aavso
let's explore.
american association of variable star observers.

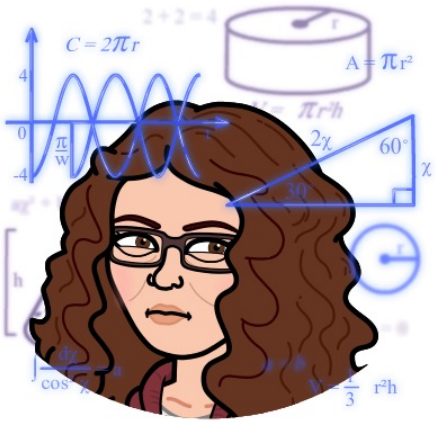
Spectroscopy with Small Telescopes

Stella Kafka, PhD
SMSWII

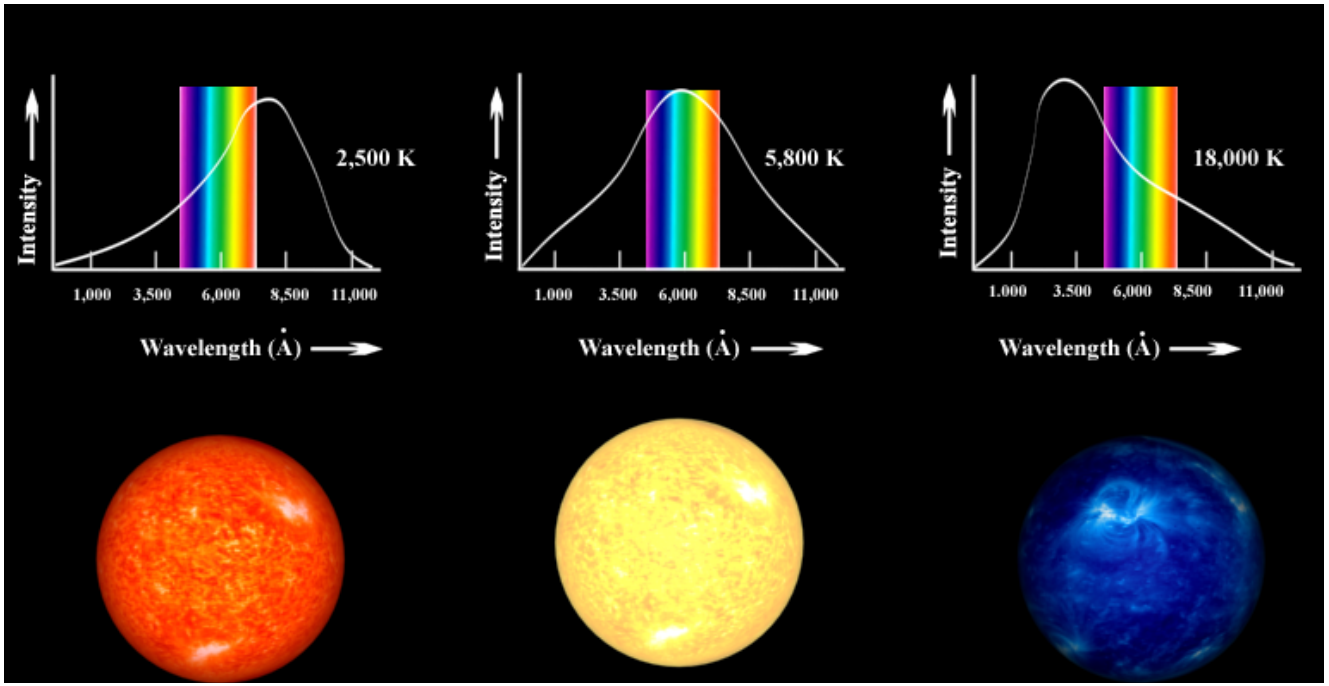
Spectroscopy with Small Telescopes: The Science

Outline

- Principles of Spectroscopy
- What do we measure from line profiles?
- Information we get from spectra
- Science cases
- More resources



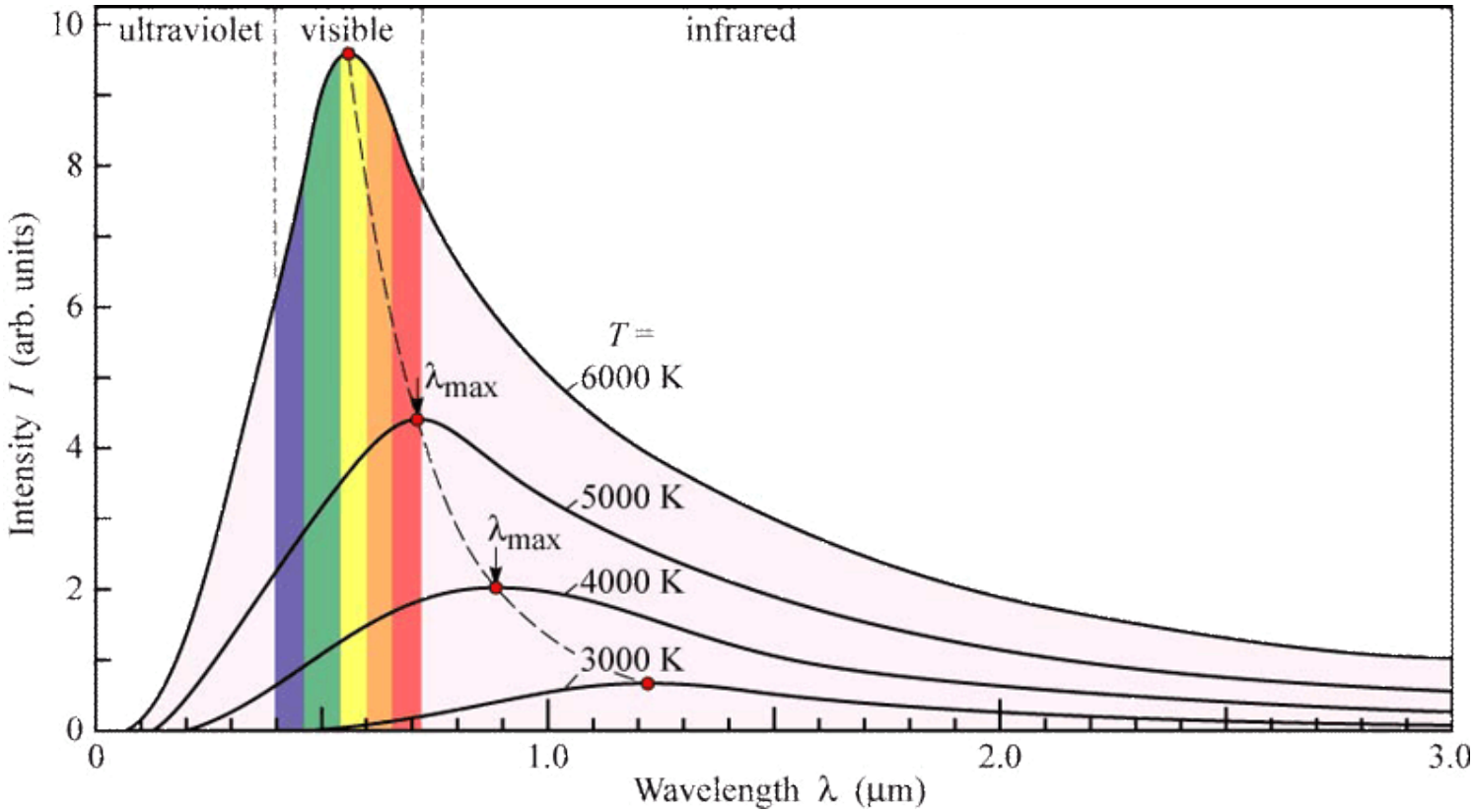
Principles of spectroscopy
I. Wien's law



Hotter objects emit most of their radiation at **shorter wavelengths**; hence they will appear to be **bluer**.

Cooler objects emit most of their radiation at **longer wavelengths**; hence they will appear to be **redder**.

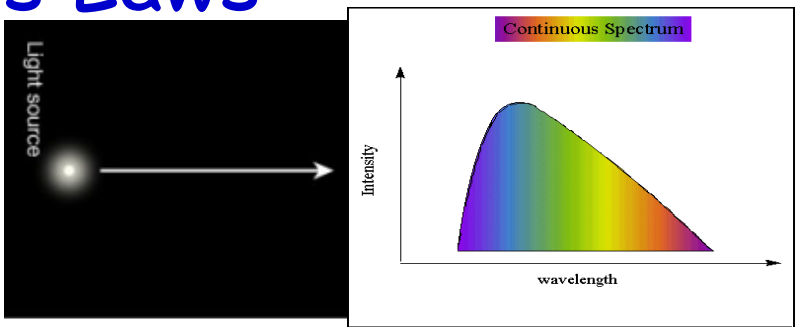
Principles of spectroscopy
I. Wien's law



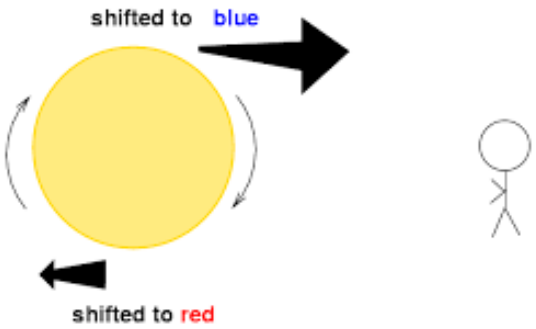
$$\text{Wavelength of Maximum Intensity (cm)} = \frac{.29}{T\ (^{\circ}K)}$$

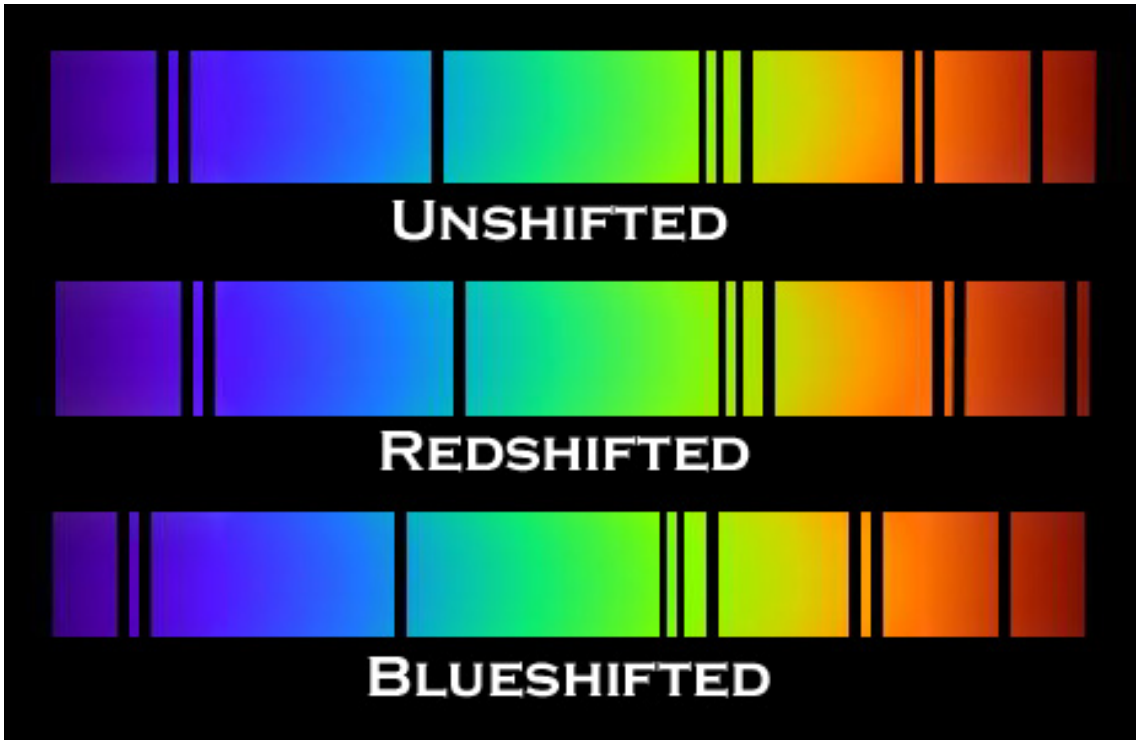
Principles of spectroscopy
II. Kirchhoff's Laws

1. A hot gas, under high pressure, gives off a **continuous** spectrum.



Principles of Spectroscopy
III. Doppler effect



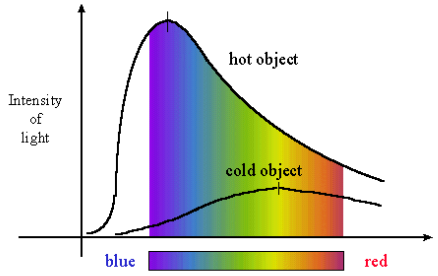


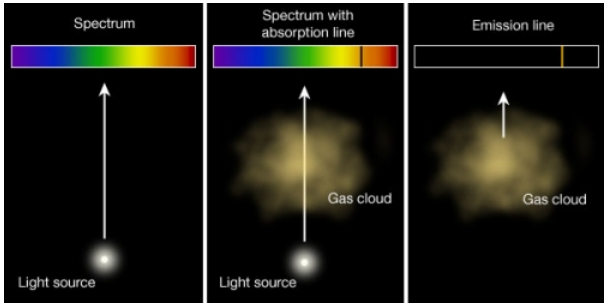
Change in wavelength because of the source moving relative to the observer

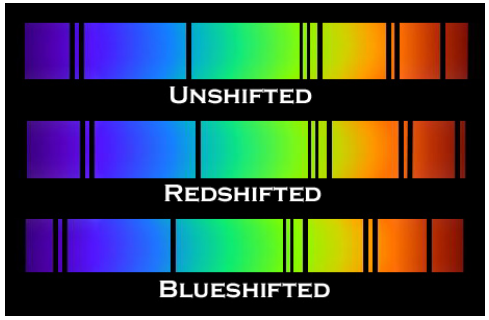
$$\frac{\Delta\lambda}{\lambda} = \frac{velocity}{c}$$

"Radial Velocity" (RV)

Principles of Spectroscopy





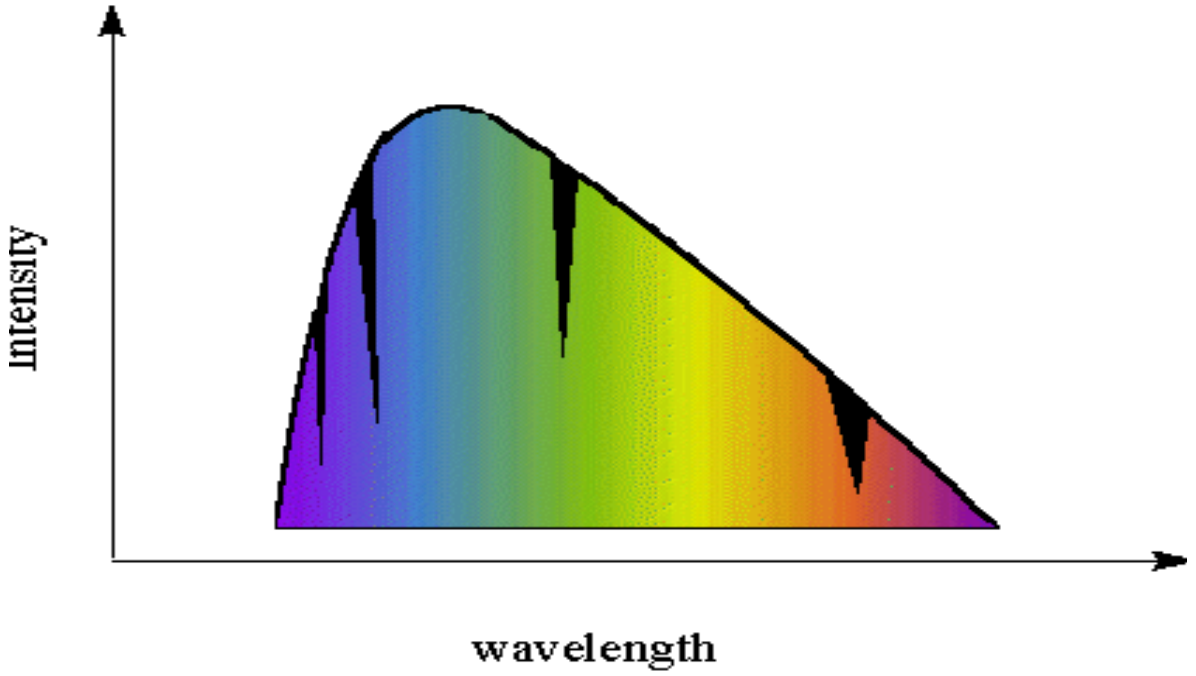


I. Wien's law (temperature vs wavelength of max intensity)

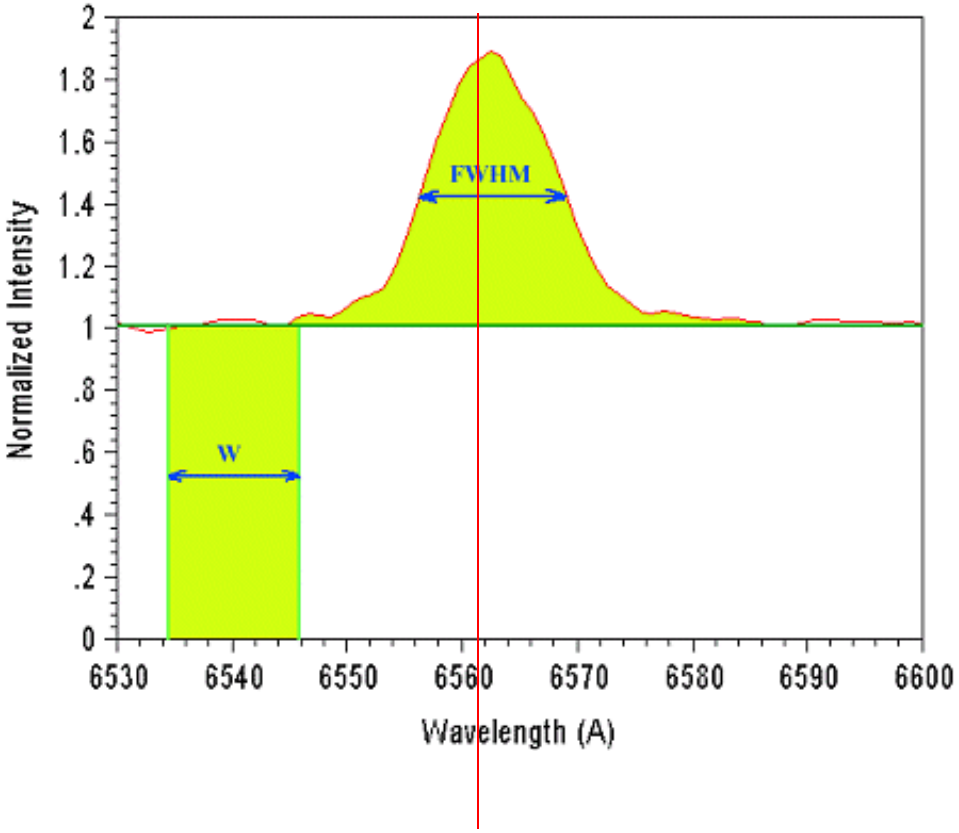
II. Kirchhoff's Laws (continuum/emission/absorption spectrum)

III. Doppler effect (RVs)

What do we measure from line profiles?



Spectral line Measurements:



- Radial velocities (RV)
- Line Equivalent Widths (W)
- Line Full Width Half Max (FWHM)

$$\frac{\Delta\lambda}{\lambda} = \frac{velocity}{c}$$

Information we get from spectra

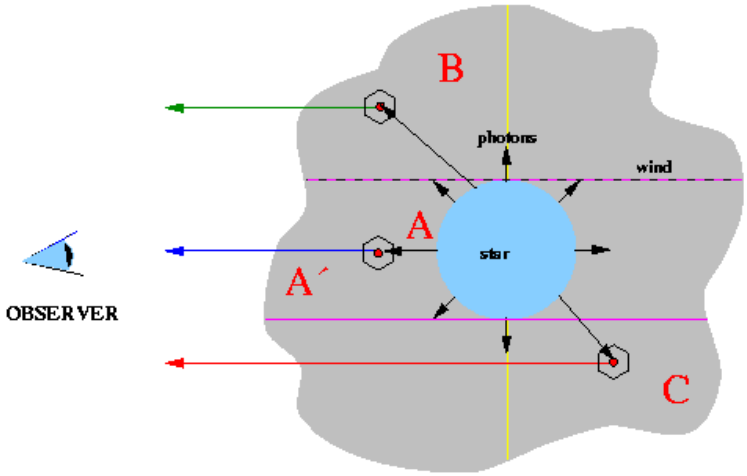
1. Elements in stellar atmospheres

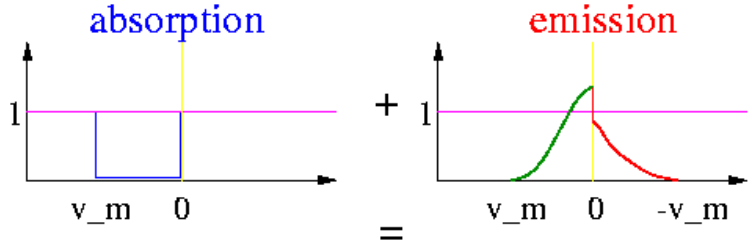
Characteristic of a barcode
(unique for a product):

- Thickness of lines
- Spacing
- Grouping

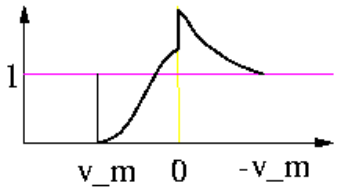
1. Elements in stellar atmospheres

2. Outflows (winds)





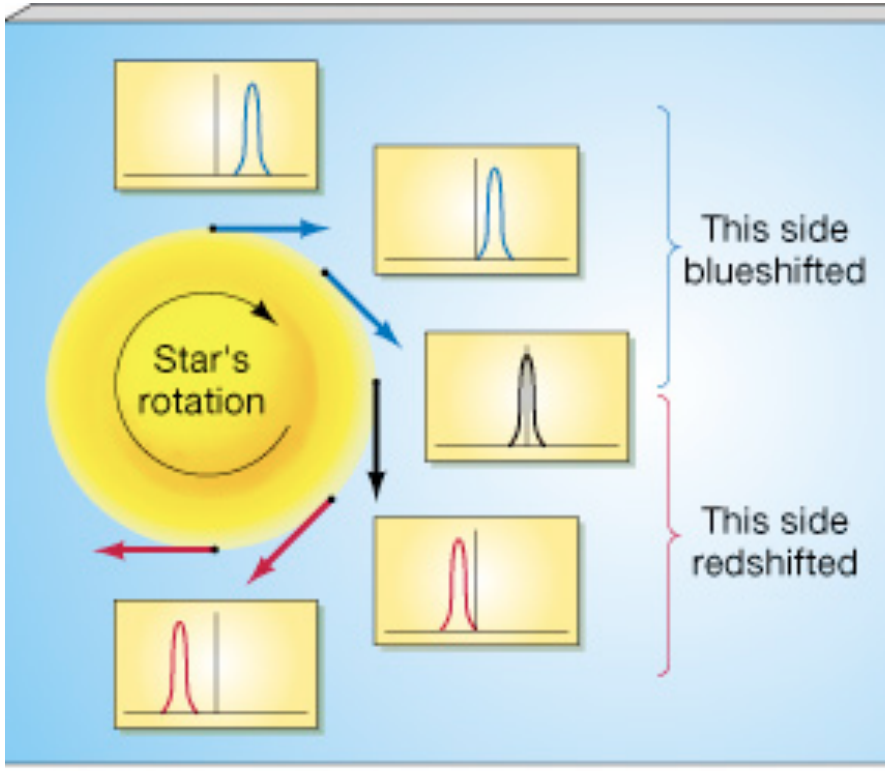
P Cygni Profile



A: Absorption from gas in front of star

B, C: Emission from expanding gas components

3. Rotational velocities



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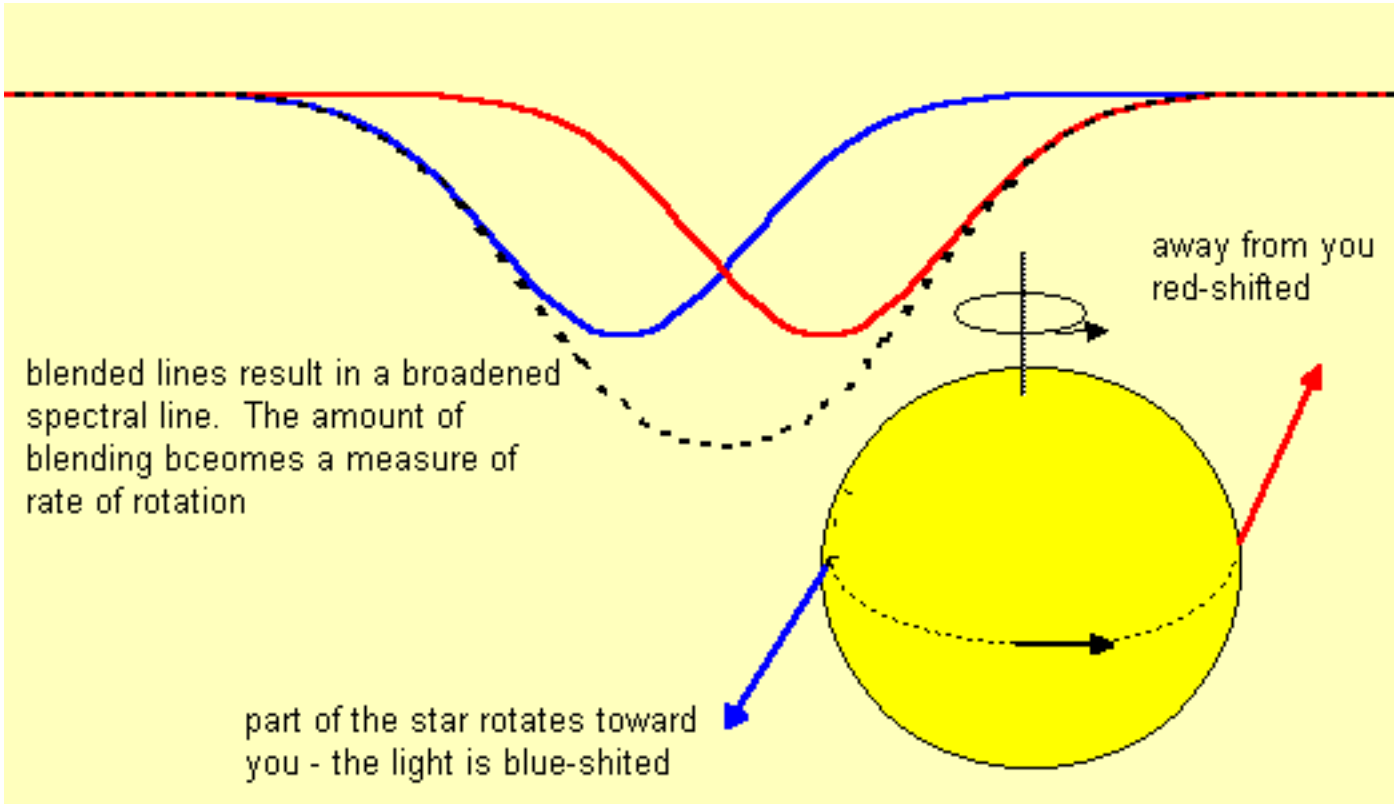

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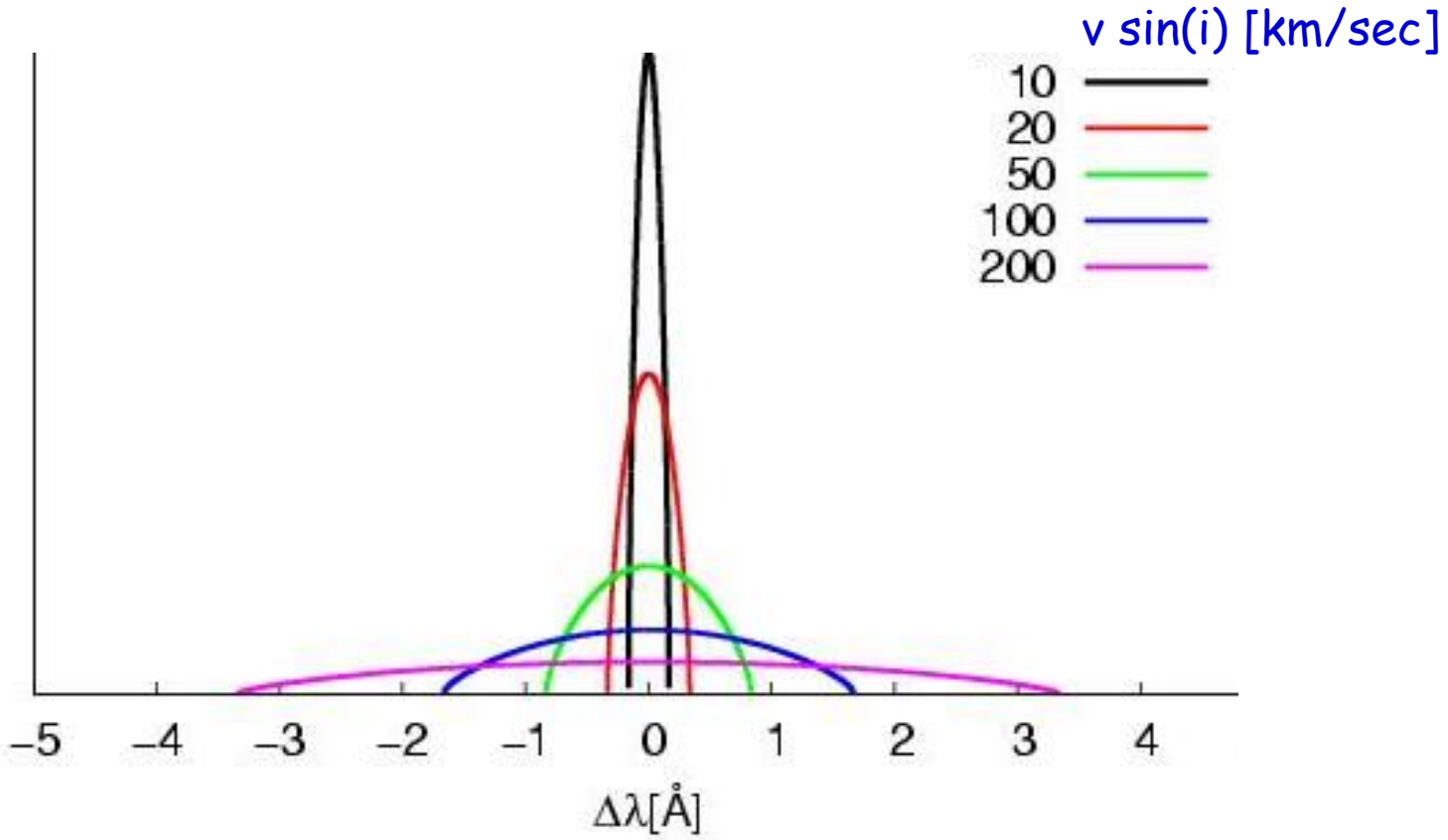
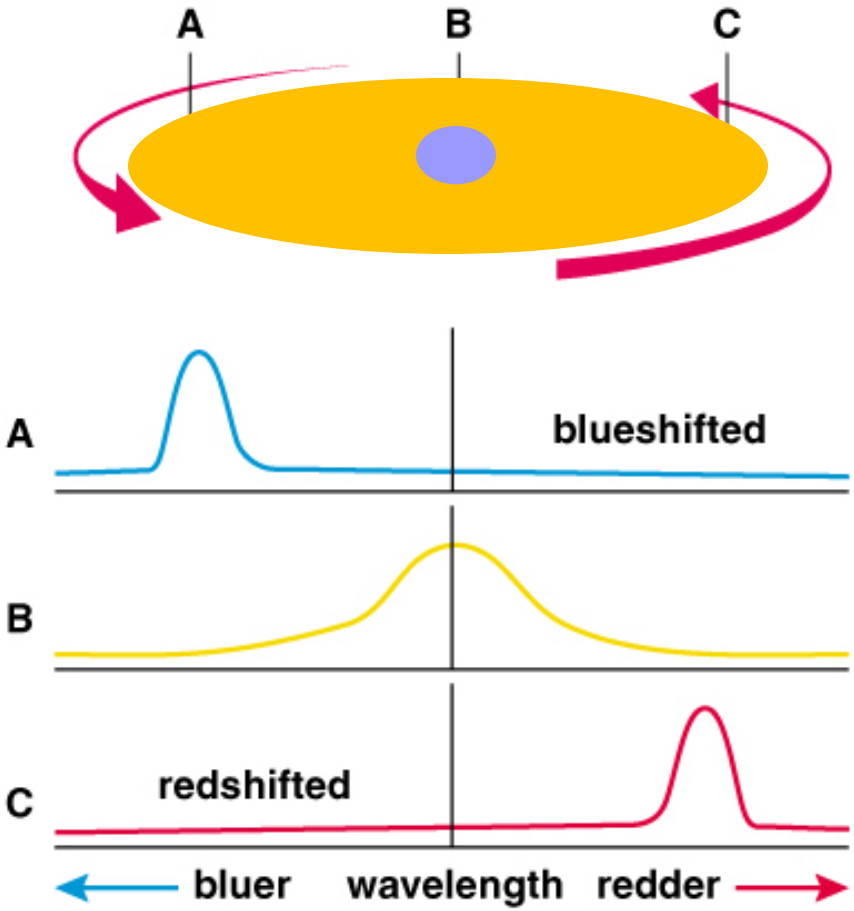
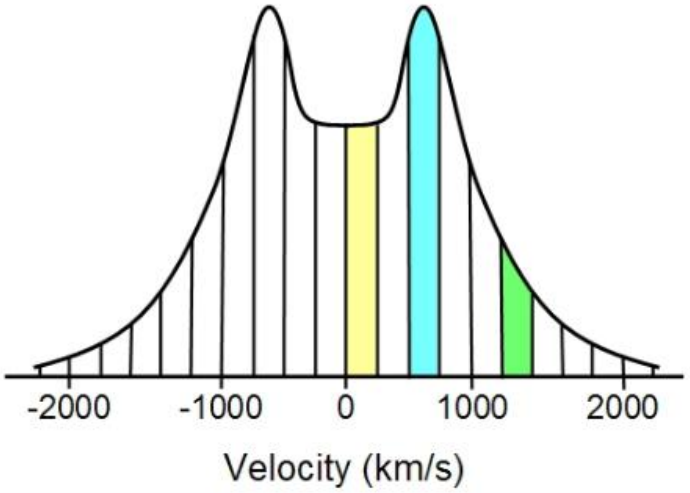
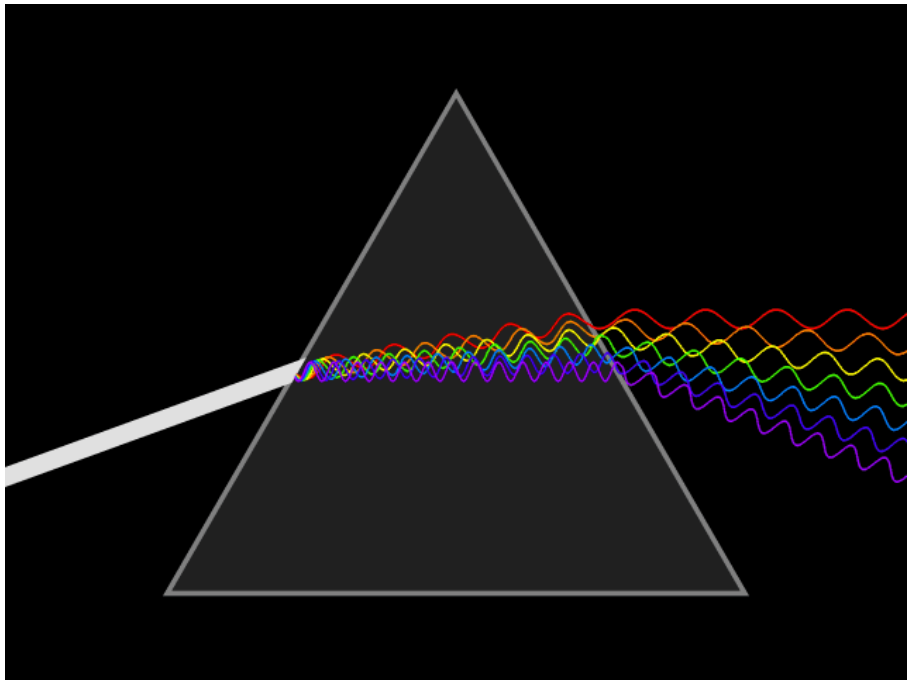


4. Accretion disks

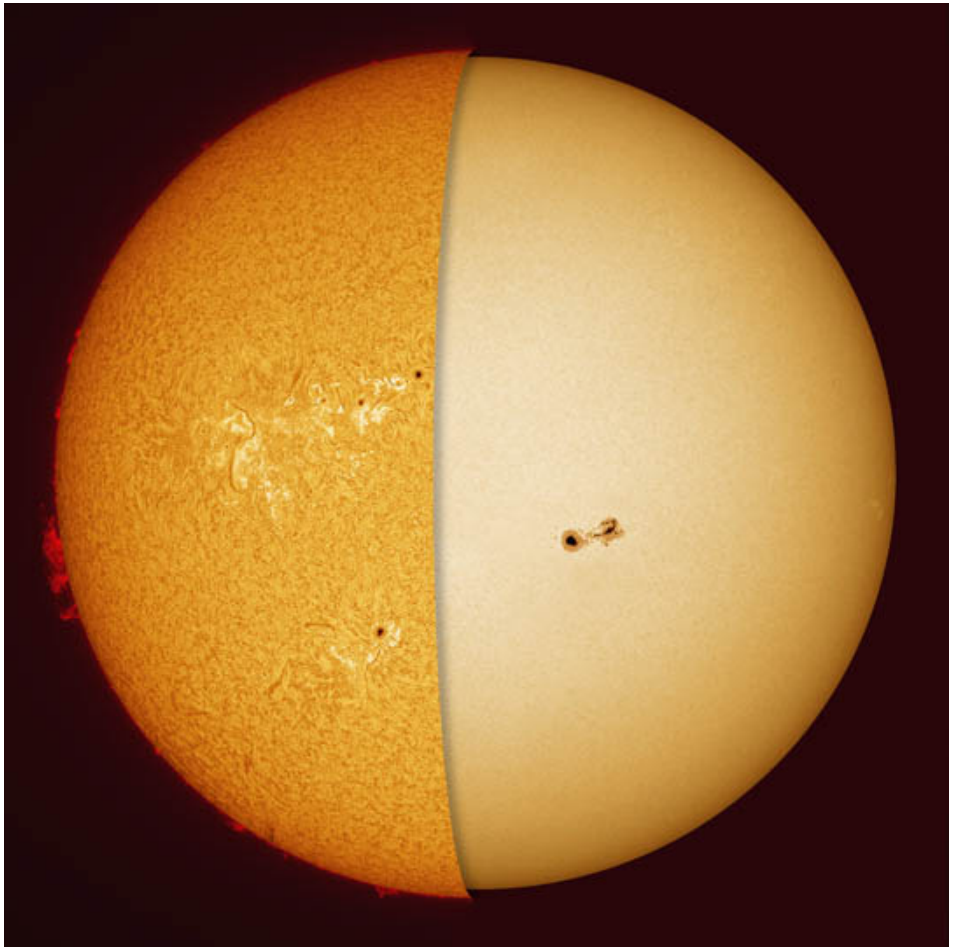




Let's do Science



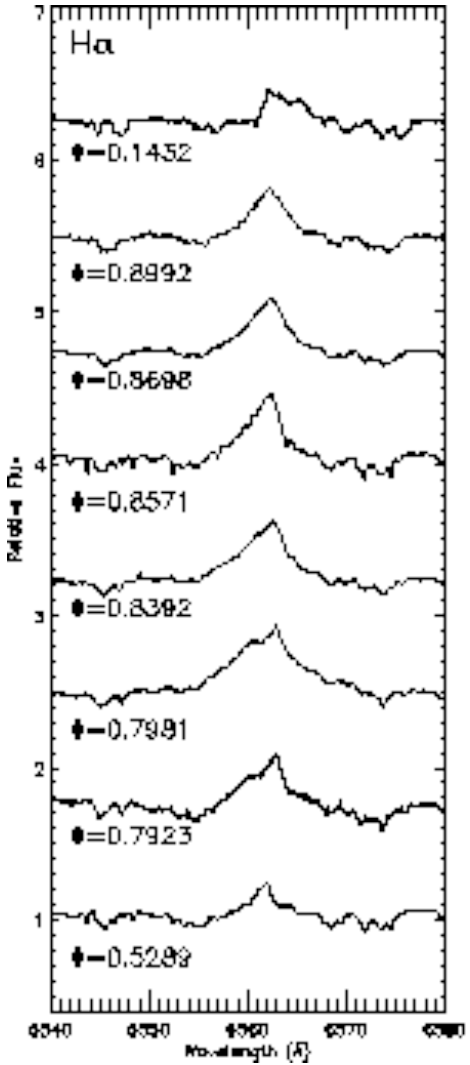
Science case 1: Chromospherically active stars

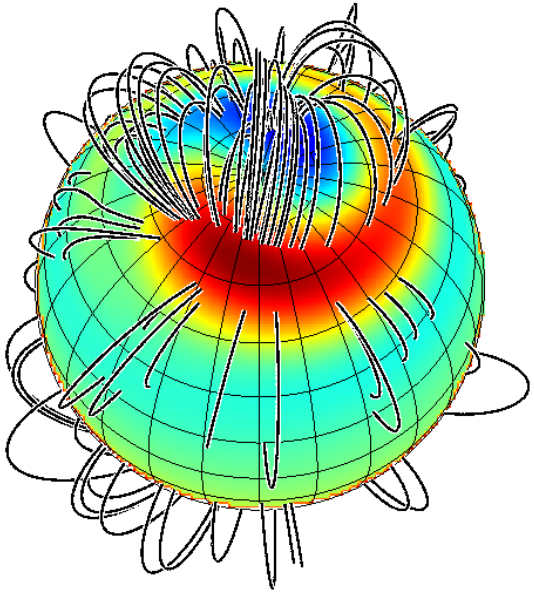


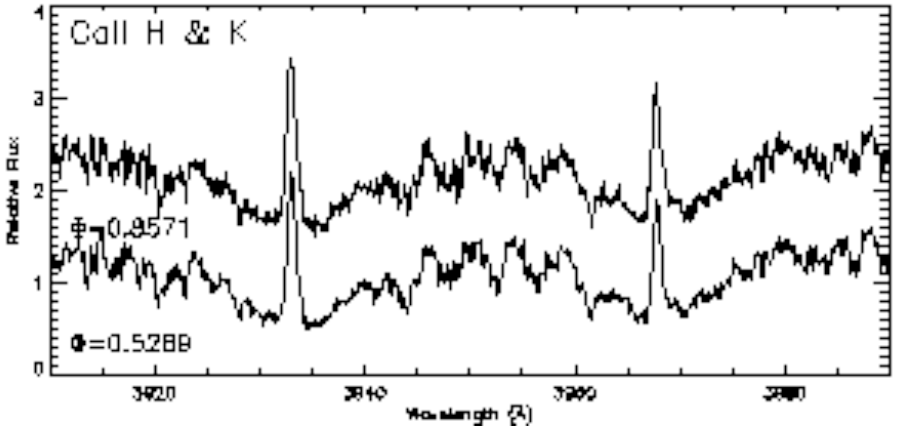
Emission regions: Hydrogen and CaII H&K (chromospheric emission)

Absorption features: CaII H&K

Science case 1: Chromospherically active stars

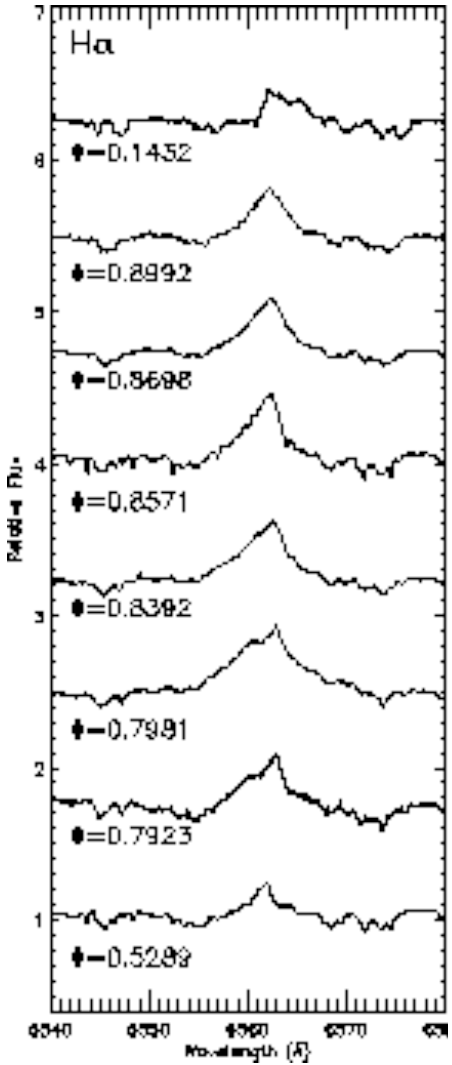


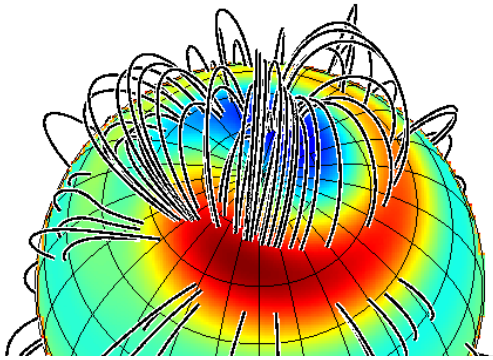




HR 1099 (RS CVn; K2)
Garcia-Alvarez et al.
A&A 2002

Science case 1: Chromospherically active stars

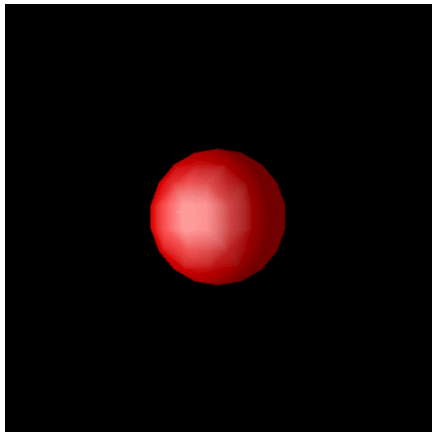


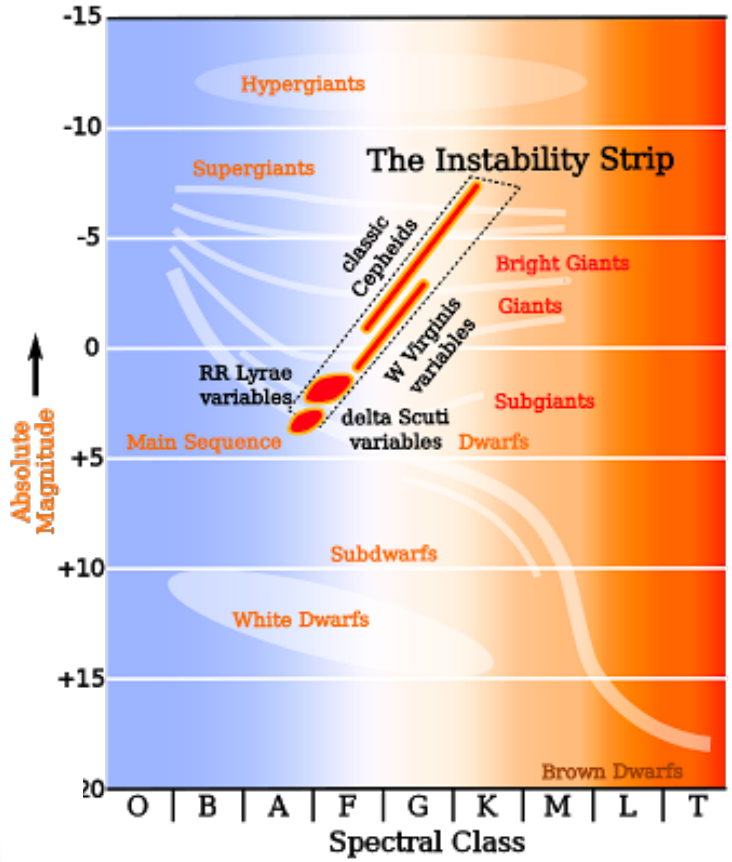


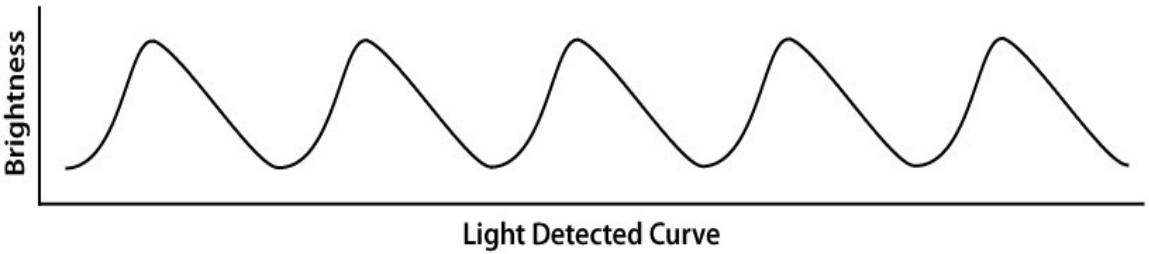
Possible targets:

- chi Dra A/B (V~3.5)
- UV Cet (M5.5V; V~6.8-13)
- Eps Eri (3.73)
- Barnard's Star (V2500 Oph; 9.55)
- RS CVn (F4V+K0IVe; V~8-9)
- BF Lyn (K2.5; V~7.7)

Science case 2: Pulsating stars







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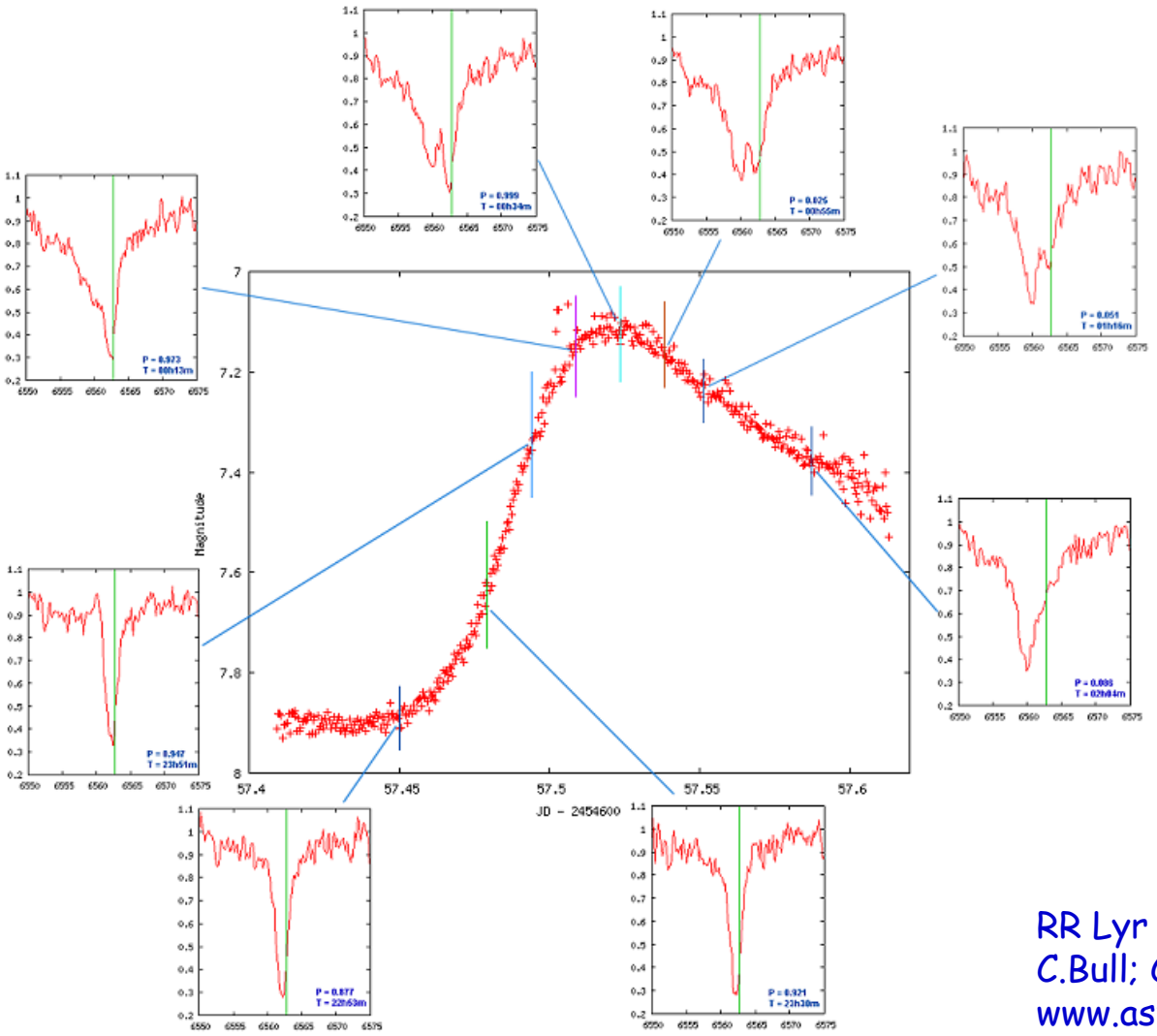
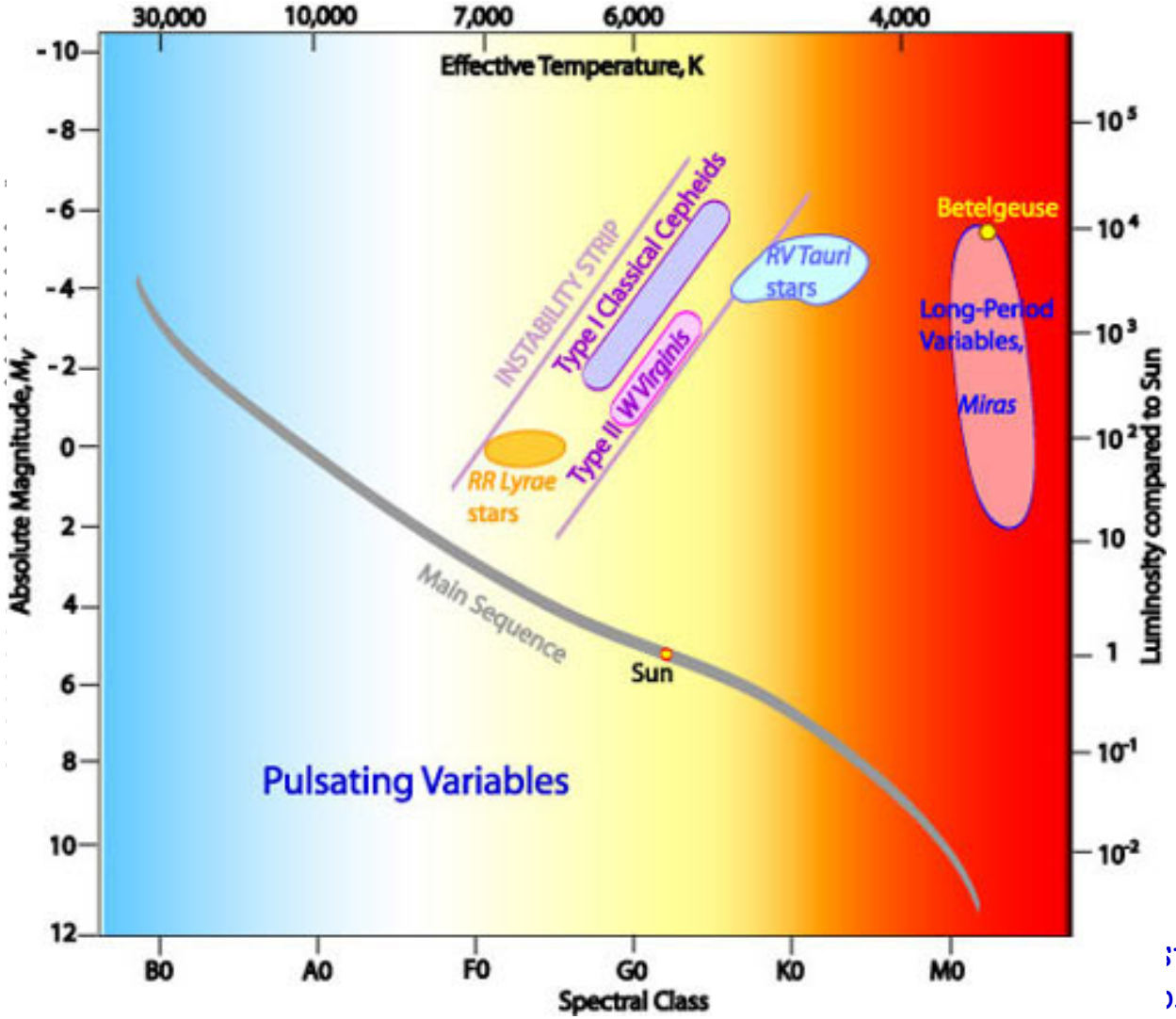


RR Lyr
C.Bull; Castanet-Tolosan obs
www.astrosurf.com

Science case 2: Pulsating stars



stanet-Tolosan obs
osurf.com

Science case 2: Pulsating stars

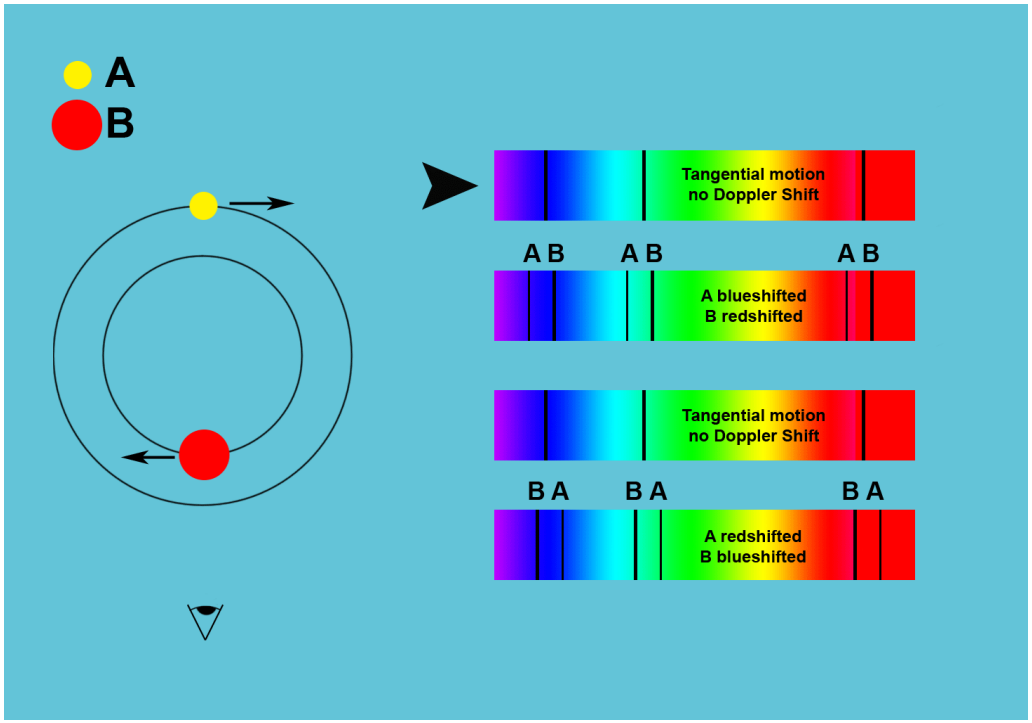
RV Tauri
- R Sct 4.9-6.9
- U Mon 5.1-7.1
- AC Her 6.4-8.7

RR Lyrae
- RR Lyr 7.17- 8.14
- MT Tel 8.70-9.25

Cepheids
- Polaris 1.97-2.00
- Delta Cep 3.49-4.36
- V473 Lyr 5.99-6.35
- V1334 Cyg 5.77-5.96

Mira
- omi Cet 2.0-10.1
- R Lep 5.5-11.7
- S Cam 7.7-11.6
- R Gem 6.0-14.0
- V Cnc 7.6-13.3
- R Leo 4.4-11.3
- S UMa 7.1-12.7
- R Hya 3.5-10.9
- V CrB 6.9-12.6
- V Oph 7.3-11.6
- X Oph 5.9-9.2
- R Aql 5.3-11.9
- Khi Cyg 3.3-14.2

Science case 3: RVs of binaries

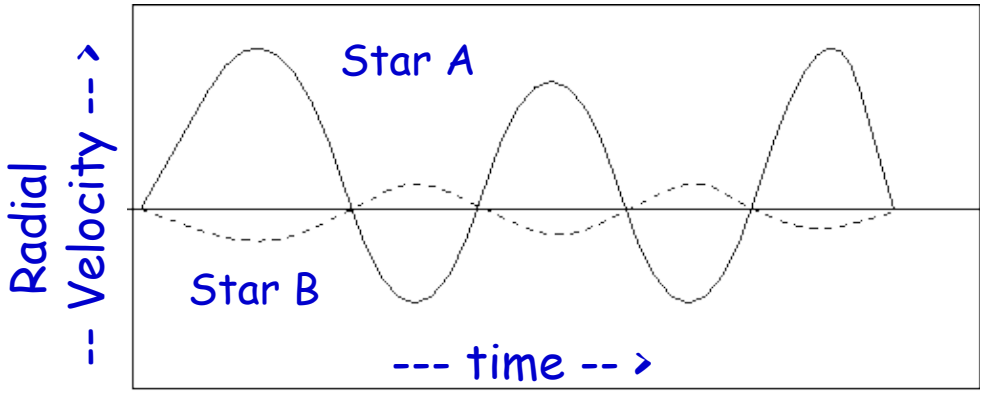


Absorption features (from each star's atmosphere) are red- or blue- shifted

▽

Measure Radial Velocity

$$\frac{\Delta\lambda}{\lambda} = \frac{velocity}{c}$$



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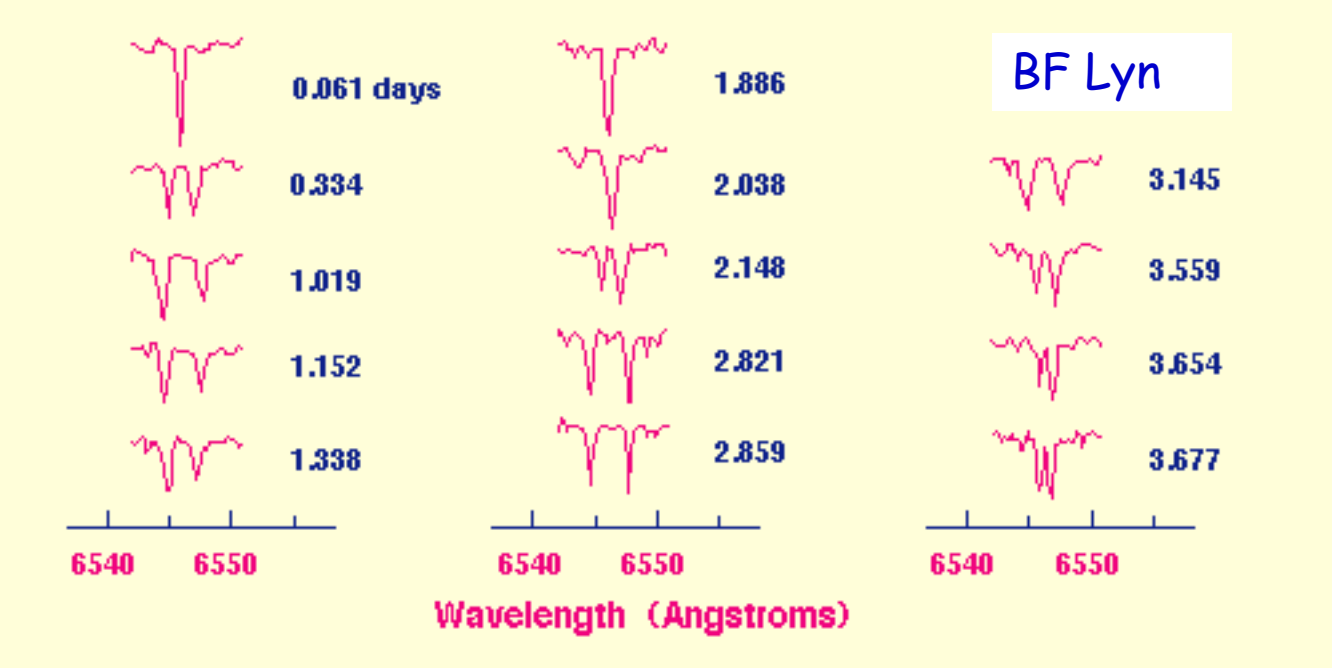
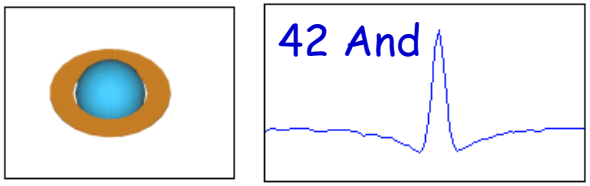
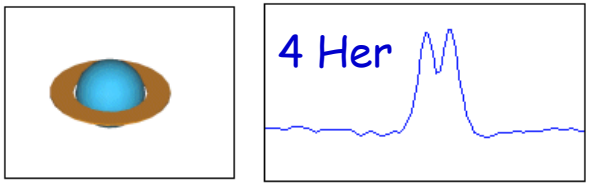


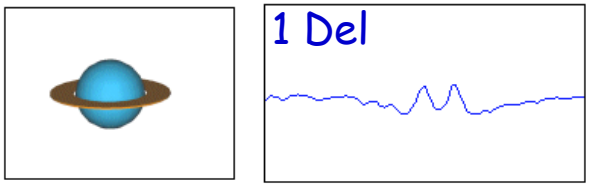
Possible Targets:

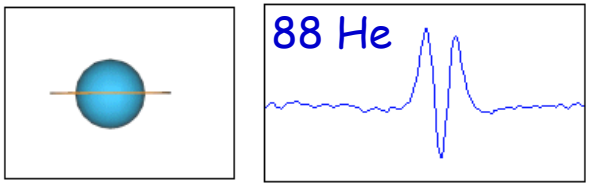
- b Persei 4.57
- Beta per (Algol) V~2.09
- zeta Cen (V~2.5)
- bet Lyr (V~3.3)
- AP Psc (V~6.04)
- TV Cas (Algol; V~7.22)

Science case 4: Be stars





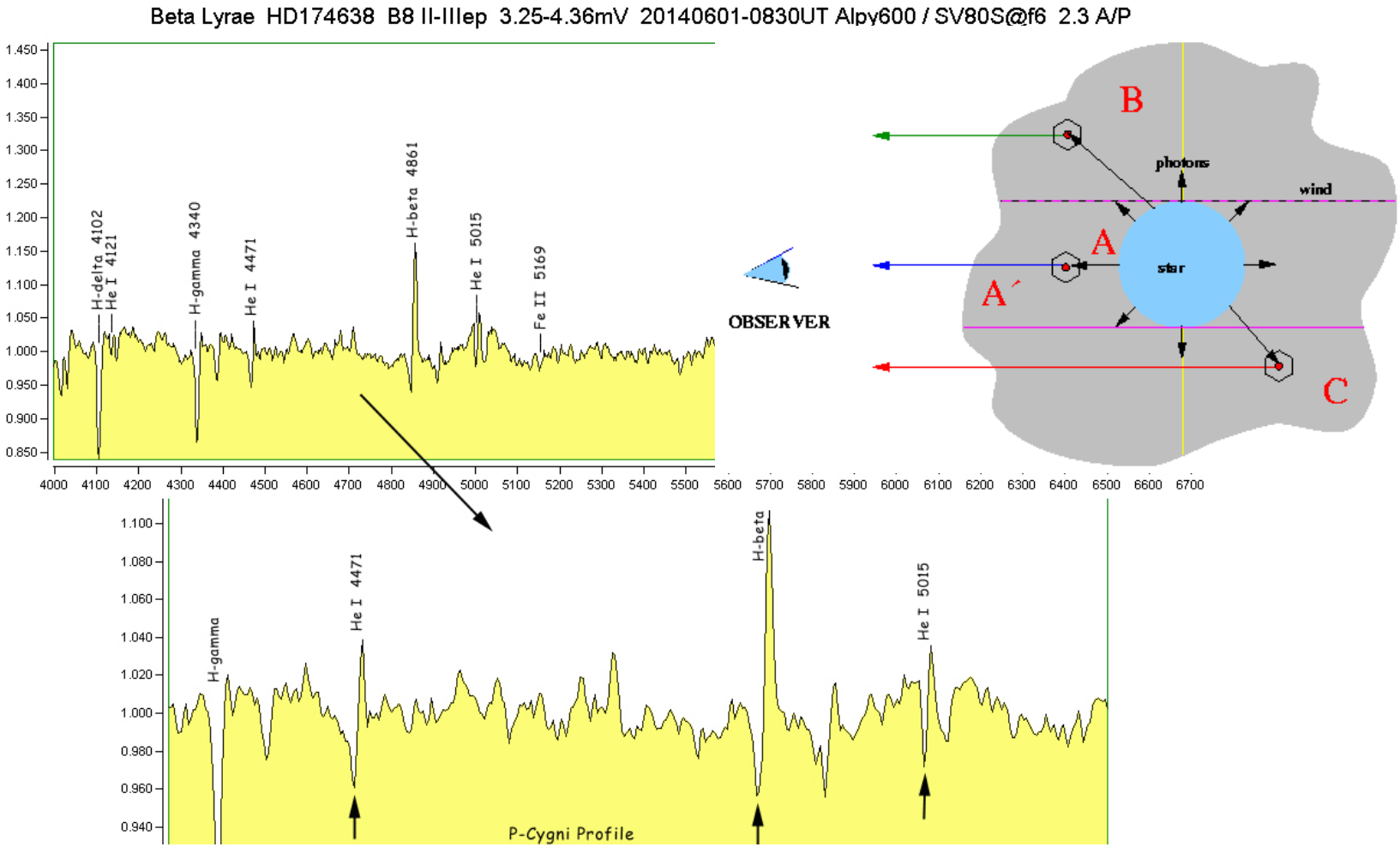




Emission regions: stellar atmosphere, accretion disk

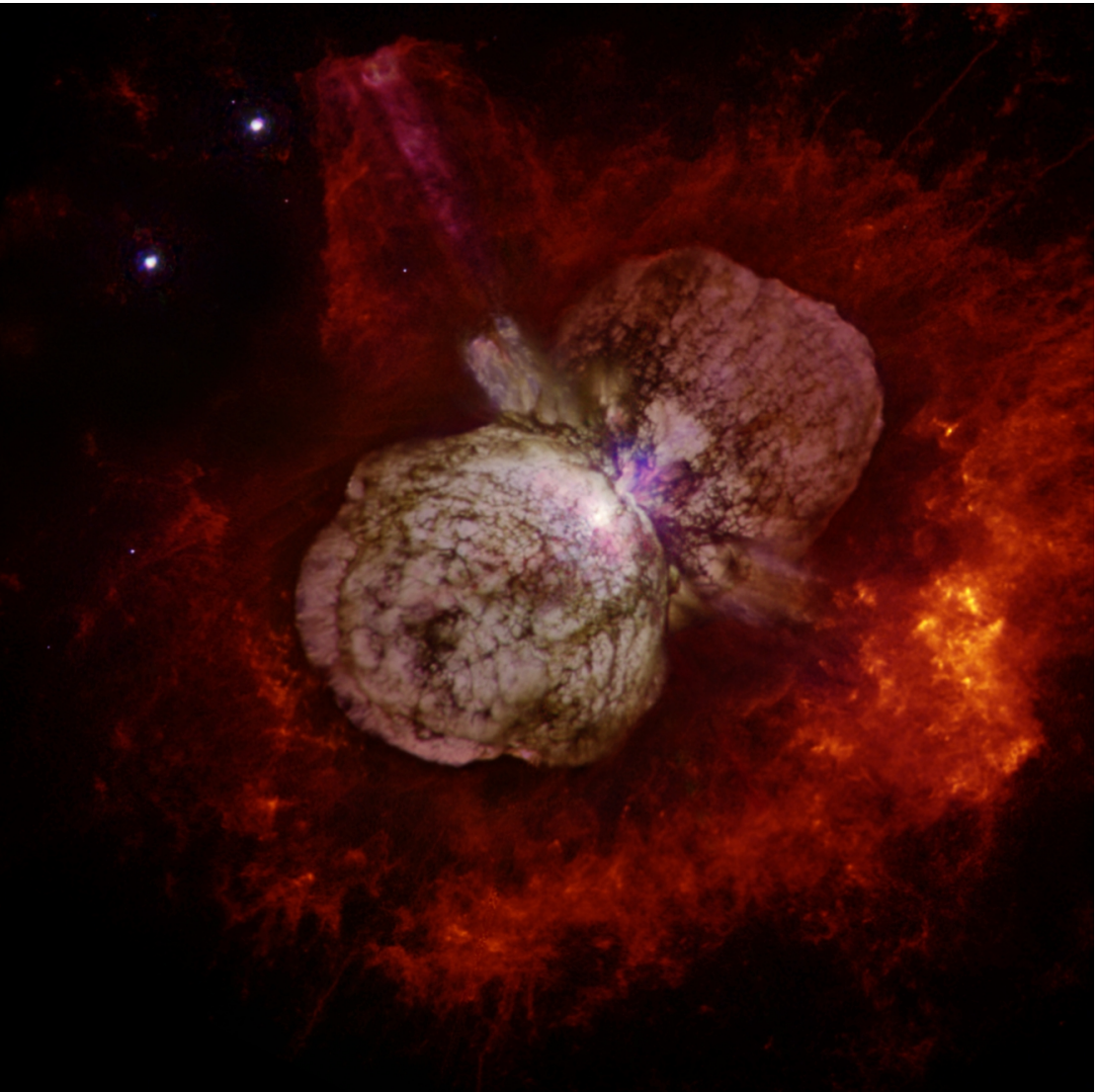
Absorption regions: outflow, accretion disk

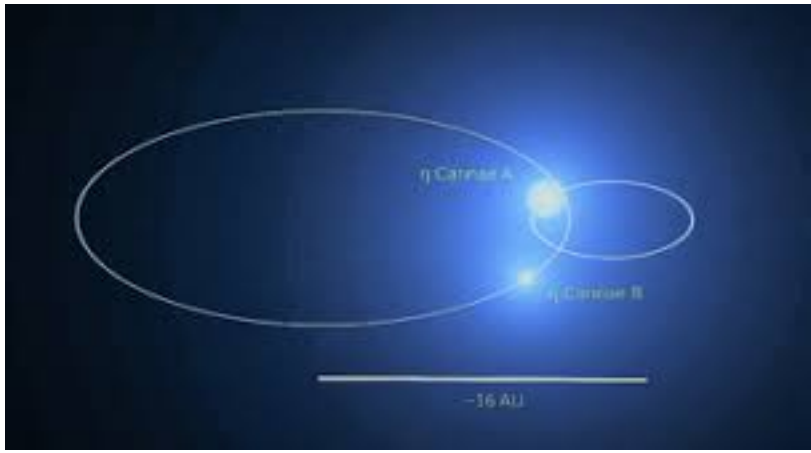
Science case 4: Be stars



Targets: BeSS Database (basebe.obspm.fr/)
Also see talks tomorrow

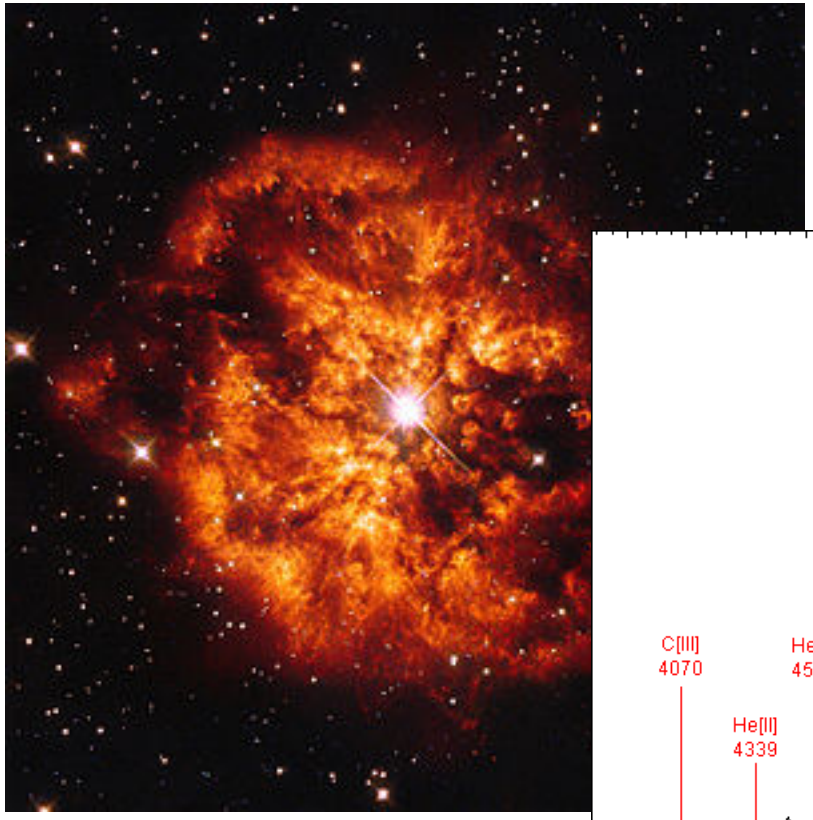
Science case 5: Massive hot stars --WR stars





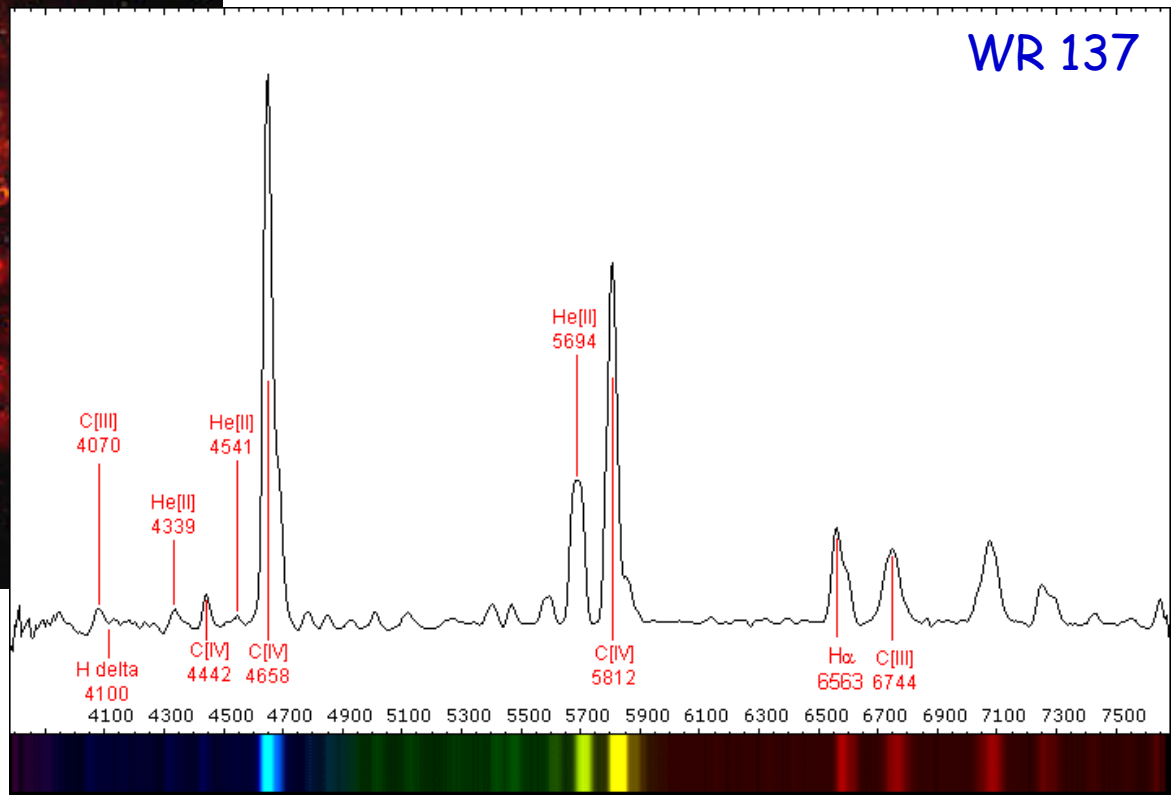
Eta Carina (NASA/HST)

Science case 5: Massive hot stars --WR stars



Nebula M1-67 around WR

Emission: highly ionized He and Ni or C; strong stellar winds, enhanced heavy elements



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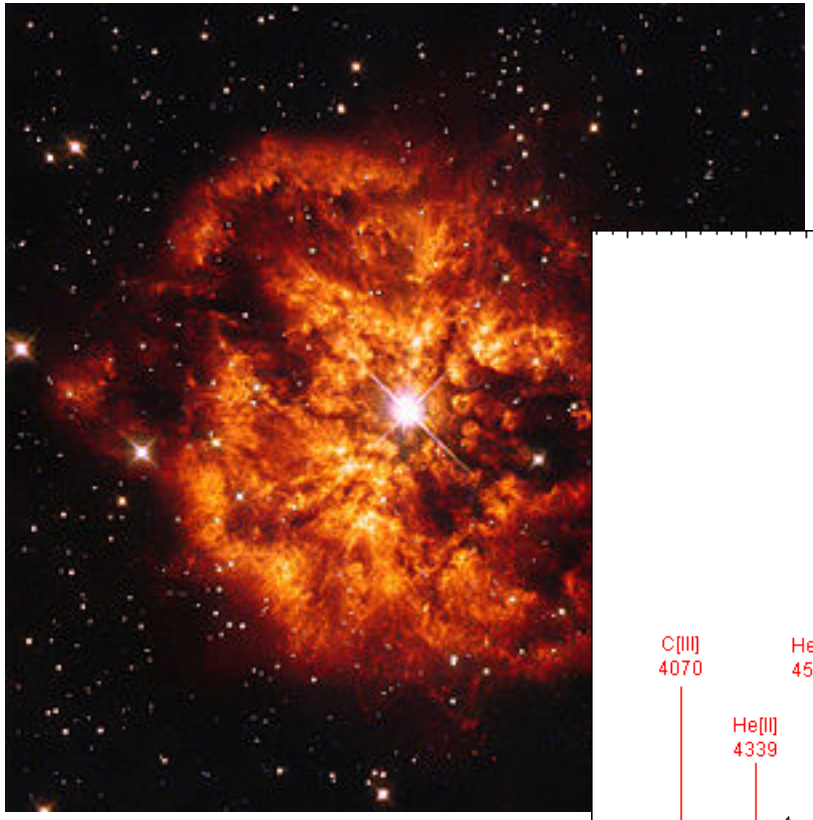

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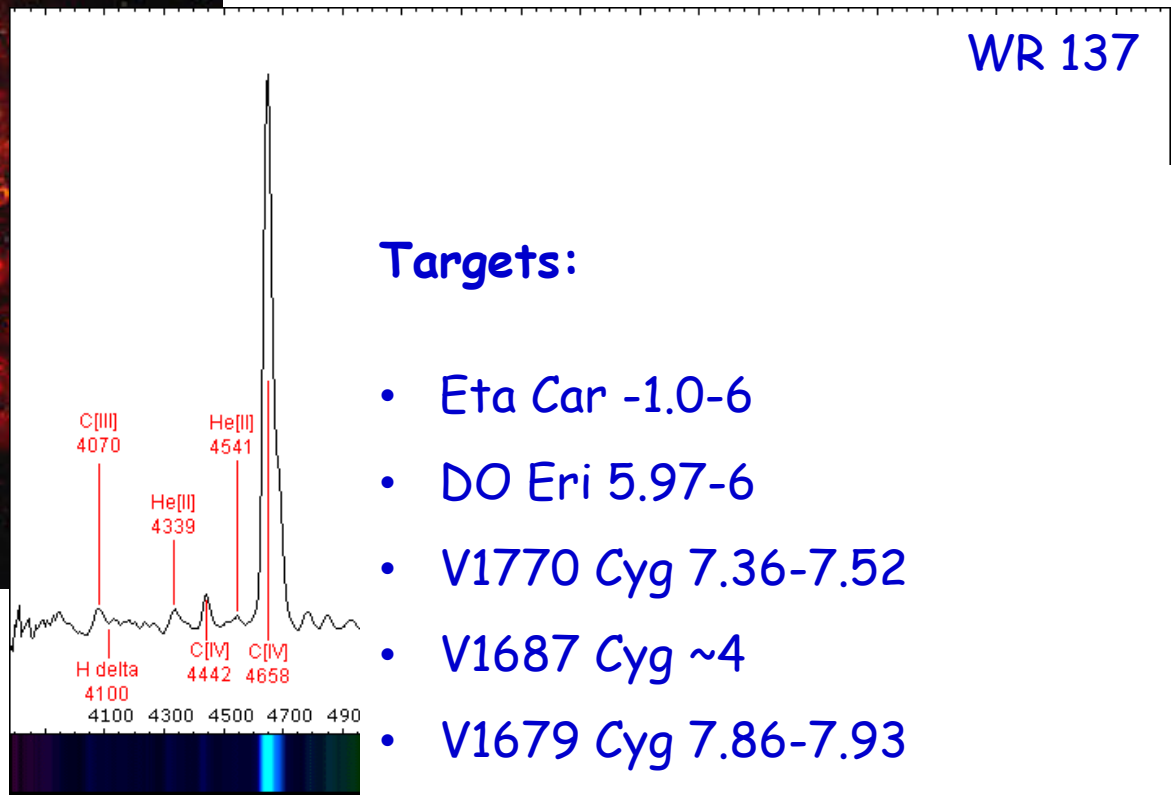
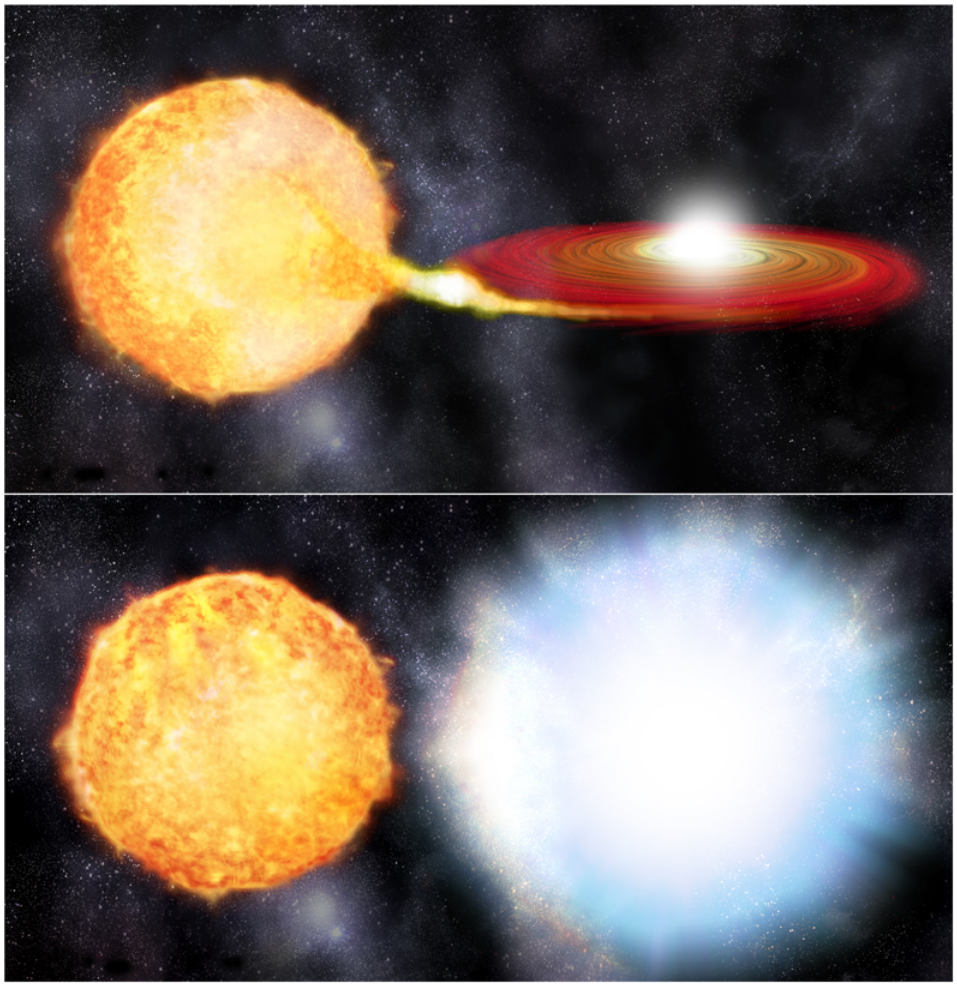


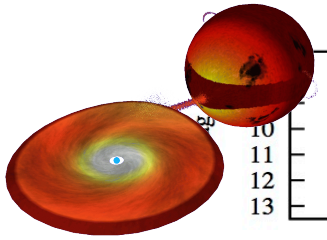
Targets:

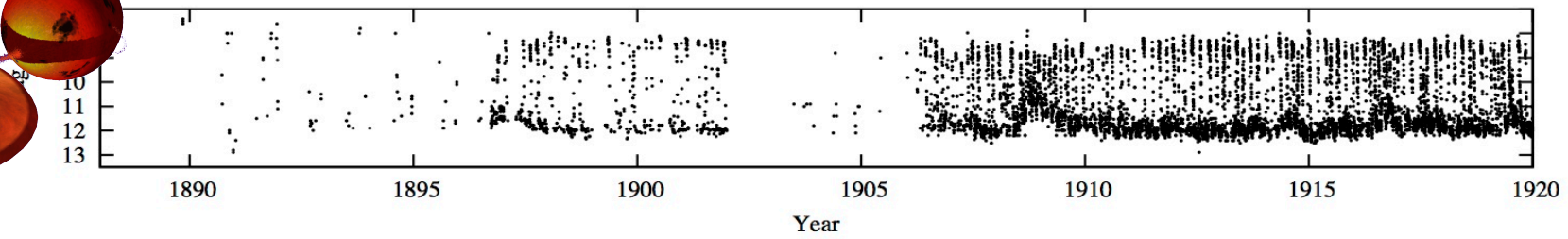
- Eta Car -1.0-6
- DO Eri 5.97-6
- V1770 Cyg 7.36-7.52
- V1687 Cyg ~4
- V1679 Cyg 7.86-7.93

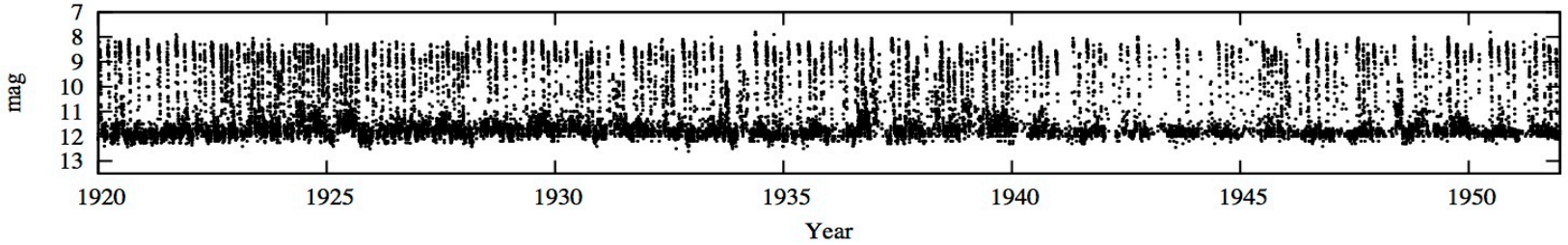
Science case 6: Cataclysmic/Symbiotic stars & Novae

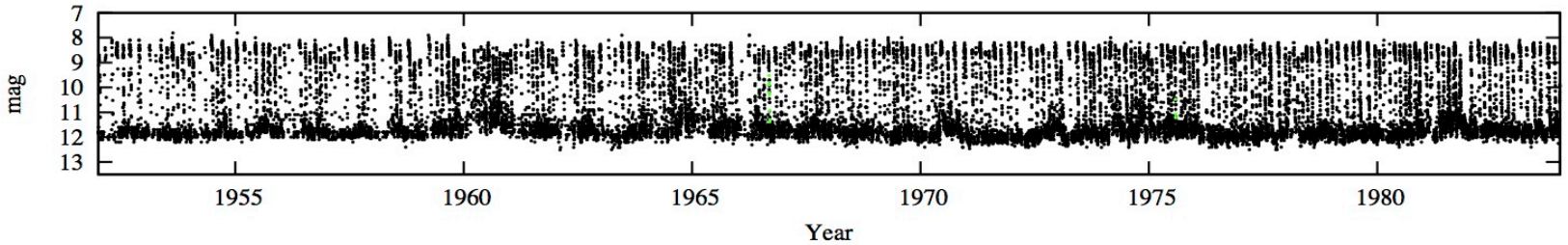


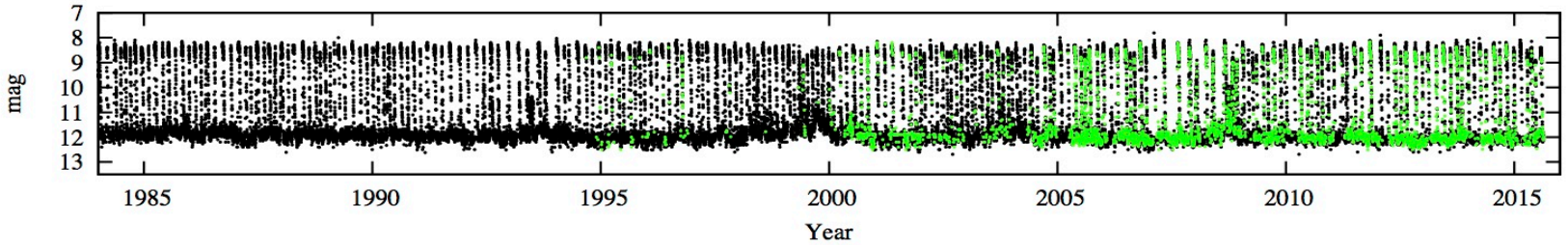
Science case 6: Cataclysmic/Symbiotic stars & Novae



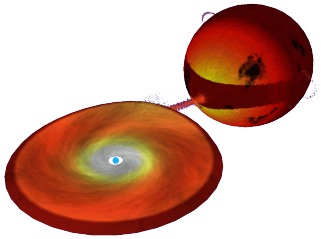


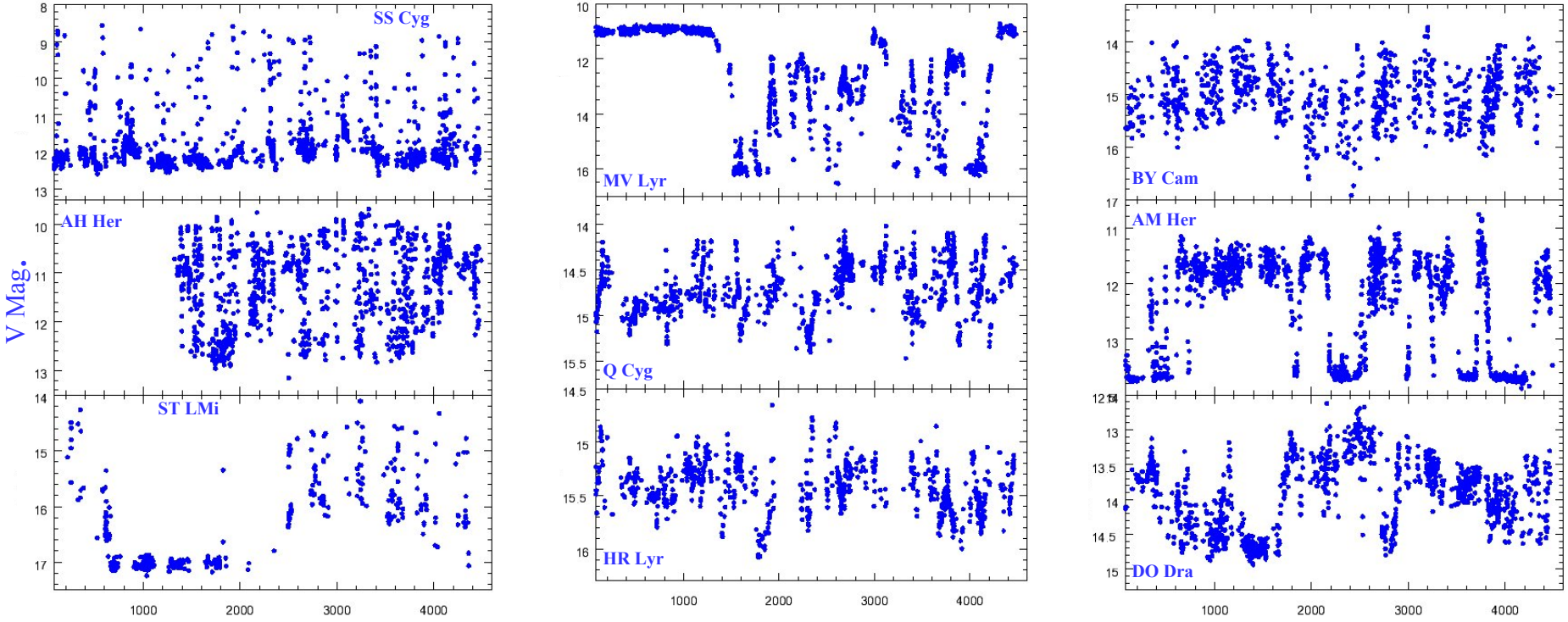






Science case 6: Cataclysmic/Symbiotic stars & Novae





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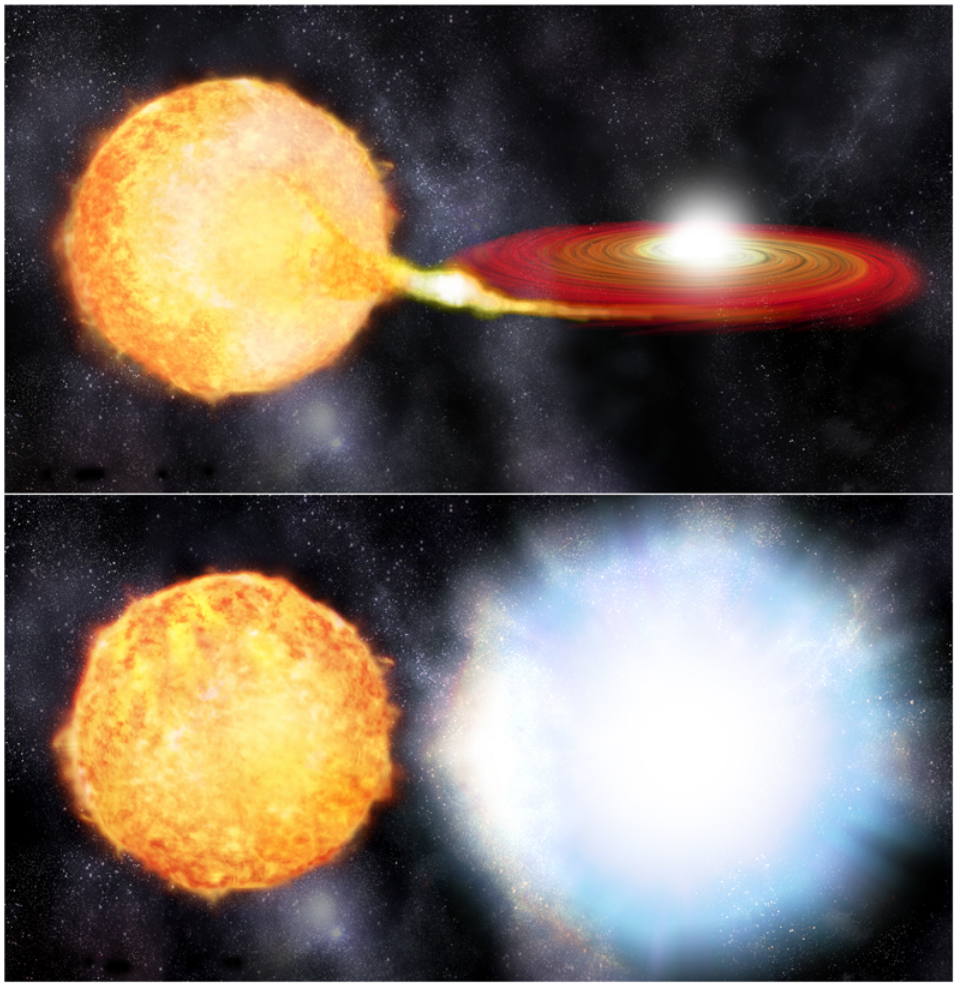
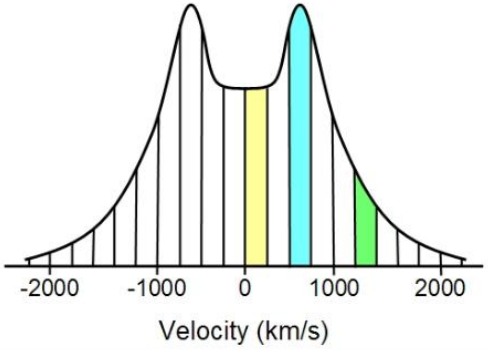
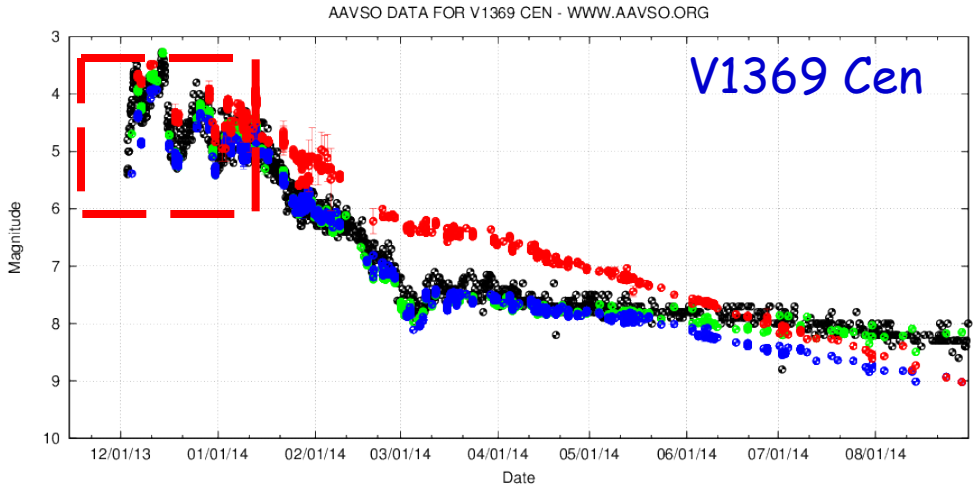


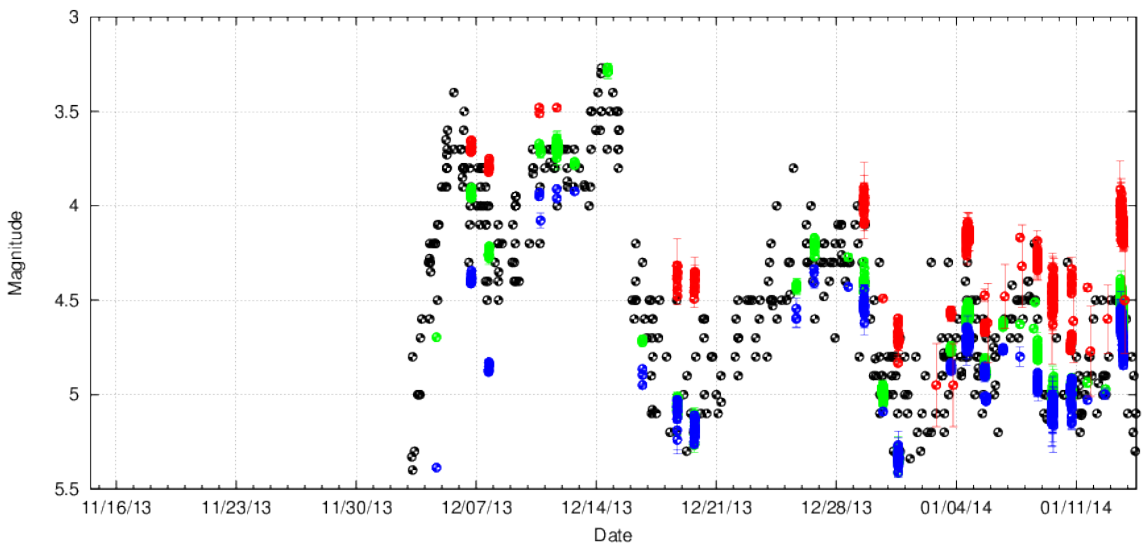
CV

- **Emission**: Accretion (disk, stream…)
  + Donor star (TiO)
- **Absorption**: WD, NaD (irradiation)

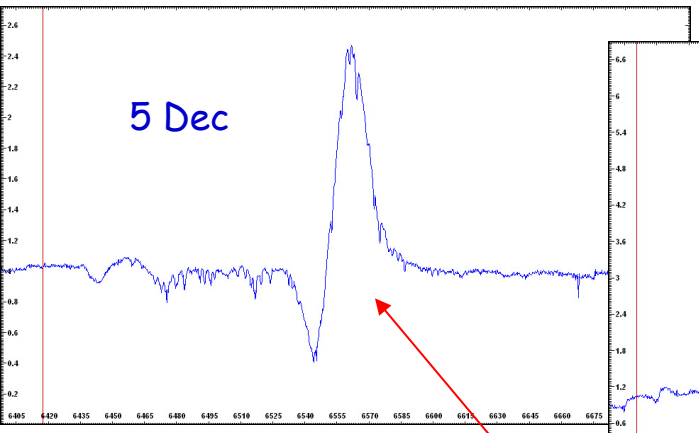


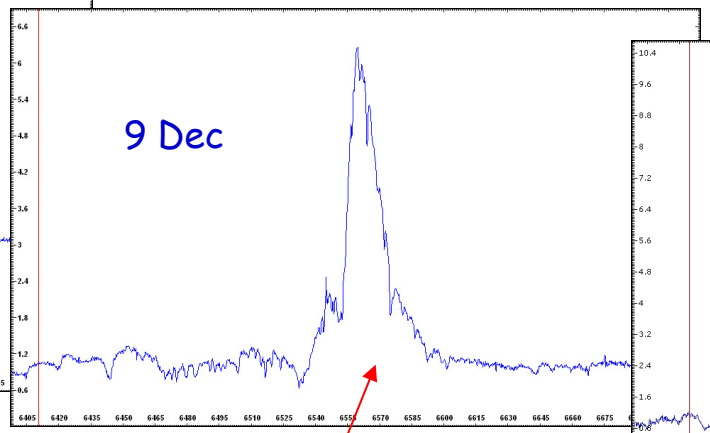
Science case 6: Cataclysmic/Symbiotic stars & Novae

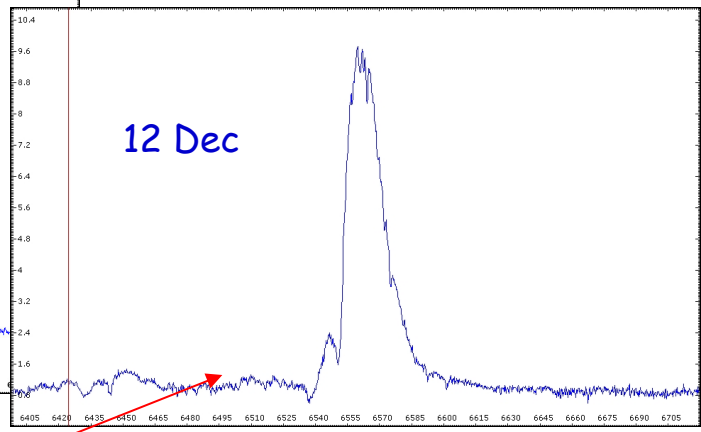


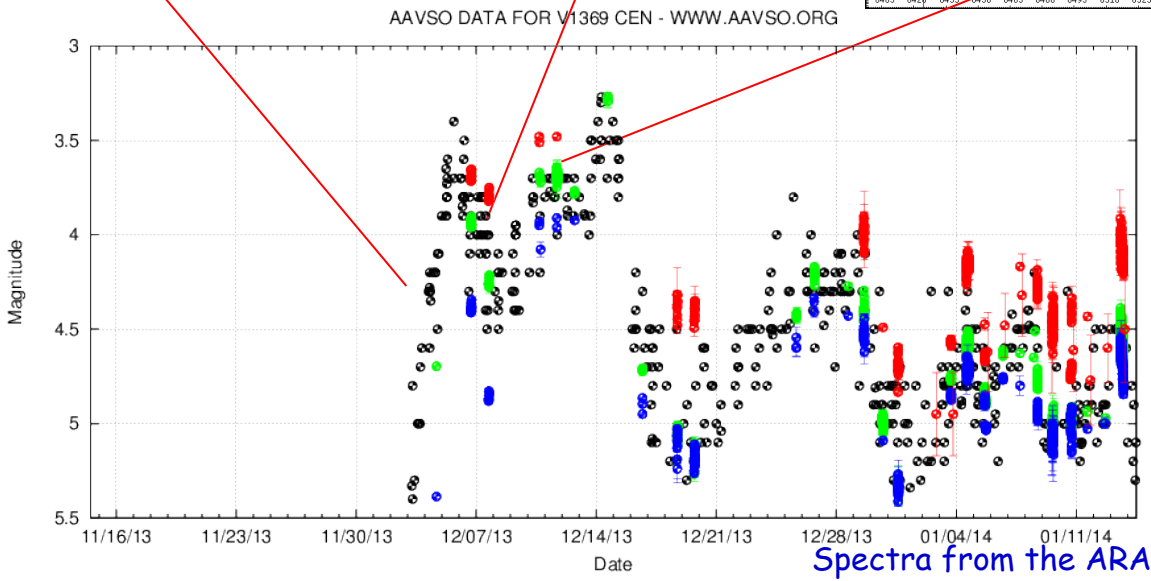


Science case 6: Cataclysmic/Symbiotic stars & Novae









Spectra from the ARAS database – T. Napoleao

Science case 6: Cataclysmic/Symbiotic stars & Novae

Dwarf novae
- SS Cyg 7.7-12.4
- U Gem 8.2-14.9
- VW Hyi 8.4-14.4
- GK Per 9.5-14.0

Nova-like
- IX Vel 9.1-10
- RW Sex 10.39-10.84
- V3885 Sgr 10.27-10.51
- TT Ari 10.2-16.5
- V603 Aql 11-12.4
- MV Lyr 12.2-18

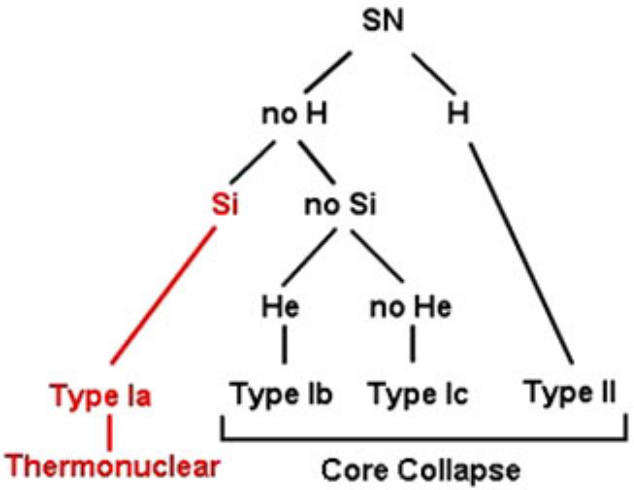
Misc. CVs of interest

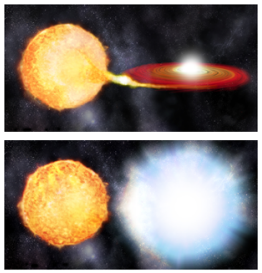
- BT Mon 14.5-16.4
- AE Aqr 10.18-12.12
- QU Car 10.9 -11.7
- V Sge 8.6-13.9

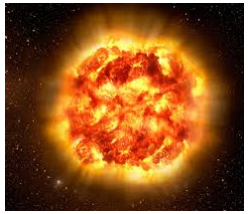
+ AAVSO Alerts

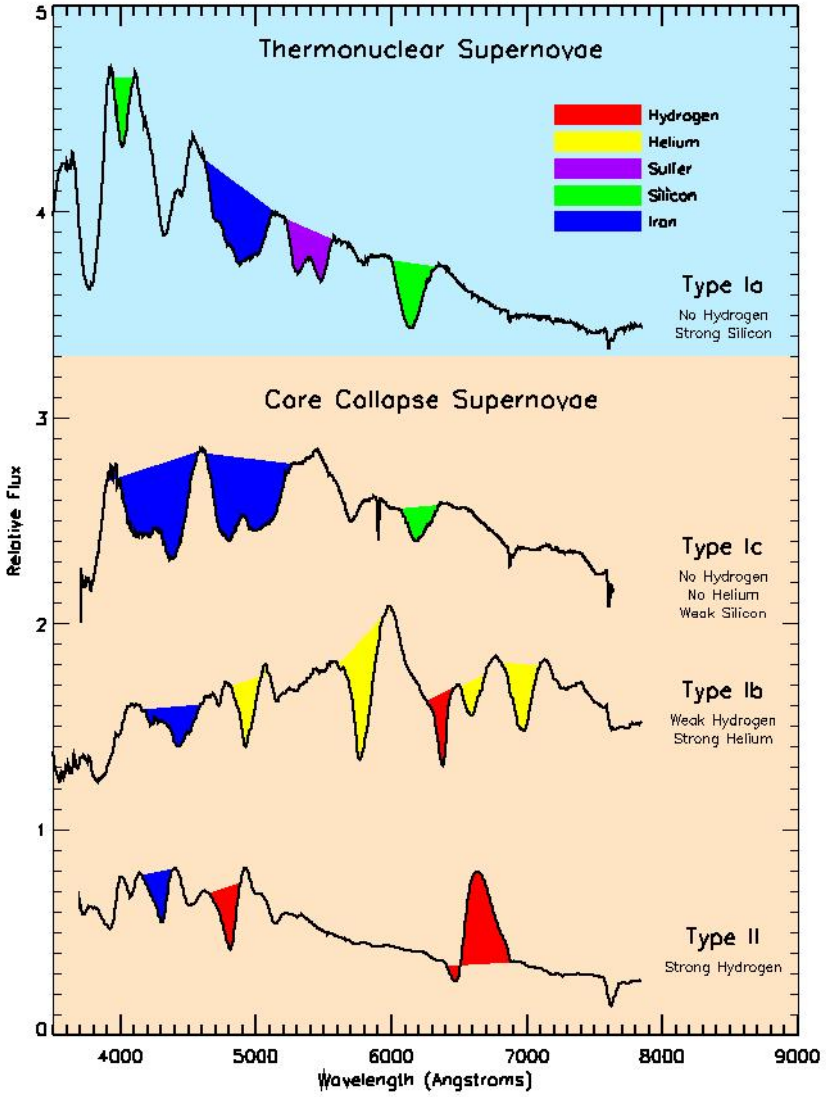
Spectra from the ARAS database – T. Napoleao

Science case 7: SNe Classification



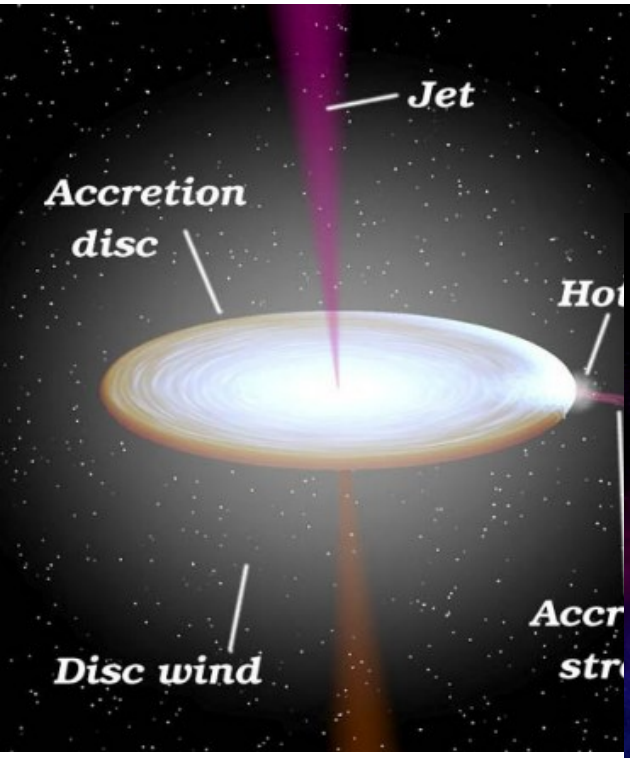


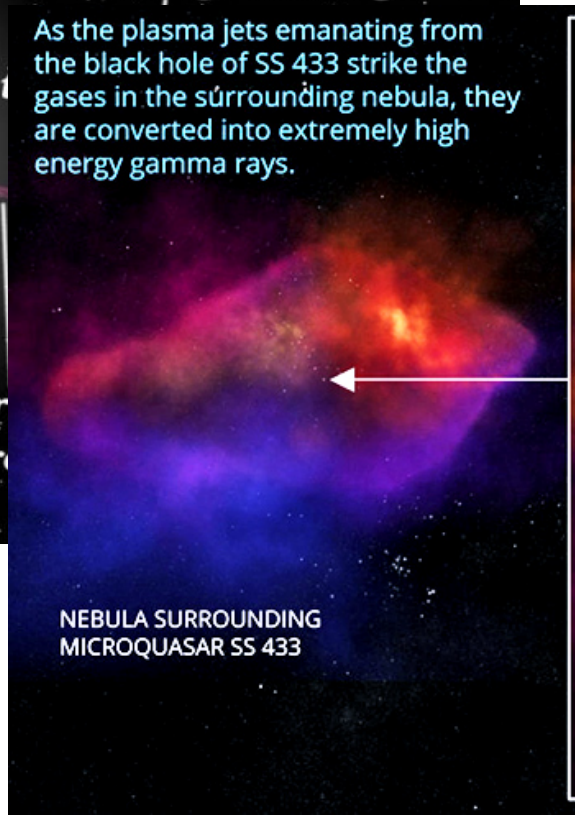


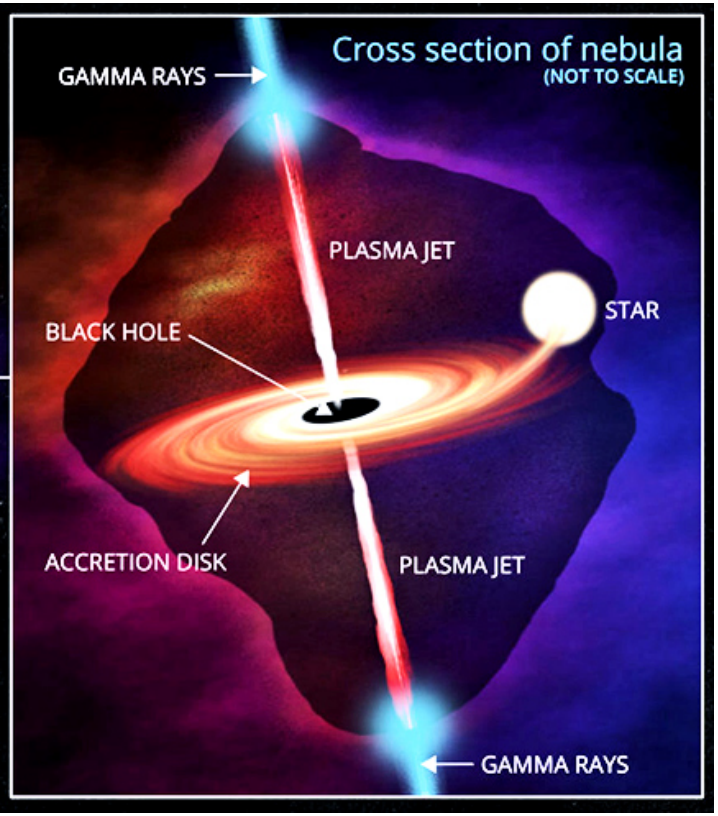


Look at ASAS-SN alerts

STRETCH GOAL
Science case 8: Microquasars







STRETCH GOAL
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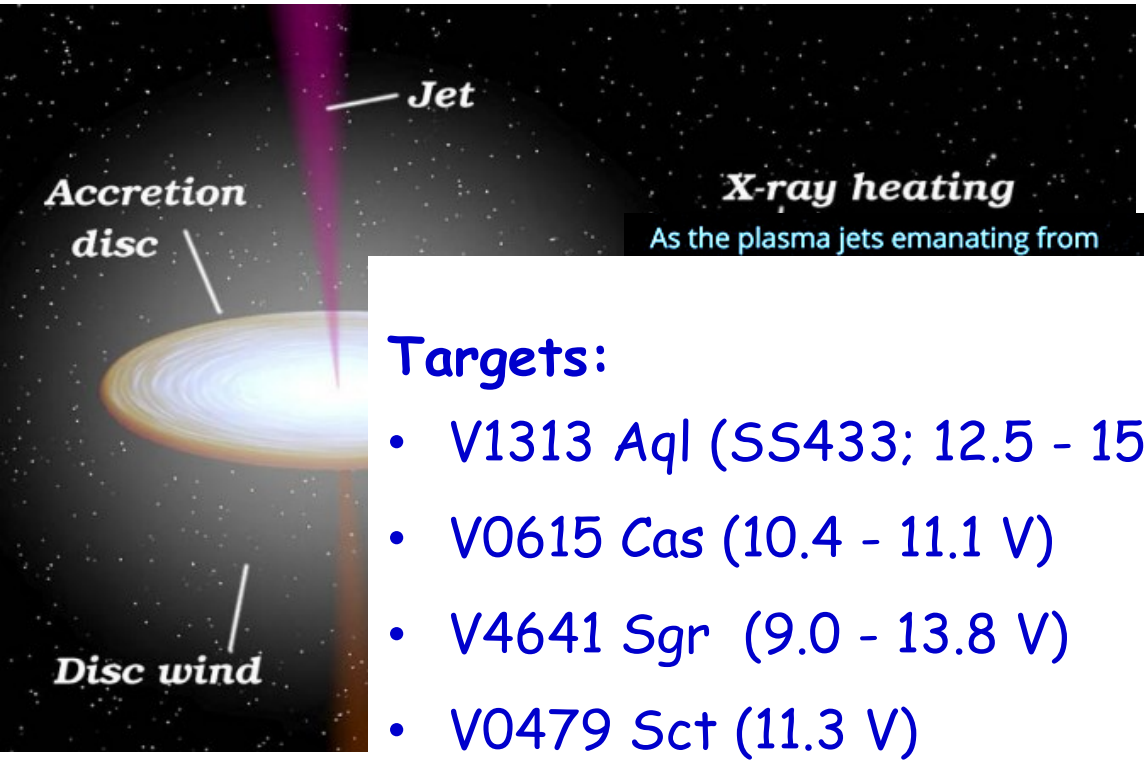
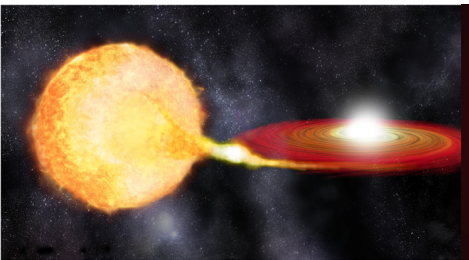
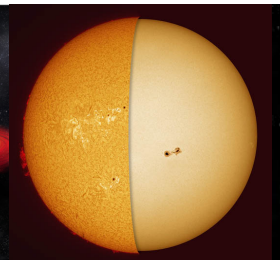
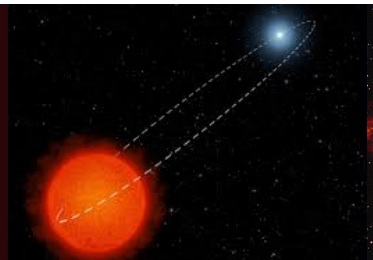


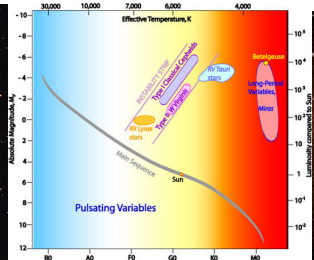
Targets:

- V1313 Aql (SS433; 12.5 - 15.2 V)
- V0615 Cas (10.4 - 11.1 V)
- V4641 Sgr (9.0 - 13.8 V)
- V0479 Sct (11.3 V)
- HD215227 (~8.7 V)
- NSV 16907 (~9.1 V)

Spectroscopy with small telescopes:

1) Chromospherically active stars
2) Pulsating stars
3) Binary stars
4) Be stars
5) WR stars (massive hot stars)
6) CVs/Symbiotics/novae
7) SNe classification
8) Microquasars

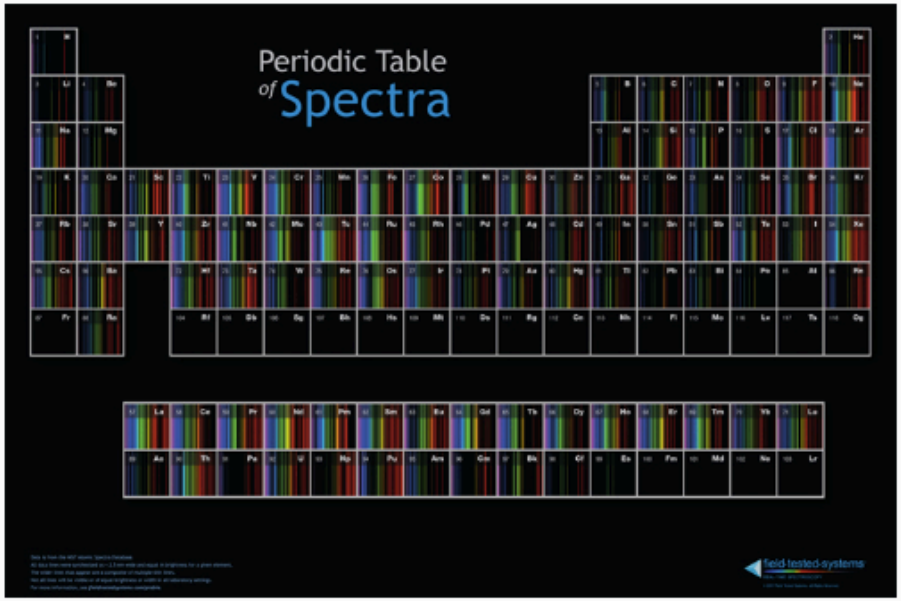






More Resources

Spectroscopy Observing Section

View | Edit



Periodic Table of Spectra (Tom Field)

Ryan Maderak, Ulisse Munari, Christian Knigge, Noel Richardson, Róbert Szabó (TESS astroseism.), Stella Kafka et al.

https://www.aavso.org/spectroscopy-observing-section

Spectroscopy Observing Section

AAVSO resources

- AAVSO Spectroscopy Manual
- AAVSO Spectroscopic Database: submit your spectra
- Help file to submit your spectra

Other resources

- Guide to Spectroscopy and Spectral Lines from Astrobites
- Video: "How to capture star spectra in your backyard" by Tom Field
- Recommended reading: "Successfully Starting in Astronomical Spectroscopy: A Practical Guide"

More Resources

Introduction

Spectroscopic monitoring of variable stars is a relatively unexplored domain within astronomy, with the potential to produce a wealth of new information. W
studied with high time resolution spectr
data for variables does not yet exist. Ma
meaning we lack the information that co
problems (such as the perplexing behav
Even for shorter period variables, there
There are many bright variables with litt
telescopes have an opportunity to make

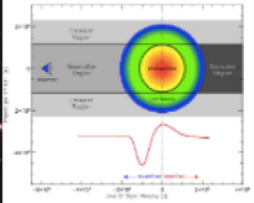
We provide here brief overviews of: th
spectroscopic data; what to consider wh
recommend for spectroscopic observati
the accompanying manuals and guides.

Introduction to Stellar Spectra

A basic stellar spectrum consists of th
absorption lines resulting from atomic e
corresponding to atomic energy level tra
element within the star, as well as the te
star's spectrum can therefore be used t
abundances/composition.

The surface temperature of a star can

Wolf-Rayet (WR) outflows (Noel Douglas Richardson)



Emission: highly ionized He, Si, O, N or C; strong stellar winds with P Cygni absorption profiles; enhanced heavy elements. Lines change with time, as winds evolve and expand. Study long-term evolution of line profiles, and evolution of P-Cygni.

Stars of interest (desired cadence: 1 spectrum per night or continuous monitoring):

Star	Bright mag (V)	Faint mag (V)	Spectral type
Eta Car	-1.0	6	pec(e)
DO Eri	5.97	6	A5p(Sr-Cr-Eu)
V1770 Cyg	7.36	7.52	WR
V1687 Cyg	~4		WR
V1679 Cyg	7.86	7.93	WR

Targets, Info, Cadence, min resolution

Guide"

https://www.aavso.org/spectroscopy-observing-section

More Resources

Introduction

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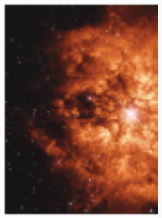


Emission: highly ic
elements. Lines ch
P-Cygni.

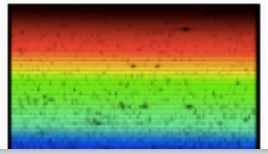
Stars of interest (d

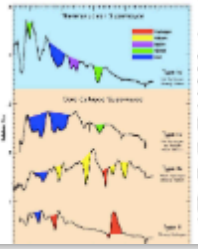
Star
Eta Car
DO Eri
V1770 Cyg
V1687 Cyg
V1679 Cyg

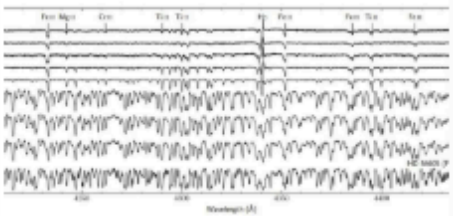
Individual targets (from alerts and campaigns; desired cadence: as frequently as possible)

Please follow the alert link for more information on spectroscopic requirements of observations

Target	Var type	Mag range	Alert link	Notes
b Persei	eclipsing	4.55-4.75	Alert 655	spectroscopy needed during eclipse
N Nor 2018	nova	10.5 (at discovery)	Alert 653	all resolutions, all spectral ranges
V1307 Ori	HerbigAeBe	9.48-9.83 V	Alert 657	H-alpha spectroscopy, all resolutions
R Mon	HerbigAeBe	11-13.8 B	Alert 657	H-alpha spectroscopy, all resolutions
V1410 Ori	HerbigAeBe	9.39-9.73 V	Alert 657	H-alpha spectroscopy, all resolutions
V346 Ori	HerbigAeBe	10.1-10.9 V	Alert 657	H-alpha spectroscopy, all resolutions
V1295 Aql	HerbigAeBe	7.87-7.89 V	Alert 657	H-alpha spectroscopy, all resolutions





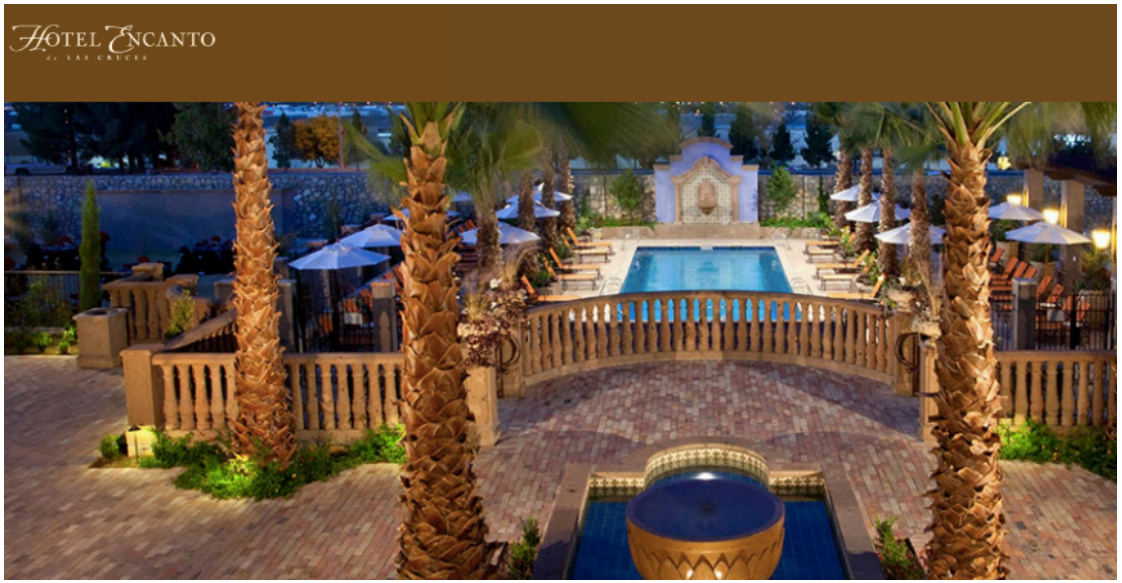


Guide"

https://www.aavso.org/spectroscopy-observing-section

"The mission of the AAVSO is to enable anyone, anywhere, to participate in scientific discovery through variable star astronomy"

Save the date:



108th Annual Meeting

"Science Under the Same Dark Skies"

October 17 - 20, 2019

Hotel Encanto

Las Cruces, NM

https://www.aavso.org/aavso-meetings

"The mission of the AAVSO is to enable anyone, anywhere, to participate in scientific discovery thr ariable star astronomy"

JUST DO IT.

Spectroscopy with small telescopes:

Resources:

- AAVSO **Alerts** (targets of interest - subscribe)

https://www.aavso.org/alert-and-special-notices AAVSO

- Spectroscopic **Observing Section**

https://www.aavso.org/spectroscopy-observing-section

Become a member!

www.aavso.org

Contact email: ***skafka@aavso.org***

Clear skies - THANK YOU!