SONG project:
Gamma Equ spectroscopy analysis

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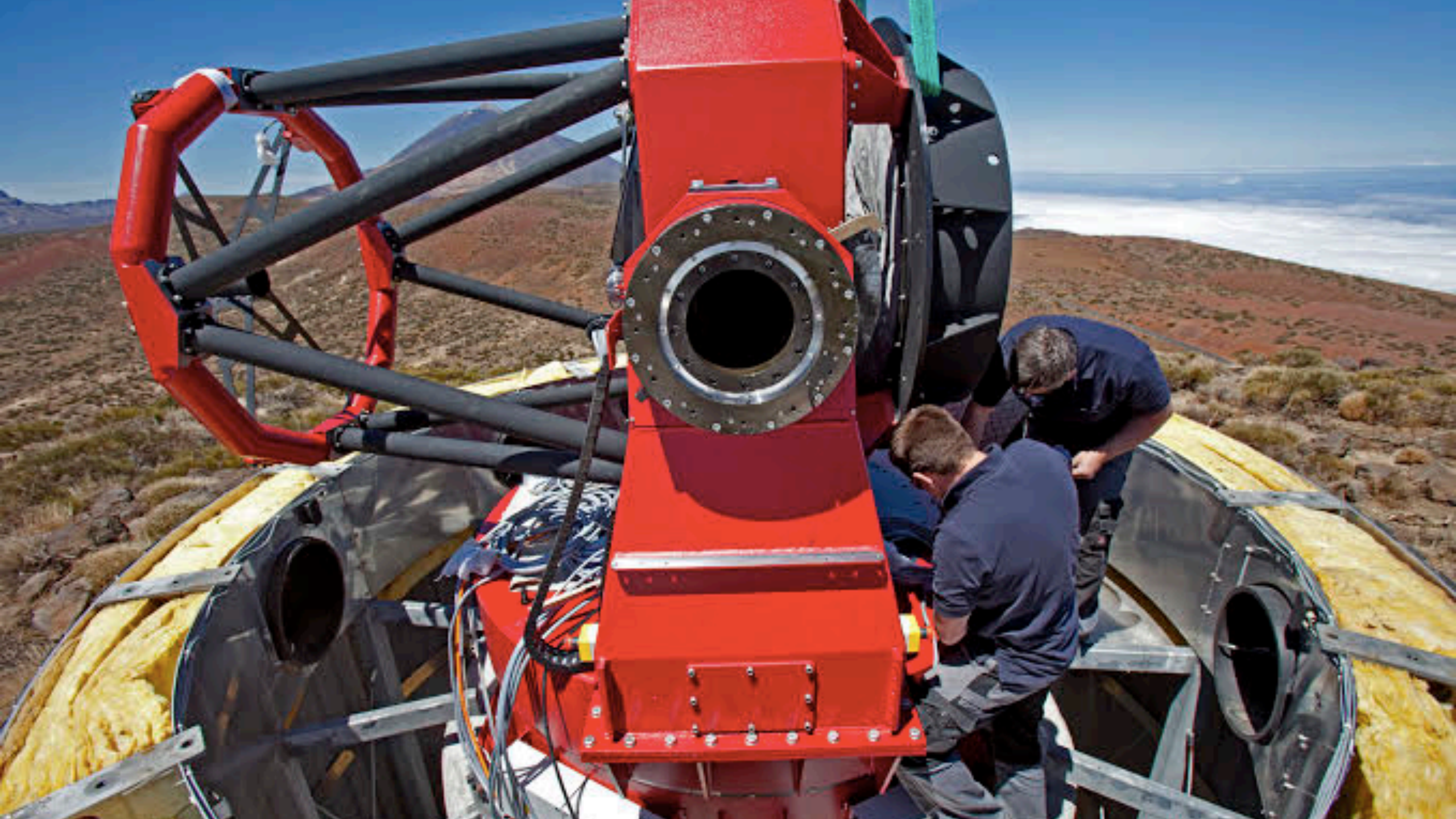
Rokas Zemaitis
Andrius Bruzas

Supervisors:
Carolina von Essen
Victoria Antoci
Hans Kjeldsen

Table of contents

SONG

- SONG stands for Stellar Observations Network Group.
- Launched in 2006.



More about SONG

- 1m diameter telescope.
- Scientific SONG goals.

Gamma Equulei

Portal | Simbad | VizieR | Aladin | X-Match | Other | Help

gamma equileii

other query modes : Identifier query | Coordinate query | Criteria query | Reference query | Basic query | Script submission | TAP | Output options | Help

Query : gamma equileii

C.D.S. - SIMBAD4 rel 1.5.7 - 2016.08.10CEST07:38:58

Available data : Basic data • Identifiers • Plot & images • Bibliography • Measurements • External archives • Notes • Annotations

Basic data :

*** gam Equ** -- Variable Star of alpha2 CVn type

Other object types:	* (*,AG,...), ** (**,ADS,...), IR (2MAS,2MASS), PM* (LSPM), a2* (Ref), V* (V*), EW (TD1)
ICRS coord. *(ep=J2000)* :	21 10 20.58005 +10 07 53.6763 [Optical] [5.79 4.58 90] A 2007A&A...474..653V
FK5 coord. *(ep=J2000 eq=2000)* :	21 10 20.580 +10 07 53.68 [5.79 4.58 90]
FK4 coord. *(ep=B1950 eq=1950)* :	21 07 54.57 +09 55 45.0 [33.32 26.64 0]
Gal coord. *(ep=J2000)* :	059.6329 -26.7630 [5.79 4.58 90]
Proper motions *mas/yr* :	48.74 -153.85 [0.66 0.52 0] A 2007A&A...474..653V
Radial velocity / Redshift / cz :	V(km/s) -16.50 [0.3] / z(~) -0.000055 [0.000001] / cz -16.50 [0.30] A 2006AstL...32...759G
Parallaxes *(mas)*:	37.55 [0.62] A 2007A&A...474..653V
Spectral type:	A9VpSrCrEu C 1985ApJS...59...95A
Fluxes (B) :	U 5.03 [~] C 2002yCat.2237....0D B 4.94 [~] C 2002yCat.2237....0D V 4.68 [~] C 2002yCat.2237....0D R 4.43 [~] C 2002yCat.2237....0D I 4.32 [~] C 2002yCat.2237....0D J 4.28 [~] C 2002yCat.2237....0D H 4.18 [~] C 2002yCat.2237....0D K 4.10 [~] C 2002yCat.2237....0D

SIMBAD query around with radius 2 arcmin

Interactive AladinLite view

VizieR photometry viewer

Search within radius Max:30 arcsec

notes:

- HIC 104521 includes the components CCDM J21104+1007A and CCDM J21104+1007B

Hierarchy : number of linked objects
whatever the membership probability is (see description here) :

Main parameters

- V_{mag} = 4.68
- V_{rad} = -16.50
- T_{eff} ~ 8600 K
- Log g ~ 4.48
- Fe_H ~ 0.73

Pulsation period

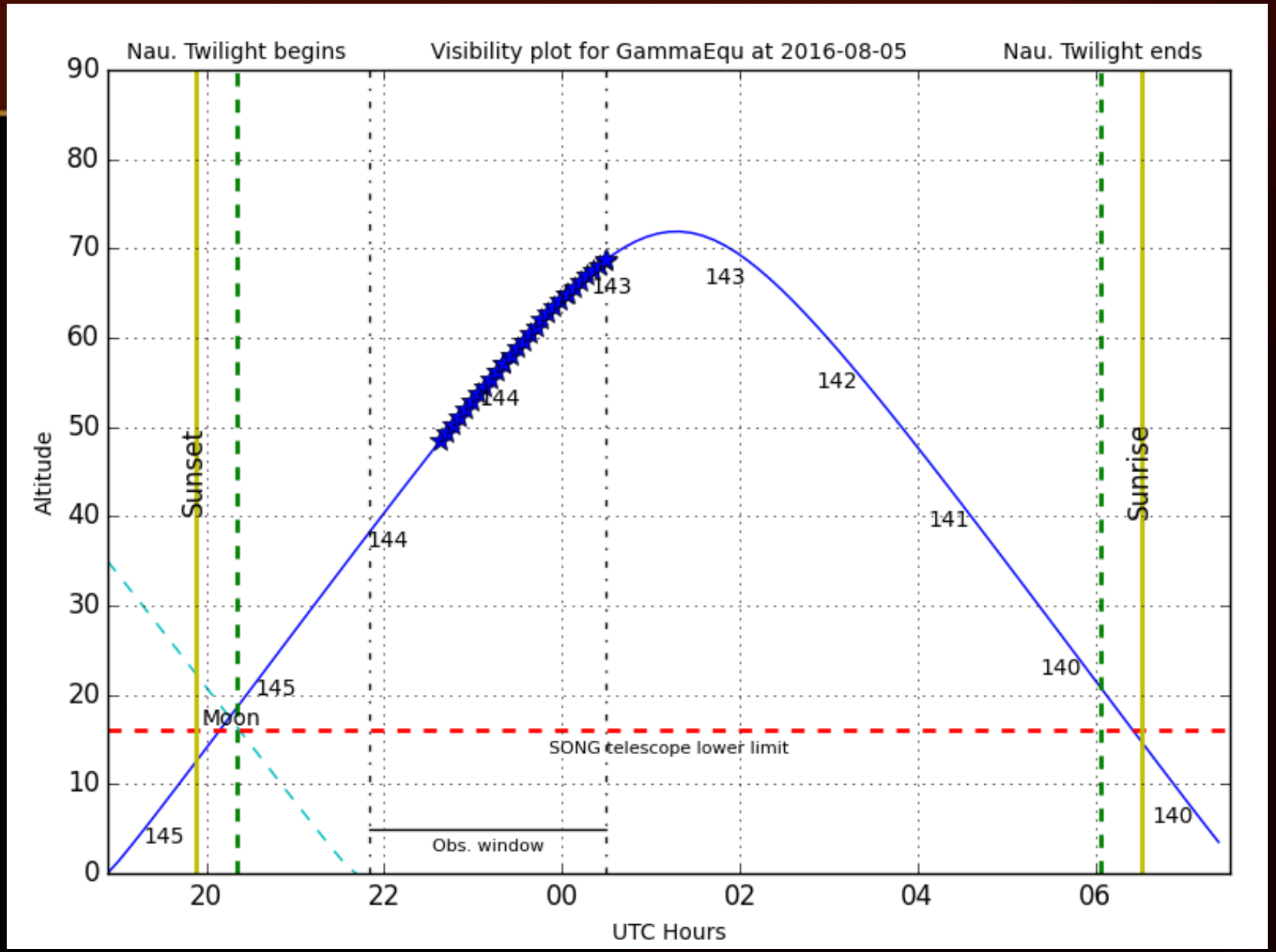
- 11,67 to 12,45 minutes.
- 12.29 (1999 July 22, CES/ESO 3.6-m)
- 12.281 2002 September 26, Gecko/CFHT

Variable lines (Angstroms)

- NdIII 6145_07
- BaII 6141_71
- FeI 6157_73

Rotation period

- P = 77± 10 yr (O. Kochukhov et al., 2001)
- P(solar) = 26.24 days


Nau. Twilight begins
Visibility plot for GammaEqu at 2016-08-05
Nau. Twilight ends
Altitude
UTC Hours
Sunset
Sunrise
Moon
SONG telescope lower limit
Obs. window
143
143
142
144
144
141
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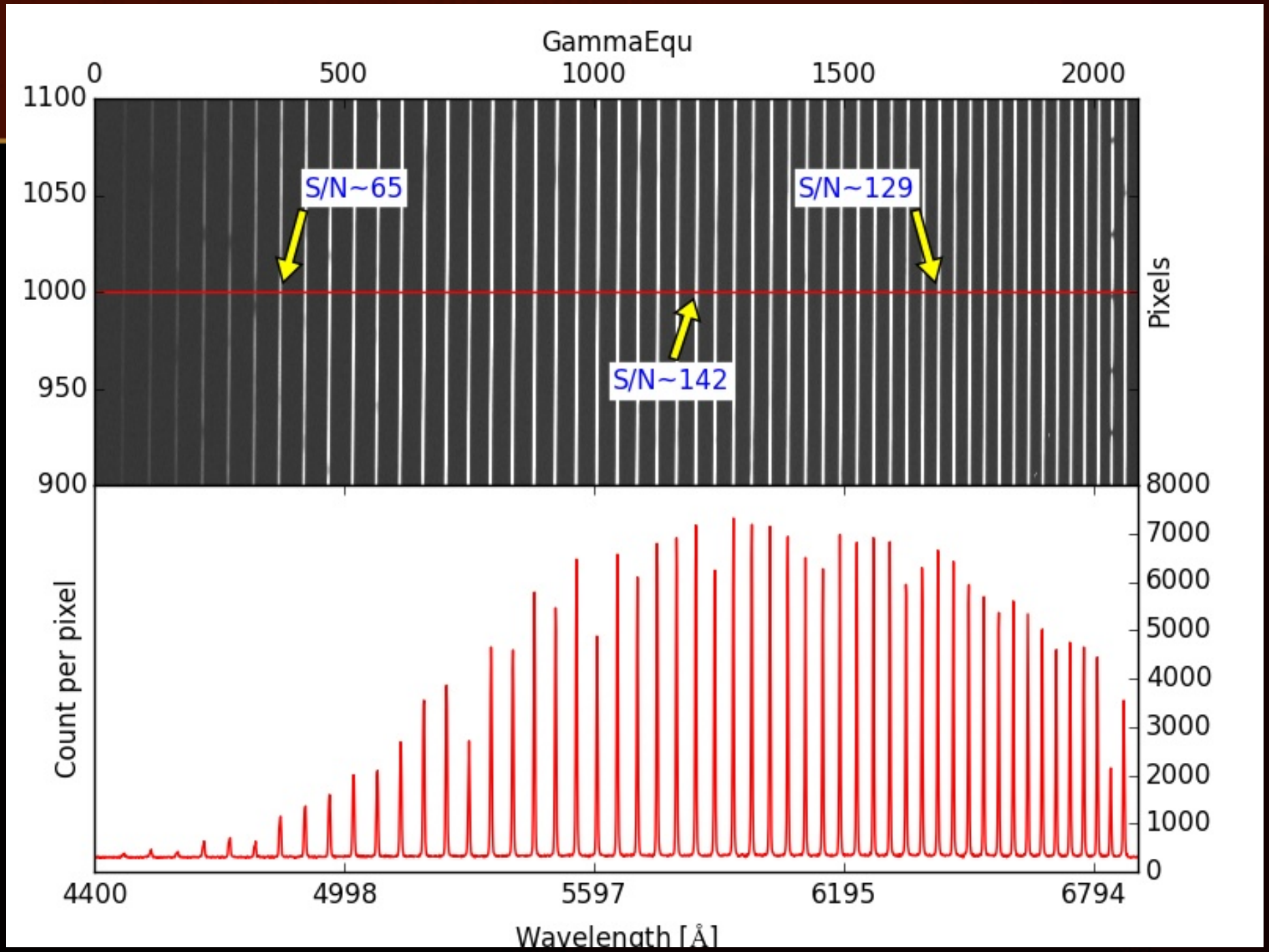
04
06


GammaEqu
0
500
1000
1500
2000
1100
1050
1000
950
900
S/N~65
S/N~129
S/N~142
Pixels
8000
7000
6000
5000
4000
3000
2000
1000
0
Count per pixel
4400
4998
5597
6195
6794
Wavelength [Å]

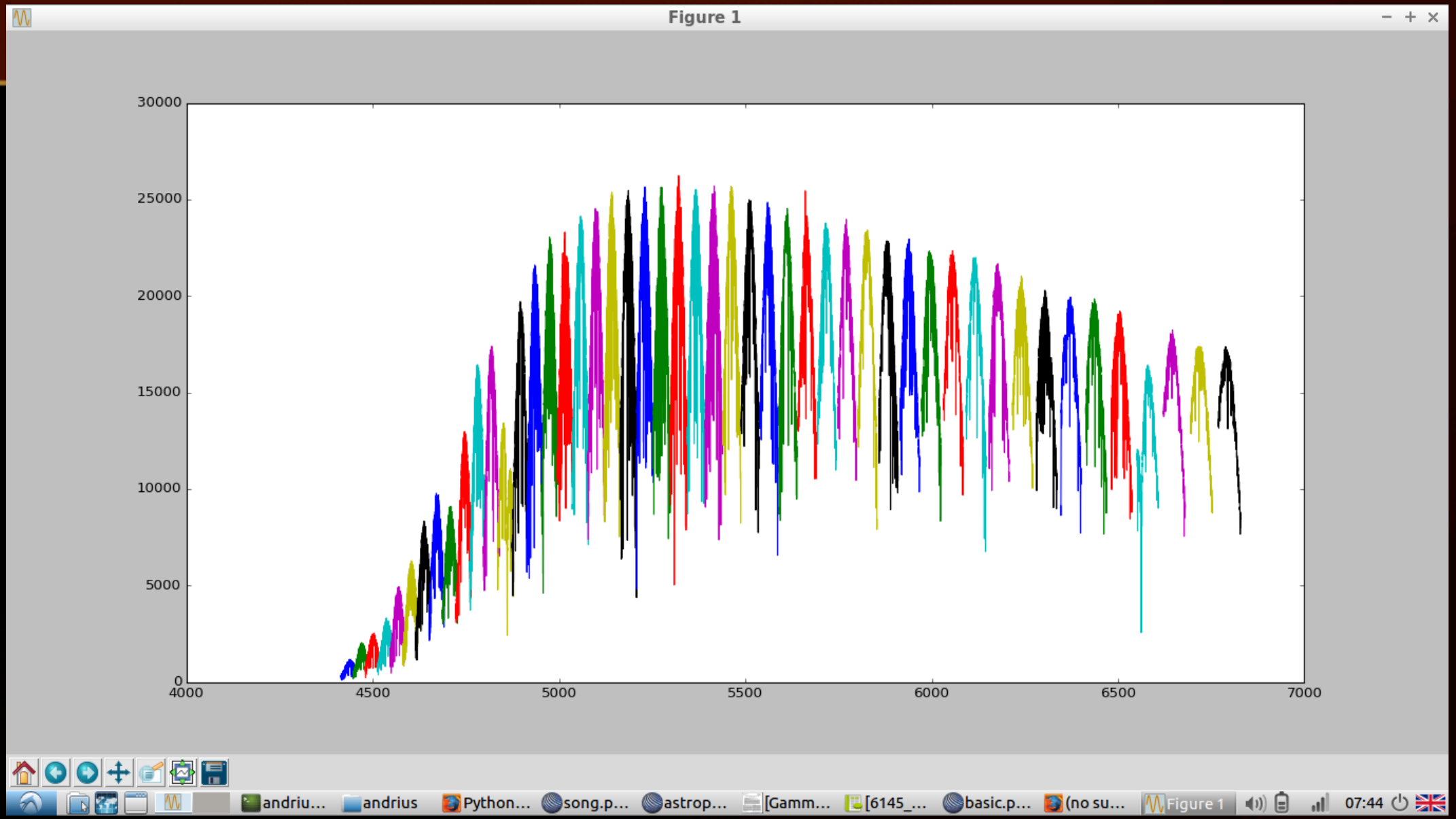


Figure 1
30000
25000
20000
15000
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5000
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4500
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5500
6000
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andriu...
andrius
Python...
song.p...
astrop...
[Gamm...
[6145_...
basic.p...
(no su...
Figure 1
07:44

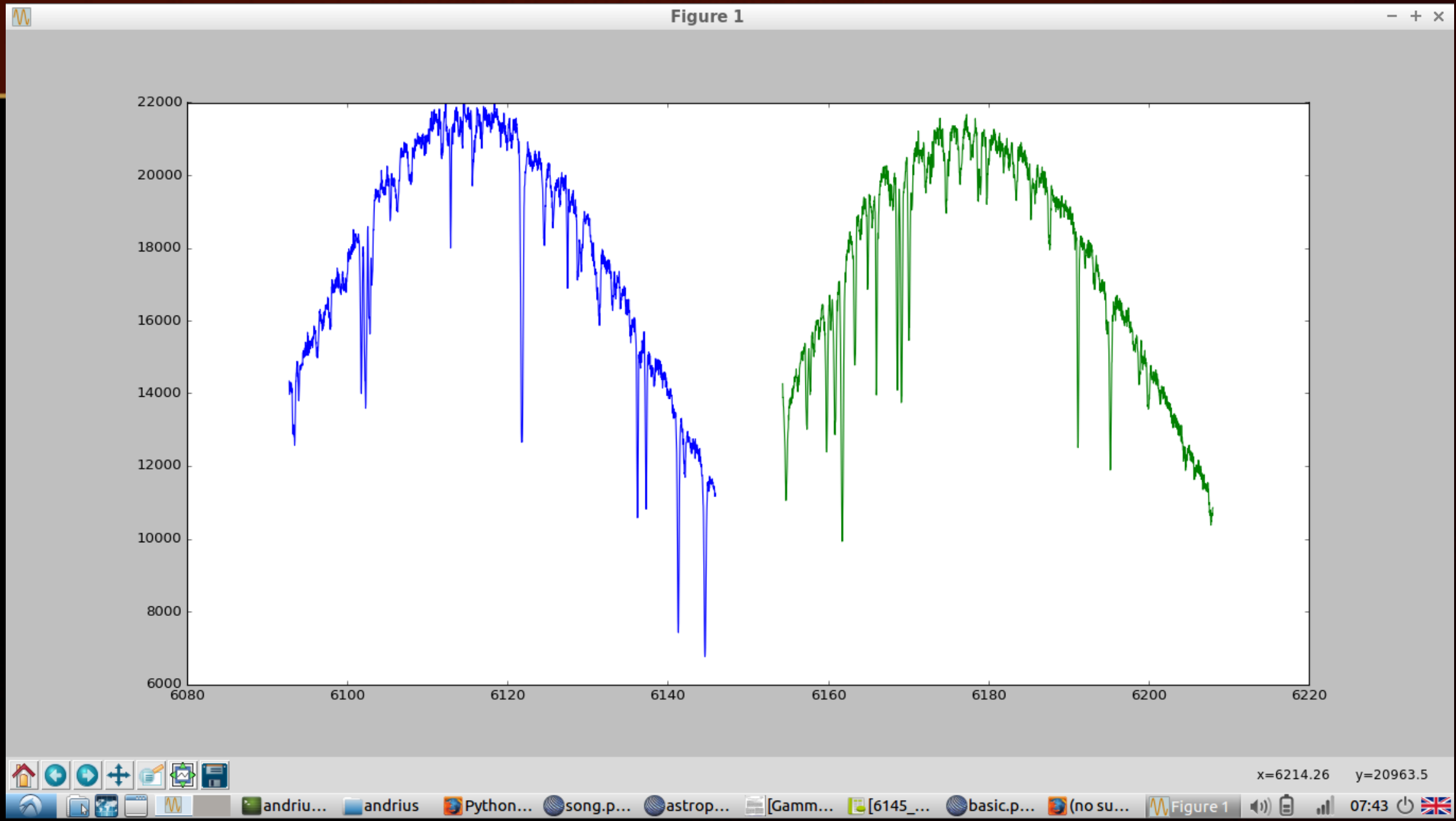
Figure 1
22000
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16000
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10000
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6220
x=6214.26
y=20963.5
andriu...
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Python...
song.p...
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Figure 1
07:43

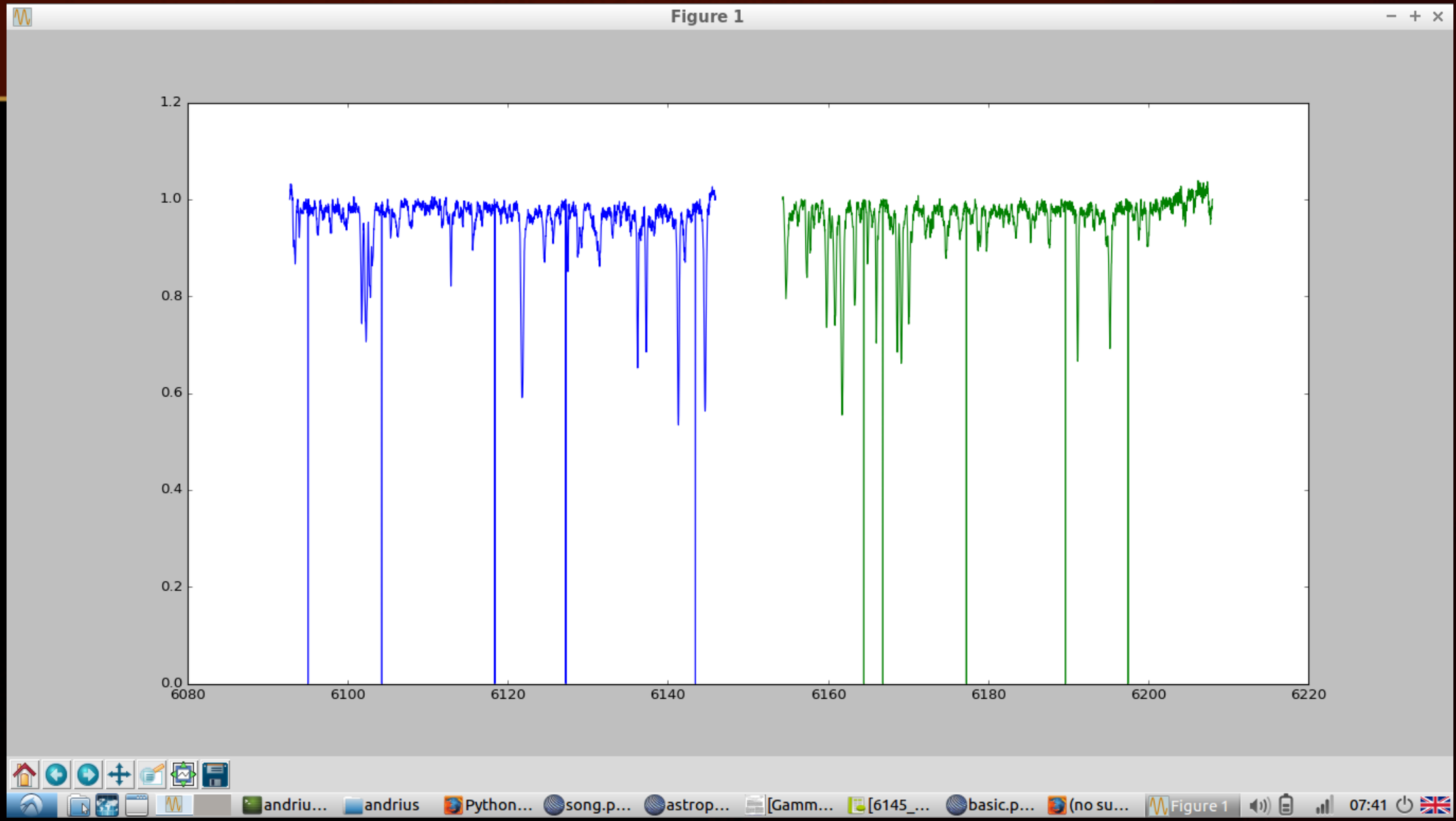
Figure 1
1.2
1.0
0.8
0.6
0.4
0.2
0.0
6080
6100
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6140
6160
6180
6200
6220
andriu...
andrius
Python...
song.p...
astrop...
[Gamm...
[6145_...
basic.p...
(no su...
Figure 1
07:41

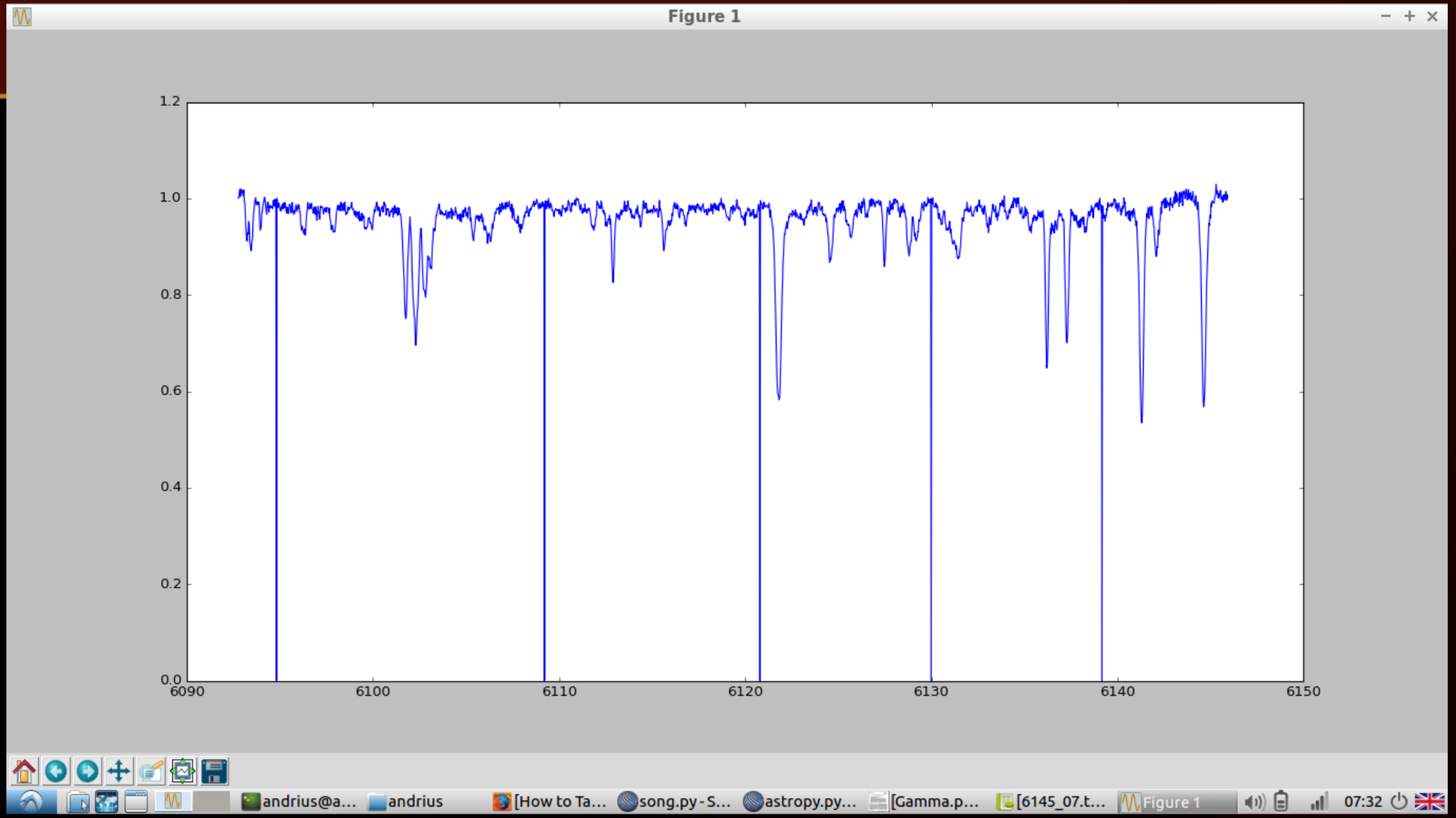
Figure 1
1.2
1.0
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0.6
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0.2
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6090
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6130
6140
6150
andrius@a...
andrius
[How to Ta...
song.py - S...
astropy.py...
[Gamma.p...
[6145_07.t...
Figure 1
07:32

song.py - SciTE

File Edit Search View Tools Options Language Buffers Help

1 song.py

```
from scipy.optimize import curve_fit
import numpy as np
import matplotlib.pylab as plt
import pyfits as pf
import numpy as np
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d
name='s1_2016-08-05T22-46-34_ext.fits'
data = pf.getdata( name )


from scipy import interpolate

# Get the data
hdr = pf.getheader( name ) # Get the full header
#print np.shape( data )
# produces: (5, 51, 2048) = (layer, order, npix)
#print hdr.get ('BVC')
#print hdr.get ('slit')
#print hdr.get ('BJD-MID')

# Plot order 30 (counting stats at 0) with the wavelength solution before the science
q= hdr.get ('BVC')
print hdr.get('BVC')
from scipy.constants import codata
z=codata.value('speed of light in vacuum')
k=0

dd=data[0,39,:]/data[2,39,:];ww=data[3,39,:]
a=[dd[0]];b=[ww[0]]
for i in range(5):
    dat=dd[i*400:i*400+399]
    mx=np.argmax(dat)
    dat[mx]=0
    mx=np.argmax(dat)
    a.append(dd[i*400+mx])
    b.append(ww[i*400+mx])
a.append(dd[2047])
b.append(ww[2047])

fck=interp1d(b,a,kind='linear')


dd=np.array(dd)/fck(ww)
#plt.plot(ww,dd)

nnn=1830
```

File Edit View

night1 night1

Places

Home Folder
Desktop
Rubbish Bin
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31 GB Volume
Documents
Music
Pictures
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Downloads

"astropy.py" (457 byt

astropy.py - SciTE

File Edit Search View Tools Options Language Buffers Help

1 astropy.py

```
from scipy.optimize import curve_fit
import numpy as np
import matplotlib.pylab as plt
import pyfits as pf
import numpy as np
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d


fls=file=open('dates.txt', 'w')
file=open('data.lst')



line=file.readline()
while line:
    name =  file.readline().rstrip('\n')
    print name
    exec(open('1song.py').read(), globals())

    BJDMID=hdr.get ('BJD-MID')
    print>>fls, BJDMID, ' ; ' ,rv

file.close()
```

26,2 GiB)

andrius@andri... night1 [How to Take a ... song.py - SciTE astropy.py - SciTE 07:13

song.py - SciTE

File Edit Search View Tools Options Language Buffers Help

1 song.py

```
dd=np.array(dd)/fck(ww)
#plt.plot(ww,dd)

nnn=1830
mmm=1870
lrest =6141.39095634
x=np.array(ww[nnn:mmm])

#gaussian = lambda x: 3*np.exp(-(lrest-x)**2/20.)

data = np.array(dd[nnn:mmm])

y = data

y = -1*y +1

plt.plot(x,y, '-')



# correction for weighted arithmetic mean
mean = sum(x * y) / sum(y)
sigma = np.sqrt(sum(y * (x - mean)**2) / sum(y))

#print mean, sigma

def Gauss(x, a, x0, sigma):
    return a * np.exp(-(x - x0)**2 / (2 * sigma**2))

popt,pcov = curve_fit(Gauss, x, y, p0=[max(y), mean, sigma], maxfev=1000000)


plt.plot(x, Gauss(x, *popt), 'r-', label='fit')
plt.show()


a=popt[1]
print a
x=a*(q*1000+z)/z
print x

rv=(x-lrest)*z/lrest
print rv
```

File Edit View

night1 night1

Places

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"astropy.py" (457 byt

astropy.py - SciTE

File Edit Search View Tools Options Language Buffers Help

1 astropy.py

```
from scipy.optimize import curve_fit
import numpy as np
import matplotlib.pylab as plt
import pyfits as pf
import numpy as np
import matplotlib.pyplot as plt
from scipy.interpolate import interp1d


fls=file=open('dates.txt', 'w')
file=open('data.lst')



line=file.readline()
while line:
        name =  file.readline().rstrip('\n')
        print name
        exec(open('1song.py').read(), globals())

        BJDMID=hdr.get ('BJD-MID')
        print>>fls, BJDMID, ' ; ' ,rv

file.close()
```

26,2 GiB)

andrius@andri... night1 [How to Take a ... song.py - SciTE astropy.py - SciTE 07:13

song.py - SciTE

File

1 son

```
fr
im
im
im
im
im
fr
na
da

fr

#
hd
#
#
#
#
#

fr
z=
k=

dd=data[0,39,:]/data[2,39,:];ww=data[3,39,:]
a=[dd[0]];b=[ww[0]]
for i in range(5):
    dat=dd[i*400:i*400+399]
    mx=np.argmax(dat)
    dat[mx]=0
    mx=np.argmax(dat)
    a.append(dd[i*400+mx])
    b.append(ww[i*400+mx])
a.append(dd[2047])
b.append(ww[2047])

fck=interp1d(b,a,kind='linear')


dd=np.array(dd)/fck(ww)
#plt.plot(ww,dd)

nnn=1830
```

andrius@andrius-HP-Stream-N...~/Downloads/SONG_data/night1

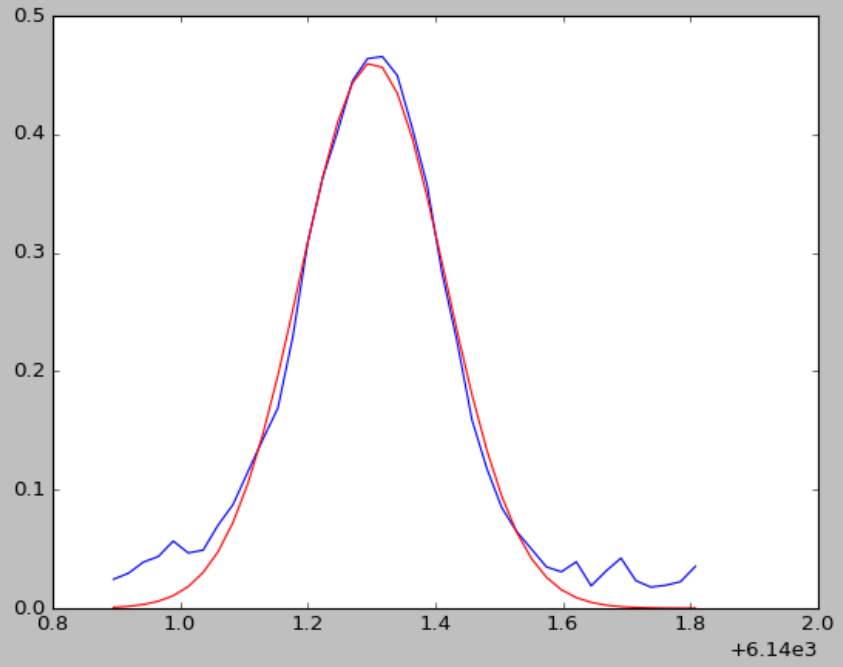
File Edit Tabs Help

```
s1_2016-08-06T21-09-26_ext.fits  s1_2016-08-07T23-33-47_ext.fits
s1_2016-08-06T21-13-39_ext.fits  s1_2016-08-07T23-38-00_ext.fits
s1_2016-08-06T21-17-52_ext.fits  s1_2016-08-07T23-42-13_ext.fits
s1_2016-08-06T21-22-04_ext.fits  s1_2016-08-07T23-46-26_ext.fits
s1_2016-08-06T21-26-18_ext.fits  s1_2016-08-07T23-51-25_ext.fits
s1_2016-08-06T21-30-30_ext.fits  s1_2016-08-07T23-55-38_ext.fits
s1_2016-08-06T21-35-35_ext.fits  s1_2016-08-07T23-59-51_ext.fits
s1_2016-08-06T21-39-49_ext.fits  s1_2016-08-08T00-04-04_ext.fits
s1_2016-08-06T21-44-02_ext.fits  s1_2016-08-08T00-08-17_ext.fits
s1_2016-08-06T21-48-15_ext.fits  s1_2016-08-08T00-12-30_ext.fits
s1_2016-08-06T21-52-28_ext.fits  s1_2016-08-08T00-16-43_ext.fits
s1_2016-08-06T21-56-41_ext.fits  s1_2016-08-08T00-20-56_ext.fits
s1_2016-08-06T22-00-54_ext.fits  s1_2016-08-08T00-25-09_ext.fits
s1_2016-08-06T22-05-07_ext.fits  sample.png
s1_2016-08-06T22-09-20_ext.fits  song.py
s1_2016-08-06T22-13-33_ext.fits  spectrum.py
s1_2016-08-06T22-18-37_ext.fits  spyder_crash.log
andrius@andrius-HP-Stream-Notebook-PC-13:~/Downloads/SONG_data/night1$ python so
ng.py
 4.5026326
6141.30159413
6141.39383136
140.344365646
```

items (27 hidden)

astropy.py - SciTE

Figure 1



andrius@andri... andrius [How to Take a ... song.py - SciTE astropy.py - SciTE Figure 1 07:15

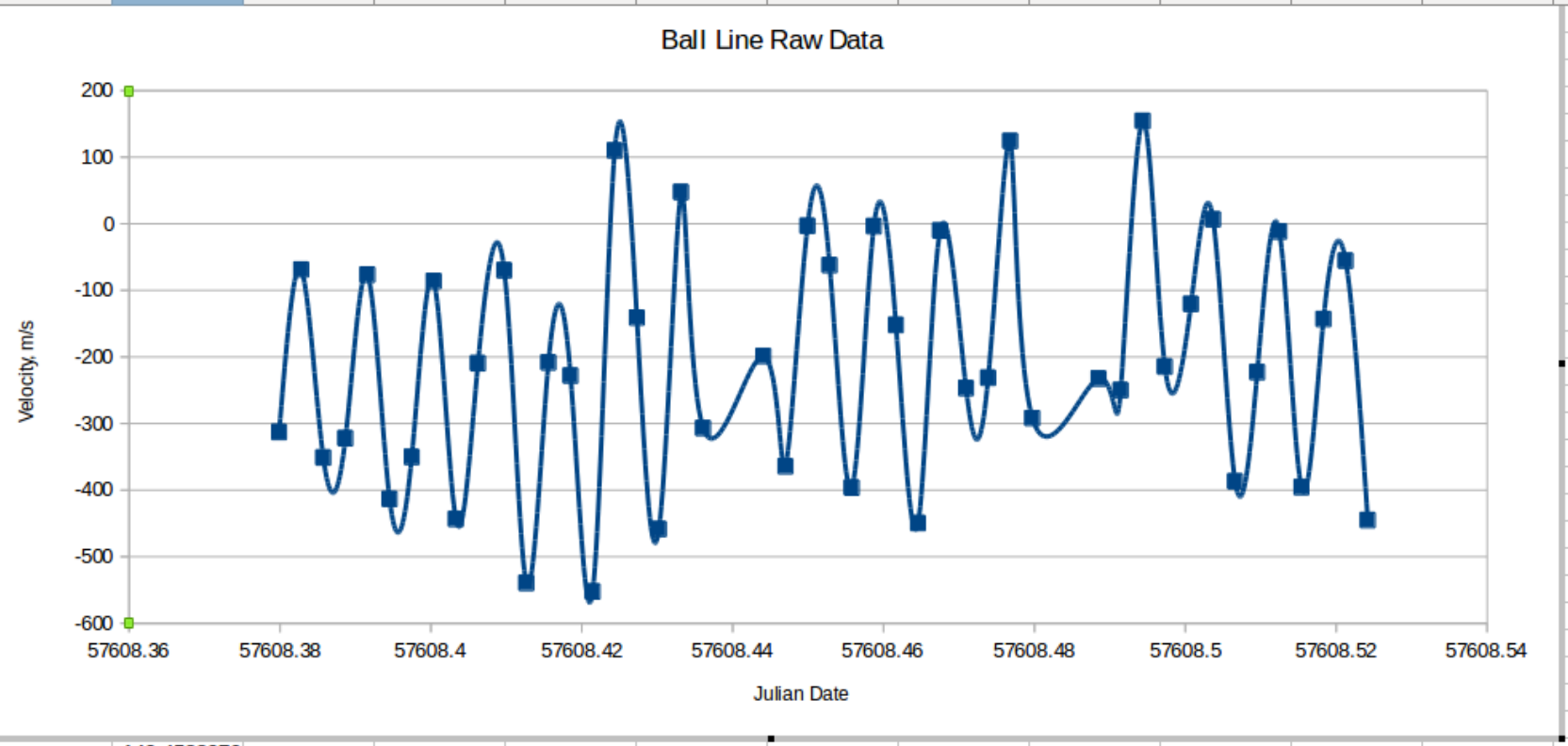
6145_07.txt - LibreOffice Calc

File Edit View Insert Format Tools Window Help

Y Axis | Chart Wall | All Axes

D31

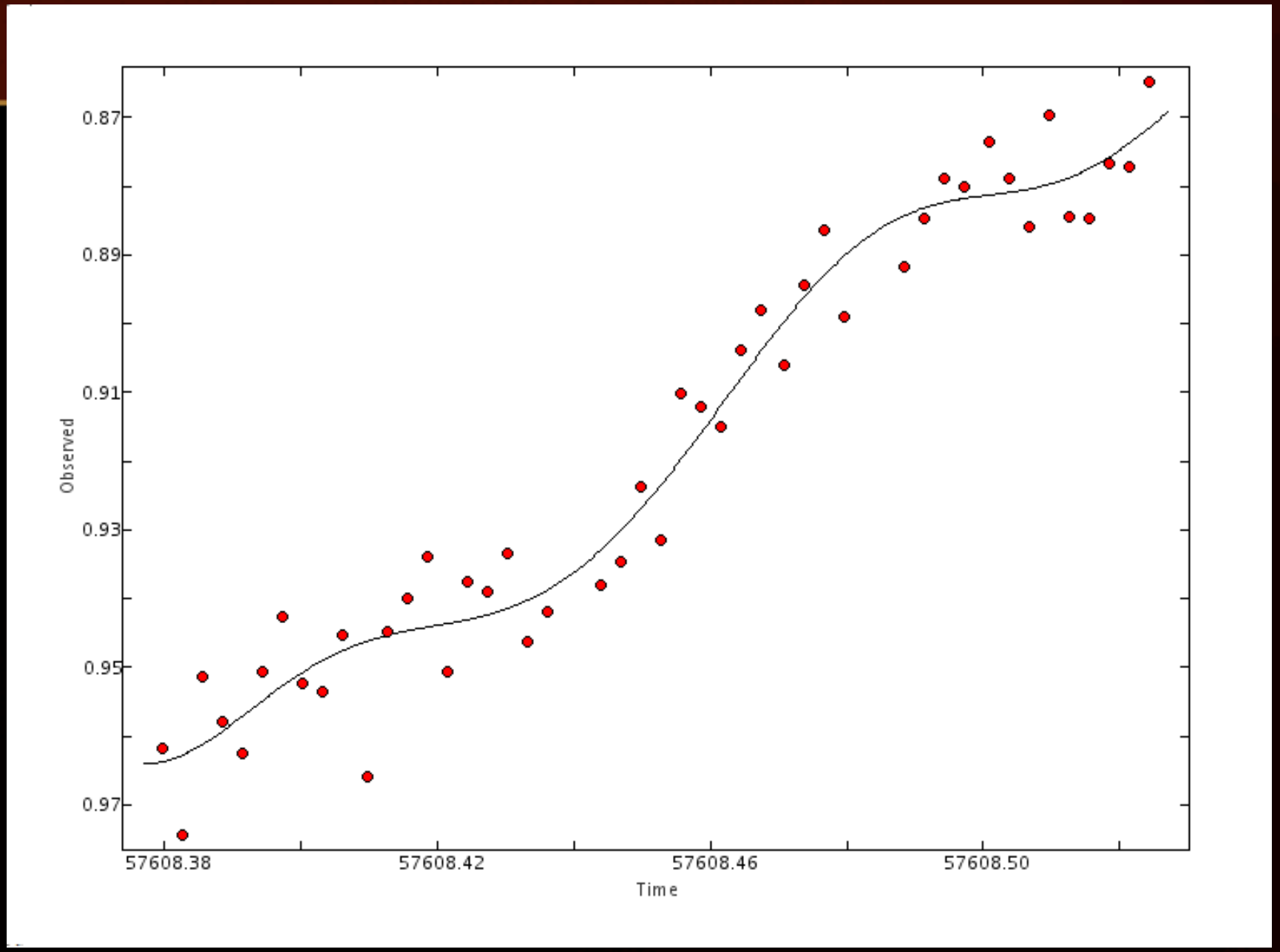
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
3	57606.4556888	-5.98590339301E-05													
4	57606.4586179	-145.529000547													
5	57606.4615473	307.823071849													
6	57606.4644782	14.4694451221													
7	57606.4674062	-227.396815399													
8	57606.4703338	307.705109217													
9	57606.4732619	-226.771478943													
10	57606.4761893	-413.749257851													
11	57606.4796743	294.045987286													
12	57606.4826041	-226.322025678													
13	57606.4855319	-37.9314873526													
14	57606.4884627	199.444229556													
15	57606.4913902	-247.721858207													
16	57606.4943197	-30.3363170516													
17	57606.4972482	170.202335323													
18	57606.5001758	-175.61326798													
19	57606.5031036	-26.3427960442													
20	57606.5060312	82.1558562127													
21	57606.5095053	-299.260241527													
22	57606.5124353	95.2140373283													
23	57606.5153628	61.2975444464													
24	57606.5182913	-144.252241298													
25	57606.5212199	48.8046888645													
26	57606.5241476	-68.0338481434													
27															
28	57607.3765261	-237.091195428													
29	57607.3794559	42.539308745													
30	57607.3823845	-424.847768589		-149.4588976											
31	57607.3853139	-10.5701873169													
32	57607.3882418	21.0471696806													
33	57607.3911703	-459.400844281													
34	57607.3940981	134.462261289													

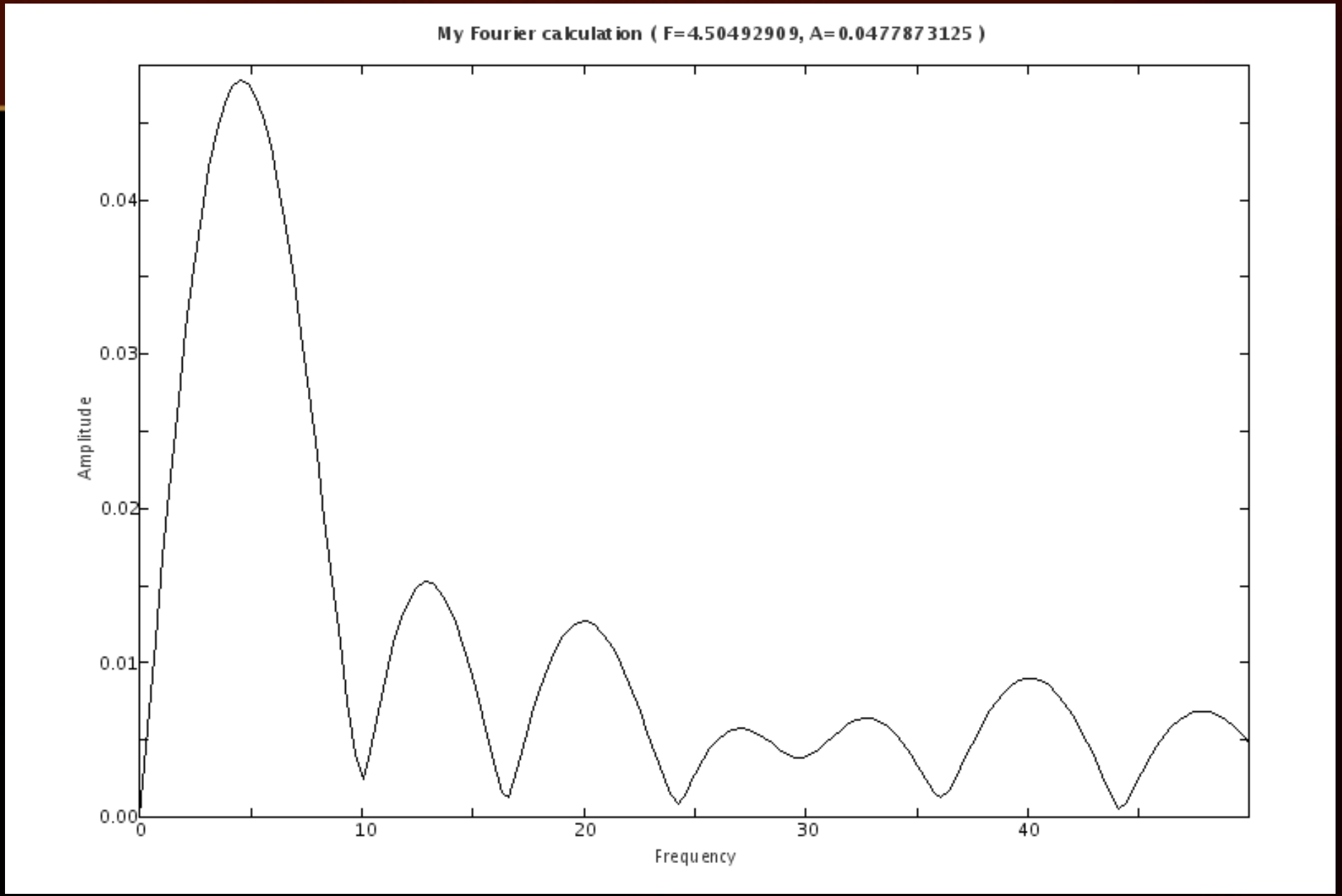


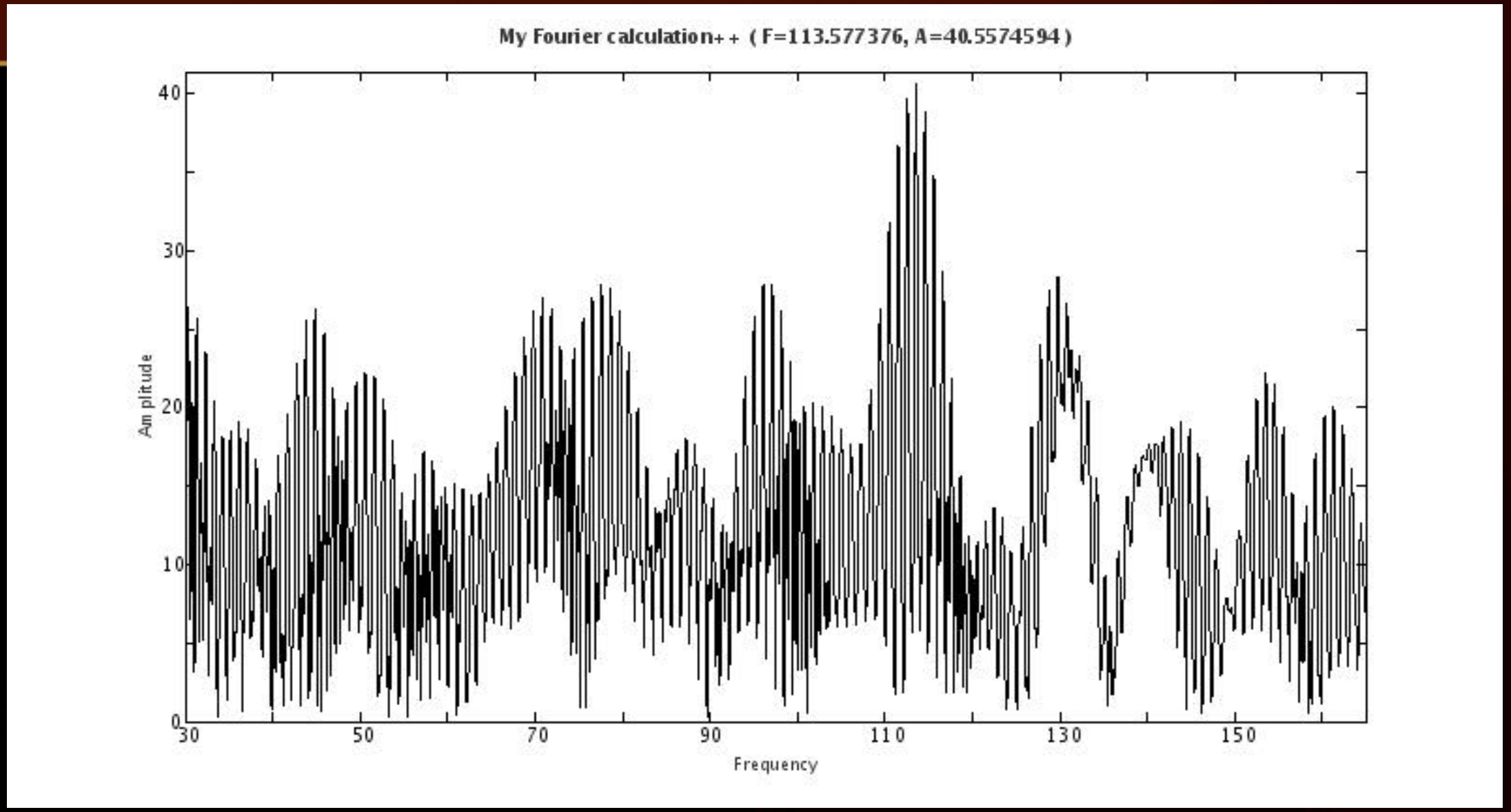
6145_07

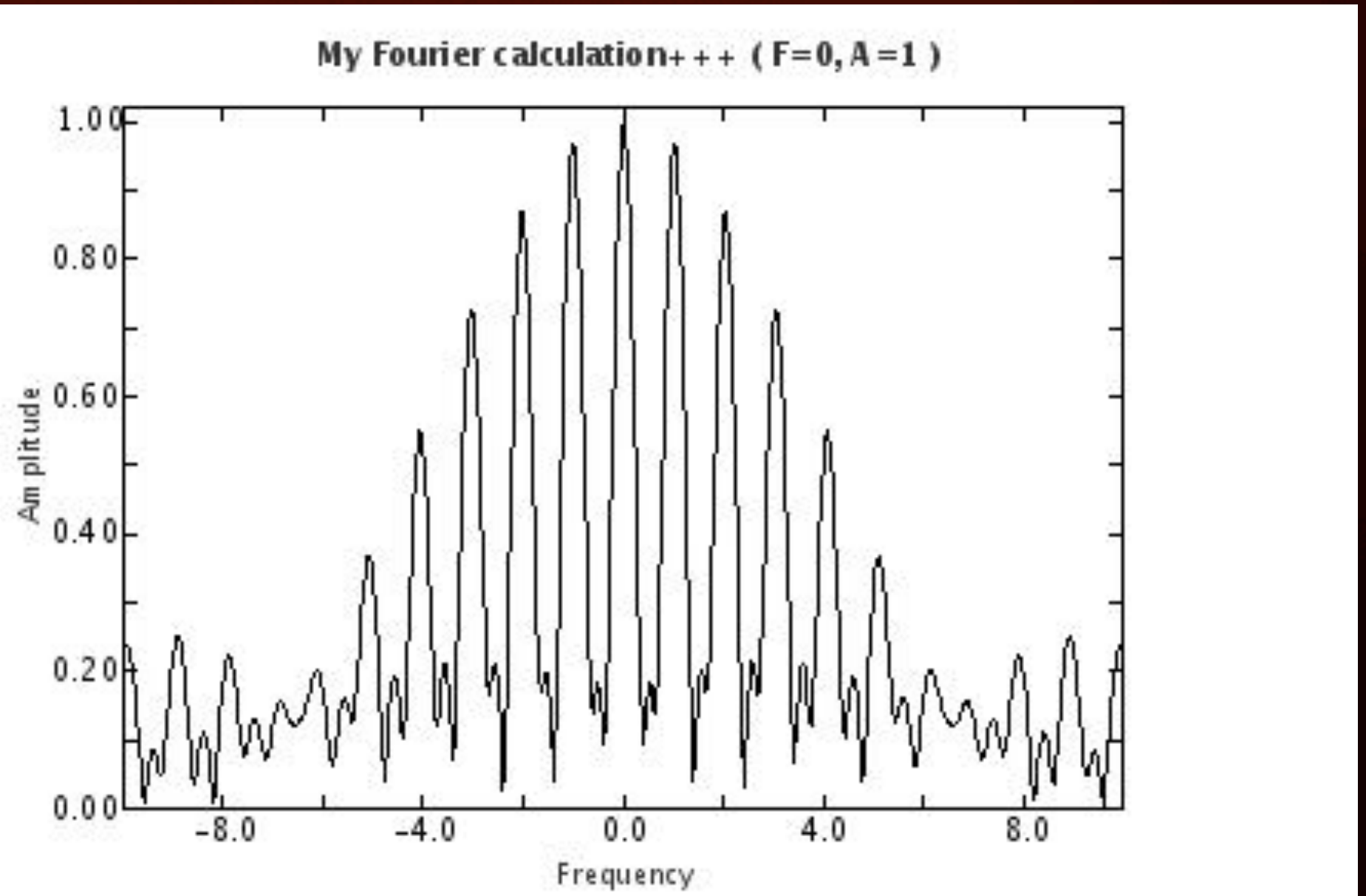
Y Axis selected

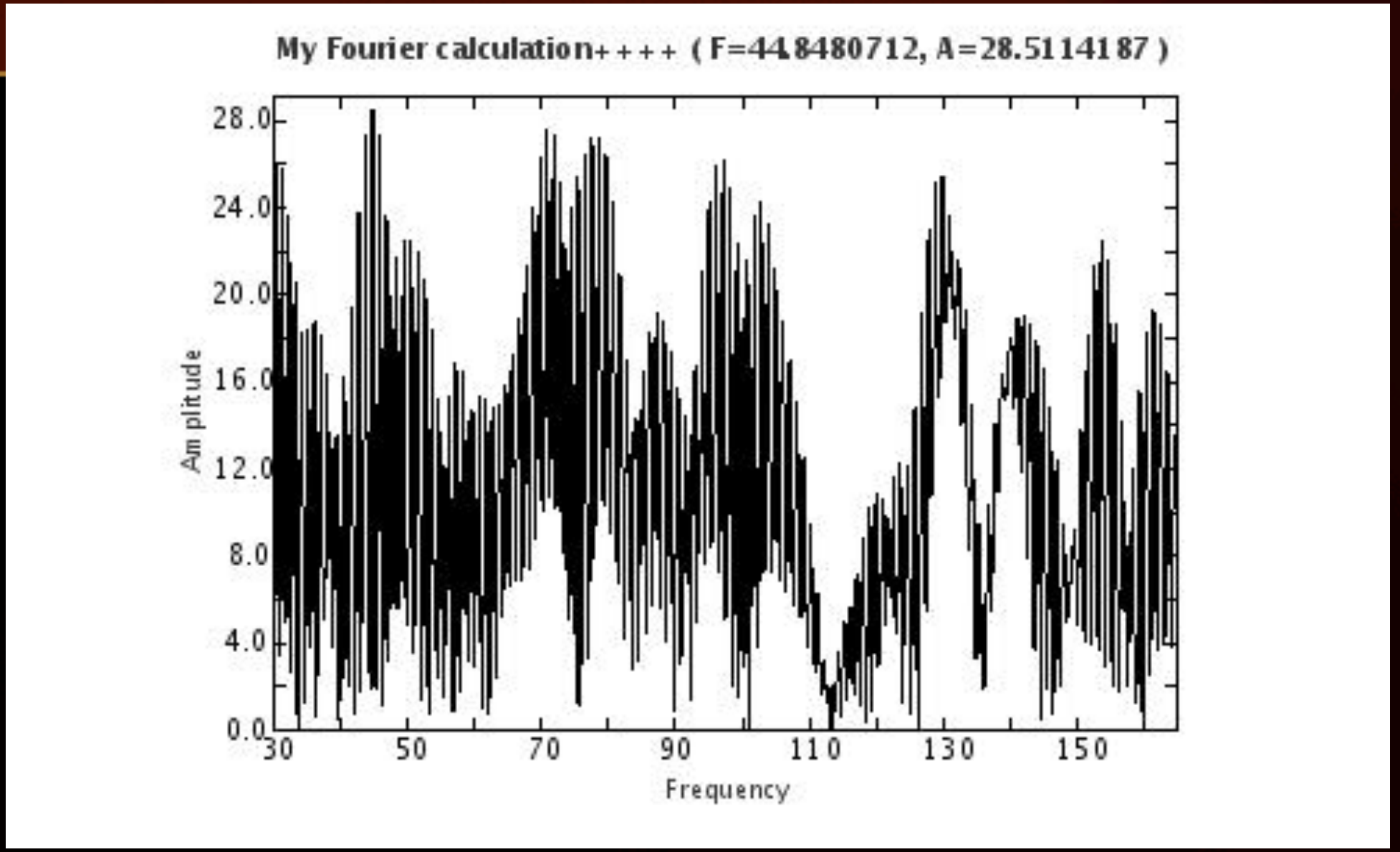
andrius@a... andrius How to Ta... [song.py - ... astropy.py... [Gamma.p... Untitled 1 -... 6145_07.tx... 07:30

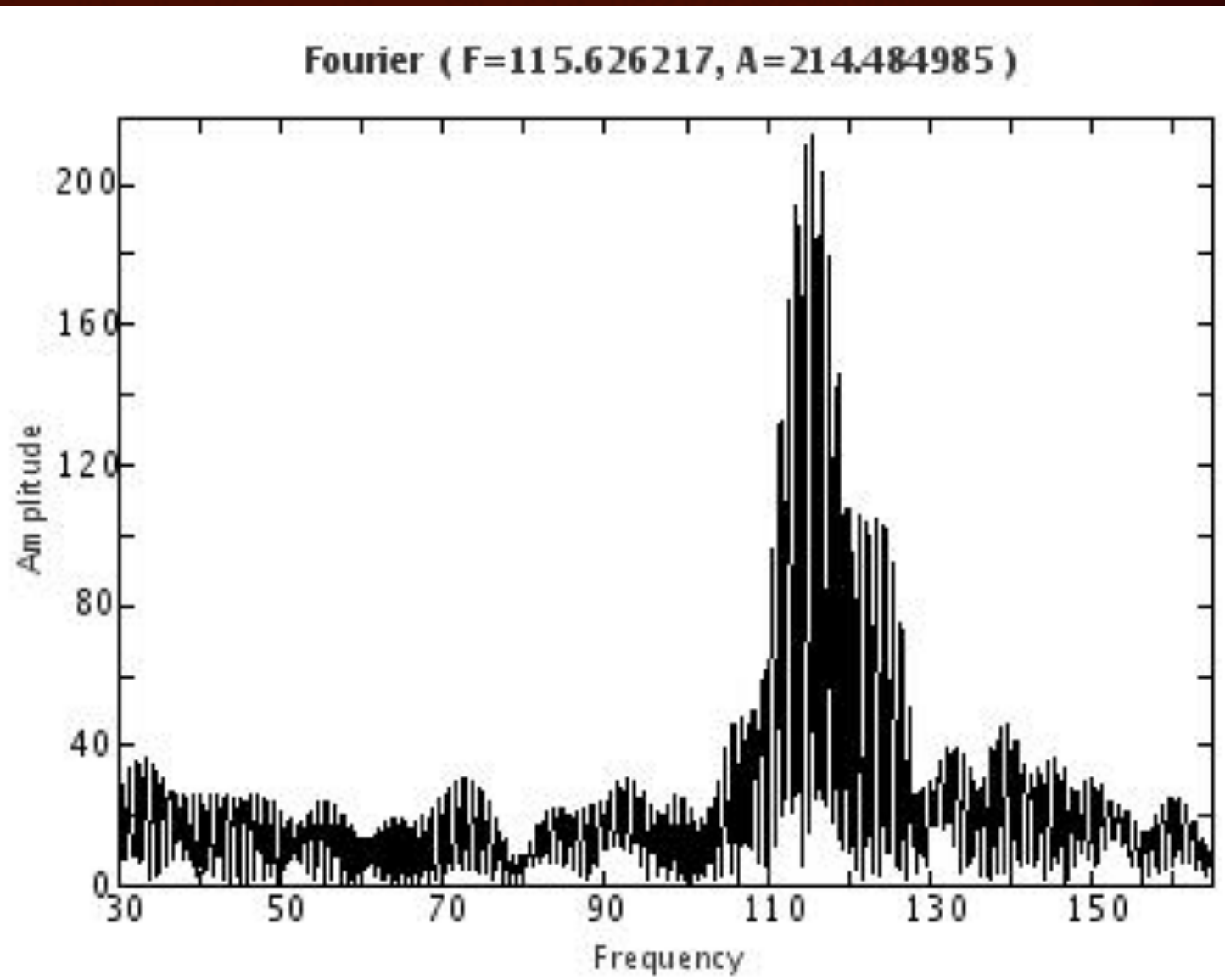

0.87
0.89
0.91
0.93
0.95
0.97
Observed
57608.38
57608.42
57608.46
57608.50
Time

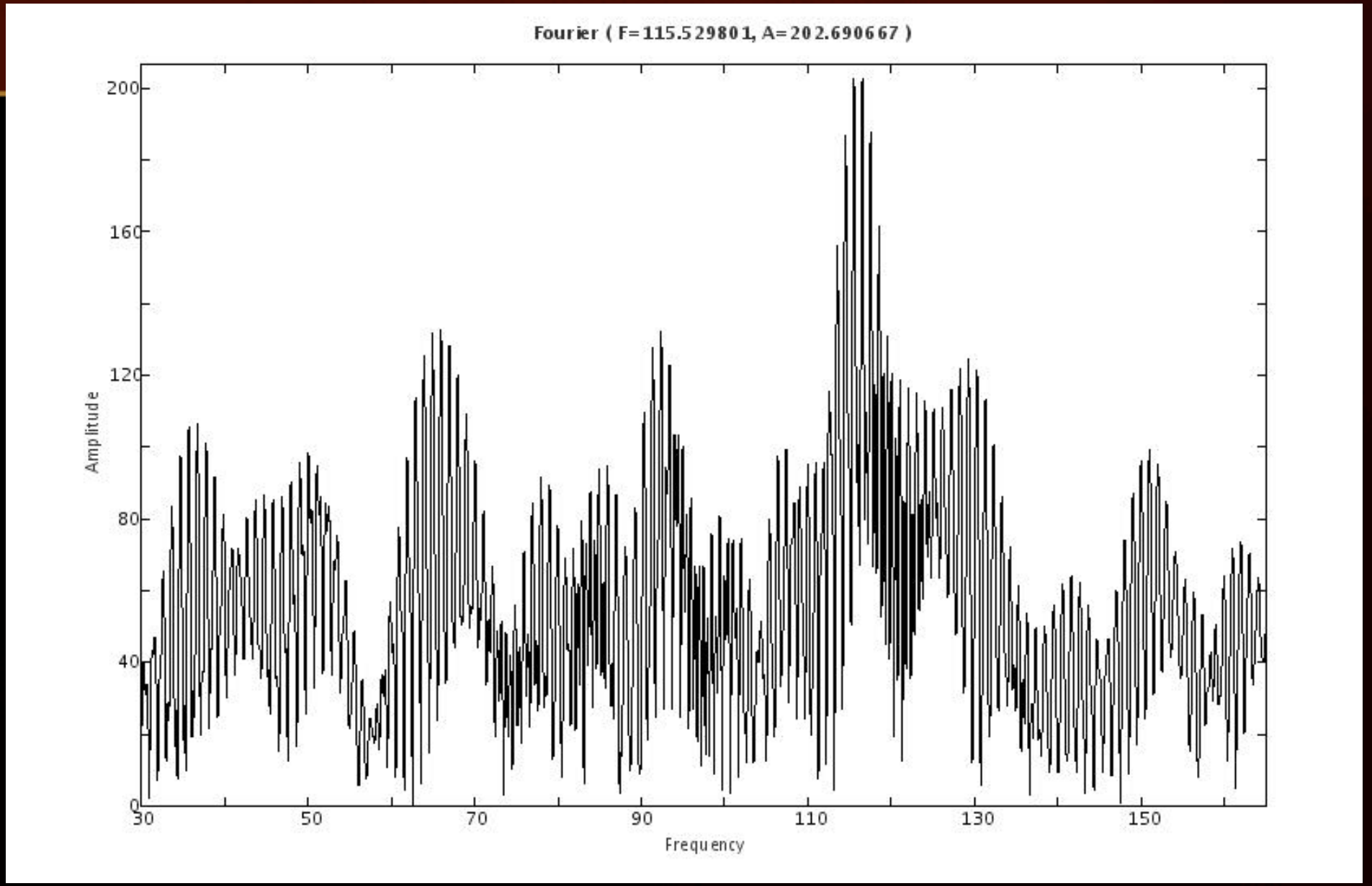

My Fourier calculation (F=4.50492909, A=0.0477873125)
Amplitude
0.00
0.01
0.02
0.03
0.04
0
10
20
30
40
Frequency


My Fourier calculation++ (F=113.577376, A=40.5574594)
Amplitude
Frequency
0
10
20
30
40
30
50
70
90
110
130
150


My Fourier calculation+++ (F=0, A=1)
1.00
0.80
0.60
0.40
0.20
0.00
Amplitude
-8.0
-4.0
0.0
4.0
8.0
Frequency


My Fourier calculation++++ (F=44.8480712, A=28.5114187)
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
Amplitude
30
50
70
90
110
130
150
Frequency


Fourier (F=115.626217, A=214.484985)
200
160
120
80
40
0
Amplitude
30
50
70
90
110
130
150
Frequency


Fourier (F=115.529801, A=202.690667)
Amplitude
Frequency
0
40
80
120
160
200
30
50
70
90
110
130
150

Variable lines (Angstroms)

- NdIII 6145_07 (115.63 1/JD)
- BaII 6141_71 (113.58 1/JD)
- FeI 6157.73 (115.52 1/JD)

Pulsation period

- 11,67 to 12,45 minutes.
- 12.29 (1999 July 22, CES/ESO 3.6-m)
- 12.281 2002 September 26, Gecko/CFHT
- Our data – 12.45 to 12.68 minutes!

Summary

- Observations over 3 nights were made with a SONG telescope
- 51 order spectrum was obtained and reduced
- By applying Gaussian fits, radial velocities of 3 lines was calculated
- Fourier transformations of time series were performed
- Line periods were found to be between 12.45 and 12.68 minutes

Acknowledgements

- Huge thanks to Šarūnas Mikolaitis, Erika Pakštienė and Lukas Klebonas for helping thoughout the jungles of data!