Search For Main sequence Runaway stars

Workshop on Observational Techniques 2023
at Ondřejov Observatory

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Introduction

- what are runaway stars
  - > 30 km/s
  - different ejection populations
    - runaways stars, hyper-runaway stars, hypervelocity stars
  - different type populations
    - MS O/B/A, sdO/B, white dwarfs

- origin of runaway stars
  - binary supernova, dynamical ejection, Hills mechanism
- characteristics
- how to study them: cluster –> runaways

  : runaways –> origin cluster

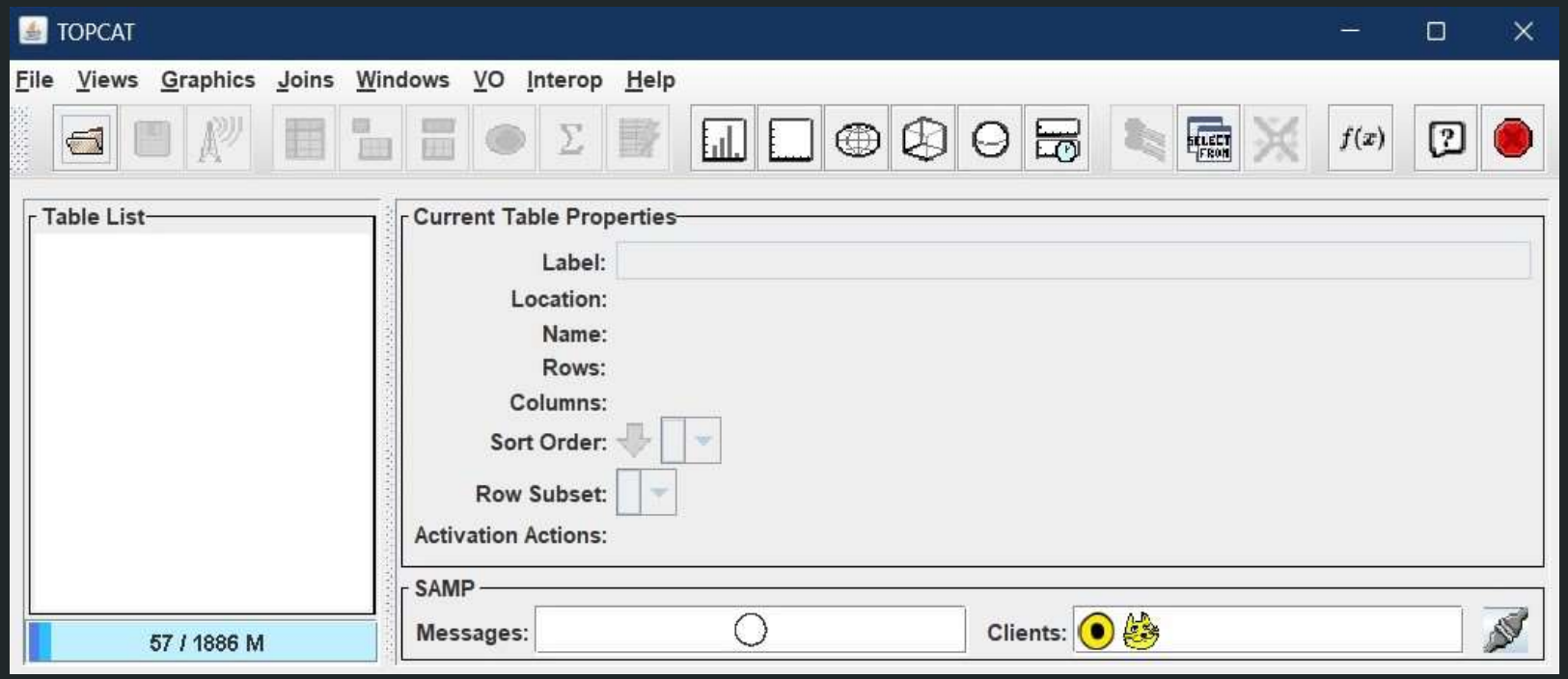
Fig. - 1 Runaway star Zeta Ophiuchi

Telescope and Spectrograph

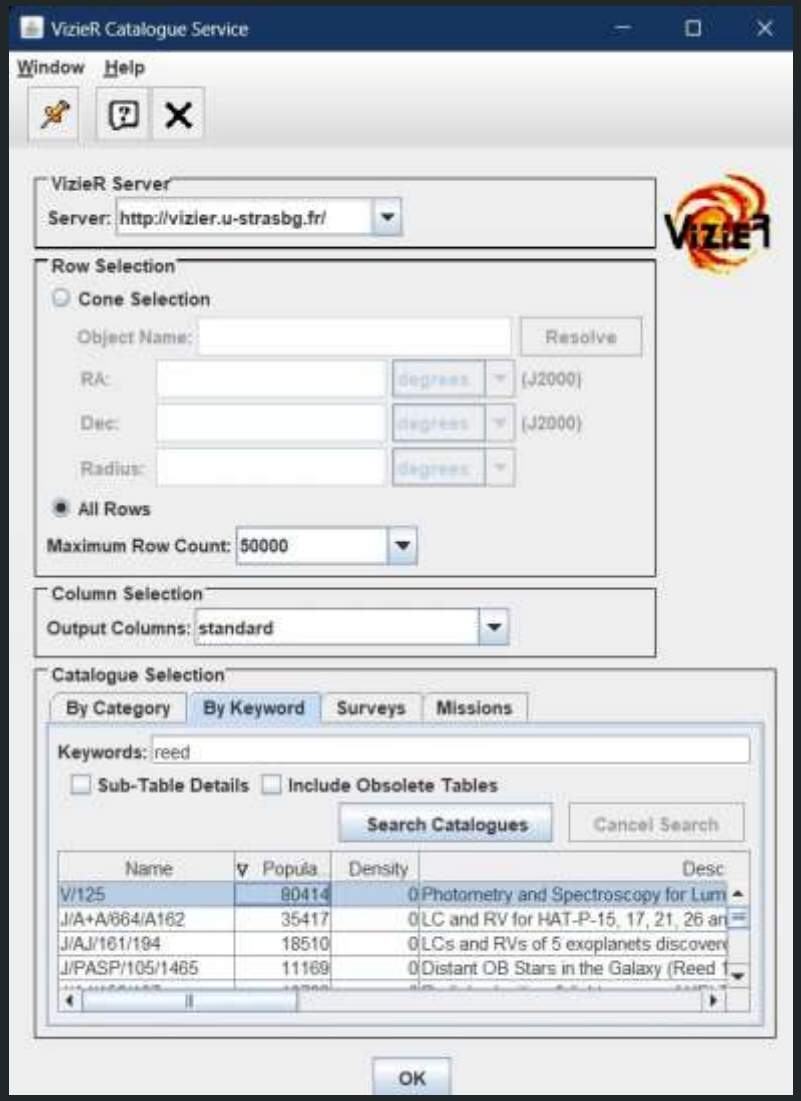
2 meter Perek telescope

Echelle spectrograph

Target Selection and Data reduction



Creating a target list



Creating a target list (TOPCAT)

TOPCAT(1): Table Browser

Window Rows Help

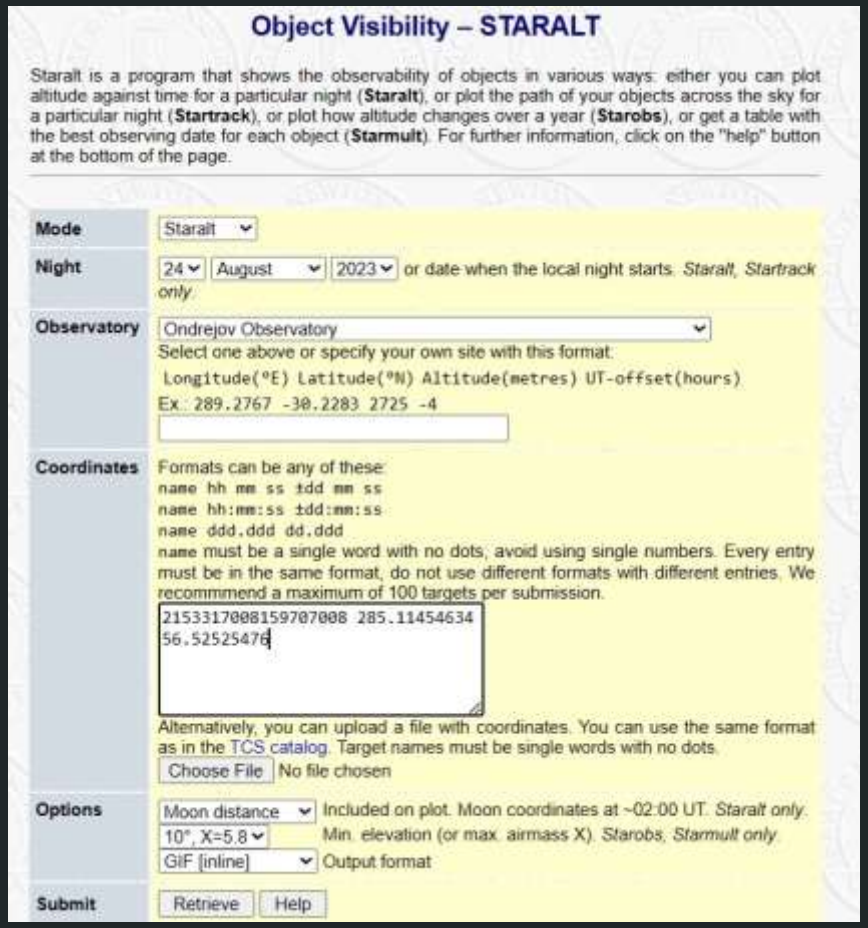
Table Browser for 1: 2final list.CSV

	source_id	designation	ra	dec	l	b	ecl_lon	ecl_la
1	2074770818063256064	Gaia DR3 2074770818063256064	301.41083	41.27983	77.27026	5.05089	320.22621	59.363
2	2074770818063256064	Gaia DR3 2074770818063256064	301.41083	41.27983	77.27026	5.05089	320.22621	59.363
3	2153317008159707008	Gaia DR3 2153317008159707008	285.11455	56.52525	86.70365	21.16369	312.53682	77.717
4	467515887487537536	Gaia DR3 467515887487537536	43.52558	63.83564	135.96295	4.11181	63.29802	44.642
5	2178380238290259584	Gaia DR3 2178380238290259584	324.86094	57.31216	99.22164	3.56276	6.40663	63.614
6	2183687855788172672	Gaia DR3 2183687855788172672	311.19458	54.50216	91.92091	7.23562	348.61035	67.037
7	2213094362988155008	Gaia DR3 2213094362988155008	344.61272	67.78055	112.53892	7.21816	37.14335	62.781
8	2083644392294059520	Gaia DR3 2083644392294059520	307.6285	47.86407	85.23069	5.04749	334.82606	63.089
9	2167668688623855232	Gaia DR3 2167668688623855232	309.46754	47.95023	86.03463	4.10681	337.19402	62.493
10	2182712073579876864	Gaia DR3 2182712073579876864	314.11243	53.94008	92.56157	5.55625	350.82406	65.478
11	2190002419784531712	Gaia DR3 2190002419784531712	312.85046	57.06198	94.52917	8.09398	355.07033	68.212
12	2083205687151476224	Gaia DR3 2083205687151476224	305.27654	46.05239	82.81613	5.32228	329.78391	62.366
13	525286152555097216	Gaia DR3 525286152555097216	20.94603	65.62897	126.26406	2.9667	52.24753	50.991
14	2072040657665363584	Gaia DR3 2072040657665363584	297.063	37.36643	72.16231	5.92257	311.55427	56.966
15	432017055072993792	Gaia DR3 432017055072993792	2.73341	64.96318	118.66105	2.42784	41.87242	55.410
16	2168210752160476544	Gaia DR3 2168210752160476544	311.10913	49.16148	87.66131	3.98603	340.63562	62.887
17	2081594352860415616	Gaia DR3 2081594352860415616	303.50669	45.06469	81.2996	5.80474	326.43104	62.098
18	2093381220584181248	Gaia DR3 2093381220584181248	282.45779	35.76198	65.4617	15.75645	289.49351	58.361
19	2167684670207187328	Gaia DR3 2167684670207187328	310.0046	48.10535	86.37641	3.91492	338.02731	62.425
20	4587447357614092416	Gaia DR3 4587447357614092416	278.47845	29.4643	58.0744	16.46813	282.18605	52.545
21	2073020563047553024	Gaia DR3 2073020563047553024	297.04063	38.78929	73.3961	6.64428	312.42217	58.311
22	2149321485982758784	Gaia DR3 2149321485982758784	274.59054	55.44685	84.04018	26.62473	283.36289	78.673
23	2035165687706631168	Gaia DR3 2035165687706631168	297.69676	33.66395	69.20979	3.61642	310.33252	53.294
24	2182012333201634304	Gaia DR3 2182012333201634304	311.39304	51.55002	89.65631	5.32178	344.18323	64.700
25	2047053607414291200	Gaia DR3 2047053607414291200	296.03571	33.93696	68.75457	4.94821	308.25365	53.972
26	2071470359021172352	Gaia DR3 2071470359021172352	307.33408	46.66638	84.13785	4.51048	333.08412	62.176
27	2038079290402686720	Gaia DR3 2038079290402686720	290.52905	28.66825	61.84865	6.57684	298.65515	50.085

Total: 80 Visible: 80 Selected: 0

Target visibility from the observatory

- go to: http://catserver.ing.iac.es/staralt/
- Gaia or object ID
- RA
- DEC.



Object Visibility – STARALT

Staralt is a program that shows the observability of objects in various ways: either you can plot altitude against time for a particular night (**Staralt**), or plot the path of your objects across the sky for a particular night (**Startrack**), or plot how altitude changes over a year (**Starobs**), or get a table with the best observing date for each object (**Starmult**). For further information, click on the "help" button at the bottom of the page.

Mode Staralt

Night 24 August 2023 or date when the local night starts. *Staralt, Startrack only.*

Observatory Ondrejov Observatory
Select one above or specify your own site with this format:
Longitude(°E) Latitude(°N) Altitude(metres) UT-offset(hours)
Ex: 289.2767 -30.2283 2725 -4

Coordinates Formats can be any of these:
name hh mm ss ±dd mm ss
name hh:mm:ss ±dd:mm:ss
name ddd.ddd dd.ddd
name must be a single word with no dots; avoid using single numbers. Every entry must be in the same format, do not use different formats with different entries. We recommmend a maximum of 100 targets per submission.

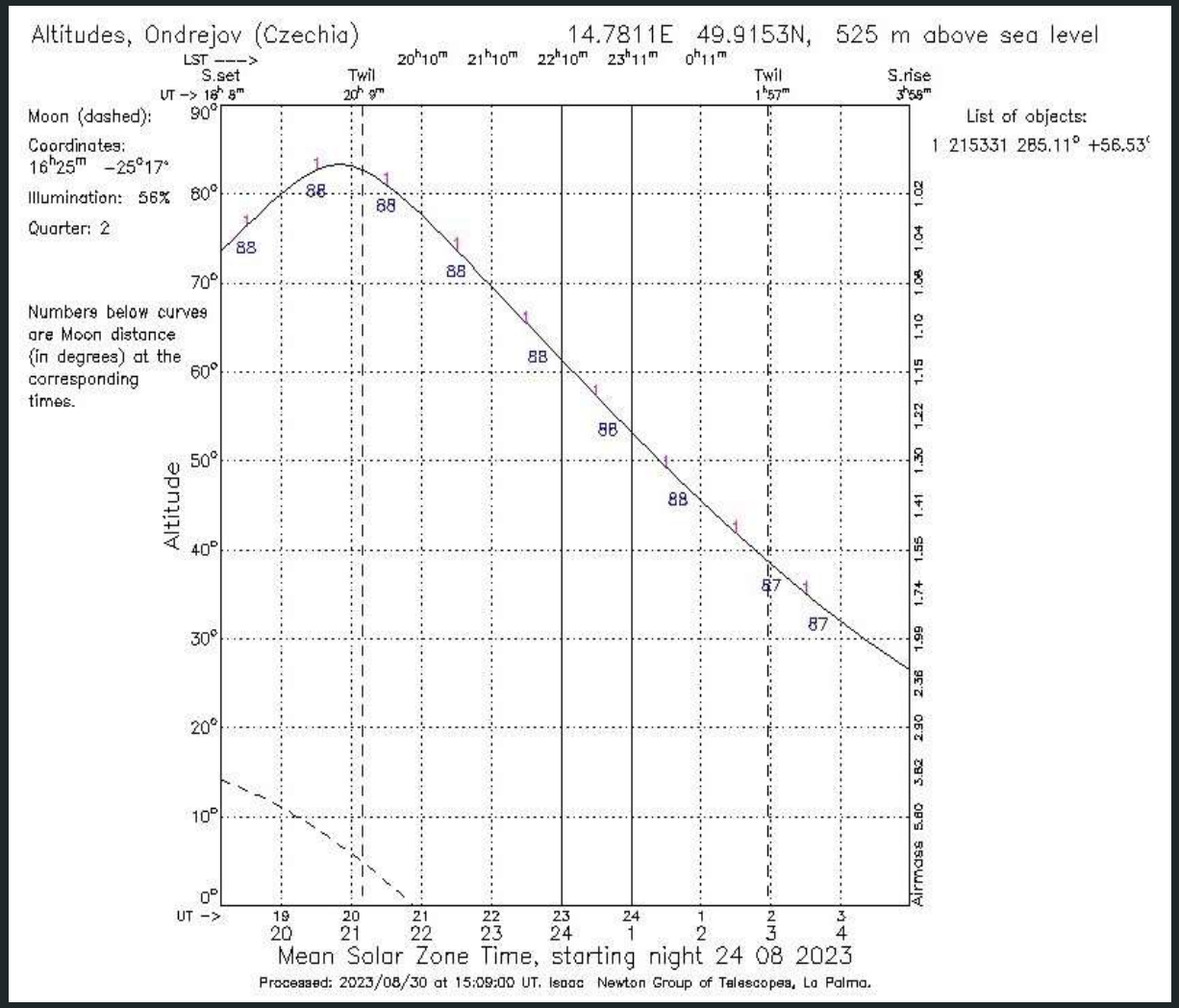
2153317008159707008 285.11454634 56.52525476

Alternatively, you can upload a file with coordinates. You can use the same format as in the TCS catalog. Target names must be single words with no dots.
Choose File No file chosen

Options Moon distance Included on plot. Moon coordinates at ~02:00 UT. *Staralt only.*
10°, X=5.8 Min. elevation (or max. airmass X). *Starobs, Starmult only.*
GIF [inline] Output format

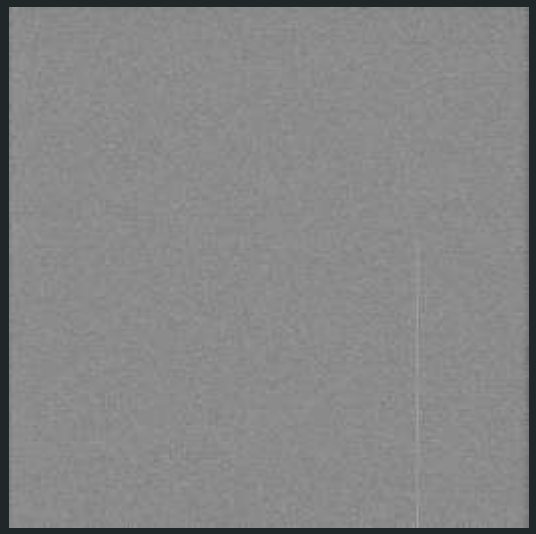
Submit Retrieve Help

Visibility Curve



Calibration frames

Zero (Bias) frame



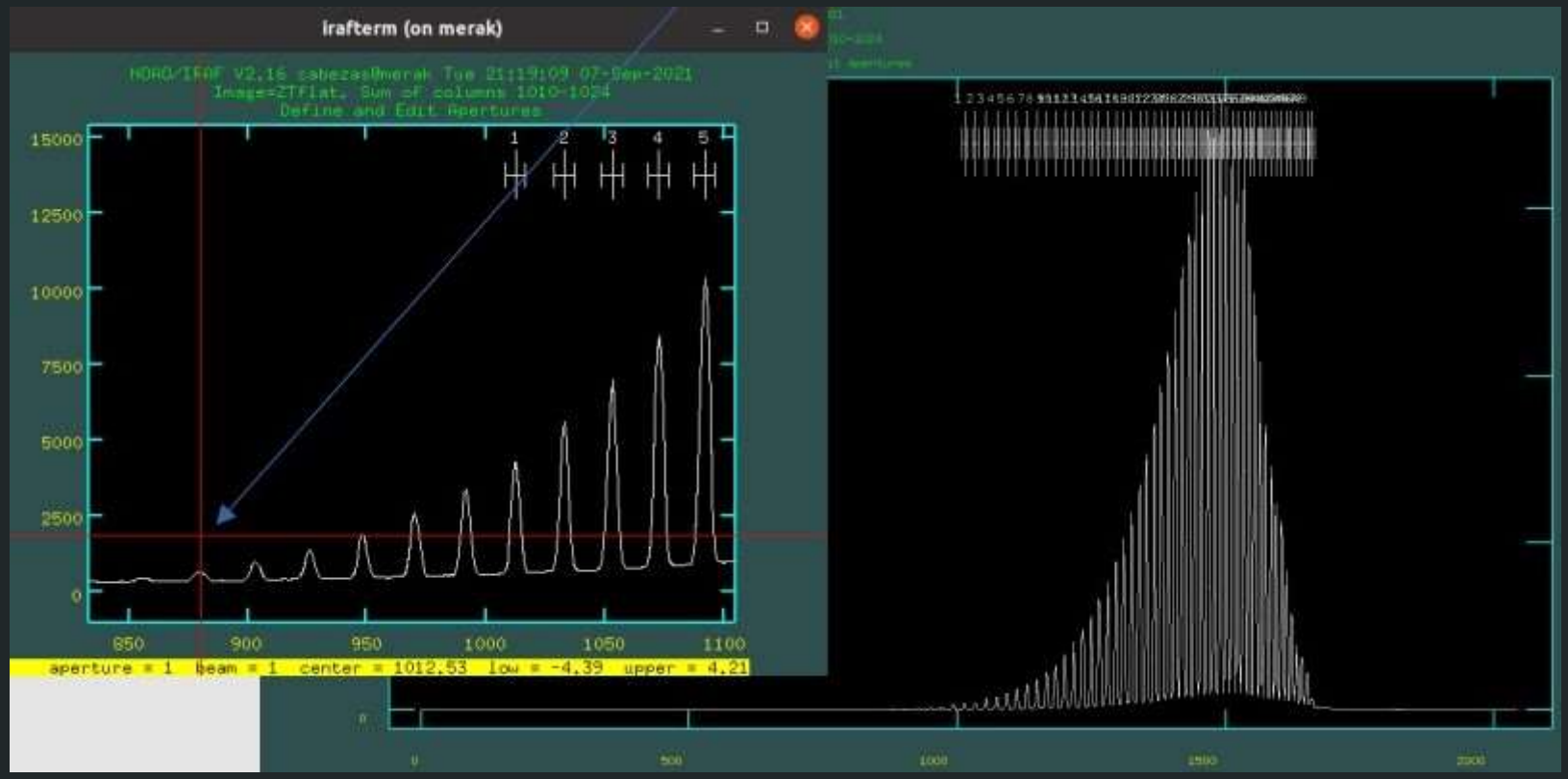
Flat frame

Comparison frame

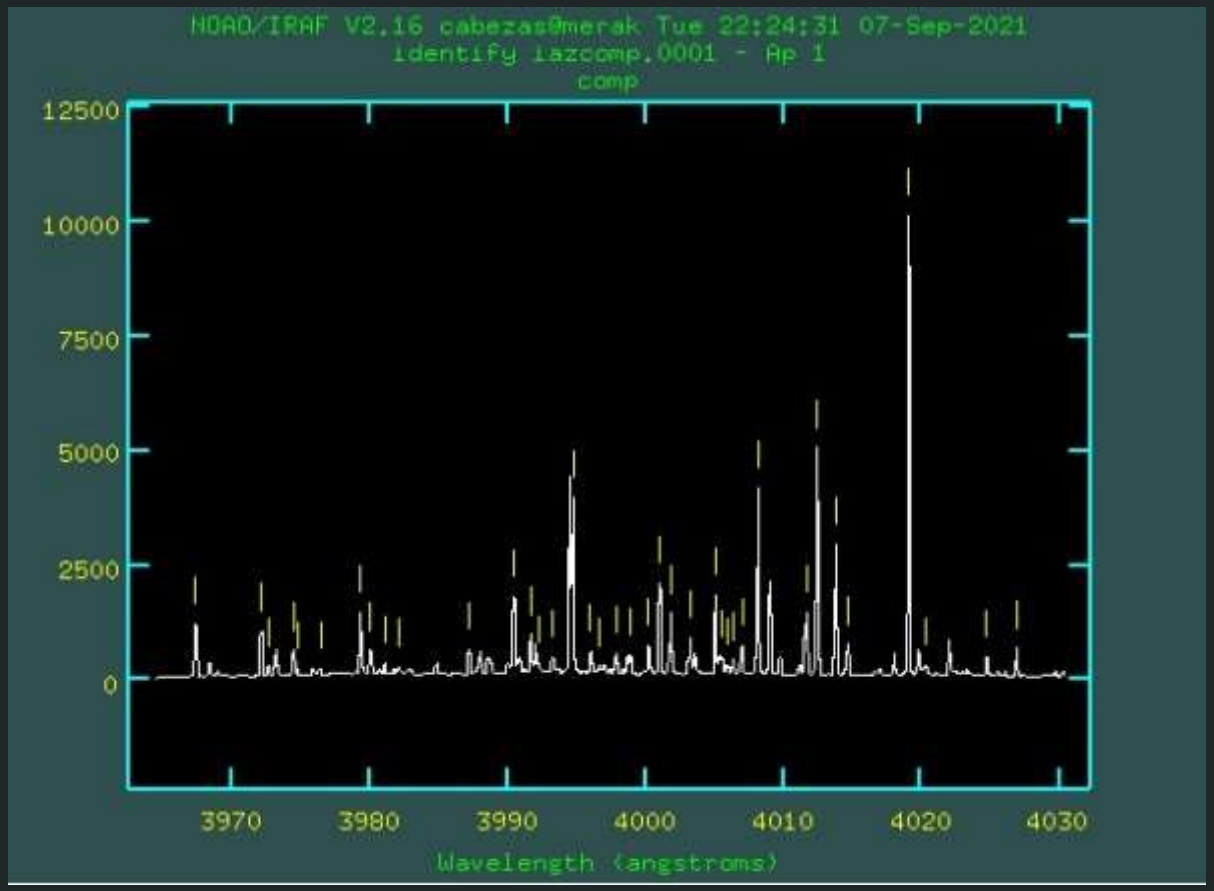
Data reduction with IRAF

```
cl

                                   I R A F
                        Image Reduction and Analysis Facility
PACKAGE = clpackage
   TASK = oesred

input   = e202308240036.fit  Spectrum target to reduce(.fit)
(output =             HD235404) Output filename
(idtarge=            HD 235404) Target name on header
(napertu=                   49) Number of apertures to be found
(id     =                 0036) Observation id number

                                # CALIBRATION PARAMETERS

(orgfile=                  yes) do you want organize files?
(zerocom=                  yes) Combine zero level images?
(trimcal=                  yes) Trim flat and comp?
(iftrimc=                  yes) Use trim flat & comp?
(zerocor=                  yes) Apply zero level correction to flat & comp?
(compcom=                  yes) Combine comparison lamp images?
(flatcom=                  yes) Combine flat field images?
(flatapa=                  yes) Extract flat apertures?
(compapa=                  yes) Extract comparison apertures?
(iddatab=                  yes) Use database folder for identification?
(idfolde=          idcomp_2307) folder name with identification database


More
                                                          ESC-? for HELP
```

Model aperture



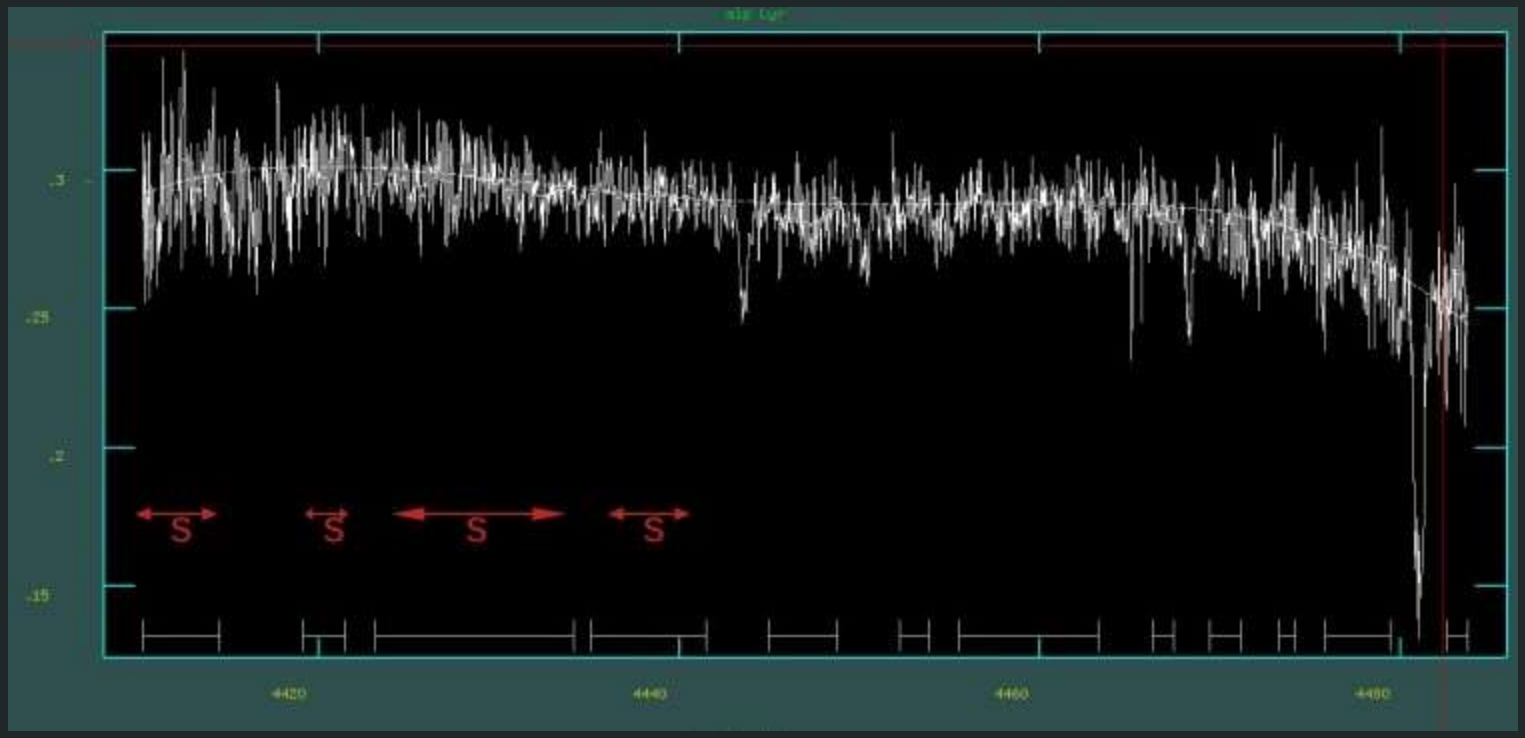
Wavelength calibration



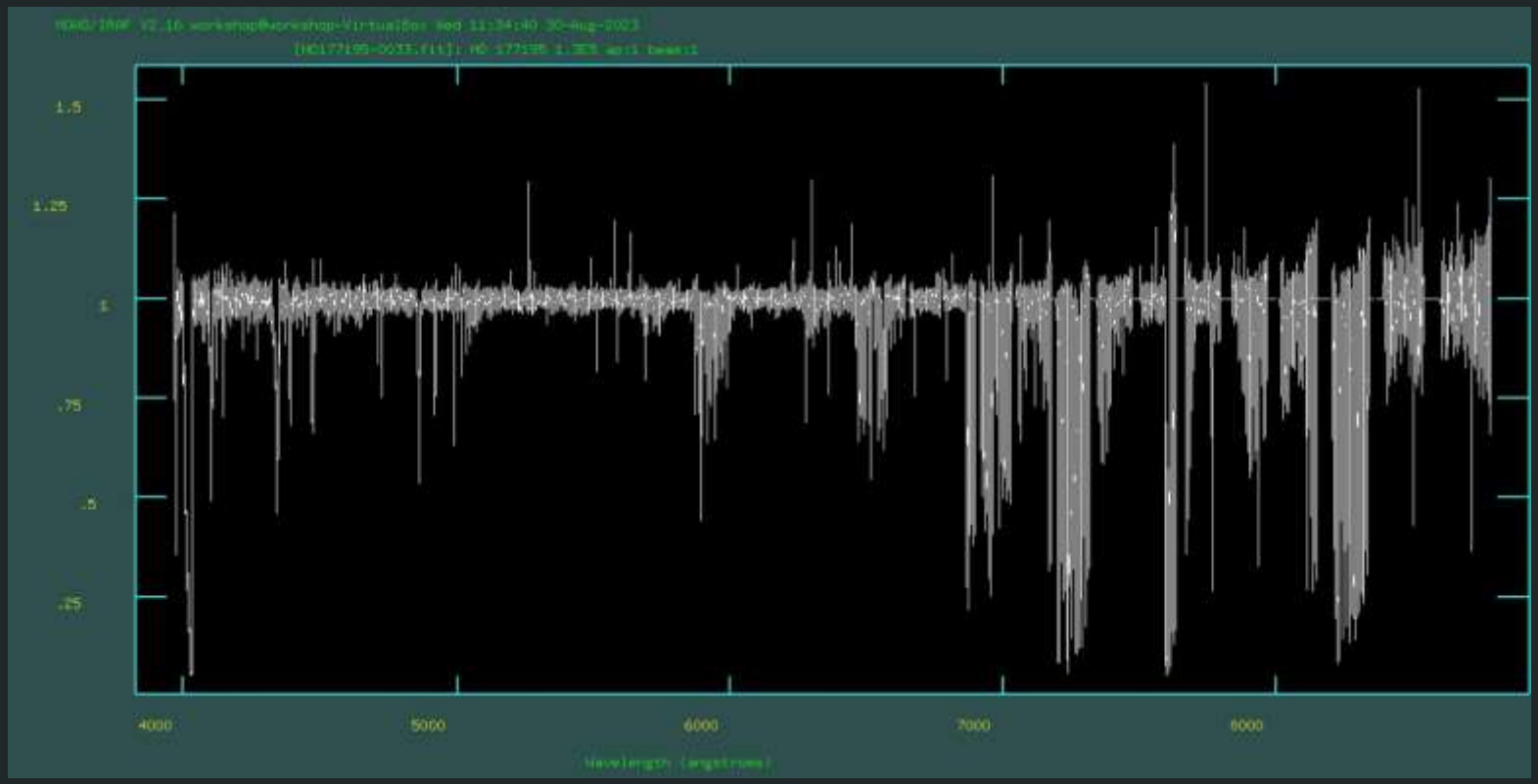
Object trimming and normalization

```
cl
                                   I R A F
                         Image Reduction and Analysis Facility
PACKAGE = clpackage
   TASK = oesred
More
(idencom=                 yes) Identify features in spectrum for dispersion solution?

                                # OBJECT PARAMETERS

(trimob =                 yes) Trim object?
(iftrimo=                 yes) Use trim object?
(zerocor=                 yes) Apply zero level correction to object?
(crays  =                 yes) Remove cosmic rays?
(ifcrays=                 yes) Use object with cosmic rays extraction?
(objecta=                 yes) Extract object apertures?
(flatcor=                 yes) Apply flat correction to object?
(helioco=                 yes) calculate JD + heliocentric correction?
(idref  =                 yes) refer database identification to images?
(norm   =                 yes) normalize spectra?
(ncombin=                 yes) combine normalized spcectra?

                                # TASK PARAMETERS

(nfuncti=             legendre) Continuum fitting function
(norder =                    5) Order of continuum fitting function
(t_funct=             spline3) Trace apertures fitting fucntion
(t_order=                    5) Order of apertures fitting function
More
                                                                  ESC-? for HELP
```

Normalization



Final merged spectrum

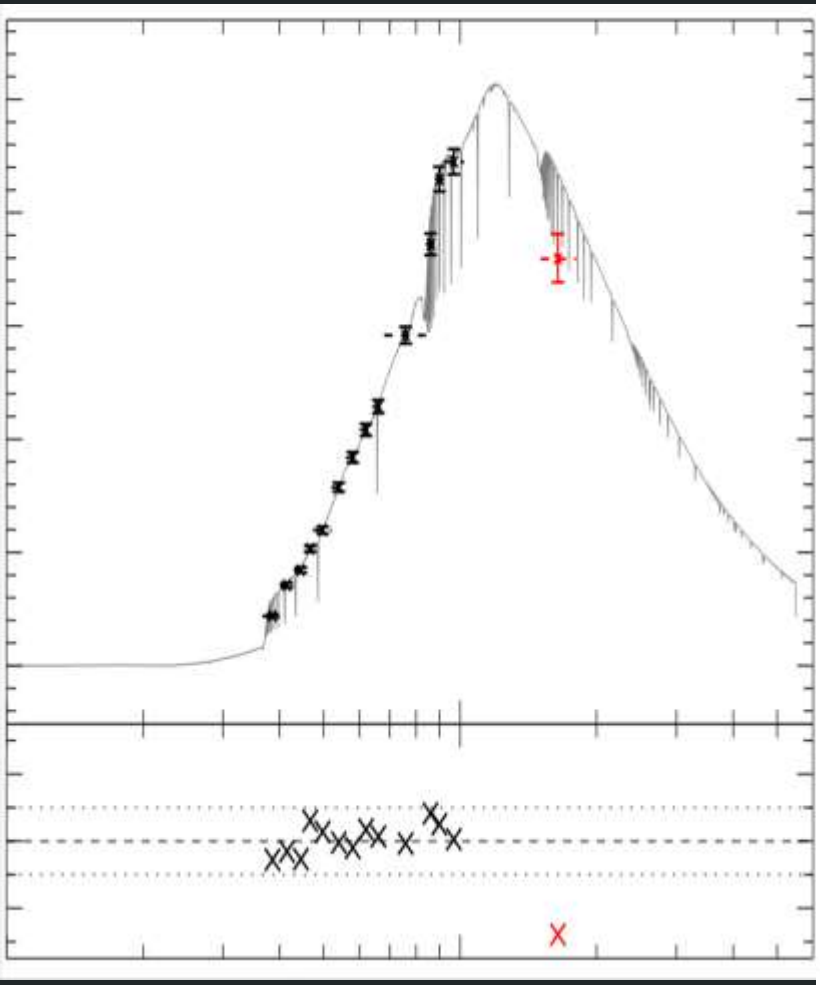


Data analysis

- identifying runaway stars
  - young (spectral type, rotation velocity, stellar parameters)
  - fast (radial velocity)

Spectral energy distribution

- temperature, luminosity, mass, radius, surface gravity...
- plot HR diagram

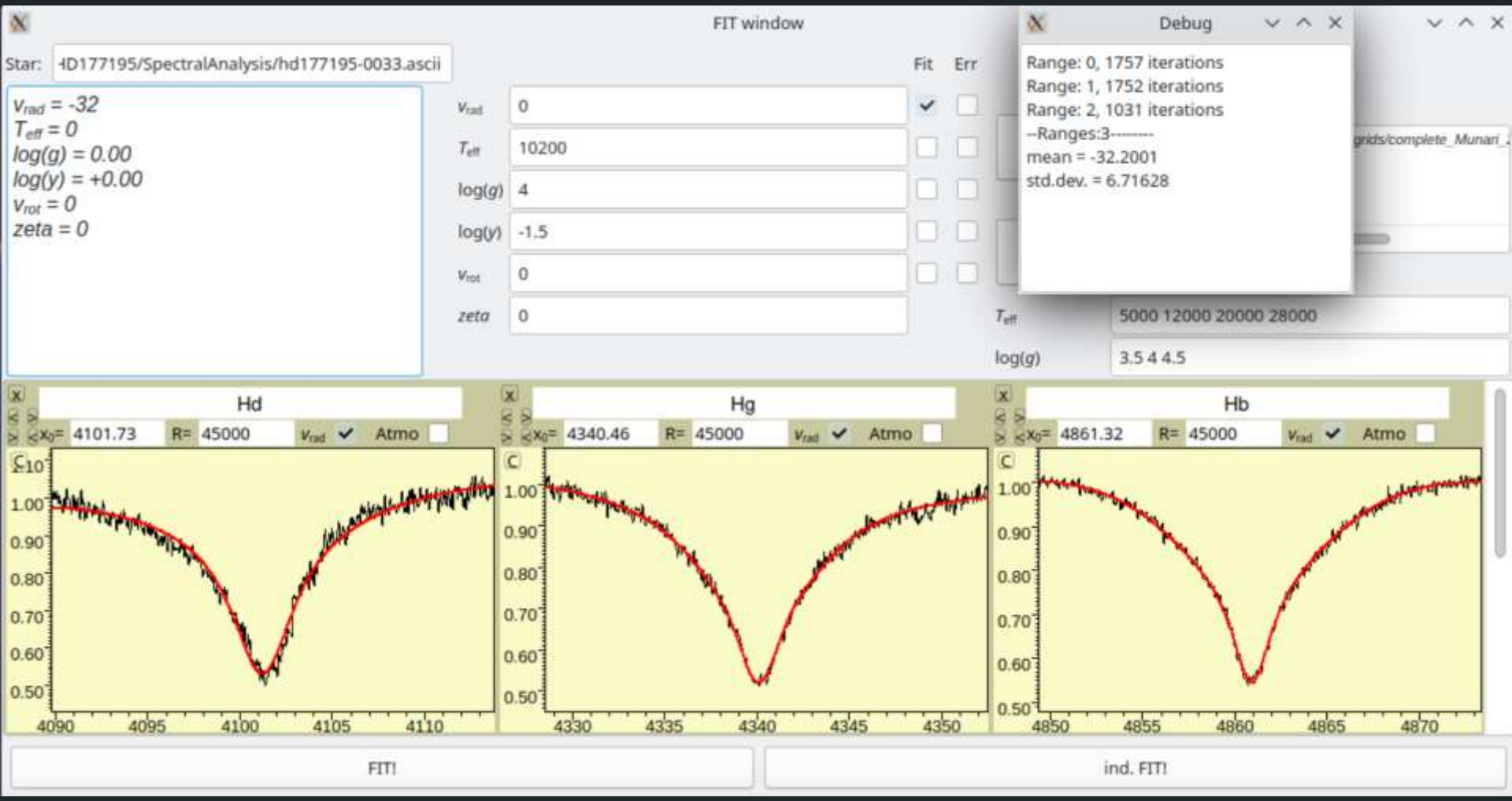


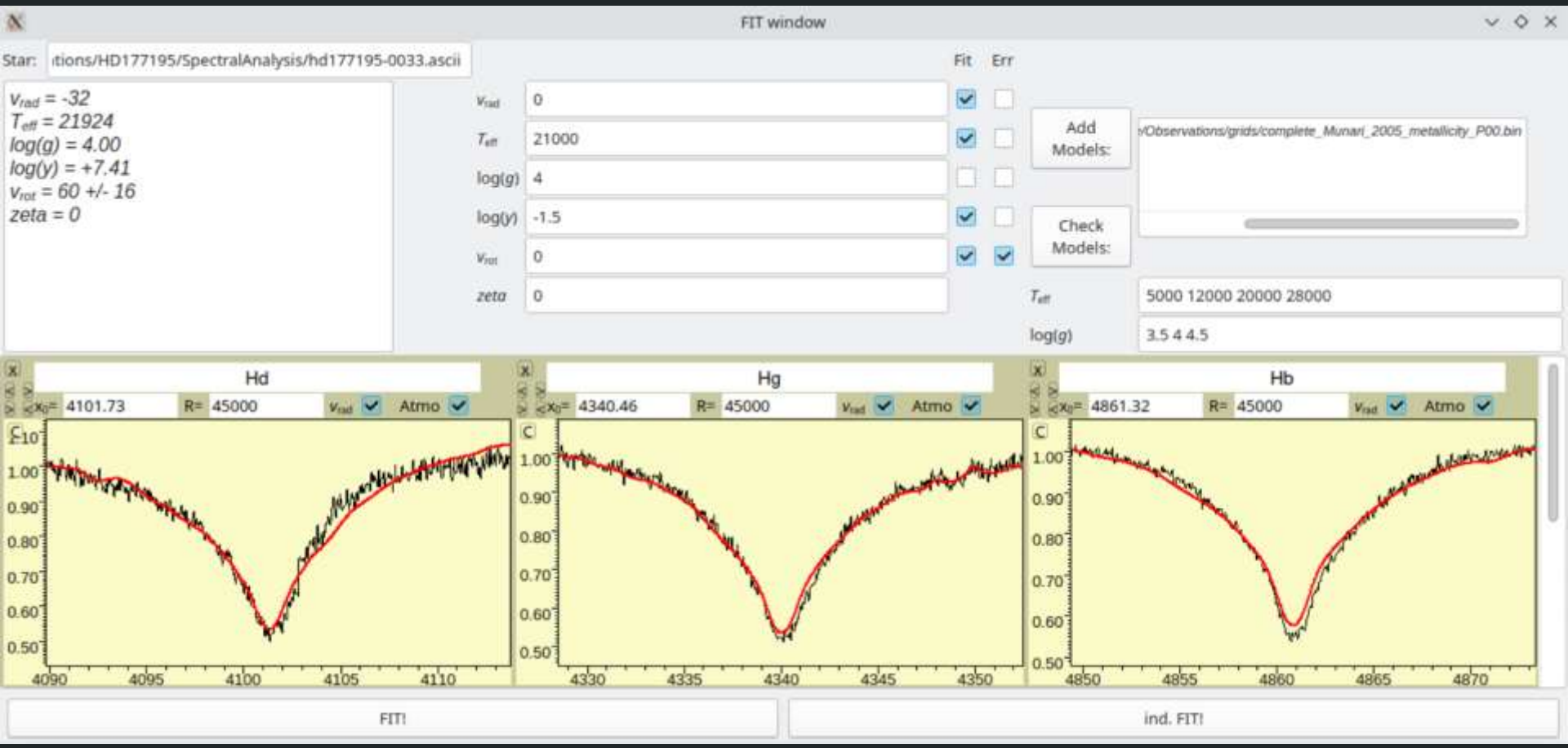
Object: HD 235404	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	1.32 ± 0.07 mag
Color excess $E(B-V)$ from S&F (2011)	1.14 ± 0.06 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.96 ± 0.11 mag
Color excess $E(44-55)$	$0.97^{+0.04}_{-0.05}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	$-9.136^{+0.030}_{-0.026}$
Parallax ϖ (*Gaia*, RUWE = 1.05, ZPO = −0.021 mas)	0.461 ± 0.016 mas
Distance d (*Gaia*, mode)	$(2.16 \pm 0.08) \times 10^3$ pc
Distance d (*Gaia*, median)	$(2.17 \pm 0.08) \times 10^3$ pc
Effective temperature T_{eff}	10200^{+1000}_{-1100} K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	$2.6^{+0.5}_{-0.6}$
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1.05
Radius $R = \Theta/(2\varpi)$ (mode)	$34.9^{+2.8}_{-2.3}\,R_\odot$
(median)	$35.3^{+2.8}_{-2.4}\,R_\odot$
Mass $M = gR^2/G$ (mode)	$3.4^{+26.9}_{-\ 3.0}\,M_\odot$
(median)	$19^{+33}_{-14}\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$\left(1.1^{+0.6}_{-0.5}\right) \times 10^4$
(median)	$\left(1.2^{+0.6}_{-0.5}\right) \times 10^4$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$0.06^{+0.48}_{-0.06}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.023 mag
Reduced χ^2 at the best fit	1.00

SPAS - Radial velocity fitting

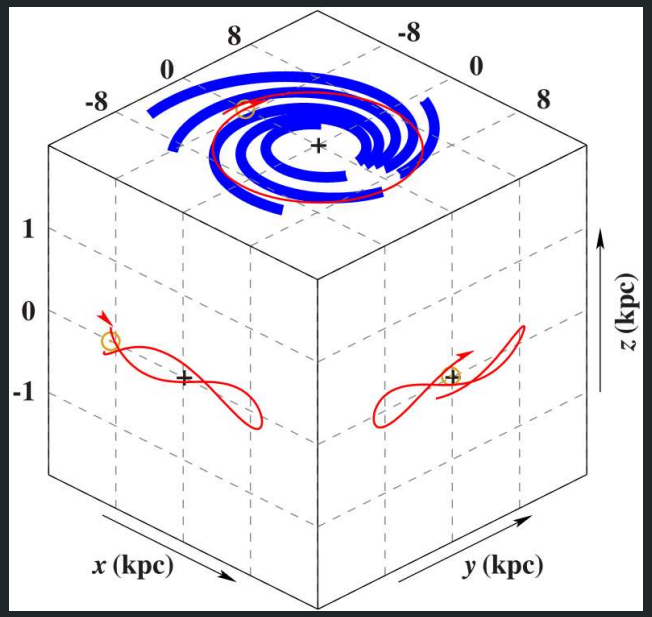
- .fit to .ascii
- selection of lines
- radial velocity, deviation

- rotational velocity with grids
- fix temperature from SED

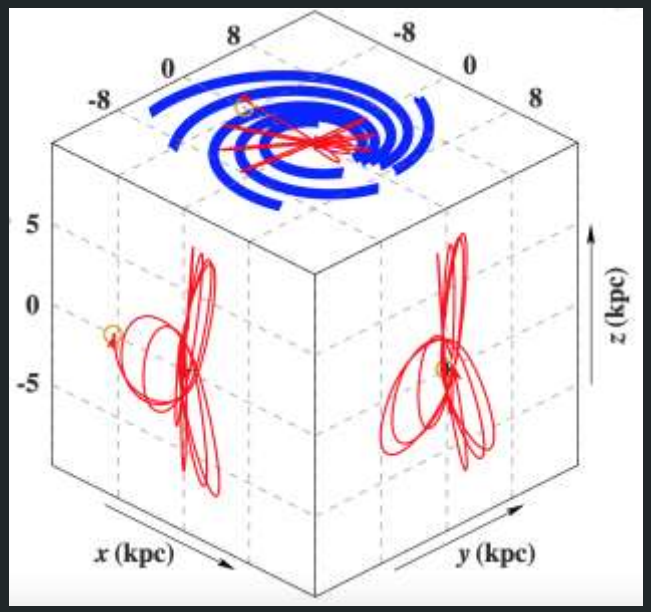

FIT window
Star: 4D177195/SpectralAnalysis/hd177195-0033.ascii
Fit
Err
v_{rad} = -32
T_{eff} = 0
log(g) = 0.00
log(y) = +0.00
v_{rot} = 0
zeta = 0
v_{rad} 0
T_{eff} 10200
log(g) 4
log(y) -1.5
v_{rot} 0
zeta 0
Debug
Range: 0, 1757 iterations
Range: 1, 1752 iterations
Range: 2, 1031 iterations
--Ranges:3--------
mean = -32.2001
std.dev. = 6.71628
T_{eff} 5000 12000 20000 28000
log(g) 3.5 4 4.5
Hd
x_0= 4101.73 R= 45000 v_{rad} Atmo
Hg
x_0= 4340.46 R= 45000 v_{rad} Atmo
Hb
x_0= 4861.32 R= 45000 v_{rad} Atmo
FIT!
ind. FIT!


FIT window
Star: tions/HD177195/SpectralAnalysis/hd177195-0033.ascii
Fit
Err
v_{rad} = -32
T_{eff} = 21924
log(g) = 4.00
log(y) = +7.41
v_{rot} = 60 +/- 16
zeta = 0
v_{rad} 0
T_{eff} 21000
log(g) 4
log(y) -1.5
v_{rot} 0
zeta 0
Add Models:
/Observations/grids/complete_Munari_2005_metallicity_P00.bin
Check Models:
T_{eff} 5000 12000 20000 28000
log(g) 3.5 4 4.5
Hd
x_0= 4101.73
R= 45000
v_{rad}
Atmo
Hg
x_0= 4340.46
R= 45000
v_{rad}
Atmo
Hb
x_0= 4861.32
R= 45000
v_{rad}
Atmo
FIT!
ind. FIT!

Galactic kinematics

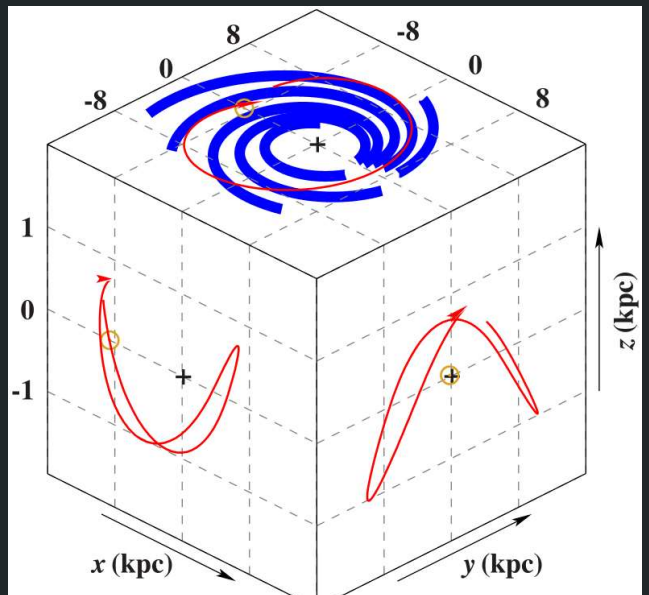


Thin disk orbit



Halo orbit

Runaway star



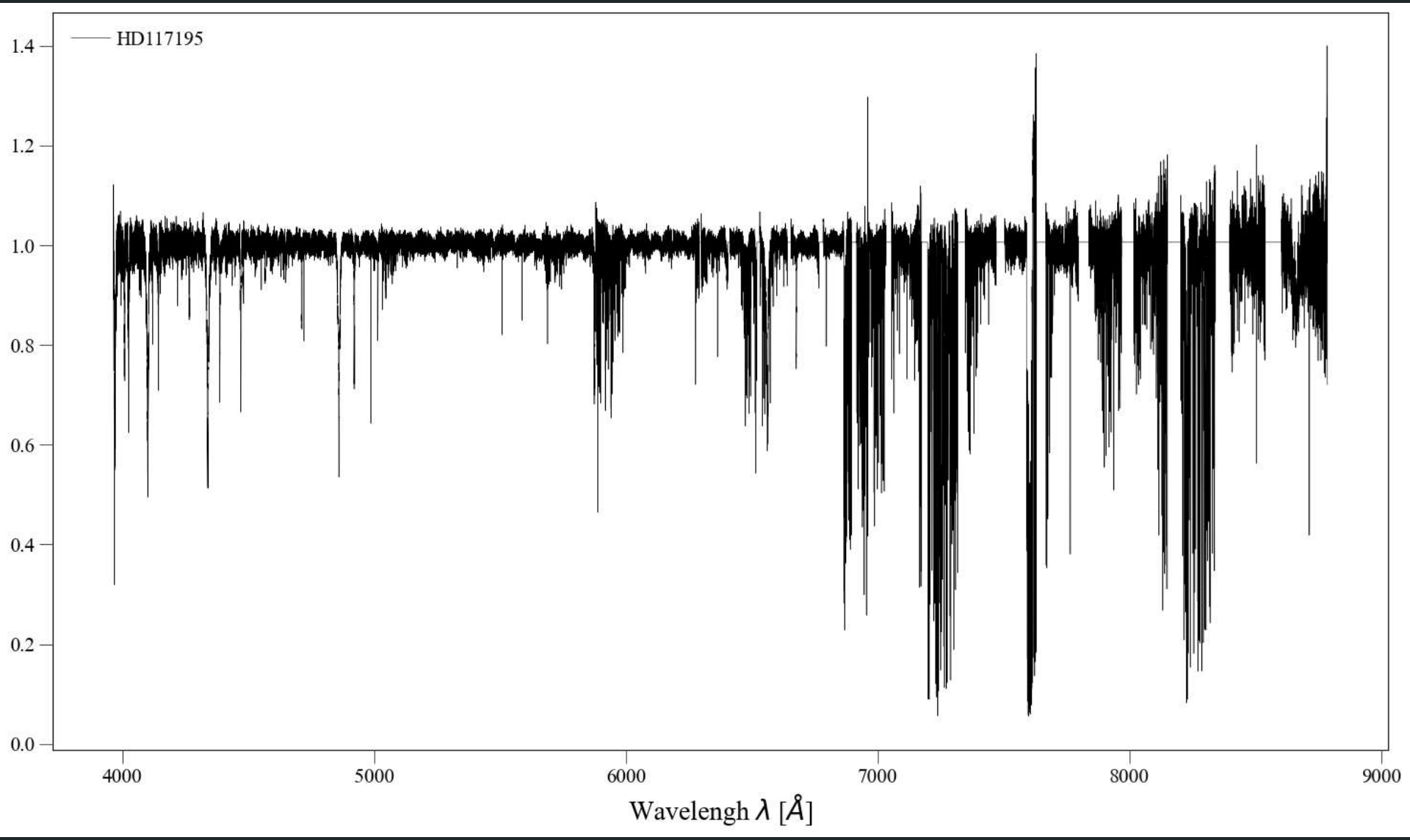
HD 177195

- B type
- ra = 19:00:27.5 (J2000)
- dec = +56:31:31.1 (J2000)
- mag = 8.74 (V)

- exp.time = 2700 s

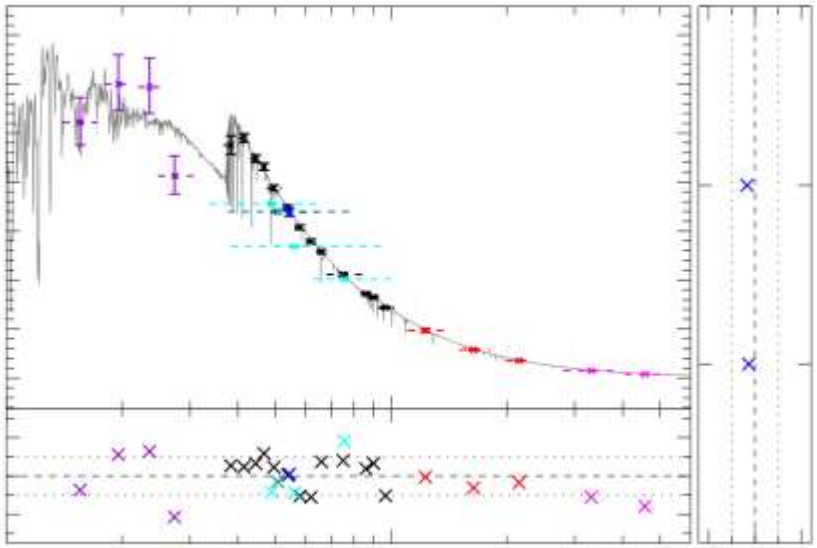
- vrad = -31.49 ± 5.37 km/s

- vrot = 64 ± 4 km/s

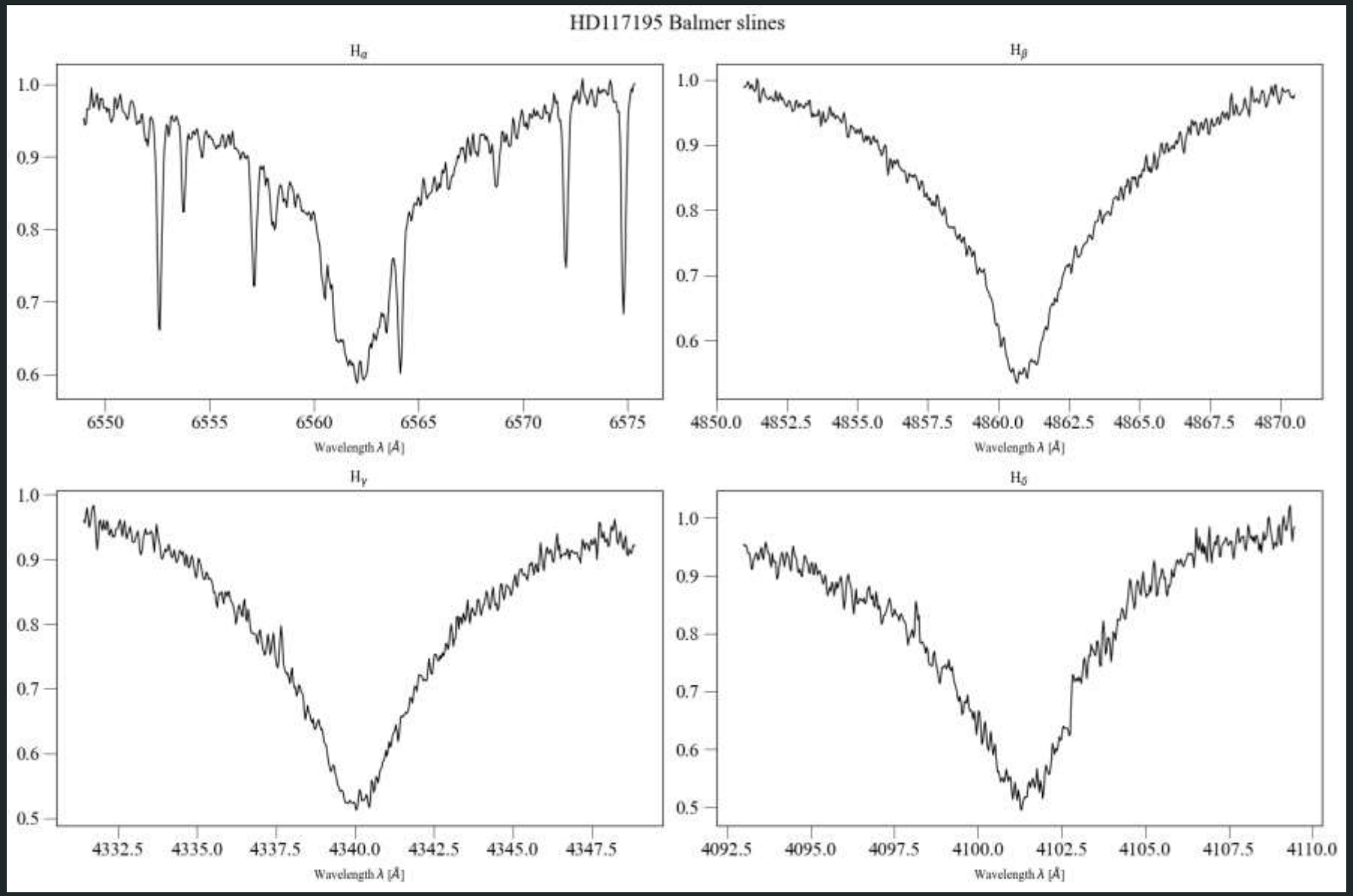

HD117195
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4000
5000
6000
7000
8000
9000
Wavelengh λ [Å]

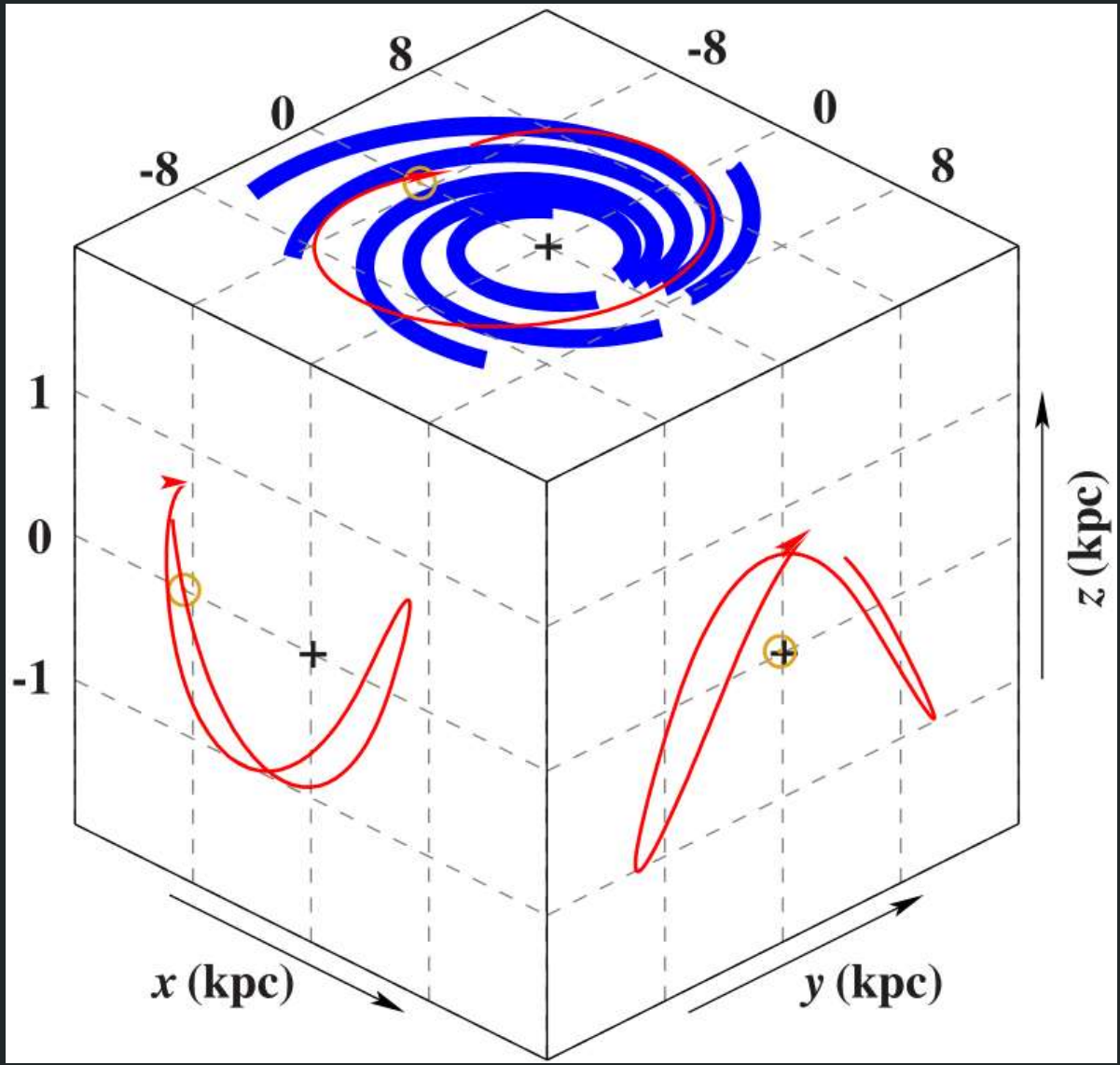
Object: HD 177195	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	0.0565 ± 0.0009 mag
Color excess $E(B-V)$ from S&F (2011)	0.0486 ± 0.0008 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.038 ± 0.012 mag
Color excess $E(44-55)$	$0.026^{+0.010}_{-0.011}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	-9.846 ± 0.010
Parallax ϖ (*Gaia*, RUWE = 1.01, ZPO = −0.013 mas)	0.49 ± 0.04 mas
Distance d (*Gaia*, mode)	$\left(2.03^{+0.16}_{-0.14}\right) \times 10^3$ pc
Distance d (*Gaia*, median)	$\left(2.05^{+0.16}_{-0.14}\right) \times 10^3$ pc
Effective temperature T_{eff}	21000^{+900}_{-1000} K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	3.7 ± 0.5
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1
Radius $R = \Theta/(2\varpi)$ (mode)	$6.4 \pm 0.5\,R_\odot$
(median)	$6.5^{+0.6}_{-0.5}\,R_\odot$
Mass $M = gR^2/G$ (mode)	$2.7^{+10.6}_{-2.2}\,M_\odot$
(median)	$8^{+15}_{-6}\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$\left(7.1^{+1.8}_{-1.5}\right) \times 10^3$
(median)	$\left(7.4^{+1.9}_{-1.5}\right) \times 10^3$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$0.27^{+1.03}_{-0.21}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.005 mag
Reduced χ^2 at the best fit	1.00

Spectral energy distribution



Radial velocity fitting




8
-8
0
0
-8
8
1
0
-1
z (kpc)
x (kpc)
y (kpc)

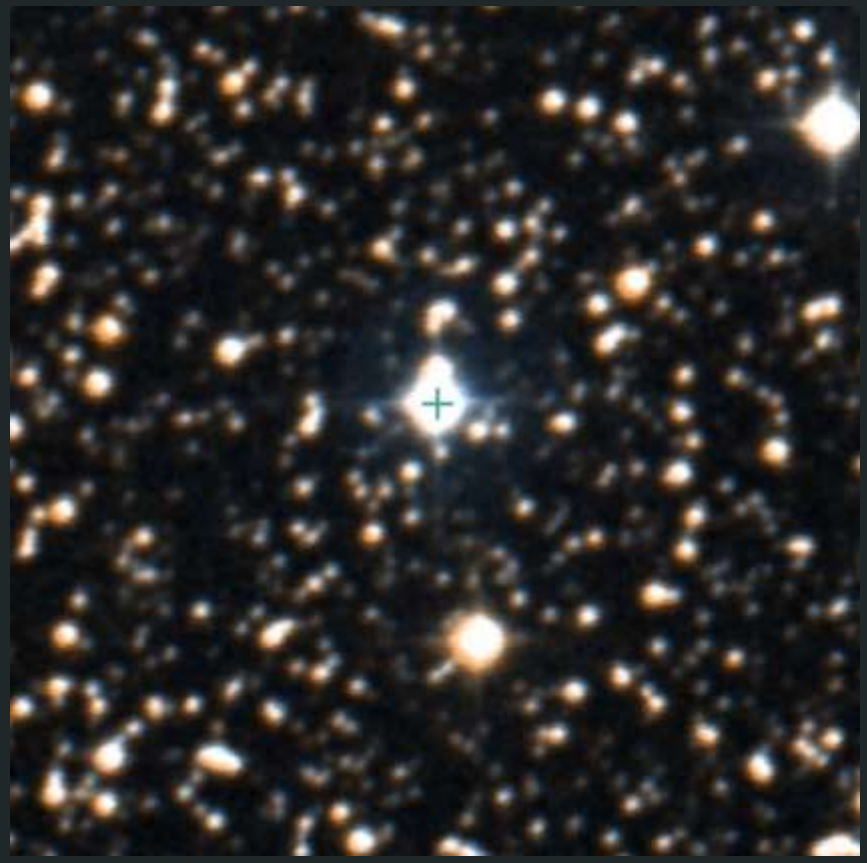
HD 225565

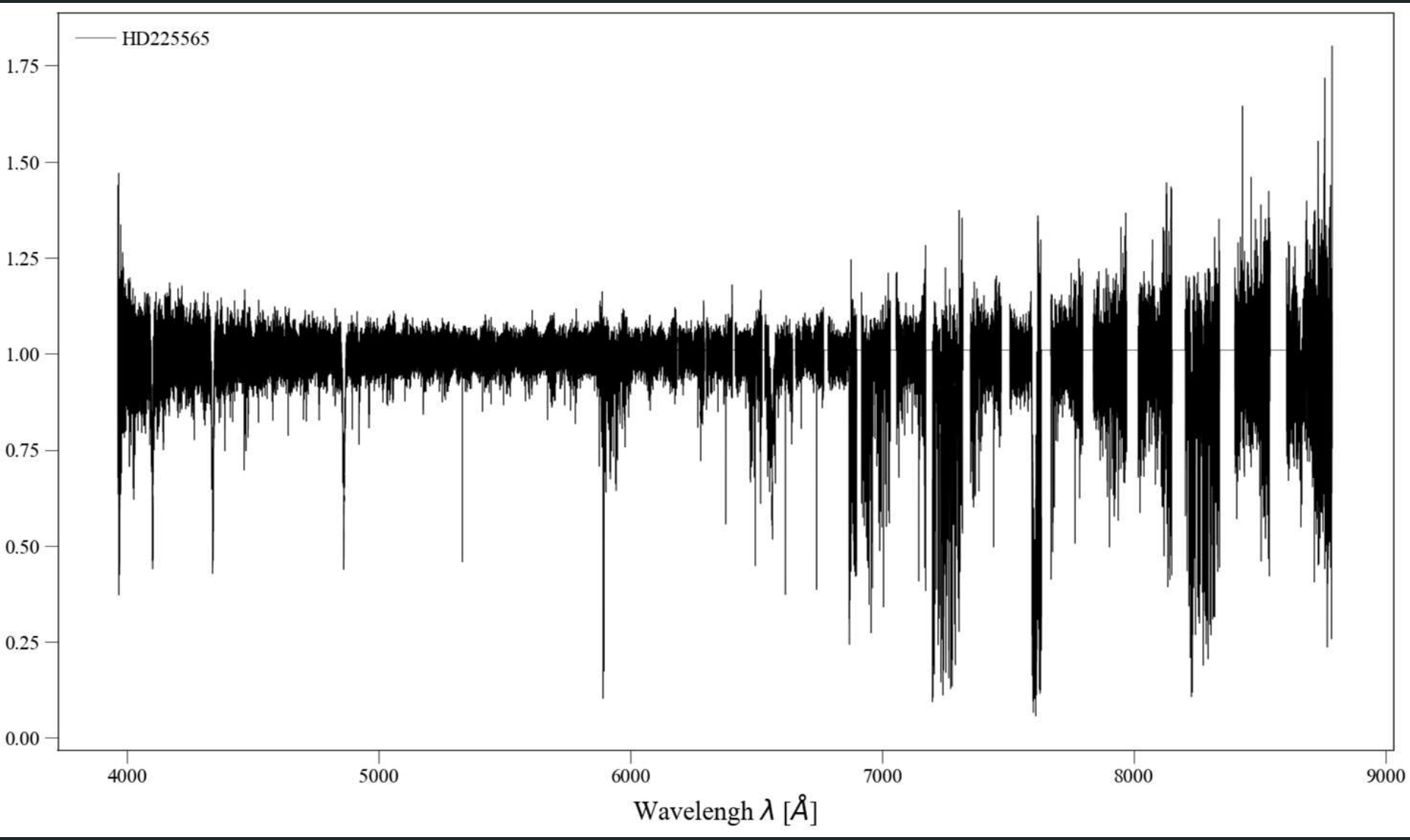
- B type
- ra = 19:44:08.6 (J2000)
- dec = +33:56:13.1 (J2000)
- mag = 9.79 (V)

- exp.time = 2700 s

- vrad = -21.62 ± 11.39 km/s

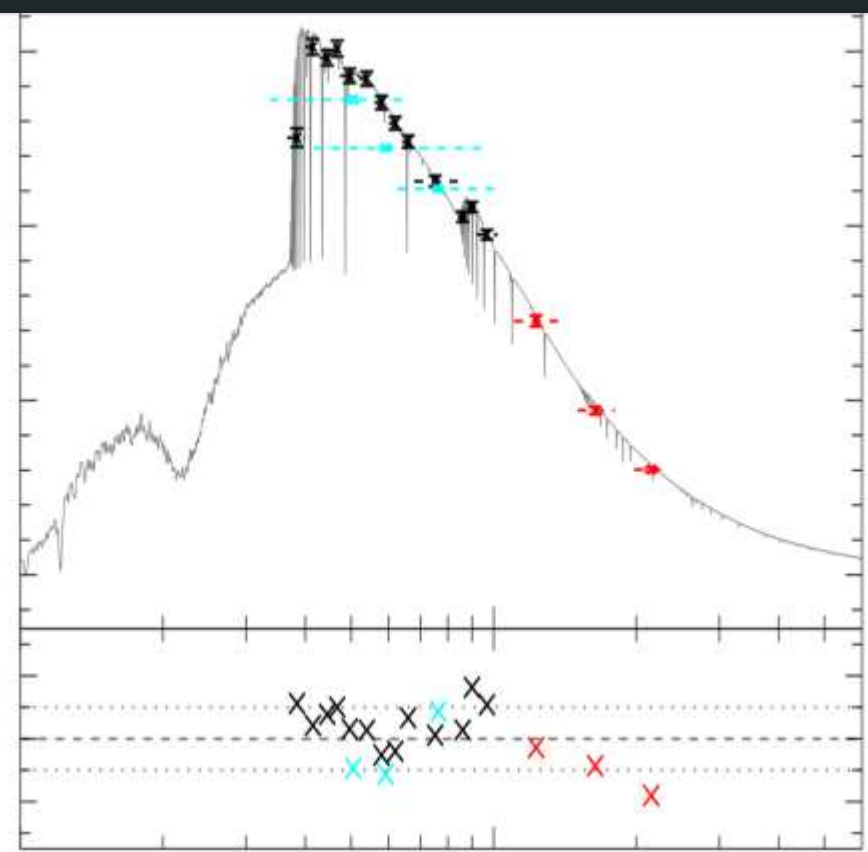
- vrot = 72 ± 19 km/s



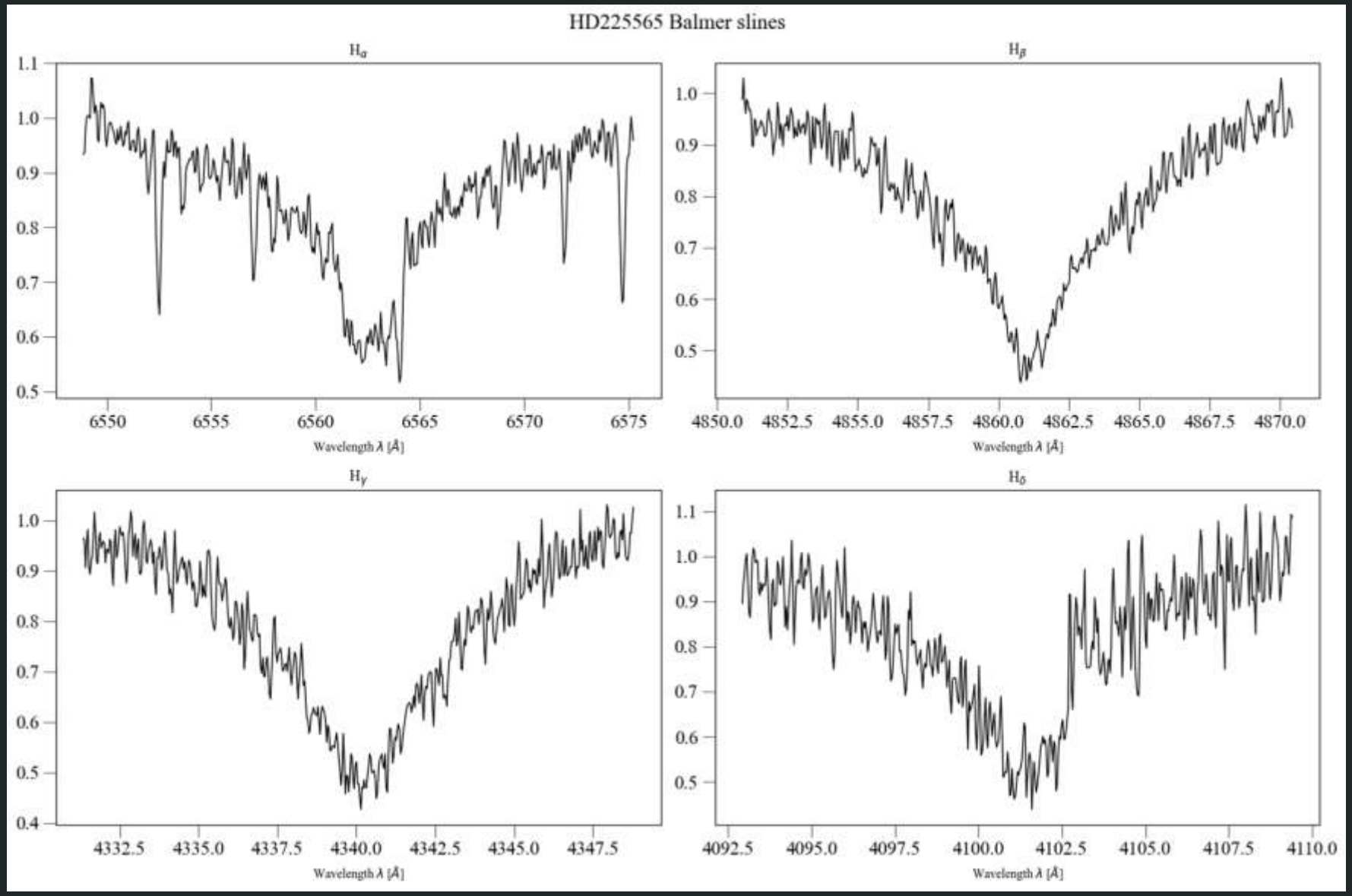

HD225565
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
4000
5000
6000
7000
8000
9000
Wavelengh λ [Å]

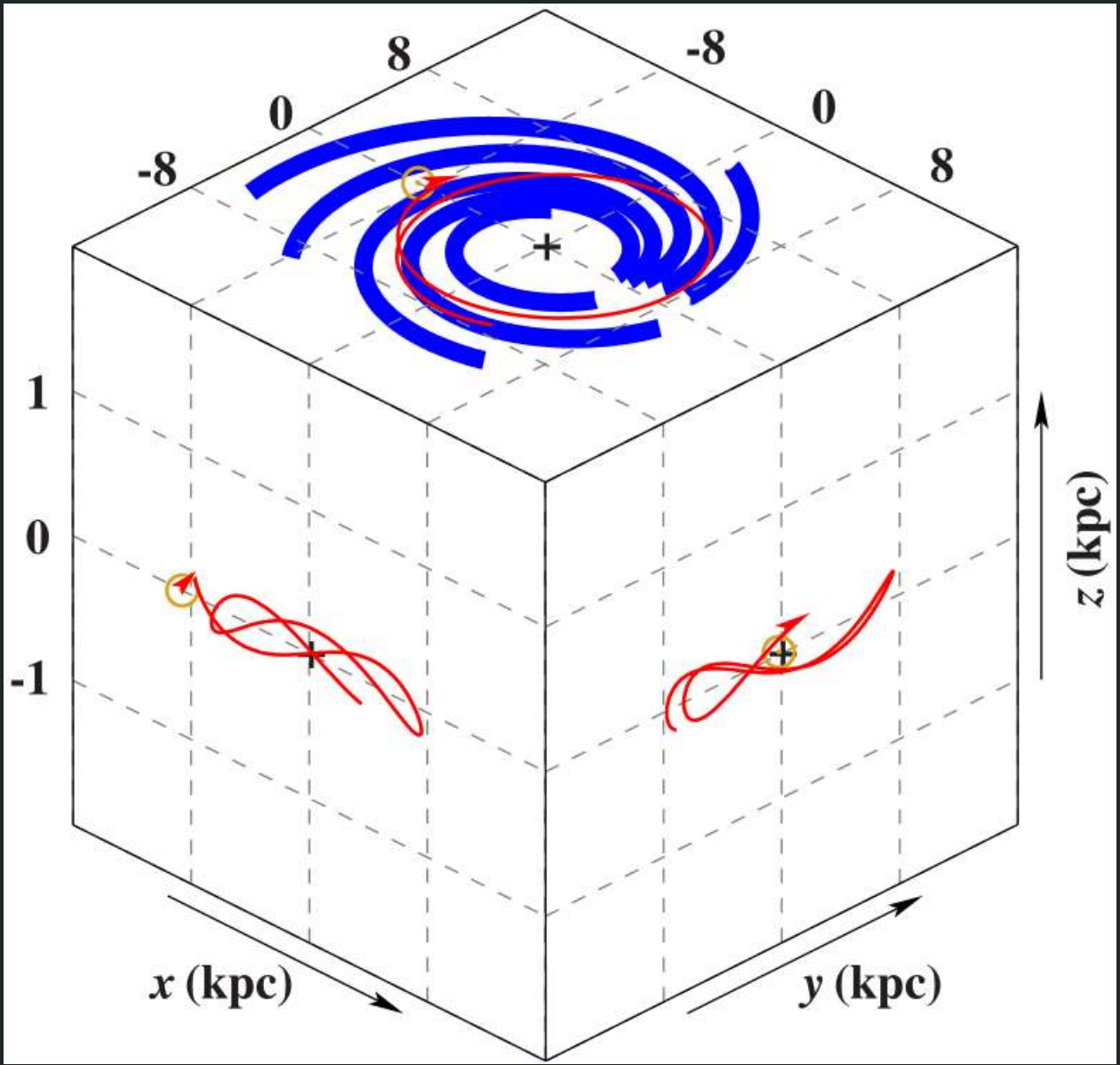
Object: HD 225565	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	0.362 ± 0.014 mag
Color excess $E(B-V)$ from S&F (2011)	0.311 ± 0.012 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.22 ± 0.03 mag
Color excess $E(44-55)$	$0.241^{+0.019}_{-0.016}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	$-9.794^{+0.014}_{-0.011}$
Parallax ϖ (*Gaia*, RUWE = 0.96, ZPO = −0.016 mas)	0.487 ± 0.020 mas
Distance d (*Gaia*, mode)	$\left(2.05^{+0.09}_{-0.08}\right) \times 10^3$ pc
Distance d (*Gaia*, median)	$\left(2.05^{+0.09}_{-0.08}\right) \times 10^3$ pc
Effective temperature T_{eff}	15300^{+1200}_{-1000} K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	$3.80^{+0.11}_{-0.00}$
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1.05
Radius $R = \Theta/(2\varpi)$ (mode)	$7.3 \pm 0.4\,R_\odot$
(median)	$7.3 \pm 0.4\,R_\odot$
Mass $M = gR^2/G$ (mode)	$12.5^{+2.3}_{-1.6}\,M_\odot$
(median)	$13.2^{+2.9}_{-1.6}\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$\left(2.5^{+1.0}_{-0.6}\right) \times 10^3$
(median)	$\left(2.7^{+1.0}_{-0.7}\right) \times 10^3$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$1.08^{+0.15}_{-0.09}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.004 mag
Reduced χ^2 at the best fit	1.00

Spectral energy distribution



Radial velocity fitting




8
-8
0
0
-8
8
1
0
-1
z (kpc)
x (kpc)
y (kpc)

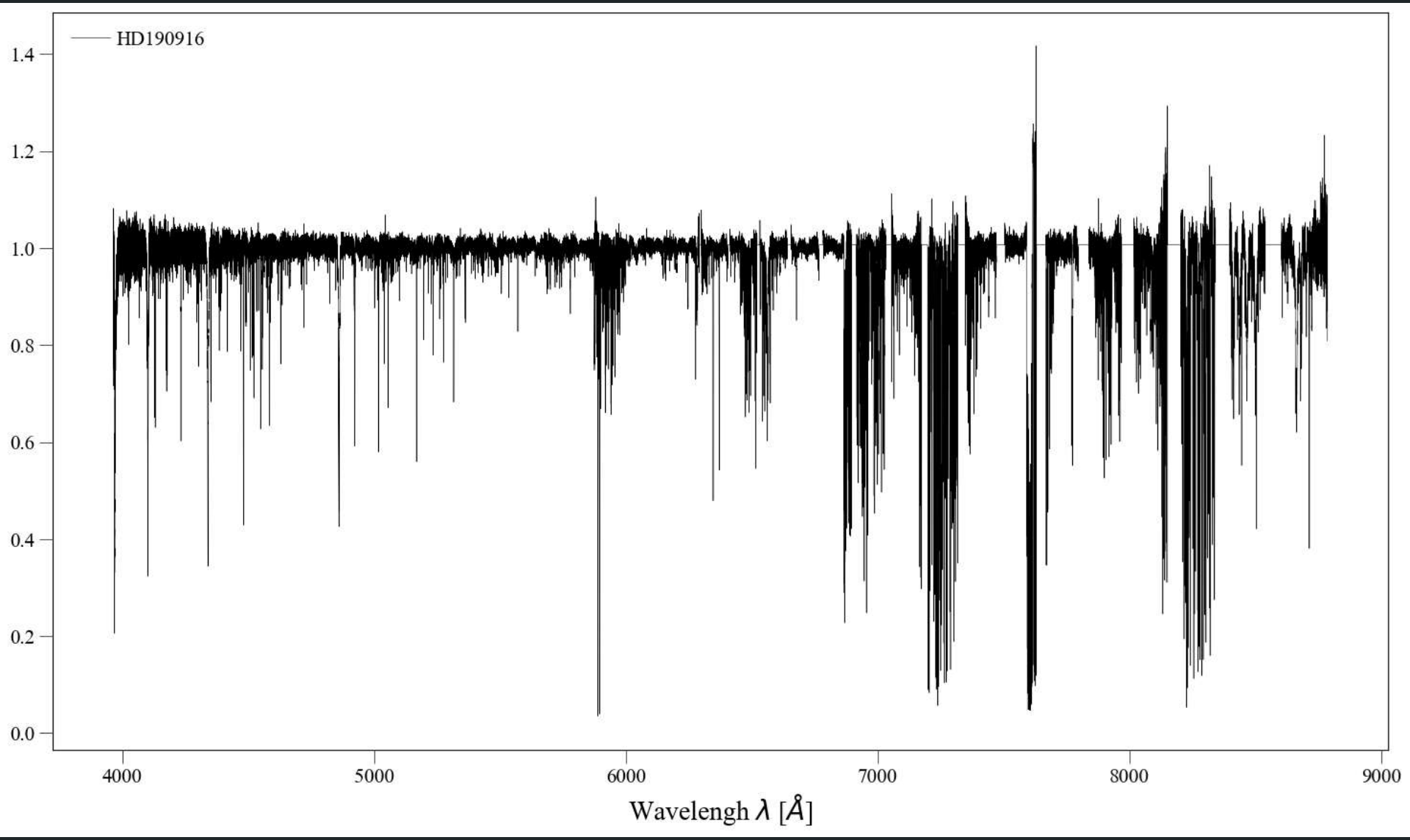
HD 190916

- A type
- ra = 20:05:38.6 (J2000)
- dec = +41:16:47.5 (J2000)
- mag = 7.61 (V)

- exp.time = 1800 s

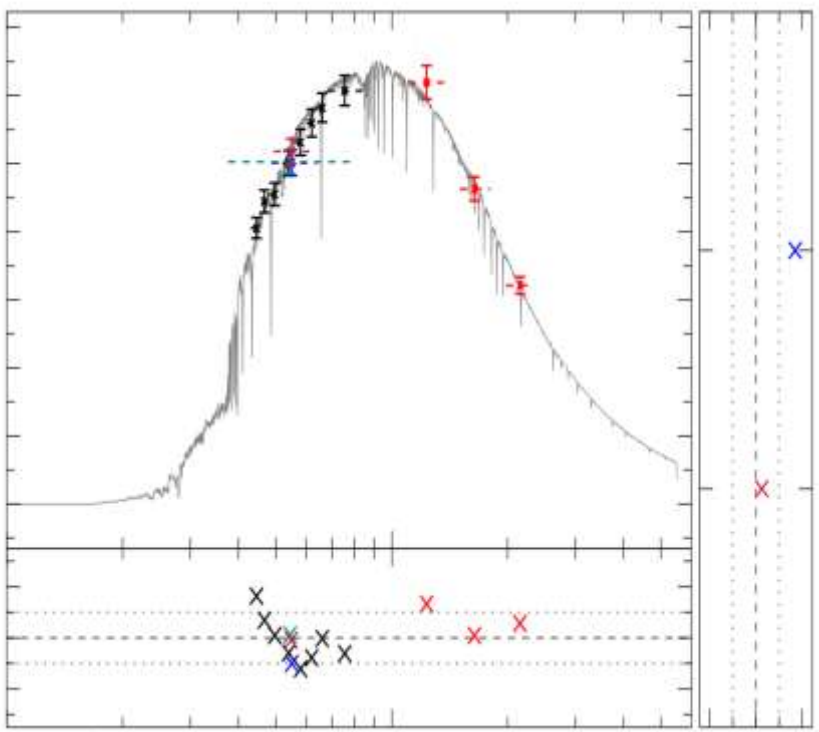
- vrad = 0.54 ± 1.09 km/s

- vrot = 0 km/s

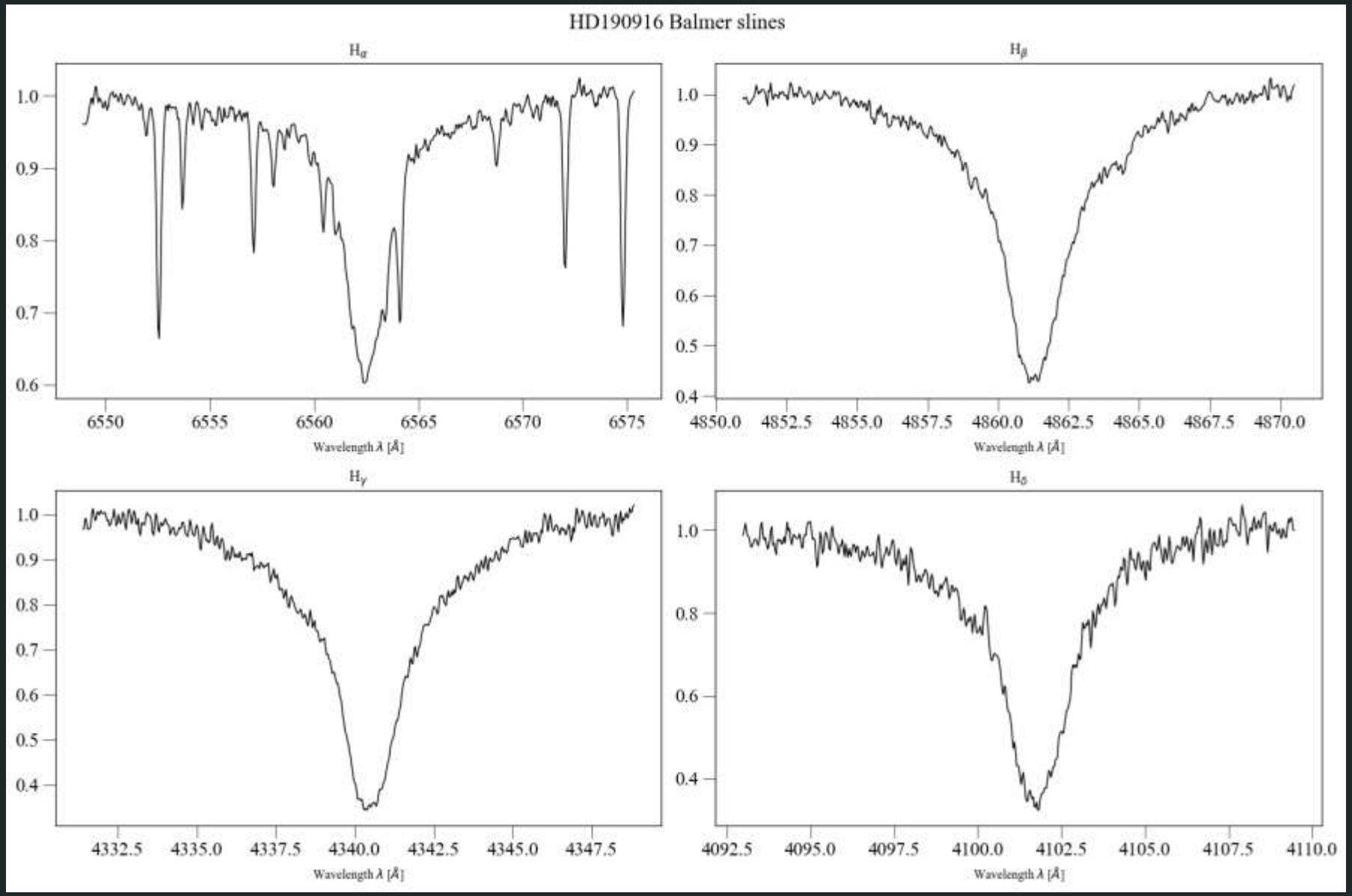

HD190916
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4000
5000
6000
7000
8000
9000
Wavelengh λ [Å]

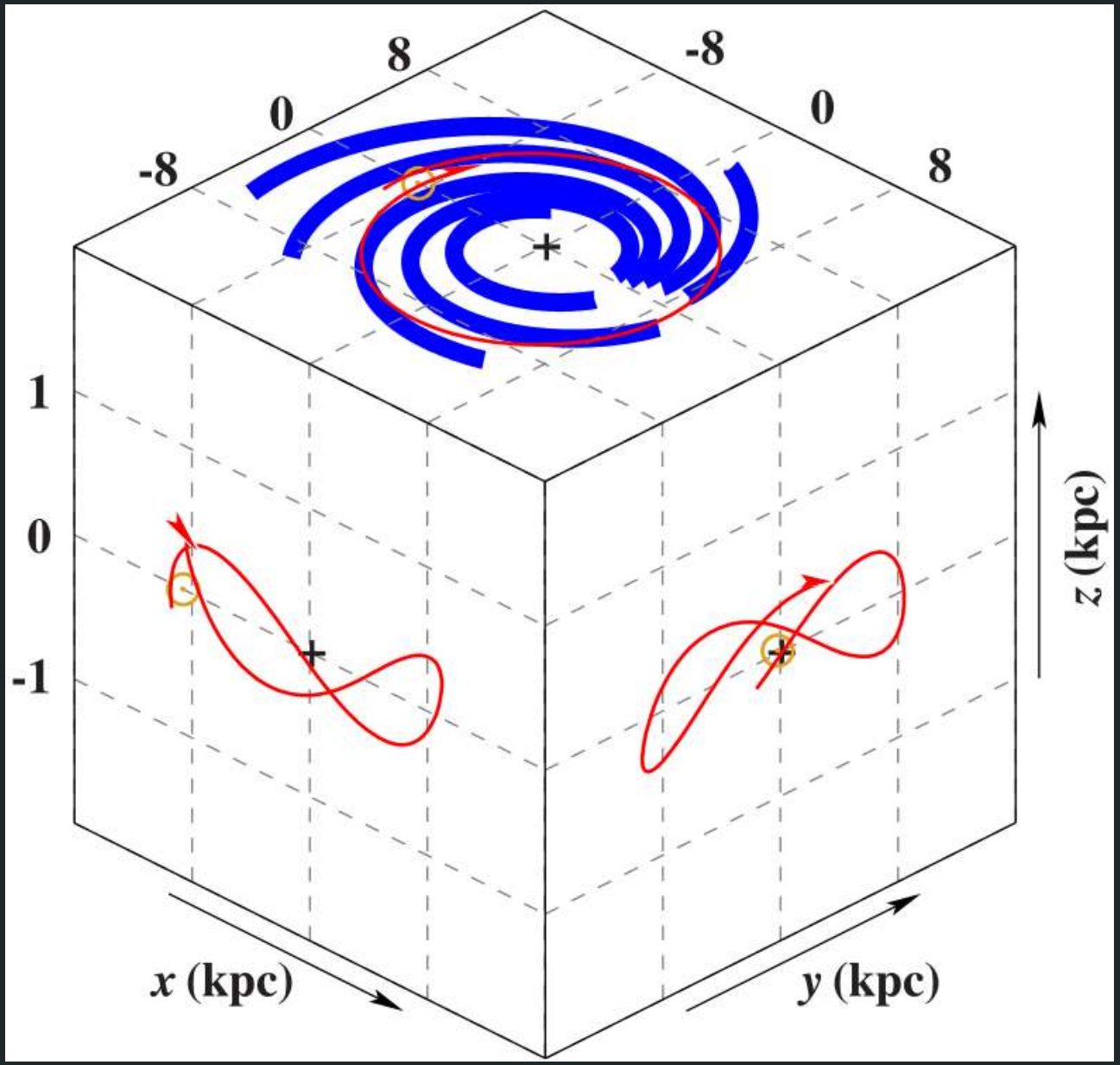
Object: HD 190916	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	1.03 ± 0.15 mag
Color excess $E(B-V)$ from S&F (2011)	0.89 ± 0.13 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.32 ± 0.06 mag
Color excess $E(44-55)$	$0.18^{+0.07}_{-0.08}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	$-8.975^{+0.015}_{-0.013}$
Parallax ϖ (*Gaia*, RUWE = 0.94, ZPO = −0.023 mas)	0.304 ± 0.017 mas
Distance d (*Gaia*, mode)	$\left(3.27^{+0.20}_{-0.17}\right) \times 10^3$ pc
Distance d (*Gaia*, median)	$\left(3.29^{+0.20}_{-0.18}\right) \times 10^3$ pc
Effective temperature T_{eff}	7100 ± 500 K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	$4.7^{+0.5}_{-0.6}$
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1.05
Radius $R = \Theta/(2\varpi)$ (mode)	$77^{+6}_{-5}\,R_\odot$
(median)	$78^{+6}_{-5}\,R_\odot$
Mass $M = gR^2/G$ (mode)	$\left(2.7^{+15.9}_{-\ 2.3}\right) \times 10^3\,M_\odot$
(median)	$\left(1.1^{+2.1}_{-0.8}\right) \times 10^4\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$\left(1.3^{+0.5}_{-0.4}\right) \times 10^4$
(median)	$\left(1.4^{+0.5}_{-0.4}\right) \times 10^4$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$22^{+130}_{-\ 19}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.036 mag
Reduced χ^2 at the best fit	1.00

Spectral energy distribution



Radial velocity fitting




8
-8
0
0
-8
8
1
0
-1
z (kpc)
x (kpc)
y (kpc)

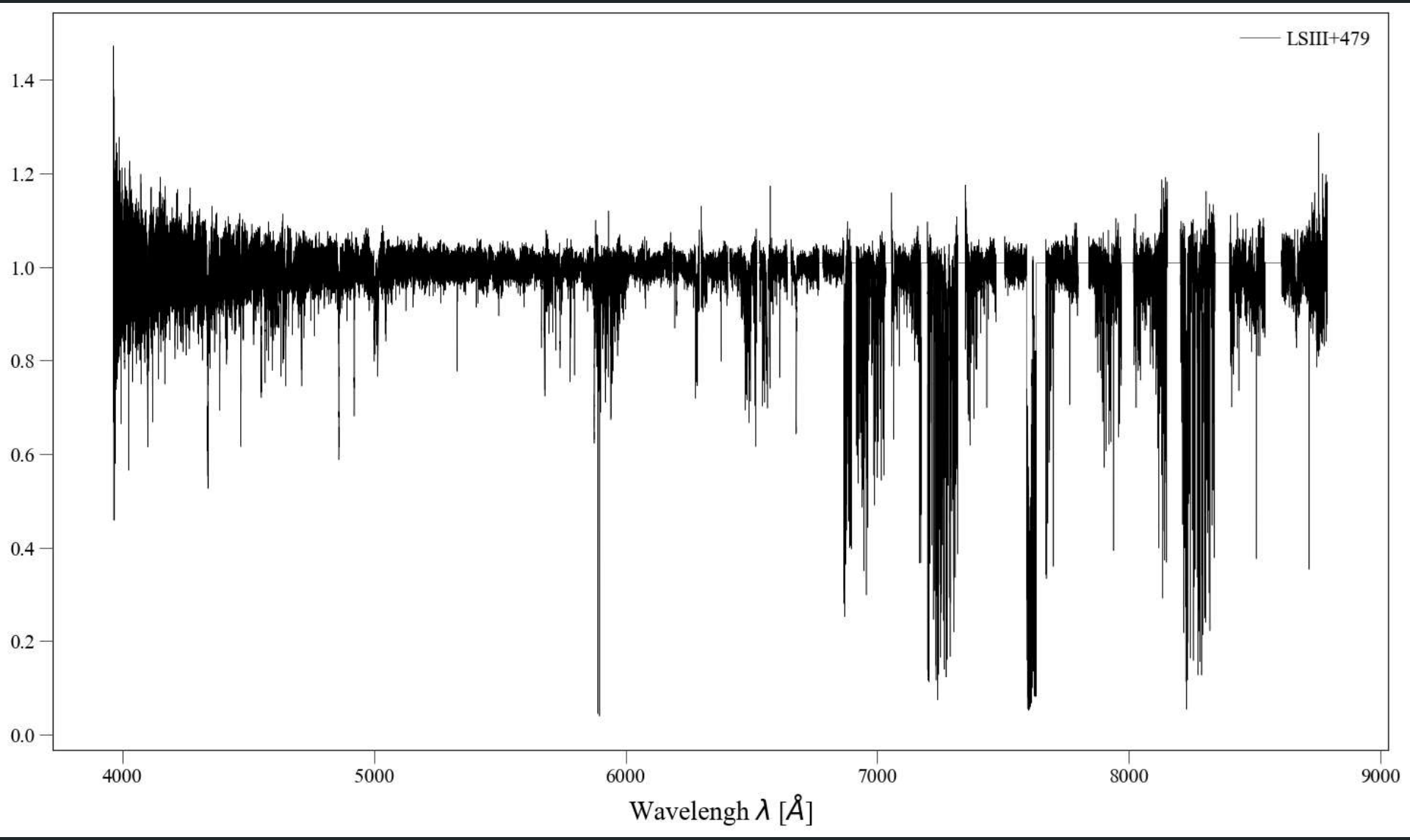
LS III +47 9

- B type
- ra = 20:37:52.2 (J2000)
- dec = +47:57:0.9 (J2000)
- mag = 9.46 (V)

- exp.time = 2700 s

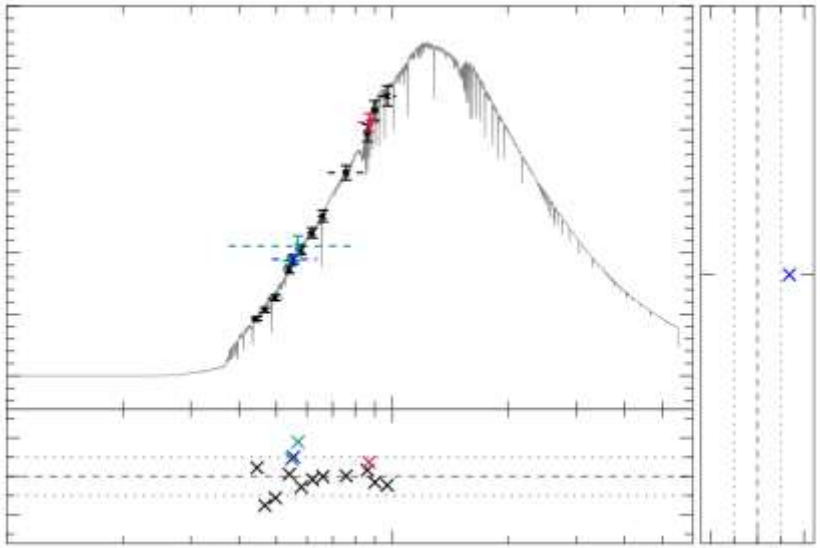
- vrad = -23.49 ± 3.28 km/s

- vrot = 191 ± 29 km/s

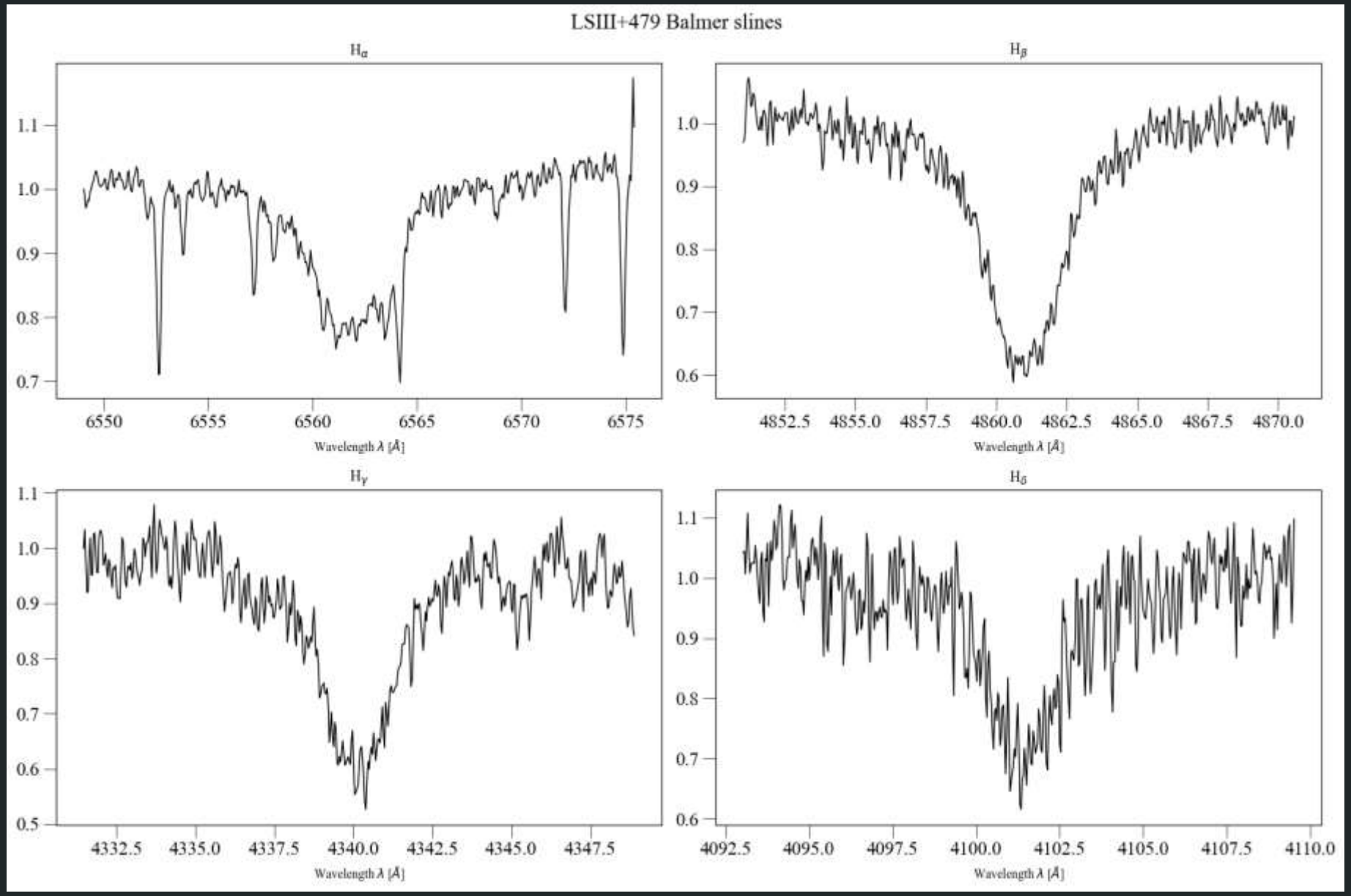

LSIII+479
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4000
5000
6000
7000
8000
9000
Wavelengh λ [Å]

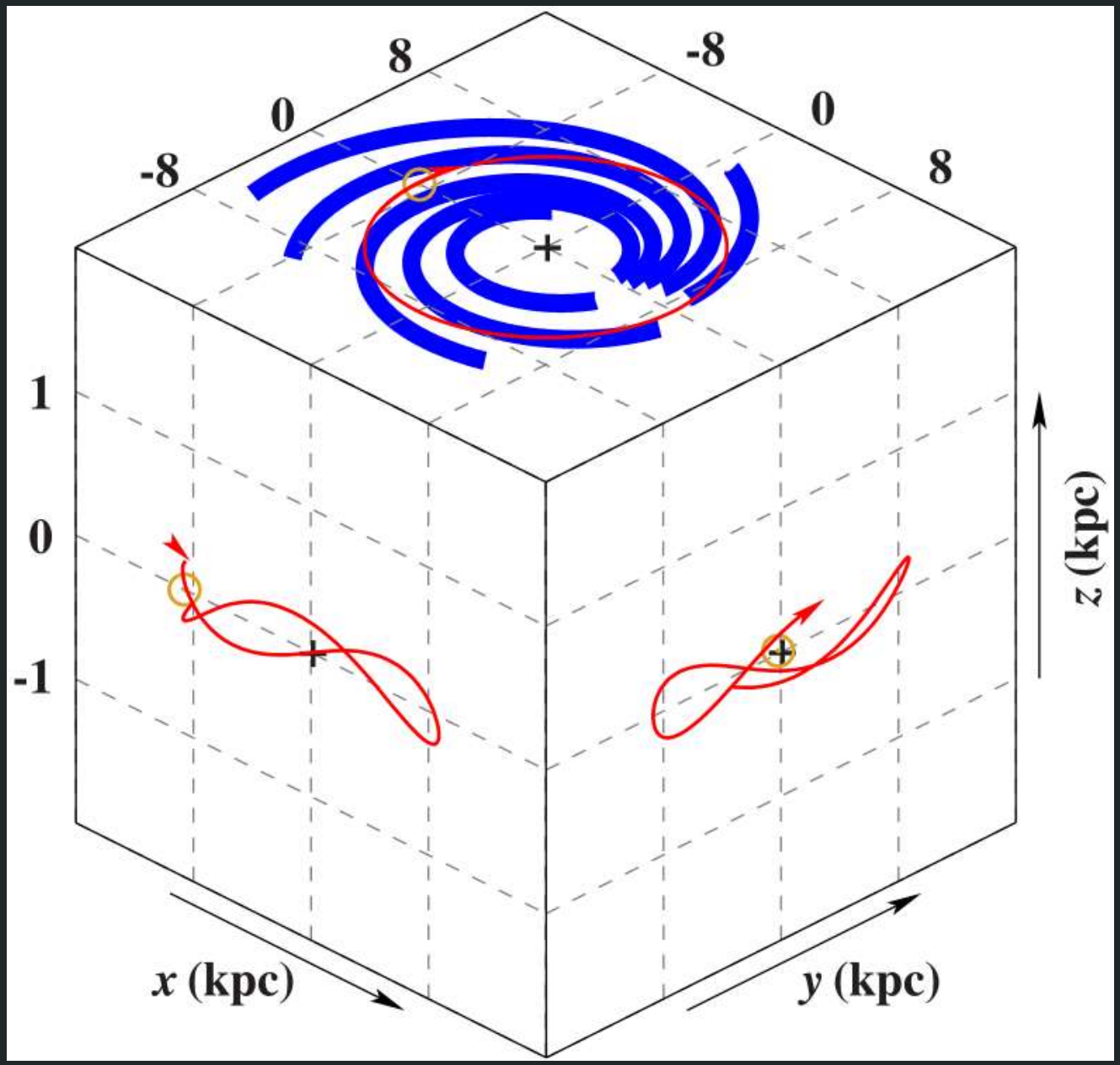
Object: LS III +47 9	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	2.48 ± 0.07 mag
Color excess $E(B-V)$ from S&F (2011)	2.13 ± 0.06 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.50 ± 0.22 mag
Color excess $E(44-55)$	$0.60^{+-0.00}_{-\ 0.05}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	$-9.039^{+0.008}_{-0.019}$
Parallax ϖ (*Gaia*, RUWE = 0.95, ZPO = −0.021 mas)	0.351 ± 0.012 mas
Distance d (*Gaia*, mode)	$(2.85 \pm 0.10) \times 10^3$ pc
Distance d (*Gaia*, median)	$(2.85 \pm 0.10) \times 10^3$ pc
Effective temperature T_{eff}	6590^{+140}_{-200} K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	$2.0^{+1.7}_{-0.0}$
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1.05
Radius $R = \Theta/(2\varpi)$ (mode)	$57.6^{+2.5}_{-2.7}\,R_\odot$
(median)	$57.4^{+2.6}_{-2.8}\,R_\odot$
Mass $M = gR^2/G$ (mode)	$12^{+114}_{-\ 5}\,M_\odot$
(median)	$14.1^{+565.1}_{-\ 2.6}\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$(5.5 \pm 0.8) \times 10^3$
(median)	$(5.5 \pm 0.8) \times 10^3$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$0.14^{+3.17}_{-0.05}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.035 mag
Reduced χ^2 at the best fit	1.00

Spectral energy distribution



Radial velocity fitting




8
-8
0
0
-8
8
1
0
-1
z (kpc)
x (kpc)
y (kpc)

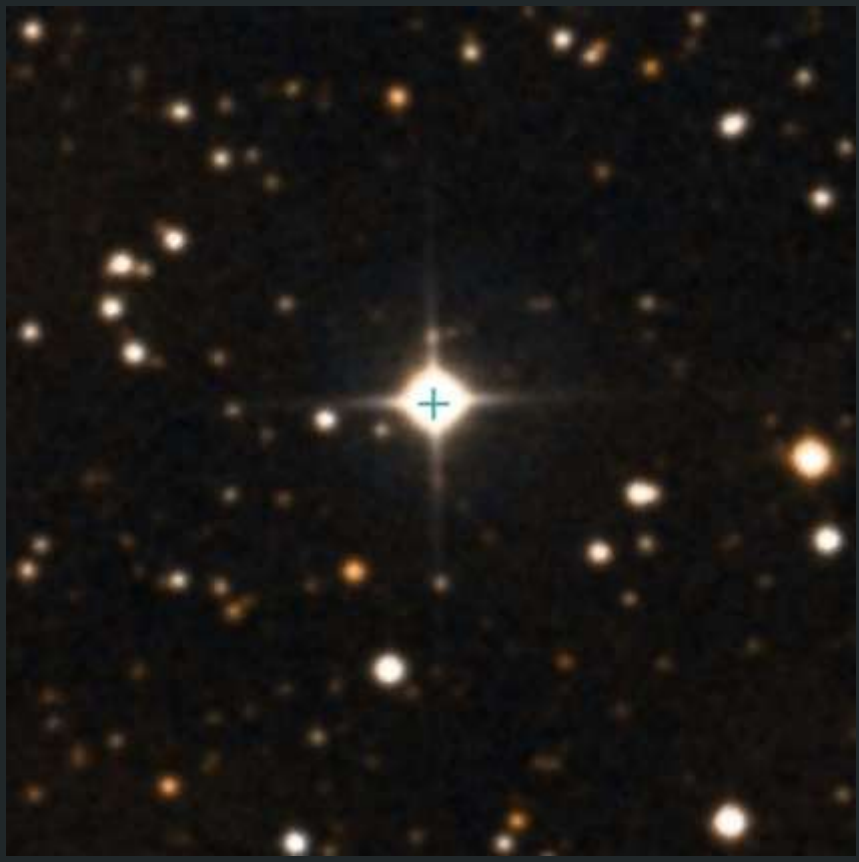
BD+47 3162

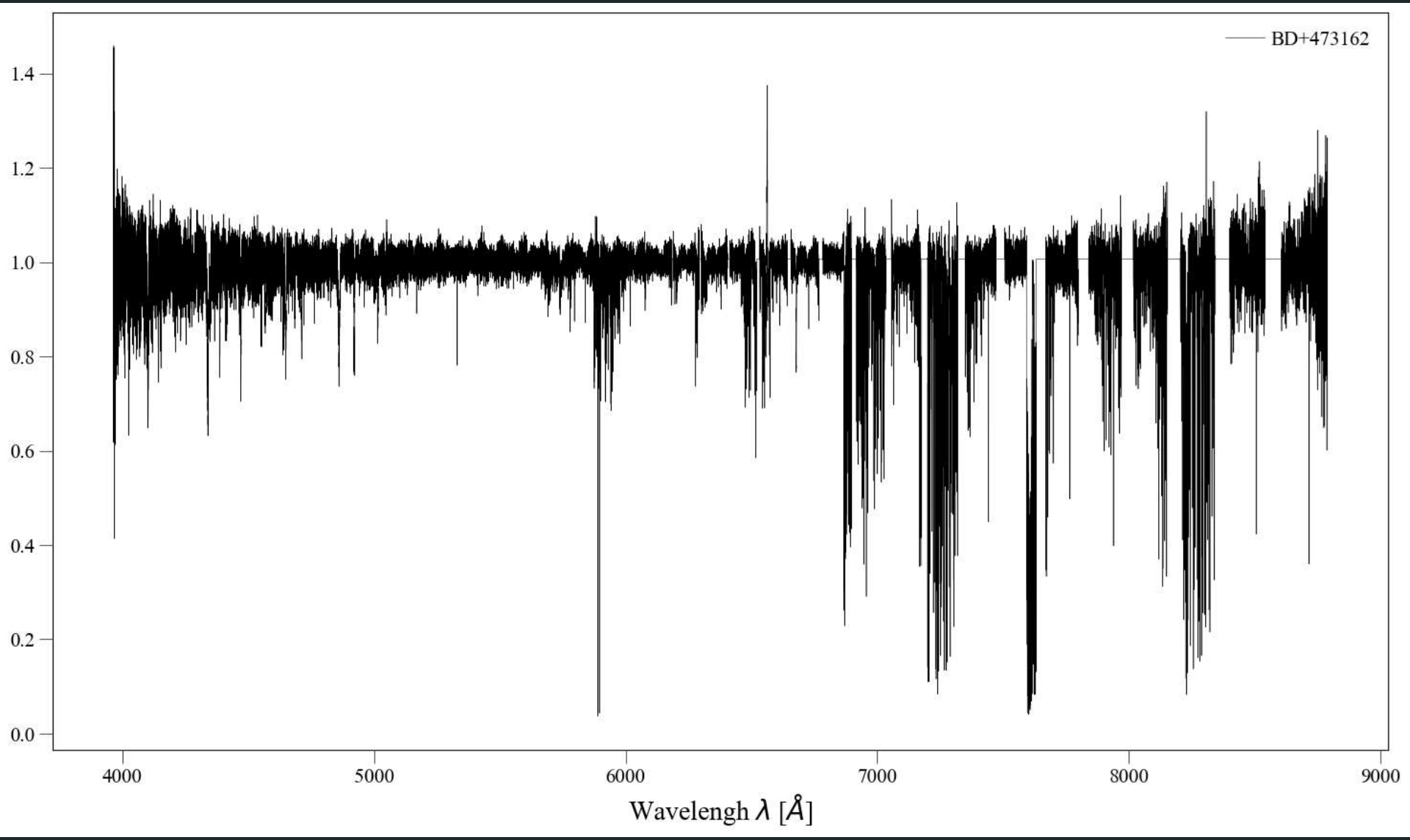
- B type
- ra = 20:40:01.1 (J2000)
- dec = +48:06:19.3 (J2000)
- mag = 9.85 (V)

- exp.time = 2700 s

- vrad = -8.06 ± 1.75 km/s

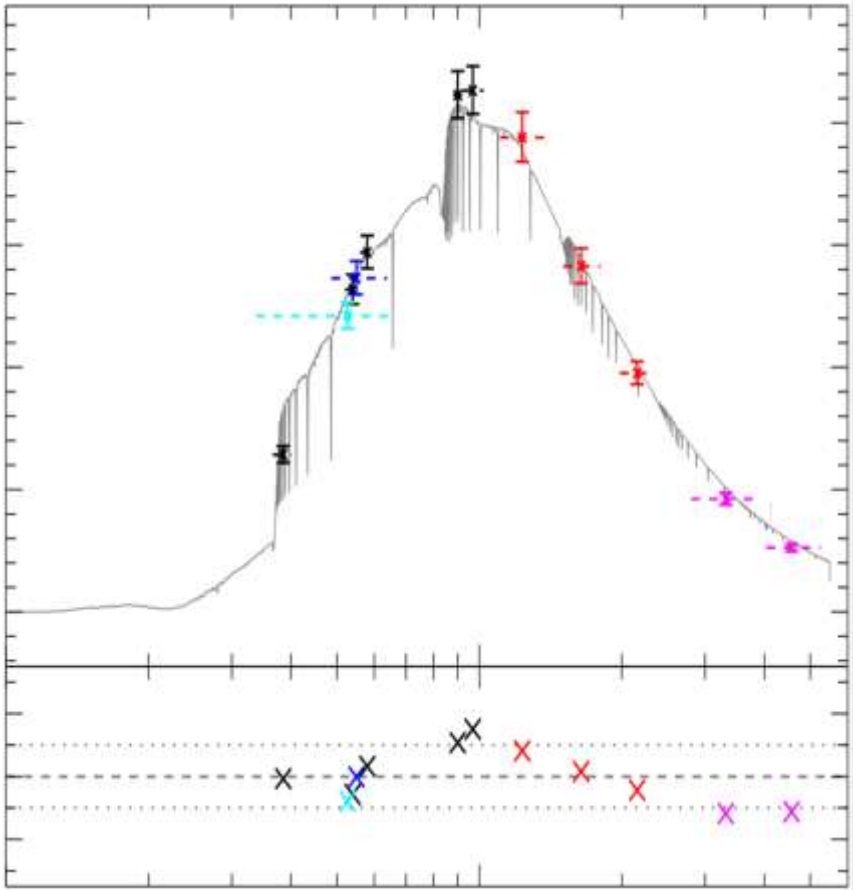
- vrot = 190 ± 15 km/s



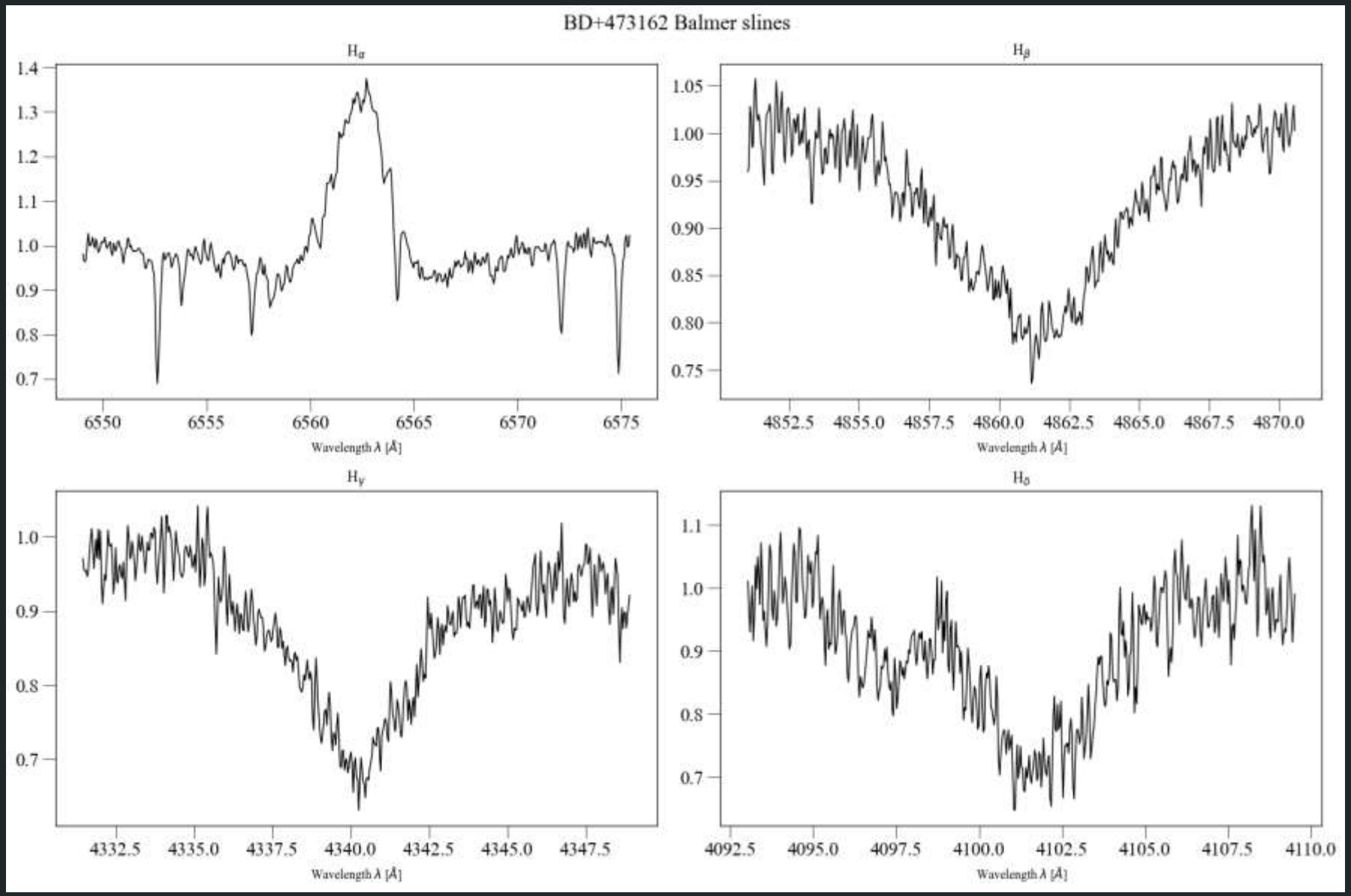

BD+473162
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4000
5000
6000
7000
8000
9000
Wavelengh λ [Å]

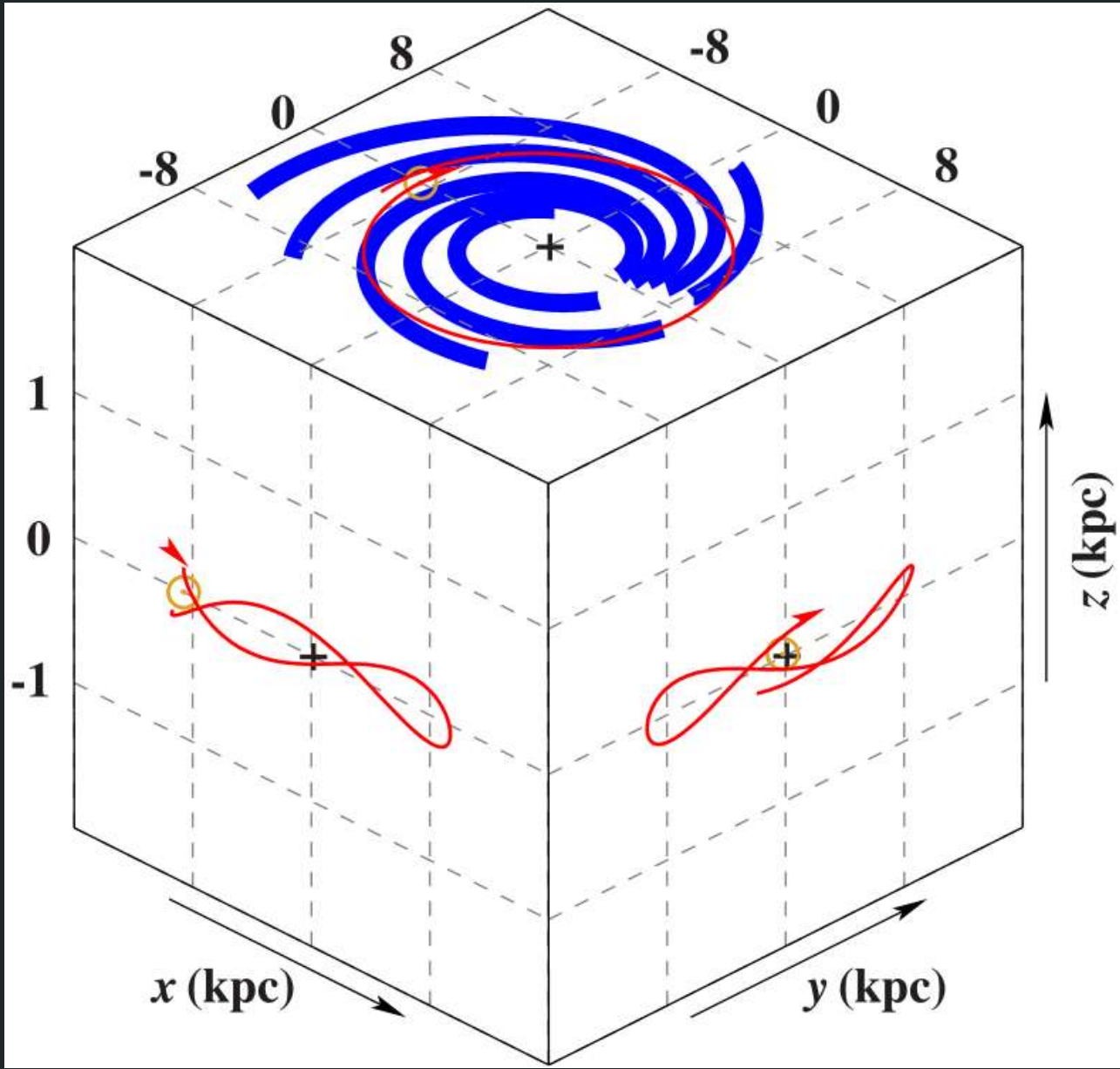
Object: BD+47 3162	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	2.34 ± 0.04 mag
Color excess $E(B-V)$ from S&F (2011)	2.01 ± 0.04 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.50 ± 0.07 mag
Color excess $E(44-55)$	$0.597^{+0.004}_{-0.082}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	$-9.429^{+0.045}_{-0.018}$
Parallax ϖ (*Gaia*, RUWE = 1.08, ZPO = −0.019 mas)	0.384 ± 0.016 mas
Distance d (*Gaia*, mode)	$(2.60 \pm 0.11) \times 10^3$ pc
Distance d (*Gaia*, median)	$\left(2.60^{+0.12}_{-0.11}\right) \times 10^3$ pc
Effective temperature T_{eff}	10800^{+500}_{-1800} K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	$2.7^{+0.6}_{-0.7}$
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1.05
Radius $R = \Theta/(2\varpi)$ (mode)	$21.2^{+2.1}_{-1.4}\,R_\odot$
(median)	$21.8^{+2.3}_{-1.5}\,R_\odot$
Mass $M = gR^2/G$ (mode)	$0.8^{+15.0}_{-0.8}\,M_\odot$
(median)	$8^{+25}_{-7}\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$\left(5.9^{+1.7}_{-2.9}\right) \times 10^3$
(median)	$\left(5.5^{+1.9}_{-2.7}\right) \times 10^3$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$0.022^{+0.432}_{-0.021}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.047 mag
Reduced χ^2 at the best fit	1.00

Spectral energy distribution



Radial velocity fitting




8
-8
0
0
-8
8
1
0
-1
z (kpc)
x (kpc)
y (kpc)

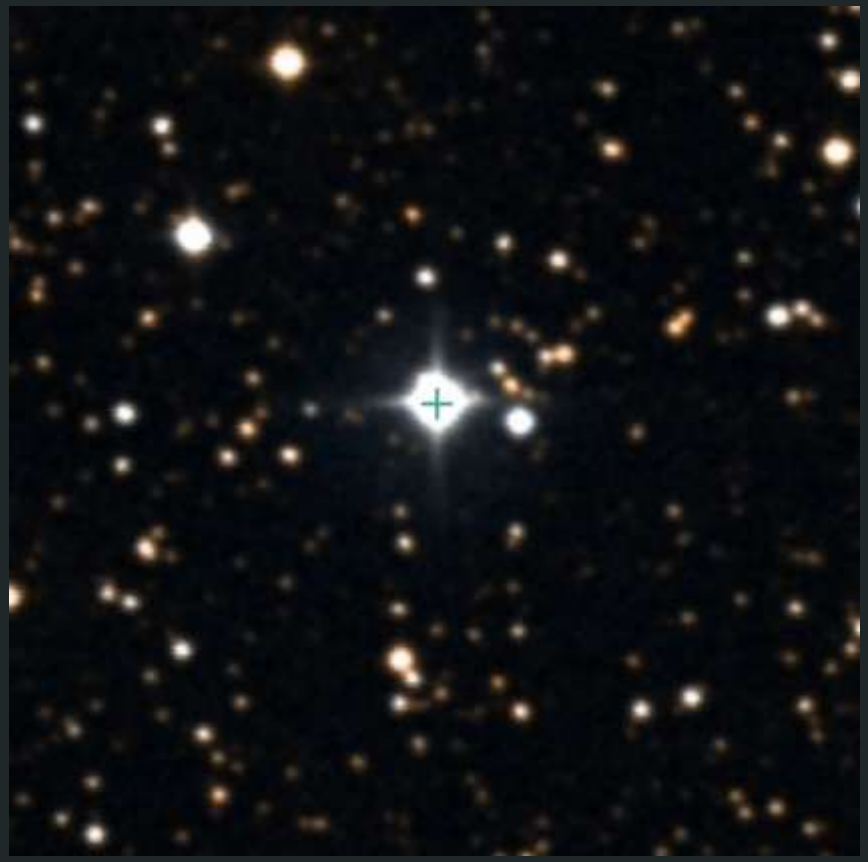
BD+51 2945

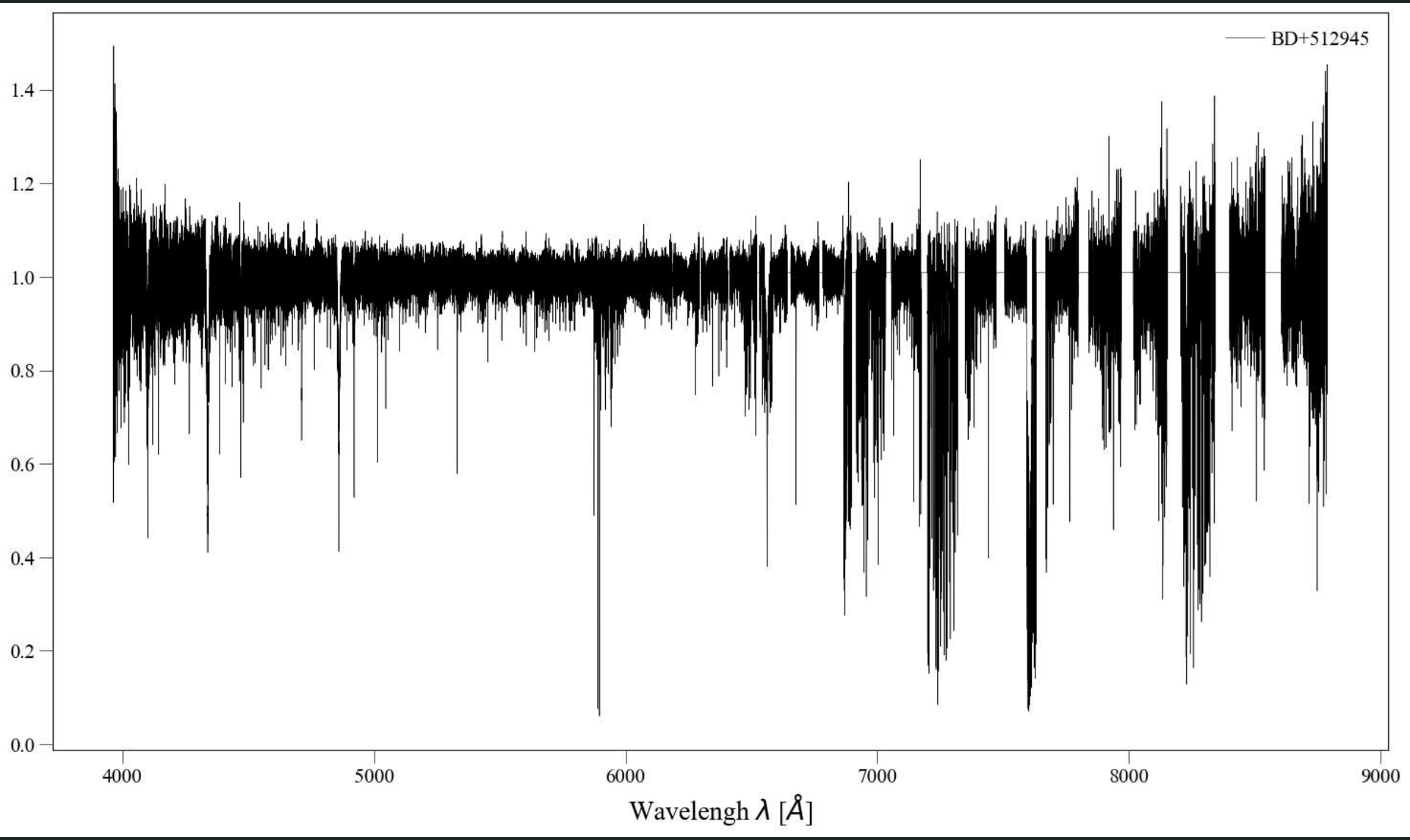
- B type
- ra = 20:45:34.3 (J2000)
- dec = +51:33:00.1 (J2000)
- mag = 9.81 (V)

- exp.time = 3000 s

- vrad = -34.99 ± 1.31 km/s

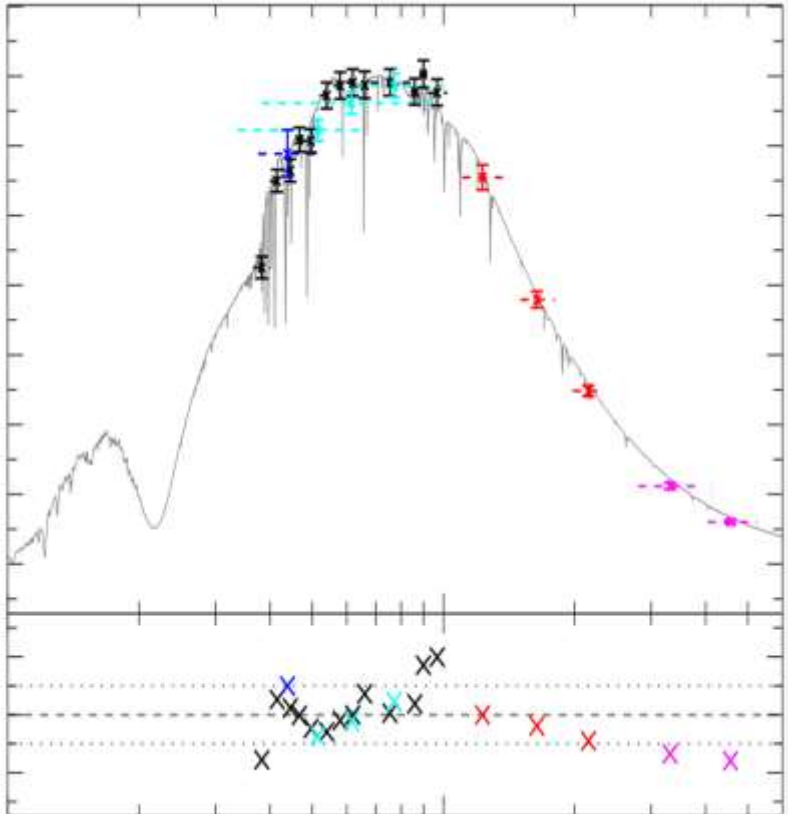
- vrot = 6 ± 8 km/s



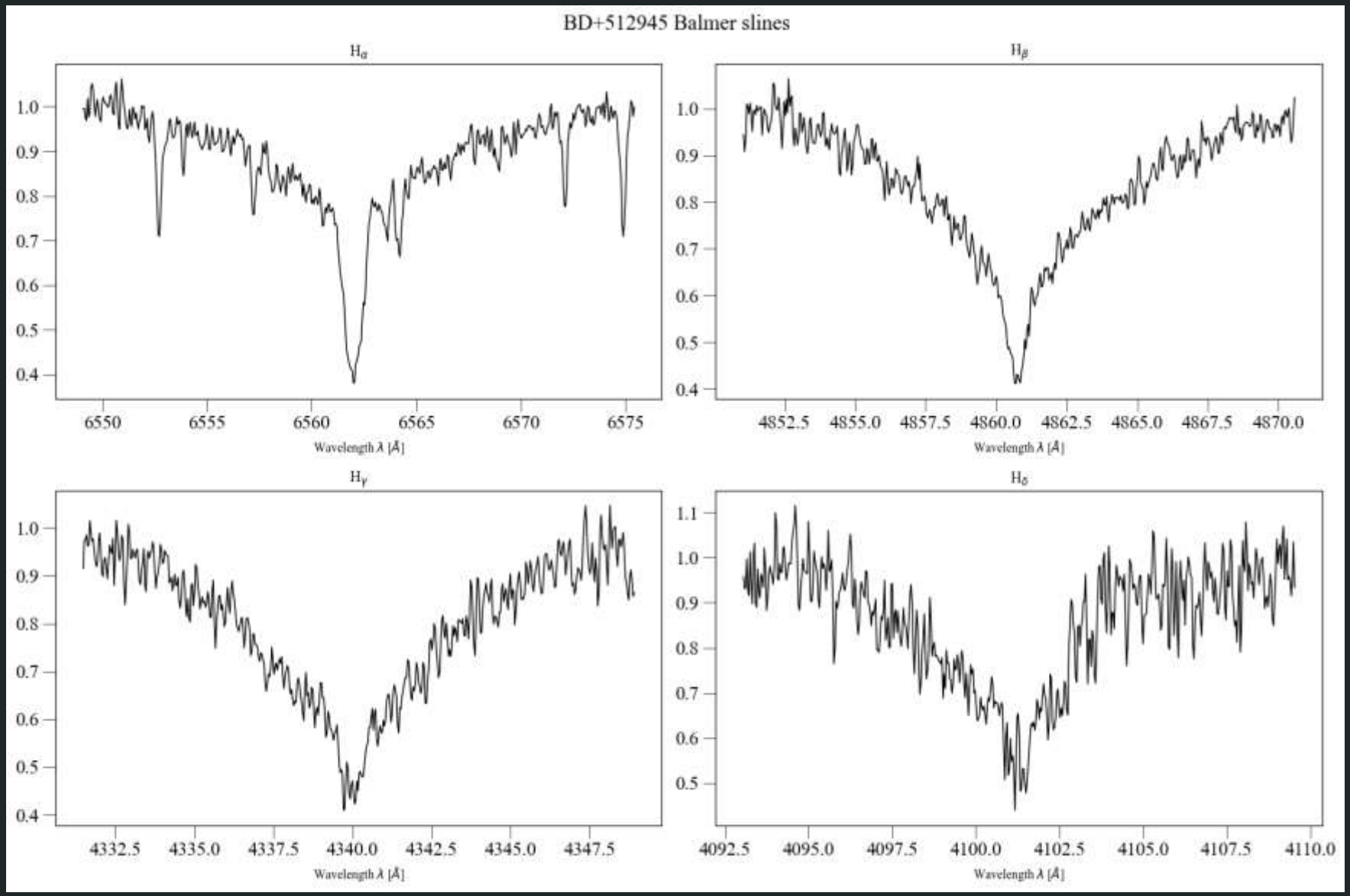

BD+512945
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4000
5000
6000
7000
8000
9000
Wavelengh λ [Å]

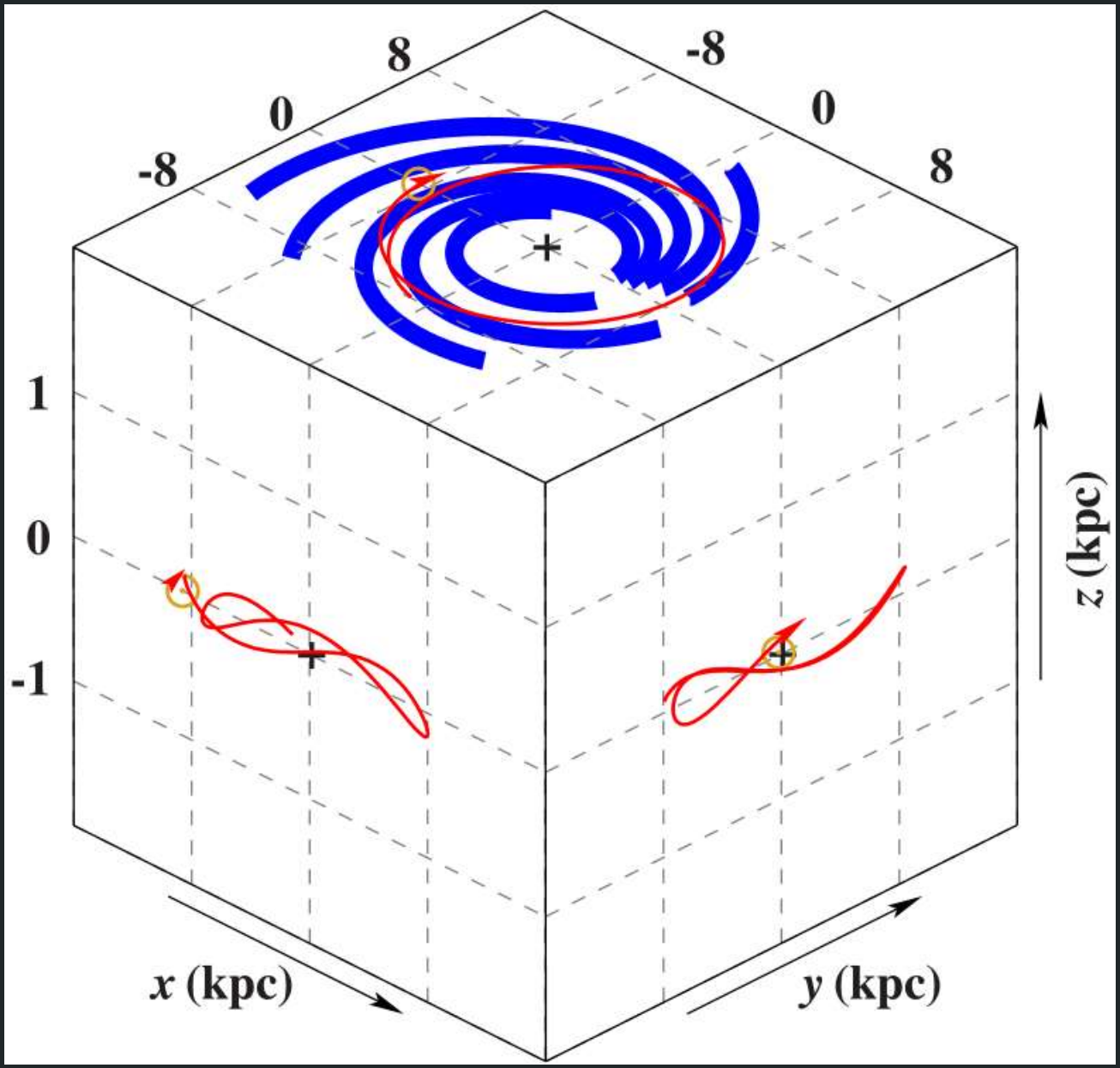
Object: BD+51 2945	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	1.41 ± 0.07 mag
Color excess $E(B-V)$ from S&F (2011)	1.21 ± 0.06 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.48 ± 0.16 mag
Color excess $E(44-55)$	$0.579^{+0.000}_{-0.024}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	$-9.791^{+0.026}_{-0.010}$
Parallax ϖ (*Gaia*, RUWE = 1.16, ZPO = −0.015 mas)	0.573 ± 0.020 mas
Distance d (*Gaia*, mode)	$\left(1.74^{+0.07}_{-0.06}\right) \times 10^3$ pc
Distance d (*Gaia*, median)	$\left(1.74^{+0.07}_{-0.06}\right) \times 10^3$ pc
Effective temperature T_{eff}	27100^{+800}_{-2700} K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	$6.34^{+0.26}_{-0.93}$
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1
Radius $R = \Theta/(2\varpi)$ (mode)	$6.24^{+0.38}_{-0.29}\,R_\odot$
(median)	$6.32^{+0.39}_{-0.30}\,R_\odot$
Mass $M = gR^2/G$ (mode)	$(-nan \pm -nan) \times 10^{2147483647}\,M_\odot$
(median)	$\left(3.1^{+2.9}_{-2.8}\right) \times 10^3\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$\left(2.0^{+0.4}_{-0.6}\right) \times 10^4$
(median)	$\left(1.9^{+0.4}_{-0.6}\right) \times 10^4$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$(-nan \pm -nan) \times 10^{2147483647}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.026 mag
Reduced χ^2 at the best fit	1.00

Spectral energy distribution



Radial velocity fitting




8
-8
0
0
-8
8
1
0
-1
z (kpc)
x (kpc)
y (kpc)

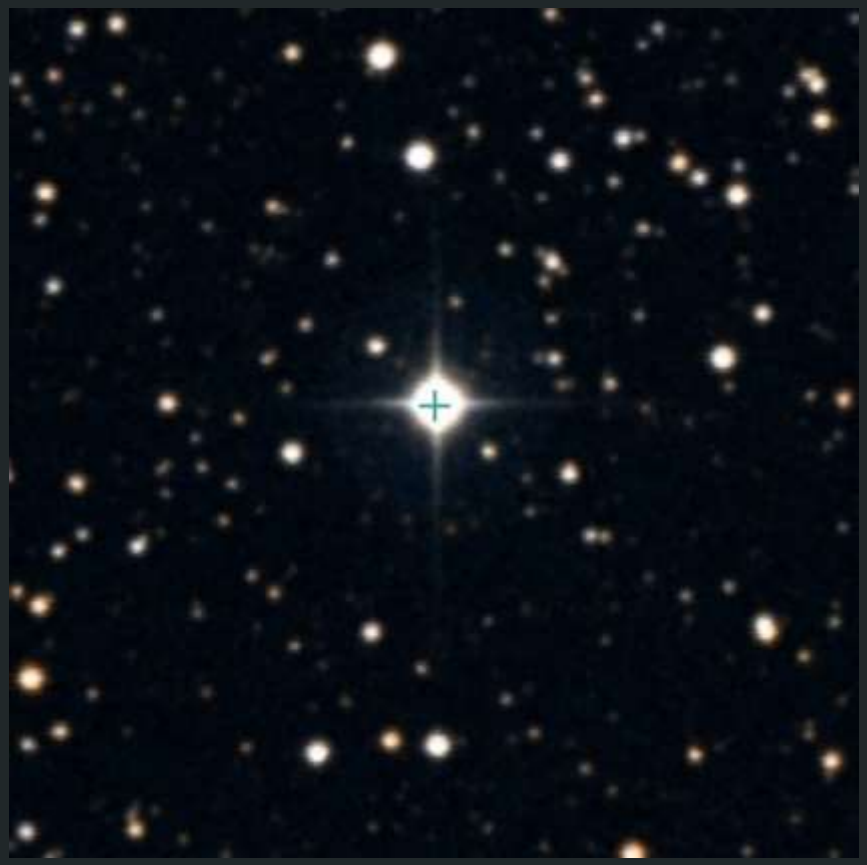
HD 235404

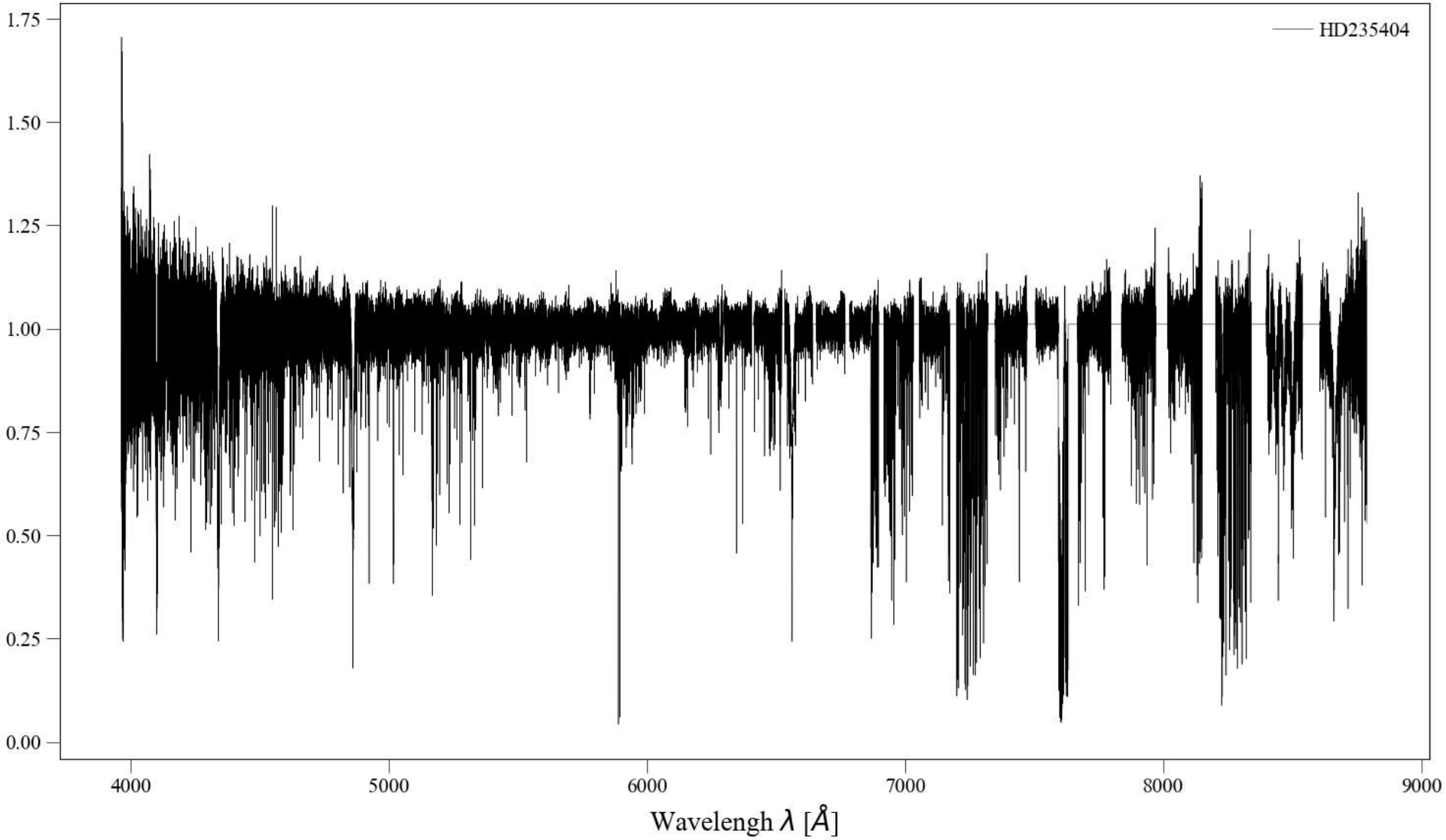
- F type
- ra = 20:56:26.9 (J2000)
- dec = +53:56:24.4 (J2000)
- mag = 9.65 (V)

- exp.time = 1800 s

- vrad = -20.13 ± 1.15 km/s

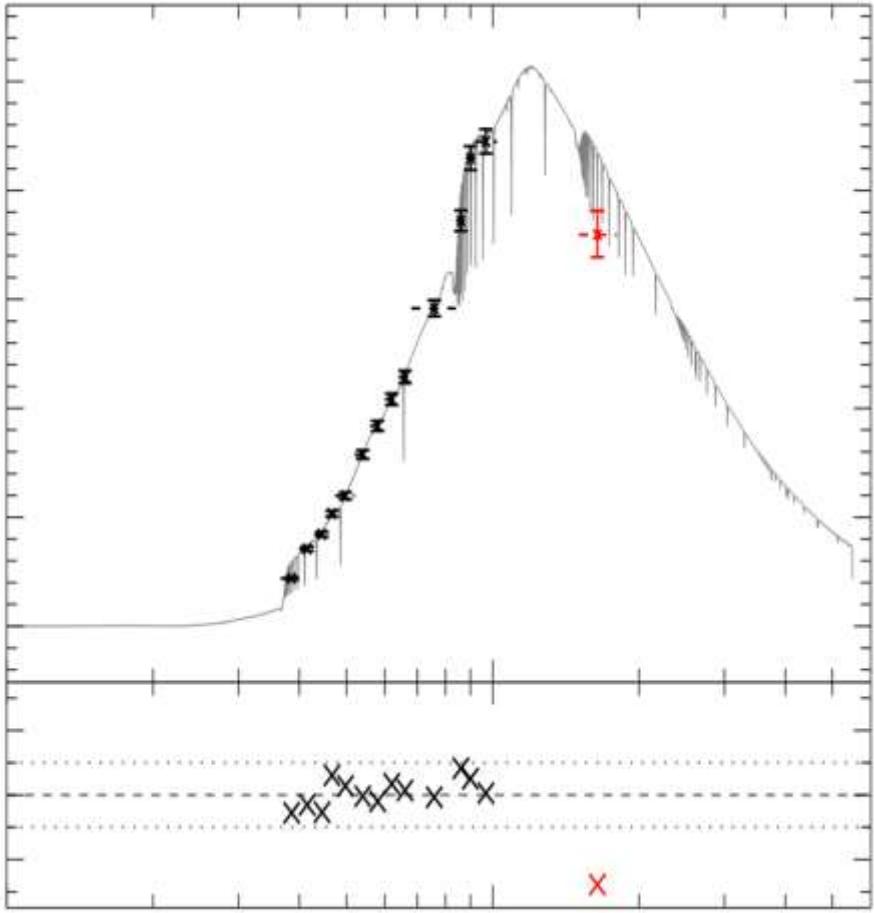
- vrot = 0 ± 4 km/s



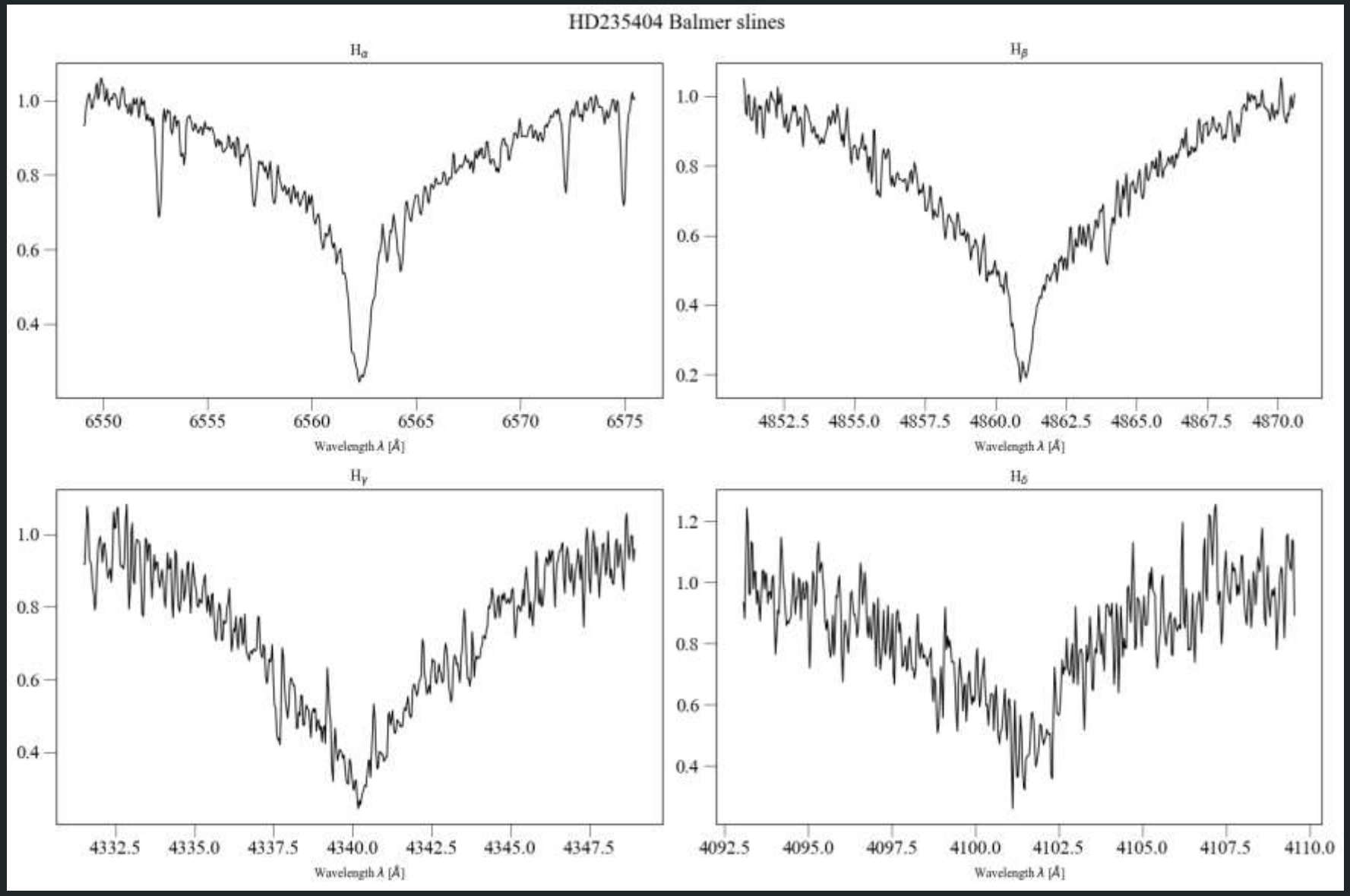

HD235404
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
4000
5000
6000
7000
8000
9000
Wavelengh λ [Å]

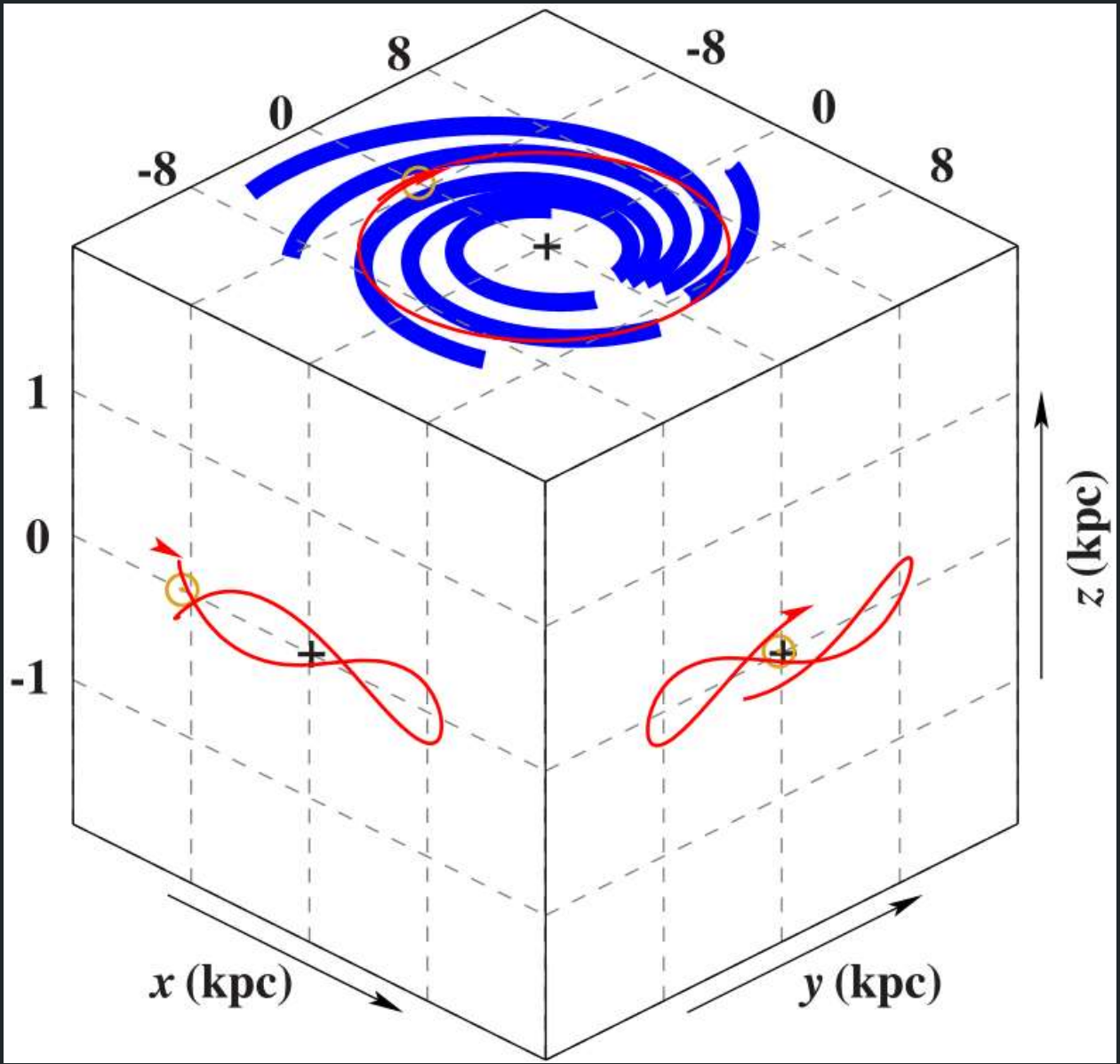
Spectral energy distribution

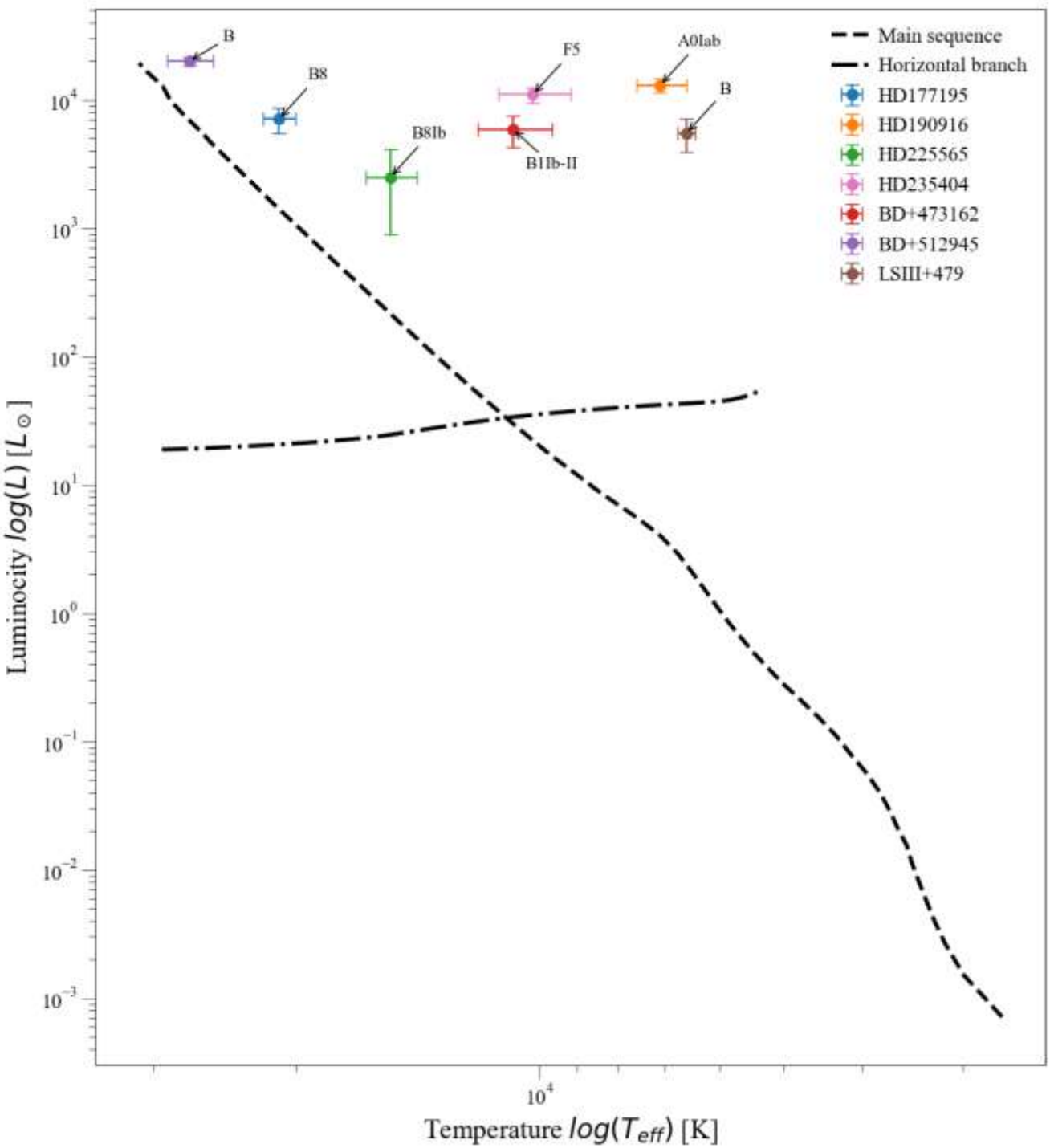
Object: HD 235404	68% confidence interval
Color excess $E(B-V)$ from SFD (1998)	1.32 ± 0.07 mag
Color excess $E(B-V)$ from S&F (2011)	1.14 ± 0.06 mag
Color excess $E(B-V)$ from Stilism (Capitanio+ 2017)	0.96 ± 0.11 mag
Color excess $E(44-55)$	$0.97^{+0.04}_{-0.05}$ mag
Extinction parameter $R(55)$ (fixed)	3.02
Angular diameter $\log(\Theta\,(\mathrm{rad}))$	$-9.136^{+0.030}_{-0.026}$
Parallax ϖ (*Gaia*, RUWE = 1.05, ZPO = −0.021 mas)	0.461 ± 0.016 mas
Distance d (*Gaia*, mode)	$(2.16 \pm 0.08) \times 10^3$ pc
Distance d (*Gaia*, median)	$(2.17 \pm 0.08) \times 10^3$ pc
Effective temperature T_{eff}	10200^{+1000}_{-1100} K
Surface gravity $\log(g\,(\mathrm{cm\,s^{-2}}))$	$2.6^{+0.5}_{-0.6}$
Microturbulence ξ (fixed)	$0\,\mathrm{km\,s^{-1}}$
Metallicity z (fixed)	0 dex
Helium abundance $\log(n(\mathrm{He}))$ (fixed)	−1.05
Radius $R = \Theta/(2\varpi)$ (mode)	$34.9^{+2.8}_{-2.3}\,R_\odot$
(median)	$35.3^{+2.8}_{-2.4}\,R_\odot$
Mass $M = gR^2/G$ (mode)	$3.4^{+26.9}_{-\ 3.0}\,M_\odot$
(median)	$19^{+33}_{-14}\,M_\odot$
Luminosity $L/L_\odot = (R/R_\odot)^2(T_{\mathrm{eff}}/T_{\mathrm{eff},\odot})^4$ (mode)	$\left(1.1^{+0.6}_{-0.5}\right) \times 10^4$
(median)	$\left(1.2^{+0.6}_{-0.5}\right) \times 10^4$
Gravitational redshift $v_{\mathrm{grav}} = GM/(Rc)$	$0.06^{+0.48}_{-0.06}\,\mathrm{km\,s^{-1}}$
Generic excess noise δ_{excess}	0.023 mag
Reduced χ^2 at the best fit	1.00

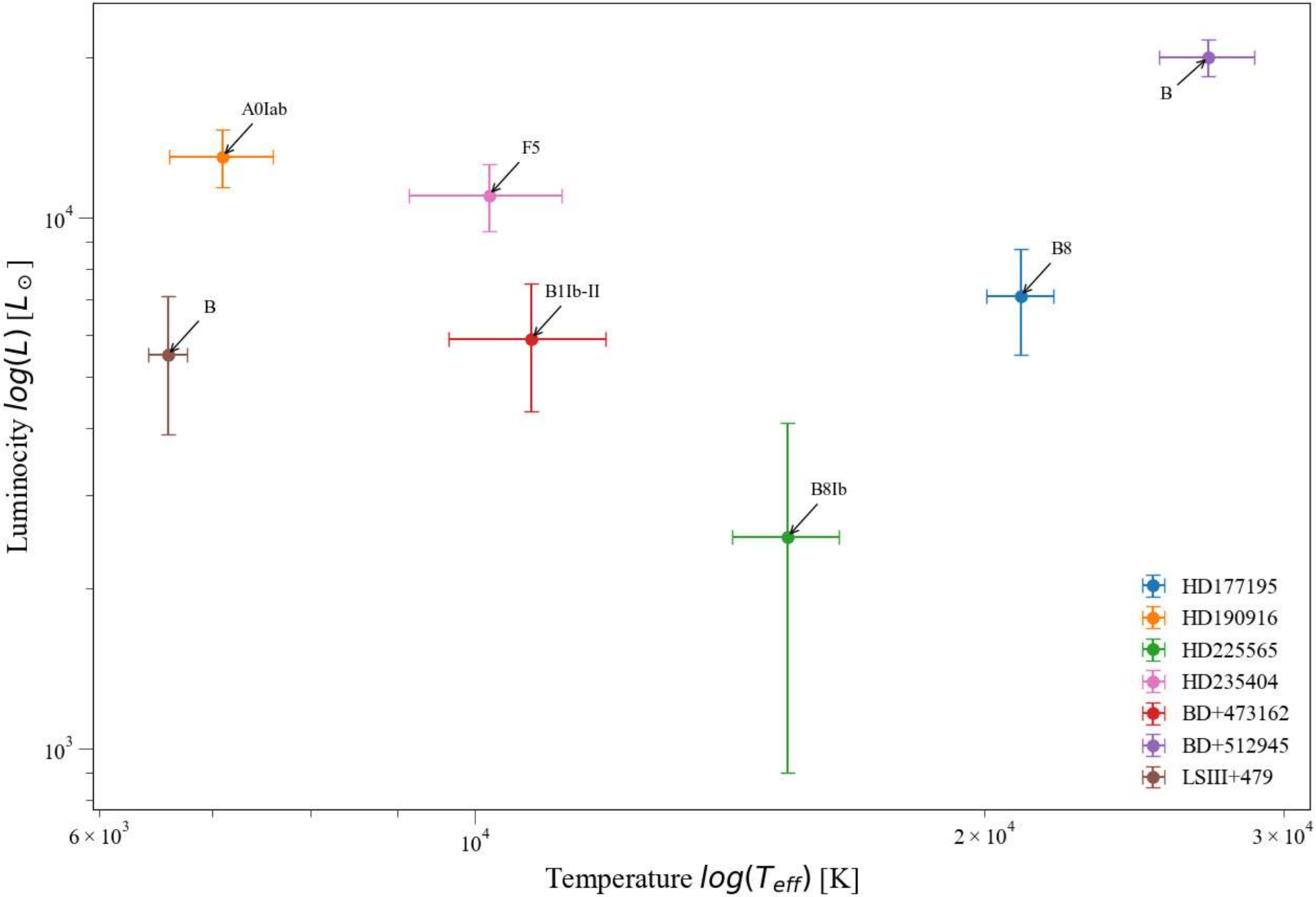


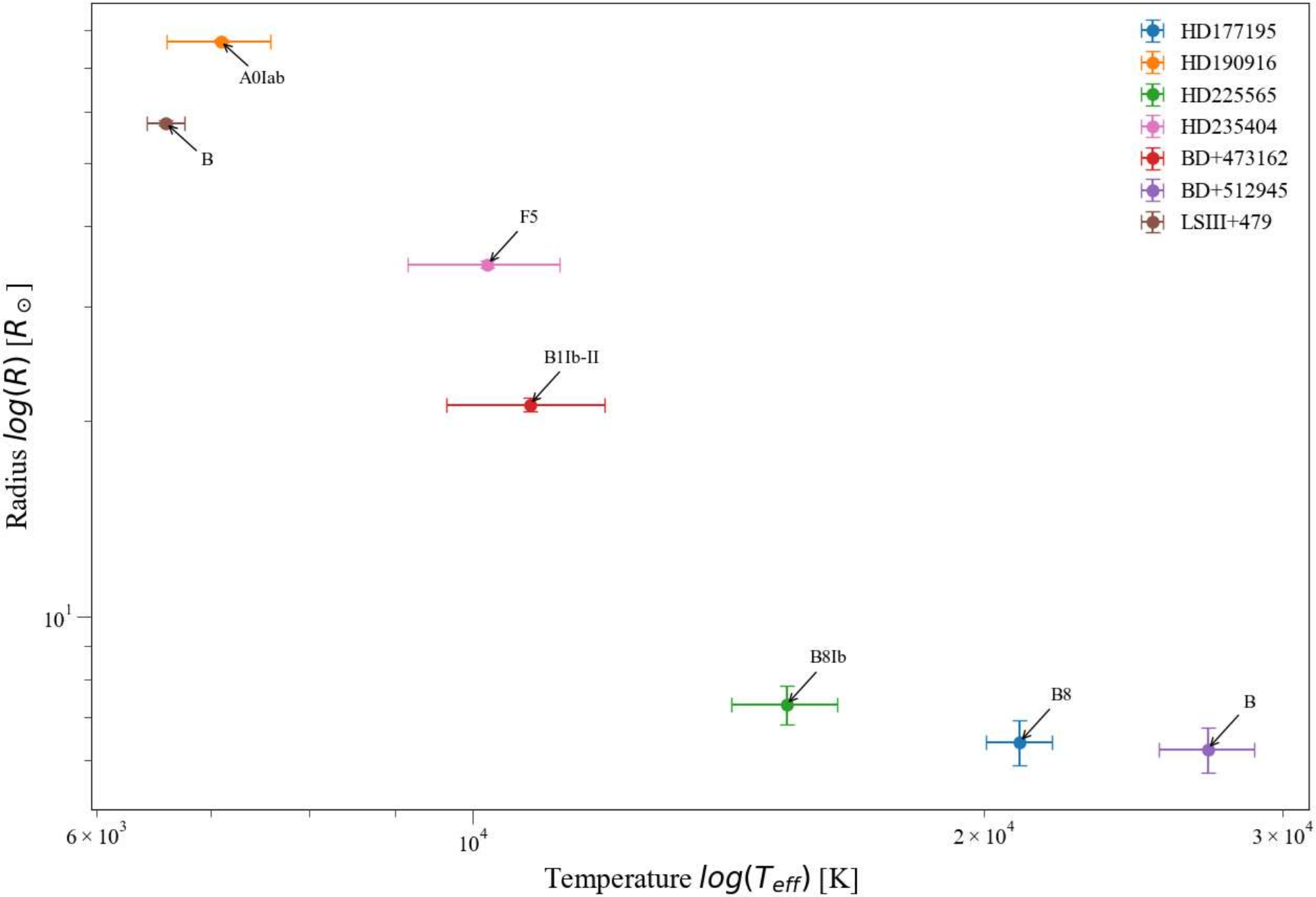
Radial velocity fitting

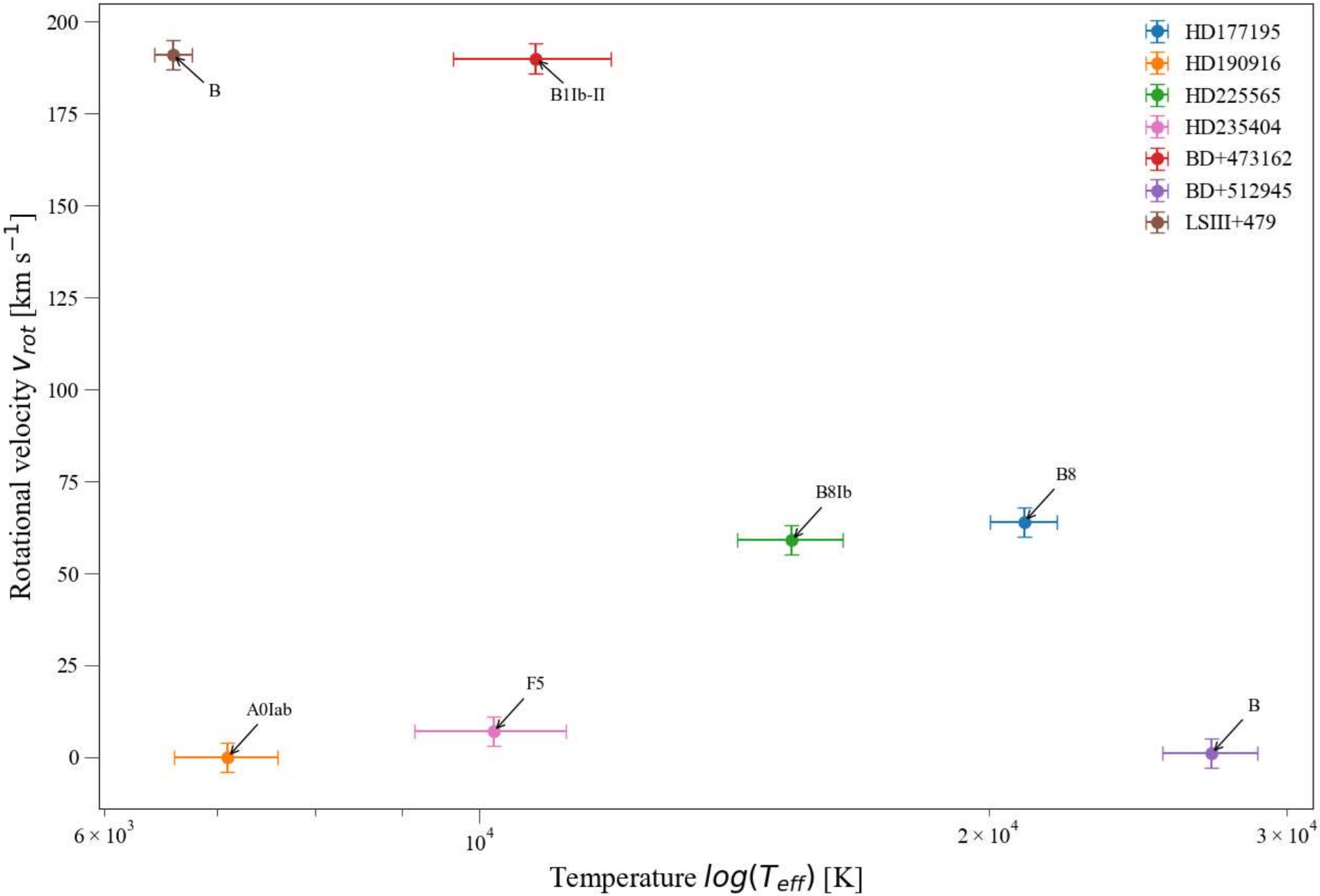


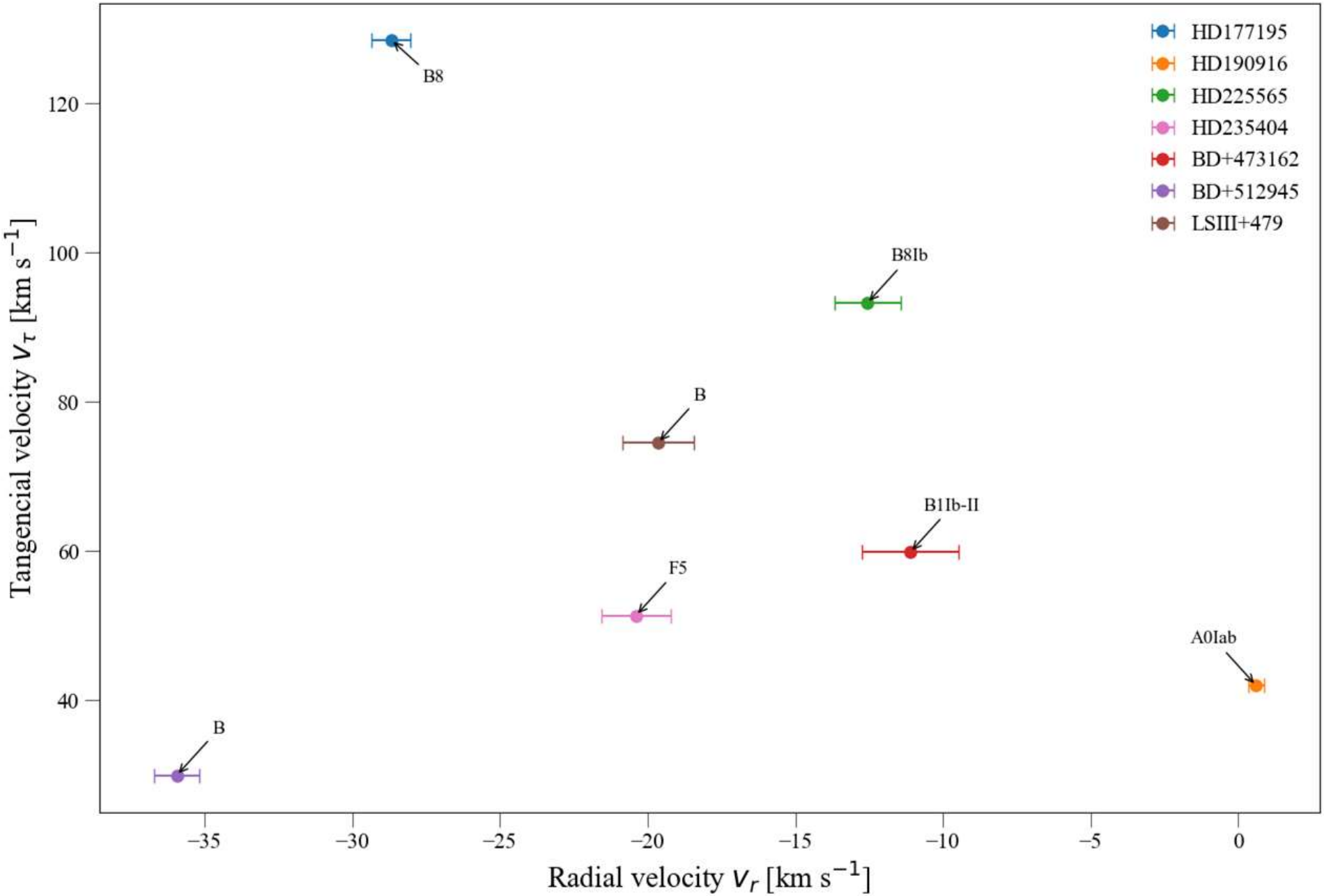

8
-8
0
0
-8
8
1
0
-1
z (kpc)
x (kpc)
y (kpc)

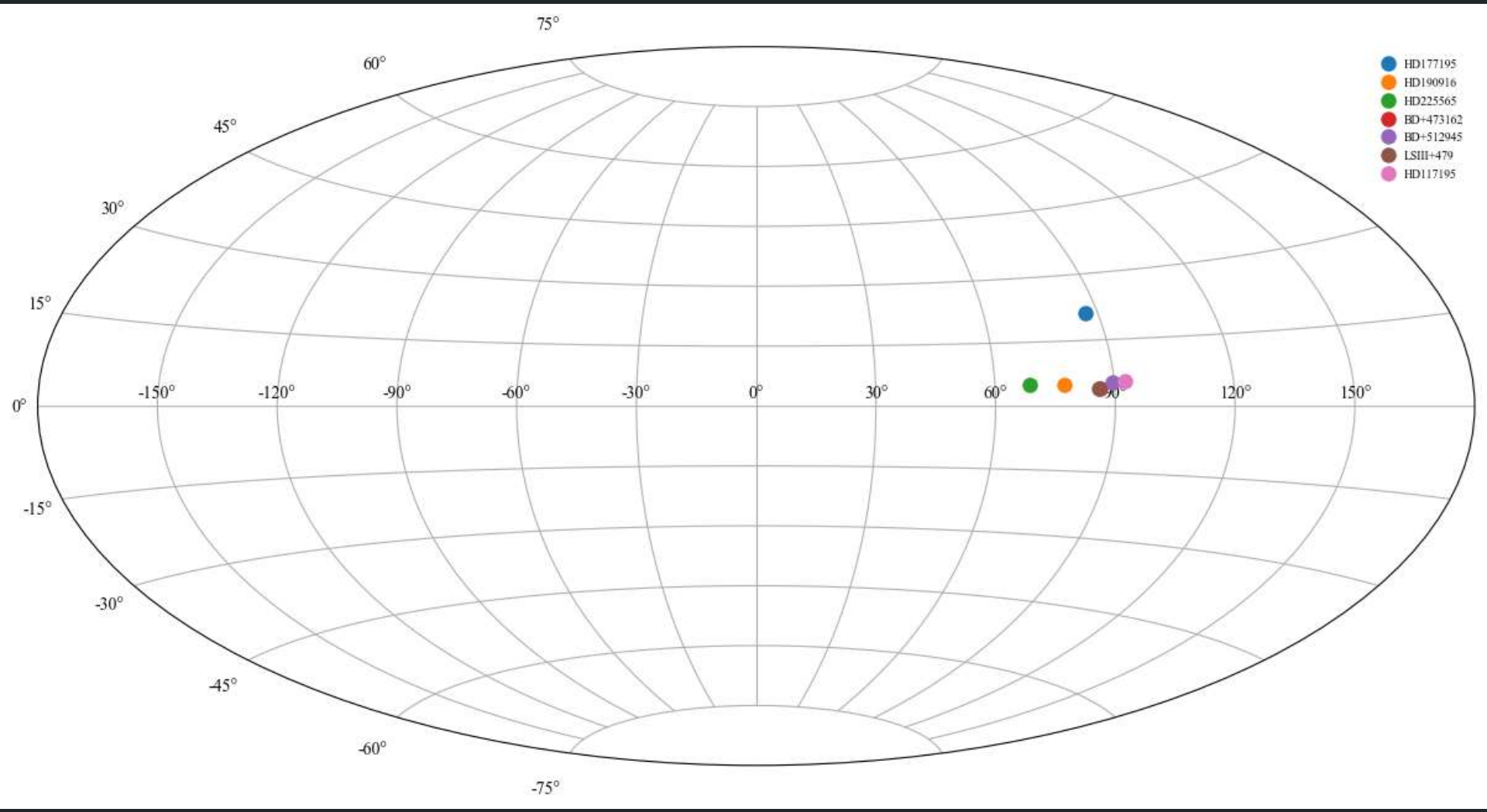

B
B8
B8Ib
F5
B1Ib-II
A0Iab
B
Main sequence
Horizontal branch
HD177195
HD190916
HD225565
HD235404
BD+473162
BD+512945
LSIII+479
Luminocity log(L) [L⊙]
Temperature log(Teff) [K]
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^4


A0Iab
F5
B
B1Ib-II
B8
B8Ib
B
HD177195
HD190916
HD225565
HD235404
BD+473162
BD+512945
LSIII+479
10^4
10^3
Luminocity $log(L)$ [$L_\odot$]
6×10^3
10^4
2×10^4
3×10^4
Temperature $log(T_{eff})$ [K]


HD177195
HD190916
HD225565
HD235404
BD+473162
BD+512945
LSIII+479
A0Iab
B
F5
B1Ib-II
B8Ib
B8
B
Radius $log(R)$ [$R_\odot$]
10^1
6×10^3
10^4
2×10^4
3×10^4
Temperature $log(T_{eff})$ [K]

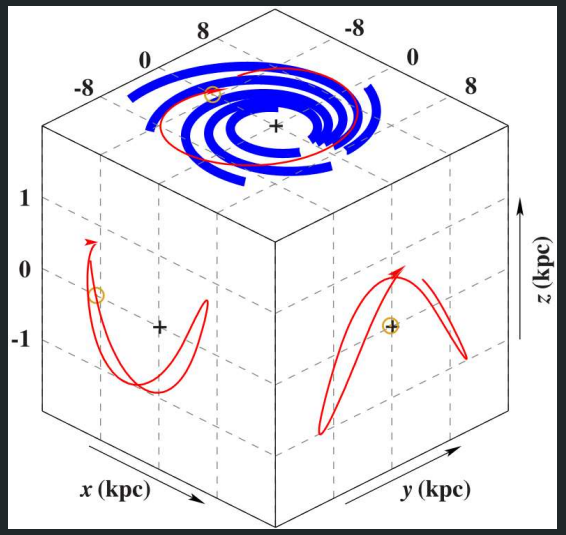

HD177195
HD190916
HD225565
HD235404
BD+473162
BD+512945
LSIII+479
B
B1Ib-II
B8Ib
B8
A0Iab
F5
B
Rotational velocity v_{rot} [km s^{-1}]
Temperature $log(T_{eff})$ [K]
200
175
150
125
100
75
50
25
0
6×10^3
10^4
2×10^4
3×10^4


HD177195
HD190916
HD225565
HD235404
BD+473162
BD+512945
LSIII+479
B8
B8Ib
B
B1Ib-II
F5
A0Iab
B
120
100
80
60
40
−35
−30
−25
−20
−15
−10
−5
0
Tangencial velocity v_τ [km s^{-1}]
Radial velocity v_r [km s^{-1}]

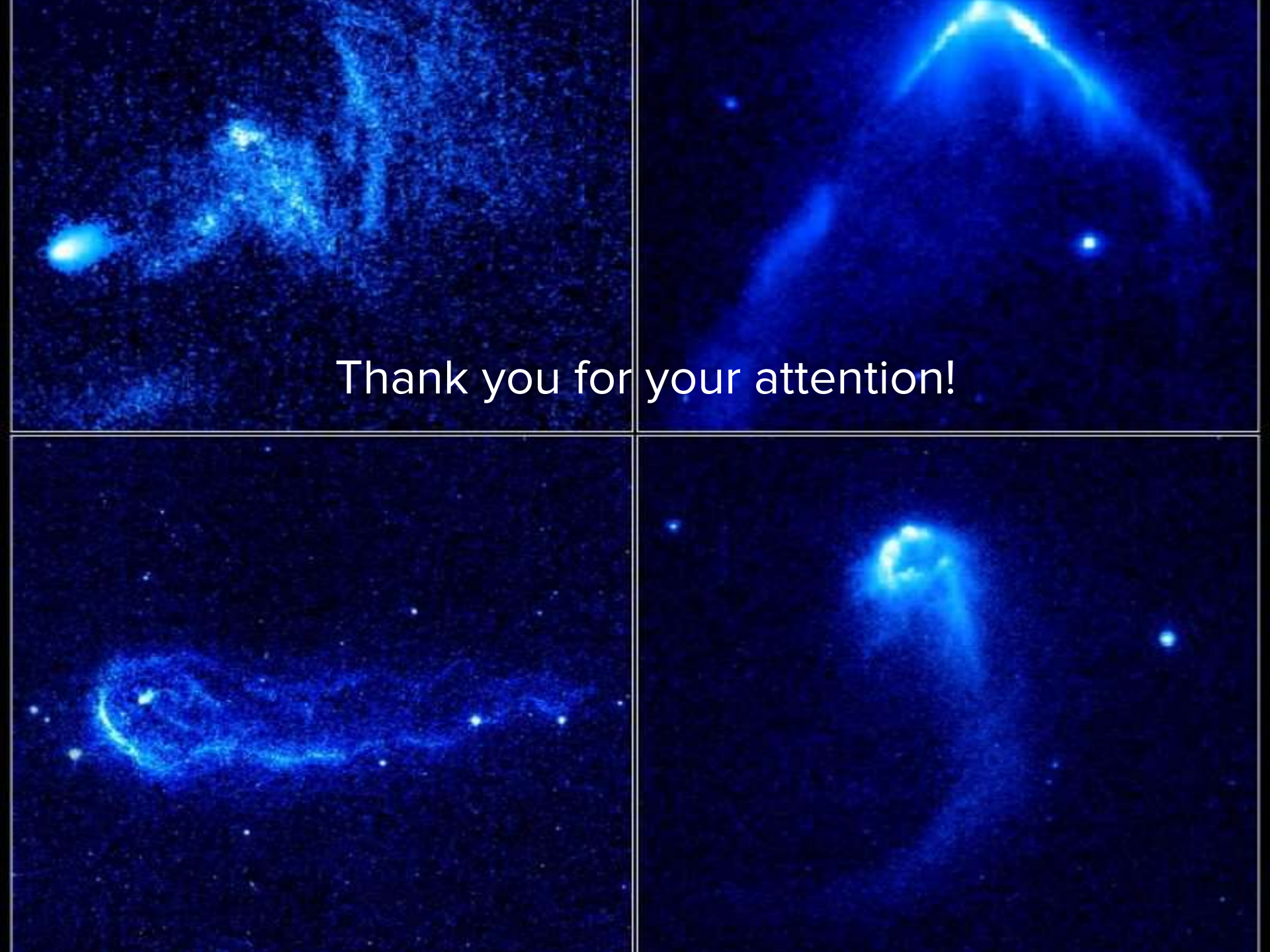

75°
60°
45°
30°
15°
0°
-15°
-30°
-45°
-60°
-75°
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°
HD177195
HD190916
HD225565
BD+473162
BD+512945
LSIII+479
HD117195

Conclusion

- one runaway star
  - HD 177195
  - B8 type star (Simbad)
  - high radial velocity



Target	Spectral type	Radial velocity	Rotational velocity	Runaway
HD 177195	B	-31.49 ± 5.37	64 ± 4	yes
HD 225565	B	-21.62 ± 11.39	72 ± 19	no
HD 190916	A	0.54 ± 1.09	0	no
LS III +47 9	B	-23.49 ± 3.28	191 ± 29	no
BD+47 3162	B	-8.06 ± 1.75	190 ± 15	no
BD+51 2945	B	-34.99 ± 1.31	6 ± 8	no
HD 235404	F	-20.13 ± 1.15	0 ± 4	no



Thank you for your attention!