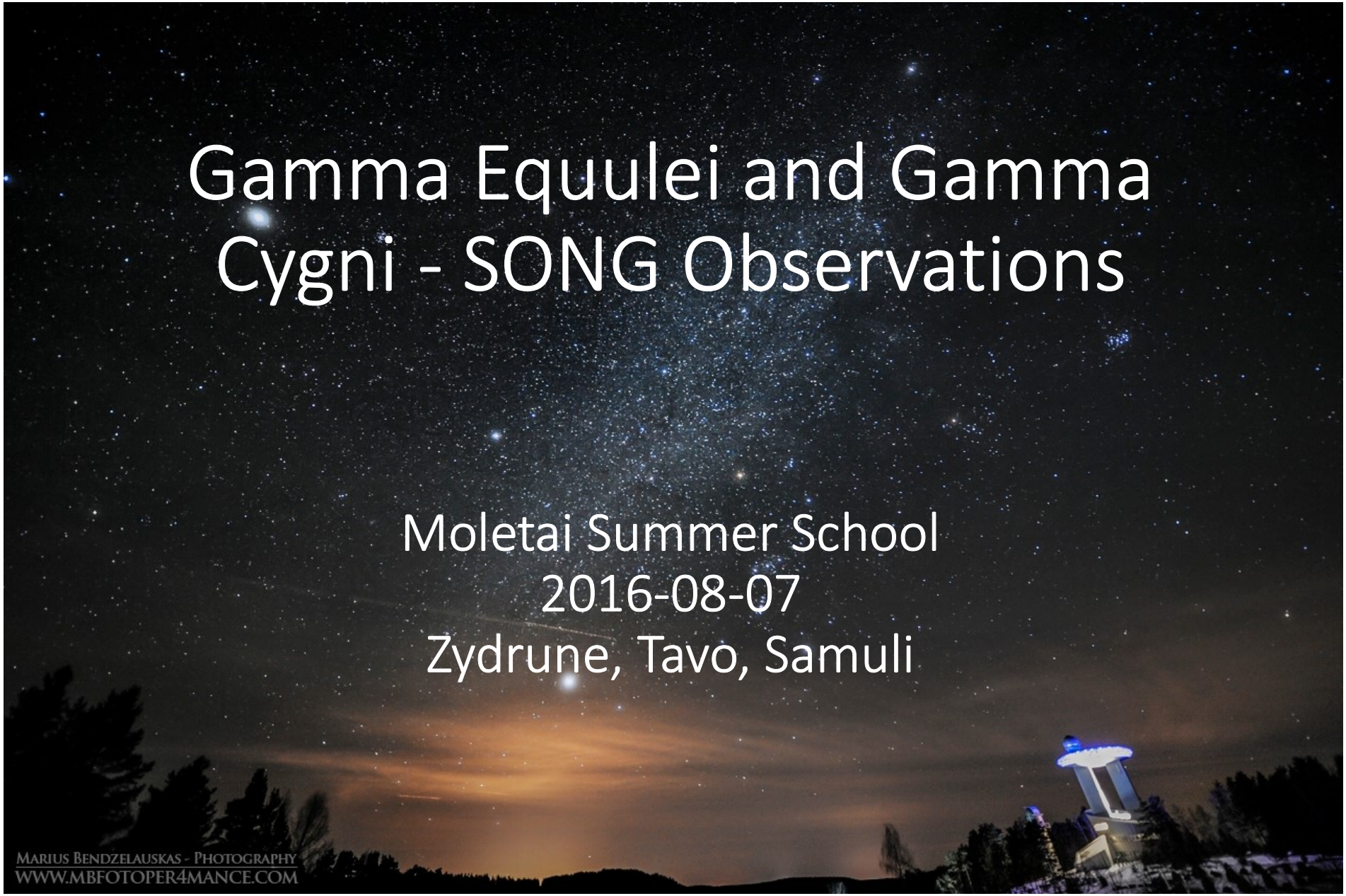


# Gamma Equulei and Gamma Cygni - SONG Observations

Moletai Summer School
2016-08-07
Zydrune, Tavo, Samuli


INTRODUCTION
Marius Bendzelauskas - Photography
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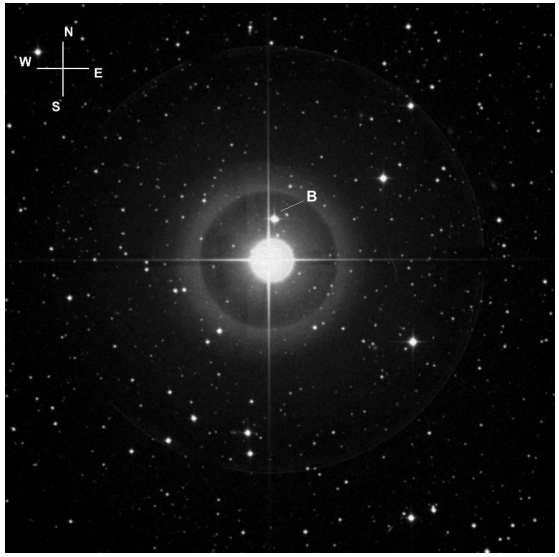
# Introduction

The project was split into two parts:
1. Analysis of observed data of γ Equulei
2. Identification of another bright star and observations of selected star: γ Cygni

Both were observed with SONG telescope.





SONG
Marius Bendzelauskas - Photography
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# SONG

- Stellar Observations Network Group
- Launched in 2006
- Fully robotic

- **Aim:**

Global network of 8 telescopes assuring continous data collection

- **Scientific goals of SONG are:**

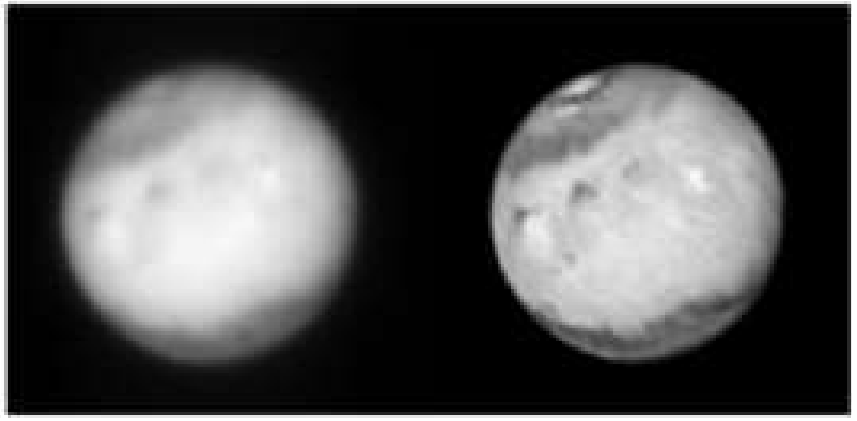
- study the internal structure and evolution of stars using asteroseismology
- to search for and characterize planets with masses comparable to the Earth in orbit around other stars.

- Currently building a telescope in China -> testing phase

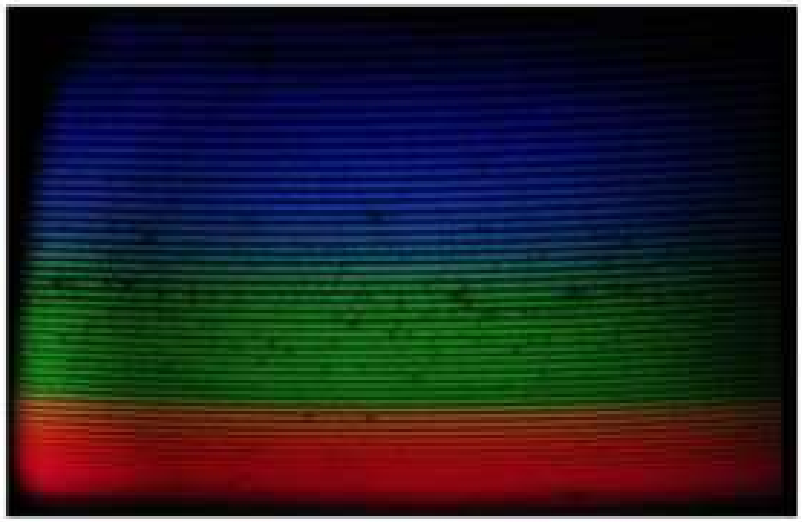
Telescope is 1m in diameter located at the Observatorio del Teide on Tenerife

# SONG Lucky Imaging

It's a technique to remove the smearing effect the atmosphere causes of stars on images.



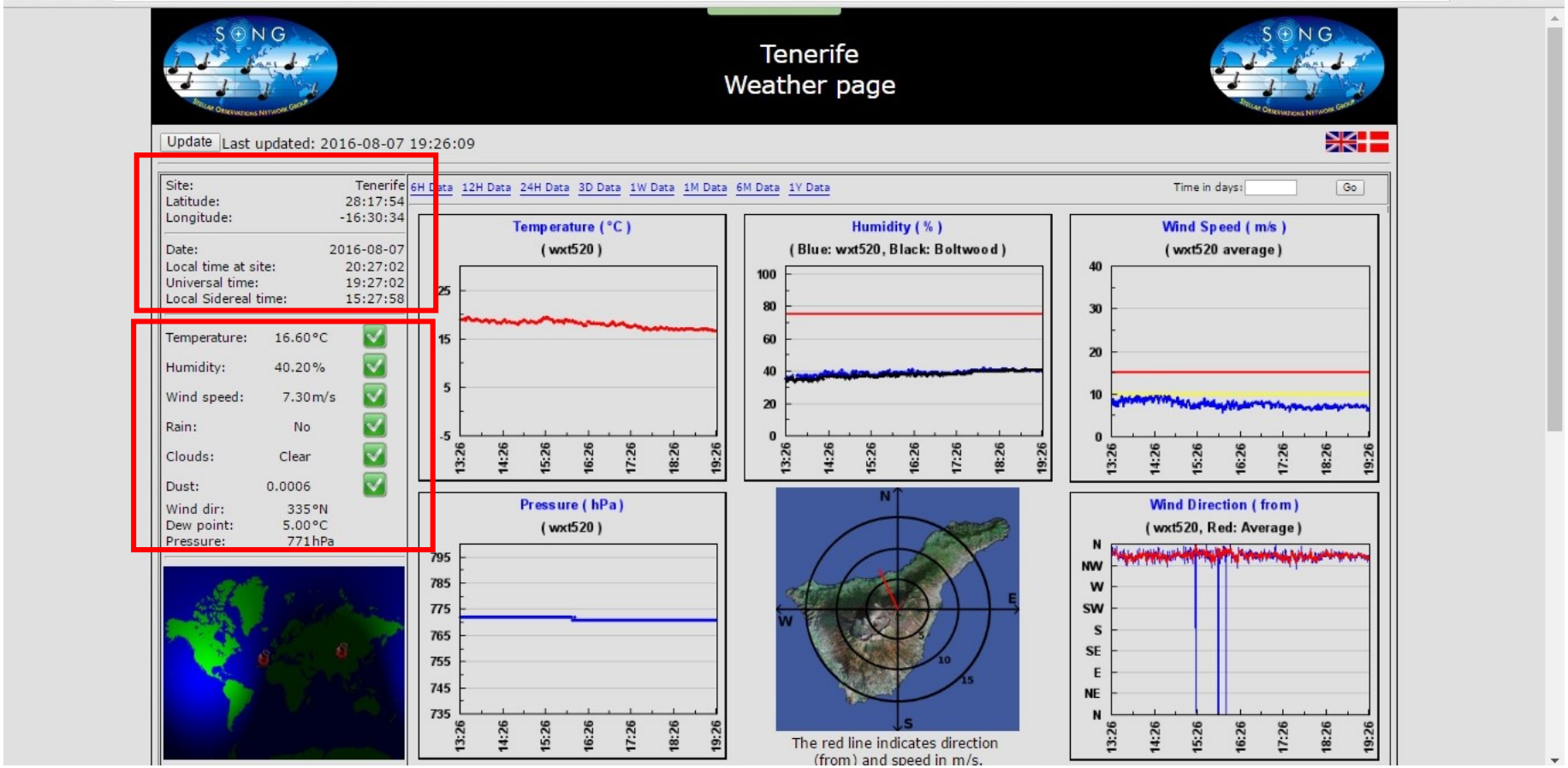
# SONG Spectrograph



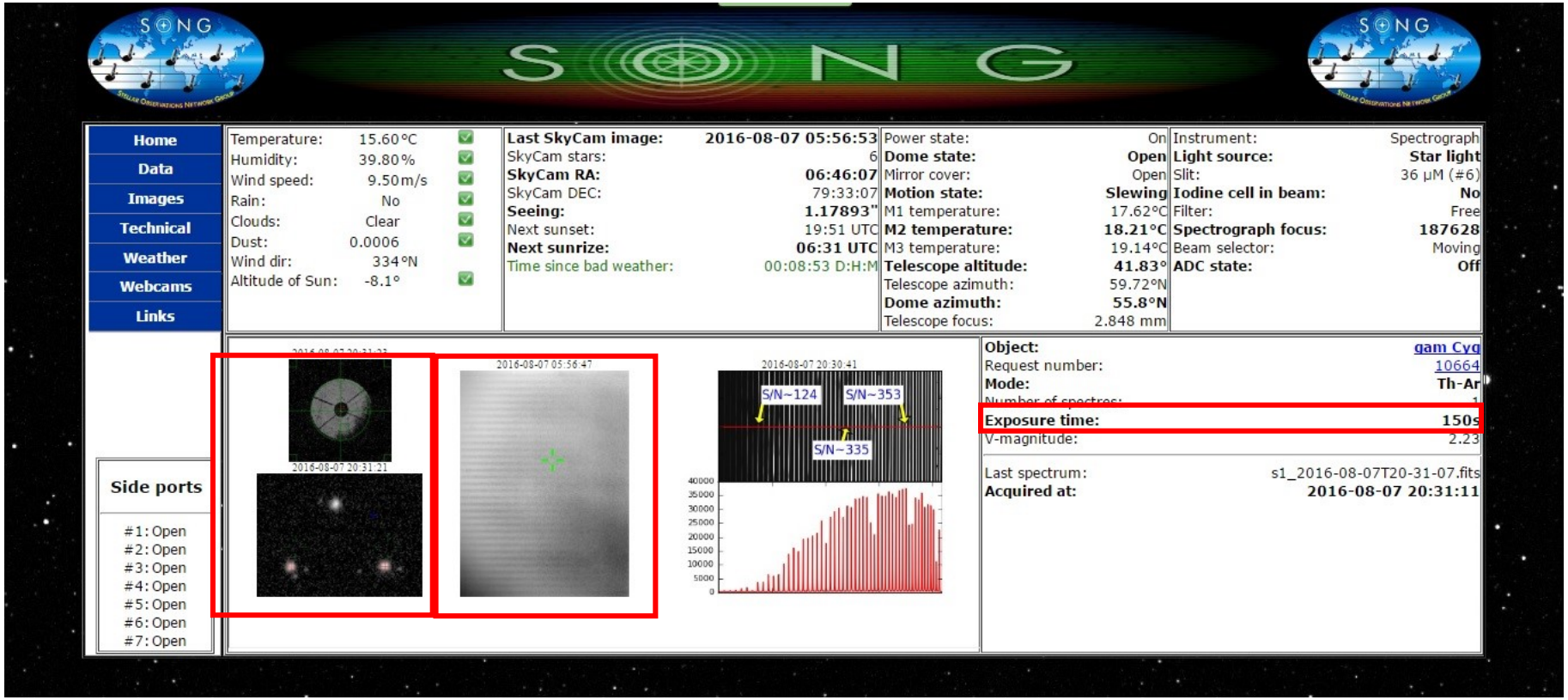
Separates the light into its different colours allowing us to study them individually which can be used to determine the mass, size and chemical composition of stars.

Picture shows the output spectrum from this spectrograph.

# WEATHER OBSERVATIONS



# DATA ACQUISITION OBSERVATIONS




GAMMA EQUULEI
Marius Bendzelauskas - Photography
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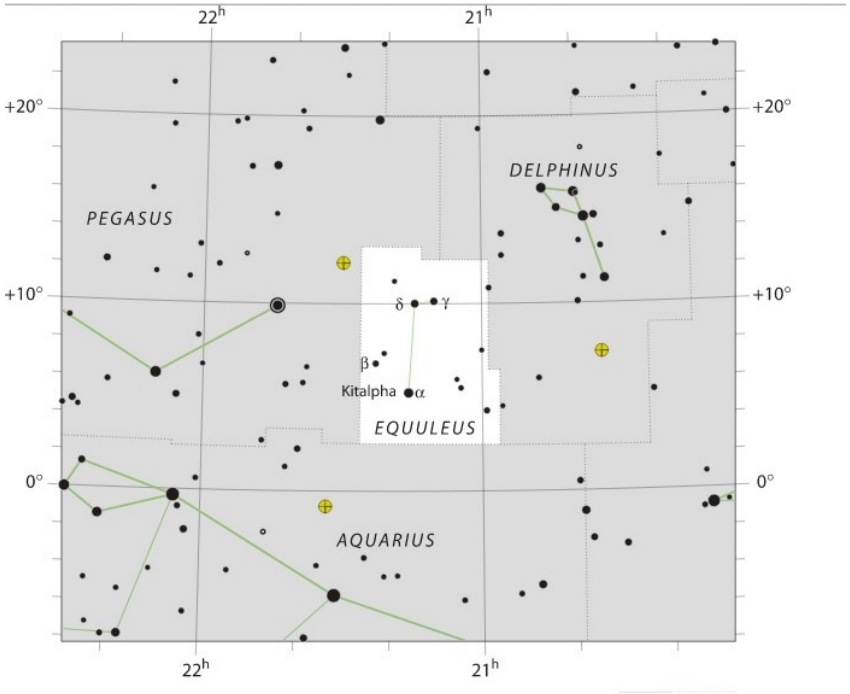
# GAMMA EQUULEI




- γ Equ is a double star in the northen constellation of Equuleus.
- At a distance of around 118 ly
- With apparent visual magnitude of 4.7
- Primary component is a chemically peculiar star of A9 type
- It undergoes periodic pulsations in luminosity
- Surface magnetic field undergoes long term variation with a period of 91.1 ± 3.6 yrs
- Variable radial velocity -17km/s
- $T_{eff}$ about 8790 (few diff. values)
- log.g = 4.49
- Vsini = 10 r
- why low **vsin i** values are good? -> slow rotator

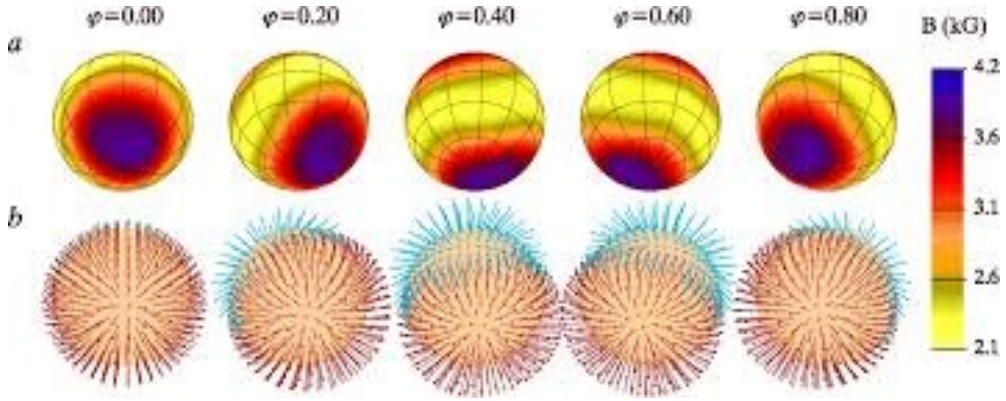
# GAMMA EQUULEI: Background [ref.1]

- γ Equulei is the second brightest roAp star. It's the slowest rotator among Ap stars with a **period of 77 ± 10 yr** which was determined from longitudinal magnetic field measurements by Leroy et al. (1994)
- Though short-term spectroscopic variability of γ Equulei may be caused by non-radial oscillations.

**So what are roAp stars?**

RoAp stars are cool magnetic Ap stars that exhibit short-timescale rapid photometric or radial velocity variations with periods in the range of 6-16 min and very low amplitudes. [ref 2] In many cases, the amplitude of the light is modulated with the rotational period of the star, as its apparent magnetic field strength.

# GAMMA EQUULEI: Background [ref.1]




Magnetic Doopler imaging of RoAp stars

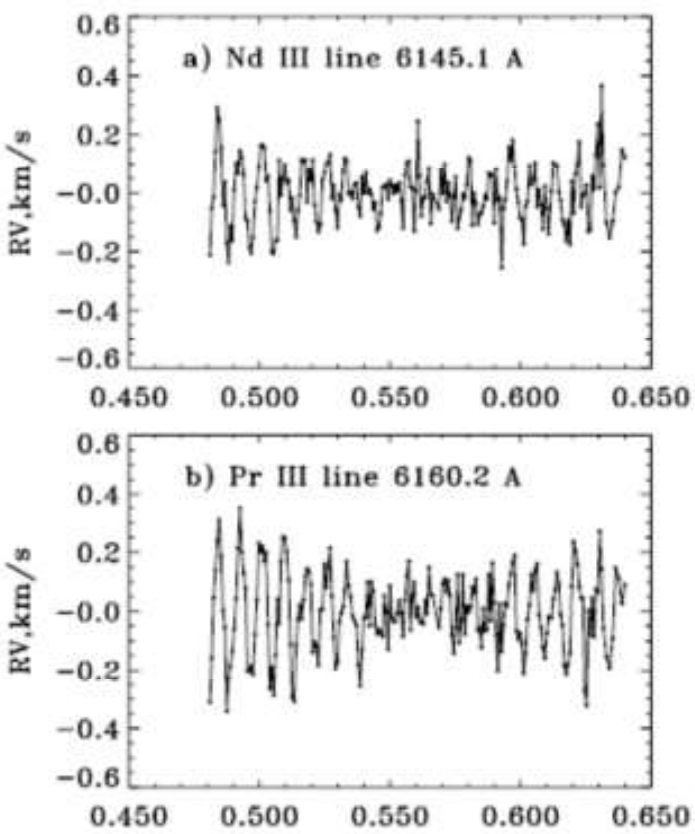
Oscillations are due to high-overtone p-mode pulsations, and appear in B and V filters of the Johnson broadband photometric system. [ref 5]

- Line profile variations in γ Equ show the classic blue-to-red travelling bumps of m-modes resolved by rotation, identified as l=2 or 3, m = -l or -l +1
- γ Equ has virtually no rotation -> no significant rotational broadening of the spectral lines and this is different from the case of rapidly rotating B stars. [ref 2]

# GAMMA EQUULEI: Background [ref.1]

- Malanushenko et al. (1998) discovered that the higest RV variations, up to 800 $ms^{-1}$ with the exception for **Nd III 6145.07Å and Pr III 6160.24Å lines with periods 12.25 ± 0.05 min and 12.35 ± 0.05 min**, respectively.
- There are no other lines in the 6140-6166 Å spectral region that are suitable for accurate movement measurement.
- So this is the reason why we will try to look at these lines while analysing the sprectra.

- From the shift between the synthetic and average observed spectrum it was found that the **mean radial velocity of γ Equ is -16.87 km/s** (Mkrtichian et al. 1998).



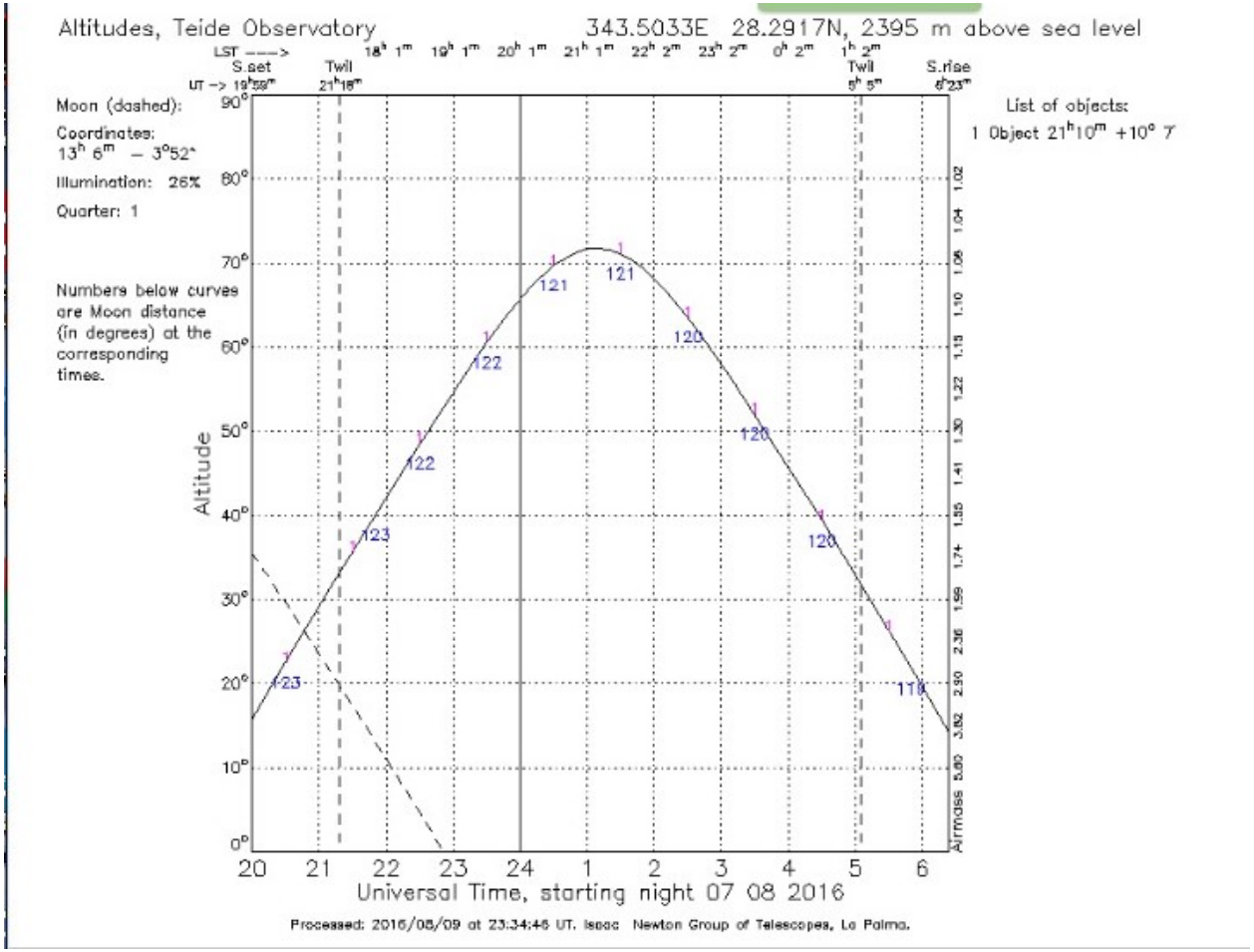
Variations of radial velocity

# GAMMA EQUULEI: Magnetic Field Variability

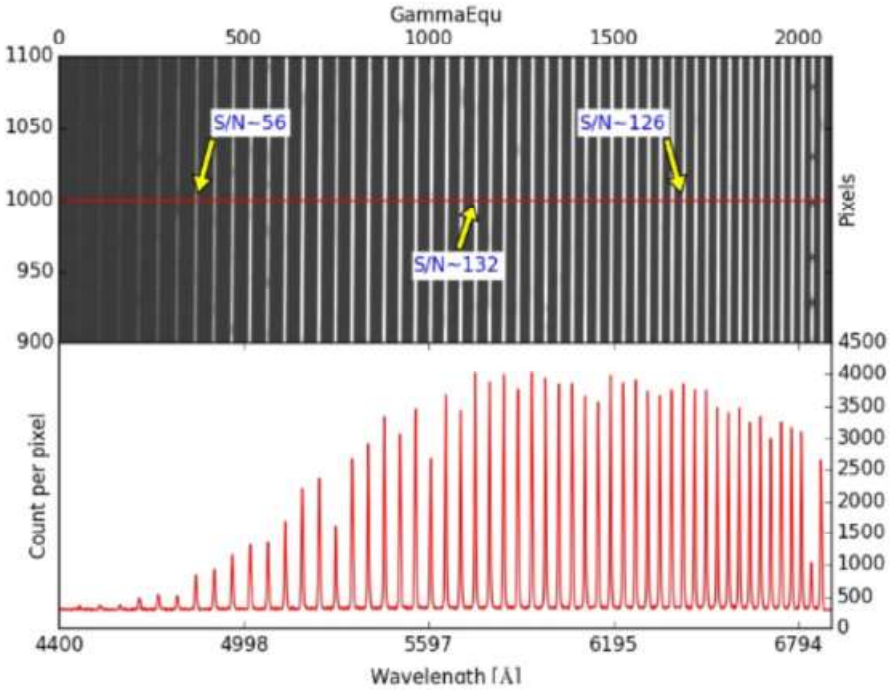
[ref.4]

- Leone and Kurtz (2003) reported a discovery of rapid variations of the stellar longitudinal (effective) **magnetic field $B_e$ with a period of 12.1 min, and the amplitude 99 ± 37 G for Fe II 6149.2 Å line.**
- Though Kochukhov et al. (2004a) found no $B_e$ variations with amplitudes above 40-60 G in the circularly polarized components of 13 Nd III lines.
- Results are inconclusive: they could be affected by a non-uniform distribution of metal lines over the stellar surface or they could have been distorted by other effects, such as complex blending of lines, cross-over effect and others.
- Exception by Hubrig et al. (2004) - obtained $B_e$ measurements in wings of the hydrogen Balmer line - $B_e$ data is free of the above effects.

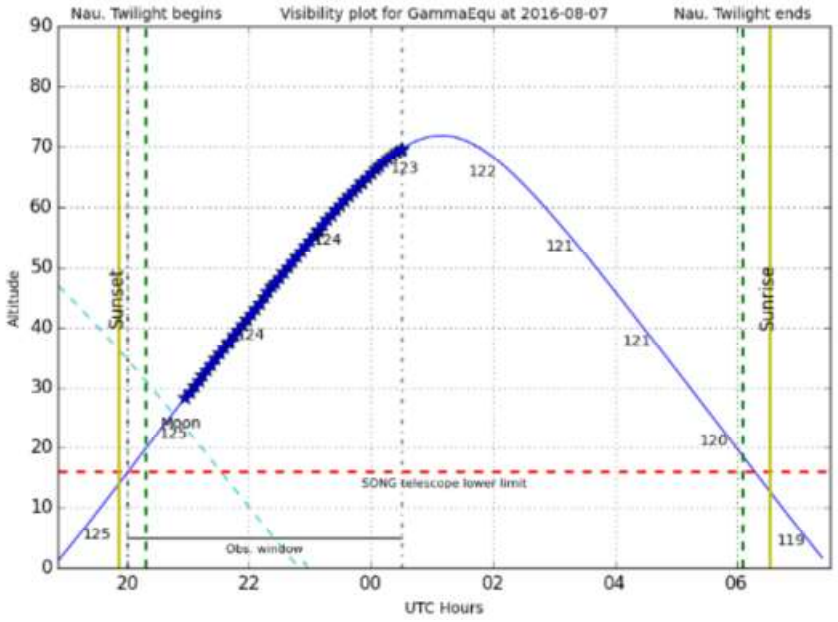
# GAMMA EQUULEI: Visibility



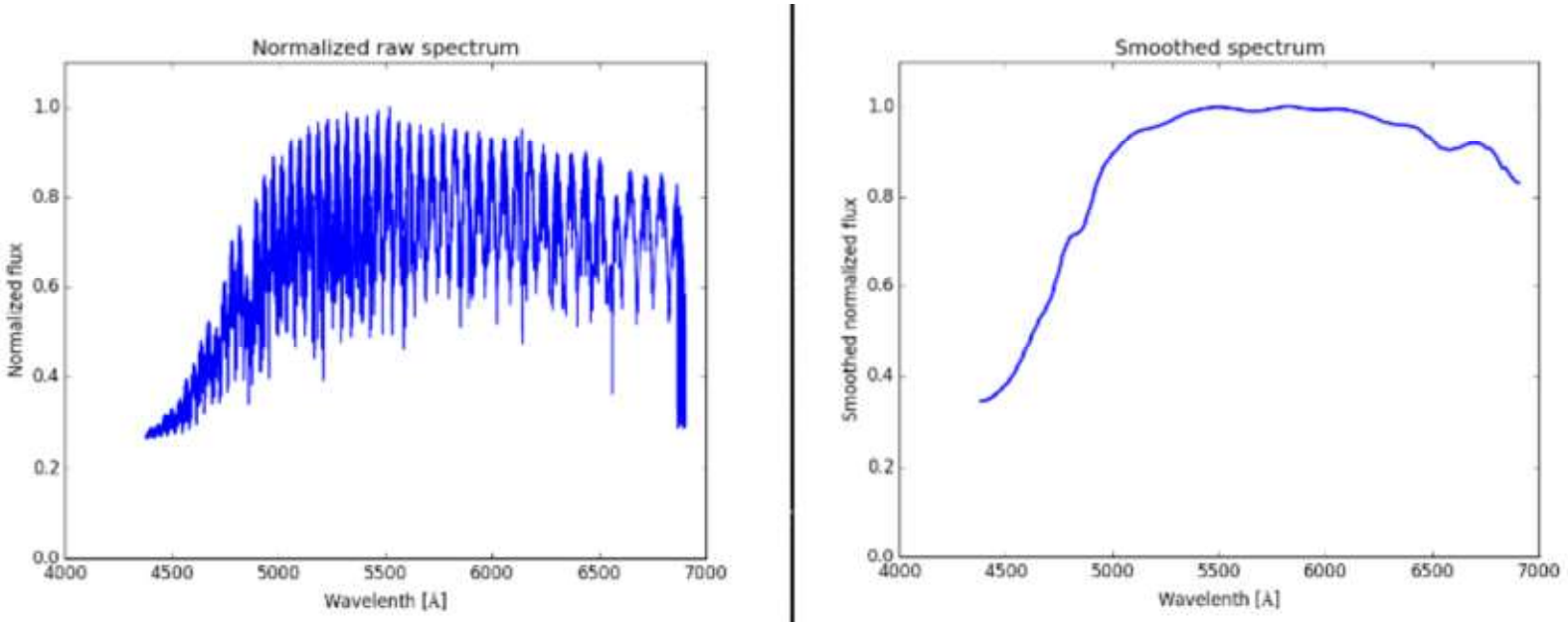
# GAMMA EQUULEI:



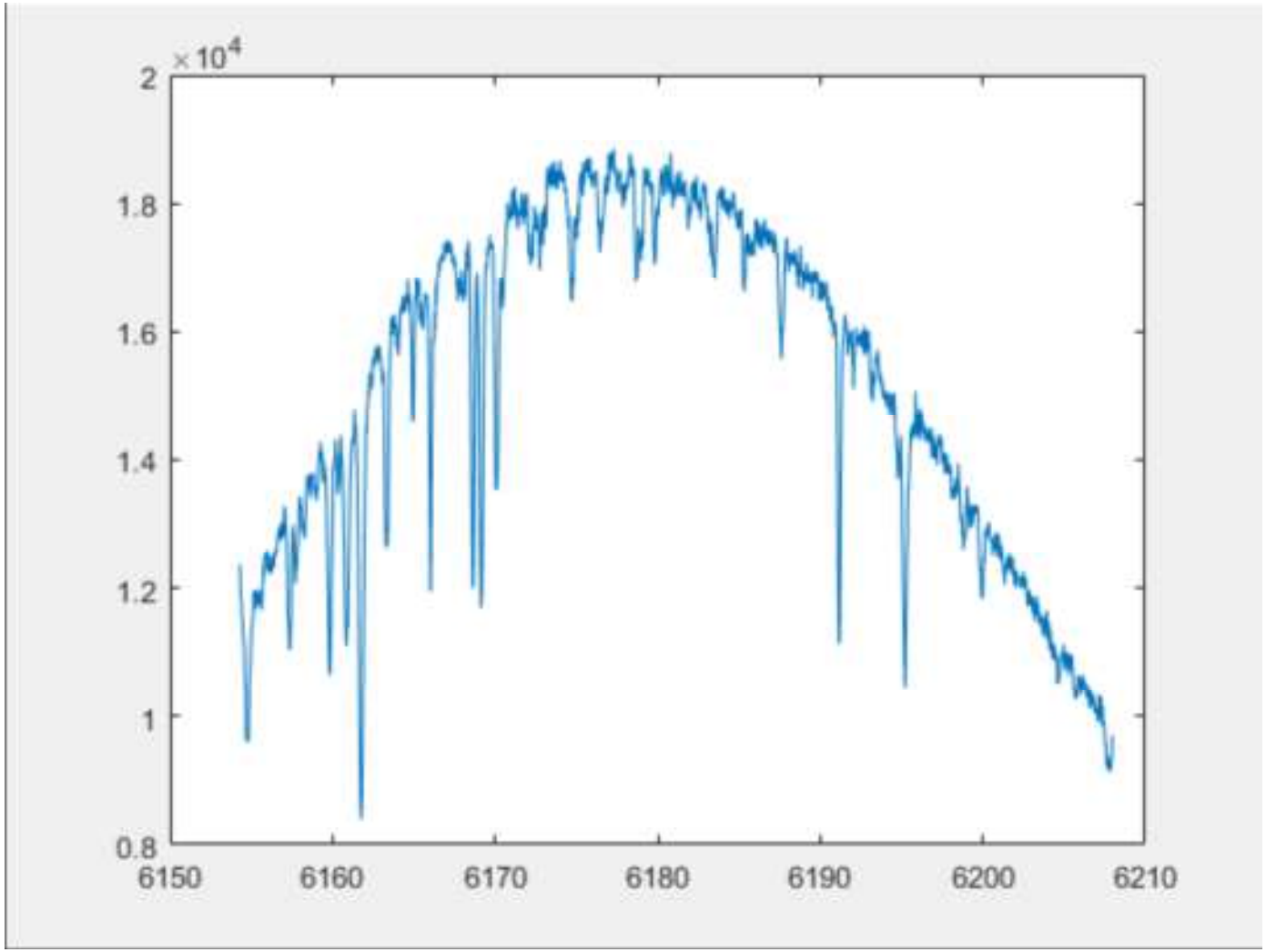

Ways to increase SNR:
- longer exposure time
- sum up spectra
- combine similar lines



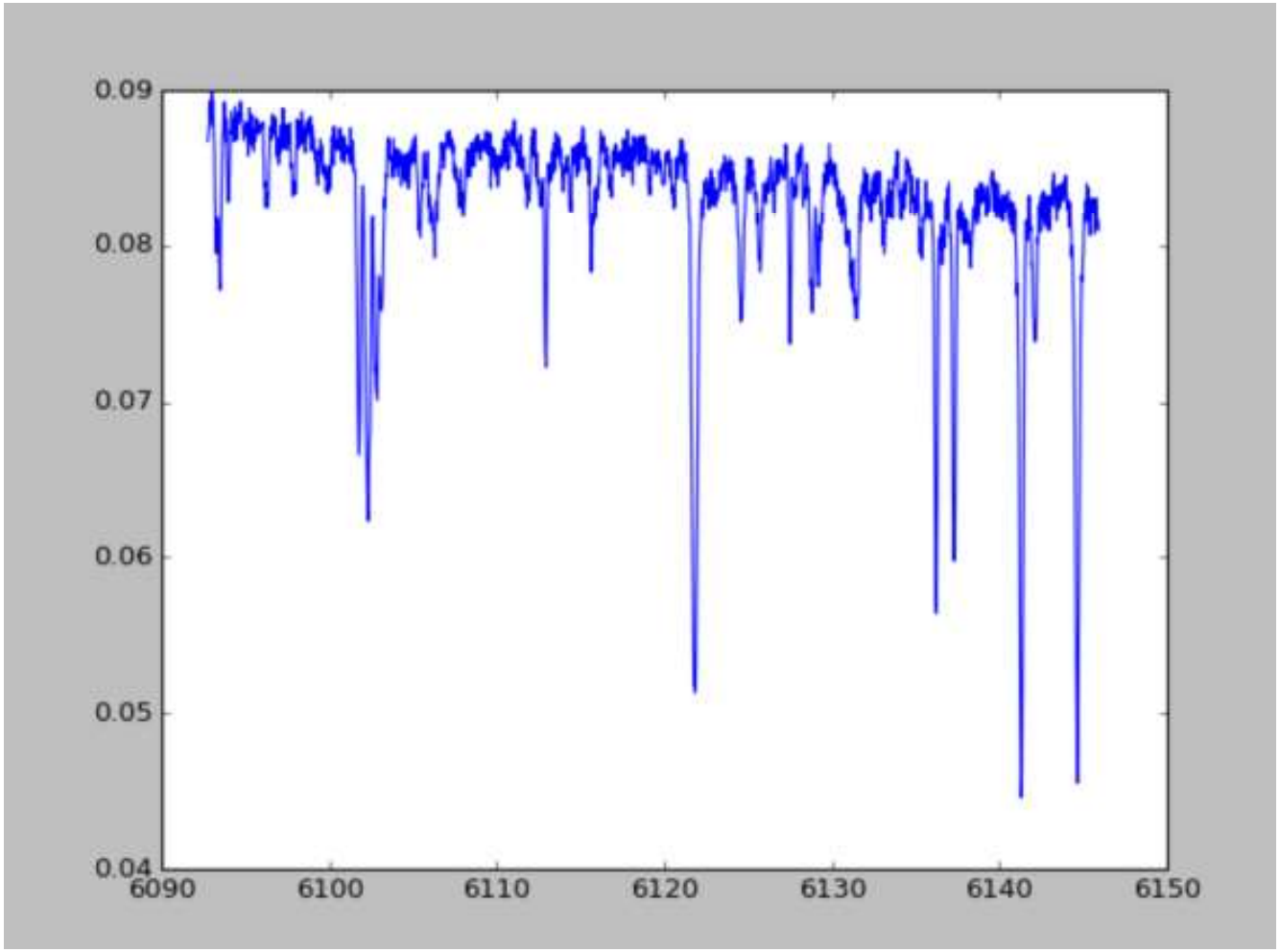
# GAMMA EQUULEI: Normalized Raw Spectrum



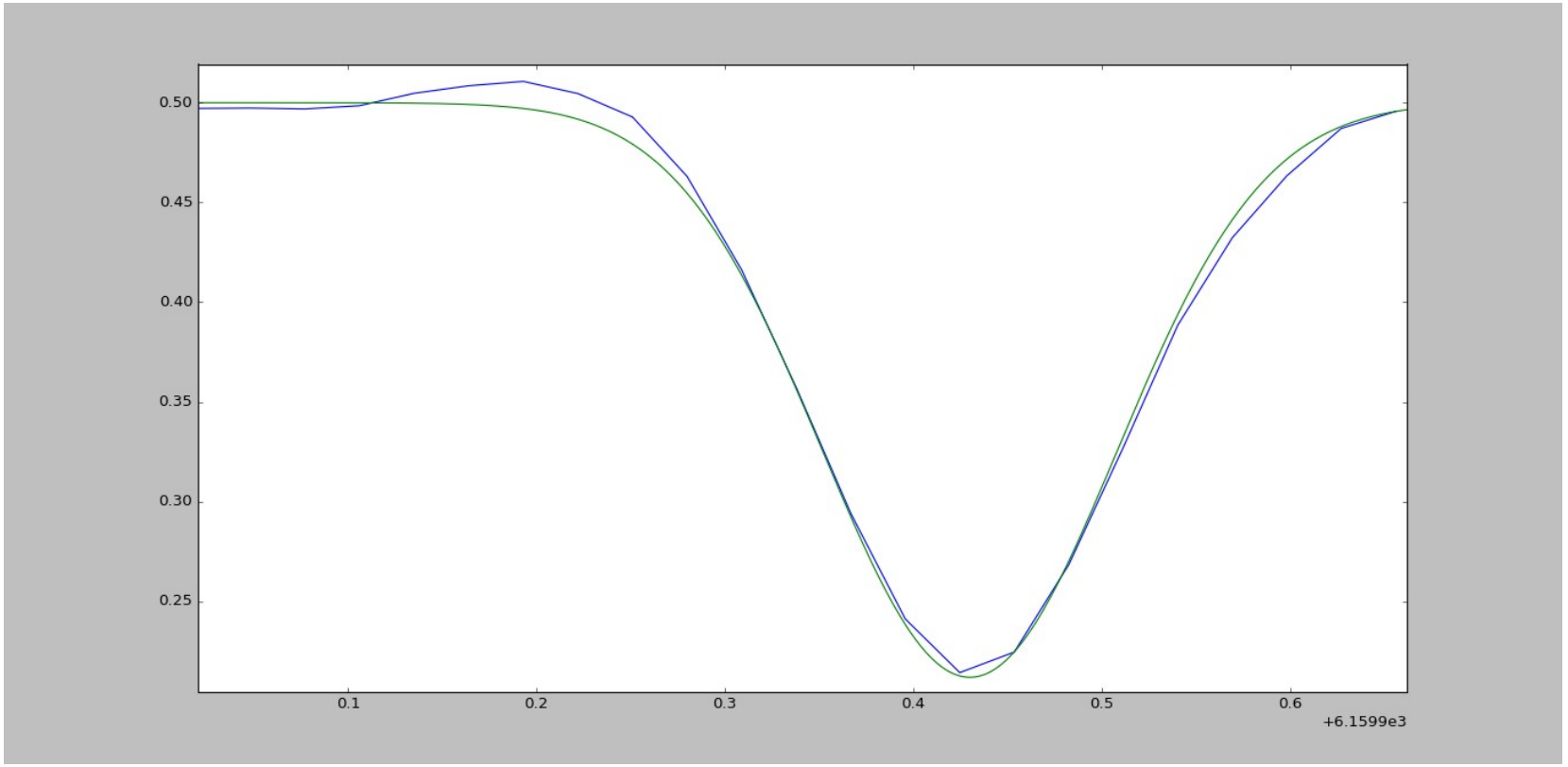
# GAMMA EQUULEI: Extracted Spectra



# GAMMA EQUULEI: Divided Normalized Spectra

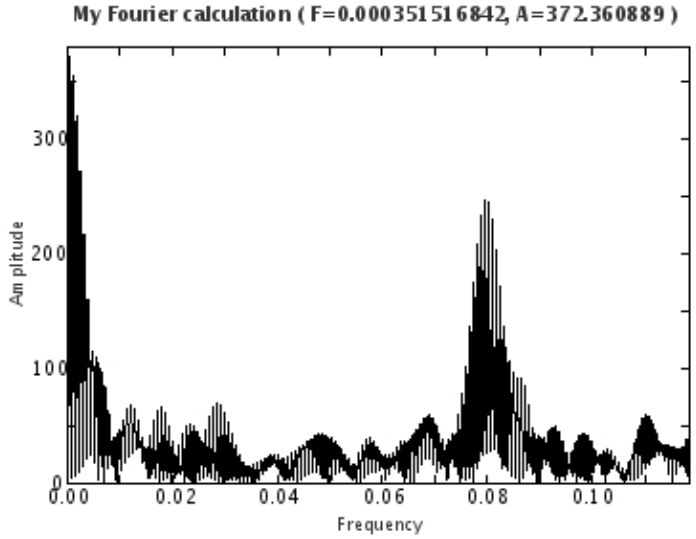


# GAMMA EQUULEI: Pr III line

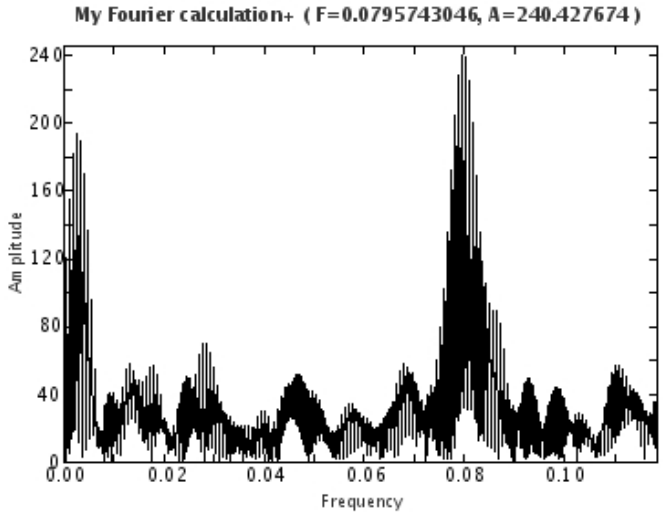


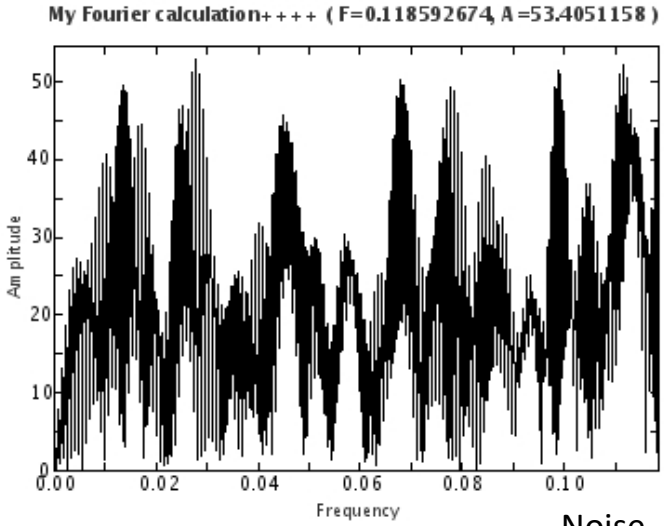

This graph shows Pr III line 6160.24 Å and polynomial fitted to it. Though we have noticed a slight shift and polynomial was centred at 6160.33 Å.

# GAMMA EQUULEI: RESULTS: Nd III 6145.07Å line




Variability at a frequency of 0.08 per min




Noise

# GAMMA EQUULEI: RESULTS:
## Radial velocity calculations for Nd III 6145.07Å line

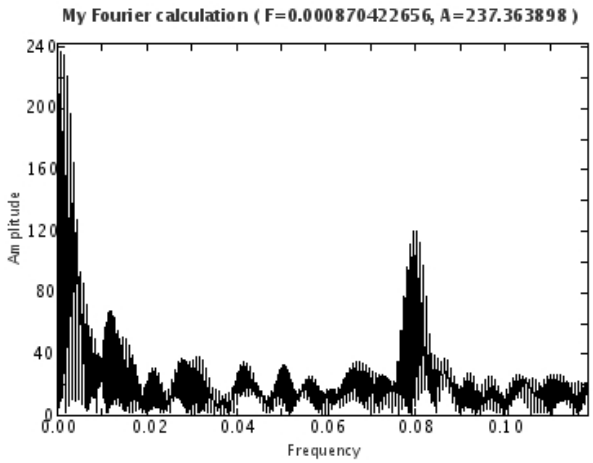
Observed wavelength = 6144.86Å
Rest wavelength = 6145.07Å

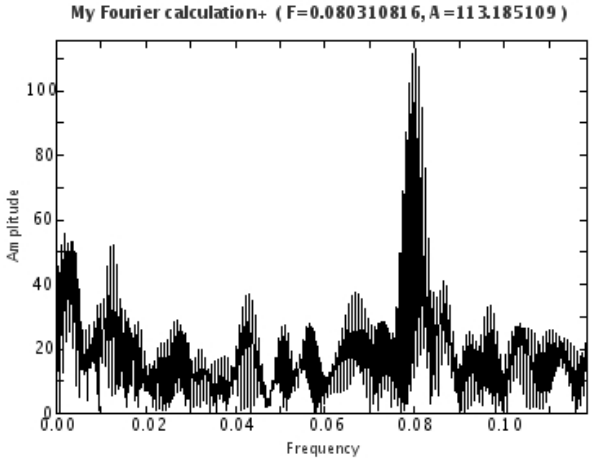
$$v = \frac{(\lambda - \lambda_0)}{\lambda_0} c$$

using the formula:

$v_r$ (6144.86-6145.07) / 6145.07 = -10217.94 m/s

# GAMMA EQUULEI: RESULTS: Fe I 6157.73Å line

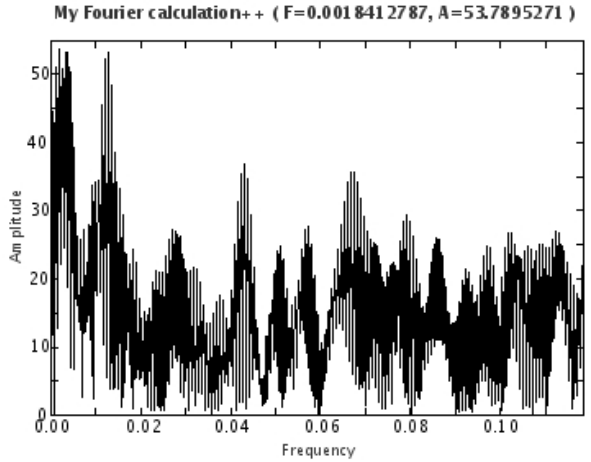



Variability at a frequency of 0.08 cycles/day

Observed wavelength = 6157.37Å
Rest wavelength = 6157.73Å

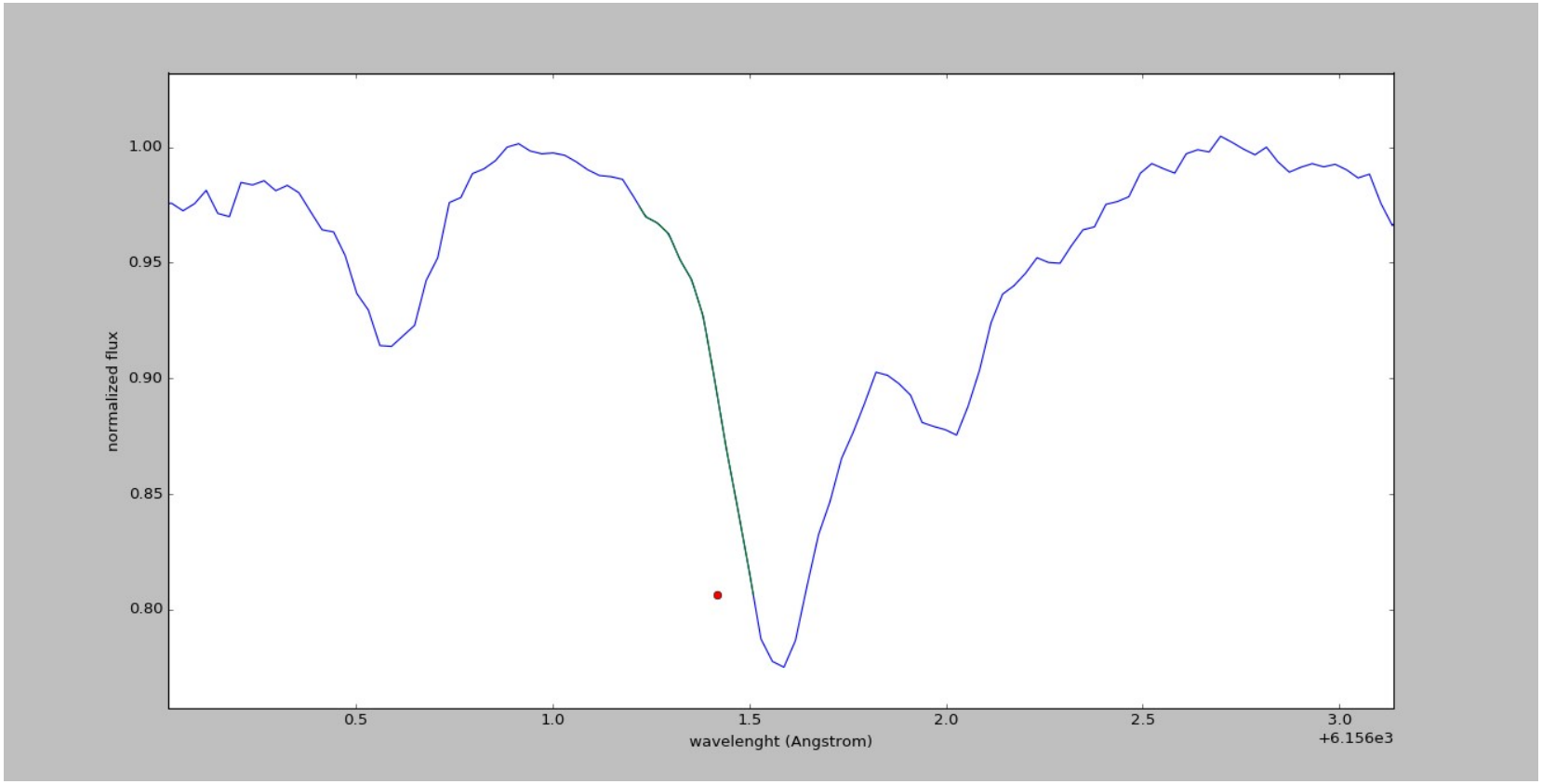
using the formula:
$v_r$ = -17480 m/s



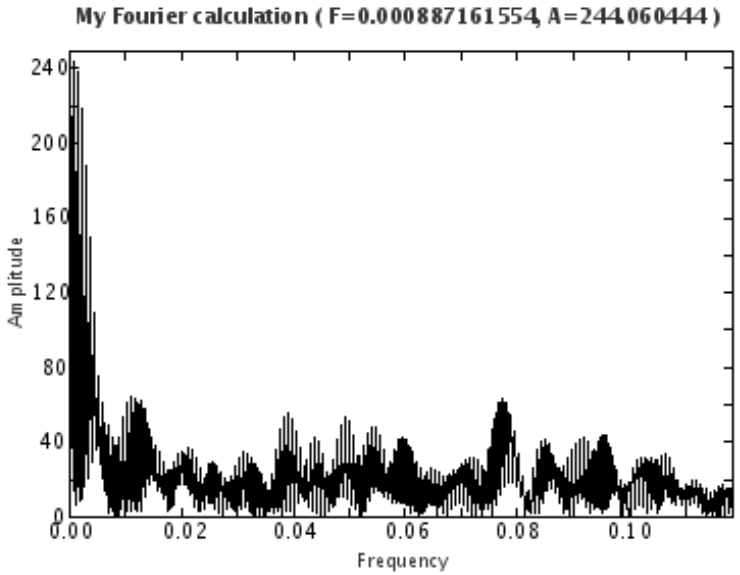

Noise

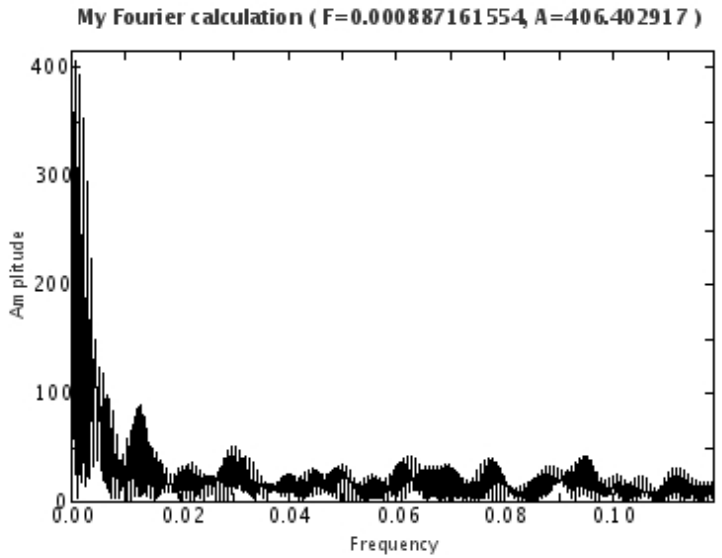
# GAMMA EQUULEI: RESULTS: Fe I 6157.73Å line

Issues with **Fe I 6157.73Å line**



# GAMMA EQUULEI: RESULTS: Sm II 6164.53Å and Fe I 6165.36Å lines




For comparison purposes


GAMMA CYGNI
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# STAR: SELECTION

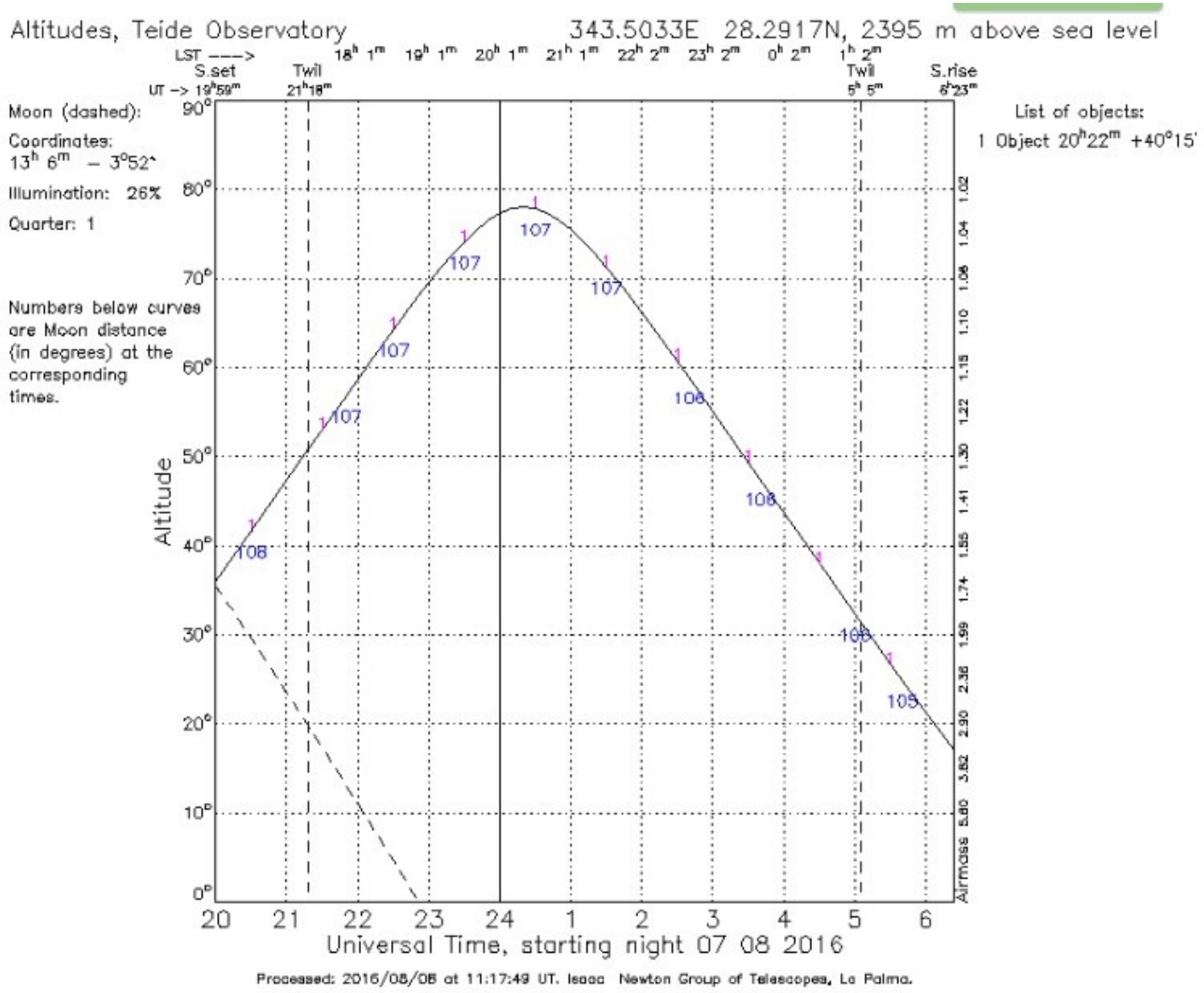
- Selection involved 3 different considerations:
  - the star has to have visible magnitude of less than 6 due to telescope limitations
  - has to be 20° above the horizon
  - had to peak before midnight due to limited telescope time allocation

*** gam Cyg** -- Variable Star

| | |
|---|---|
| Other object types: | * (*,AG,...), ** (ADS,CCDM,...), IR (IRAS,IRC,...), V* (CSV,NSV), UV (TD1) |
| **ICRS** coord. *(ep=J2000) :* | 20 22 13.70184 +40 15 24.0450 (Optical) [ 2.02 2.02 90 ] A 2007A&A...474..653V |
| **FK5** coord. *(ep=J2000 eq=2000) :* | 20 22 13.702 +40 15 24.04 [ 2.02 2.02 90 ] |
| **FK4** coord. *(ep=B1950 eq=1950) :* | 20 20 25.93 +40 05 44.5 [ 11.68 11.68 90 ] |
| **Gal** coord. *(ep=J2000) :* | 078.1486 +01.8671 [ 2.02 2.02 90 ] |
| Proper motions *mas/yr* : | 2.39 -0.91 [0.23 0.23 0] A 2007A&A...474..653V |
| Radial velocity / Redshift / cz : | V(km/s) -6.40 [0.3] / z(~) -0.000021 [0.000001] / cz -6.40 [0.30] A 2006AstL...32..759G |
| Parallaxes *(mas)*: | 1.78 [0.27] A 2007A&A...474..653V |
| Spectral type: | F8Ib C 2001AJ....121.2148G |
| Fluxes (8) : | U 3.44 [~] C 2002yCat.2237....0D |
| | B 2.90 [~] C 2002yCat.2237....0D |
| | V 2.23 [~] C 2002yCat.2237....0D |
| | R 1.74 [~] C 2002yCat.2237....0D |
| | I 1.40 [~] C 2002yCat.2237....0D |
| | J 1.11 [~] C 2002yCat.2237....0D |
| | H 0.83 [~] C 2002yCat.2237....0D |
| | K 0.72 [~] C 2002yCat.2237....0D |

# Gamma Cygni - middle star of Northern Cross

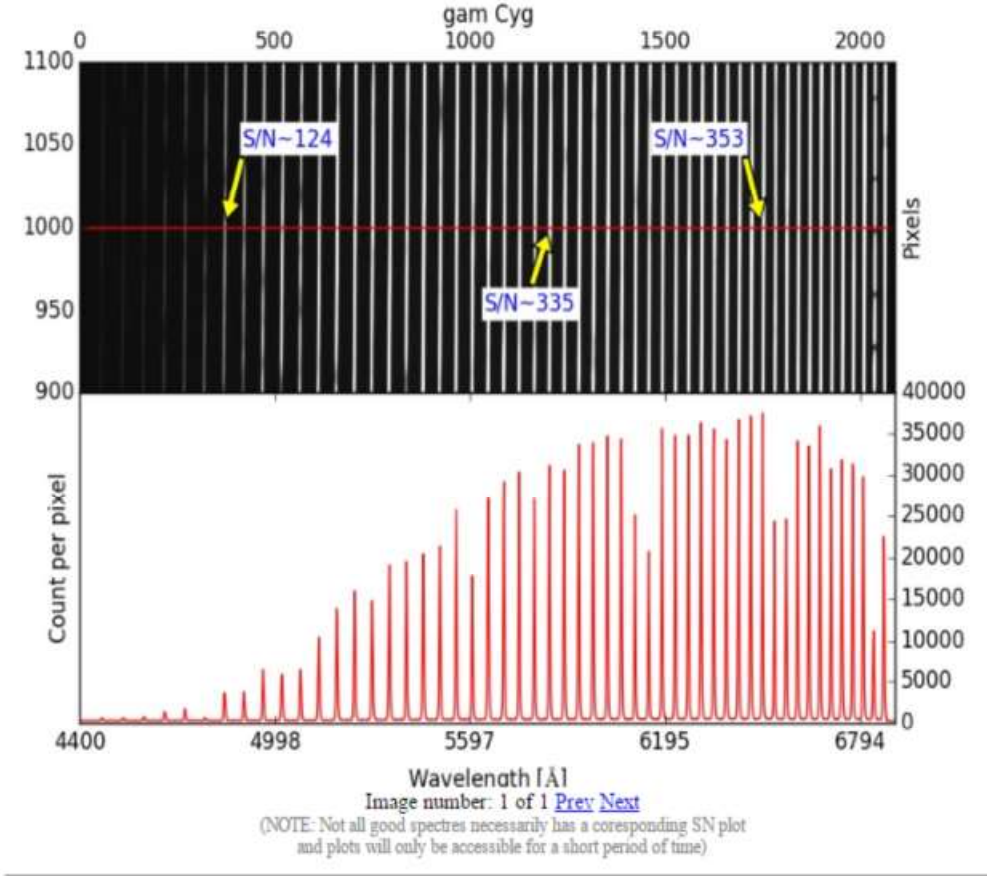
# Gamma Cygni VISIBILITY

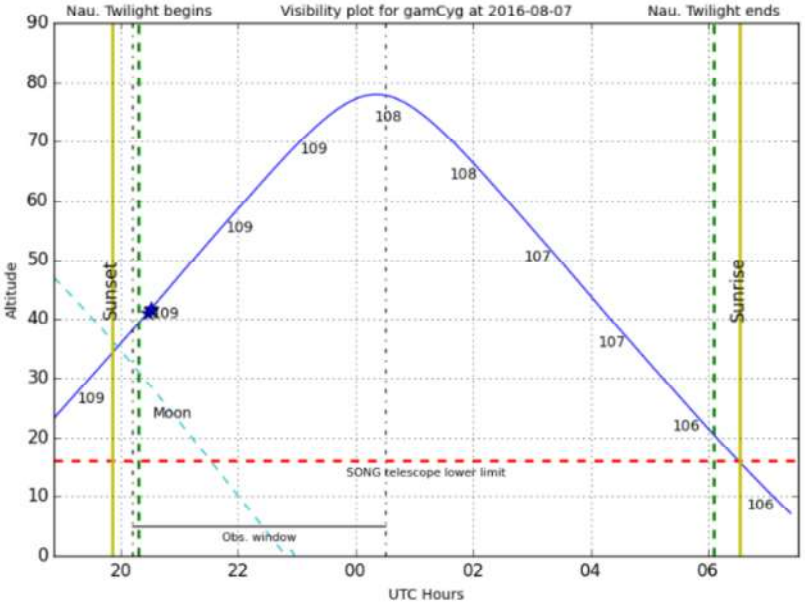


# WHY THIS STAR IS INTERESTING?

- The spectrum of this star shows some unusual dynamic features, including variations in radial velocity of up to 2 km/s, occurring on a time scale of 100 days or more.
- γ Cygni lies close to the instability strip and its spectrum is markedly like that of a Cepheid variable.
- Low **v sin i**
- IT'S A VARIABLE STAR.

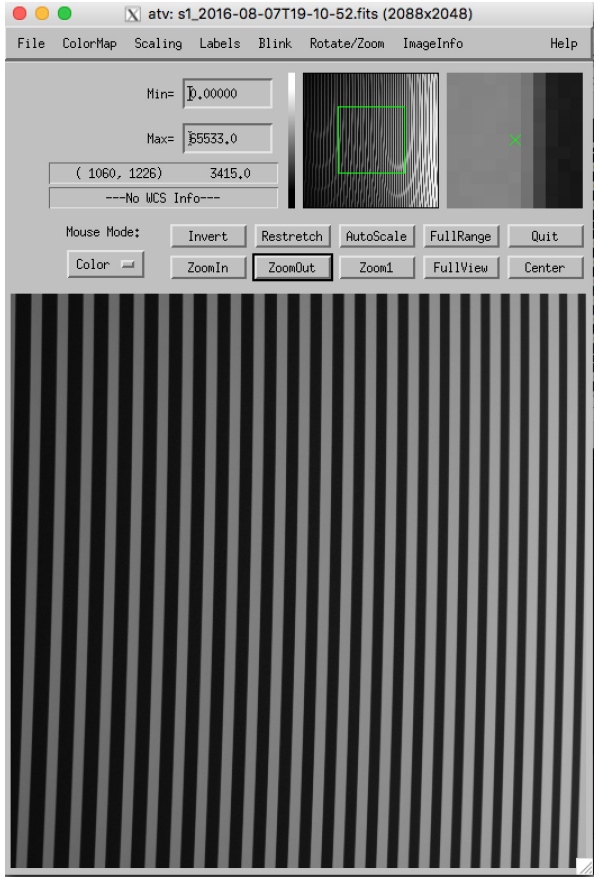
# RESULTS


gam Cyg
S/N~124
S/N~353
S/N~335
Pixels
Count per pixel
Wavelength [Å]
Image number: 1 of 1 Prev Next
(NOTE: Not all good spectres necessarily has a coresponding SN plot
and plots will only be accessible for a short period of time)


Nau. Twilight begins
Visibility plot for gamCyg at 2016-08-07
Nau. Twilight ends
Sunset
Sunrise
Moon
SONG telescope lower limit
Obs. window
Altitude
UTC Hours

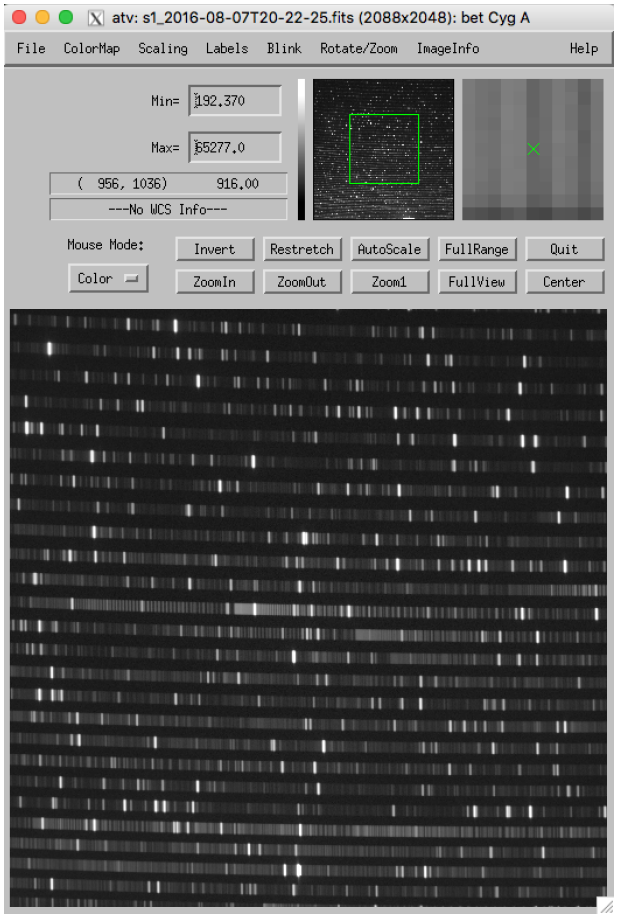
# CALIBRATION FRAMES

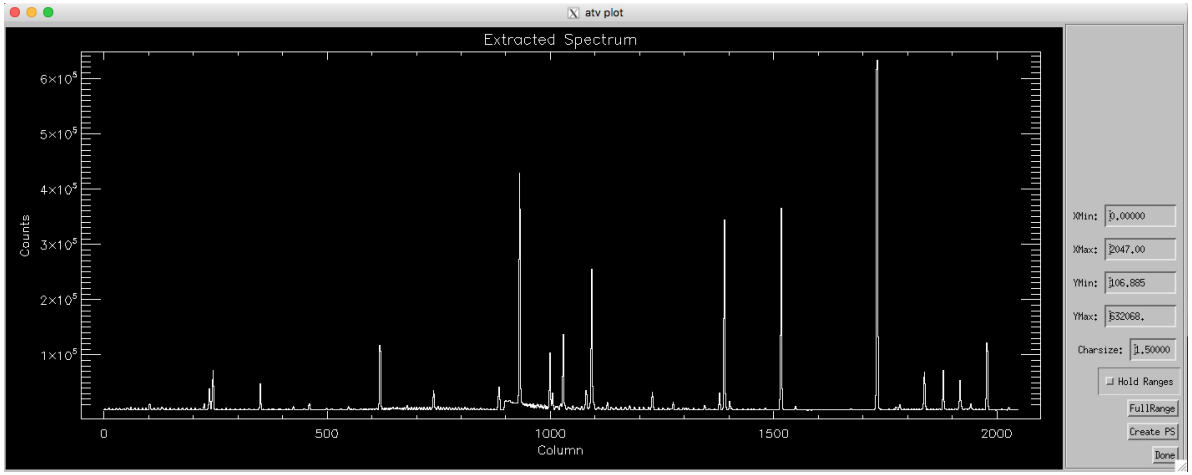
FLAT



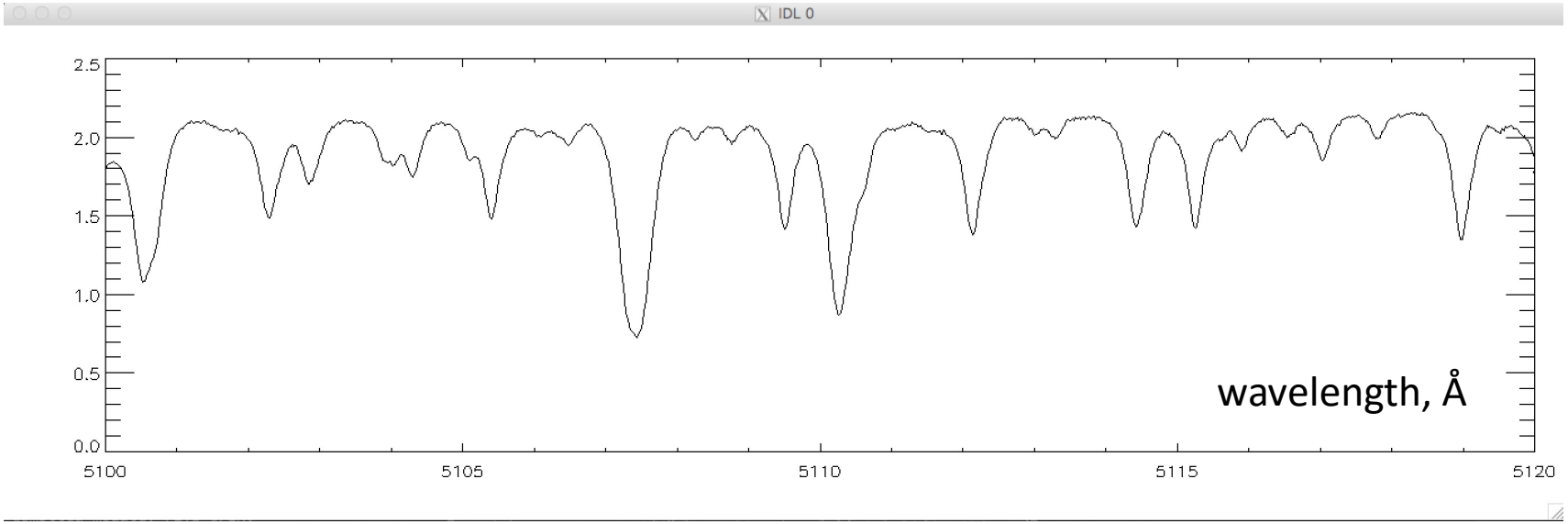

BIAS

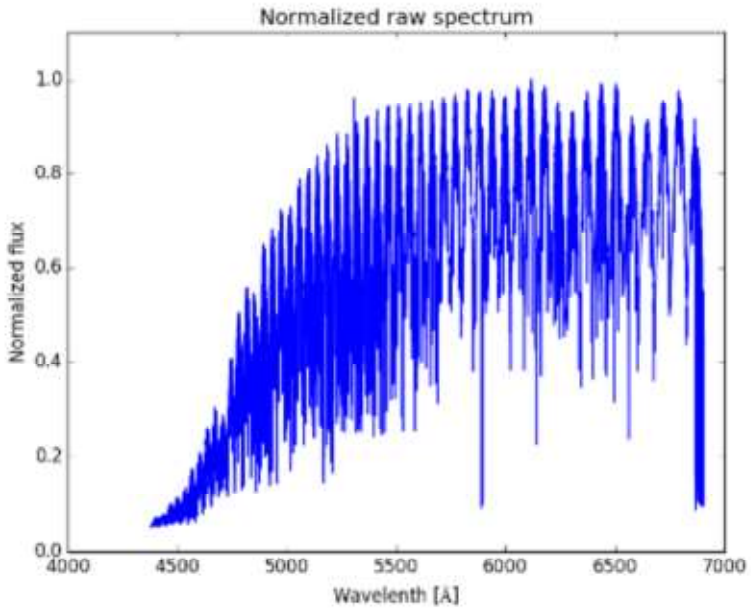
# CALIBRATION SPECTRUM

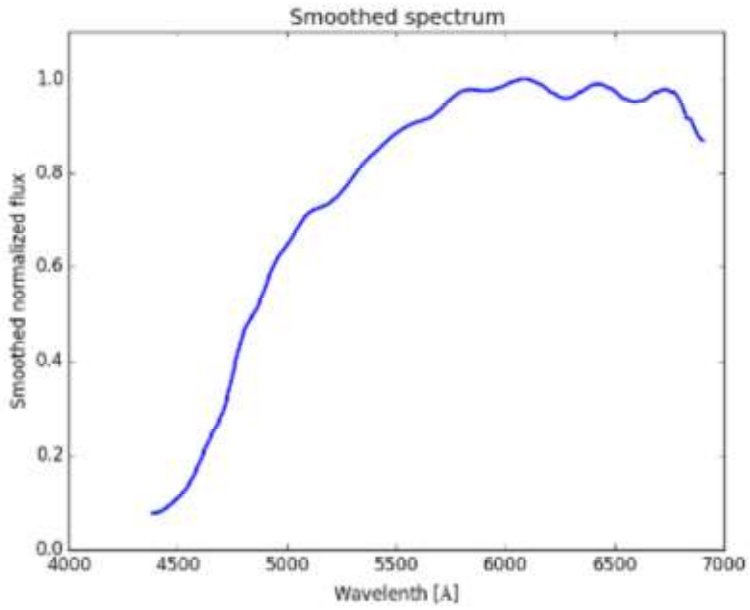


# STAR SPECTRUM




REFERENCES
Marius Bendzelauskas - Photography
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# REFERENCES

1. Search for radial velocity and magnetic field pulsational variations in the roAp star γ Equulei by I. Savanov, S.Hubrig, G. Mathys, A. Ritter, D. W. Kurtz 2005

2. Line profile variations in Gamma Equ: A puzzle by H. Shibahashi, D. Kurtz, E. Kambe, D. Gough 2004

3. http://song.au.dk/about-song/

http://song.au.dk/about-song/song-explained/

4. Investigation of the Rapid Magnetic Field Variability in gamma Equulei by V.D. Bychkov, L.V. Bychkova, J. Madej 2005


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