



# BRASS

Contact day meeting  
19<sup>th</sup> September 2017  
mike.laverick@kuleuven.be

## The Belgian Repository of fundamental Atomic data and Stellar Spectra

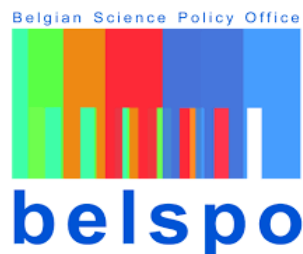
Mike Laverick Alex Lobel Pierre Royer Christophe Martayan  
Thibault Merle Mathieu Van der Swaelmen Peter van Hoof

University of Leuven, Belgium

Royal Observatory of Belgium, Brussels

European Southern Observatory, Chile

Université Libre de Bruxelles, Belgium

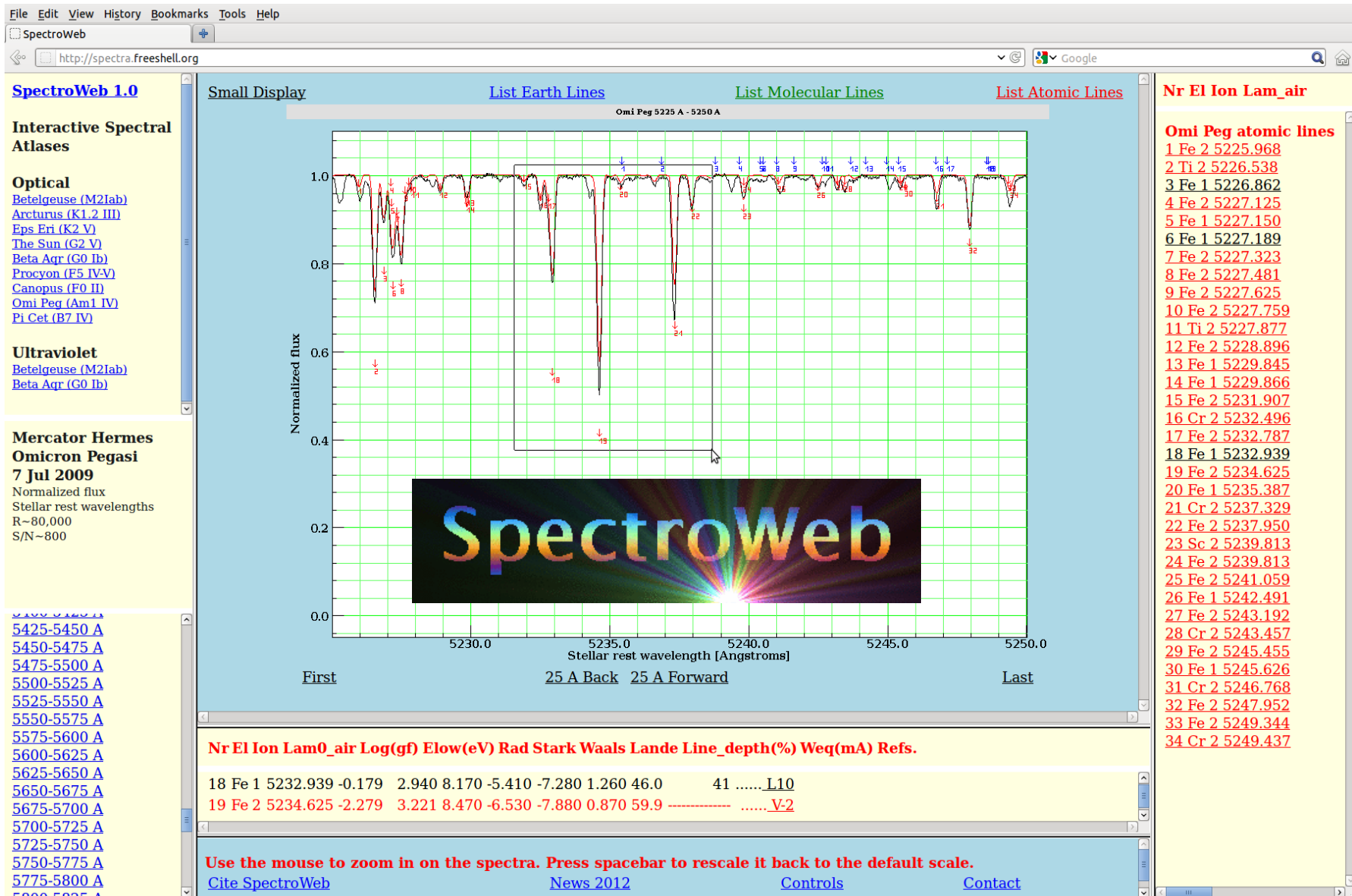


# Science motivation

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- First steps towards removing systematic errors from input atomic data in stellar spectroscopy
- Compilation of high-quality optical spectral atlases of bright benchmark BAFGK stars with confirmed line identifications and quality-tested atomic data.
- Perform detailed spectral synthesis calculations to test quality of atomic line input data from literature and online data providers (VALD/NIST/etc) by modeling bright benchmark stars.
- Provide observed and theoretical spectra combined with quality-tested atomic data in a new public online database called BRASS

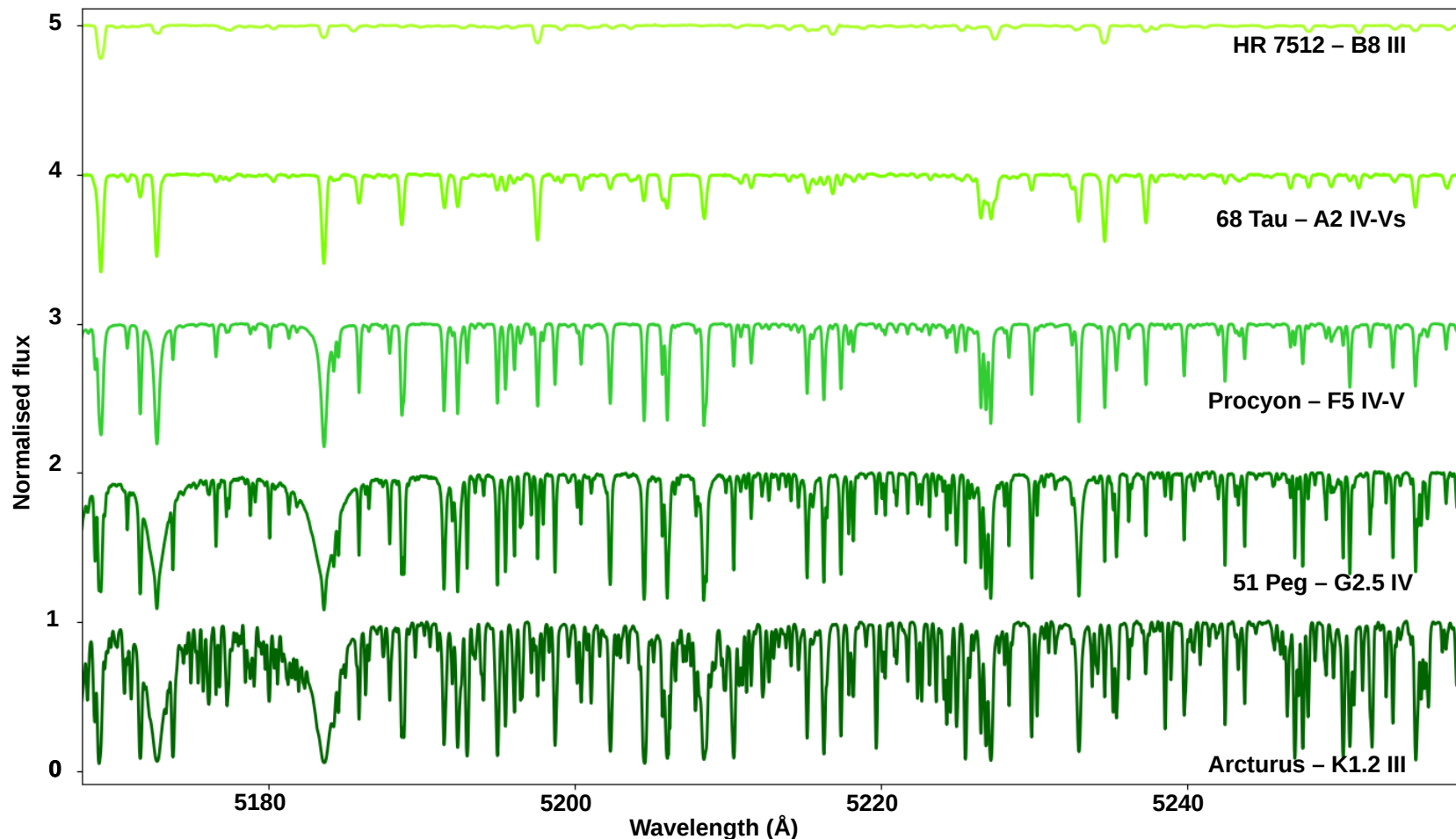
# Science motivation : previous literature work



# Science motivation : benchmark spectra

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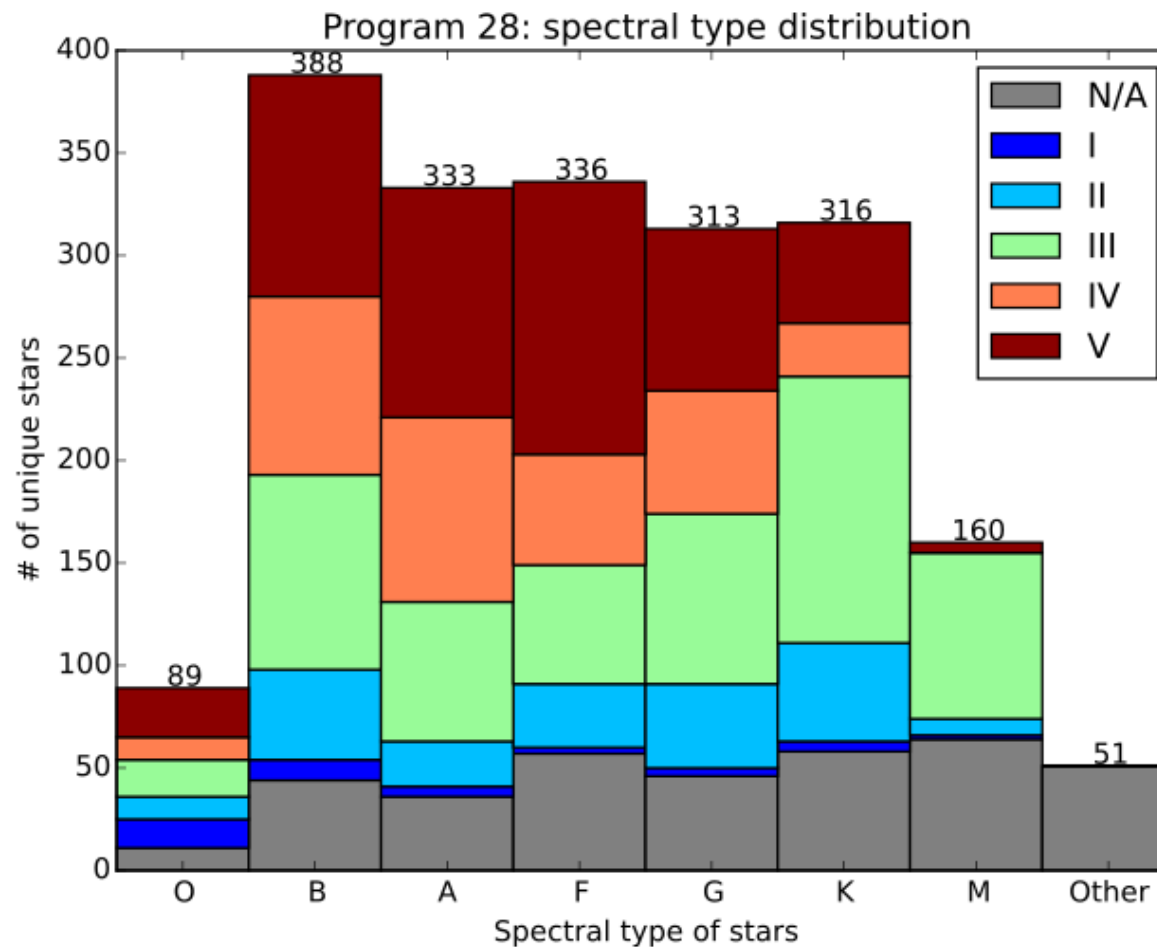
- ~30 spectra of bright BAFGK stars with S/N ratio ~1000, taken using the Mercator-HERMES and VLT-UVES high-resolution spectrographs



# Science motivation : high-quality spectra

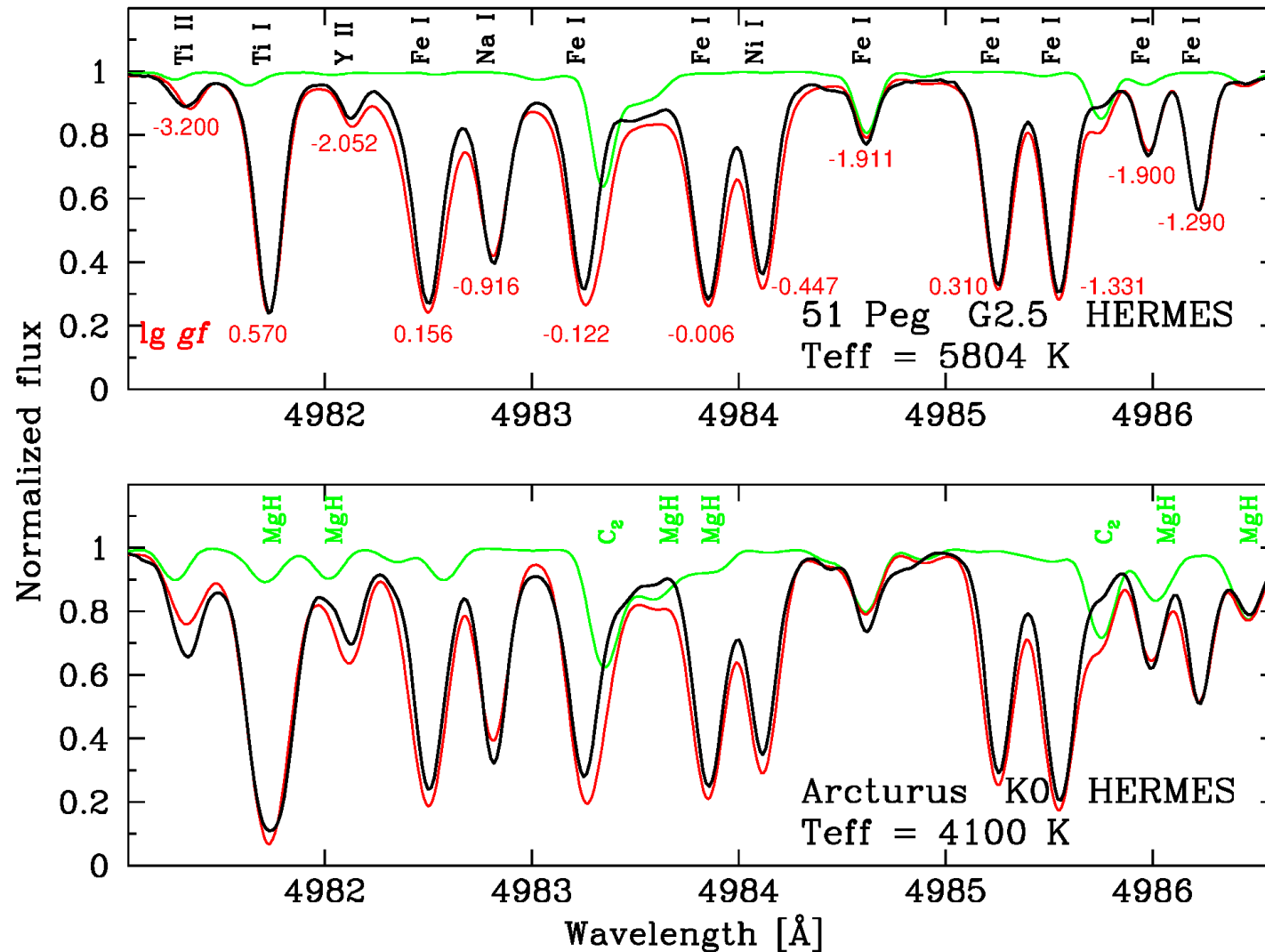
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- Over 1000 spectra of BAFGK stars with good stellar parameter-space coverage. S/N ratios of ~100-300+ and taken with Mercator-HERMES.



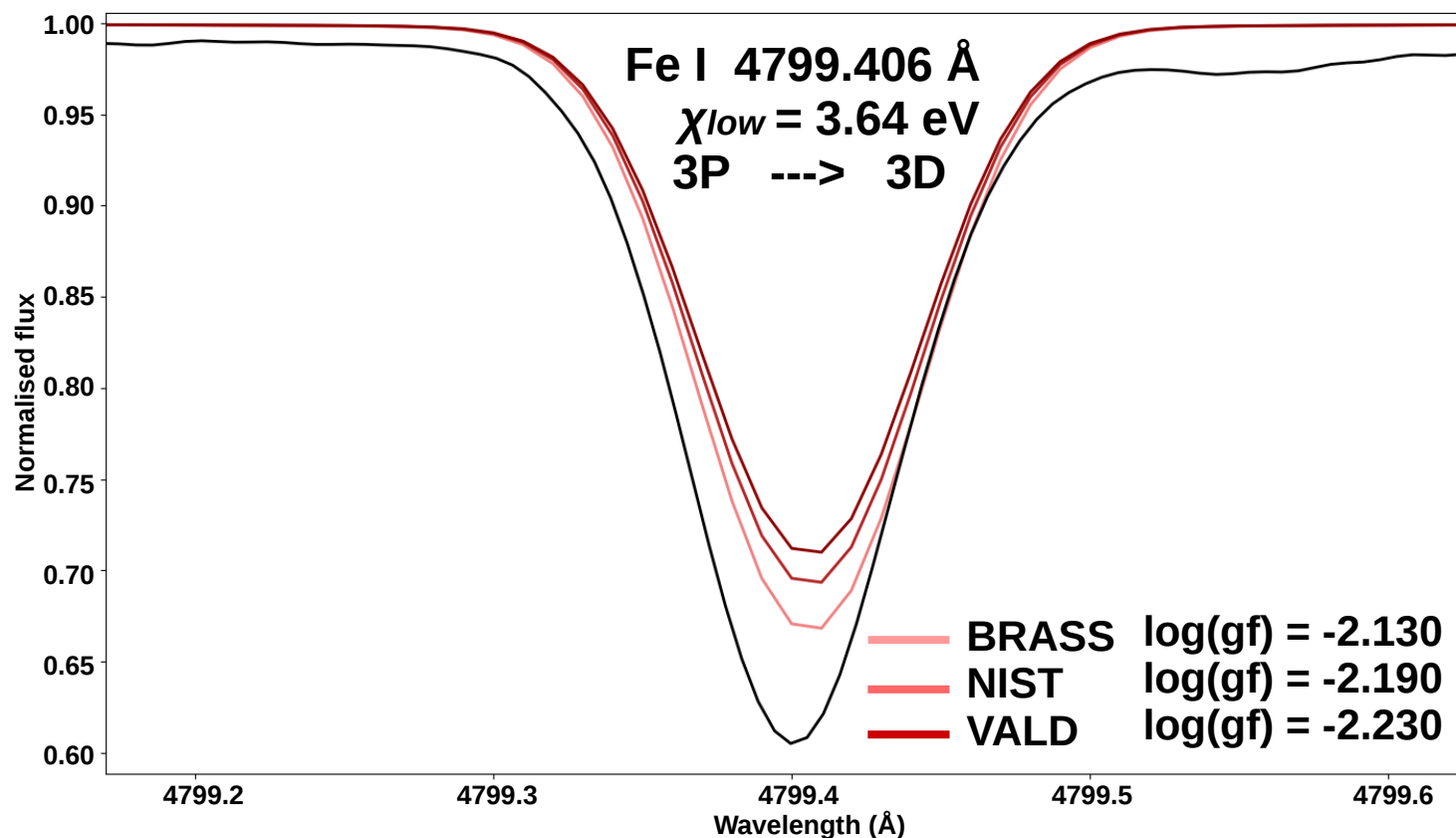
# Science motivation : synthesis & line identification

- Detailed spectral calculations of entire benchmark spectra (inc. molecules)

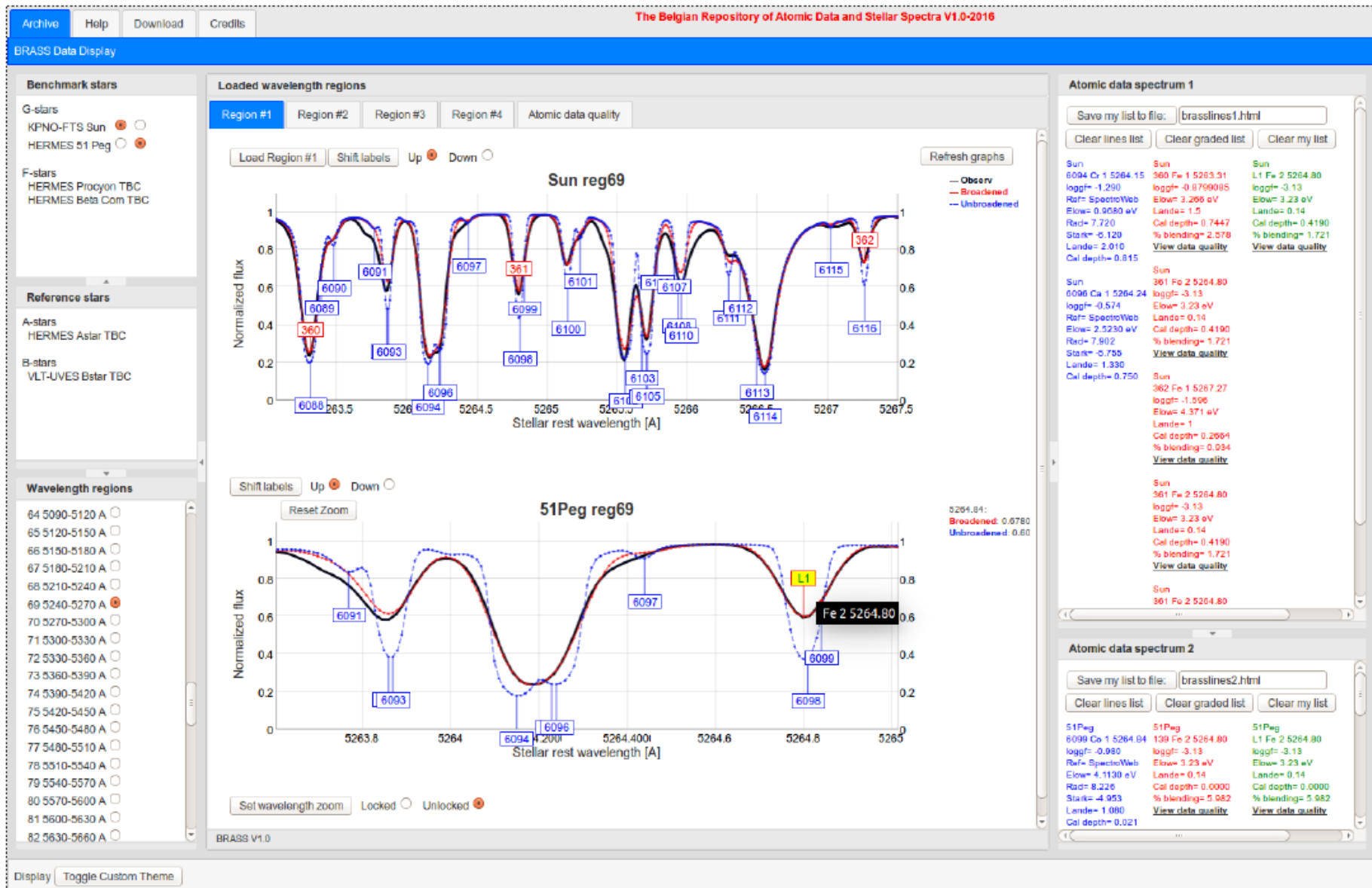


# Science motivation : quality-assessed atomic data

- Benchmark spectra quality high enough to compare and assess literature atomic data on the largest scale to date ( $\lambda$ , spectral type, quantity)
- Scatter in atomic data can have significant impact on stellar parameters



# Science motivation : BRASS database (brass.sdf.org)





# Where do I fit in to BRASS?

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- Compilation of high-quality optical spectral atlases of bright benchmark BAFGK stars with confirmed line identifications and quality-tested atomic data.
- Perform detailed spectral synthesis calculations to test quality of atomic line input data from literature and online data providers (VALD/NIST/etc) by modeling bright benchmark stars.
- Provide observed and theoretical spectra combined with quality-tested atomic data in a new public online database called BRASS

# Where do I fit in to BRASS? - Atomic lines!

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- ~~Compilation of high quality optical spectral atlases of bright benchmark BAFGK stars with confirmed line identifications and quality tested atomic data.~~
- Perform detailed spectral synthesis calculations to test quality of atomic line input data from literature and online data providers (VALD/NIST/etc) by modeling bright benchmark stars.
- ~~Provide observed and theoretical spectra combined with quality tested atomic data in a new public online database called BRASS~~

# Atomic lines

Laverick et al: BRASS I. Cross-matching atomic databases of astrophysical interest

**Table 4.** (a) - (c) show three sets of cross-matched lines. (a) the Mn II pair have been correctly cross-matched by both the parametric and non-parametric methods. (b) the Cr I pair have been incorrectly cross-matched using the parametric method and not the non-parametric method. (c) the Fe II pair have been incorrectly cross-matched using the parametric method and not the non-parametric method.

	Ion	$\lambda$ (Å)	$E_{low}$ (eV)	$E_{up}$ (eV)	$J_{low}$	$J_{up}$	Configuration: lower - upper	references
(a)	Mn II	4639.152	10.774	13.446	3	2	$3d^4(^5D)4s4p(^3P^o) w^5P^o - 3d^5(^6S)7s^5S$	K09 <sup>a</sup>
	Mn II	4639.160	10.774	13.446	3	2	$3d^4(^5D)4s4p(^3P^o) w^5P^o - 3d^5(^6S)7s^5S$	L562 <sup>b</sup>
(b)*	Cr I	4244.770	3.890	6.810	4	5	$3d^5(^4F)4s a^5F - 3d^5(^4G)5p v^3H^o$	K10 <sup>a</sup>
	Cr I	4244.340	3.857	6.777	4	5	$3d^4(^5D)4s4p(^3P^o) z^5F^o - e^5F$	L808 <sup>c</sup>
(c)**	Fe II	6207.273	11.051	13.048	7/2	5/2	$3d^6(^5D)5p 6P^o - 3d^6(^5D)5d 6S$	K13 <sup>a</sup>
	Fe II	6207.342	11.051	13.048	7/2	5/2	$3d^5(^4P)4s4p(^3P) 6P^o - 3d^6(^5D)5d 6G$	RU <sup>d</sup>

**Notes.** \*Cross-matched using  $\Delta E = \pm 0.1$  eV \*\*Cross-matched using  $\Delta E = \pm 0.0005$  eV <sup>a</sup>Kurucz 1999-2014 <sup>b</sup>Kramida & Sansonetti 2013 <sup>c</sup>Saloman 2012 <sup>d</sup>Raassen & Uylings 1998

Laverick et al 2017 (Submitted)

- Several line lists and repositories cross-matched against our BRASS atomic line list (including VALD3, NIST, SpectroWeb, Chianti, TIP/TOPbase)
- ~130,000 transitions cross-matched with our BRASS list of 80,000 lines

# Atomic lines : (available at brass.sdf.org)

- Cross-matched atomic data available via the brass.sdf.org → “lines” Tab (currently under development)

QUERY BRASS ATOMIC LINES DATA

Search BRASS database

Element (e.g. Fe, fe):

Start wavelength (Å, >4000):

End wavelength (Å, <6800):

Present as:  plot  table

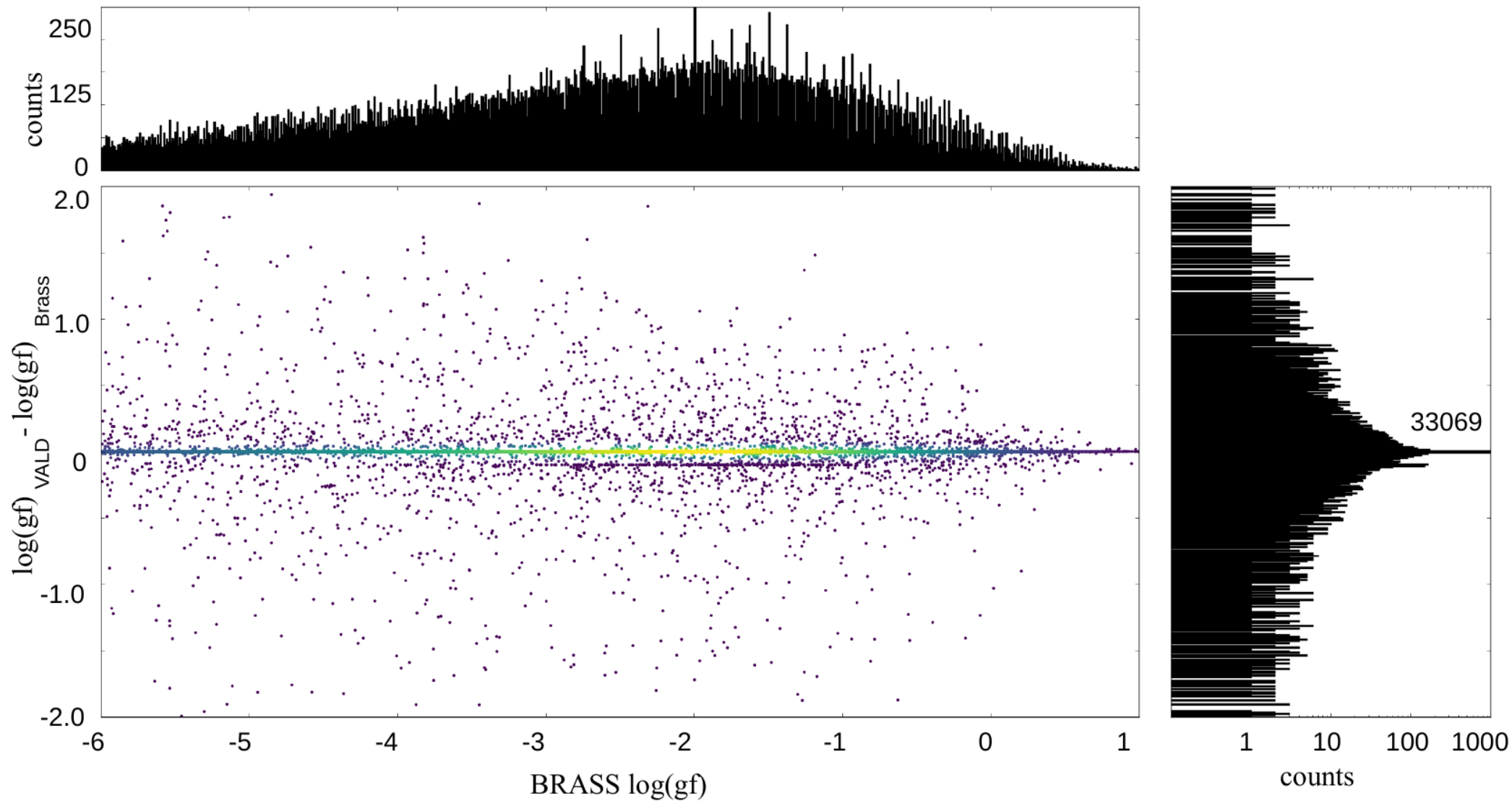
Sort by (matters for table presentation only):  wavelength  sigmaLoggf

Lines of fe

ID BRASS	Source	Wavelength	E low	E up	Element	Ion	Log(gf)	Lower level	Upper level	Reference
<input type="checkbox"/> 56925	BRASS	6005.5415	2.588	4.652	Fe	1	-3.605	LS 3p6.3d6.4s2 b3F	LS 3p6.3d7.(4F).4p y3F*	[Kurucz, R. L. 2007, Robert L. database of observed and predicted transitions]
	VALD3									
	NIST									
56925	SpectroWeb	6005.543	2.58798	4.65189	Fe	1	-3.692	"	"	KFE-PDP-0.5
	CHIANTI									
	spectrw3									
56925	TIPbase	8590.13	3.008085	4.456516	Fe	1	-2.791	'0s b3F'	'4p y3F*'	M
	TOPbase									
							-3.363			
							0.406			
							3			
<input type="checkbox"/> 56932	BRASS	6006.1719	3.635	5.699	Fe	1	-5.729	LS 3p6.3d6.4s2 b3D	LS 3p6.3d6.(a3F).4s.4p.(3P*) x5G*	[Kurucz, R. L. 2007, Robert L. database of observed and predicted transitions]
	VALD3									
	NIST									
56932	SpectroWeb	6006.172	3.63512	5.69879	Fe	1	-5.126	"	"	KFE
	CHIANTI									
	spectrw3									
	TIPbase									
	TOPbase									
							-5.427			

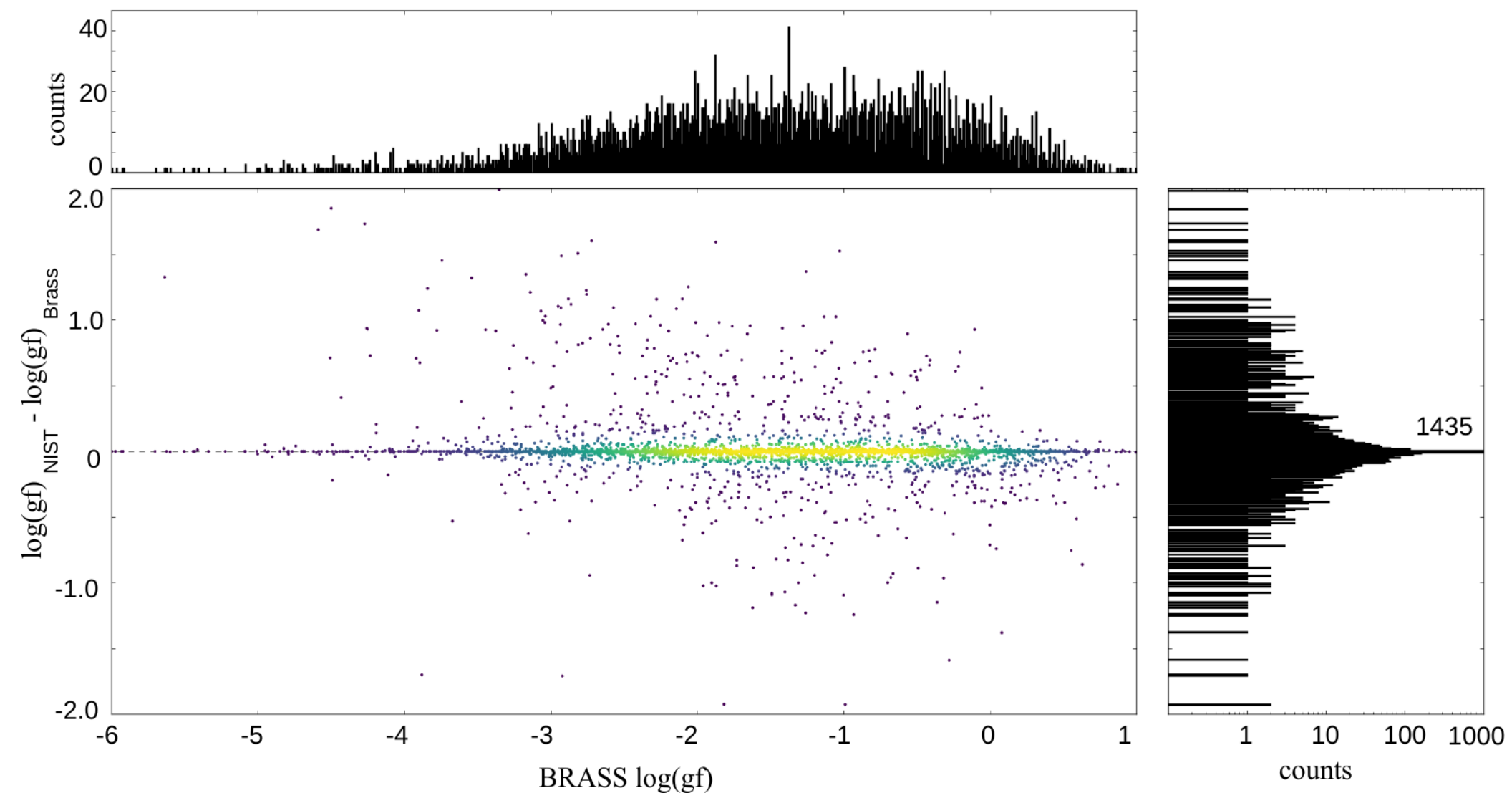
# Atomic lines : BRASS vs VALD3 (2012 vs 2016)

- Updates to literature  $\log(gf)$  values over time. Scatter up to 2 dex!



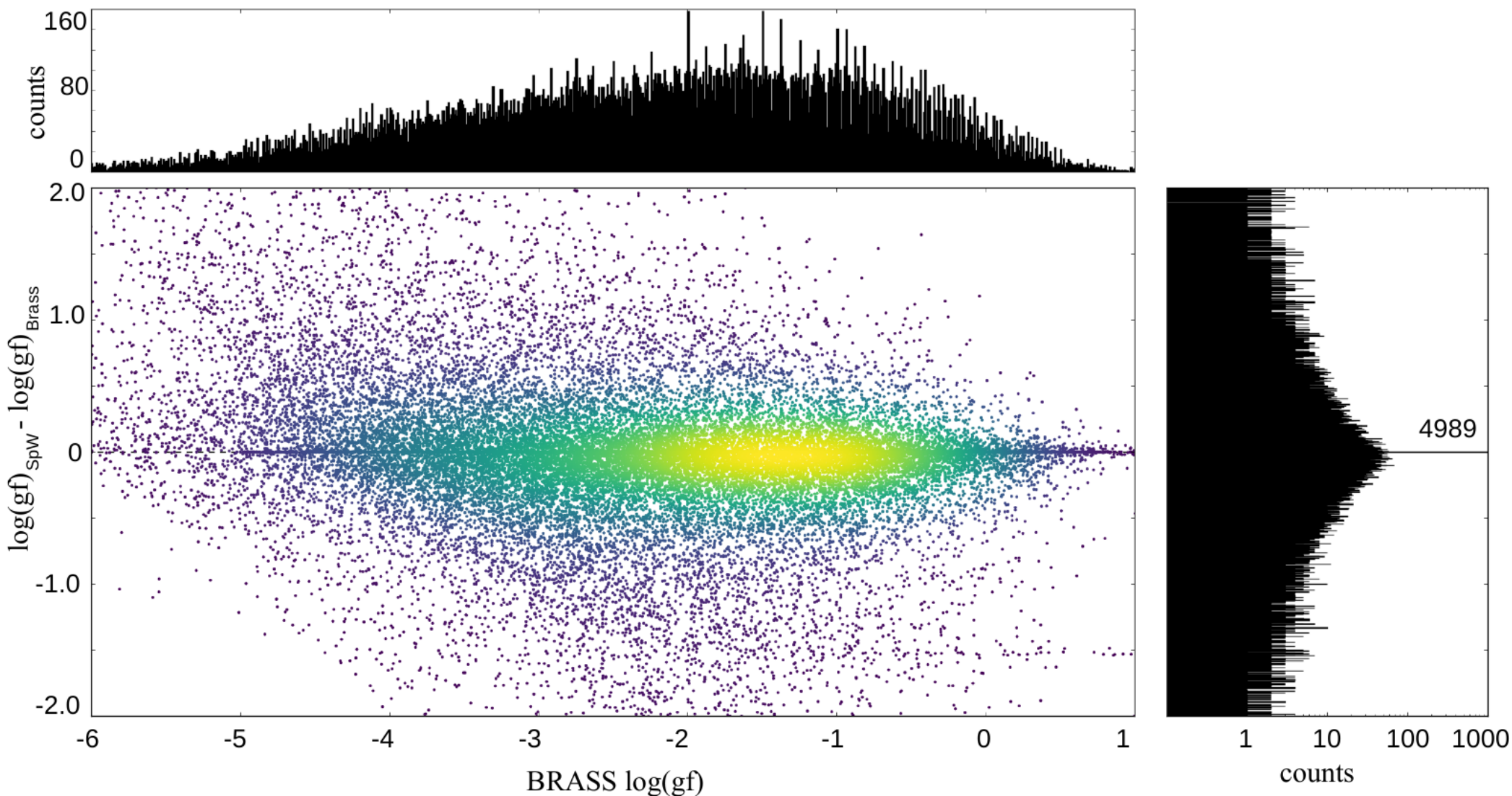
# Atomic lines : BRASS vs NIST (2012 vs 2016)

- Scatter still up to 2 dex!



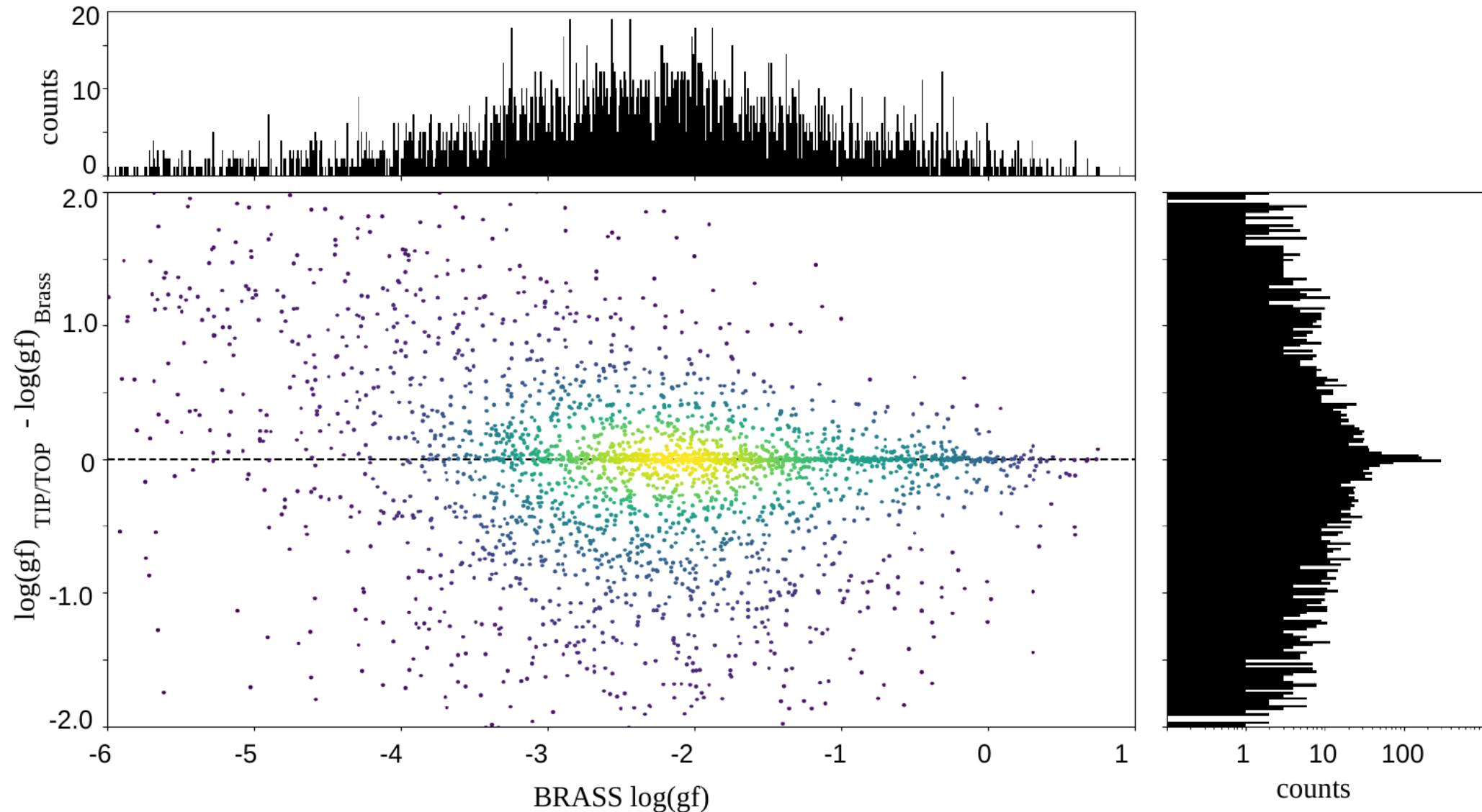
# Atomic lines : BRASS vs SpectroWeb (2012 vs 2008)

- Scatter up to 4 dex for older transitions!



# Atomic lines : BRASS vs TOPbase (2012 vs 1993)

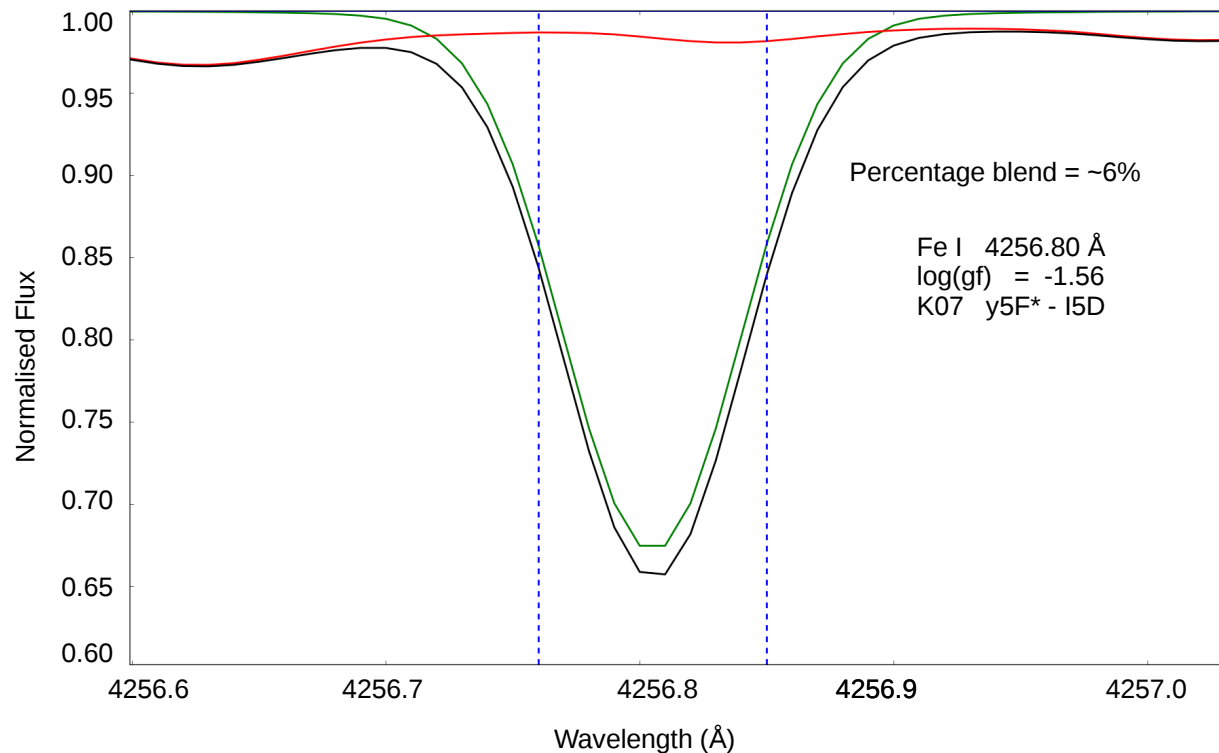
- Changes in  $\log(gf)$  values lead to similar changes in line abundances !!!





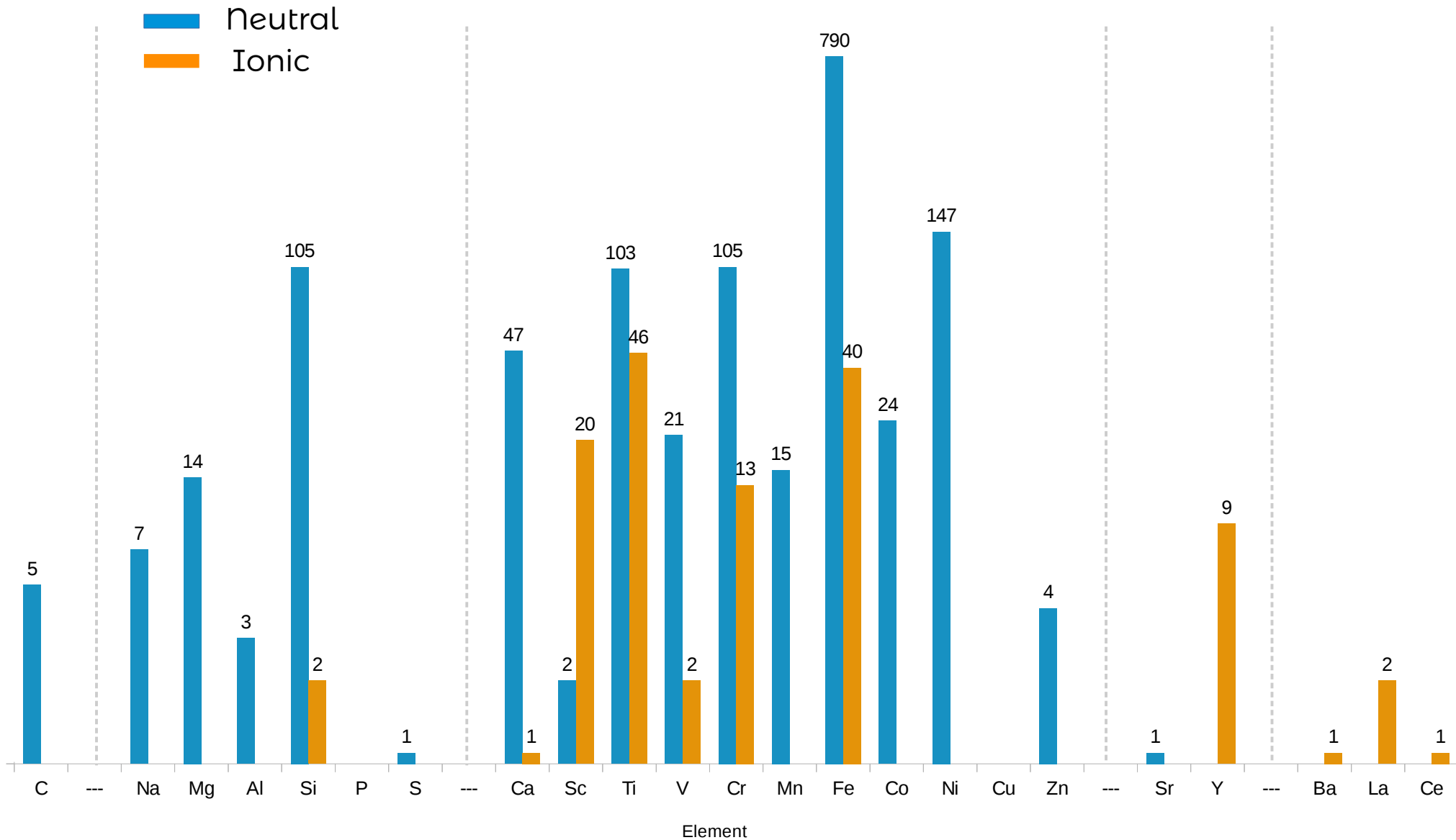
# Atomic lines : line selection

- Systematic selection of deep + unblended lines using our 80,000 lines, performed for each BAFGK spectral type
- Synthesise each line individually - line considered “unblended” if it reproduces at least 90% of the total synthetic line profile



# Atomic lines : line selection

- G type stars : ~1500 theoretically deep and unblended lines to assess



# Atomic lines : quality assessment

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- ~1500 theoretically deep and unblended G type lines to assess!

1) Measure the equivalent width of the observed line profile in one star

# Atomic lines : quality assessment

The Belgian Repository of Atomic Data and Stellar Spectra V4.0-2017

Spectra Lines Help Download Register Credits

BRASS Spectra and Data Display

## Benchmark stars

### K-stars

HERMES Arcturus    
HERMES K bench 2

### G-stars

KPNO-FTS Sun    
HERMES 51 Peg

### F-stars

HERMES Procyon    
HERMES Beta Com TBC

### A-stars

HERMES 68 Tau    
HERMES A bench 2

### B-stars

## Reference stars

### A-stars

HERMES Astar TBC

### B-stars

VLT-UVES Bstar TBC

## Wavelength regions

64 5090-5120 A   
65 5120-5150 A   
66 5150-5180 A   
67 5180-5210 A   
68 5210-5240 A   
69 5240-5270 A   
70 5270-5300 A   
71 5300-5320 A

## Loaded wavelength regions

Region #1 Region #2 Region #3 Region #4 Atomic data quality Gauss line fit

run top Gauss fit

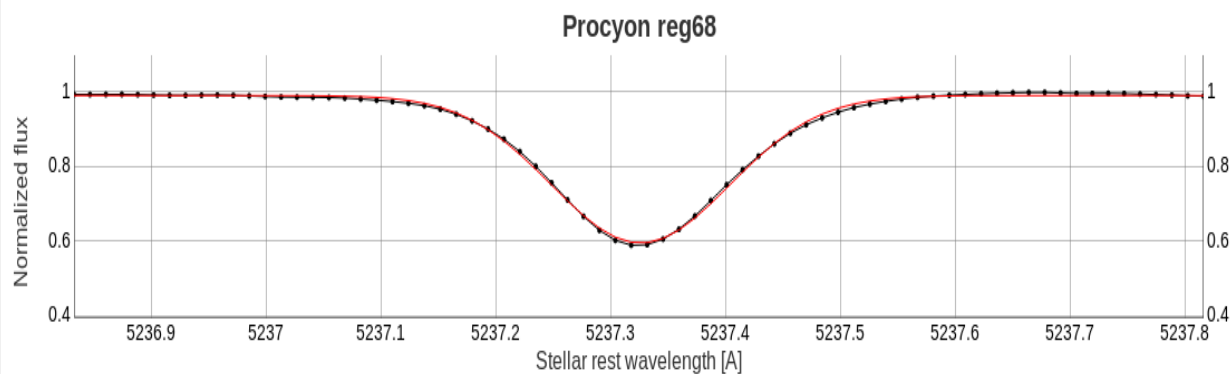
Reset zoom

Shift top labels

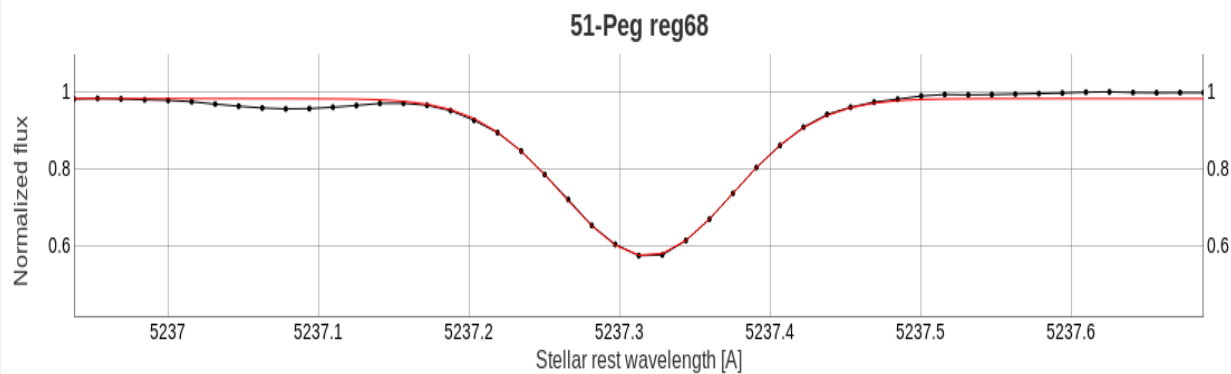
Up  Down

Add top fit to my list

Refresh



Procyon reg68  
Single Gauss best fit parms.  
Line wavel. = 5237.3262 A  
Bkgr. flux level = 0.9916  
Gauss sigma = 77.62 mA  
Norm. line depth = 0.4036  
Eqv. width = 78.54 mA  
Eqv. width error = 1.63 mA  
Used fit points = 72  
Fit quality = 0.99462



51-Peg reg68  
Single Gauss best fit parms.  
Line wavel. = 5237.3184 A  
Bkgr. flux level = 0.9847  
Gauss sigma = 56.50 mA  
Norm. line depth = 0.4237  
Eqv. width = 60.01 mA  
Eqv. width error = 2.17 mA  
Used fit points = 49  
Fit quality = 0.98882

run bottom Gauss fit

Reset zoom

Shift bottom labels

Up  Down

Add bottom fit to my list

BRASS V4.0

Display Toggle Custom Theme

# Atomic lines : quality assessment

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- ~1500 theoretically deep and unblended G type lines to assess!
  - 1) Measure the equivalent width of the observed line profile in one star
  - 2) Use the theoretical Curve of Growth and measured EW to “adjust” the BRASS  $\log(gf)$  value

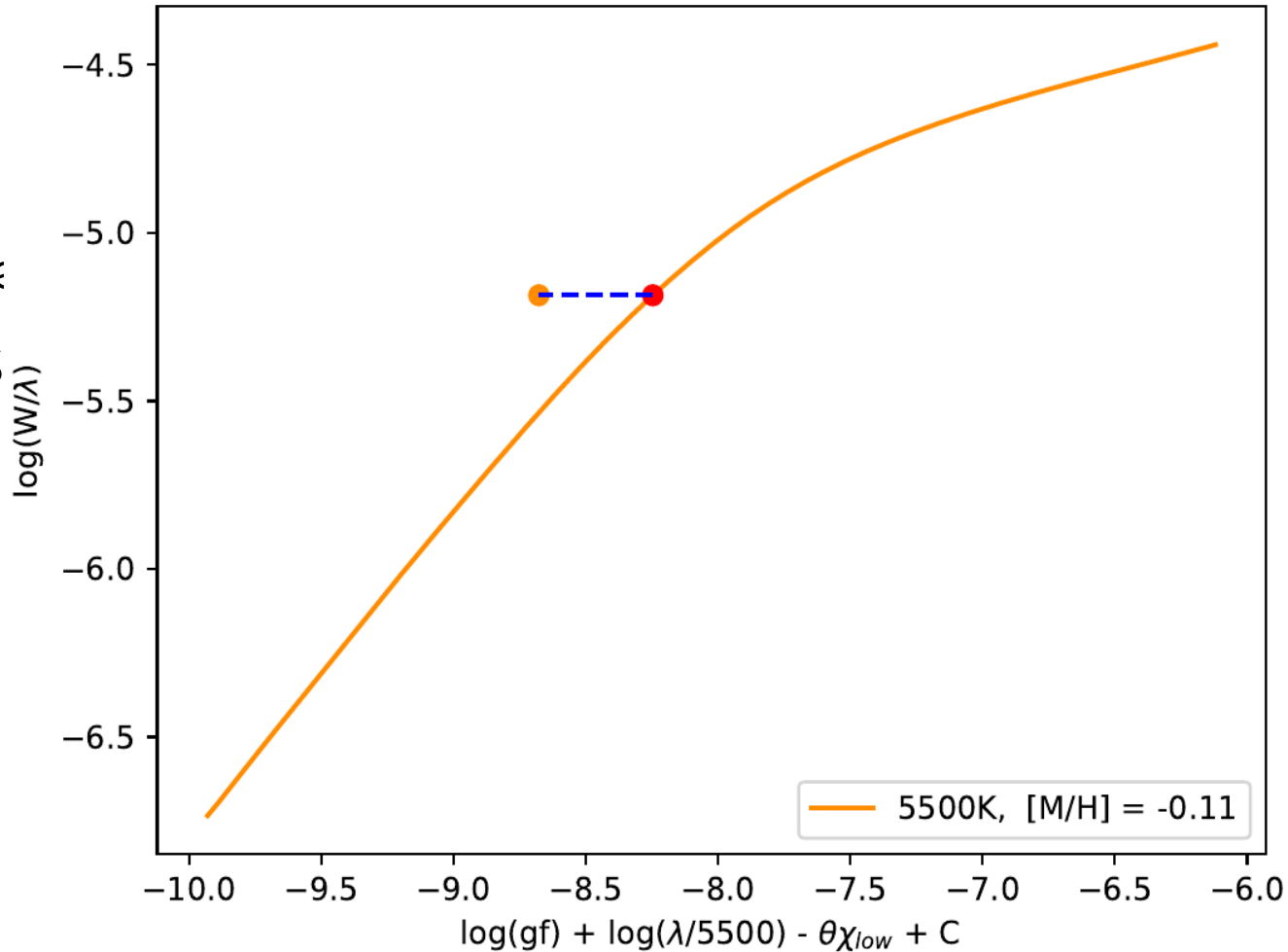
# Atomic lines : quality assessment

- ~1500 theoretically deep and unblended G type lines to assess!

1) Measure

2) Use the

BRASS



in one star

“adjust” the

# Atomic lines : quality assessment

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  - 3) Repeat for all G-type benchmarks. Calculate mean “adjustment”

# Atomic lines : quality assessment

• ~1500 th

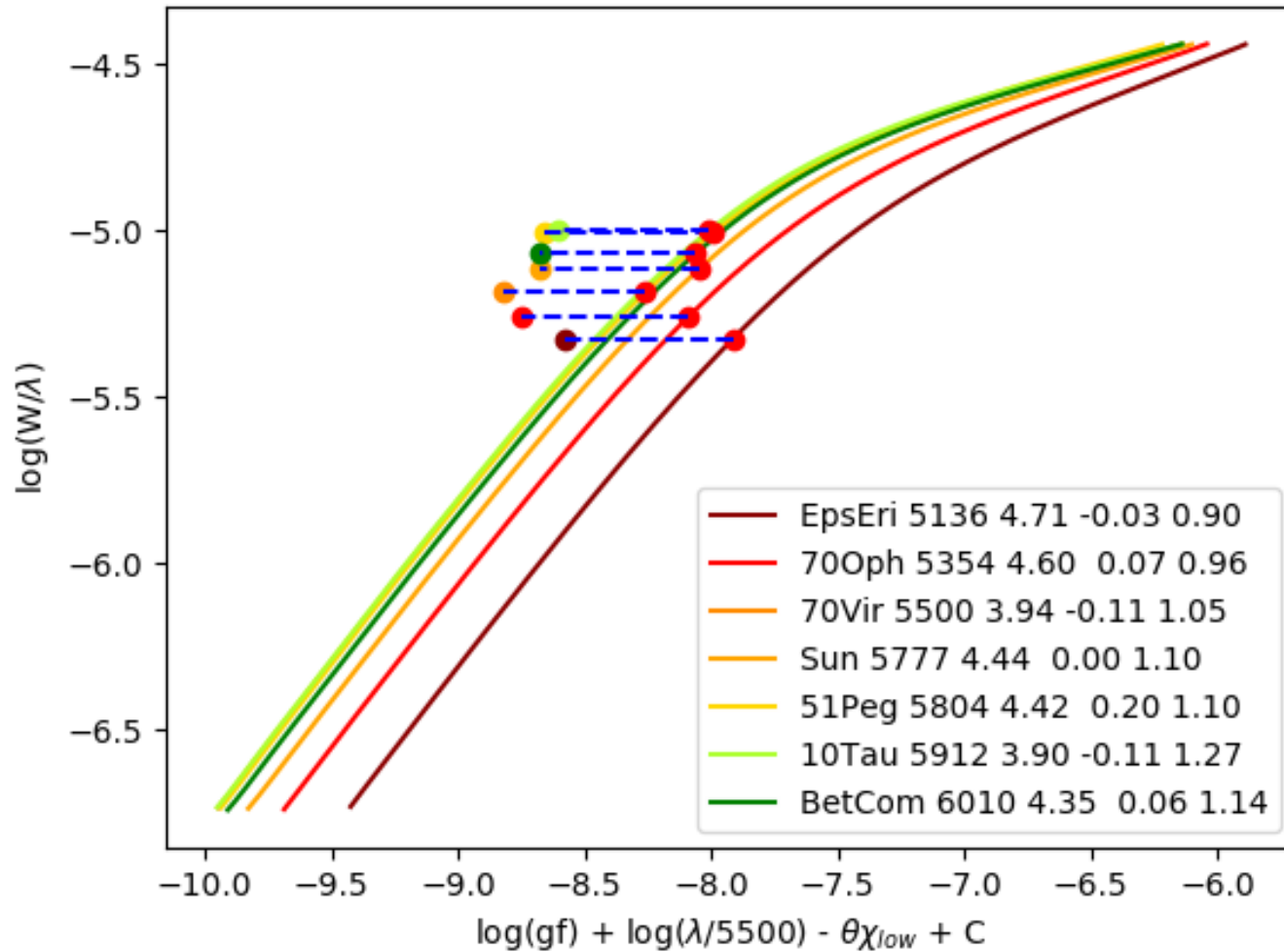
1) Meas

2) Use th

BRAS

3) Repec

CoG plots for graded G lines



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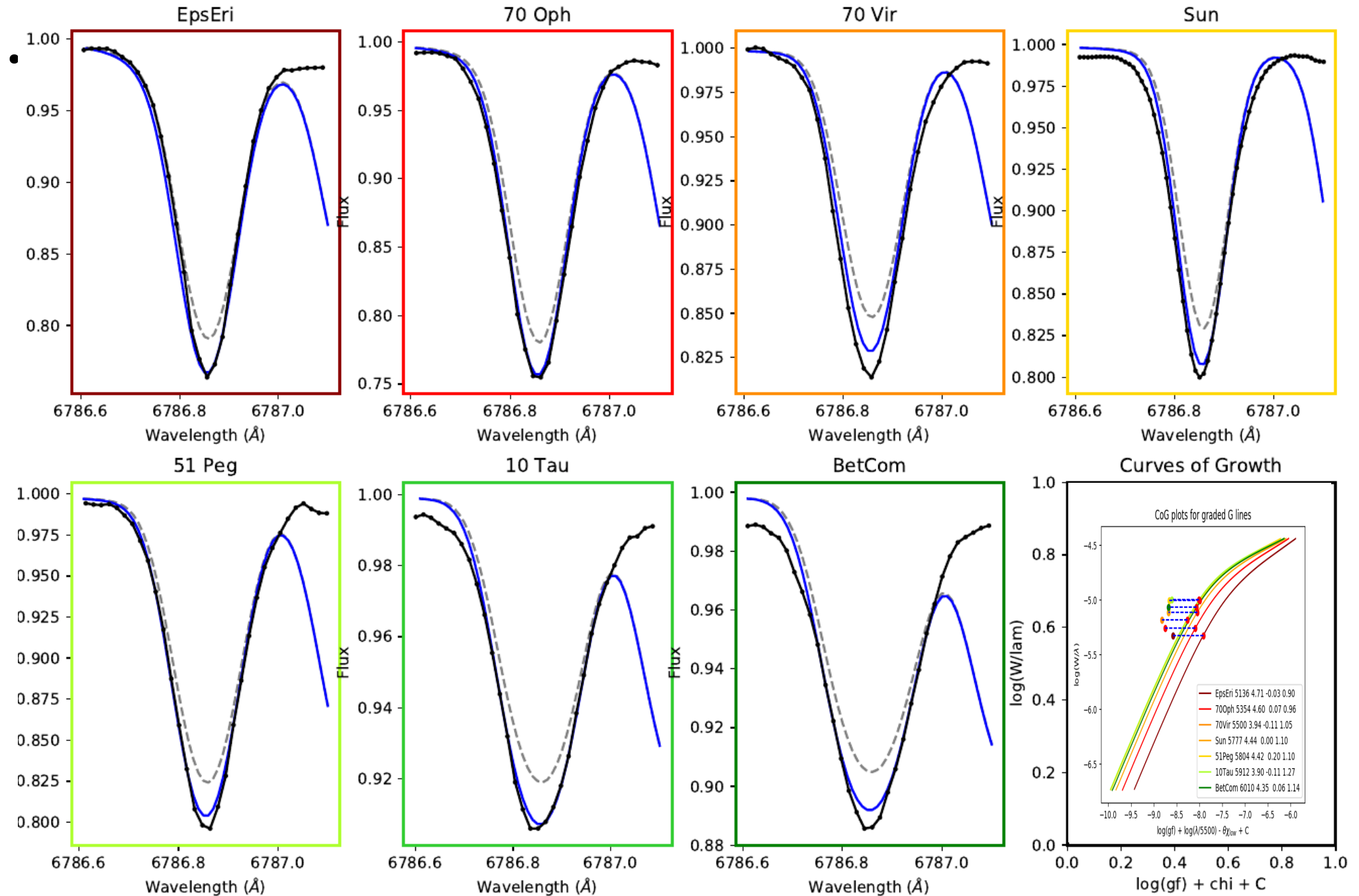


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  - 4) Re-synthesise with the “adjusted”  $\log(gf)$  value, check the quality of fit against all G-type benchmark spectra

# Atomic lines : quality assessment

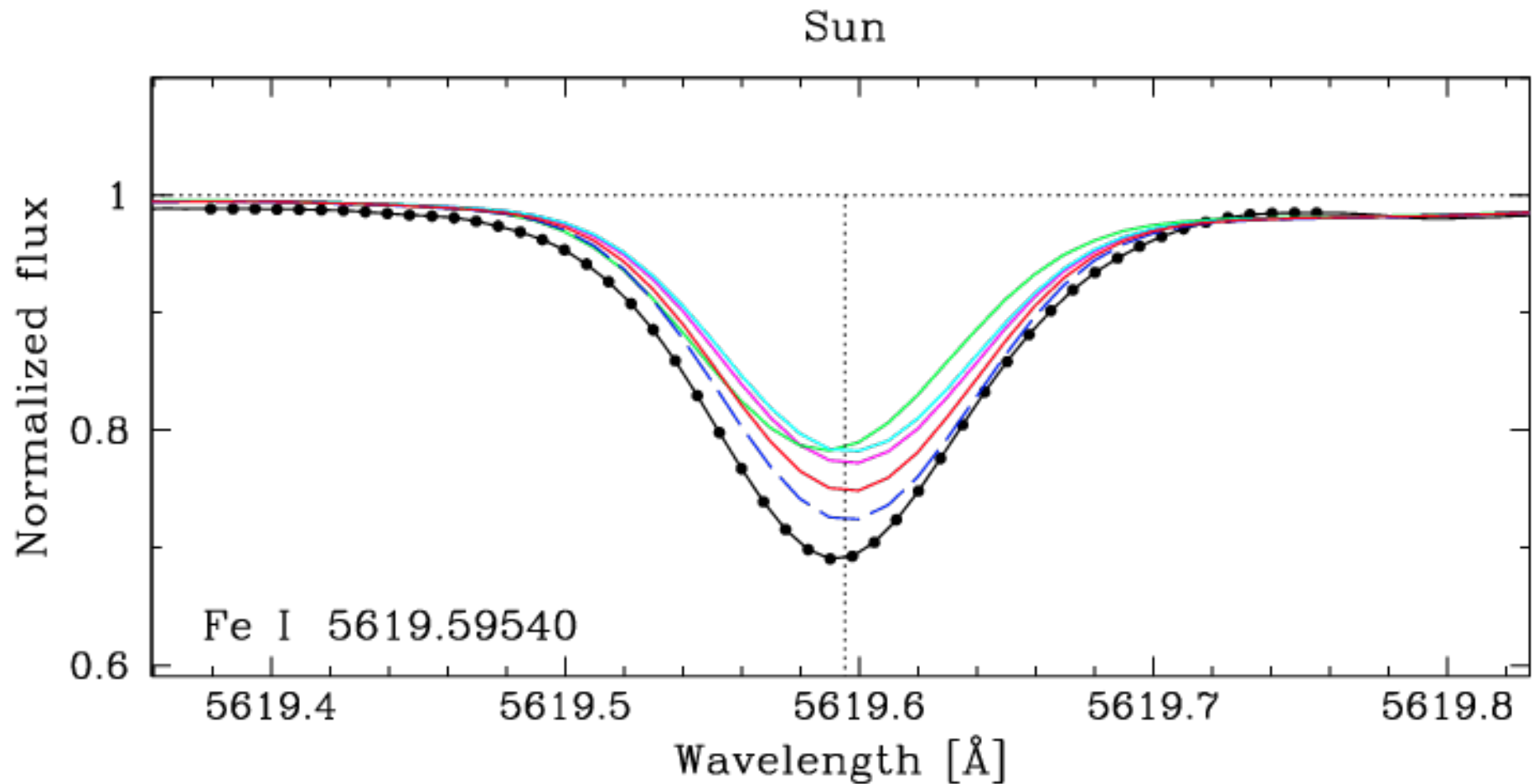


# Atomic lines : quality assessment

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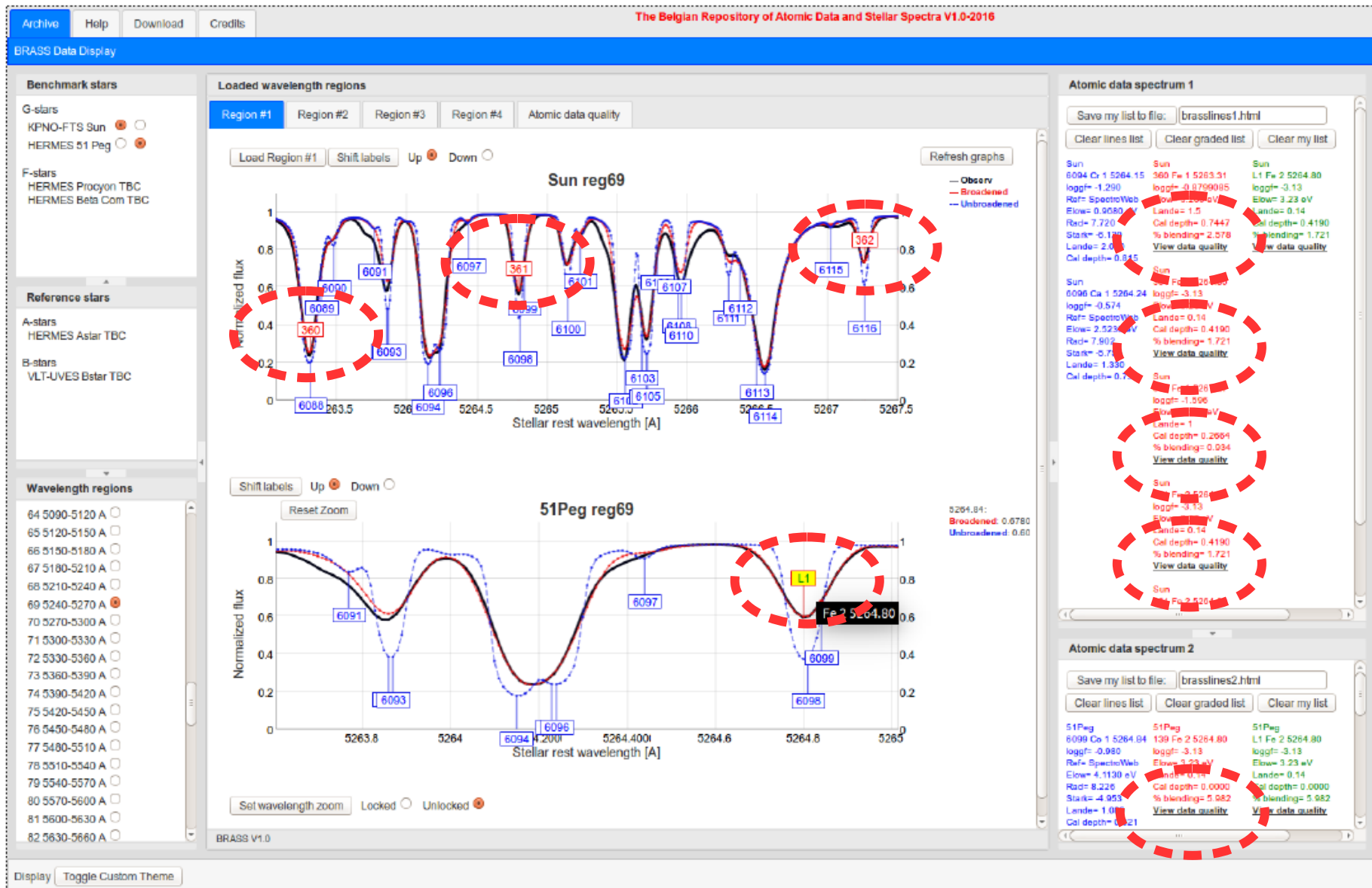
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  - 1) Measure the equivalent width of the observed line profile in one star
  - 2) Use the theoretical Curve of Growth and measured EW to “adjust” the BRASS  $\log(gf)$  value
  - 3) Repeat for all G-type benchmarks. Calculate mean “adjustment”
  - 4) Re-synthesise with the “adjusted”  $\log(gf)$  value, check the quality of fit against all G-type benchmark spectra
  - 5) Good fits means line can be assessed. Bad fits are likely hidden blends

# Atomic lines : quality assessment results



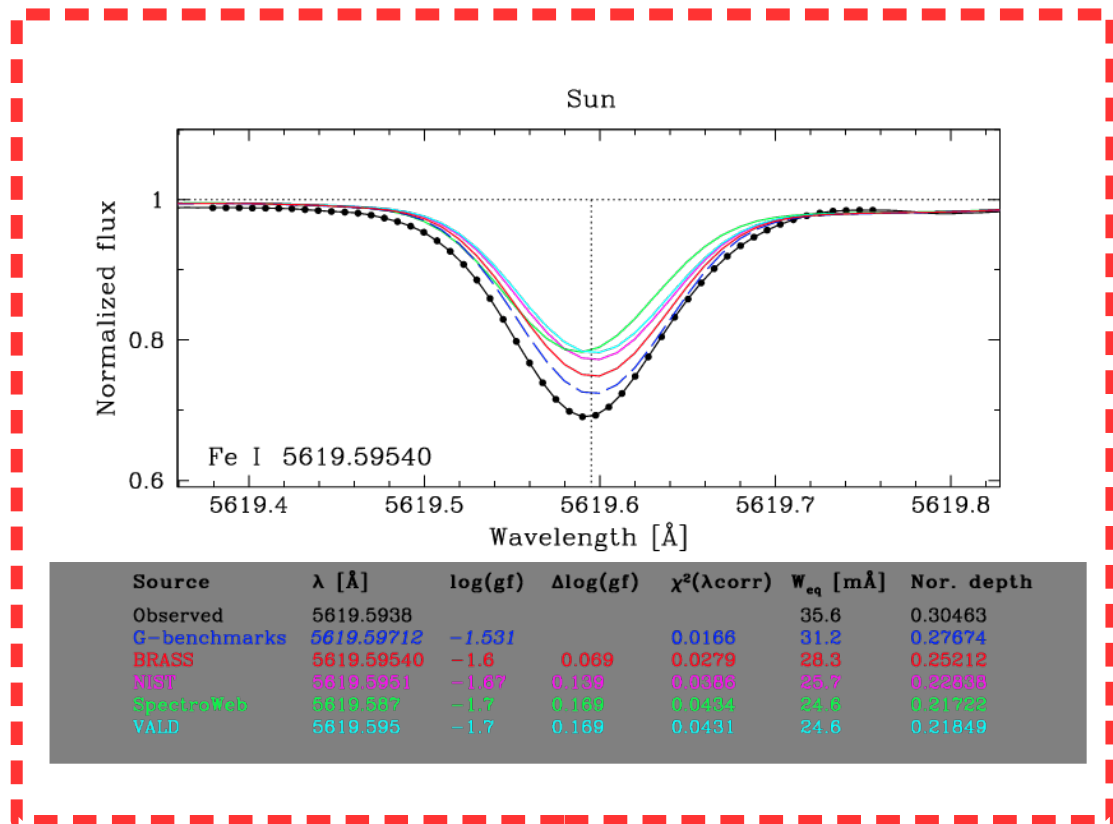
Source	$\lambda$ [Å]	$\log(gf)$	$\Delta\log(gf)$	$\chi^2(\lambda_{\text{corr}})$	$W_{\text{eq}}$ [mÅ]	Nor. depth
Observed	5619.5938				35.6	0.30463
G-benchmarks	5619.59712	-1.531		0.0166	31.2	0.27674
BRASS	5619.59540	-1.6	0.069	0.0279	28.3	0.25212
NIST	5619.5951	-1.67	0.139	0.0386	25.7	0.22838
SpectroWeb	5619.587	-1.7	0.169	0.0434	24.6	0.21722
VALD	5619.595	-1.7	0.169	0.0431	24.6	0.21849

# BRASS : Results and future work



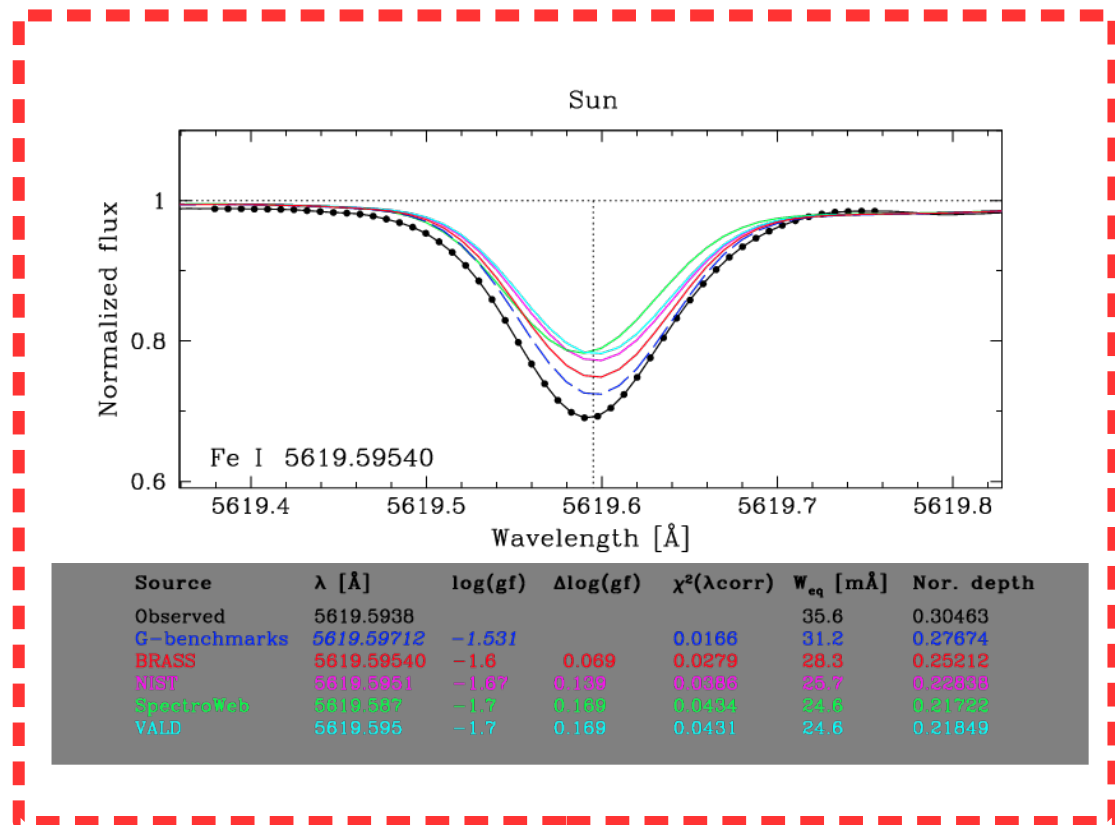
# BRASS : Results and future work

- Preliminary results available online at [brass.sdf.org](http://brass.sdf.org)
- Quality assessment for ~700 G-type atomic lines
- Publication of complete g-type results by the end of the year



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- Publication of complete g-type results by the end of the year



- Expand quality assessment work to B,A,F,K spectral types
- Complete spectral processing work of over 1000 different targets
- Fully release the BRASS database including all data products



# BRASS

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**Thank you for listening!**

**Questions?**

