# Stellar Observations Network Group


Frank Grundahl on behalf of the SONG group:

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Kennet Harpsøe, Jesper Skottfelt, Pere Palle, Katrien Uyetterhoeven, Licai Deng,
Xiaojun Jiang, Hampus Nilsson, Henrik Hartmann.....

*Future Science with Metre-Class Telescopes – Belgrade 2012*

# What is SONG ?

# SONG Goals

## Do for stars what GONG does for the Sun

well, almost..... (BiSON, IRIS, GOLF on SOHO)

**- Asteroseismology (doppler, daytime solar obs.)**

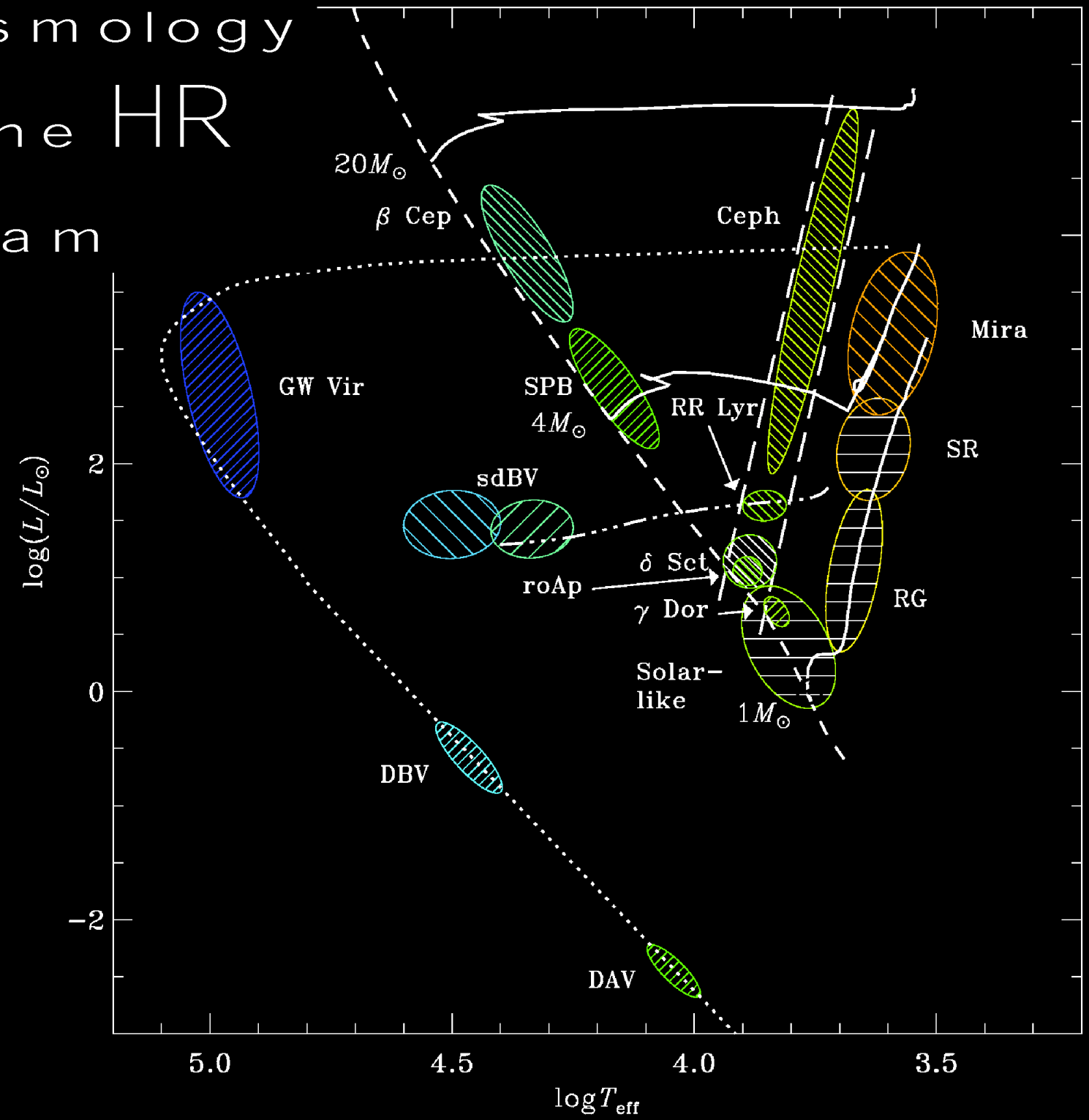
Main focus on solar-like oscillators

**- Exoplanets (microlensing, doppler)**

Microlensing can potentially detect very small planets
Set limits on occurrence of planets

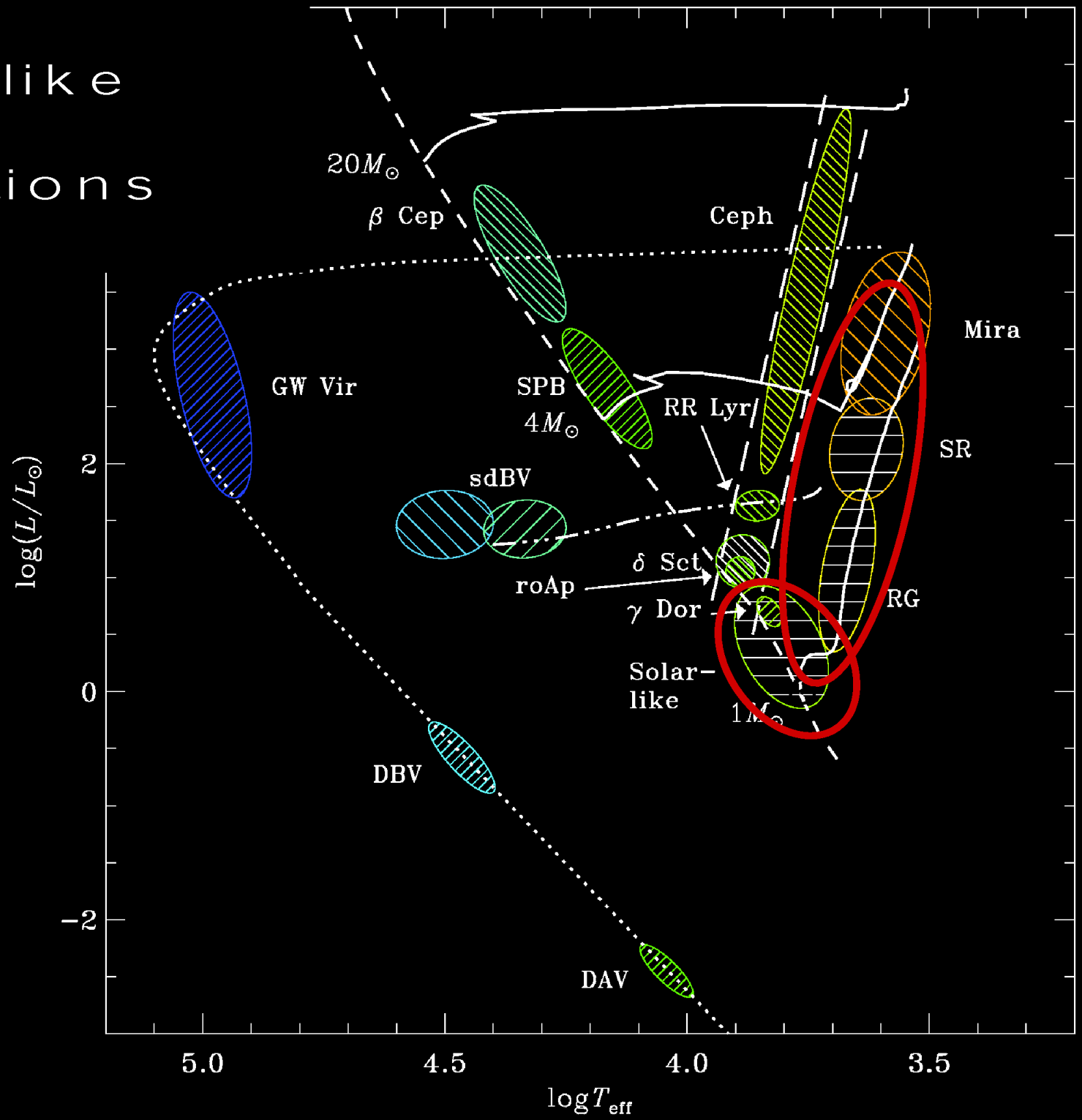
Use *Lucky-Imaging* (photometry)

# Asteroseismology across the HR diagram




J. Christensen-Dalsgaard

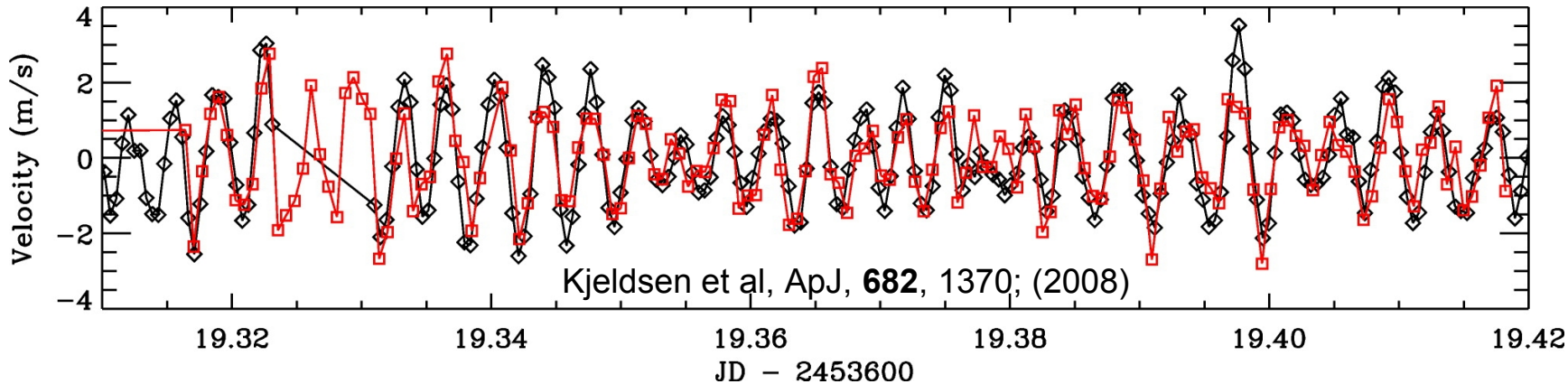
# Solar-like oscillations



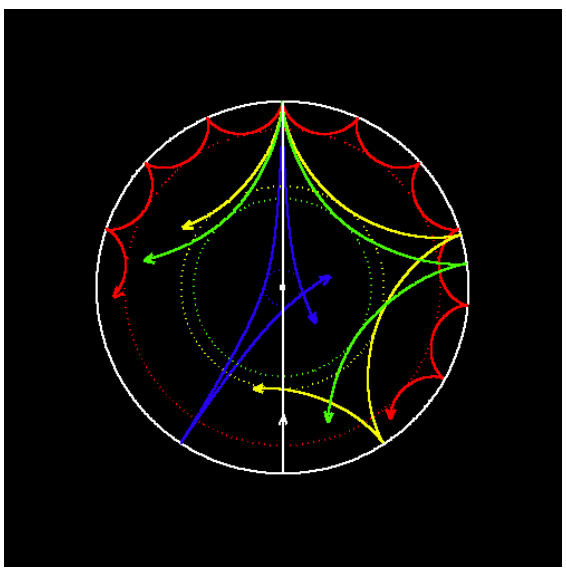

J. Christensen-Dalsgaard

- The oscillation amplitudes are small (m/s, ppm)

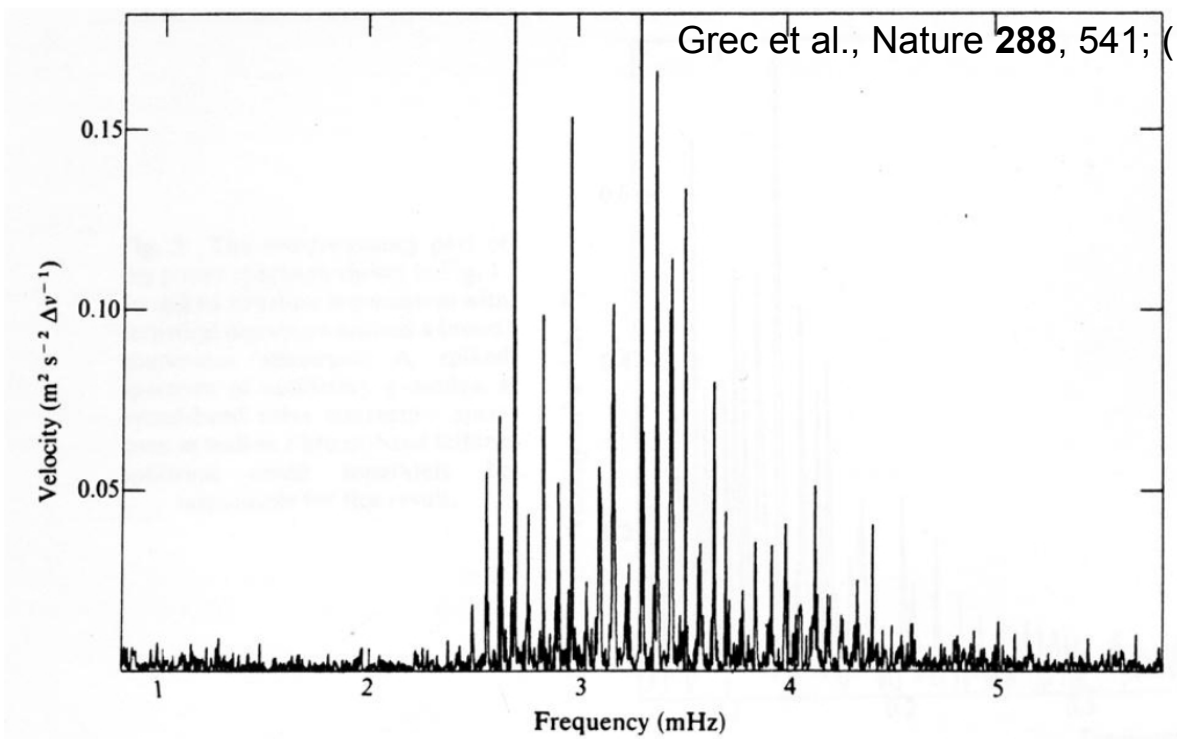
- Oscillation frequencies are closely spaced (long obs).




Kjeldsen et al, ApJ, **682**, 1370; (2008)

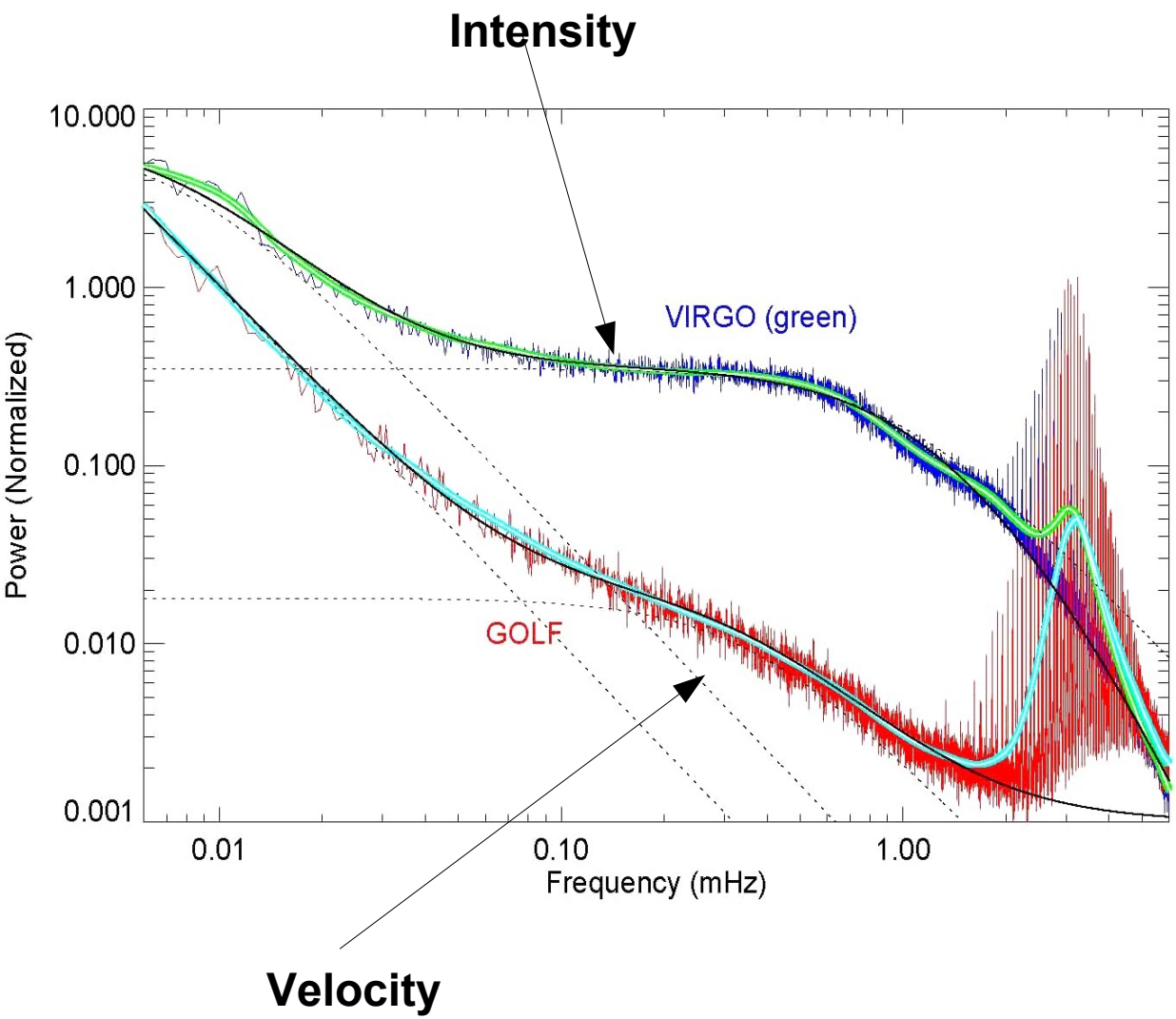


Oscillations probe the internal structure of the stars




Grec et al., Nature **288**, 541; (1980)

# *Use radial velocities for solar-like oscillations superior to photometry (from the ground)*




Seismology targets: V < 6

Long, continuous periods

Bright, nearby targets, get *R* from interferometry, *d* from parallaxes, activity levels

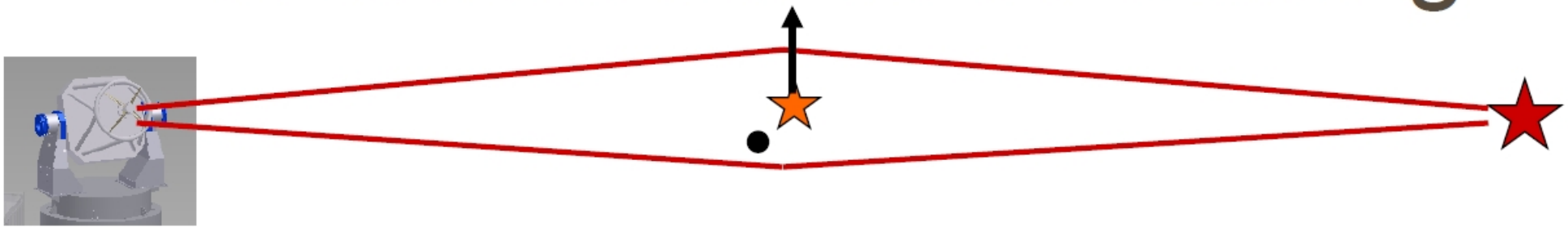
Relatively few but well studied targets

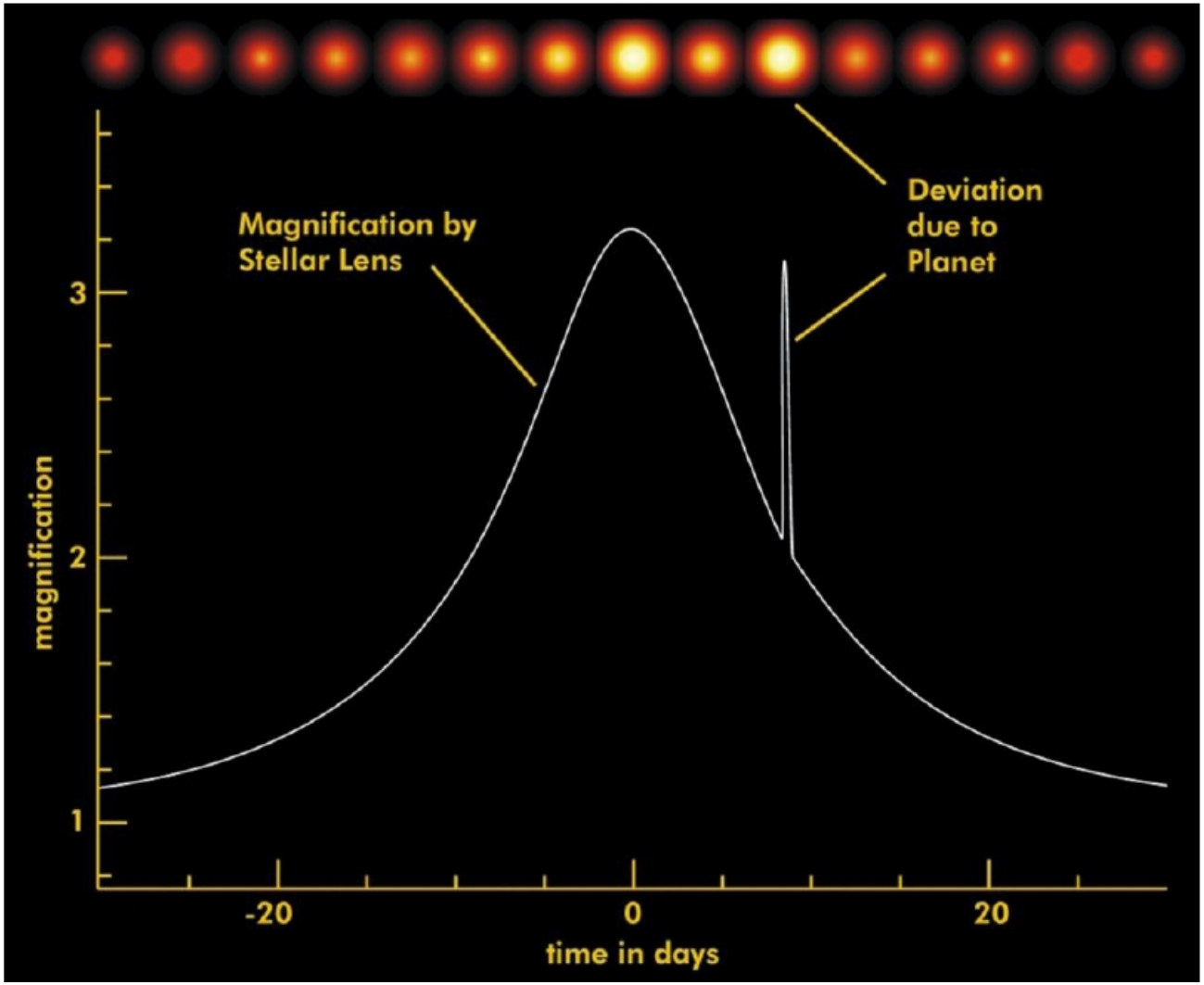
Complementary to the space Missions

*l* = *3* + lower frequencies

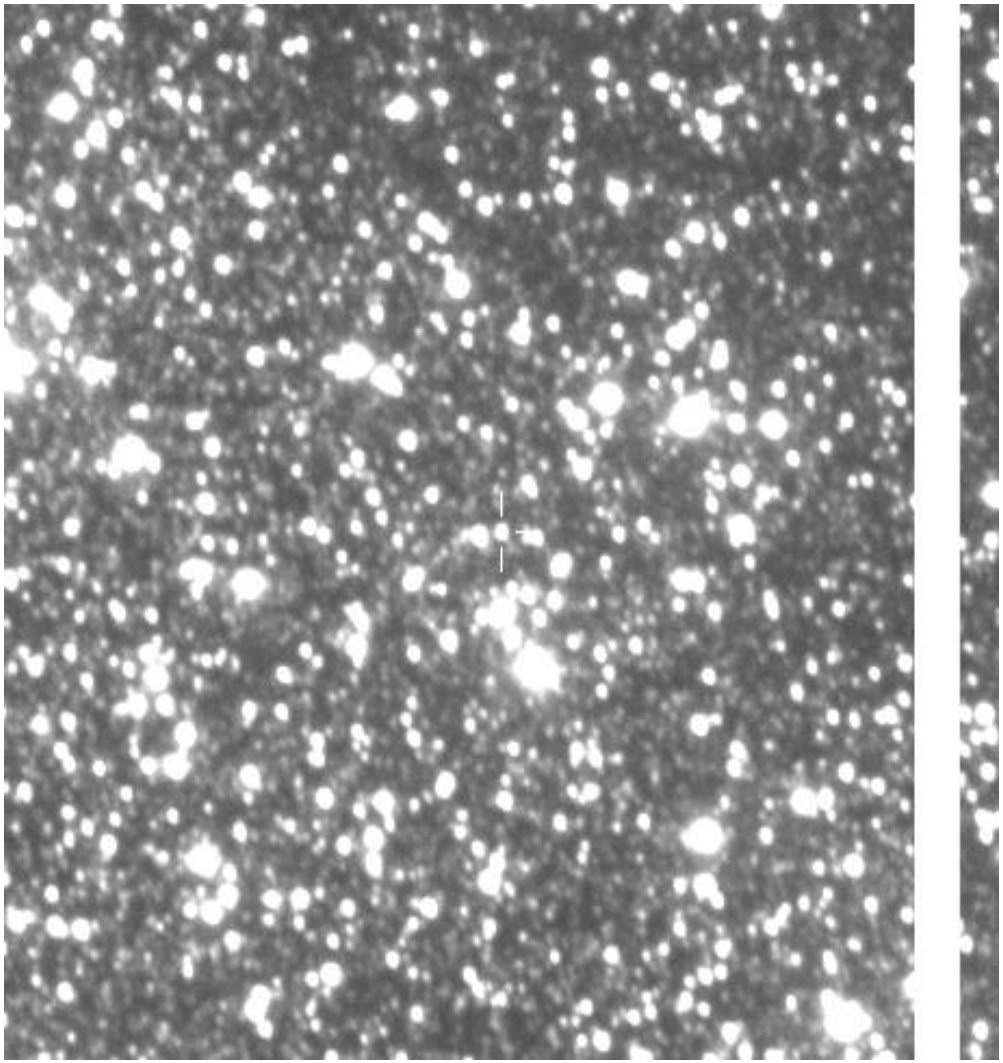
**All basic information will be available for the SONG targets!**

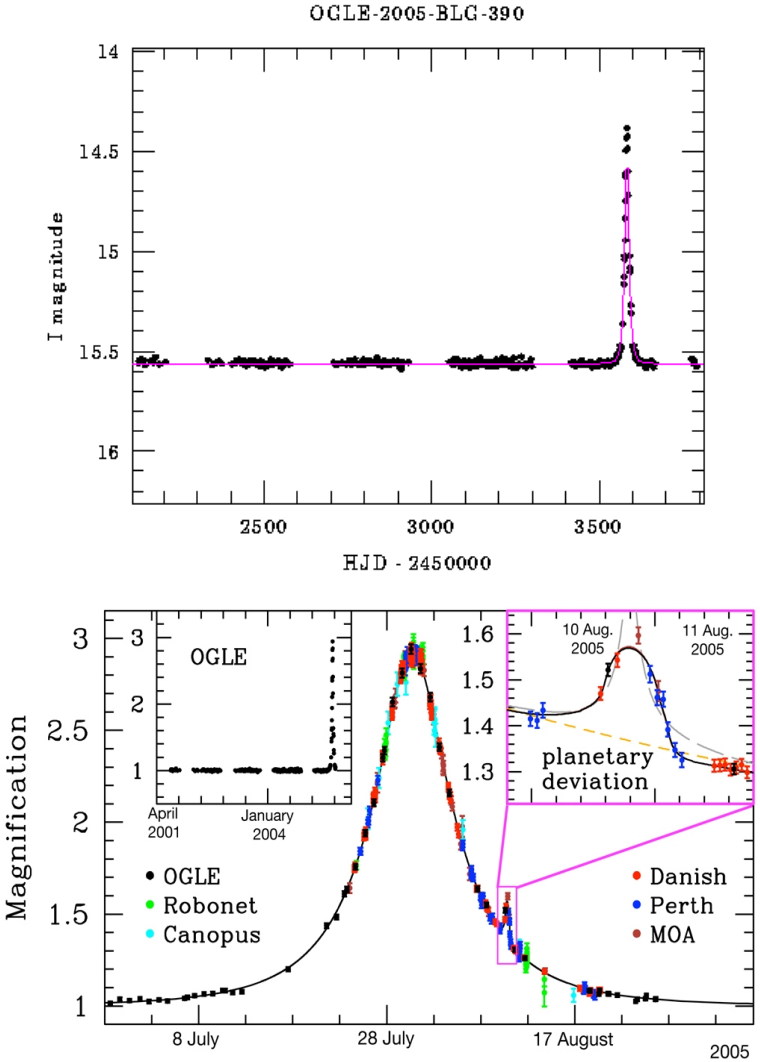
# Gravitational micro-lensing





FOV 2' x 2'






Light Curve of OGLE-2005-BLG-390

ESO PR Photo 03b/06 (January 25, 2006)



The field of the 5.5 Earth mass planet discovered by microlensing (Nature, 439, 437, 2006).

... crowded fields, sharp images desirable!

# Overall design drivers:

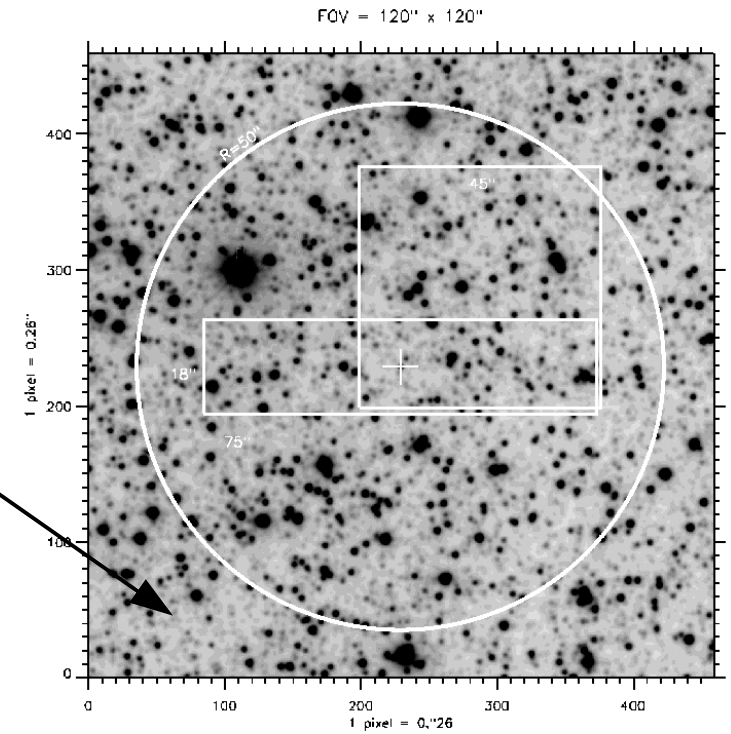
Optimize the design for the primary science purposes:

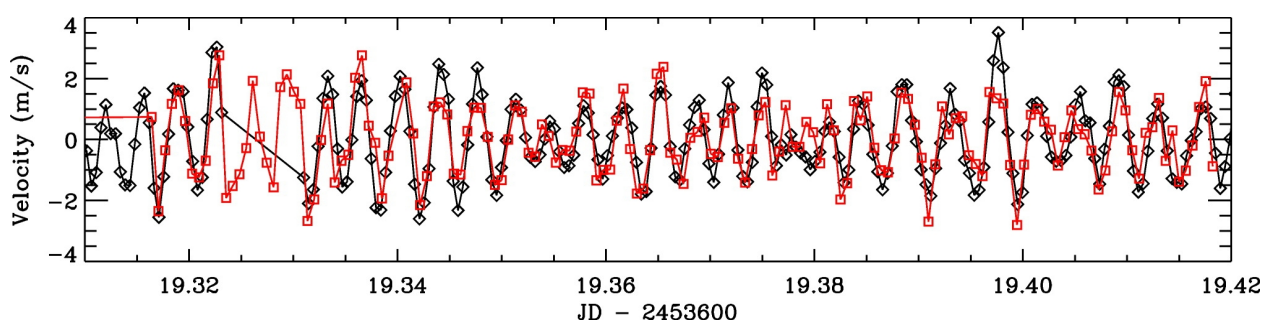
**Precise radial velocities (bright stars)**
- asteroseismology and exoplanets

**Photometry in crowded fields**
- exoplanets (microlensing)

**High duty-cycle and long timebase**
- time-series

**Robust operations and a long lifetime**
- operation costs



# Design requirements:

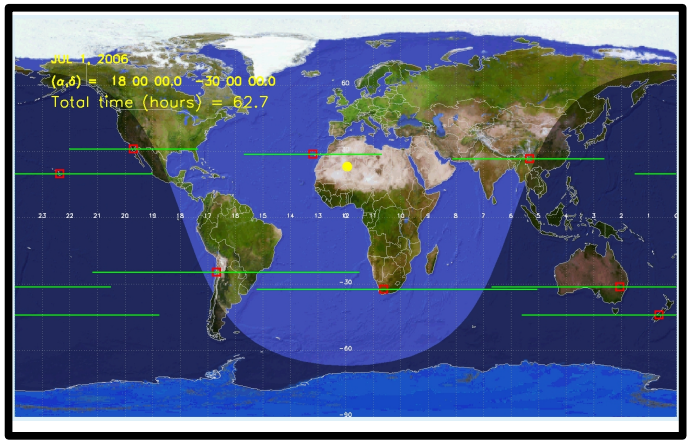
**Spectrograph:** deliver 1m/s velocity precision for bright $V \leq 2$ stars, with high cadence (1-2 min.)

**Imaging:** deliver images with FWHM < 0."5 for a significant fraction of the observing time and close to the diffraction limit for the best images.

**All-sky capability**

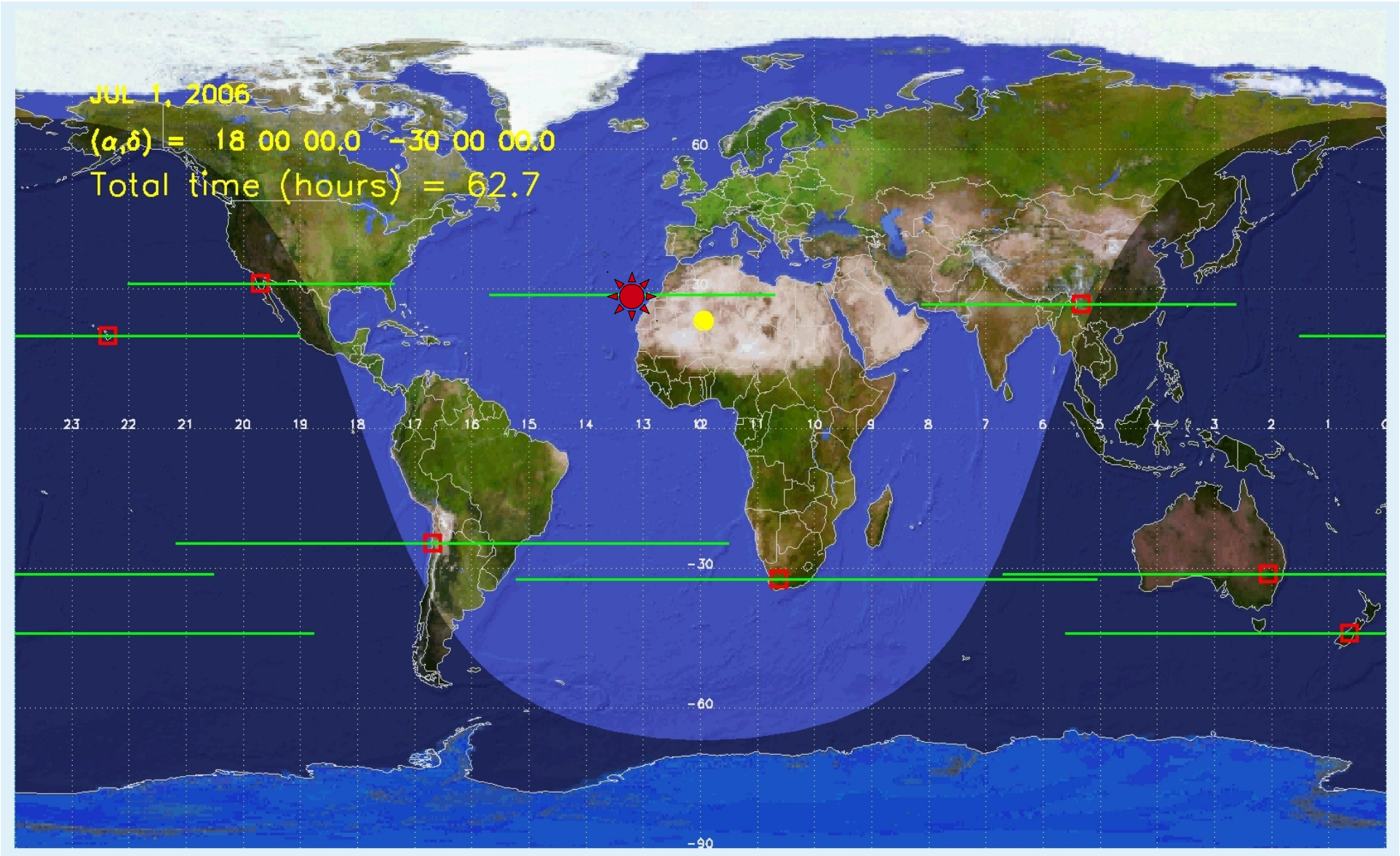
## SONG baseline configuration:

- 8 network nodes (4S / 4N) at existing sites
- 1.0m telescopes at each node
- Instruments: spectrograph + lucky imager
- Optimized for main science goals
- Automatic operations




**The first step is the construction of a full prototype node**

# The prototype will be located at Observatorio del Teide



# Project status – the short version

- Instruments are ready and installed

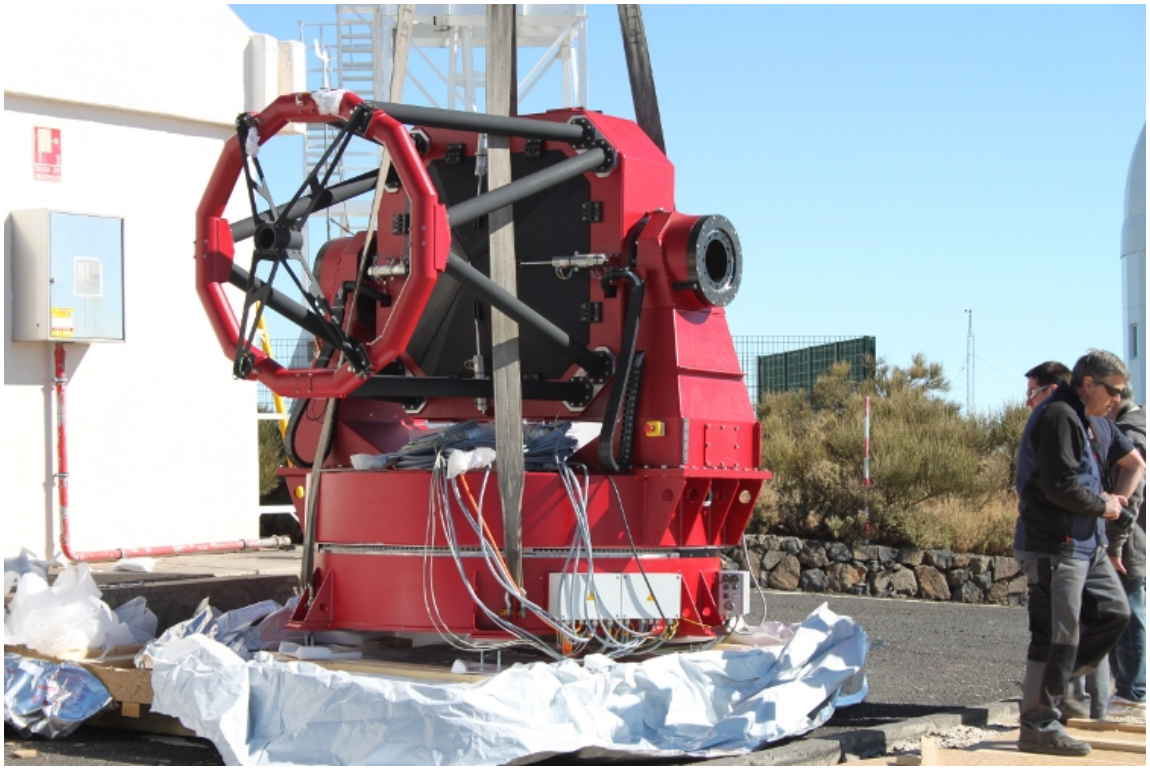
- The spectrograph is tested and 'commisioned'

- The imaging camera(s) are ready

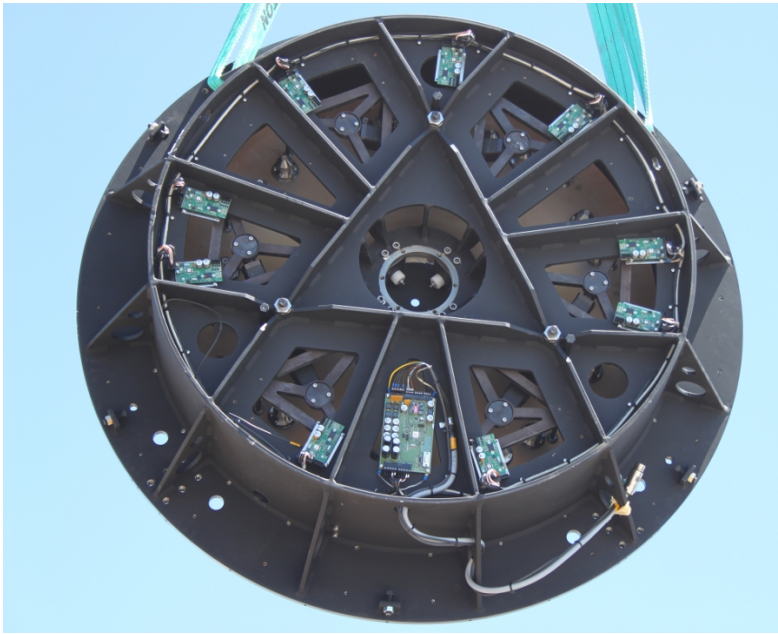
- The telescope is installed, awaiting final acceptance and 'tweaking'.

- We are pursuing additional funding and collaborators beyond the 2$^{nd}$ node

# Izaña – July 2012



Installation, April, 2012.



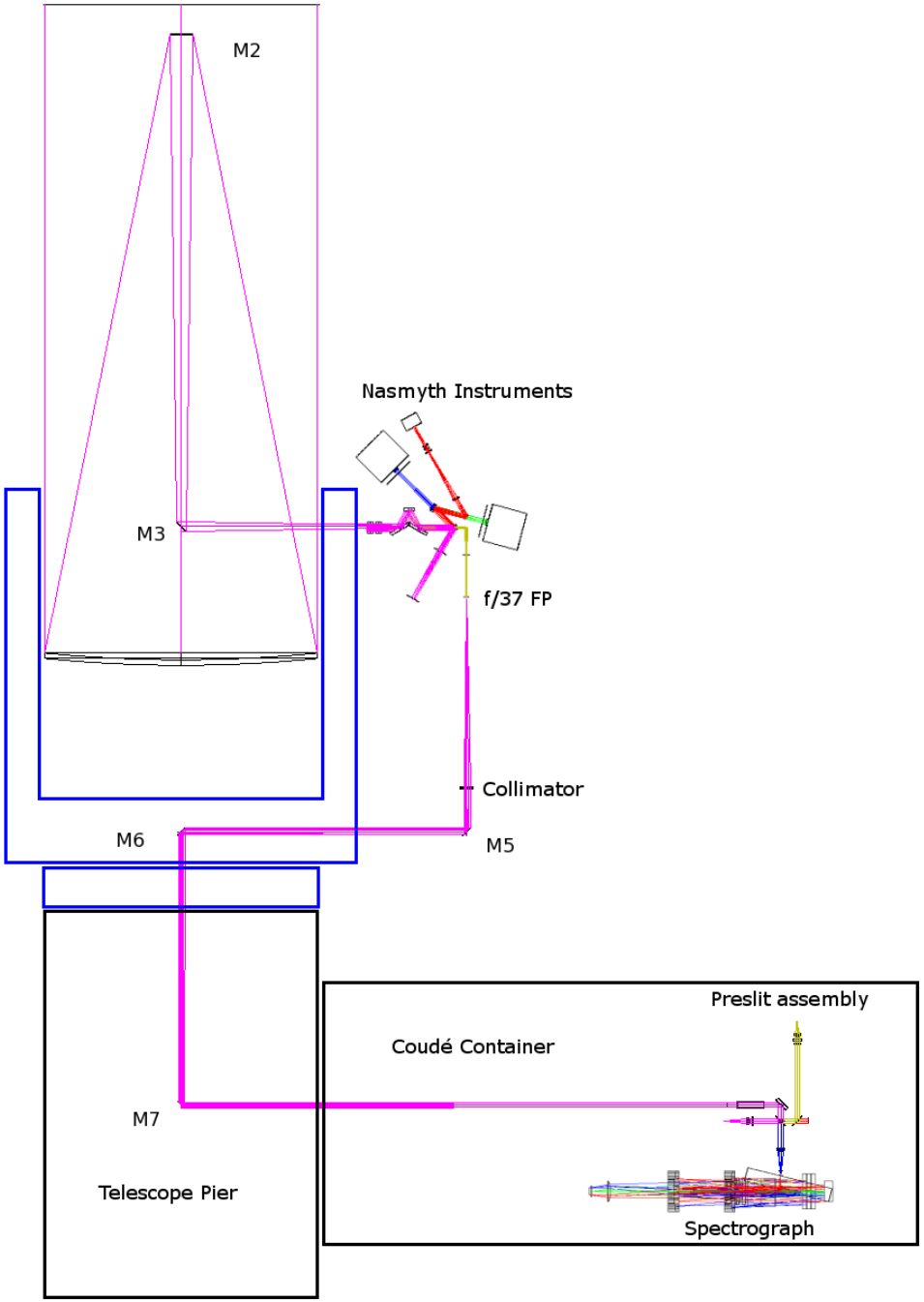
Mirror cell w. mirror

Use mirrors and lenses with optimized coatings over the spectrograph working wavelength range (off-the-shelf products!):

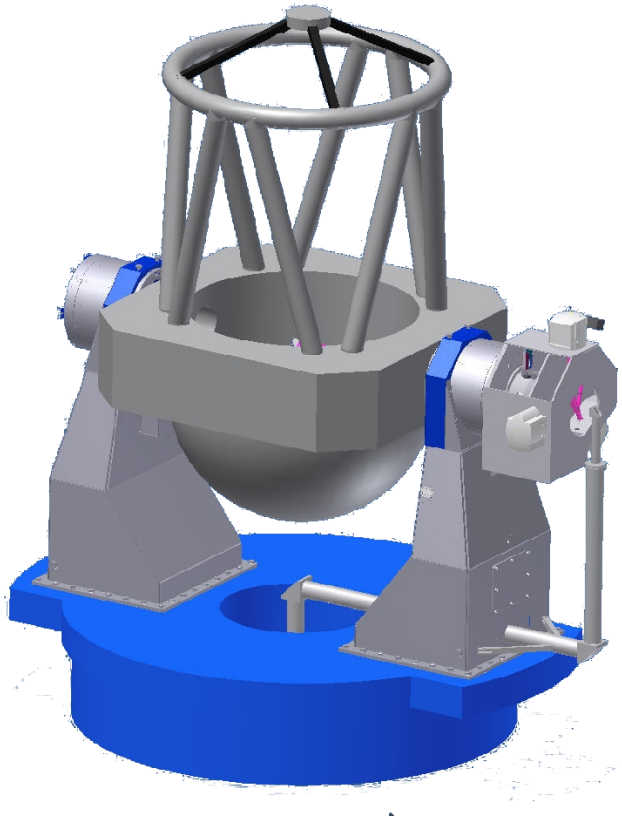
R > 99%

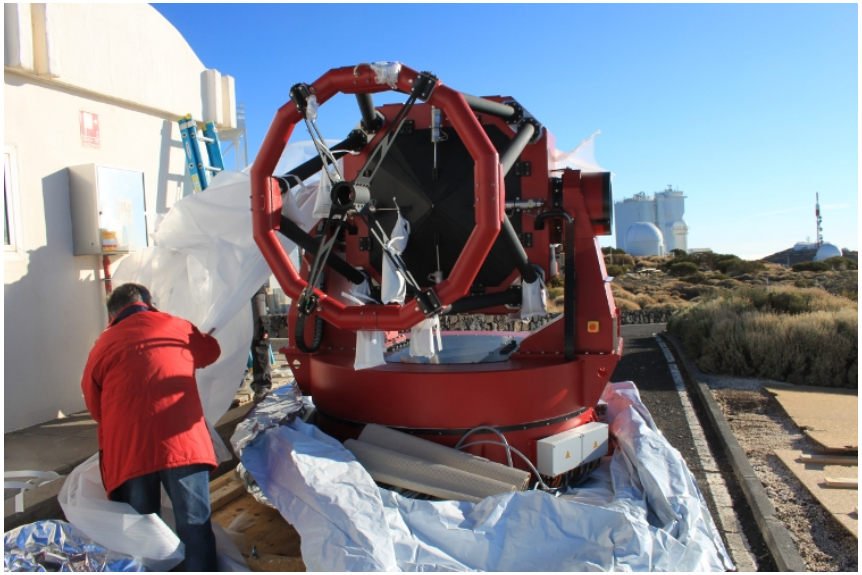
T > 99%

Coudé path in vacuum tubes @ 0.01 x atmospheric pressure, this reduces maintenance and prolong coating lifetime.



- 1m telescope, alt-az mount
- 5” pointing precision and ZD < 80°
- Thin (5cm), controllable primary mirror with Shack-Hartmann WFS (Active Optics)
- M2 on high-precision hexapod
- Rapid re-pointing (20deg/s)
- 2 Nasmyth foci (< 60s switching)
- ADC (lucky imaging)
- Optical de-rotator
- 5m Ash dome and sideports
- Wind-screen for dome
- Coudé focus for the spectrograph



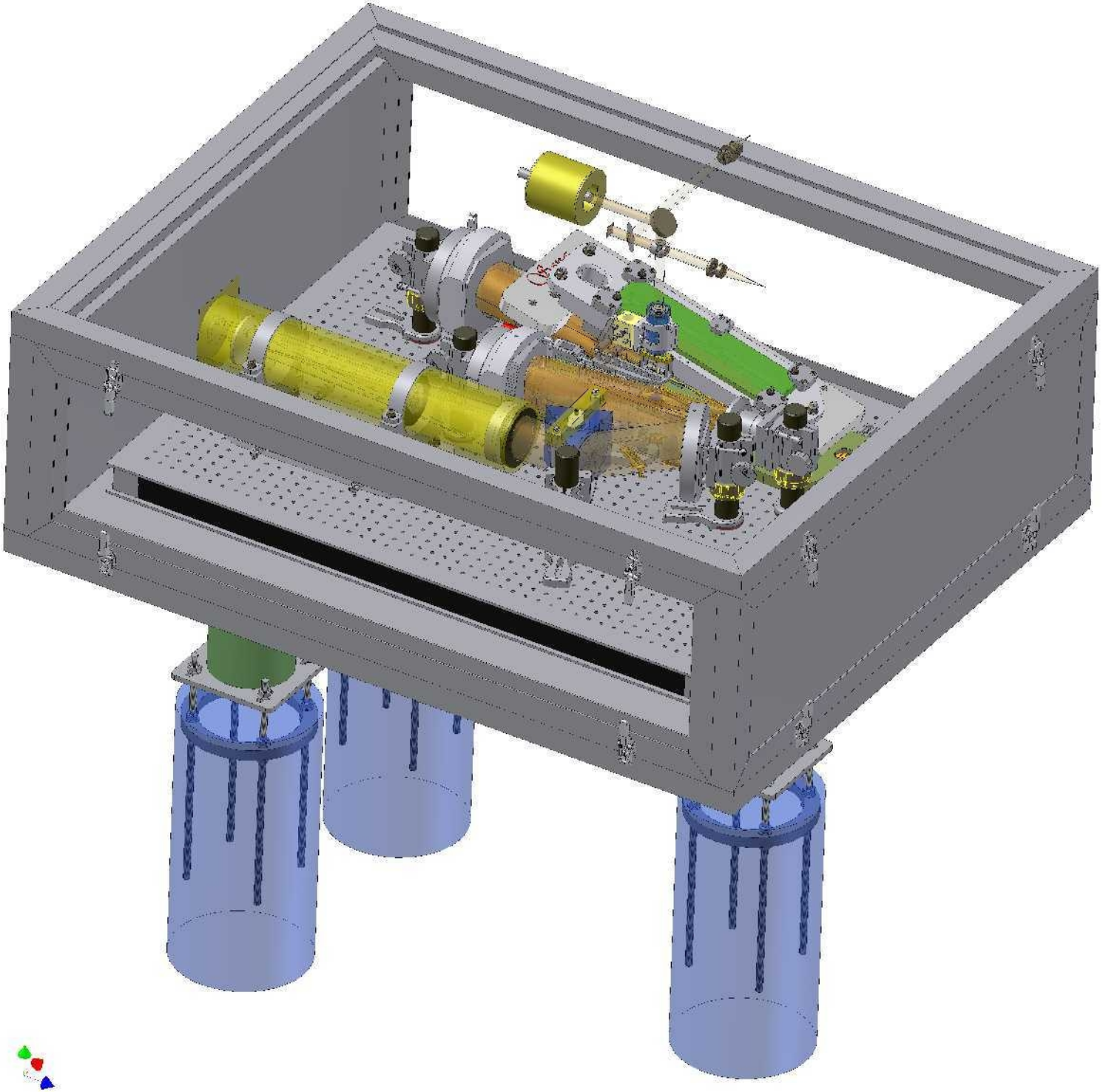


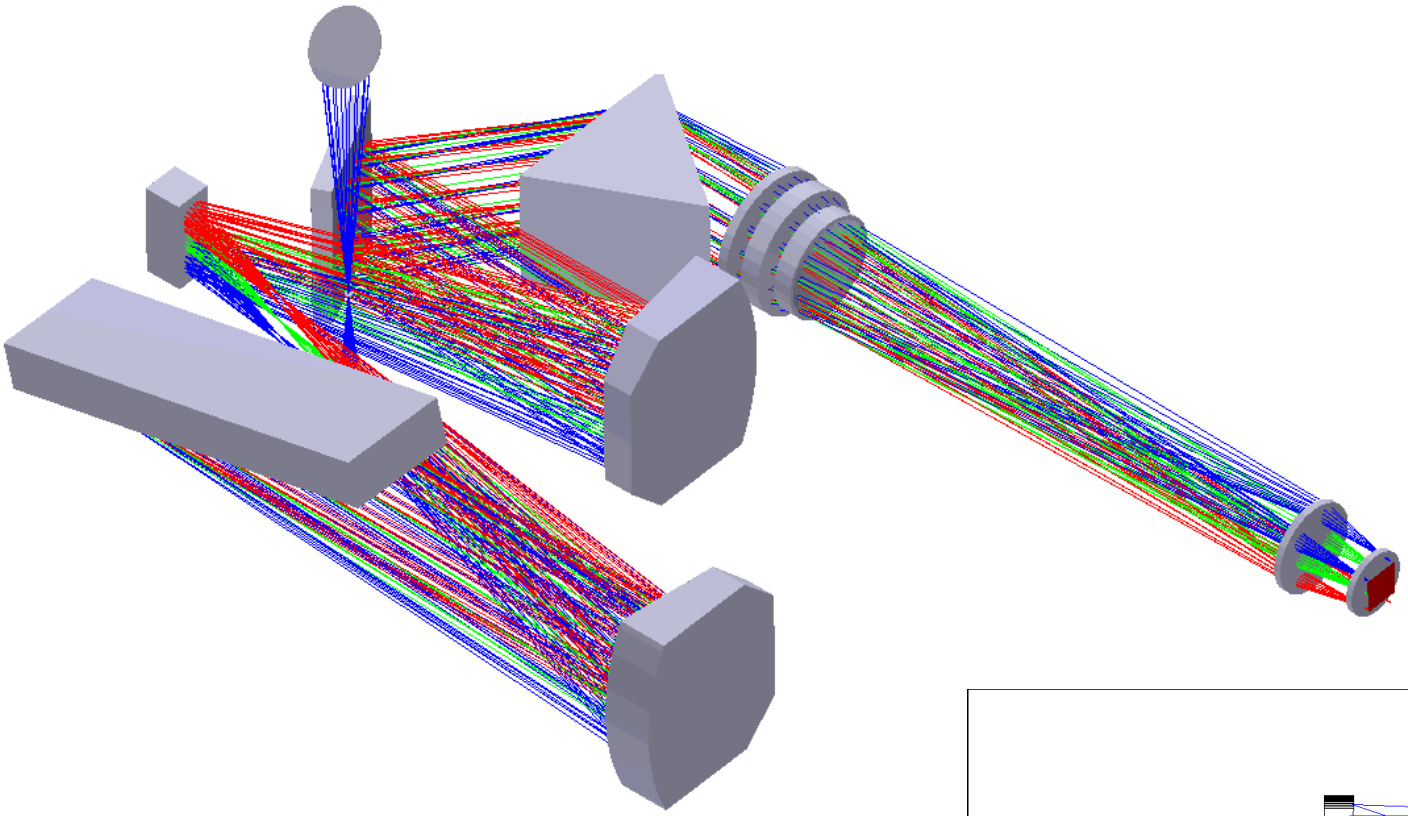
M2 and M3 dimensioned for ø15' field in the 2nd Nasmyth port

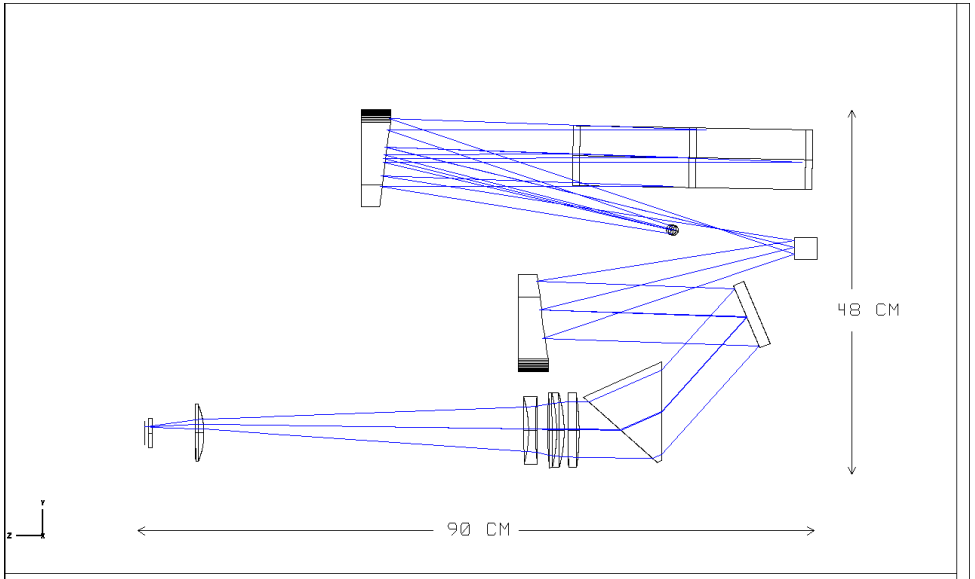
# Instruments

# Spectrograph @ Coudè focus

- Ultimate RV. precision of ~1m/s expected with **iodine cell**. Temp. control.
- Wavelength range 4500-6700Å.
- R = 36.000 – 120.000 (6 slits).
- Uniform PSF over detector area.
- High throughput (~7% TOTAL expected).
- Tip-tilt correction.
- Pupil correction/control/monitoring.
- Focus control and monitoring.
- Photon-weighted midtime of exposure calculation.
- “Ordinary” operation is possible (no $I_2$ cell, ThAr calib.)








3D LAYOUT

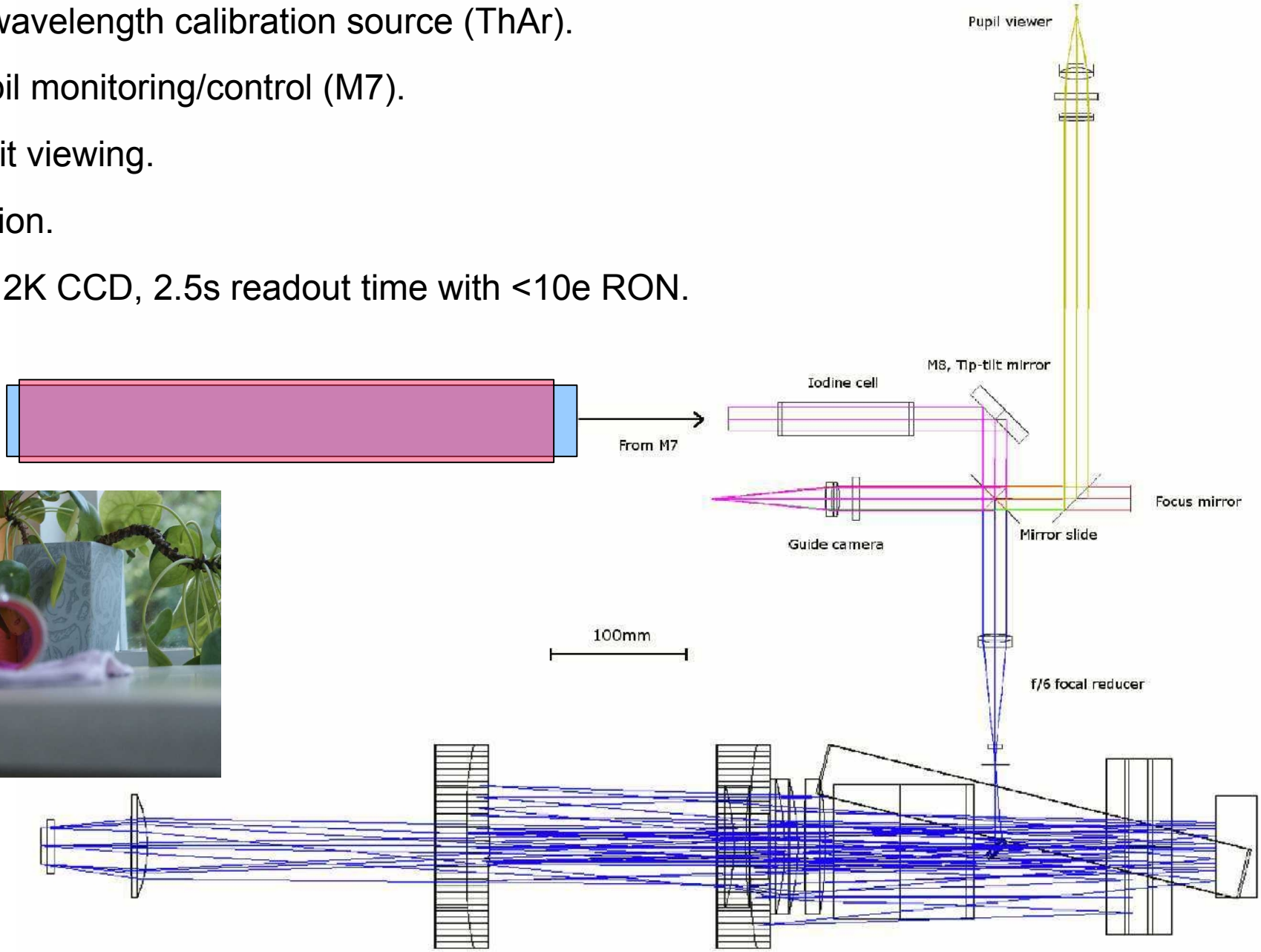
SONG SPECTROGRAPH
MON JUN 16 2008
SCALE: 0.2000

100.00 MILLIMETERS

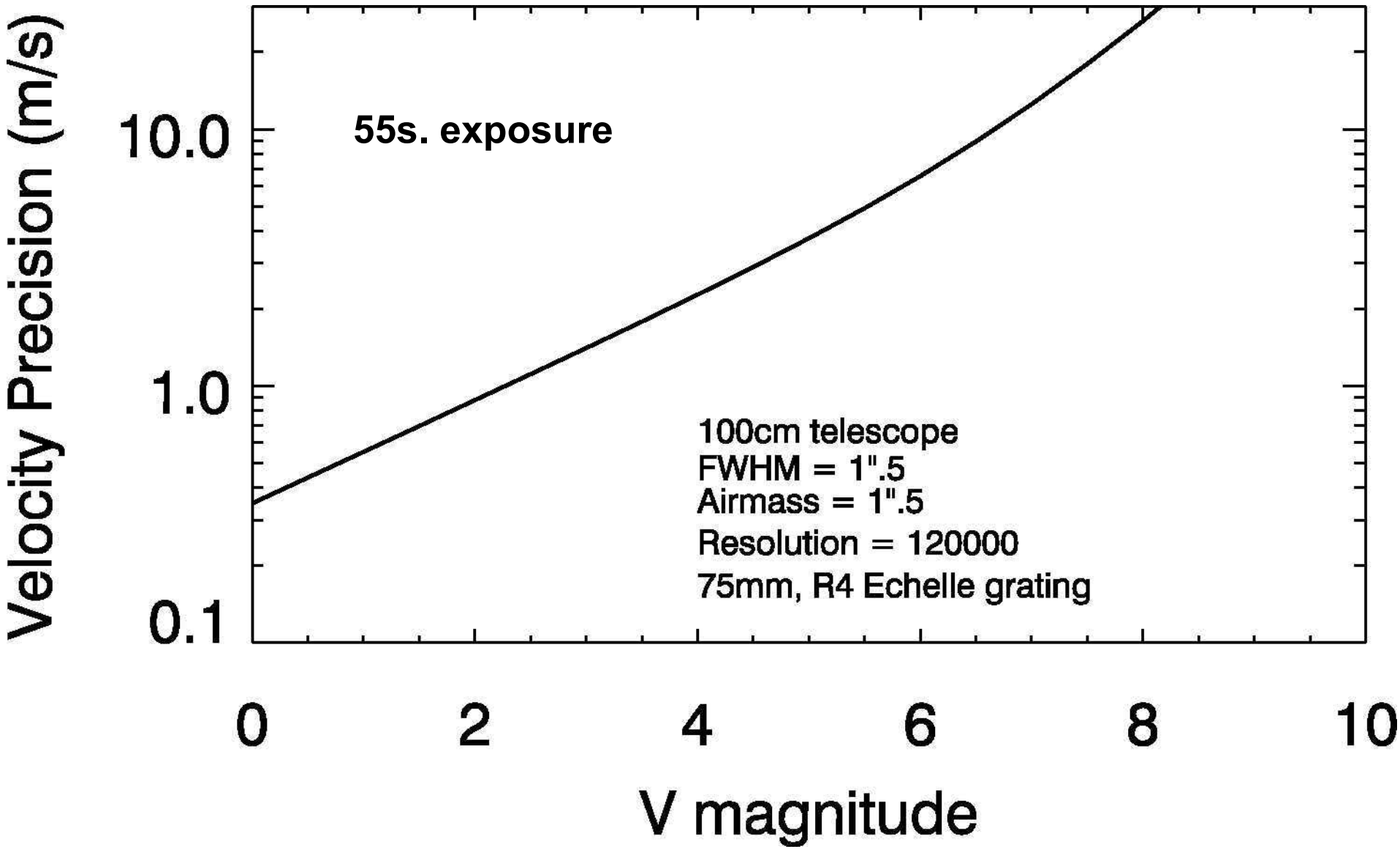
P. SPANO'
INAF

CONFIGURATION 1 OF 10

- Iodine Cell
- Flat field and wavelength calibration source (ThAr).
- Telescope pupil monitoring/control (M7).
- Guiding and slit viewing.
- Tip/Tilt correction.
- Andor iKON-L 2K CCD, 2.5s readout time with <10e RON.



# Velocity precision of the SONG spectrograph

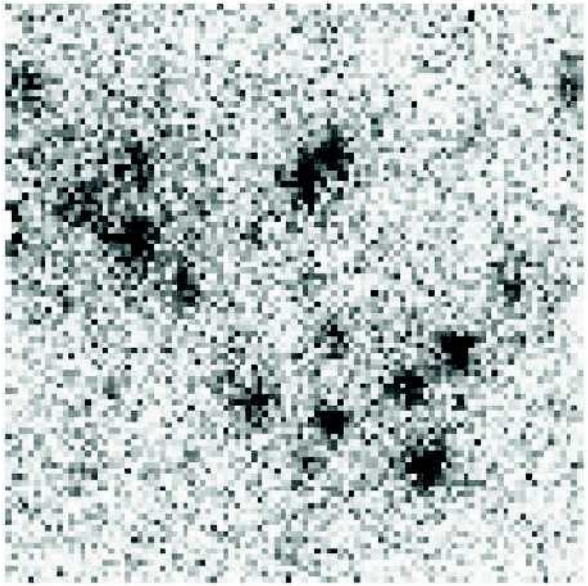


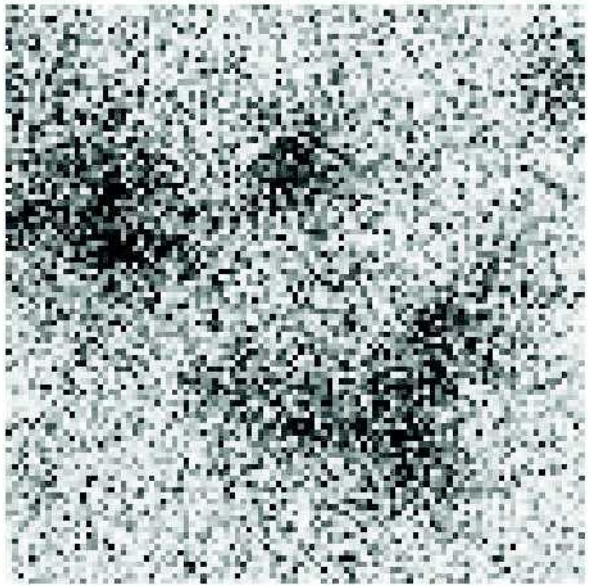
# Imaging @ Nasmyth focus

- Dual color lucky imaging – wavelength split at 650nm.
- FOV 46" × 46" with 0.09 pixels to sample diffraction limited imaging.
- Up to 6 filters possible for each channel (4 + dark + grey filter).
- Continuous monitoring of the focus.
- Full frame-rate up to 34Hz.
- Near-diffraction limited performance during best weather conditions.
- Conventional CCD mode possible with low RON and ~1s readout.
- Extra port available to cover up to 75” field in third position.

**Good !** **BAD!**

Martin Glitrup, 2010.

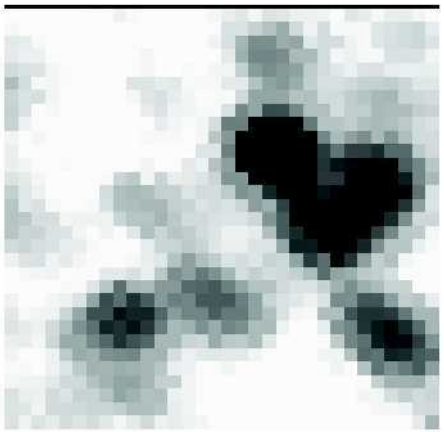




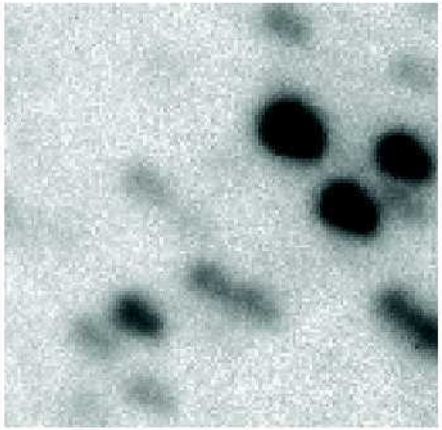
Experiment with Danish 1.54m on La Silla, Summer, 2009, same pixel-size (0".09) as SONG.

DFOSC

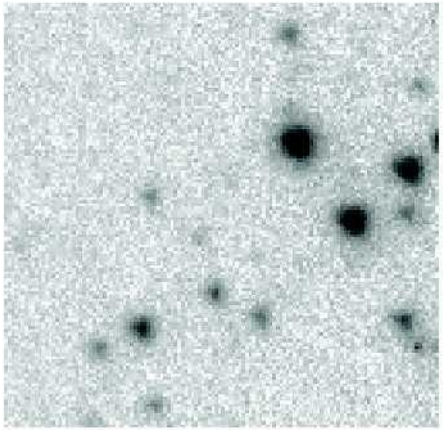
0".4 per pix.



(a) *DFOSC image*



(b) *Andor 100%*

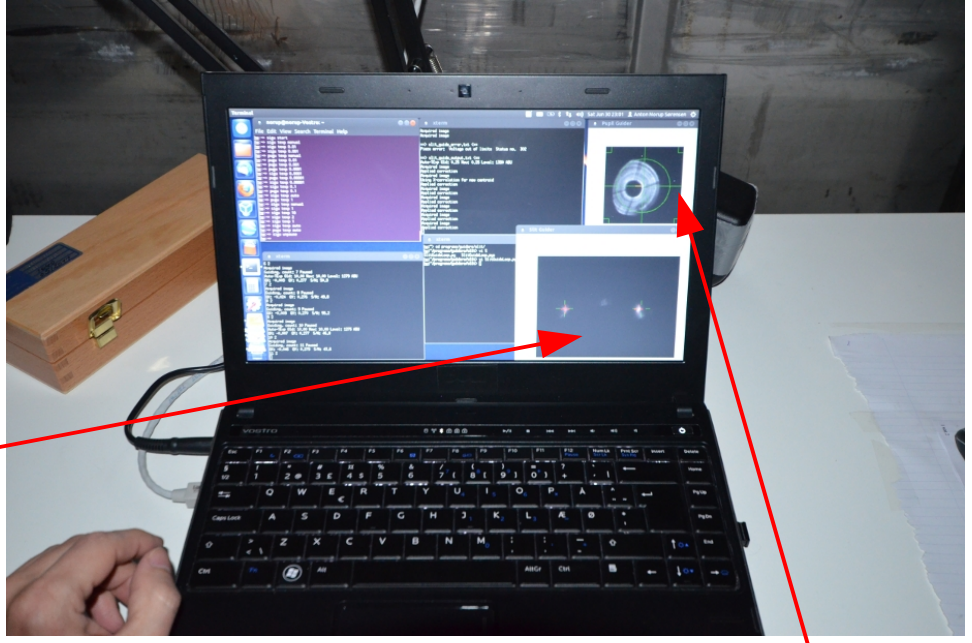


(c) *Andor 5% selection*

DFOSC 100% 5%

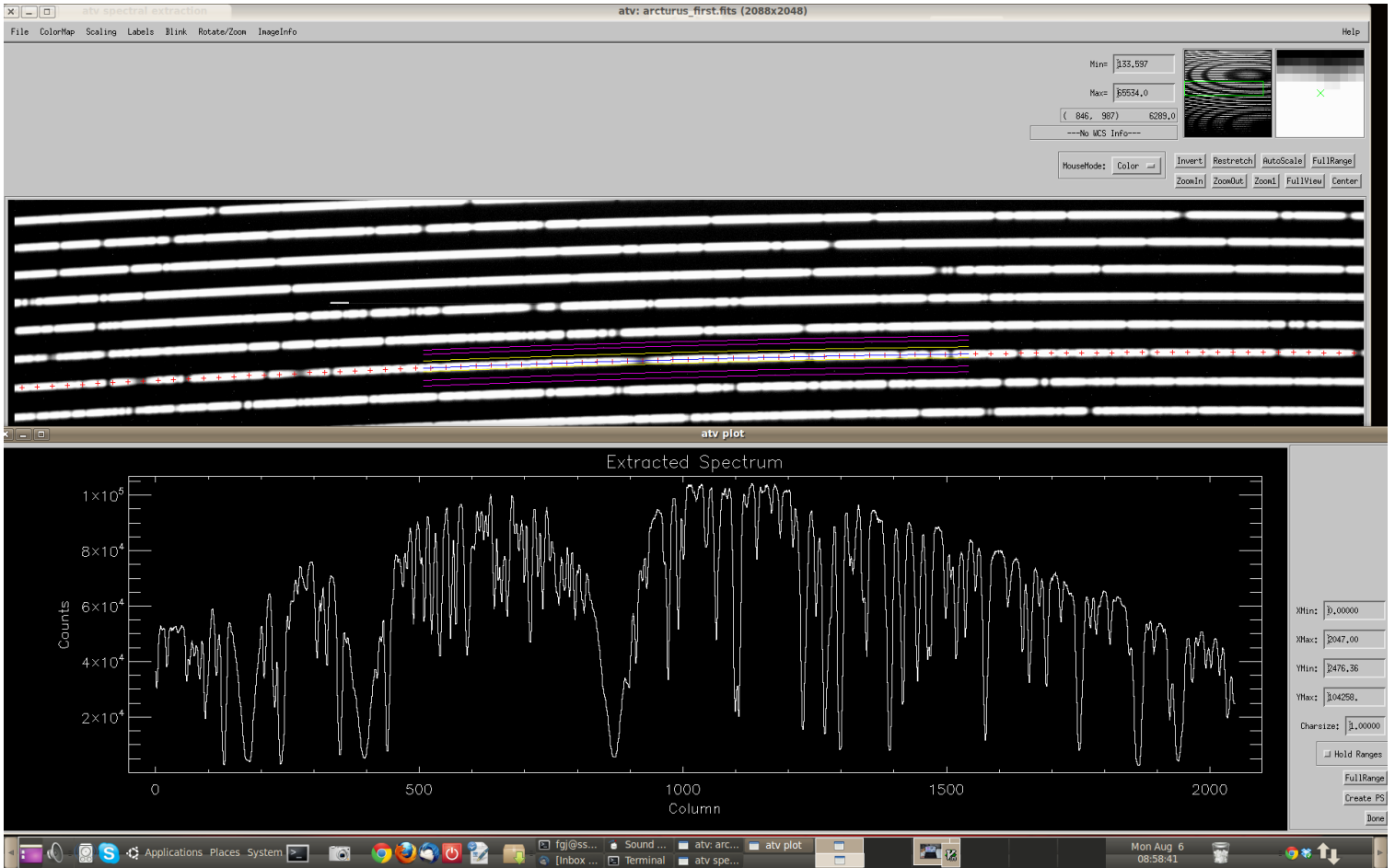
# First light spectra, 30 June, 2012

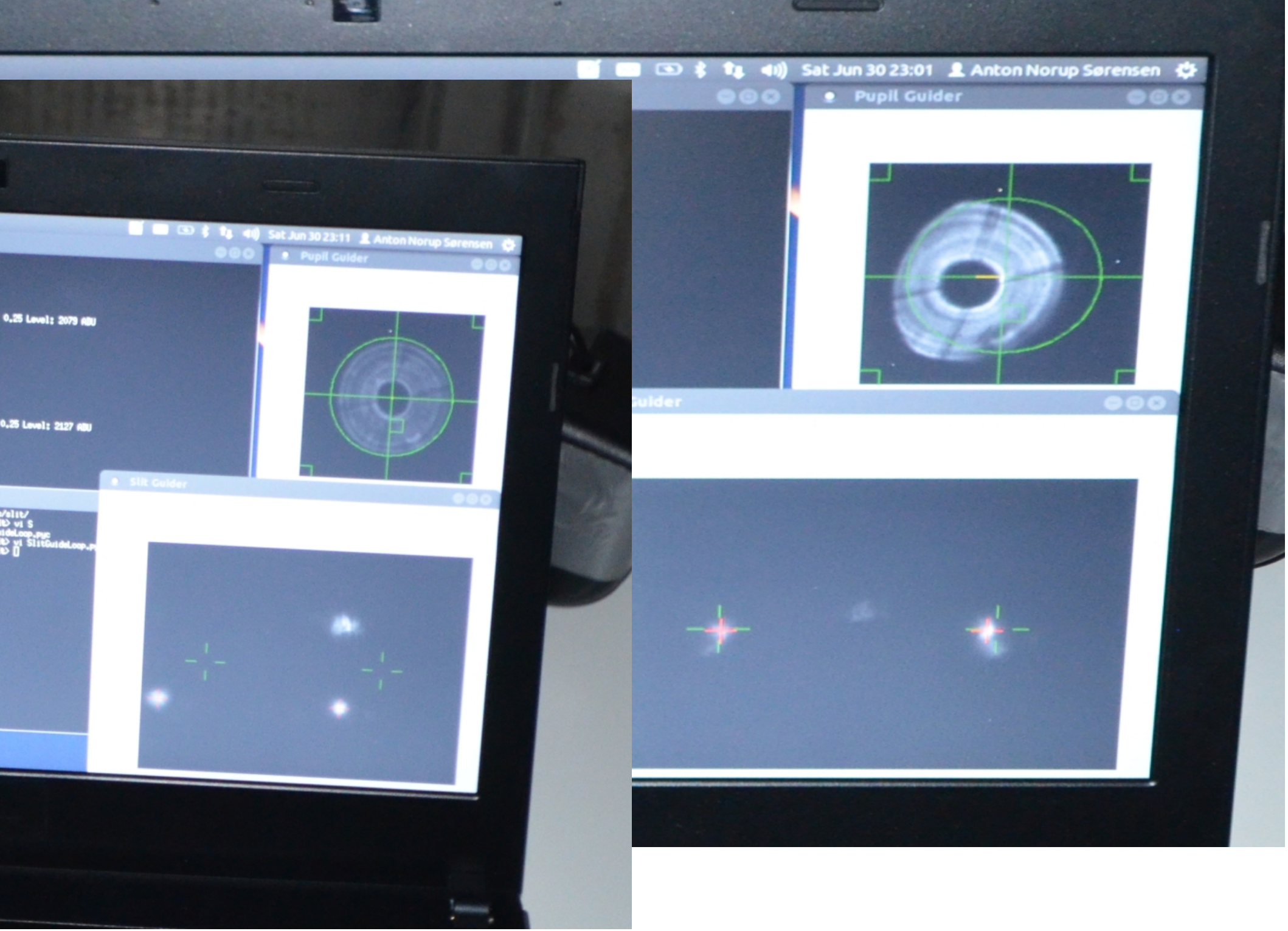
# Arcturus.

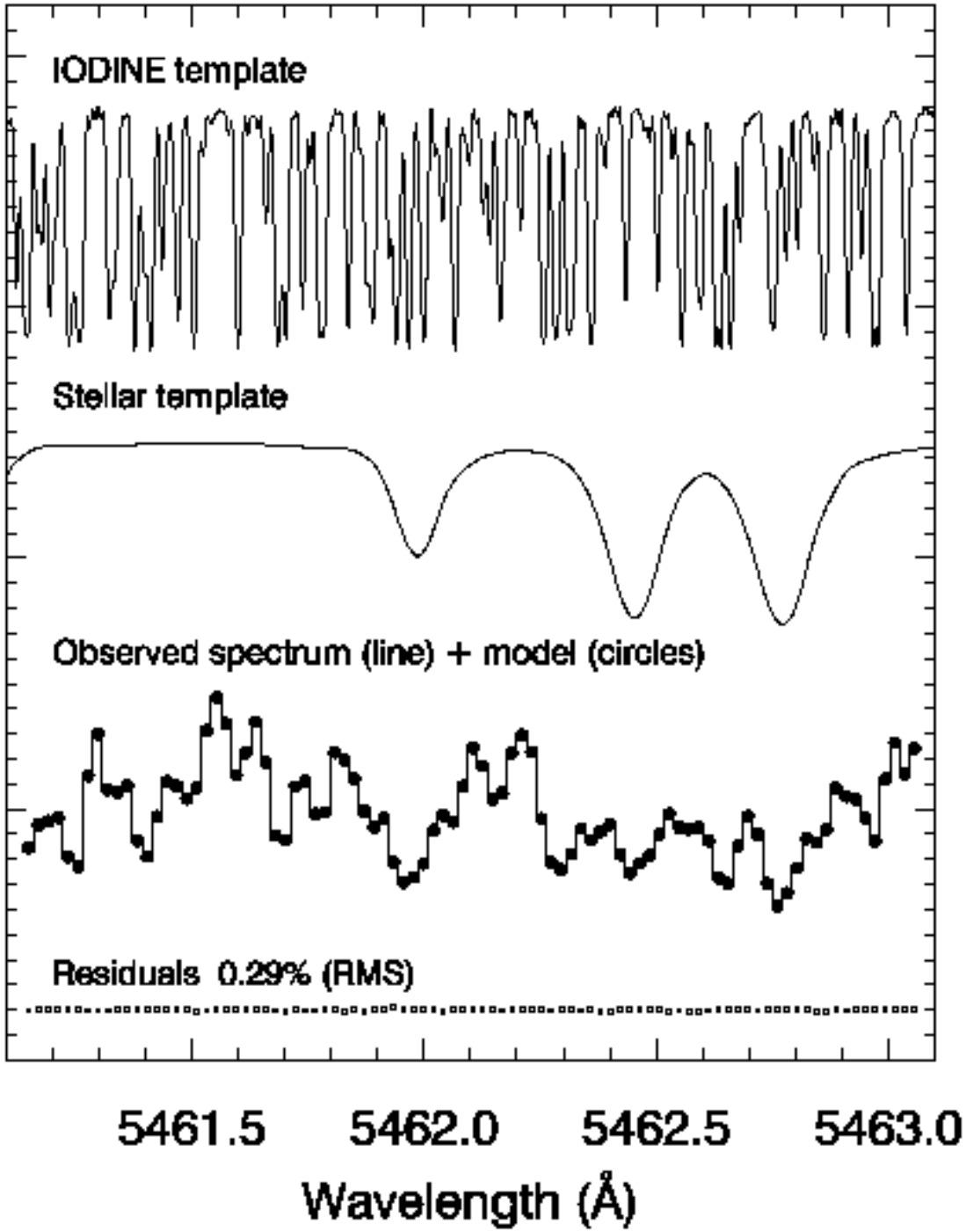


Slit guider

Pupil guide

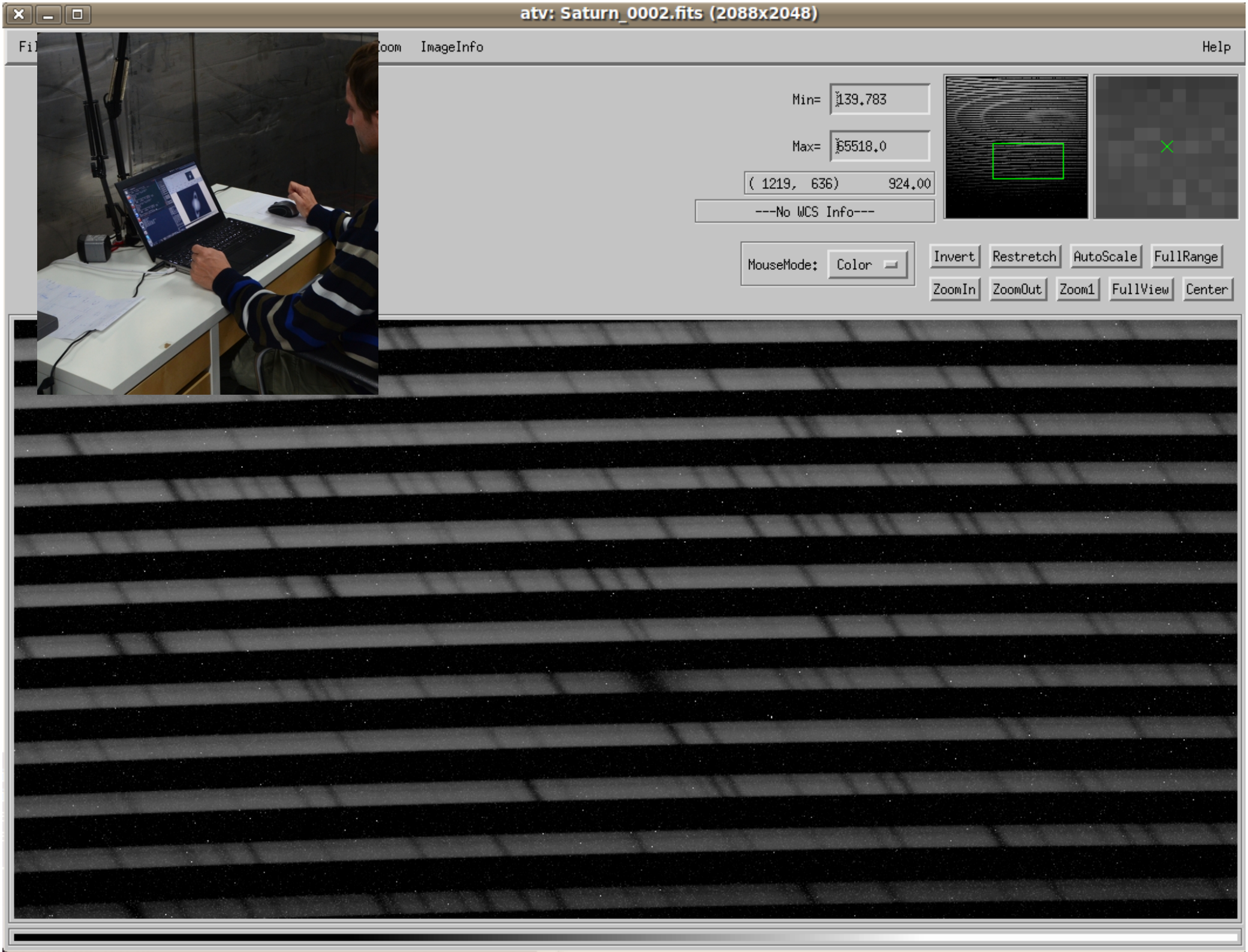



Sat Jun 30 23:11
Anton Norup Sørensen
Pupil Guider
0.25 Level: 2079 ADU
0.25 Level: 2127 ADU
Slit Guider
Sat Jun 30 23:01
Anton Norup Sørensen
Pupil Guider



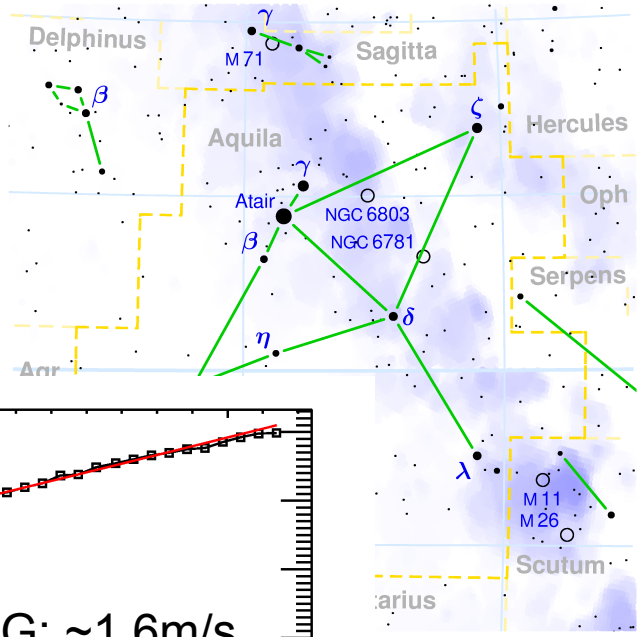

Modellering af et spektrum

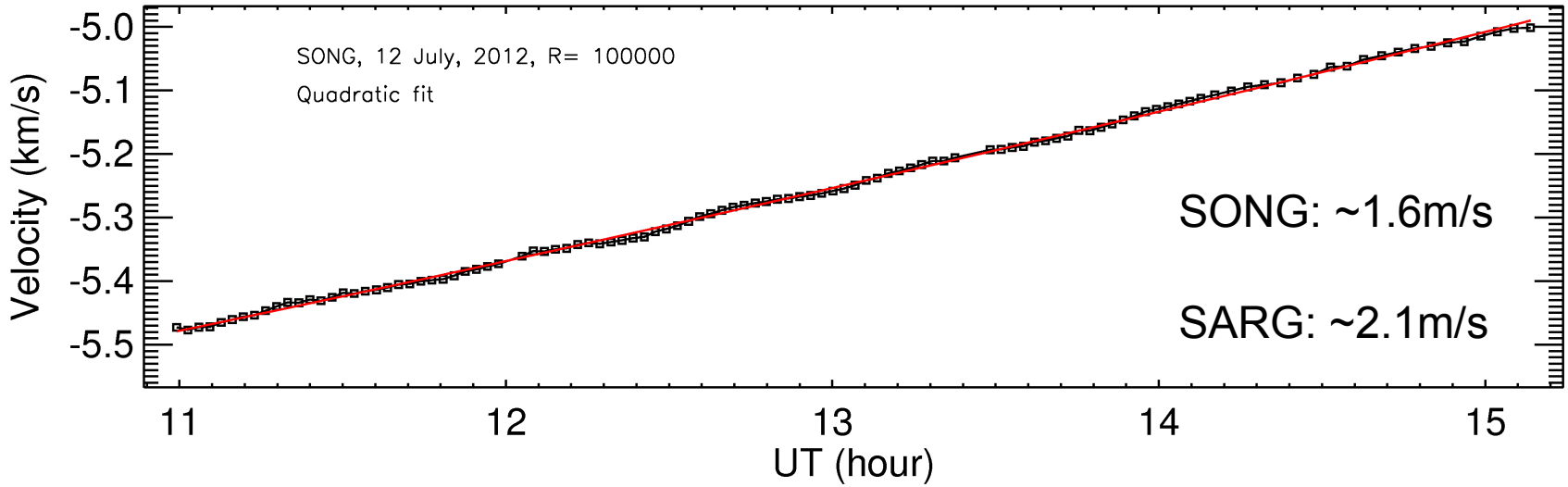
Optaget gennem en iod-celle.

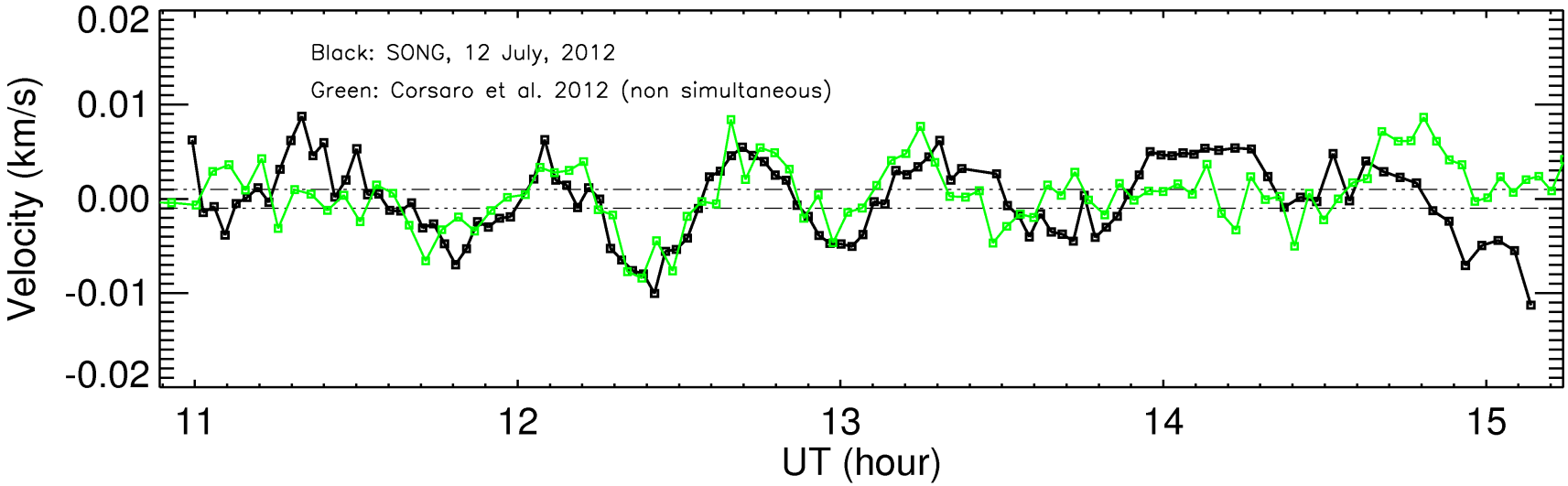

atv: Saturn_0002.fits (2088x2048)
Fil
oom
ImageInfo
Help
Min=
139.783
Max=
65518.0
( 1219, 636) 924.00
---No WCS Info---
MouseMode:
Color
Invert
Restretch
AutoScale
FullRange
ZoomIn
ZoomOut
Zoom1
FullView
Center

# First timeseries observation

# 4h of Beta Aquilae.... V = 3.71.



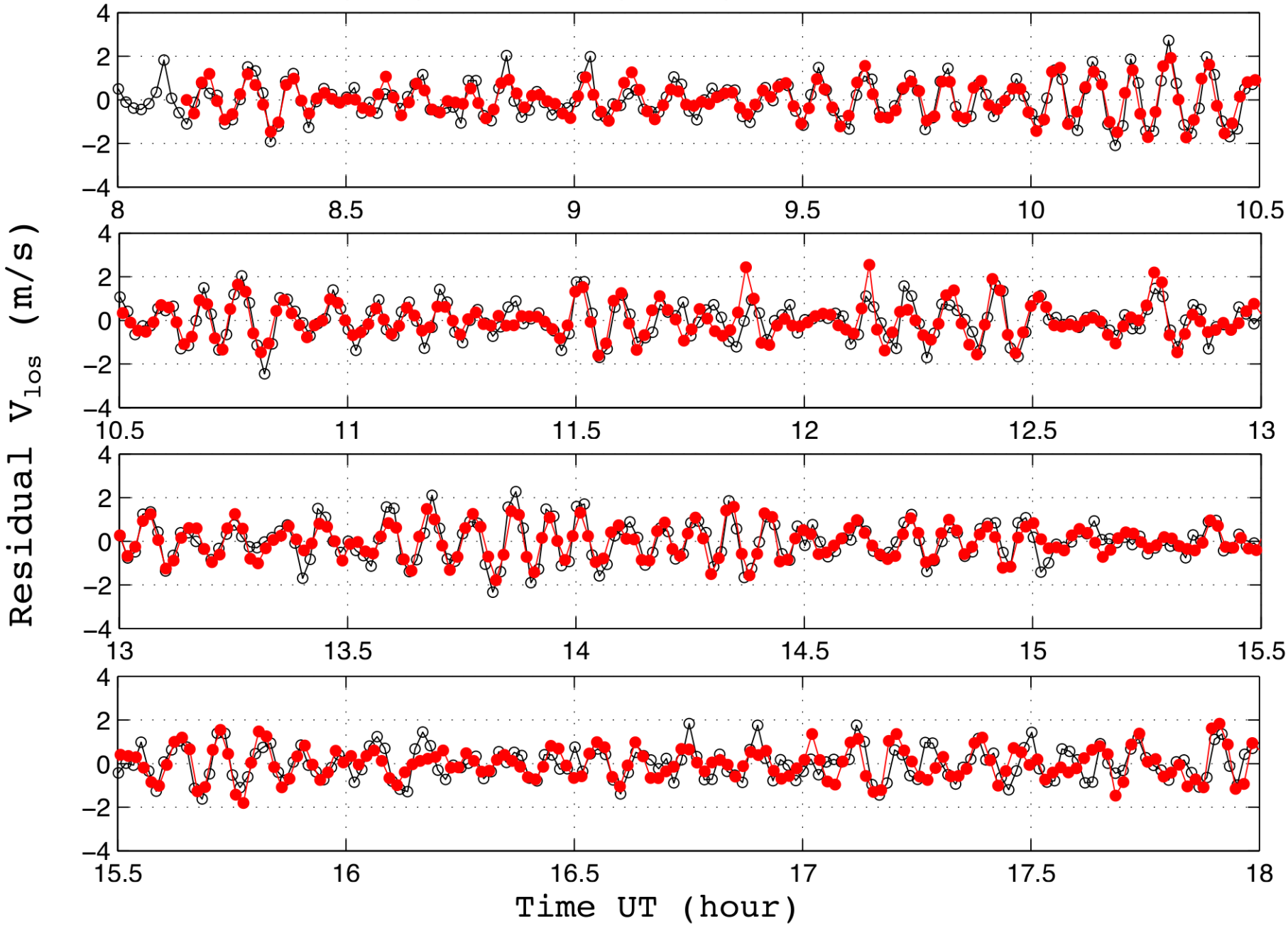
**Solar observations using a 400µm telescope....**

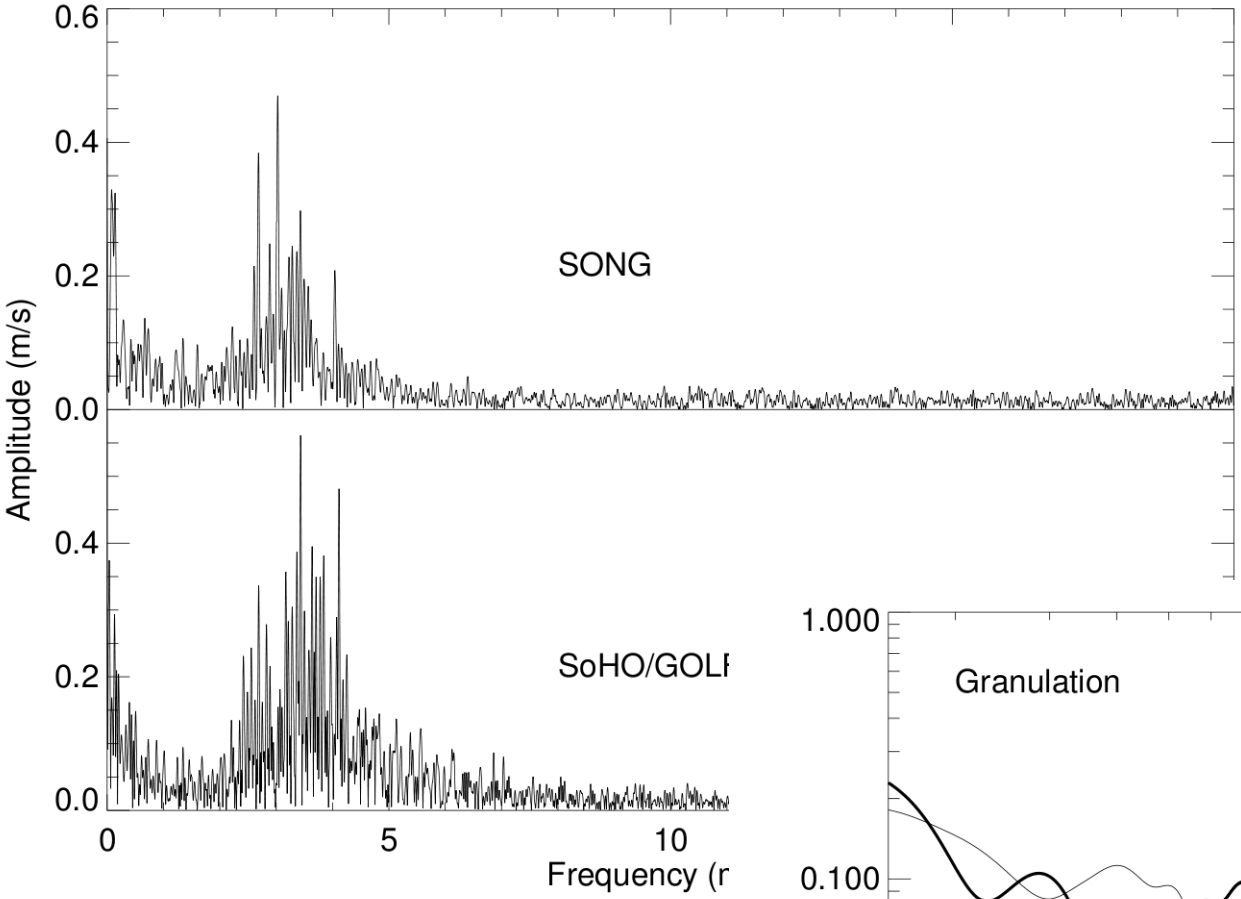
... can we measure the solar 5-min. oscillations.... ??

0.5s + 2.31s --> 12500 images ~ per 10h..... + 1 uge på 30 CPU computer...

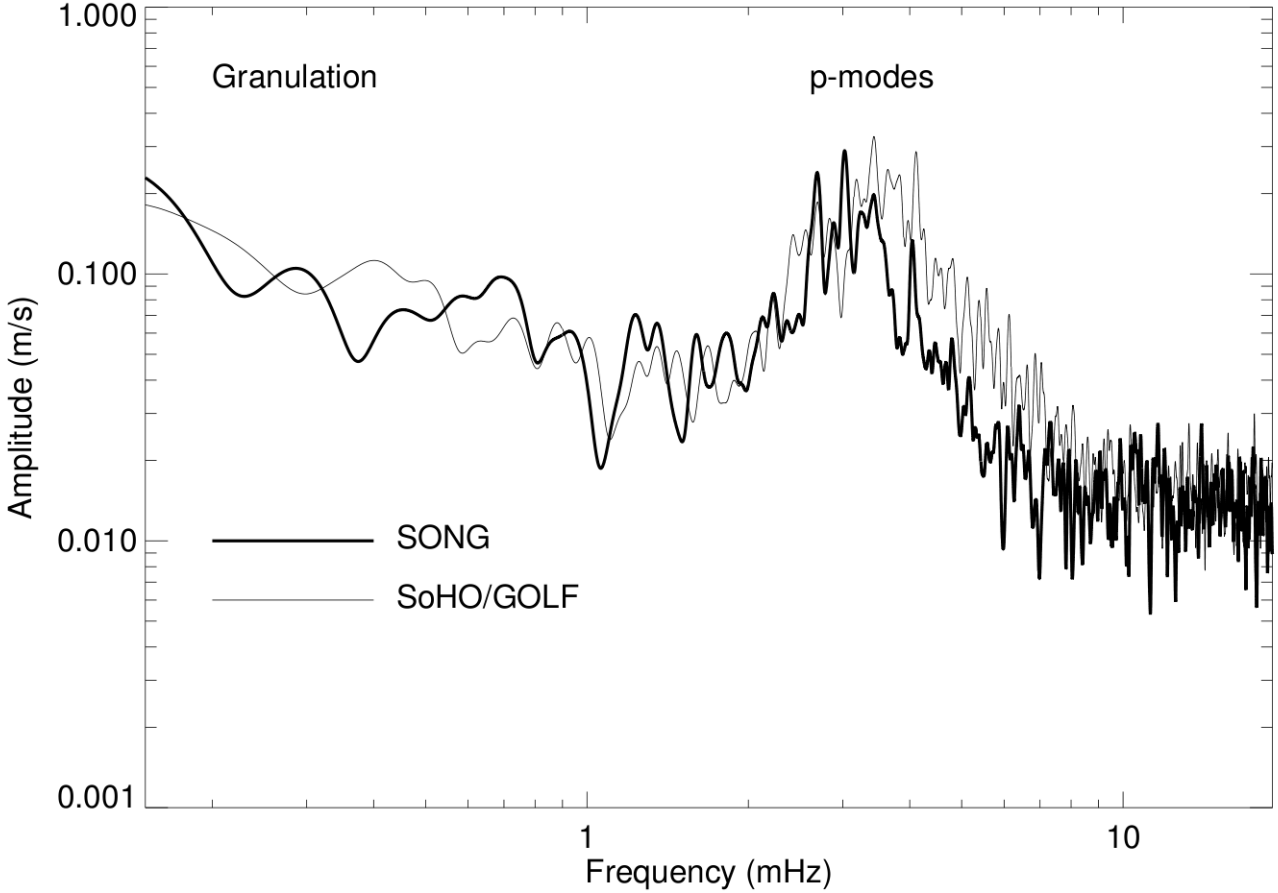
**... yes we can**

Solar Run. SONG (red) & Mark-I (black). Obs. Teide 11June2012. $\Delta t$=60s.






... Næsten som SOHO satelliten ....



## The next steps:

Full commissioning.... and GET MORE NODES !

- A Chinese group (PI: Yan Li and Licai Deng) is currently Building the second node to be ready by late 2013.

# http://song.phys.au.dk

2nd node in factory (Nanjing, China).

Installation expected mid 2013 at the

Delingha (3200m) observing station.