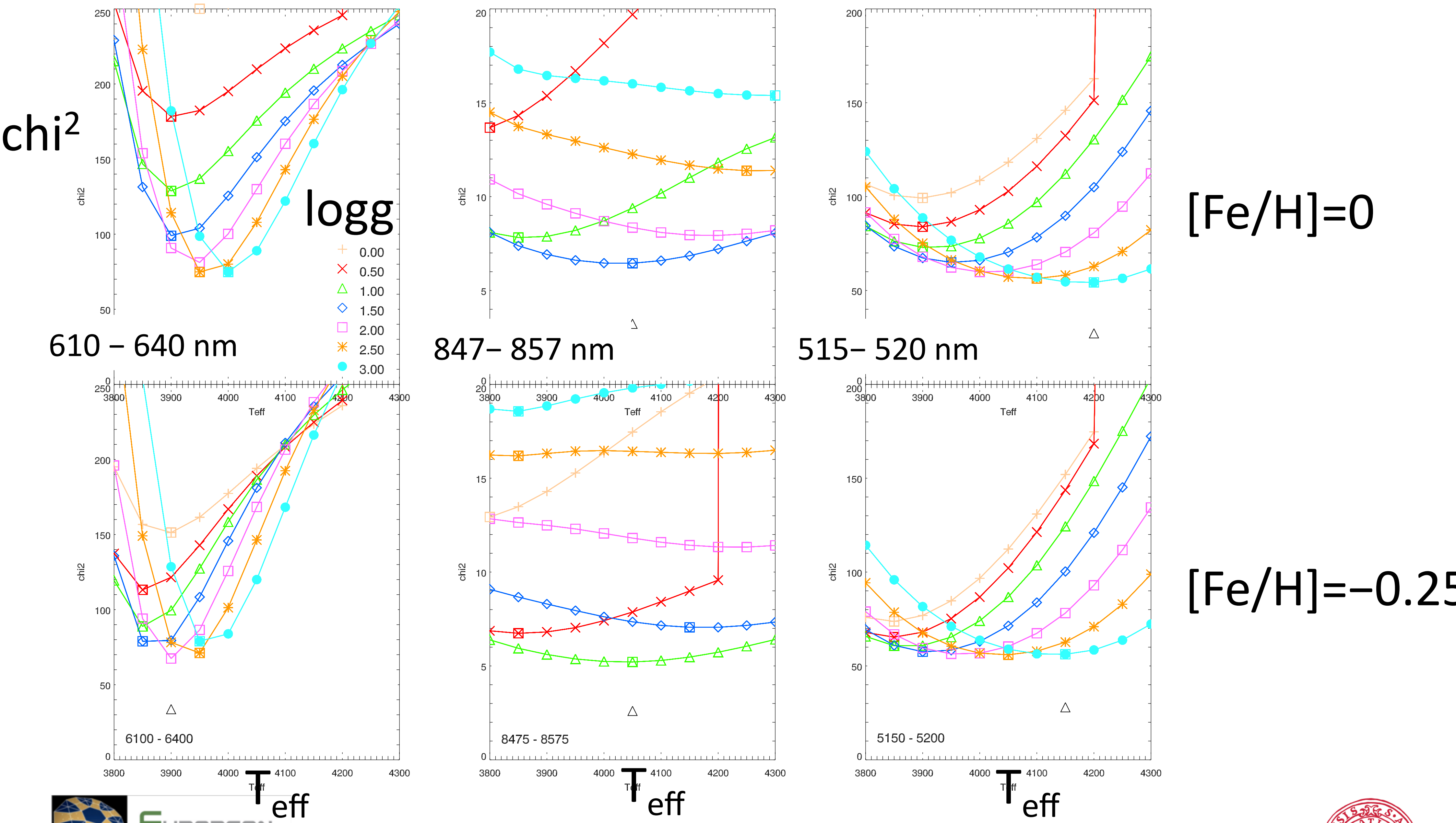
- **Stellar spectra**
  - α Tau and α Cet at R=80 000 from 490 to 975 nm
  - "Star 3 and 4" at R=50 000 from 1546 to 1567 nm
  - Approximate broad-band colors provided
- **Fundamental parameters** for α Tau and α Cet from measured angular diameter, bolometric flux, parallax, mass

$$F_{\rm bol} = \sigma (0.5\theta_{\rm LD})^2 T_{\rm eff}^4 \qquad g = \frac{GM}{R(\theta_{\rm LD}, \pi)^2}$$

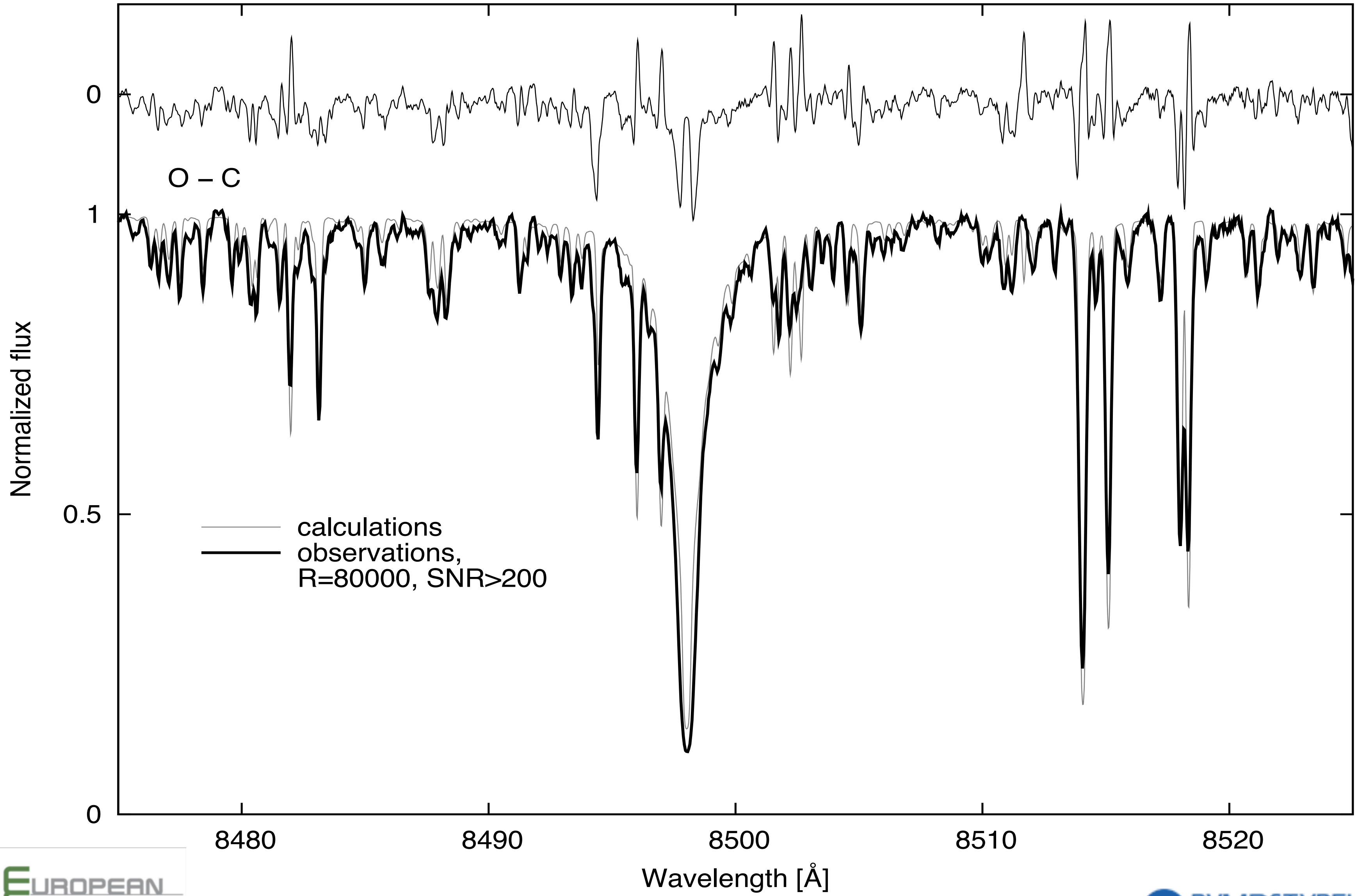
Participating groups

Name et al.	Institute	M	Stars	Name et al.	Institute	M	Stars	
Nowotny	Vienna	M	12	Maldonado	Madrid	A	12	EW
Plez	Montpellier	M	12	Neilson	Bonn	A	34	
Worley	Nice	M	12	Peterson	UCO/Lick	A	1	
Eriksson	Uppsala	M	1	Goswami	India	A	1	EW
Abia	Granada	M	34	Short	Halifax	P	12	
Merle	Nice	M	1	Ireland	Sydney	C	2 4	
Wahlgren	GSFC	A	1 3	Tsuji	Tokyo	T	4	EW

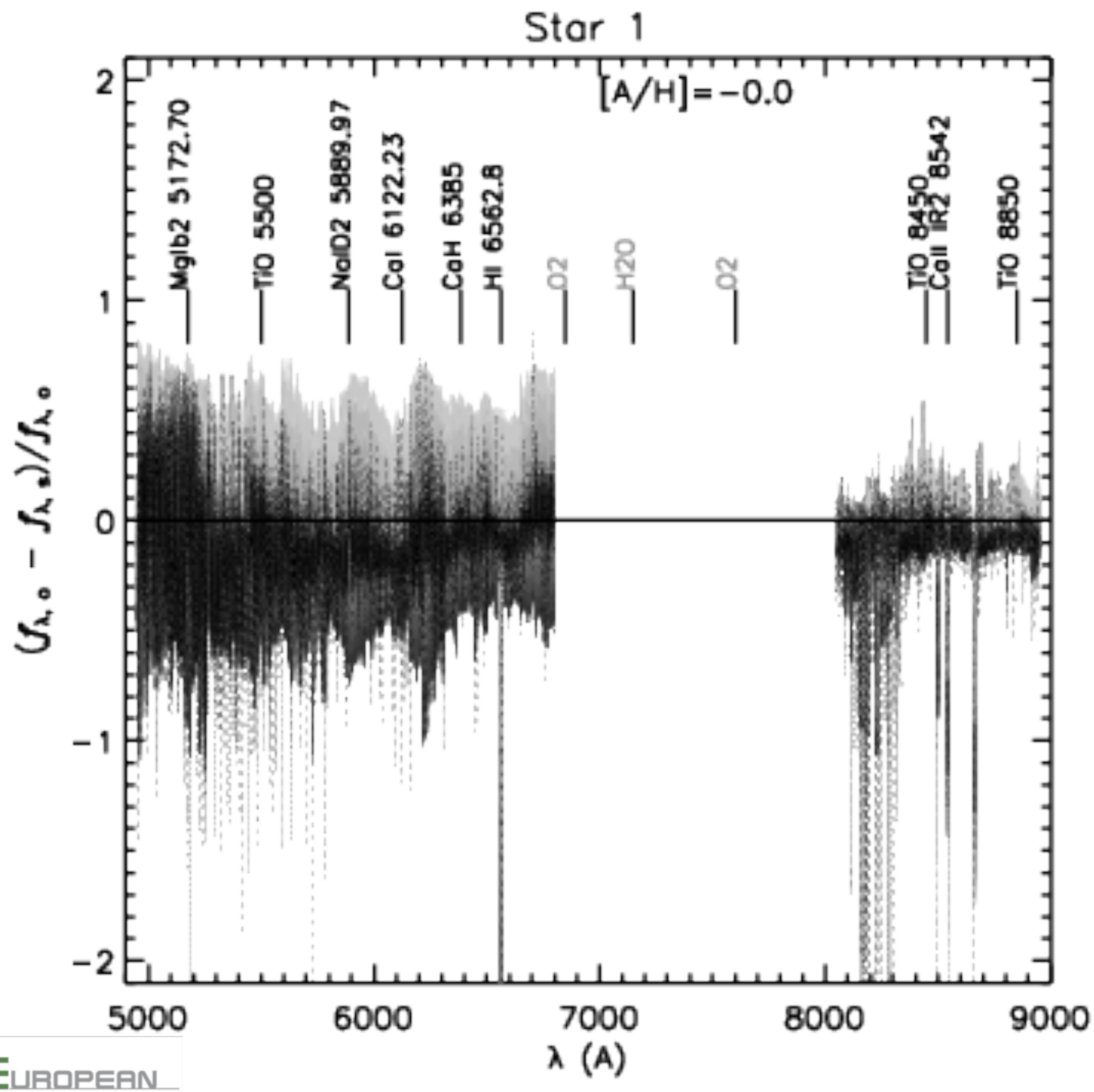
Chi-square analysis of α Tau with MARCS



One of the models (best fit) for α Tau at IR Ca triplet line



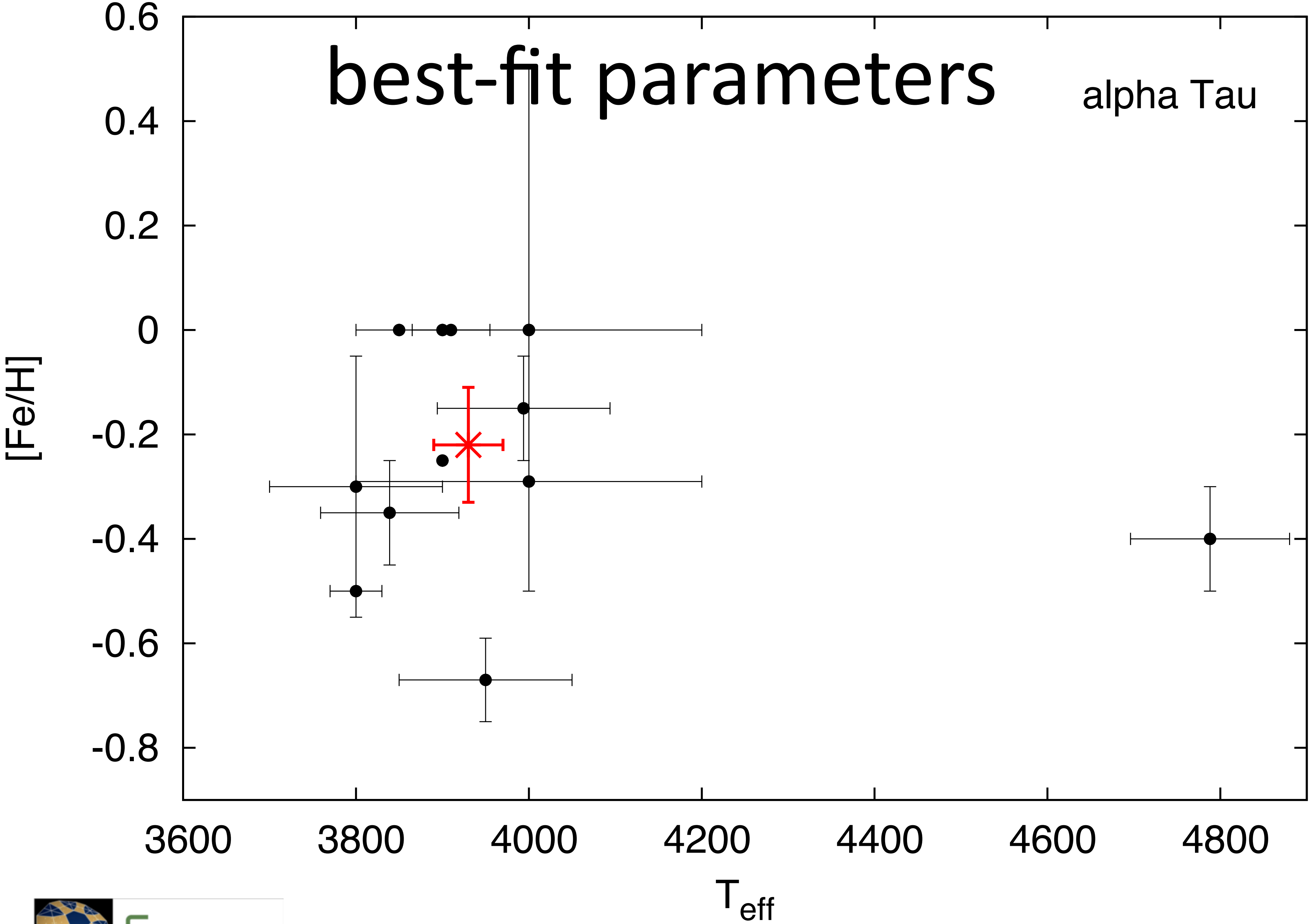
PHOENIX O–C for whole α Tau spectrum

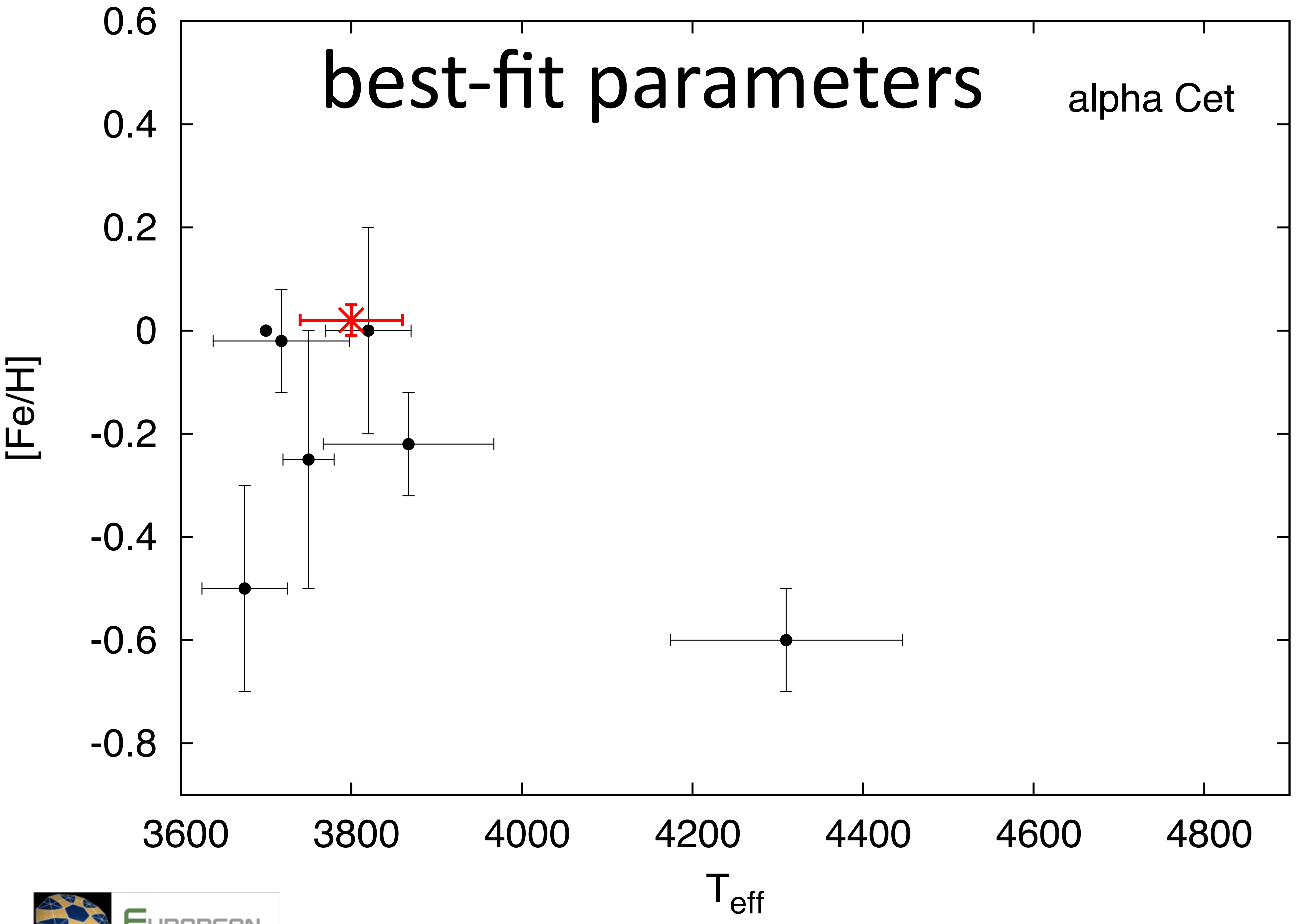


grey – model grid

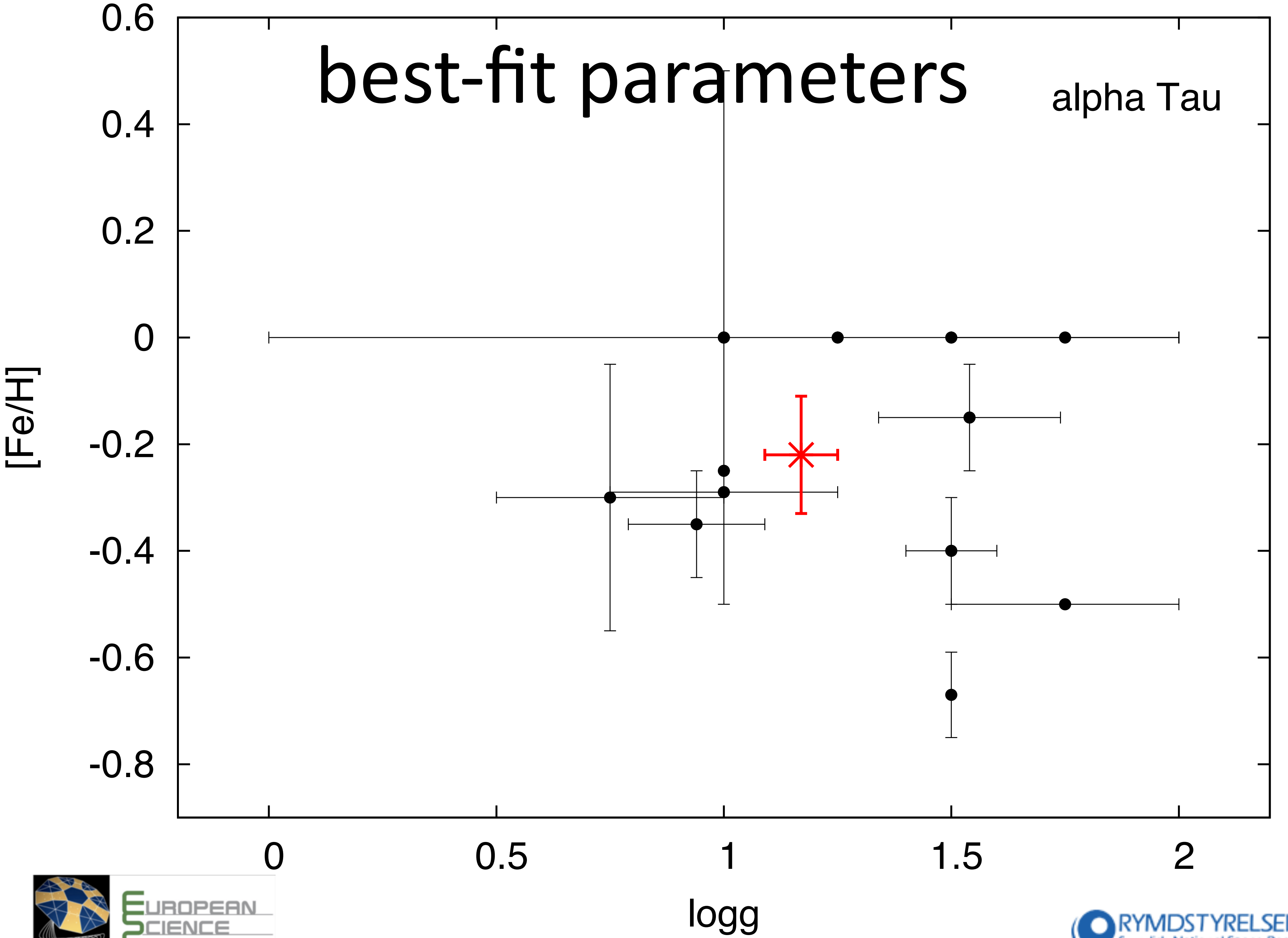
black – best fit model

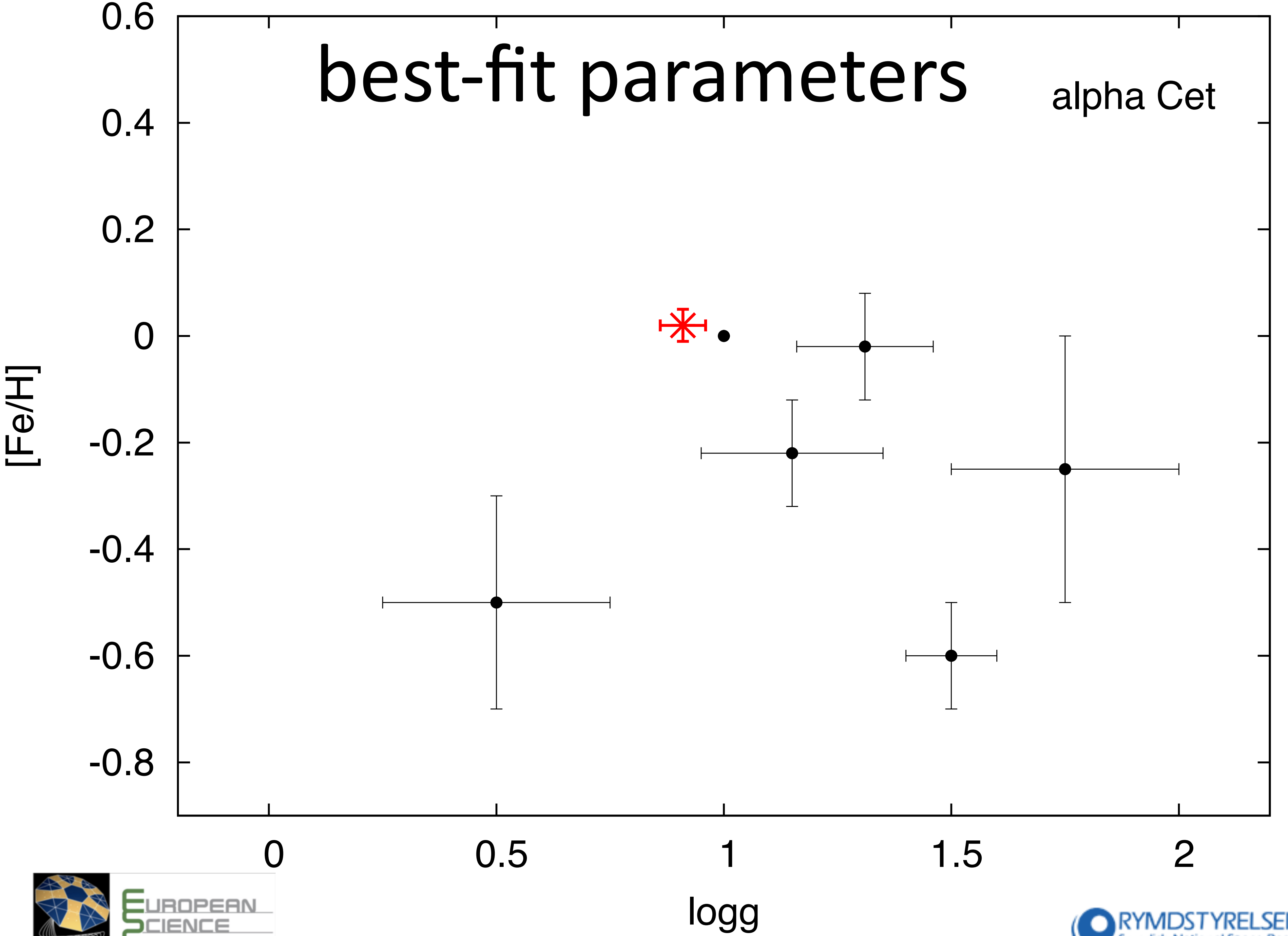
best-fit parameters



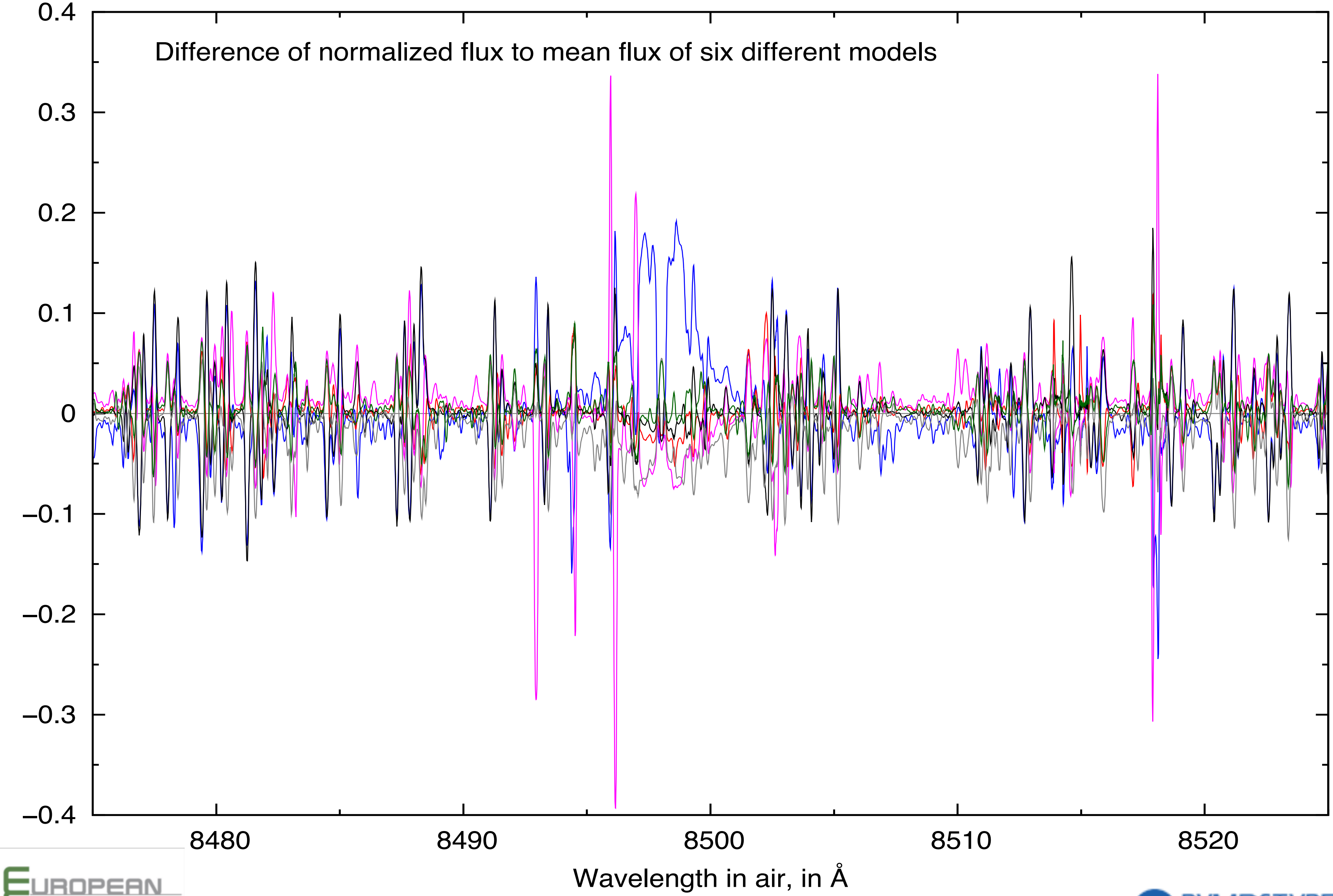

best-fit parameters
alpha Cet
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
[Fe/H]
3600
3800
4000
4200
4400
4600
4800
T_eff

best-fit parameters

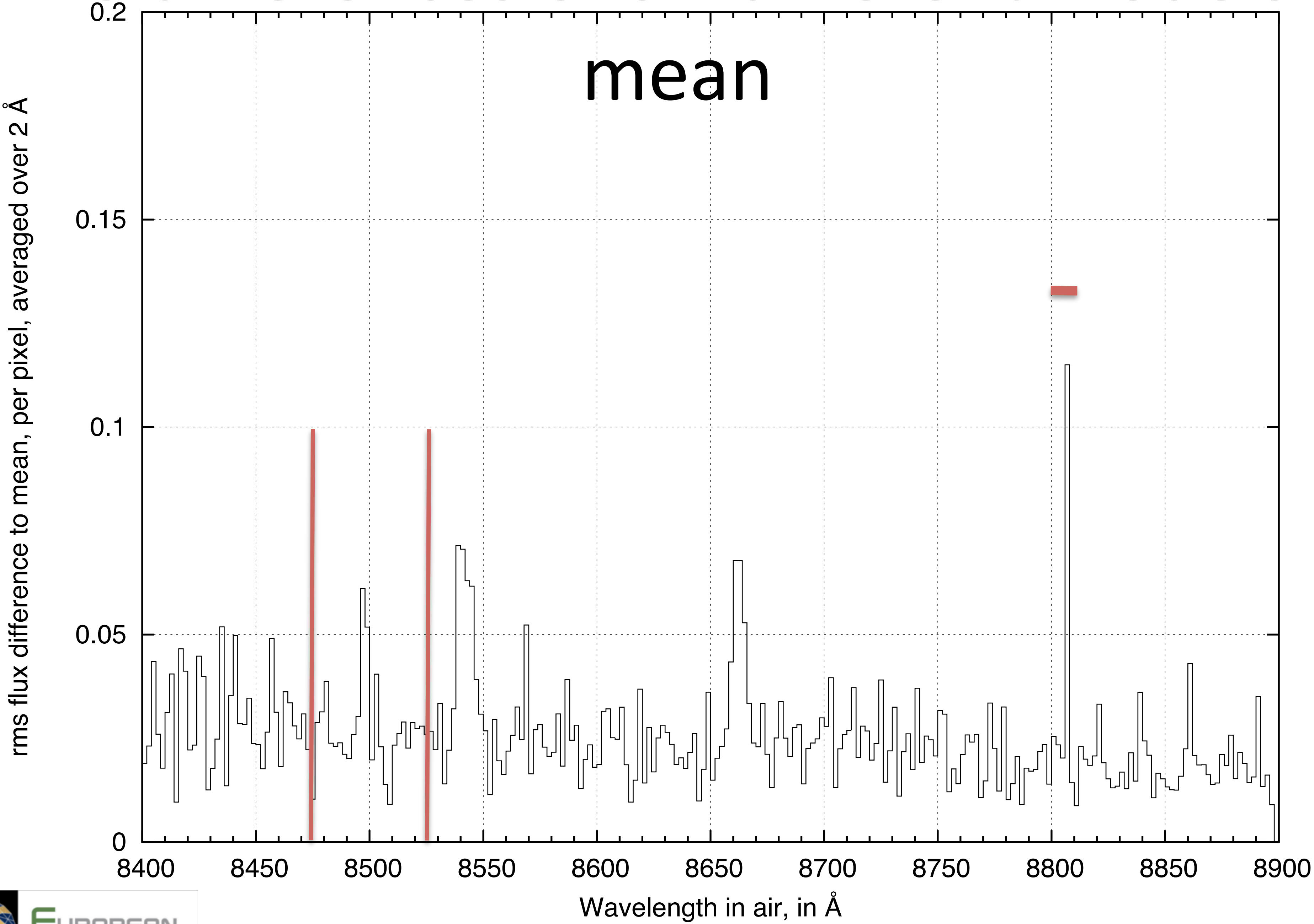



best-fit parameters
alpha Cet
[Fe/H]
logg
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.5
1
1.5
2

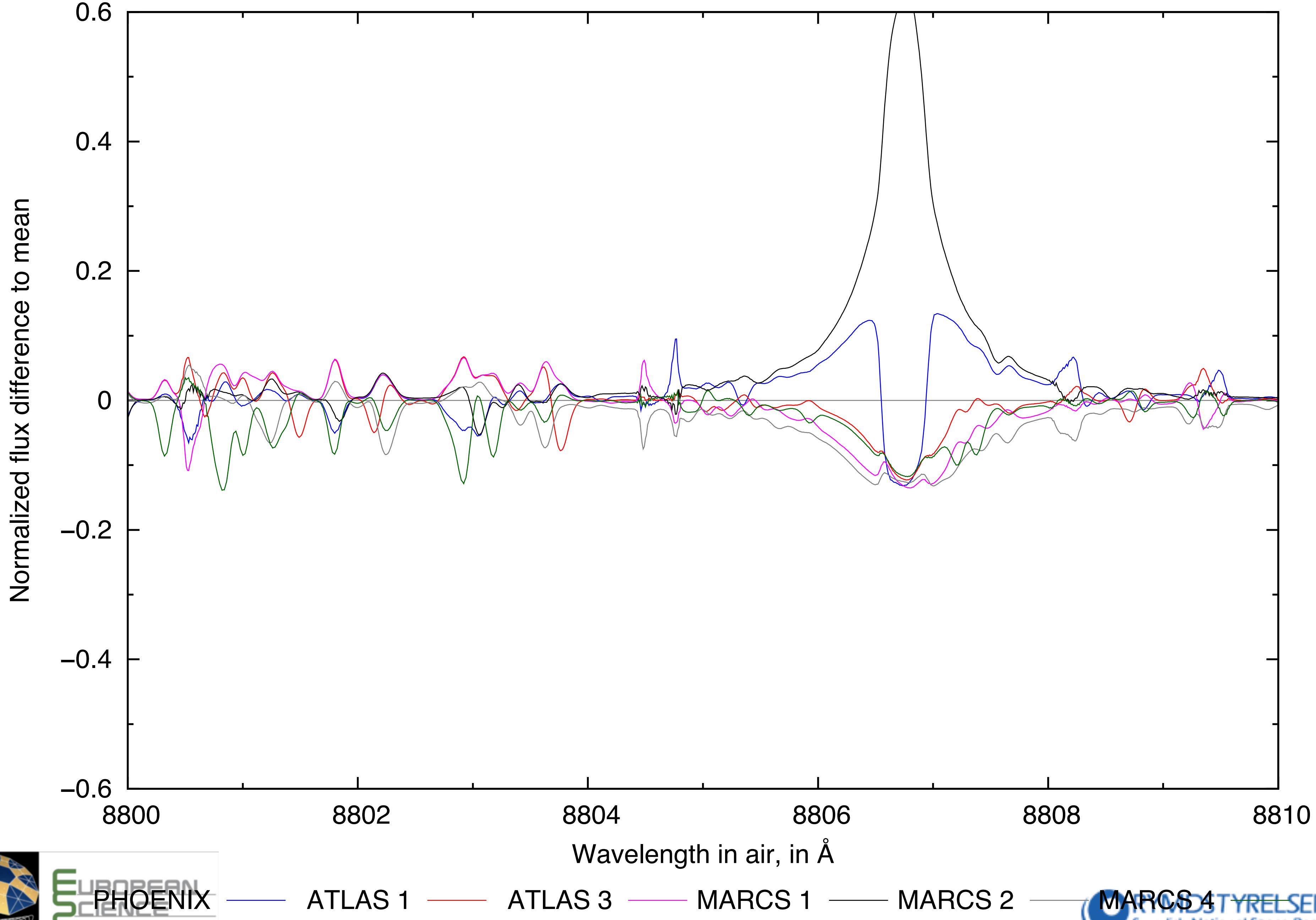
Model differences for spectra with equal parameters, but different model atmospheres, line lists, and line formation

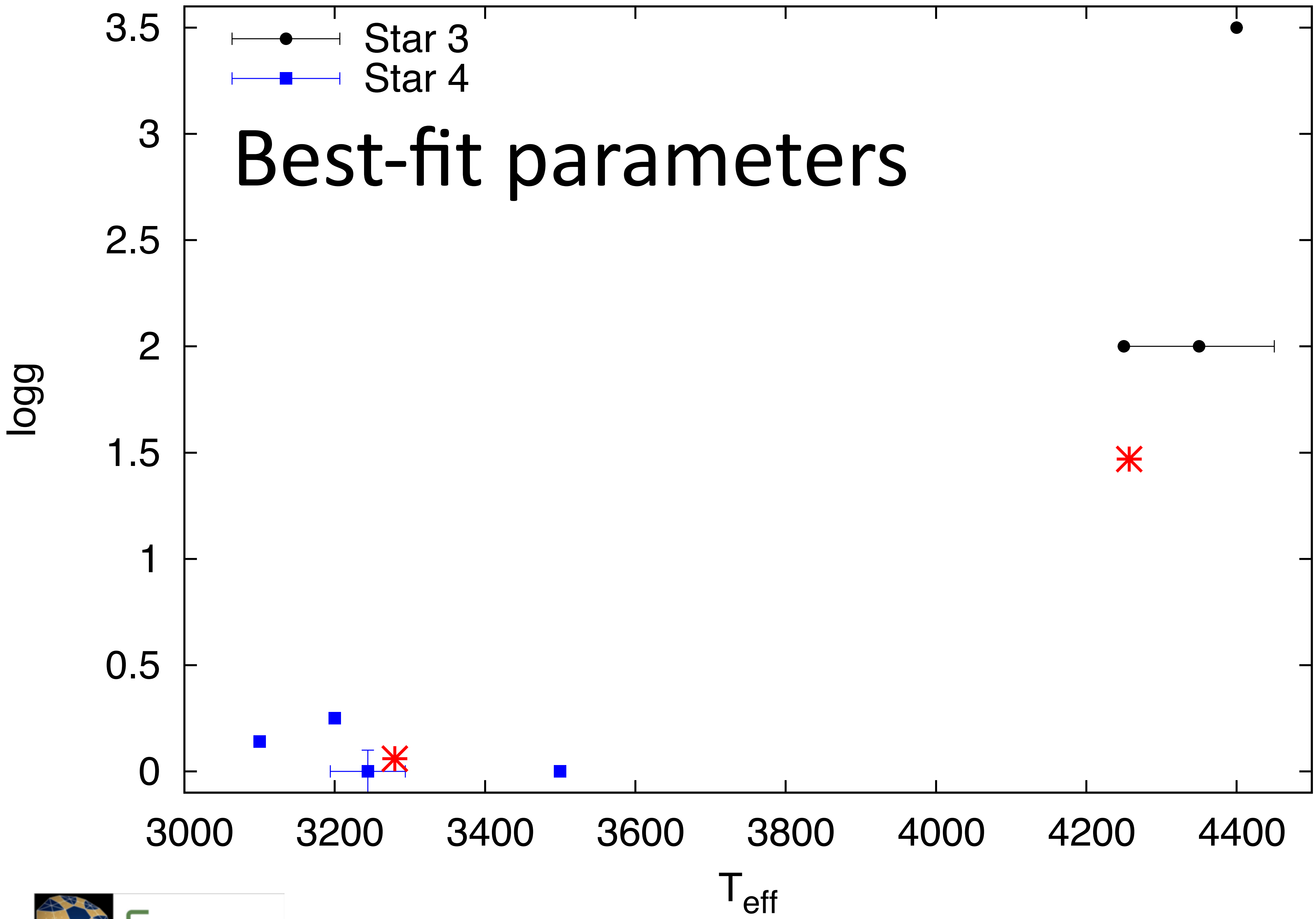


RMS differences of six different models to mean

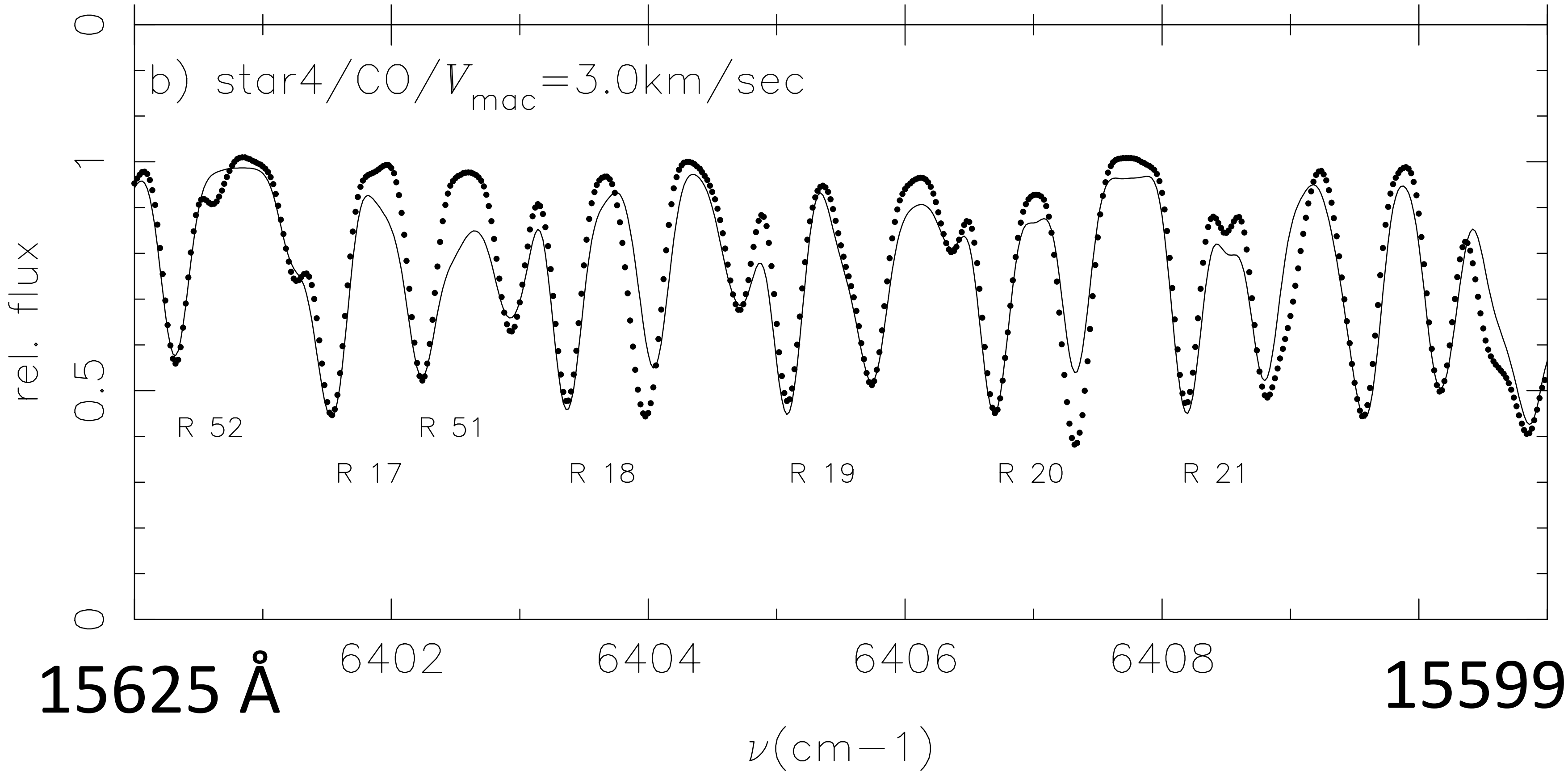


Model differences at 886 nm




Best-fit parameters
Star 3
Star 4
logg
T_{eff}
3.5
3
2.5
2
1.5
1
0.5
0
3000
3200
3400
3600
3800
4000
4200
4400

Best-fit model spectrum for Star 4



15625 Å

15599 Å

Conclusions

- Experiment illustrates the need to **be cautious when comparing or combining stellar parameters** from different model atmospheres and analysis strategies
- **No systematic differences between "model families"** (MARCS, ATLAS, …) are apparent
- **No clear trends** for effect of given assumption **could be derived** due to complexity of problem
- Experiment represents a **typical situation in observational astrophysics** and provides a snapshot of the current status of this field