Simultaneous photometry and spectroscopy of the *exceptional* asteroid (3200) Phaethon

Huib Henrichs
Amsterdam

Salzburg, 4 May 2019

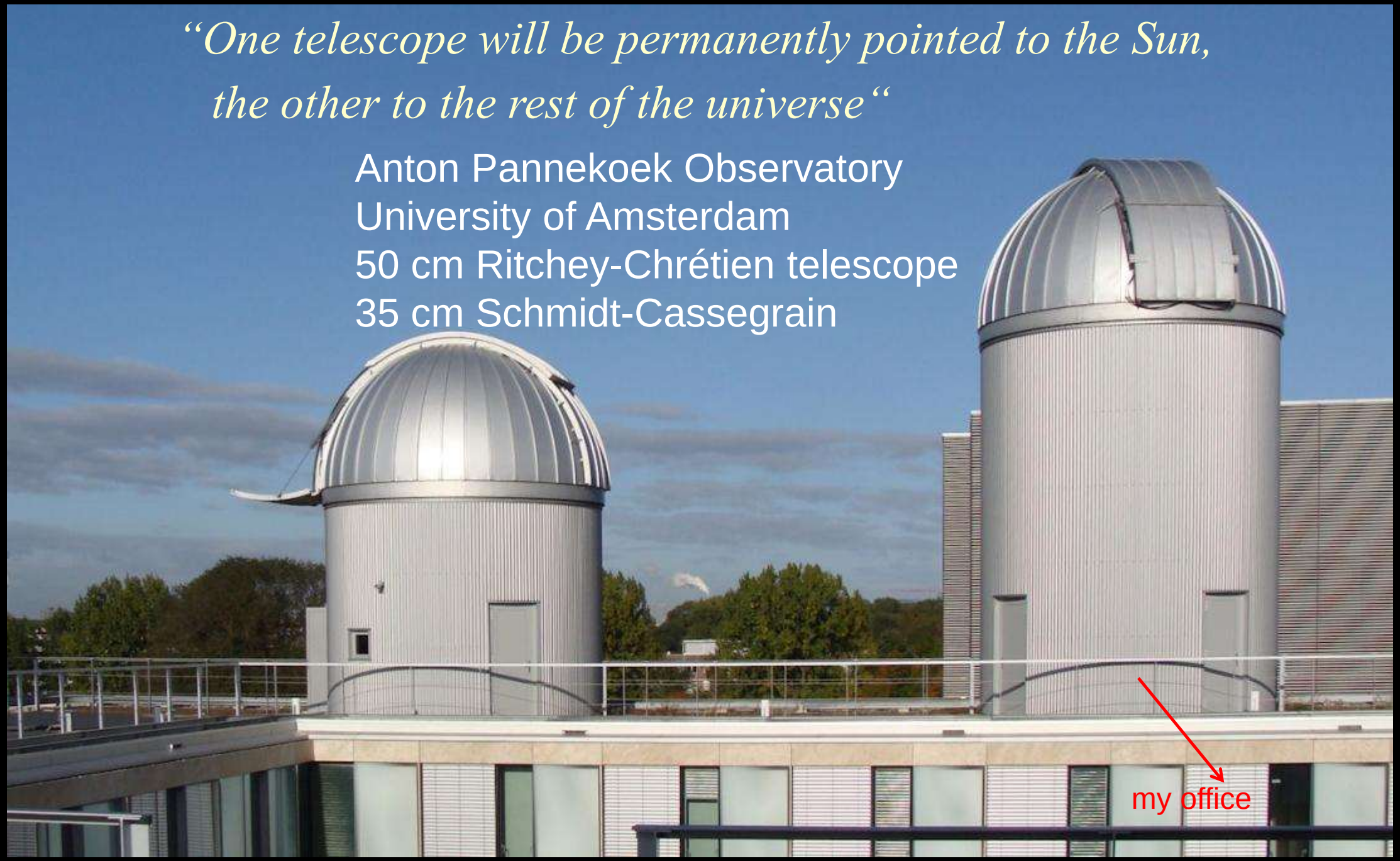
Unique opportunity:

Phaethon closely passed the Earth on December 2017

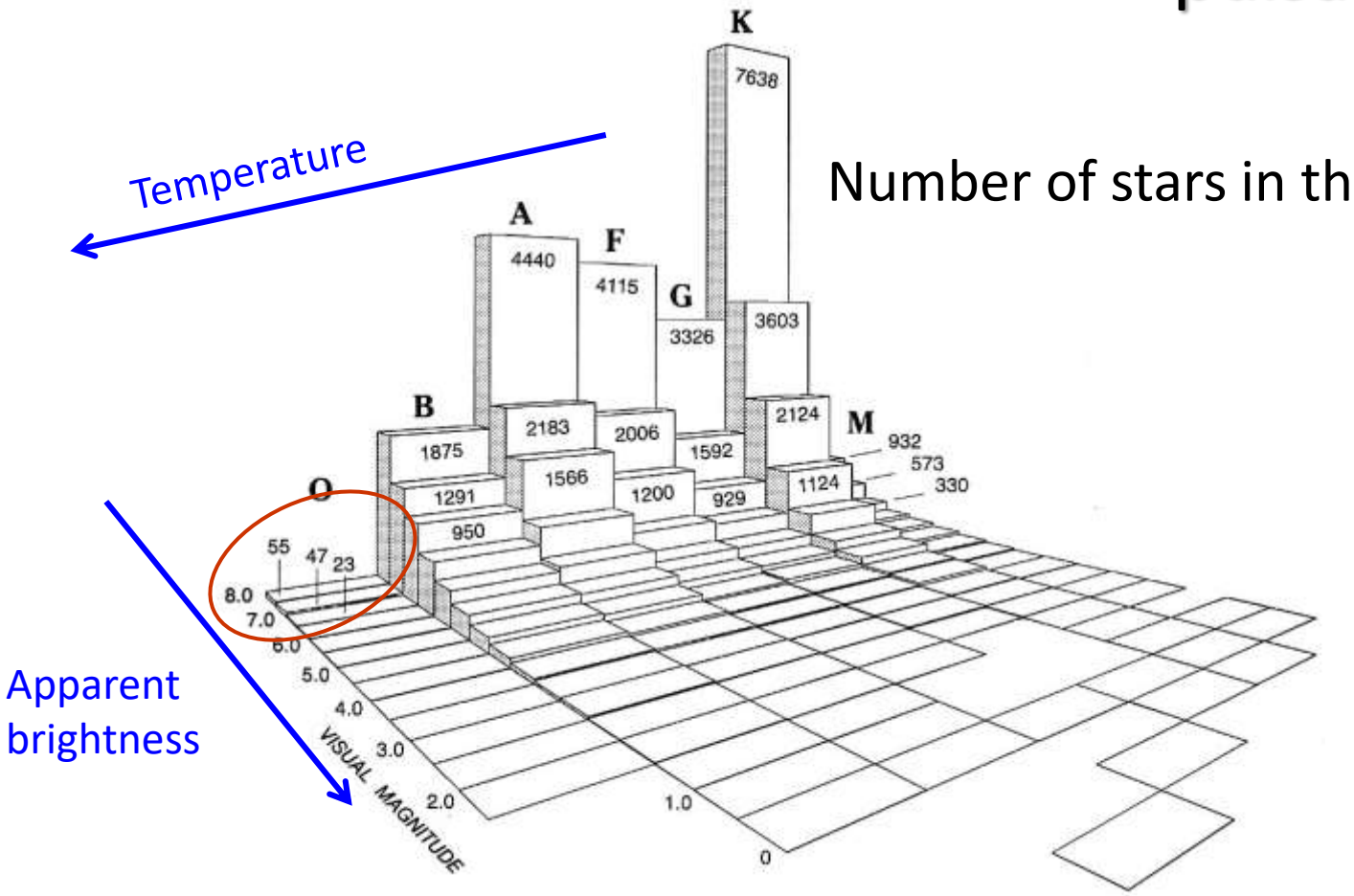
1. Technical part: my remotely controlled observatory in Amsterdam
2. Example spectroscopy projects: supernova, quasars
3. The exceptional Phaethon:
   simultaneous spectroscopy and photometry

"One telescope will be permanently pointed to the Sun, the other to the rest of the universe"

Anton Pannekoek Observatory
University of Amsterdam
50 cm Ritchey-Chrétien telescope
35 cm Schmidt-Cassegrain

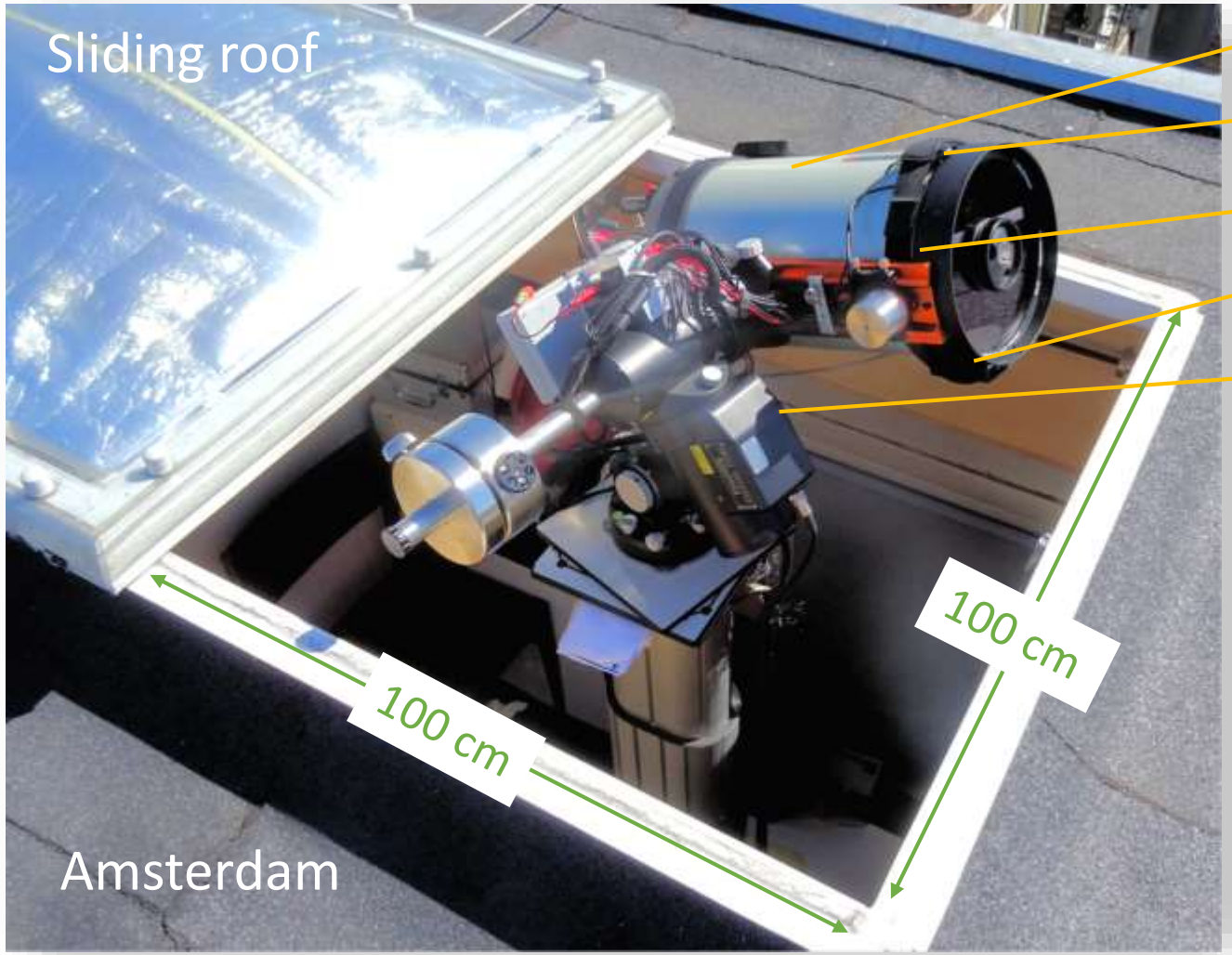


I study massive stars type O and B: magnetic fields stellar winds pulsations

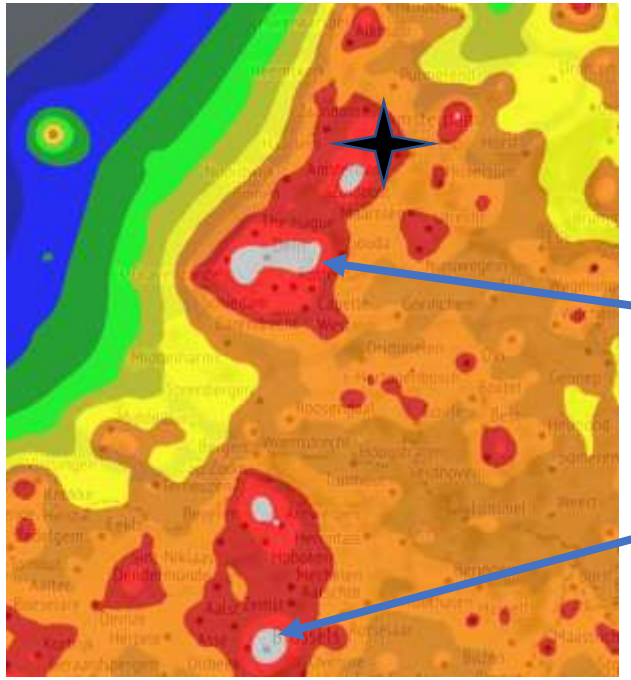


O stars are very rare: ~ 50 visible with the naked eye

1. Rooftop observatory and equipment

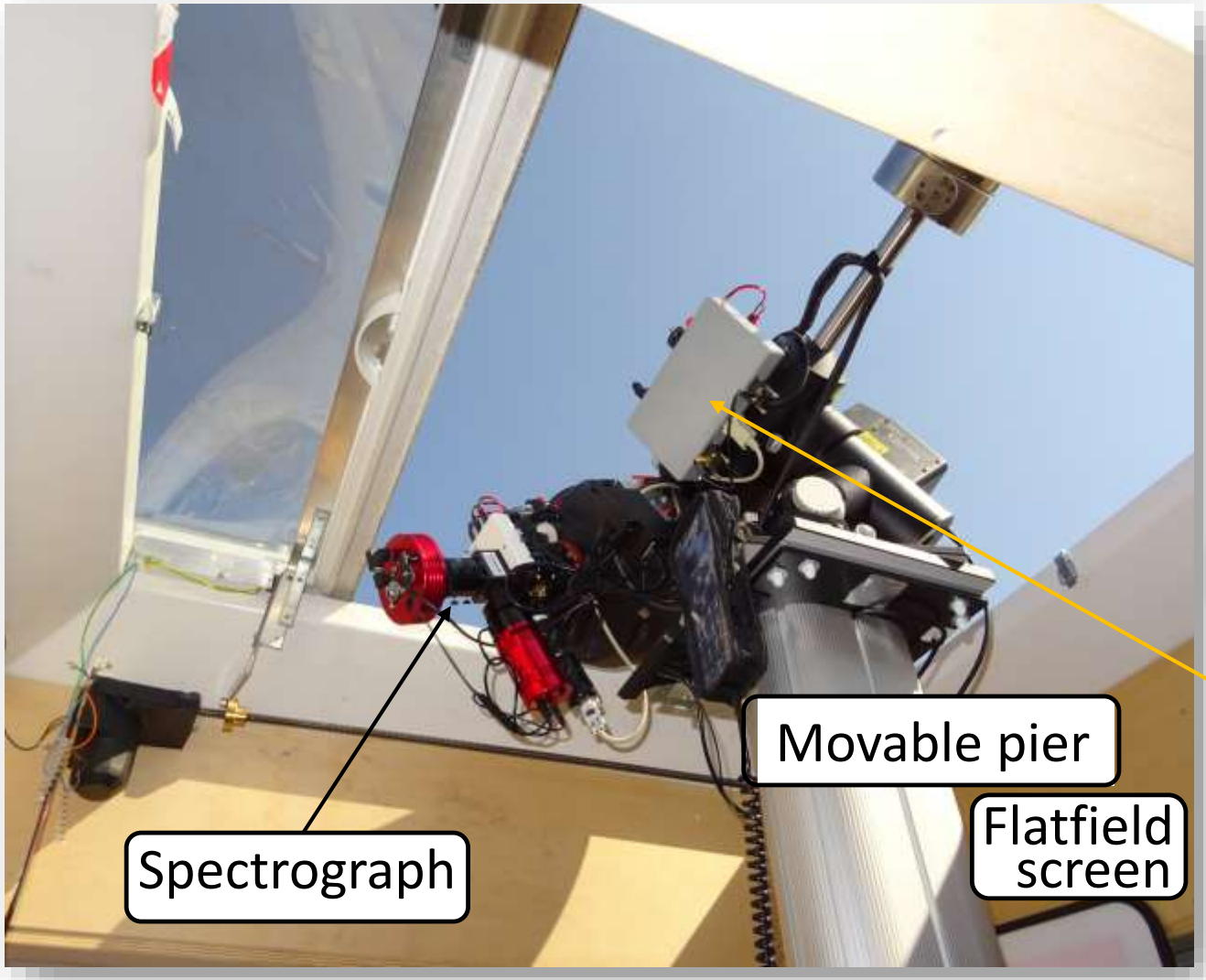


- Celestron 9.25''Edge, 23.5 cm diameter
- GPS
- Dew heater
- Unihedron *Sky Quality Meter* (clouds!)
- 10micron GM1000 (absolute encoders)




Laptop
with webcam
CELESTRON

Remote view from laptop

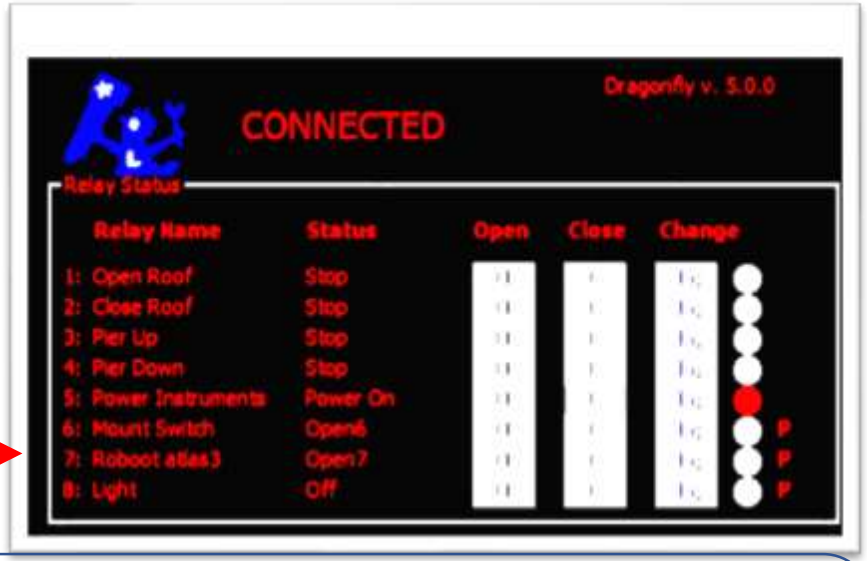


Remote control through internet with *Lunatico Dragonfly*:

Roof, Pier, Power, Mount, Laptop reboot

through docking station

Reboot



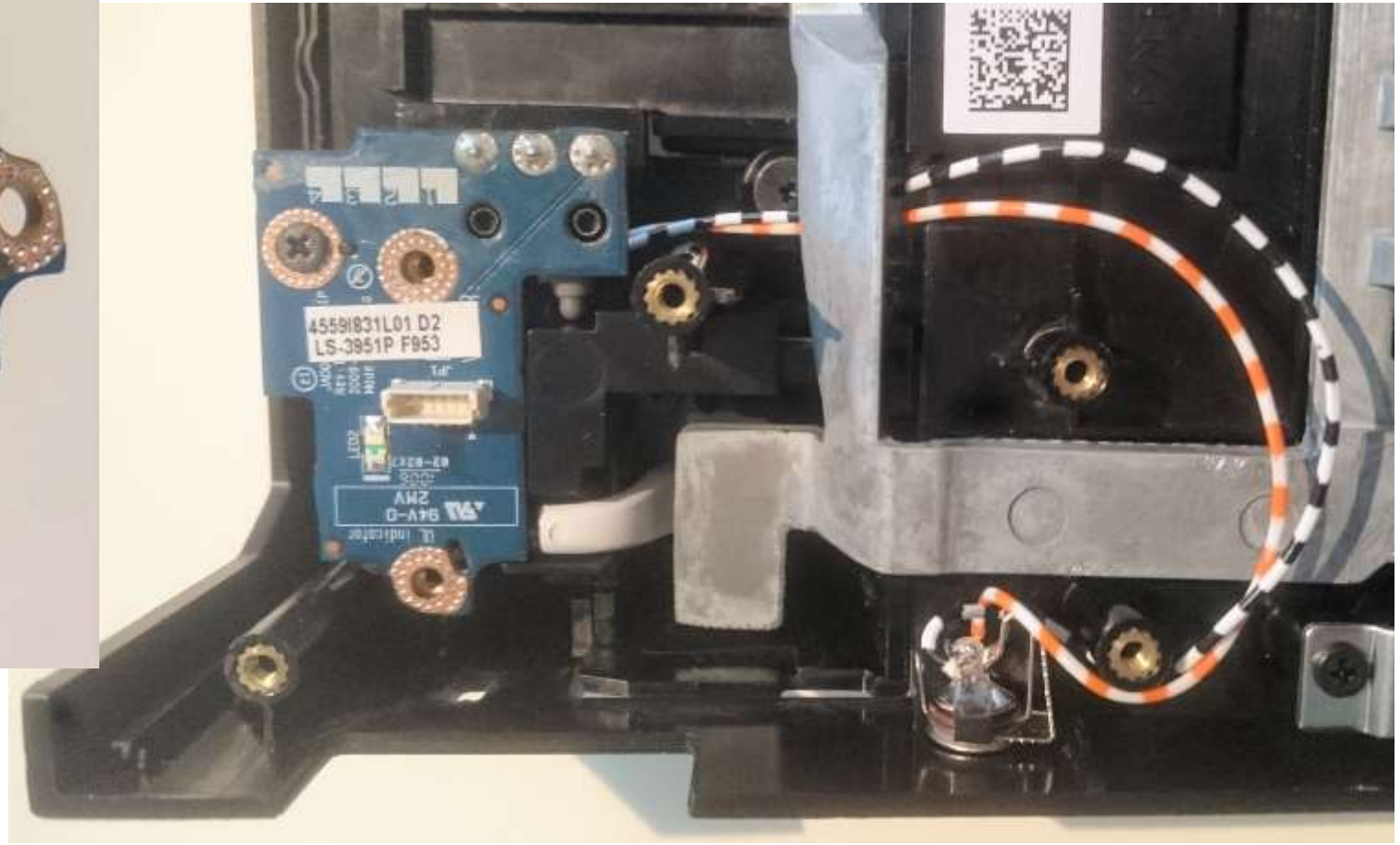
Instrument control by *Lunatico Platypus*:

focusers + dew heater

+ spectrograph calibration lamps

Software: *Teamviewer*

Laptop remote switch



Projects

➢ *Astro Art*

Neodynium light-pollution block

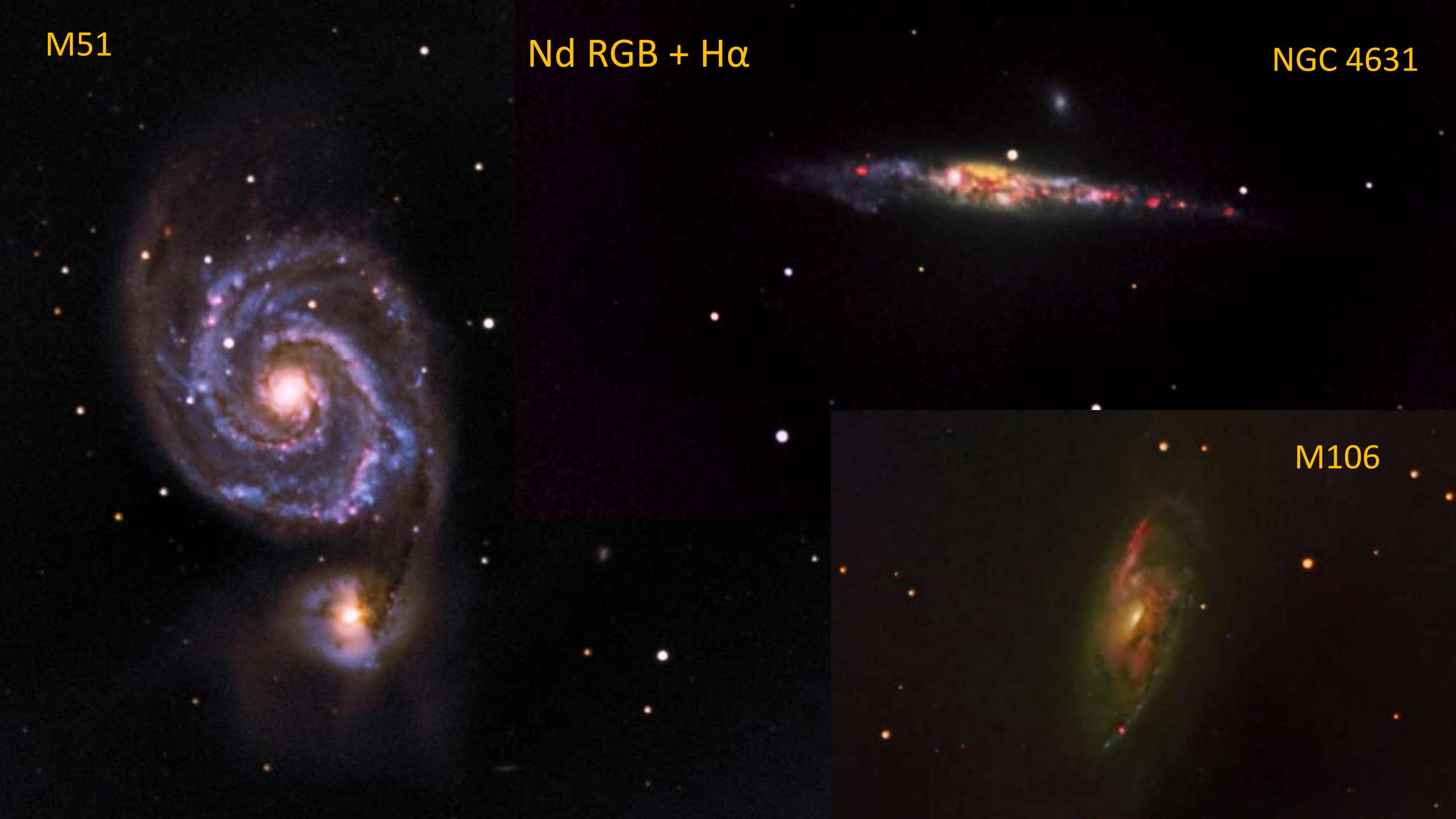
Imaging with filters:

- Broadband Nd, RGB (without disturbing moon): galaxies etc.
- Narrowband Hα, OIII, SII: nebulae

Fast color: moon/planets

➢ *Science*

- *Photometry RVB*: supernovae, transients, asteroids
- *Spectrocopy*: quasars, supernovae, stars, asteroids


M51
Nd RGB + Hα
NGC 4631
M106


M42 Orion
RGB (4 h)

SII-Hα-OIII (Hubble palette)

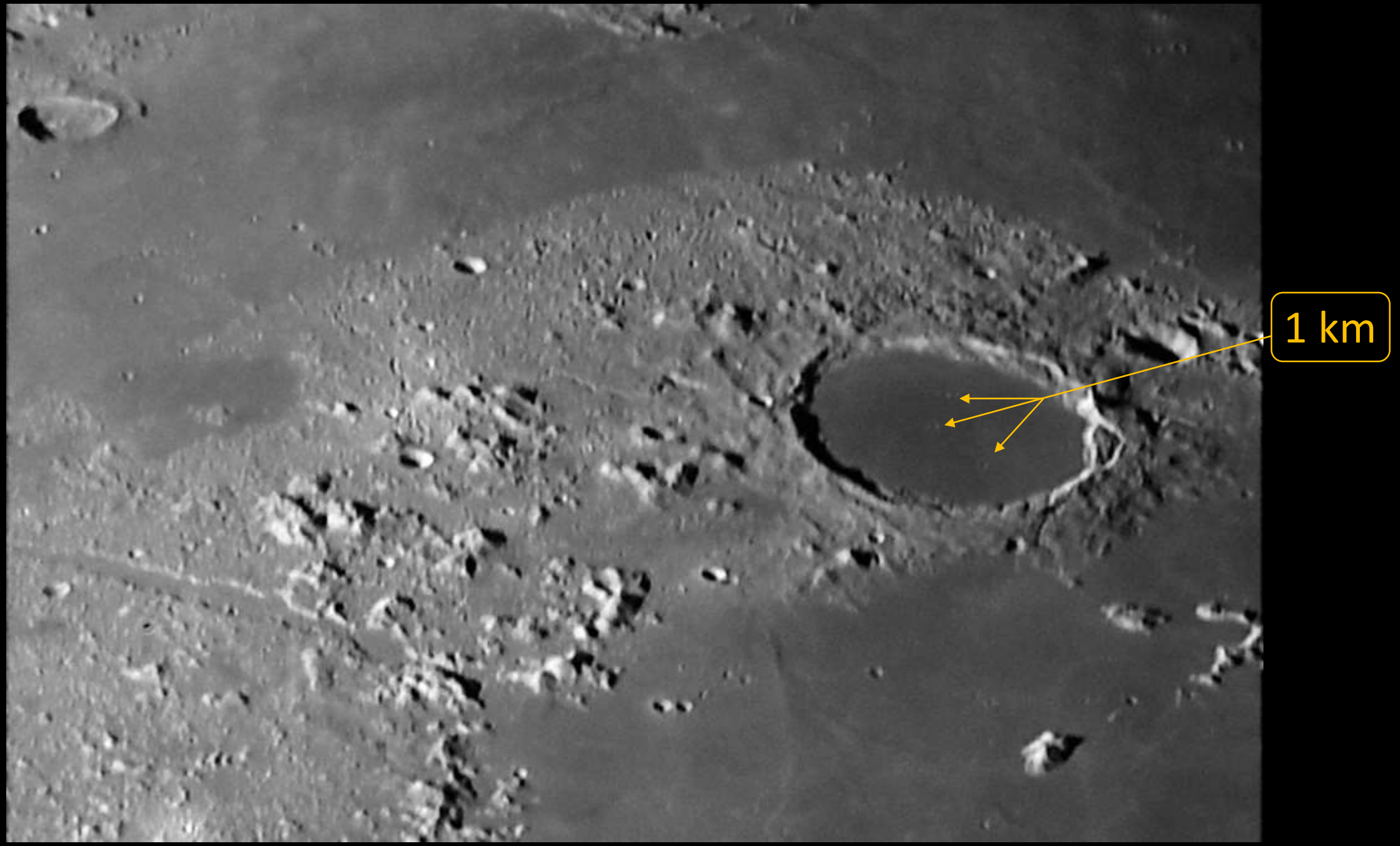
←NGC 6996 Cyg (8 h)

NGC 7635 Cas (6 h)
↓

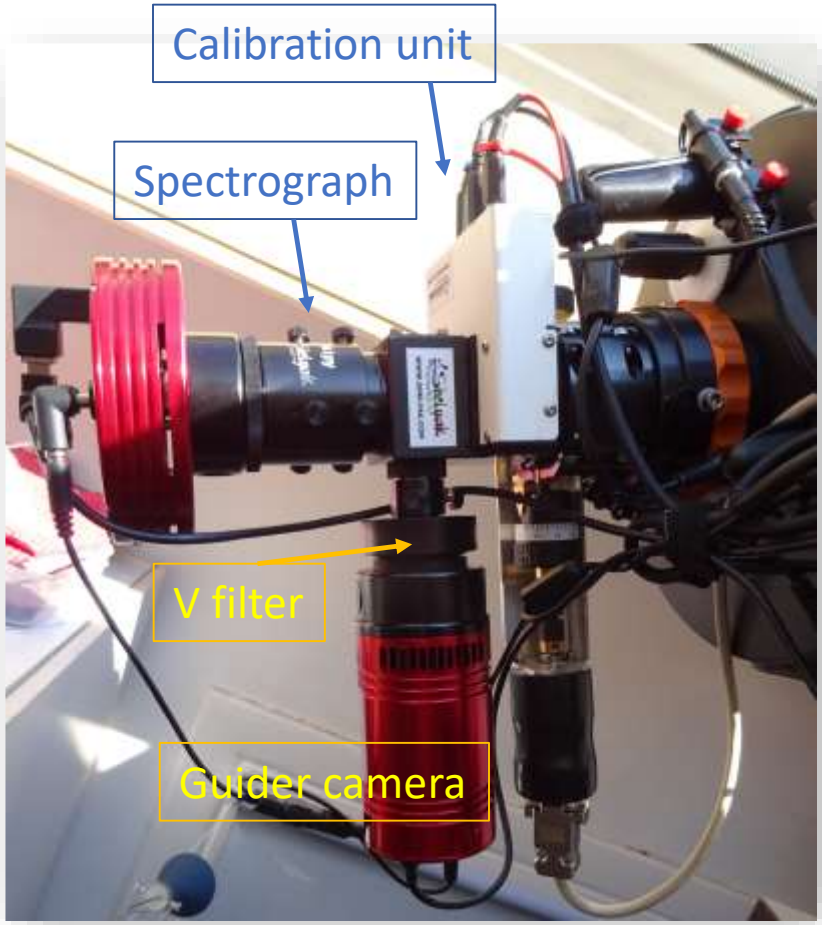
In prime focus: **HyperStar → f/2.3** **3° view**

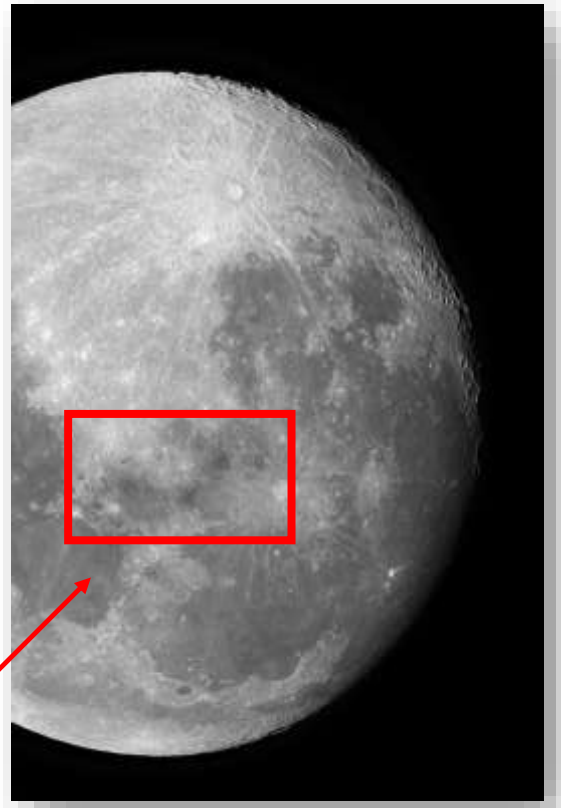

Hyperstar f/2.3
Hα-OIII-SII
(10 h)


Rosetta
Hyperstar f/2.3
Hα-OIII (11 h)


1 km

Spectrograph: Alpy (Shelyak)



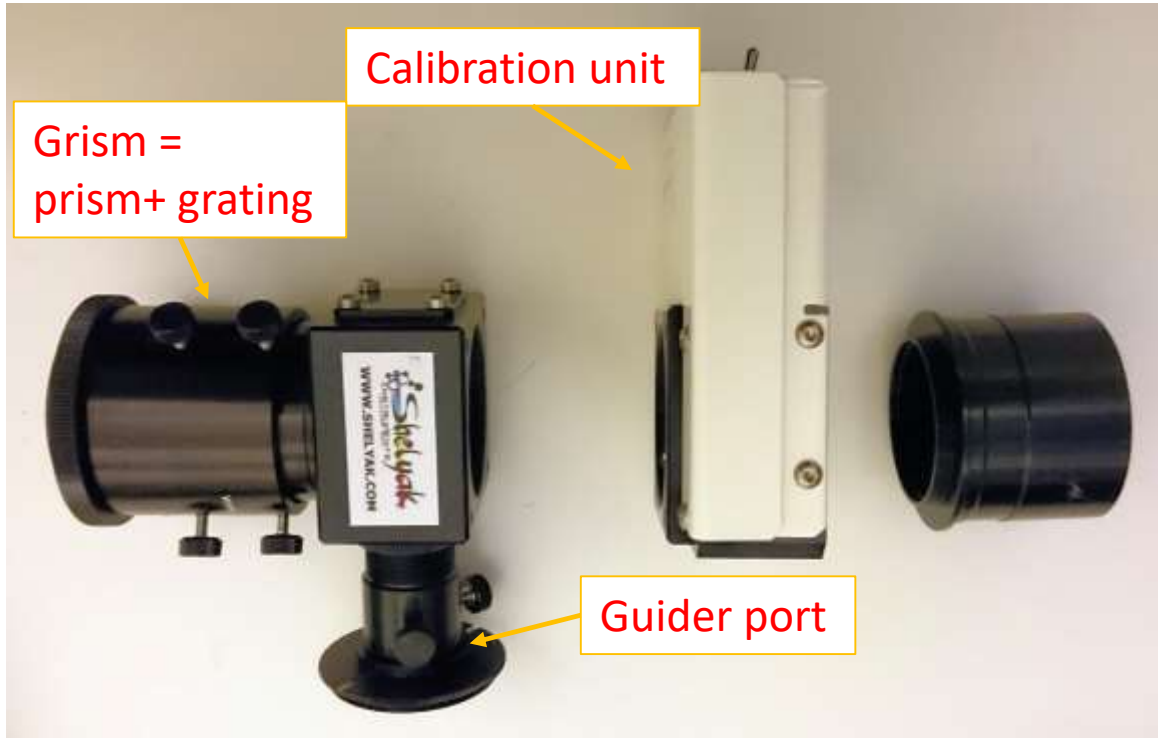


- Range: 3700 – 7500 Å
- Low resolution ≈ 400 – 600
- Ne-Ar and FF calibration lamps
- Guiding module, slit 25 µm
- Guider camera, Field of View: 9′ x 5′
- **Johnson V filter in light path of guider camera**

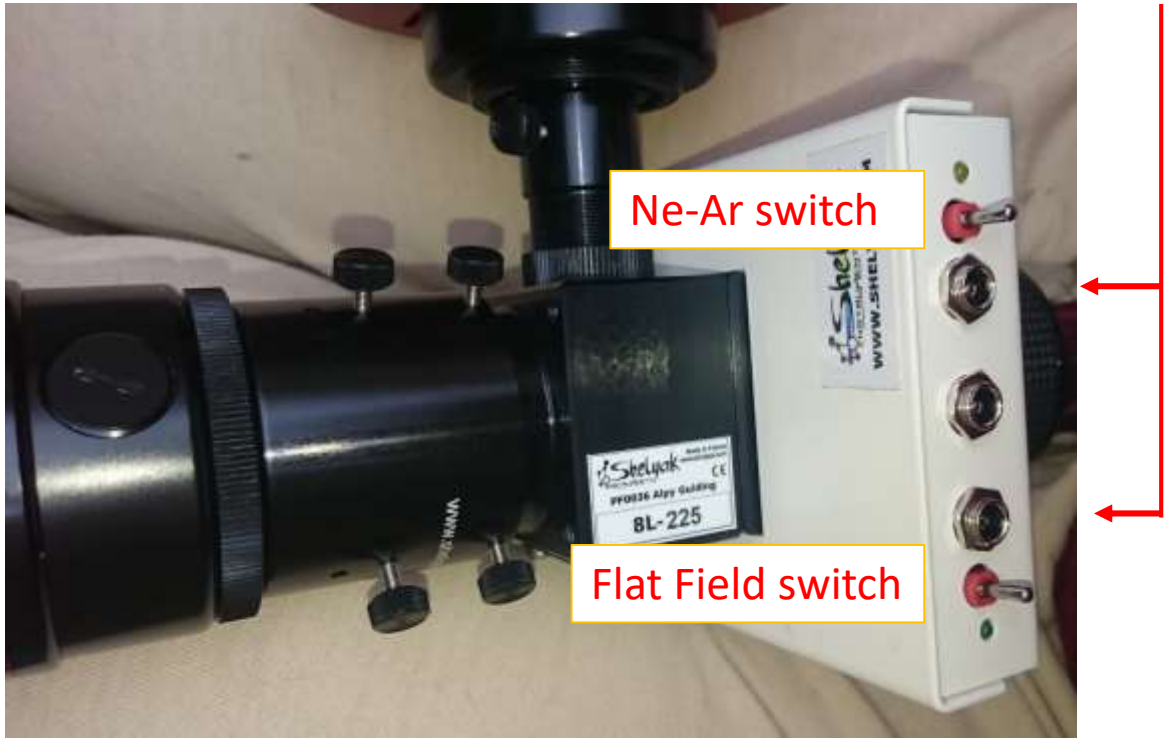
  → **Photometry**

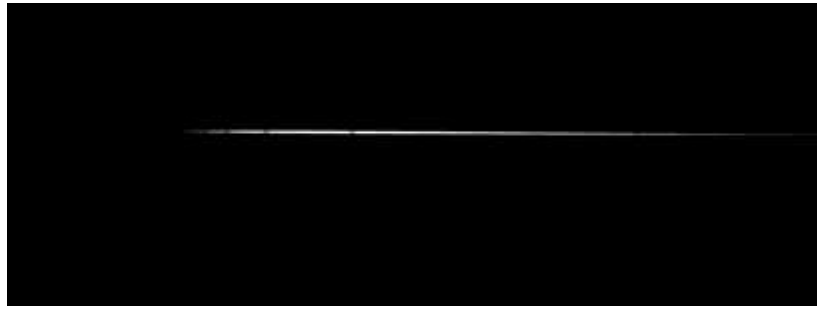
- Acquisition software: *MaxImDL*

Shelyak Alpy spectrograph



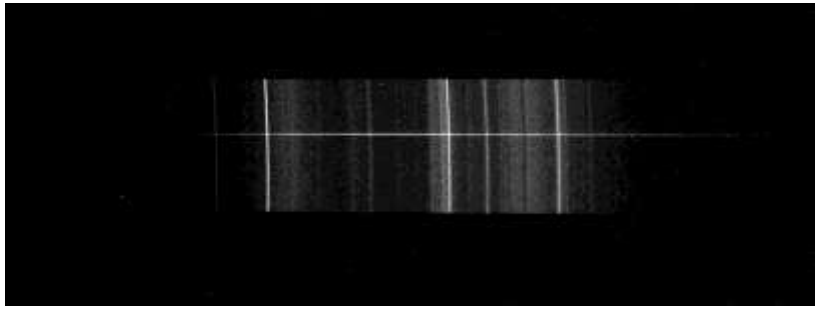
Remote control



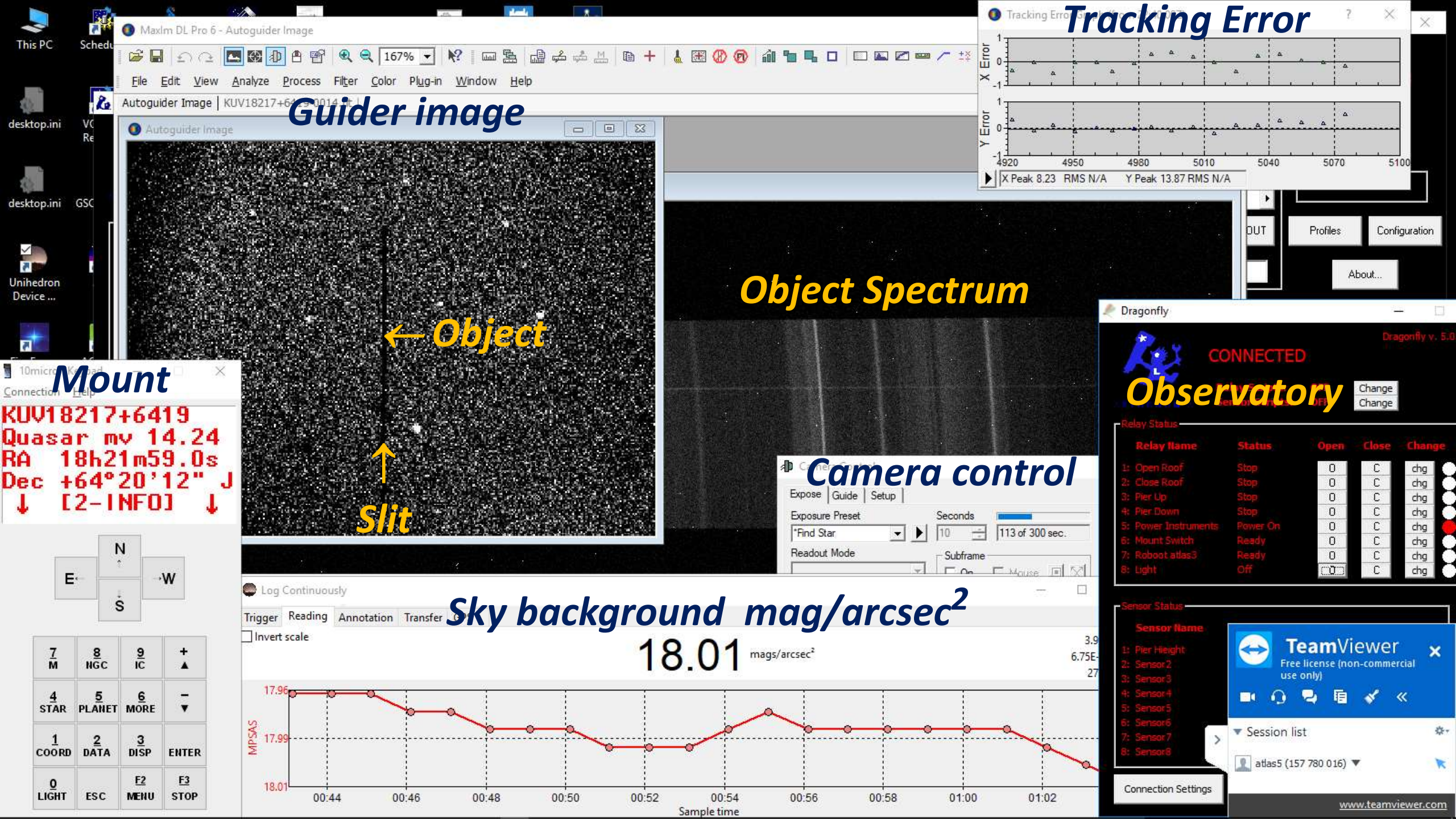


V= 5.9 Exp. 1 min

Binning
1x2



V = 14.6 Exp. 5 min

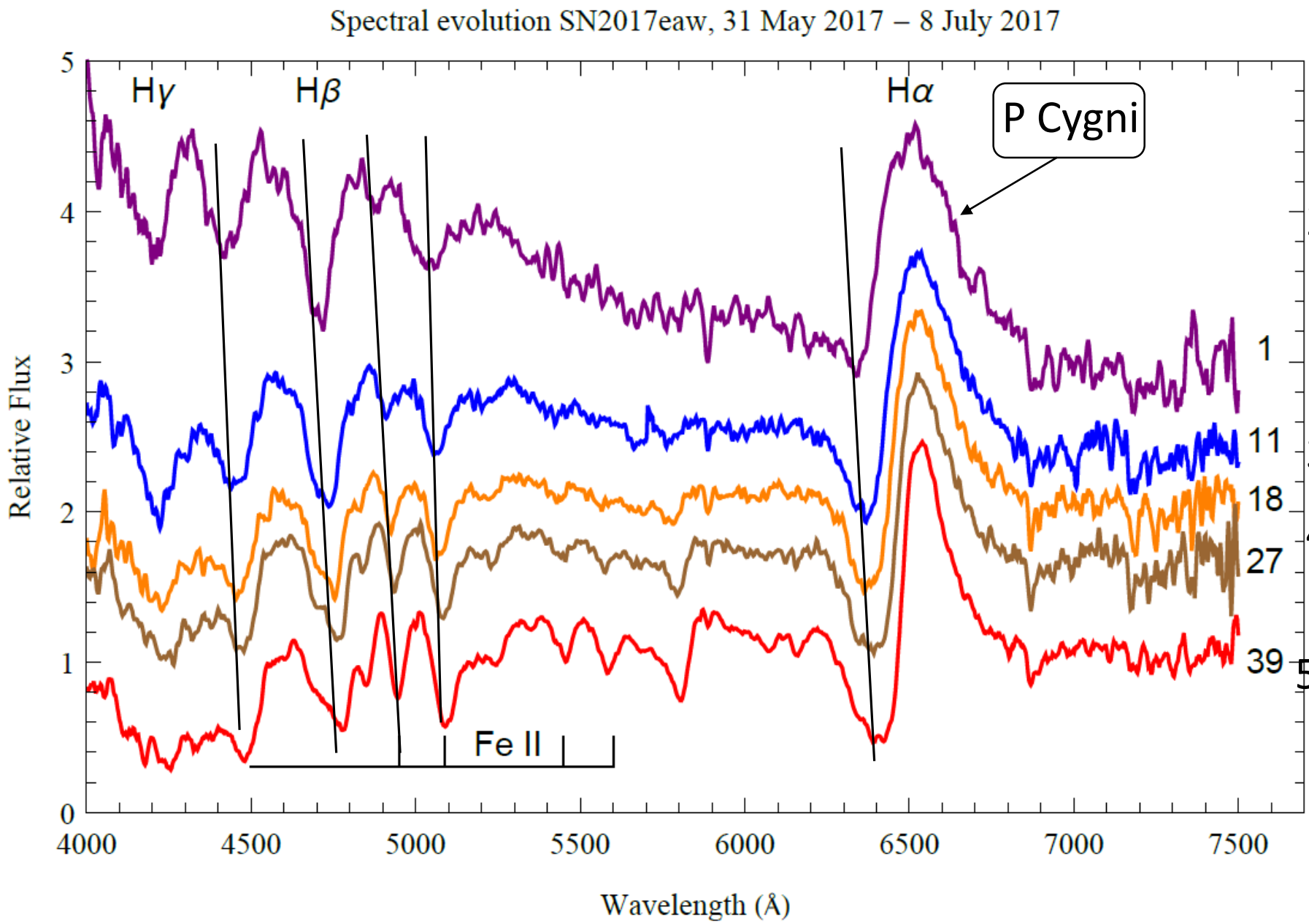

Tracking Error
Guider image
Object Spectrum
← Object
Slit
Mount
Camera control
Observatory
Sky background mag/arcsec²
Maxim DL Pro 6 - Autoguider Image
Autoguider Image
Tracking Error
X Error
Y Error
X Peak 8.23 RMS N/A
Y Peak 13.87 RMS N/A
Profiles
Configuration
About...
Dragonfly
CONNECTED
Relay Status
Relay Name
Status
Open
Close
Change
Sensor Status
Sensor Name
Log Continuously
Trigger
Reading
Annotation
Transfer
Invert scale
18.01
mags/arcsec²
MPSAS
Sample time
Expose
Guide
Setup
Exposure Preset
Seconds
Readout Mode
Subframe
TeamViewer
Free license (non-commercial use only)
Session list
Connection Settings
www.teamviewer.com
KUV18217+6419
Quasar mv 14.24
RA 18h21m59.0s
Dec +64°20'12" J
[2-INFO]

Project examples with low-resolution spectroscopy

- Supernova
- Quasars
- Phaethon

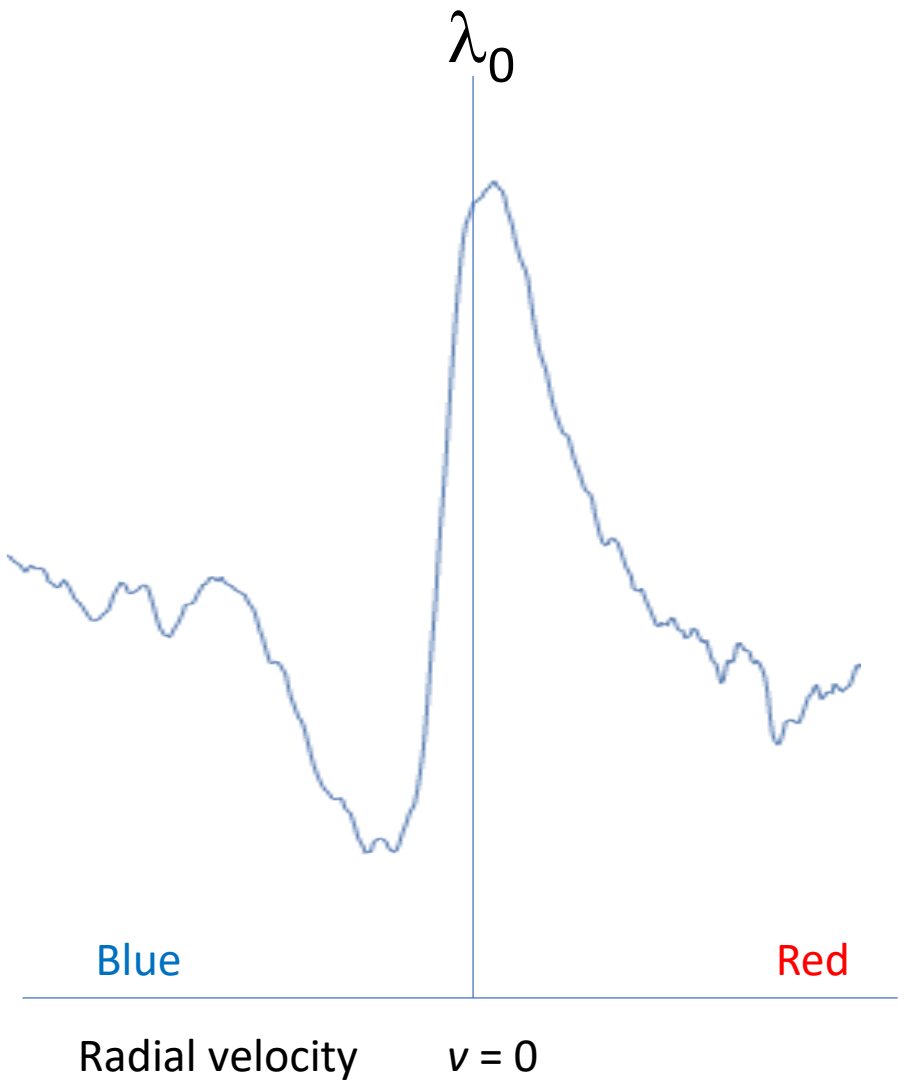
SN2017eaw in NGC 6946 (Cepheus) “Fireworks galaxy”
13 May 2017 11 supernovae in last 100 yrs

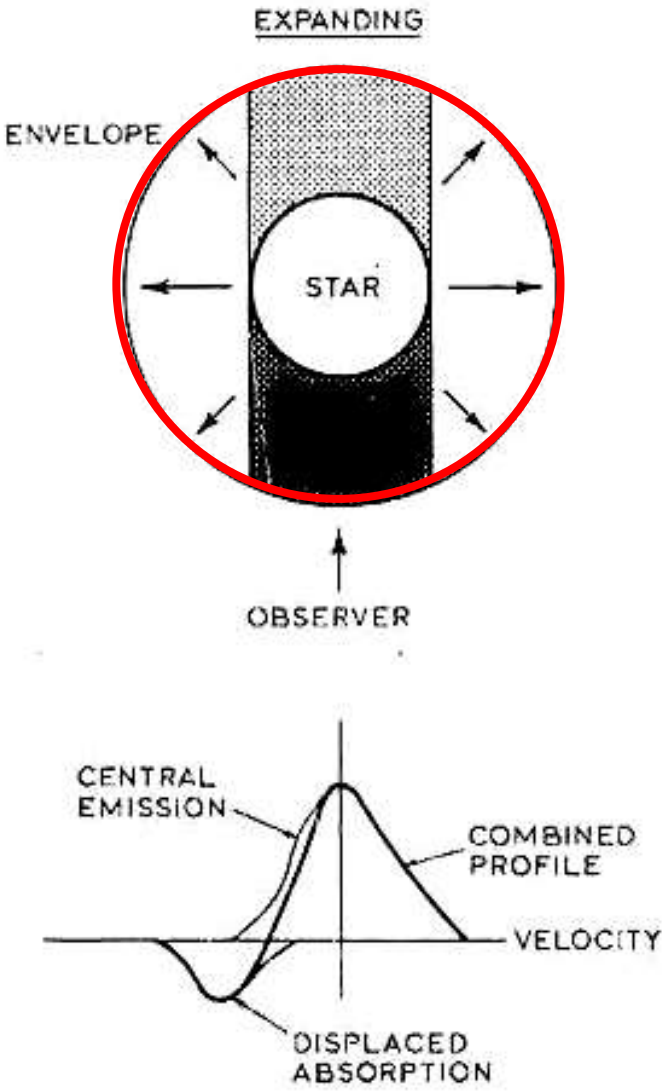
8 spectra during 38 days
Starting 17 days after discovery



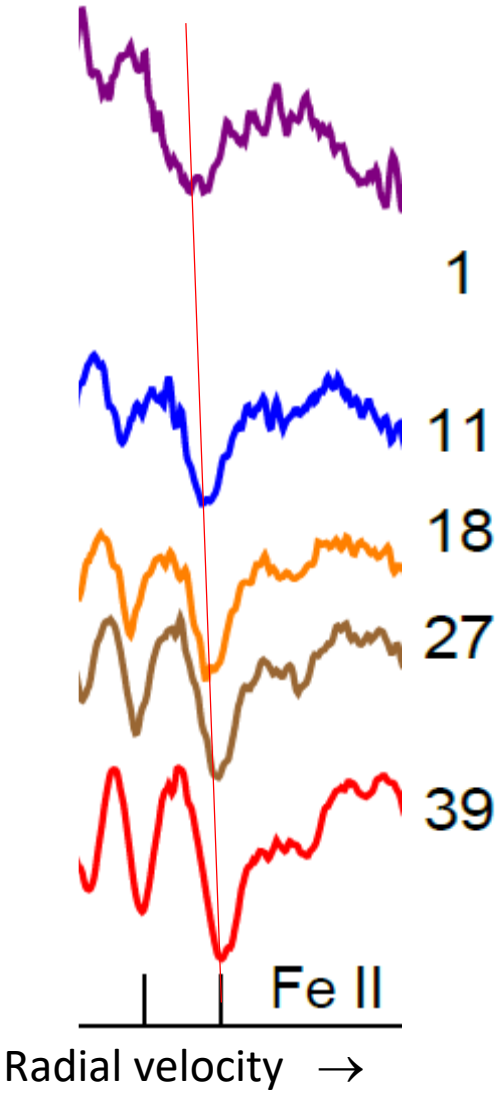
1. Color evolves from blue object to red
2. H lines → collapse of massive star into neutron star or black hole
3. Fe II lines grow stronger
4. H lines show P Cygni profile → outflow
5. Expansion velocity decreases

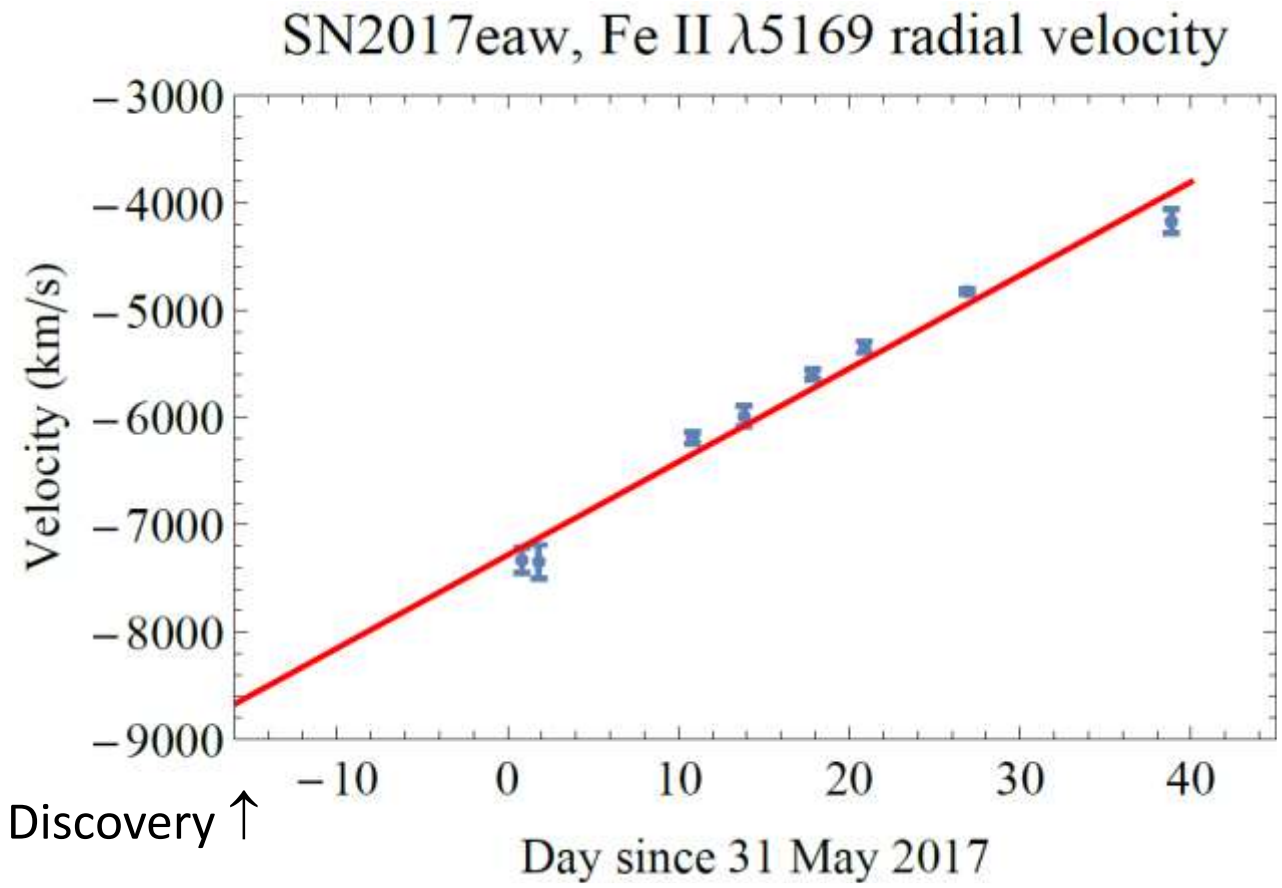
P Cygni profiles ⇔ expanding shell





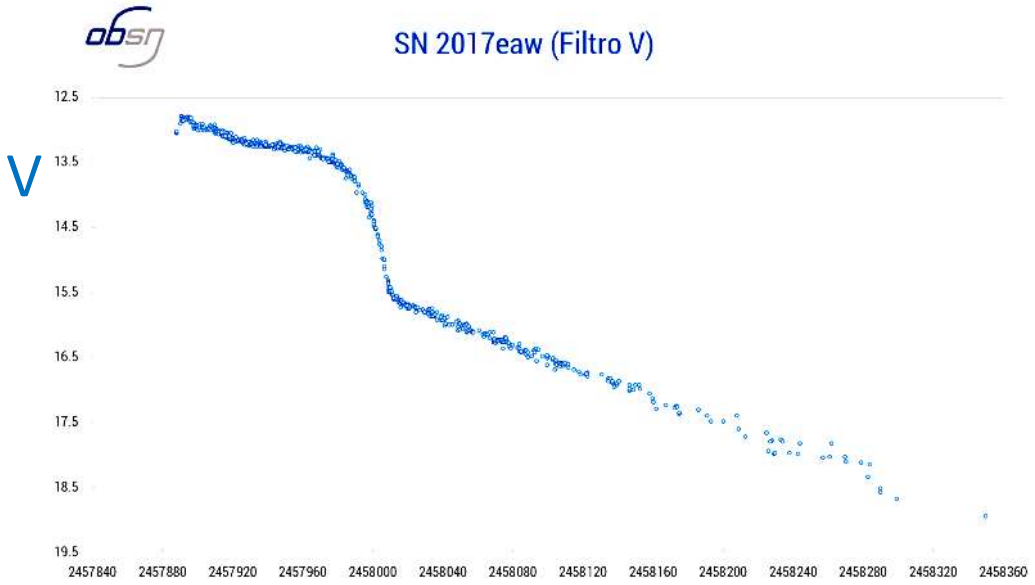
Decelerating velocity of expanding shell

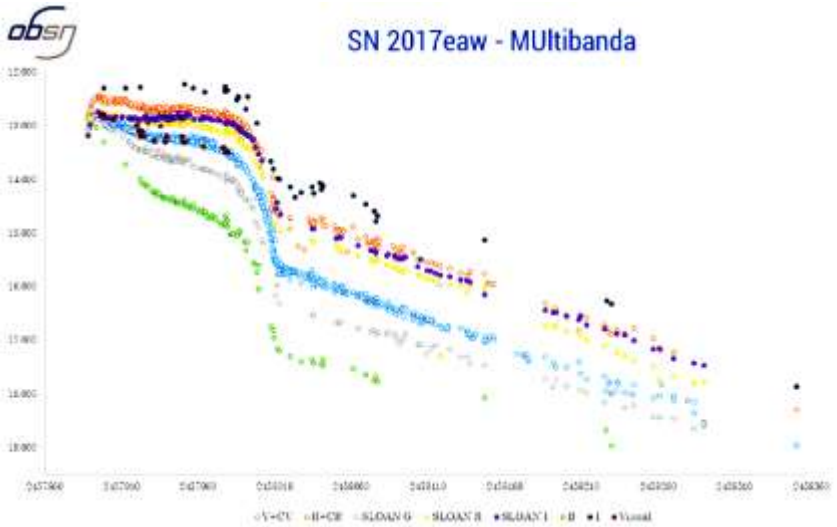




Conclusion: supernova exploded with v = 9000 km/s

Supernova Type IIP (P → Plateau in light curve)



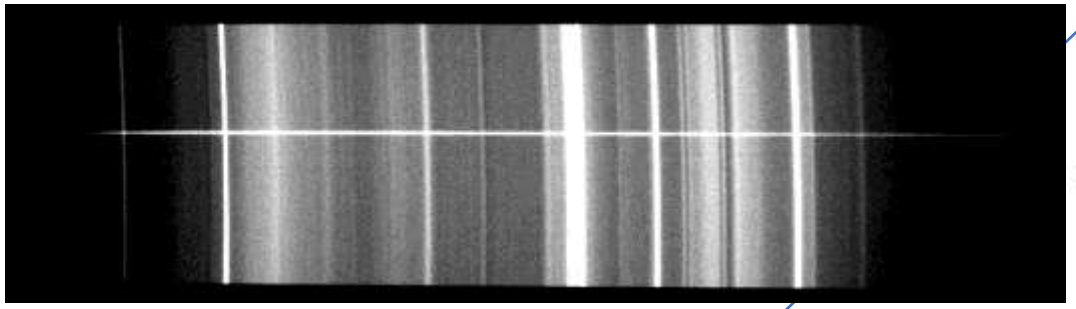


(ObSN)

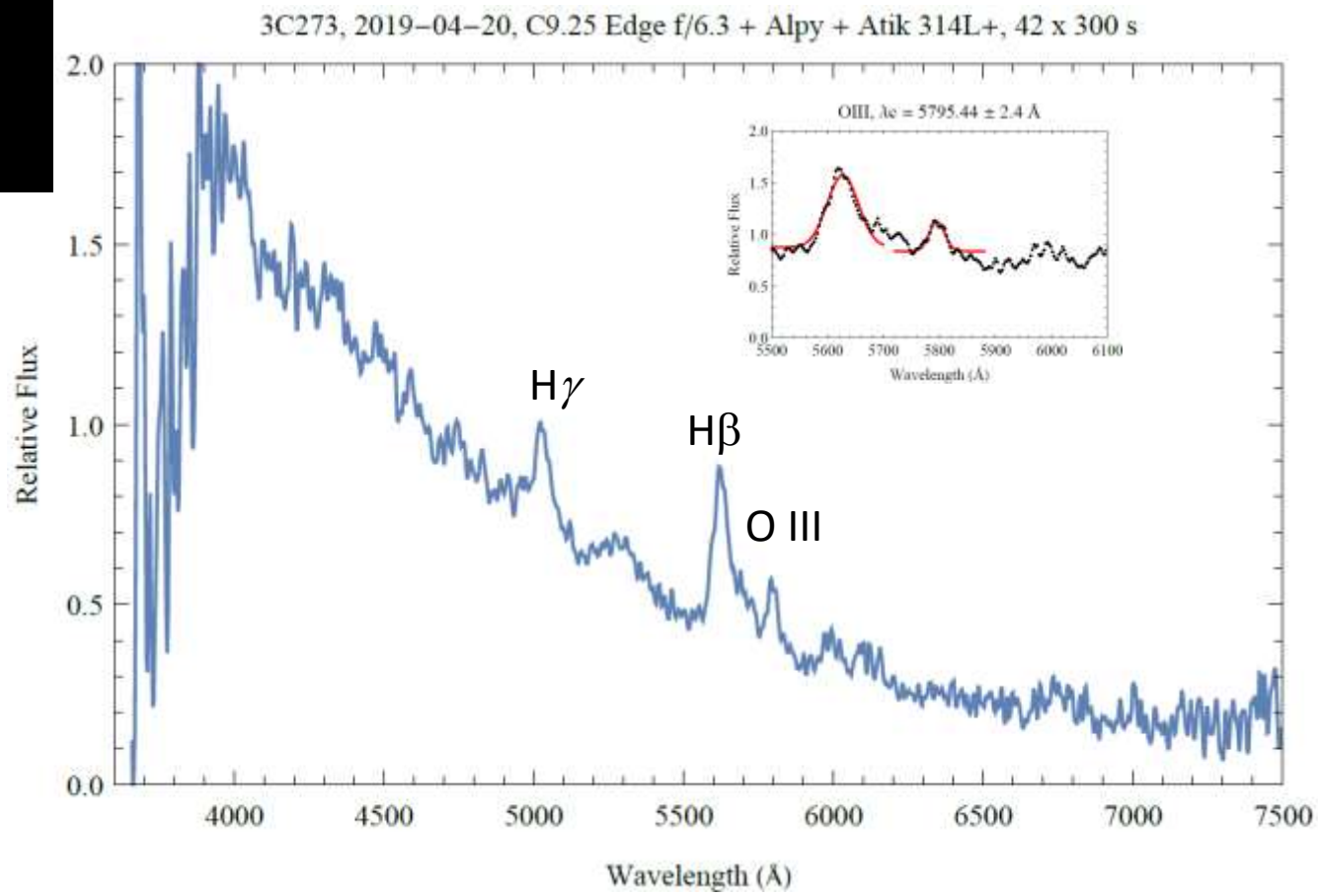
- (Type I: white dwarf of 1.4 $M_\odot$ implodes to neutron star in a binary)
- Type II: Core collapse of massive star: 8 to ~ 50 $M_\odot$
- Remnant is neutron star (1 $M_\odot$) or black hole (> 3 $M_\odot$)
- In NGC 6946 all 11 supernovae were core-collapse SN (massive stars): never observed before; reason unknown

Sorry for C. Doppler (Salzburg, 1803)

Quasar 3C 273 (the easiest quasar in the sky, V≈14.5)



Redshift $z = \frac{\lambda - \lambda_0}{\lambda_0}$ (*not Doppler effect*)



Measured OIII, Hβ, Hγ SIMBAD

Redshift z = 0.158 z = 0.158

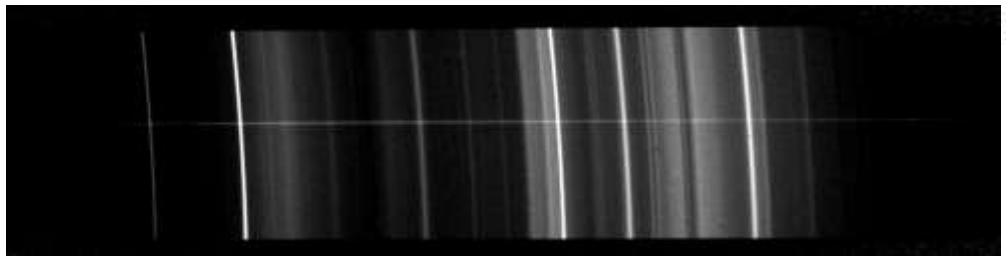
Velocity v = 43650 km/s v = 43750 km/s

≈ 0.145 c

z = 0.158 means:
universe has expanded 1.158 larger

Look-back time is 2.0 Gyrs

Quasar HS0624+6907 in Cam, t_exp = 5.2 h

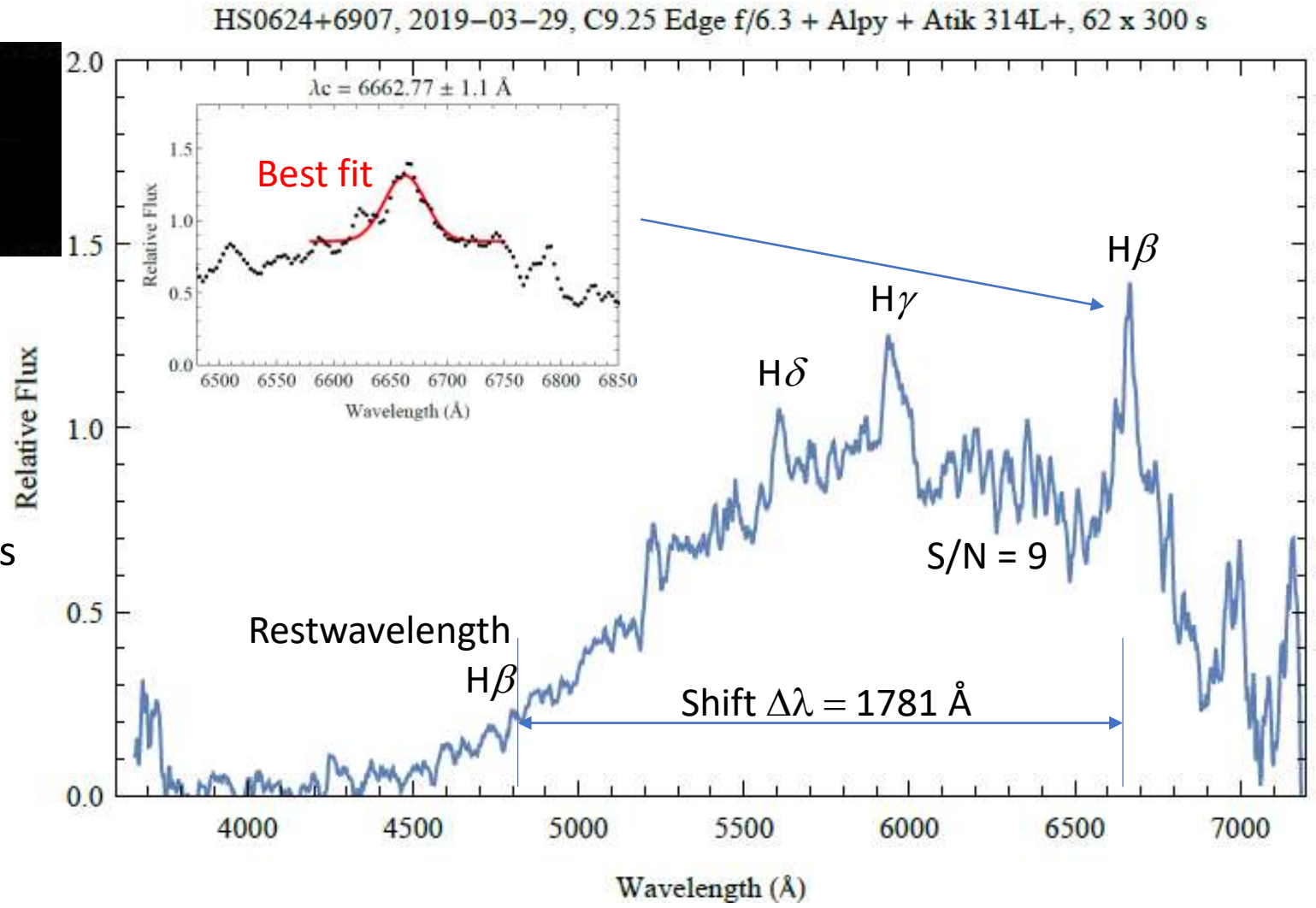


$$z = \frac{\lambda - \lambda_0}{\lambda_0}$$

Measured Hβ, Hγ, Hδ	SIMBAD
Redshift $z = 0.37$	$z = 0.374$
Velocity $v = 91250$ km/s	$v = 92171$ km/s
≈ 0.3 c	

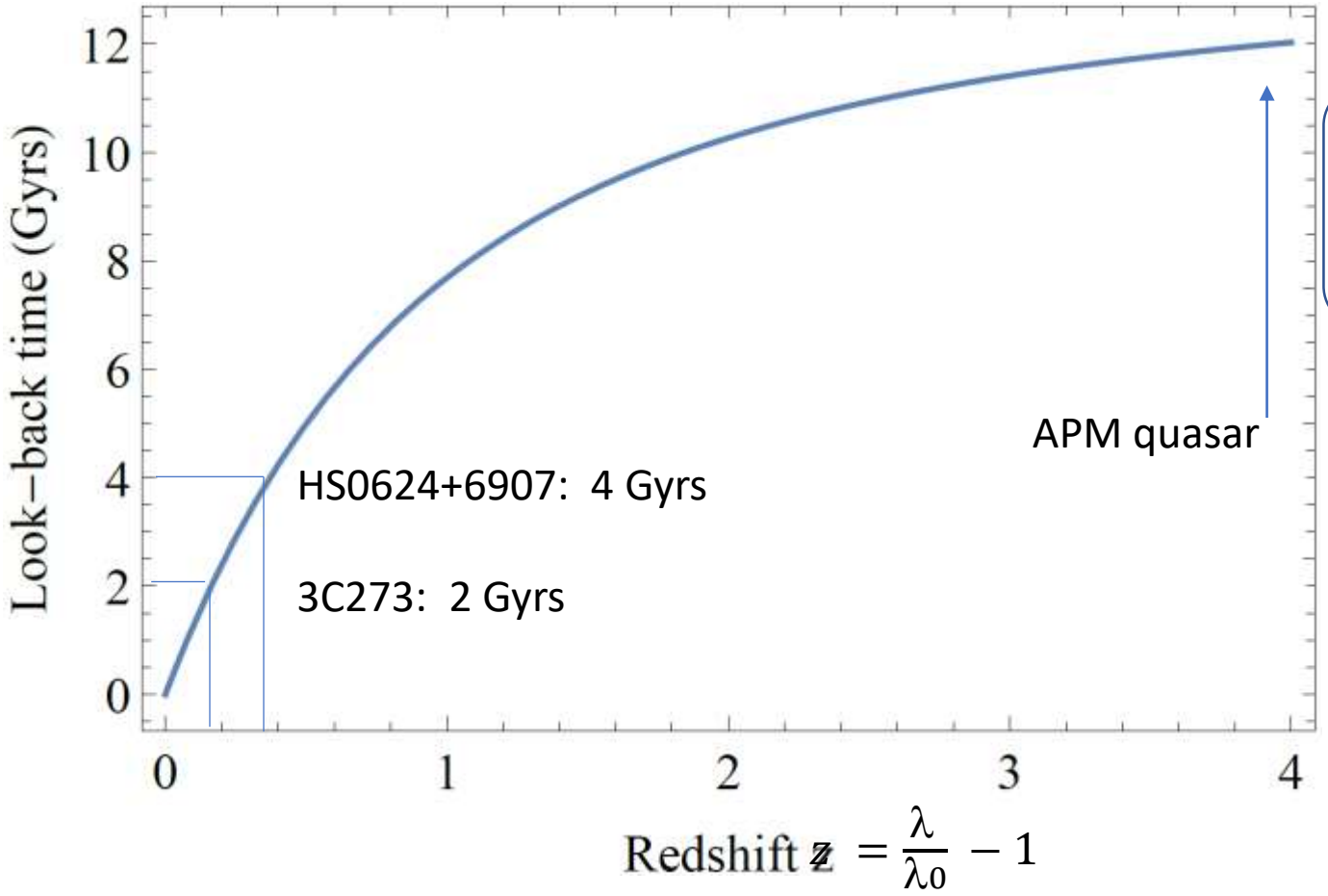
$z = 0.37$ means:
universe has expanded 1.37 larger

Look-back time is 4.0 Gyrs



Cosmology: look-back time: depends on model of the universe (Hubble constant, Flatness..)

$$\frac{1}{\mathrm{H0}} \int_0^z \frac{1}{(1+x)\sqrt{\Omega(1+x)^3 + \Omega_k(1+x)^2 + \Omega_\Lambda}}\,\mathrm{d}x$$



Current model:

$$13.7\ \mathrm{Gyrs} \int_0^z \frac{1}{(1+x)\sqrt{0.27(1+x)^3 + 0.73}}\,\mathrm{d}x$$

Phaethon: closely passed the Earth in December 2017

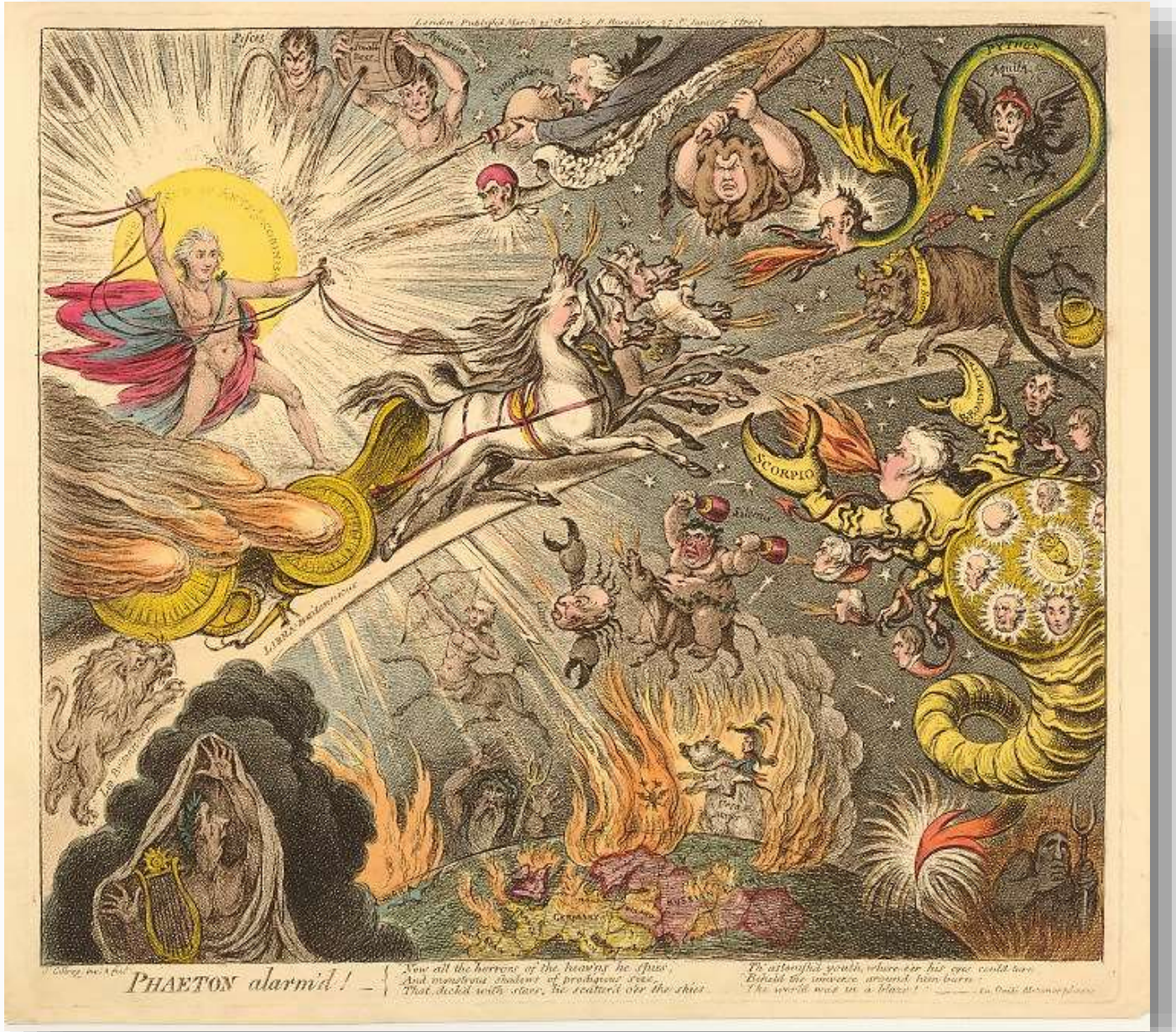
- Who is Phaethon
- Why is Phaethon exceptional
- Simultaneous spectroscopy and photometry

- Scientific part: - rapid motion
  - brightness variations
  - spectroscopic identification

1. Who is Phaethon?

(Greek mythology, Ovidius)

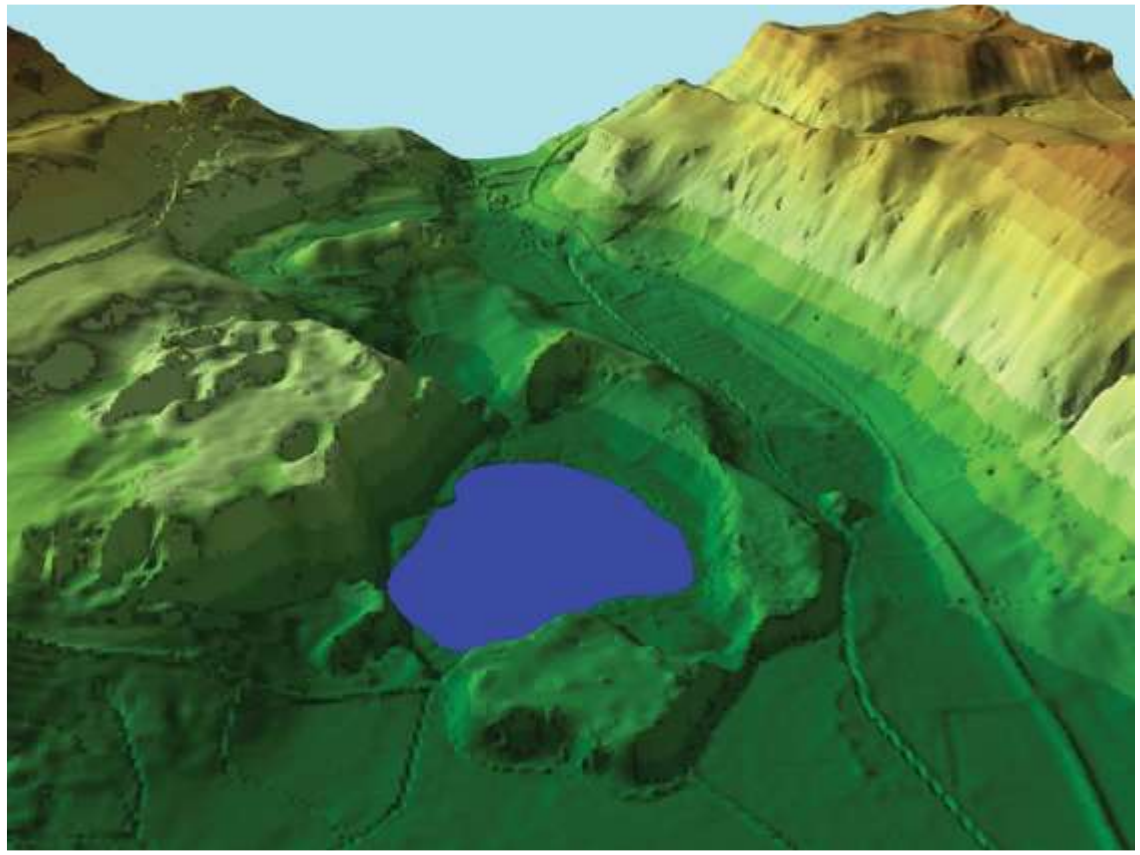
Son of Helios
Allowed to drive the sun chariot
Lost control → collision course
Set the earth on fire
Killed by lightning strike from Zeus
Felt in river Eridanus
Tears from his sisters turned into amber



National Maritime Museum
Greenwich, London

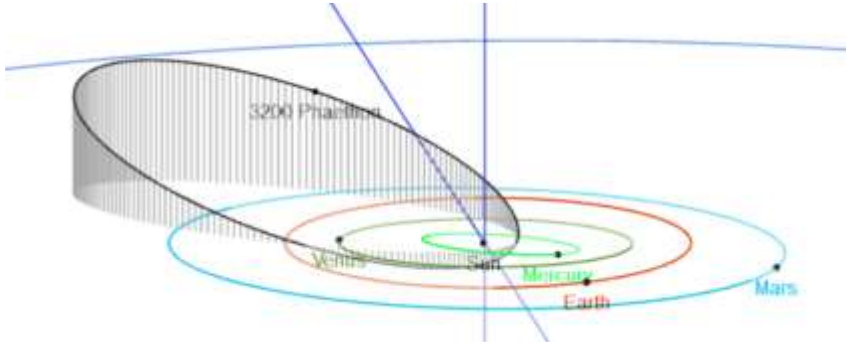
Geomythology: origin of myth of Pheathon?

- Tüttensee crater, Bavaria
- Impact dated around Homer's time → given rise to myth



What makes Phaethon so exceptional

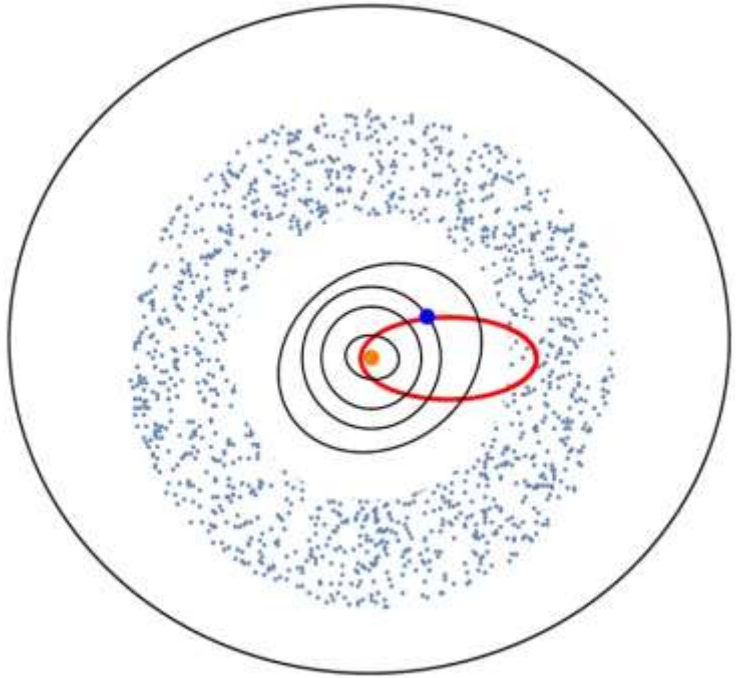
(discovered in 1983 by IRAS satellite)



- Orbital period = 1.43 years, very accurately known
- Crosses Earth's orbit → **Potentially hazardous asteroid**
- Eccentricity: 0.89 → **test for Einstein's General Relativity**
- Parent body of the December ***Geminids*** **meteor shower**

  but: Temperature at perihelium: 600°C → **cannot be a comet**

  How come?

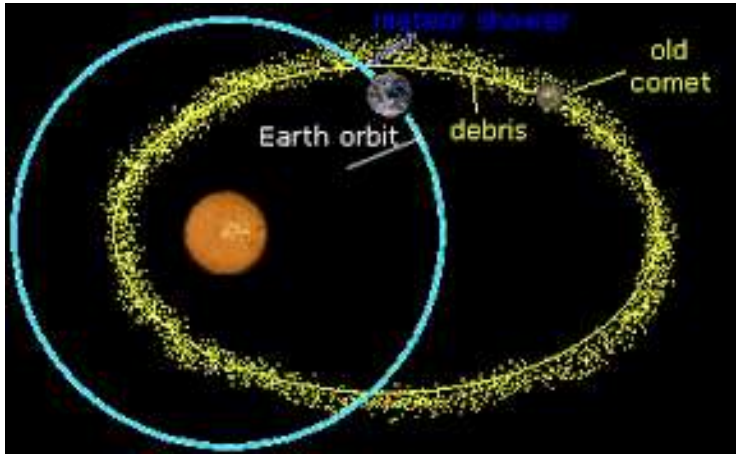


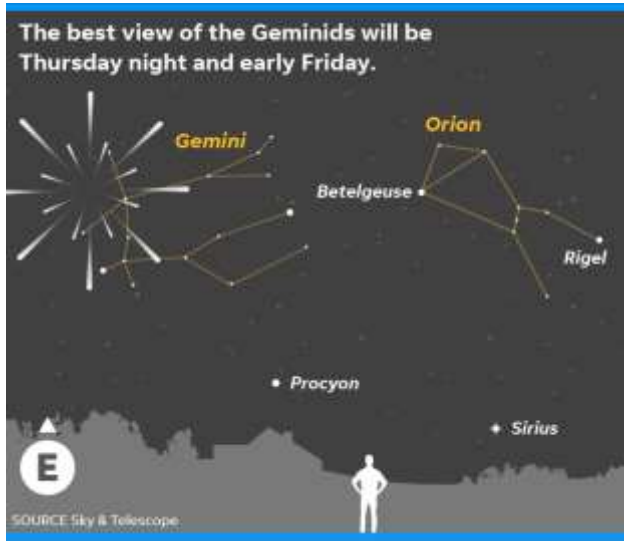
- Closest approaches to Earth:
  - 16 December 2017 at 27 lunar distances
  - In 2093 at 8 lunar distances

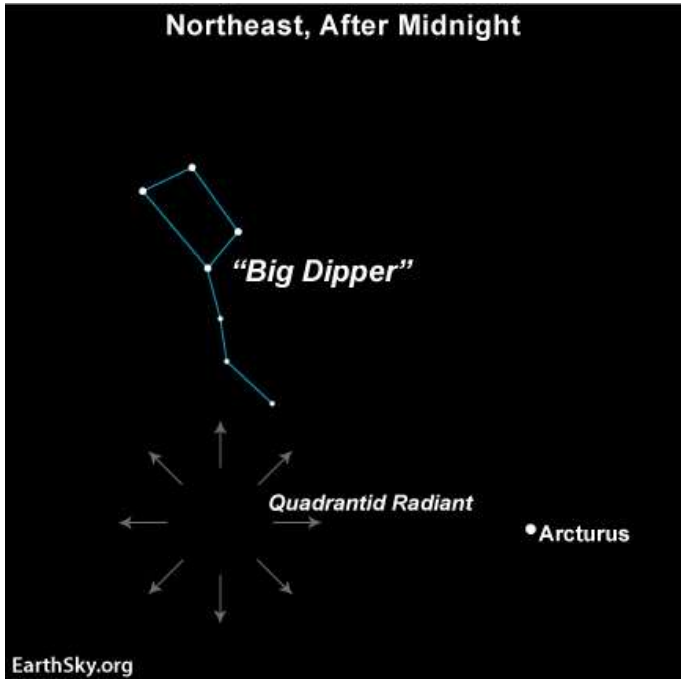
Meteor showers

- >100 well established (~ 800 known)
- All come from (older) comets
- Two exceptions: Geminids ← Phaethon
  Quadrantides ← 2003 EH

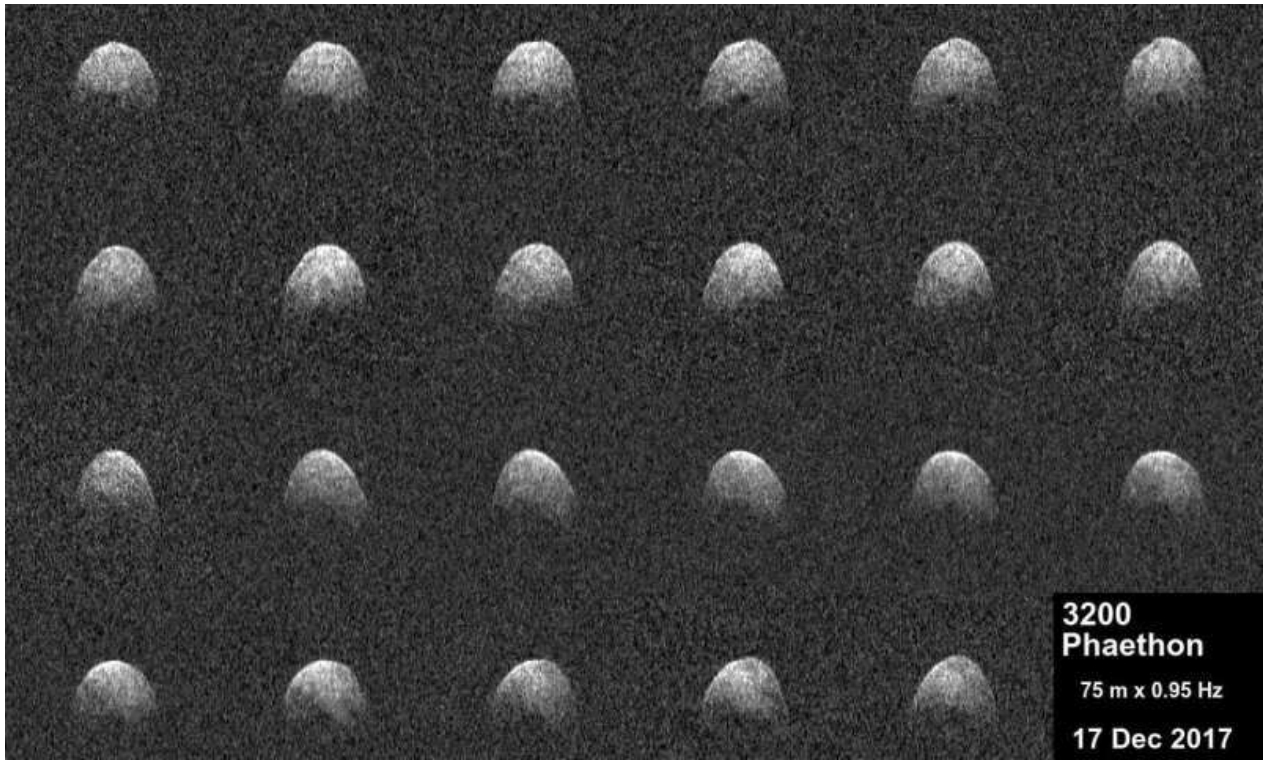
How ??







Shape

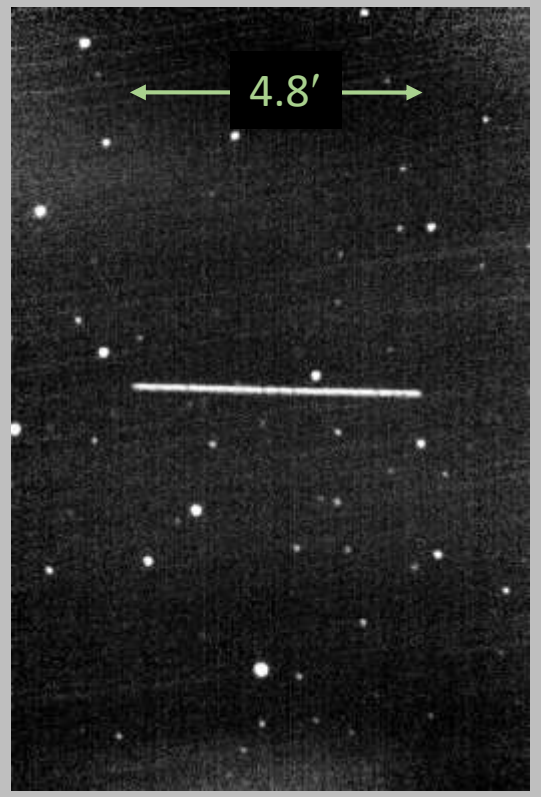


https://phys.org/news/2018-10-astrophysicists-asteroid-phaeton.html

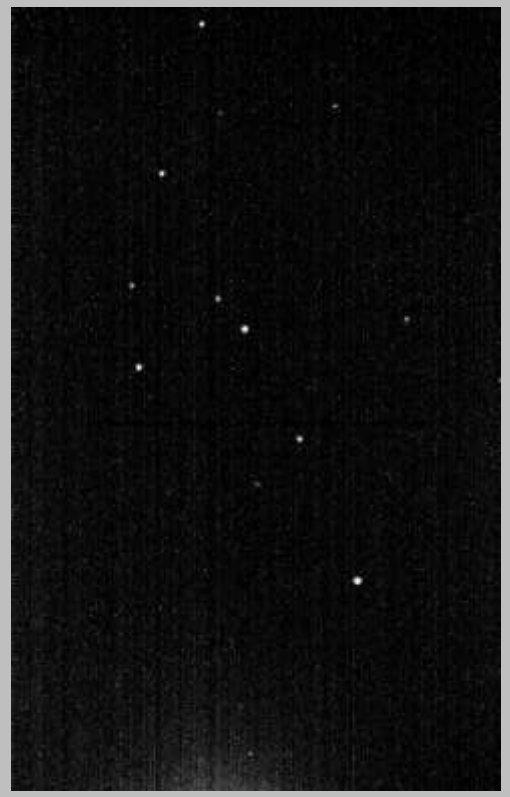
Model by S. de Vet

2. Imaging with guider camera

4 days before closest approach

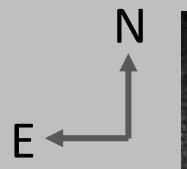


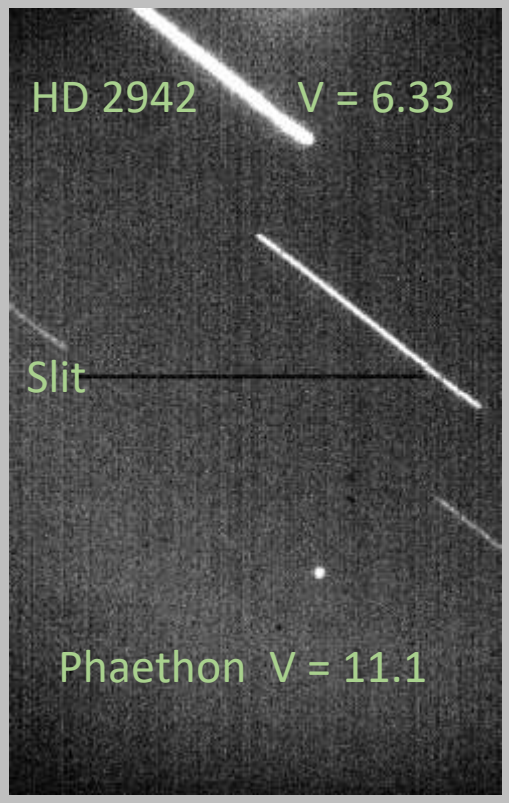
17 min motion



200 x 5 sec exp.

2 hours before closest approach





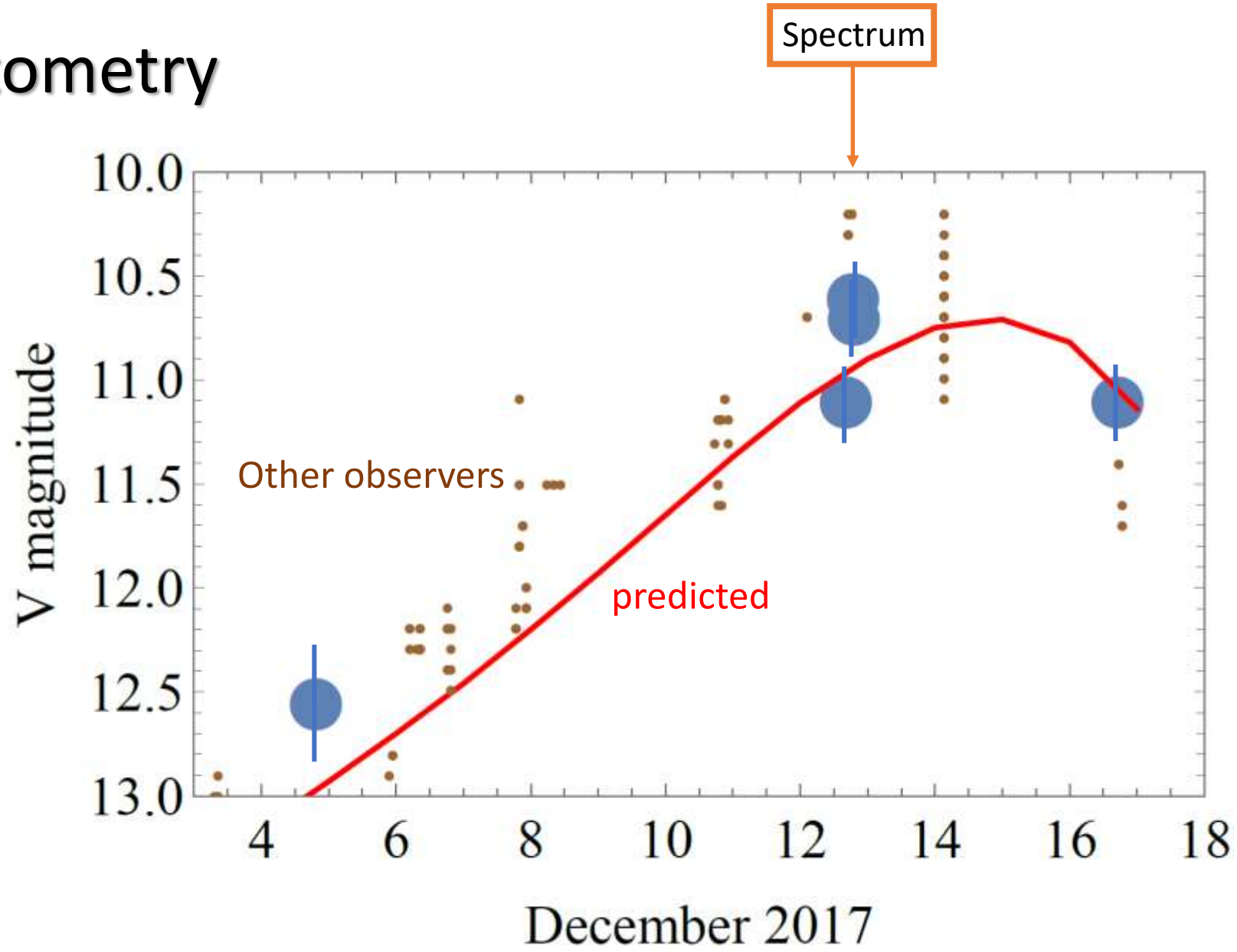
8 min star tracks

100 x 5 sec exp.

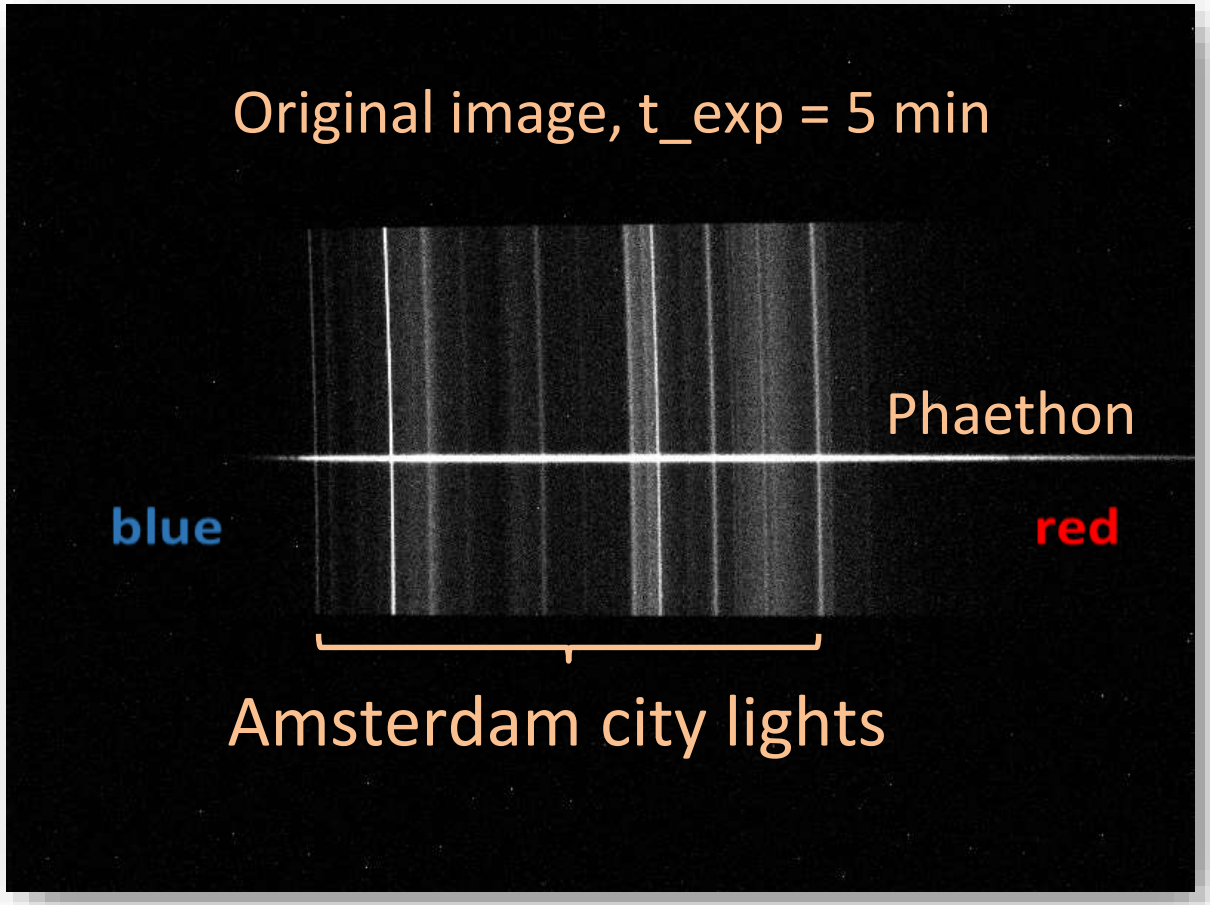
17 min motion

200 x 5 sec exp.

Photometry


Spectrum
Other observers
predicted
V magnitude
10.0
10.5
11.0
11.5
12.0
12.5
13.0
4
6
8
10
12
14
16
18
December 2017

Spectroscopy



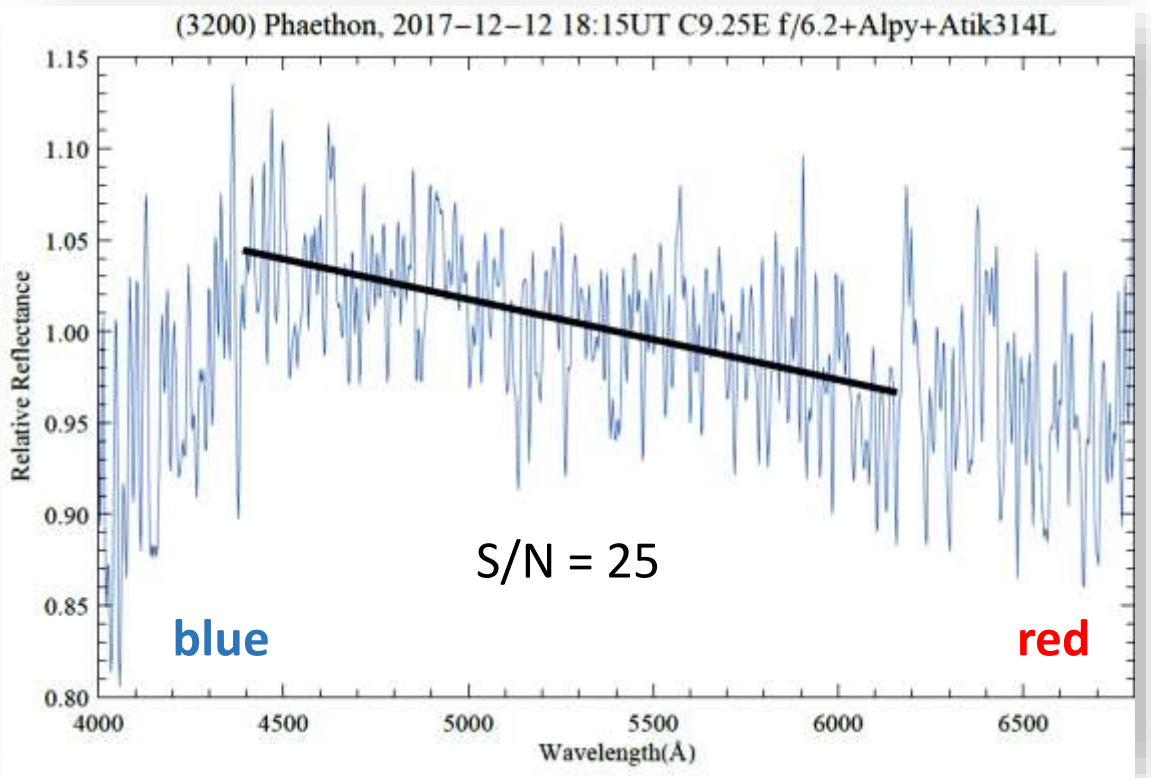
Processing (Mathematica):

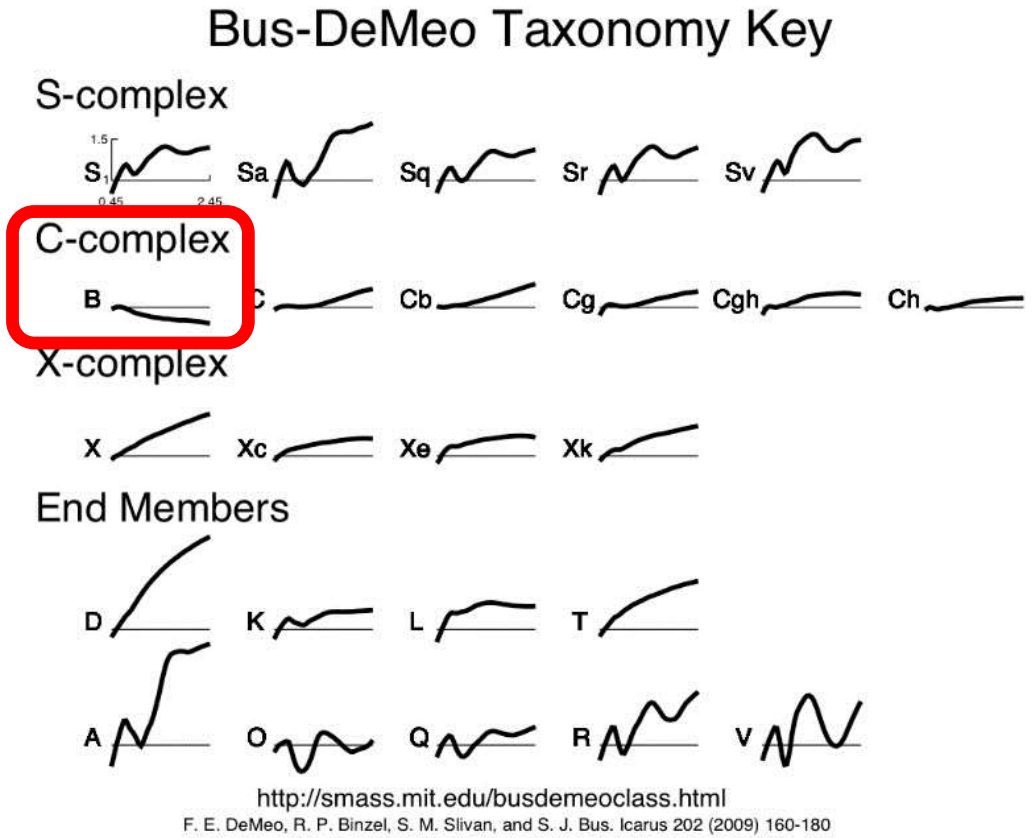
Corrections for:

- Dark en Flatfield
- City-light background
- Spectrograph response curve

- Solar contribution removal with spectrum of HD 245, a solar-type star

Identification





Phaethon reflection spectrum → C-complex Type B

(same as found by Licandro et al 2007, with the 4.2m William Herschel Telescope on La Palma, also with t_exp = 5 min)

Science conclusions and future

- Phaethon is a Carbon-type asteroid : **an exceptionally blue object**

  → hydrated-silicates surface, similar to Pallas-type meteorites

- During close passages near the Sun **'active' surface outbursts** occur (?)

  → fragmentation(?) → **Geminids meteor showers** (not understood)

- Future:

  2022 launch of Japanese DESTINY+ Flyby at 500 km

  14 December 2093 at 8 lunar distances (IAU 174 years)

  Dynamical lifetime is few million years → orbit will desintegrate

  Will Phaethon ever collide with the Earth ????

Greek mythology answer: no collision