Brazil, Russia, India, China, South Africa

Astronomy

NNUVS

The Near UV Spectrographs Network

Institute of Astronomy, Russian Academy of Sciences

2025-2035: The new UV Space Mission Era

- **WSO – UV (launch 2024)**

- **CSSOS** (launch 2022-2025).

The Chinese space station optical survey, high-resolution near-UV imaging and slitless spectroscopy in the optical.

- **LUVOIR** (launch 2035), NASA

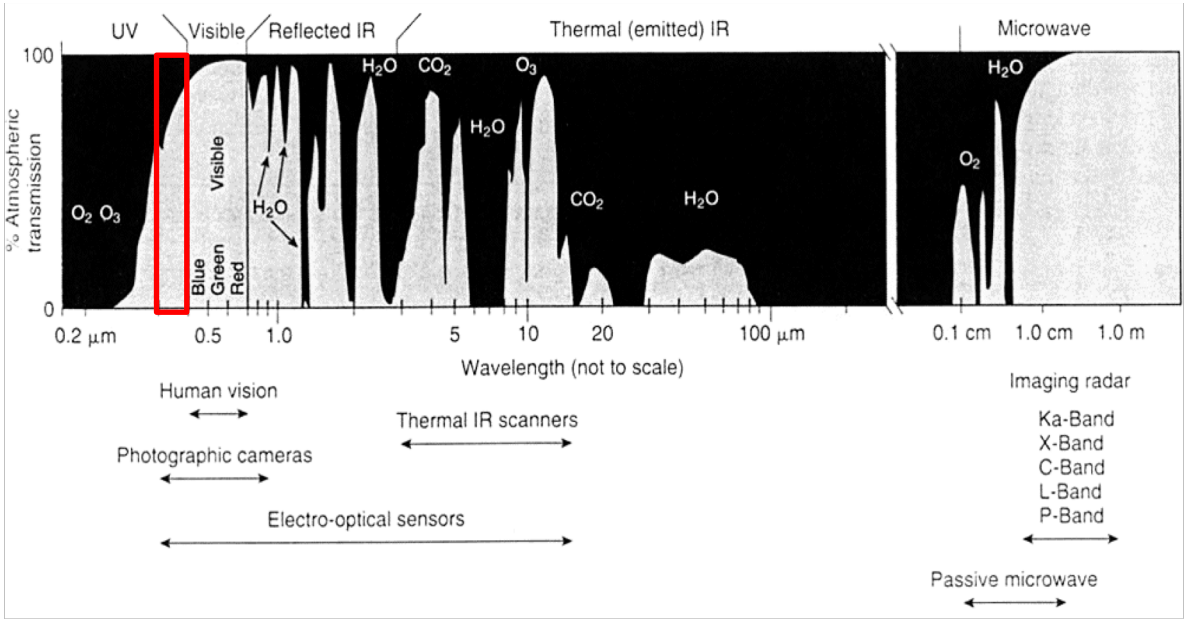
The Large UV/Optical/IR Surveyor (LUVOIR) is a concept for a highly capable, multi-wavelength space observatory with ambitious science goals.

- Small UV Missions

Our proposal: NNUVS

NNUVS - the network of high-resolution spectrographs for ground-based NUV region – 300…400 nm

- **Main goal: ground spectroscopic support of the “WSO-UV” mission**
- Observations in overlapping spectral range (UV 300 – 310 nm) and up to 400 nm
- Simple and highly efficient optical design, such as WSO-UV spectrograph
- High spectral resolution (R 50,000 – 80,000)



Why Near UV? Scientific Goals

Galactic science

- stellar abundance studies
- Novae, close binaries and compact stars
- ISM
- opportunities for the observation of comets (*OH lines (308.5nm) as possible tracer of Water in Comets*)
- planets and exoplanets
- Normal B stars
- Metal-deficient stars

Important: Line density increases from the visual region to UV - region

Why Near UV? Scientific Goals

UV spectra of stars contain a high density of key absorption lines including many elements that are unique to this spectral range:

- Be II resonance lines at λ=313.1065 and λ=313.0420 nm
- Bi I 302.4635nm, unique measurable line of Bismuth (given that the Bi I 306.7nm line is severely blended), that can be important as a reference element, which together with uranium, can be used to derive stellar ages;
- Ge I 303.907nm: Germanium can serve as a key element to constrain physical conditions for the r-process nucleosynthesis.
- Other lines: Ag I 328.07nm, Ag I 346.47nm, Lu I 307.76nm, Re II 330.22nm, Ru II 349.894nm, Ta II 313.74nm and many others
- VALD database (Kupka F., Ryabchikova T.A., Piskunov N.E., Stempels H.C., Weiss W.W., 2000, Baltic Astronomy, vol. 9, 590-594)

Why Near UV? Scientific Goals

Carbon, nitrogen and oxygen abundances from molecular lines
strong OH lines occurring in the range 300 – 330 nm:

- NH band at 336 nm
- CN band at 388.3 nm.

Extragalactic science

- investigations of active galactic nuclei (AGN)
  [Ne V]342.6nm, [O II]372.7nm, [Ne III]386.8nm
- inter-galactic medium (IGM).

-IGM at intermediate redshifts ($z \simeq 1.5-2$), its physical state (temperature, ionization) but also its metal content (through O VI),

-the interstellar medium of high redshift galaxies and in particular its molecular content (H_2 for z>2; CO for z>1)

Why Network?

- Each countries of BRICS have a high mountain observatories for NUV-band observations.
- One cost-effective NUV spectrograph for each country.
- For the network time slot is much better.
- Excellent sky coverage from north and south hemispheres.
- Excellent longitude coverage. Each event can be observed for a long time.

Why Network?

The BTA-6
6m Large Altazimuth Telescope
2070m

The Yunnan Lijiang observatory
2,4m robotic telescope, 3240m

The Peak Terskol observatory
2,0m Zeiss telescope, 3150m

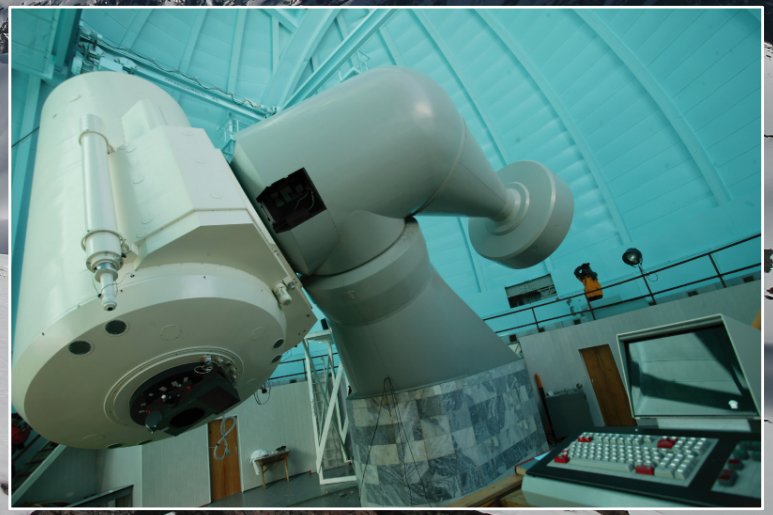
The Southern African Large Telescope, **SALT**, hexagonal array of 11.1m x 9.8 m, 1798m

The Pico dos Dias observatory
1,6m telescope, 1864m

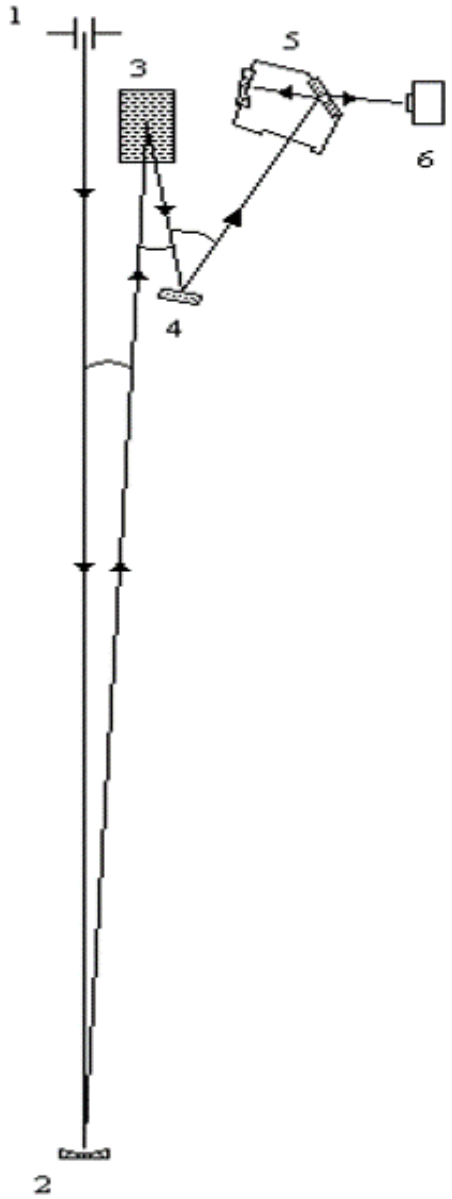
The Himalayan Chandra Telescope 2,01m
Hanle Observatory, 4500m

Ground based NUV spectrograps: TUVES

Terskol branch of Institute of astronomy RAS – 2 meter telescope

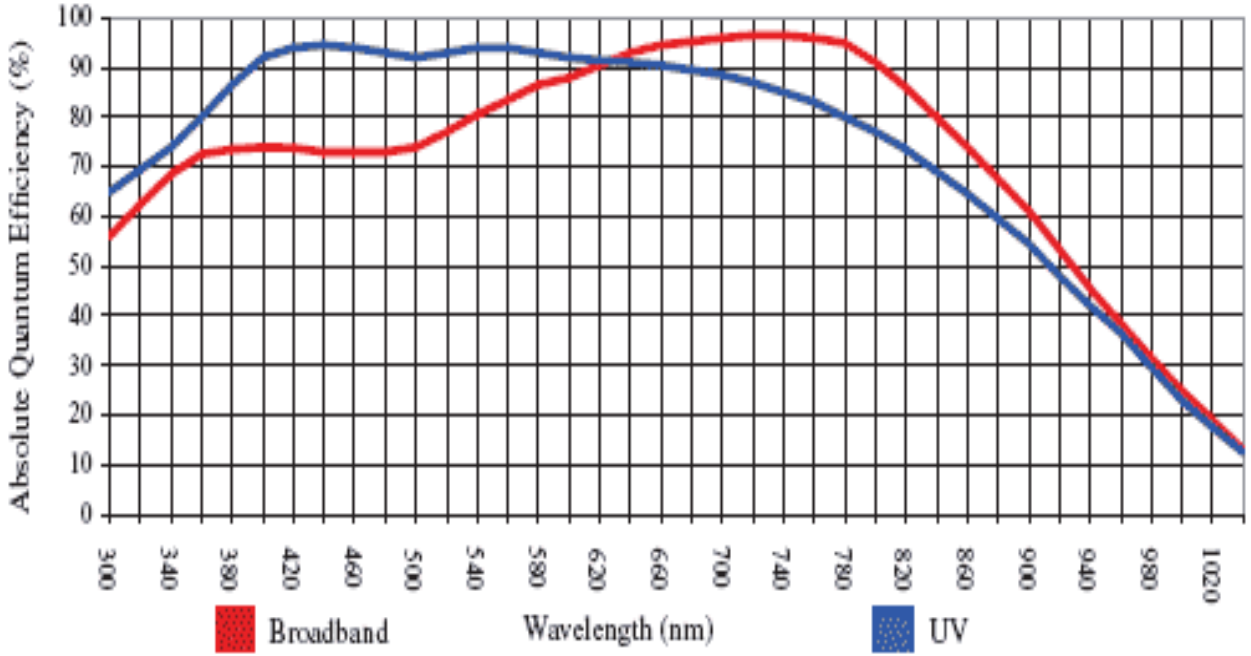


Ground based NUV spectrograps : TUVES

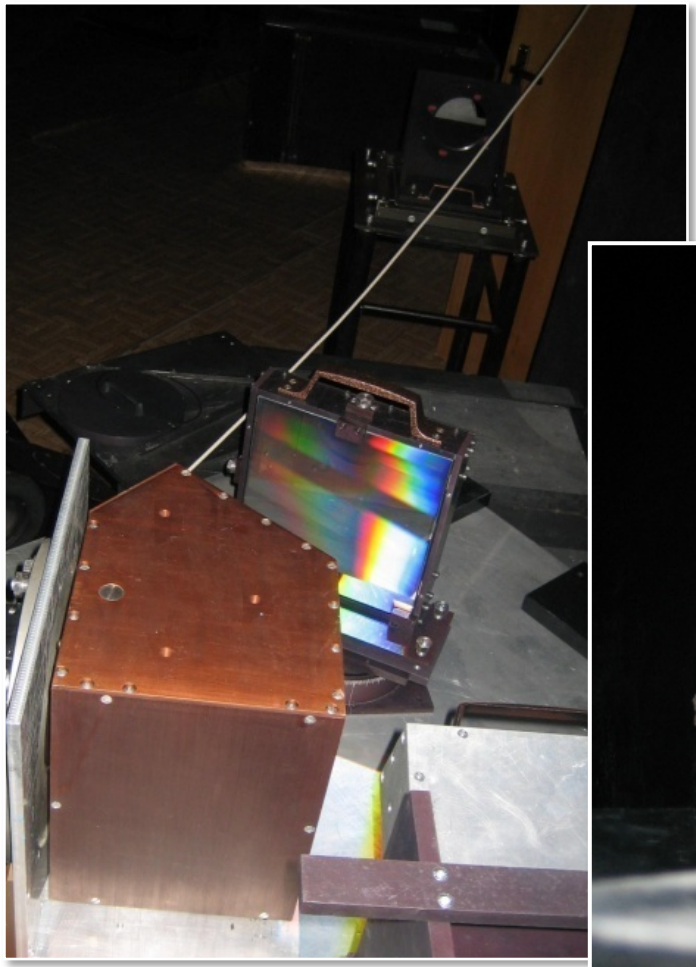


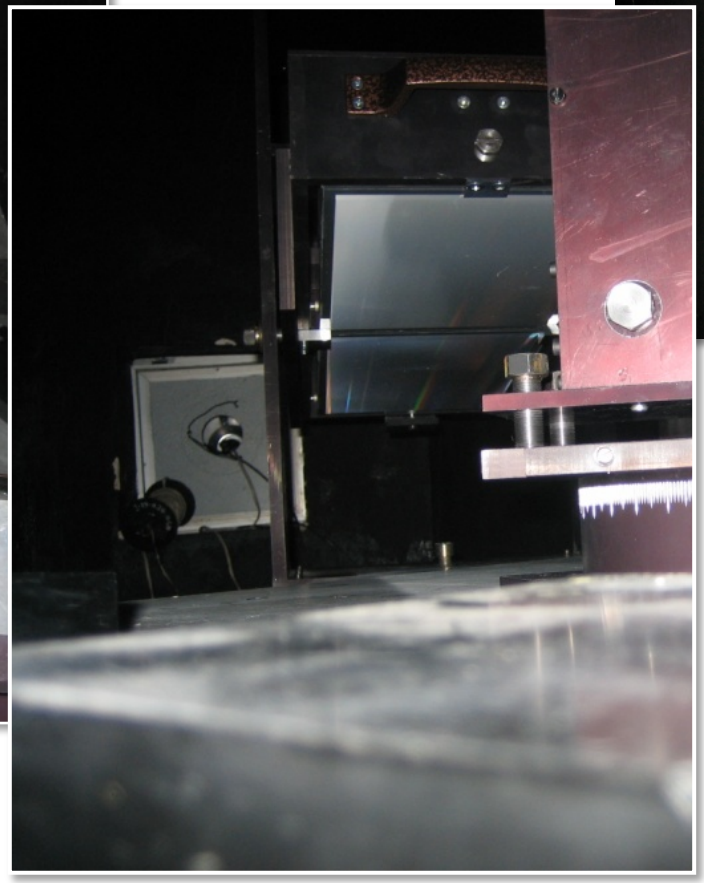
Optical layout and main properties

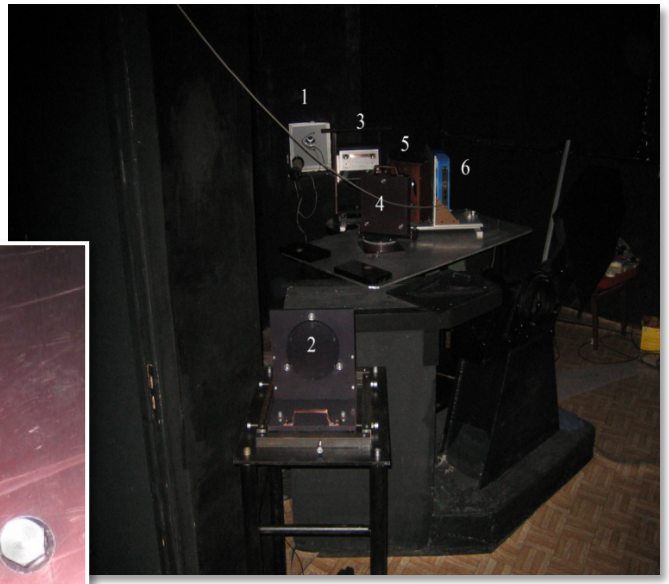
- R= 18000, 32000, 50000.
- R= 800, 1700
- Apogee Alta U3041 UV-enhanced CCD



Ground based NUV spectrograps : TUVES





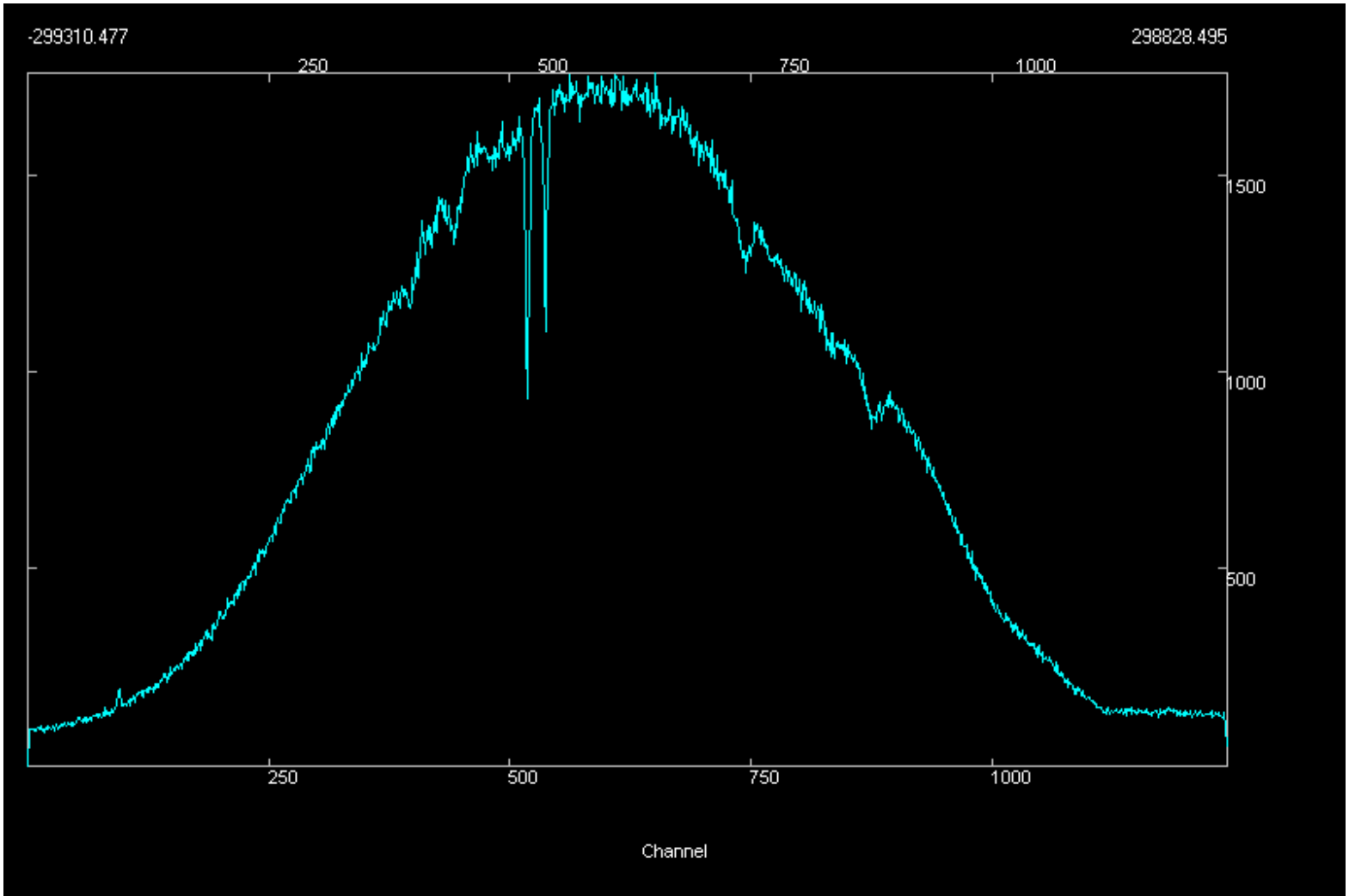


Ground based NUV spectrograps : TUVES

Images of the solar spectrum (evening sky) and spectrum of Vega

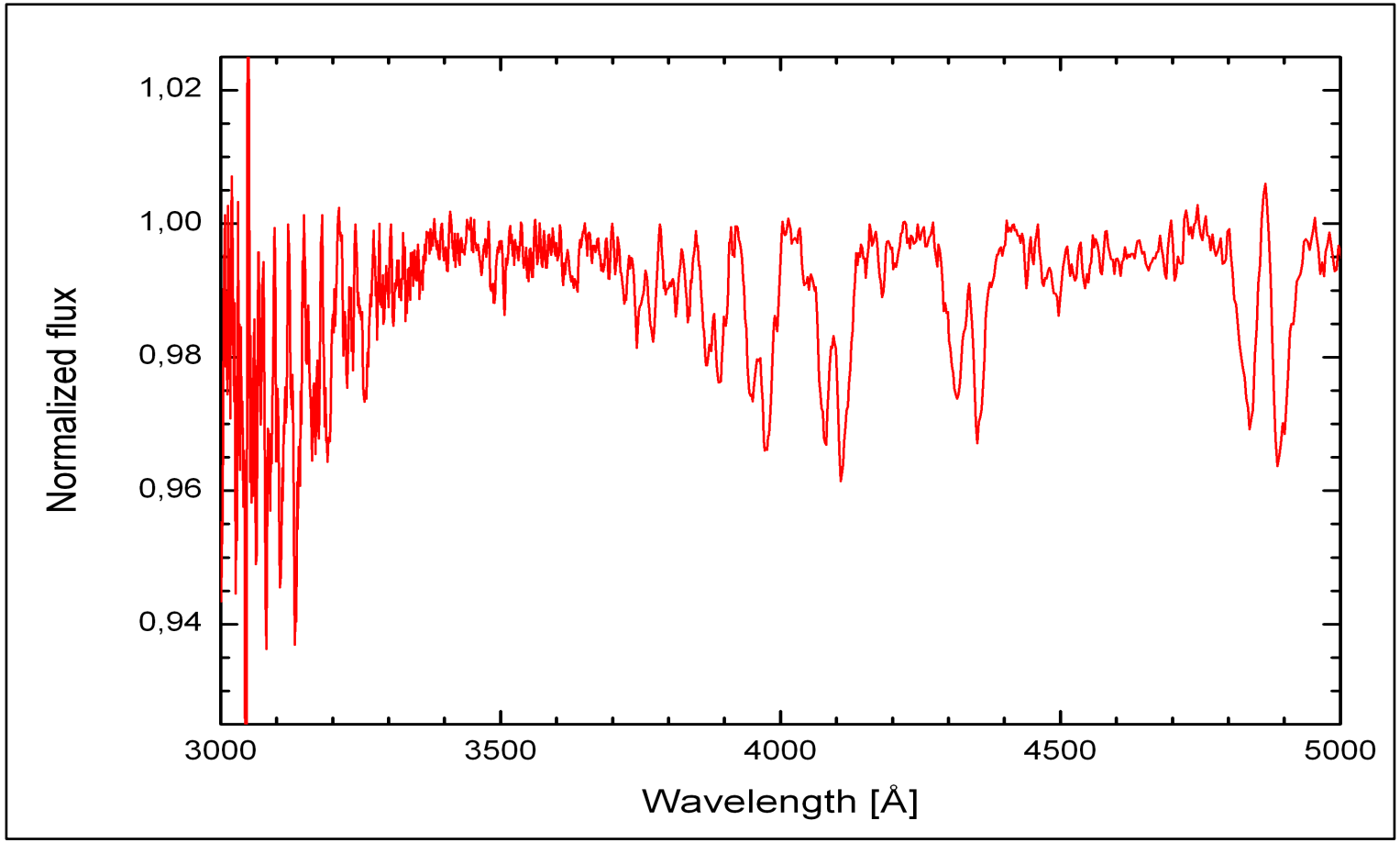
Ground based NUV spectrograps : TUVES

HD34078 Sp O9.5V B = 6.2^{m}



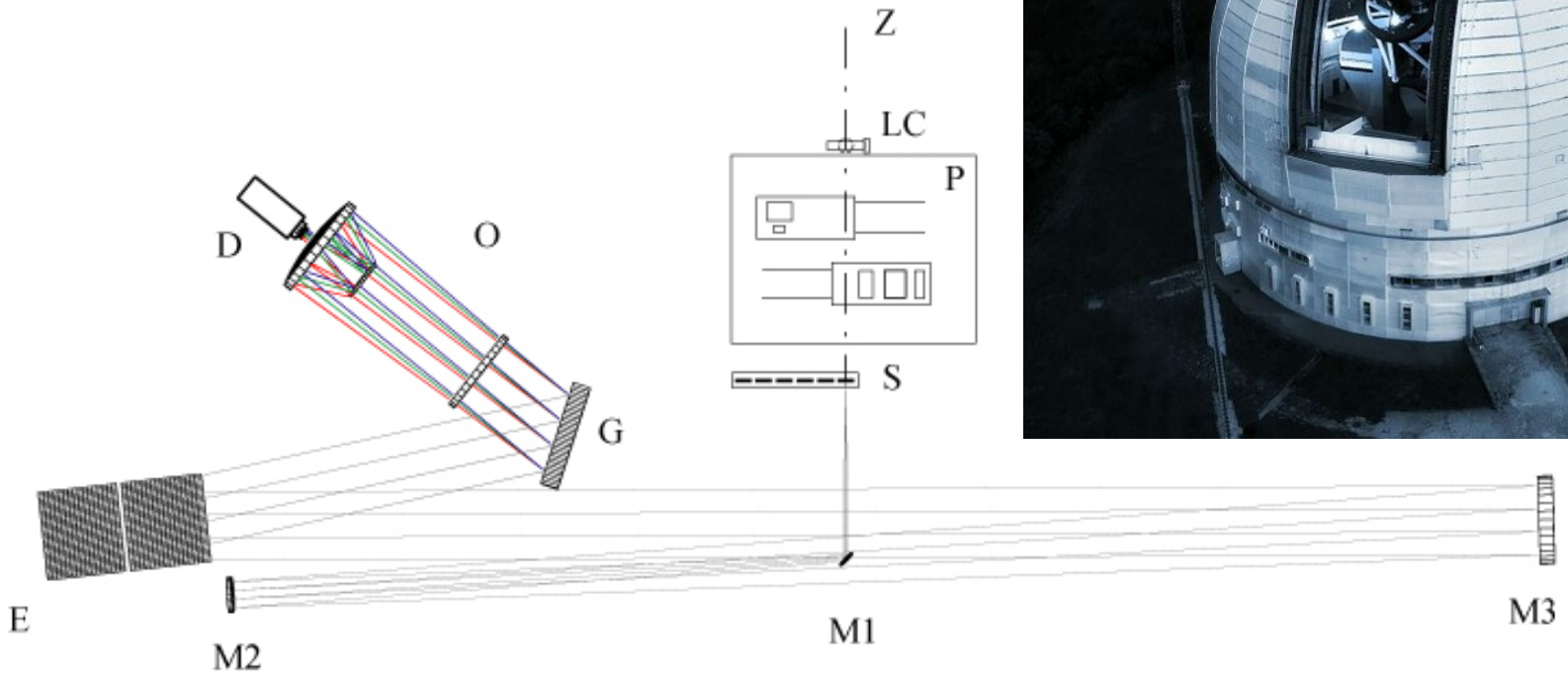
Ground based NUV spectrograps : TUVES

CV type star SS Cyg in active phase (www.aavso.org V= 8, ^{m}3)
Exp= 600 sec, R=1700



Ground based NUV spectrographs: NES

The Nasmyth Echelle Spectrograph (NES) spectrograph at the 6-meter Russian telescope BTA

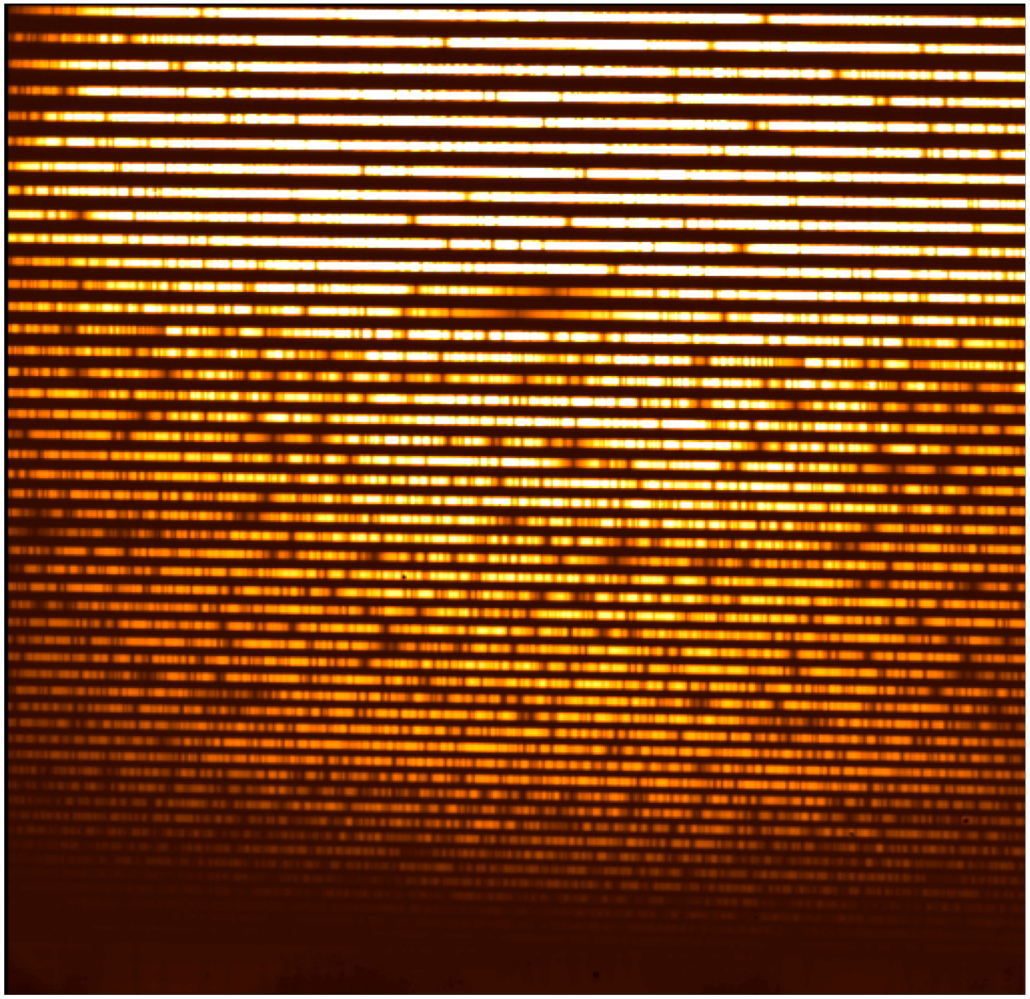


Optical layout

Ground based NUV spectrographs: NES

The Nasmyth Echelle Spectrograph (NES)

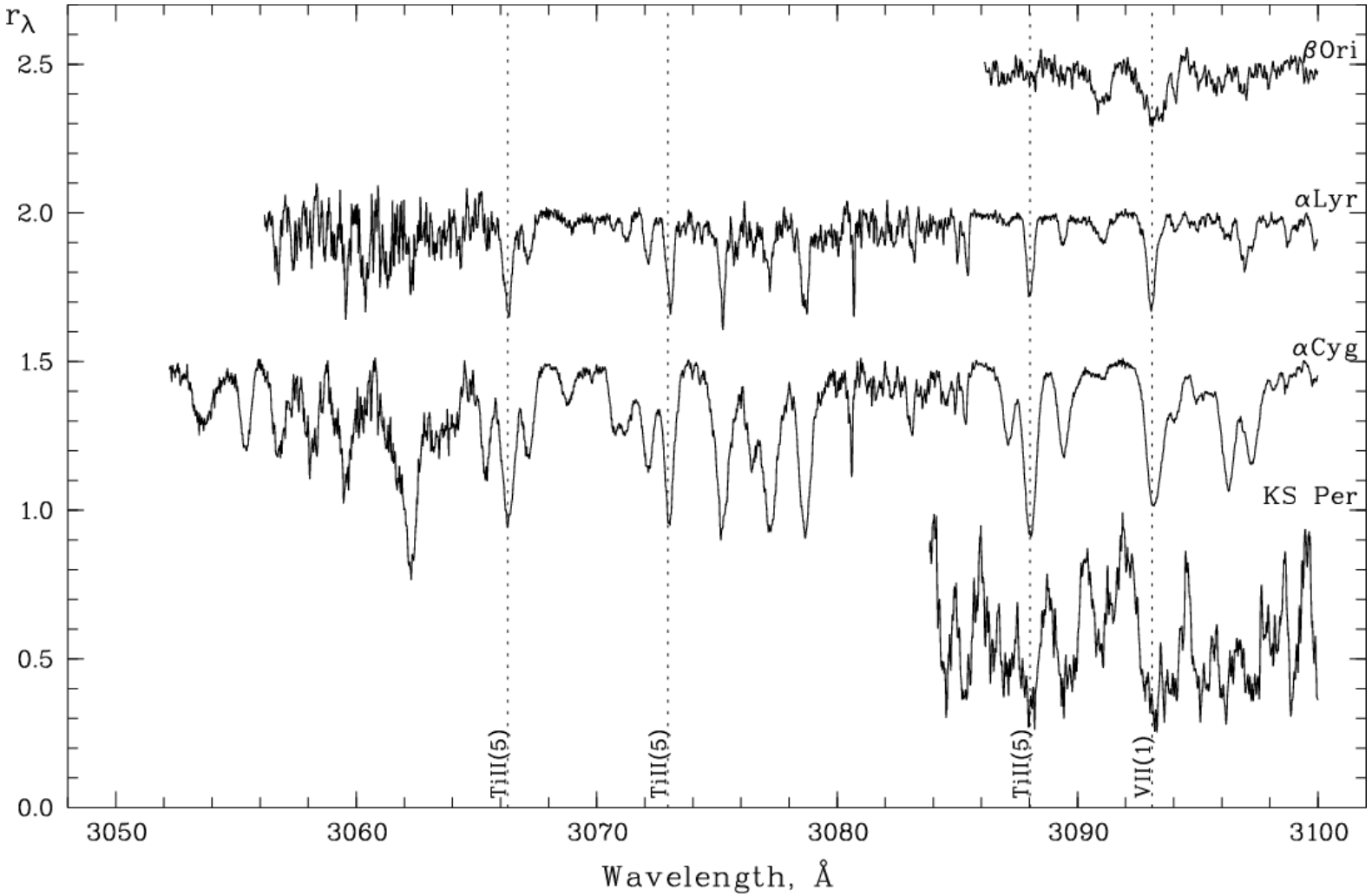
CCD image of NES echelle spectrum
λλ=2950÷4450ÅÅ



Ground based NUV spectrographs: NES

The Nasmyth Echelle Spectrograph (NES)

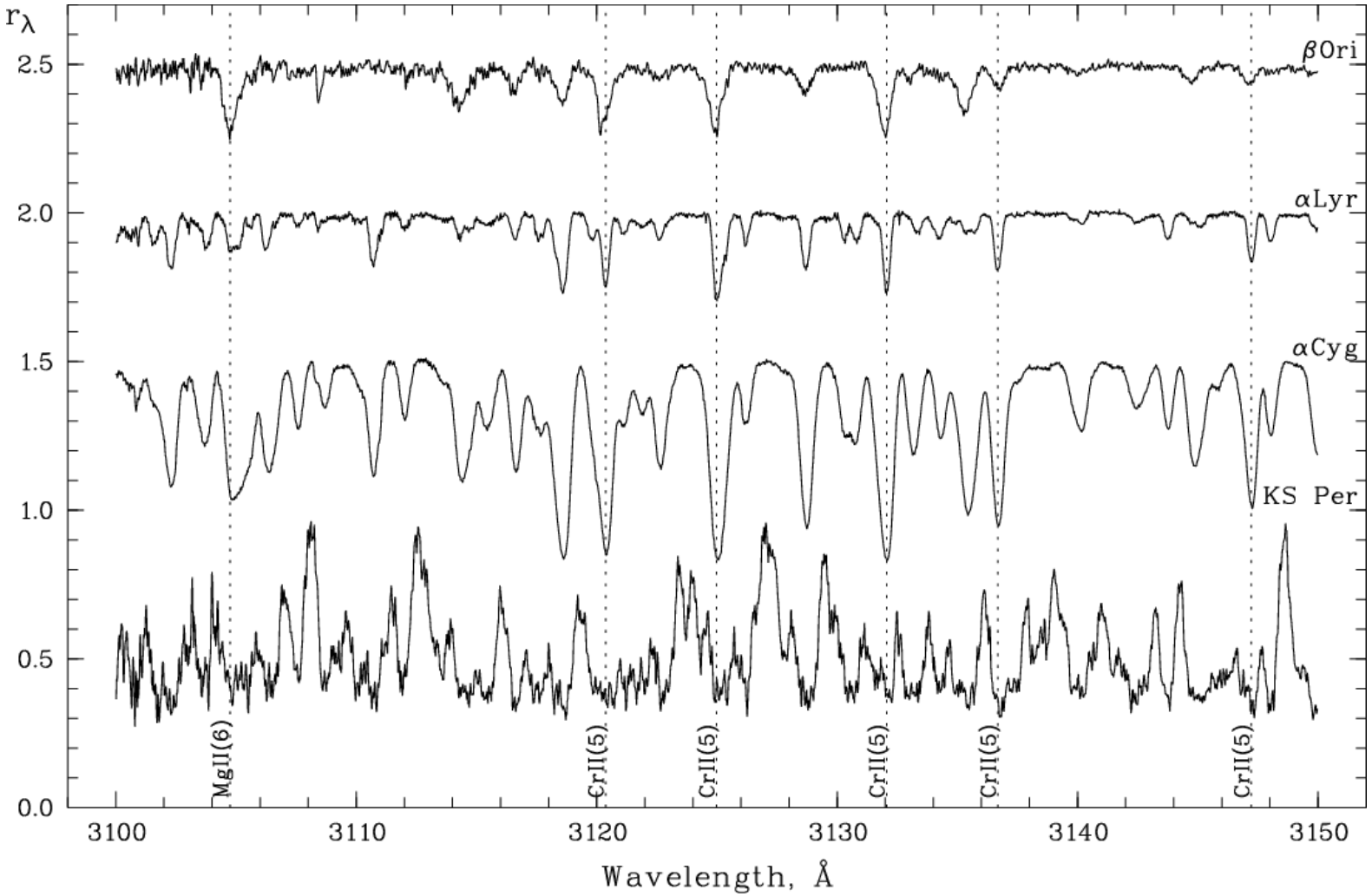
Spectral atlas of the selected stars



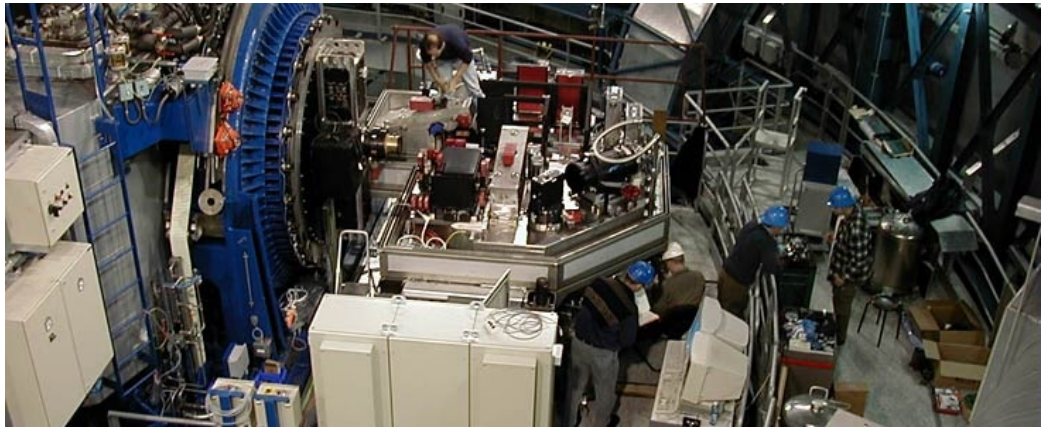
Ground based NUV spectrographs: NES

The Nasmyth Echelle Spectrograph (NES)

Spectral atlas of the selected stars

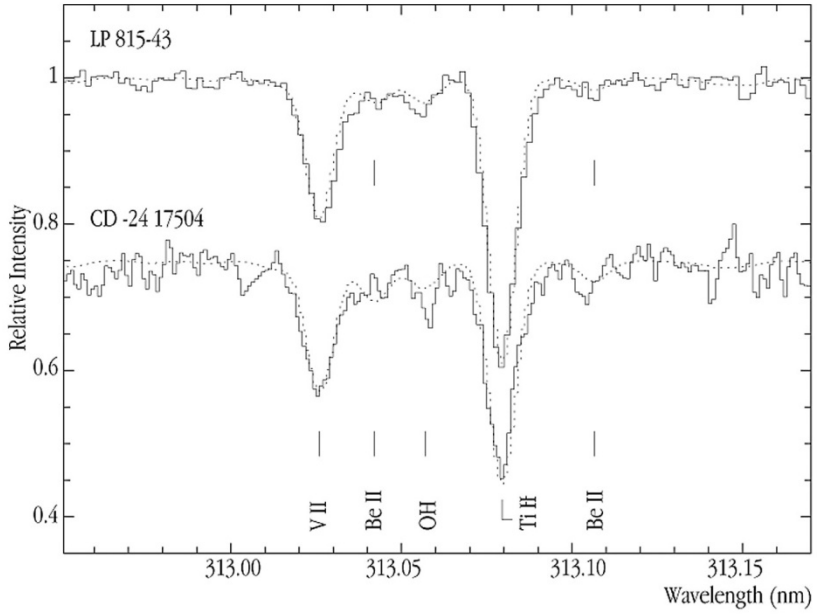


Ground based NUV spectrographs: VLT UVES



UVES - Ultraviolet and Visual Echelle Spectrograph of the VLT located at the Nasmyth B focus of UT2.

- UVES is a cross-dispersed echelle spectrograph designed to operate with high efficiency from the atmospheric cut-off at 300 nm to the long wavelength limit of the CCD detectors (about 1100 nm).
- The resolving power is about 40,000 when a 1-arcsec slit is used.
- The maximum (two-pixel) resolution is 80,000 or 110,000 in the Blue- and the Red Arm, respectively.



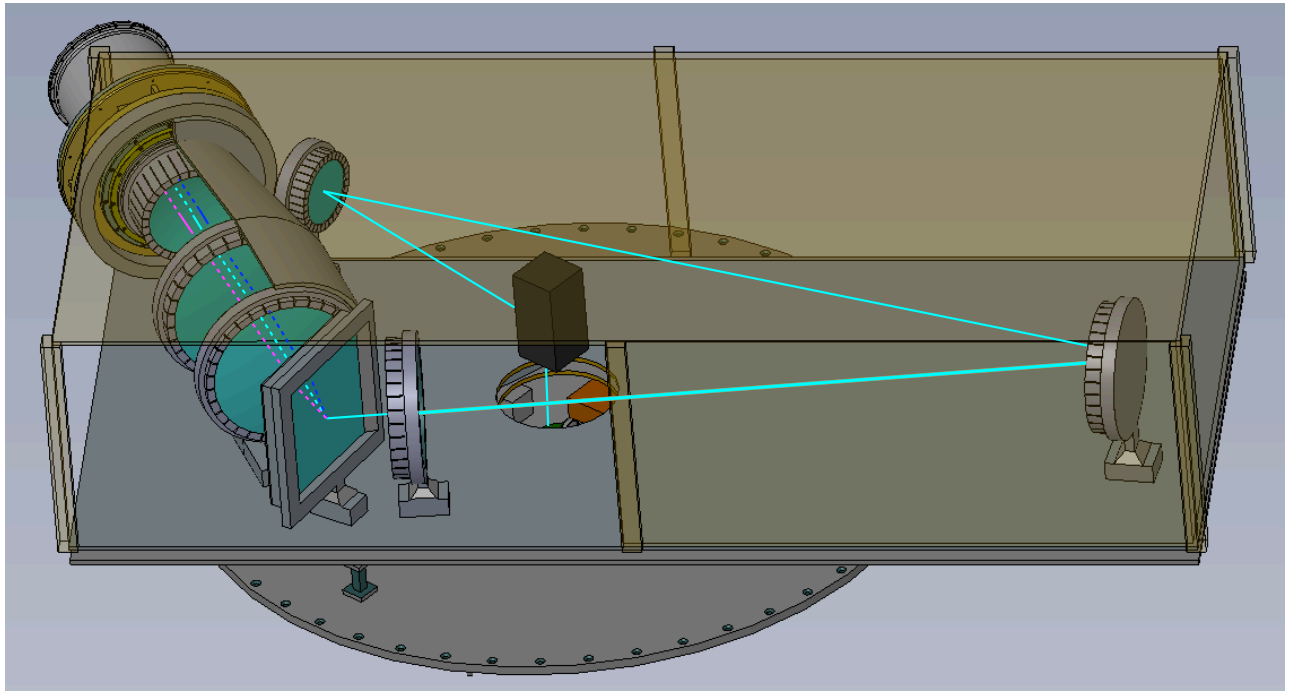
Ground based NUV spectrographs: CUBES

Cassegrain **U**ltraviolet **B**razilian **E**SO **S**pectrograph

Top Three Top Level Requirements

- Significantly improve upon throughput (or better S/N) of existing ground based UV spectrographs
- Achieve R≥20,000
- Cover the wavelength range 310-360nm (302-385nm)

Design team:
Beatriz Barbuy
Bruno Castilho
Hans Dekker
Bernard Delabre
Clemens Gneiding
Jean-Louis Lizon
Vanessa B. P. Macanhan
Roland Reiss
Joël Vernet

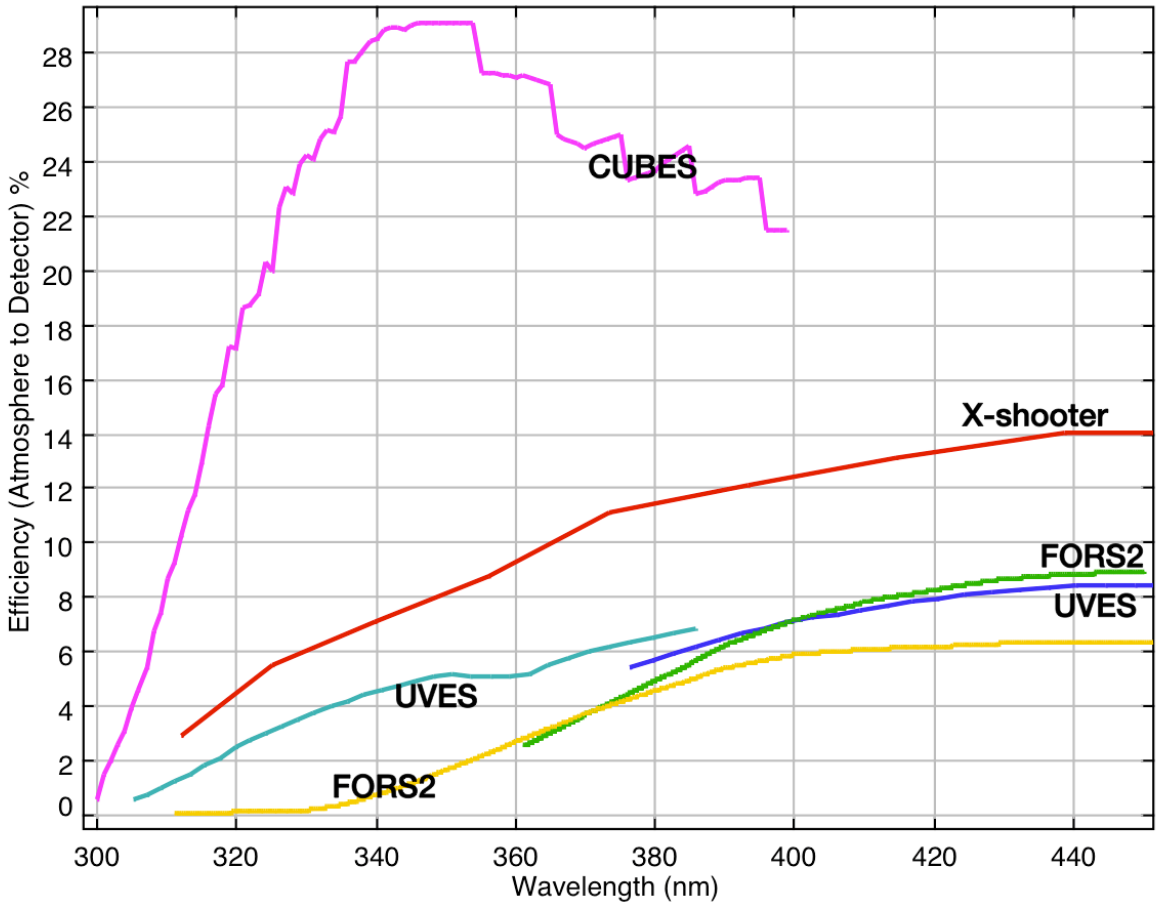


Ground based NUV spectrographs: CUBES

Actually four…:

- VLT 8m diameter collecting area
- Paranal seeing and extinction
- Interface with VLT infrastructure
- “Campaign mode”

Efficiency



Ground based NUV spectrographs: CUBES

- The CUBES design is dedicated to providing *significant SNR improvement relative to existing ground based UV spectrographs*
- CUBES will be *easy to build, easy to operate and maintain and easy to calibrate*

Slicer	No. slices>=7; slit let widths<=0.3”
Transmission grating	~3200mm^{-1}; 1st order; Ruled width~260mm; >80%@320nm
Detector Array	4 array 4K × 2K × 15µm×15µm; 250mm x 30mm QE>85% @320nm; Dark current <0.001e^{-}/pix/s; RON <2.5e^{-}
Wavelength Range	302-390nm (TBC)
Resolving Power	20,000

The CUBES project today – only in the design stage…

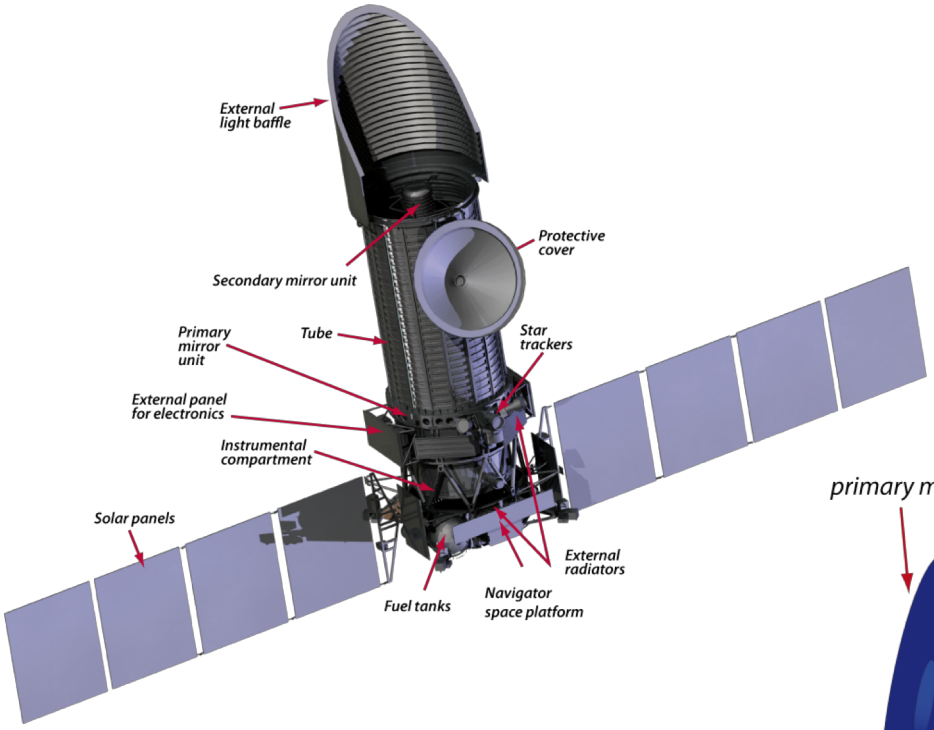
Ground based NUV spectrographs: problems

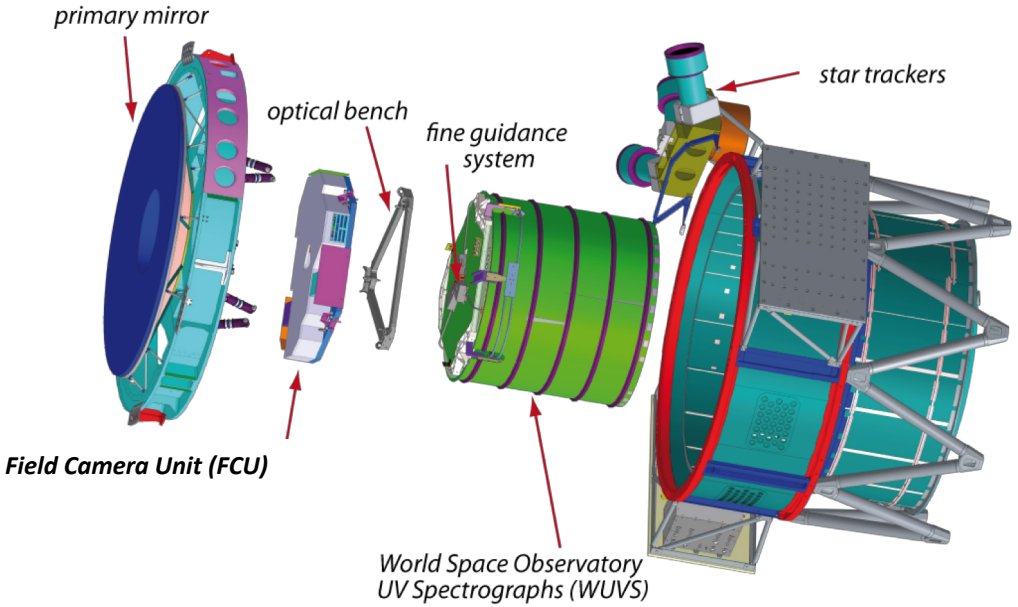
The main problem for all ground-based UV-spectrographs is **low light transmission**!

We propose a most simple and highly efficient optical design, such as WSO-UV spectrograph

WSO-UV

WSO-UV mission concept





WSO-UV

WUVS (WSO-UV Spectrograph)

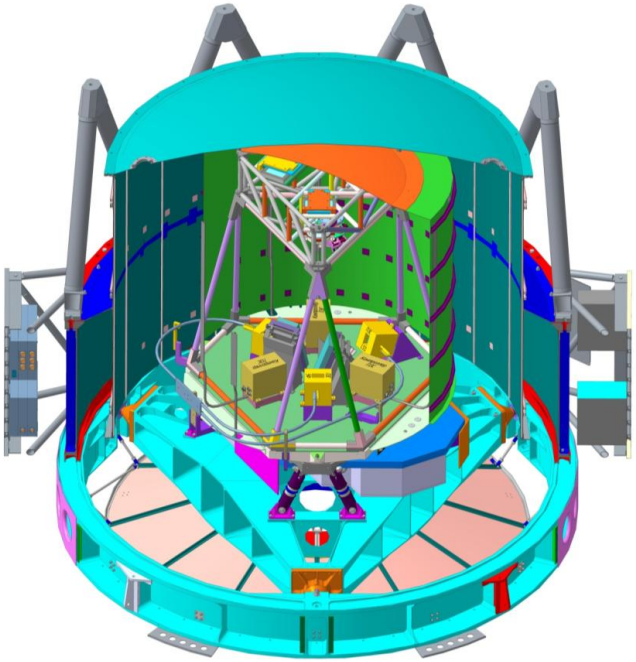
Three channels (spectrographs) of the WUVS :

Vacuum Ultraviolet Echele Spectrograph
VUVES - 115-176 nm, R ≈ 50 000

Ultraviolet Echele Spectrograph
UVES - 174-310 nm, R ≈ 50 000

Long Slit Spectrograph
LSS - 115-305 nm, R=1000

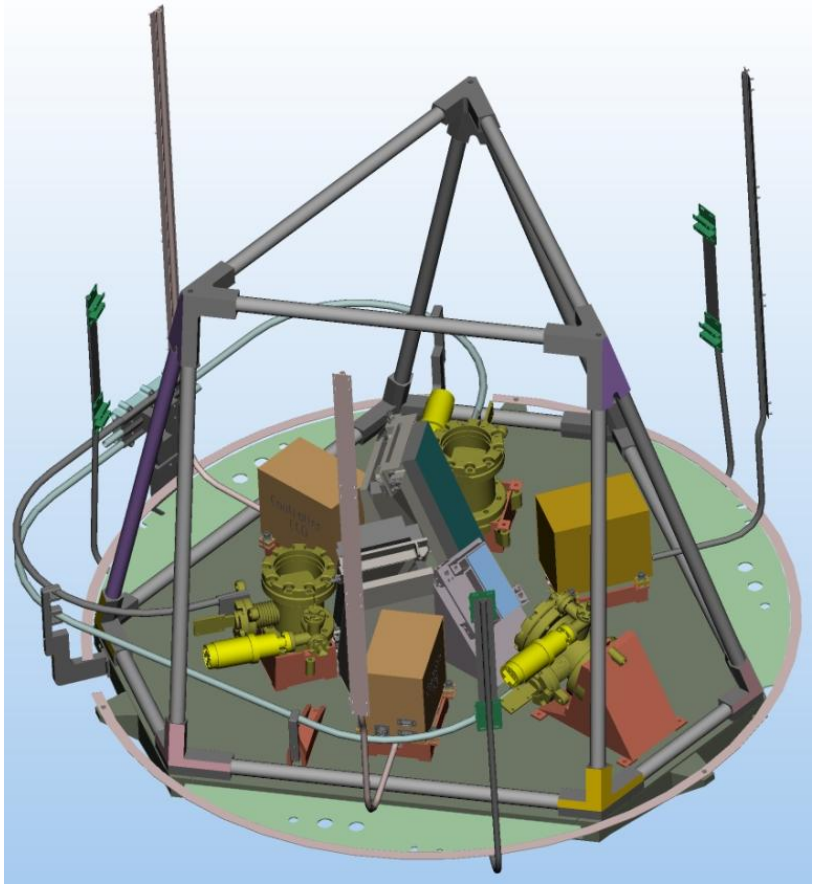
All three spectrographs are equipped with e2V CCDs

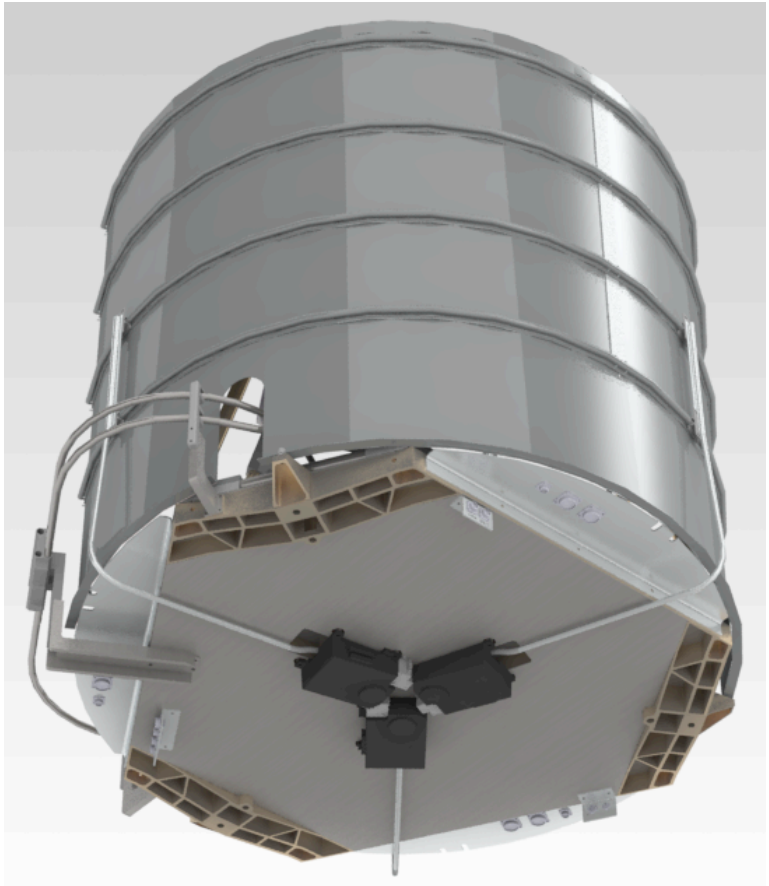


WSO-UV

3D-model of WUVS (02.2014)

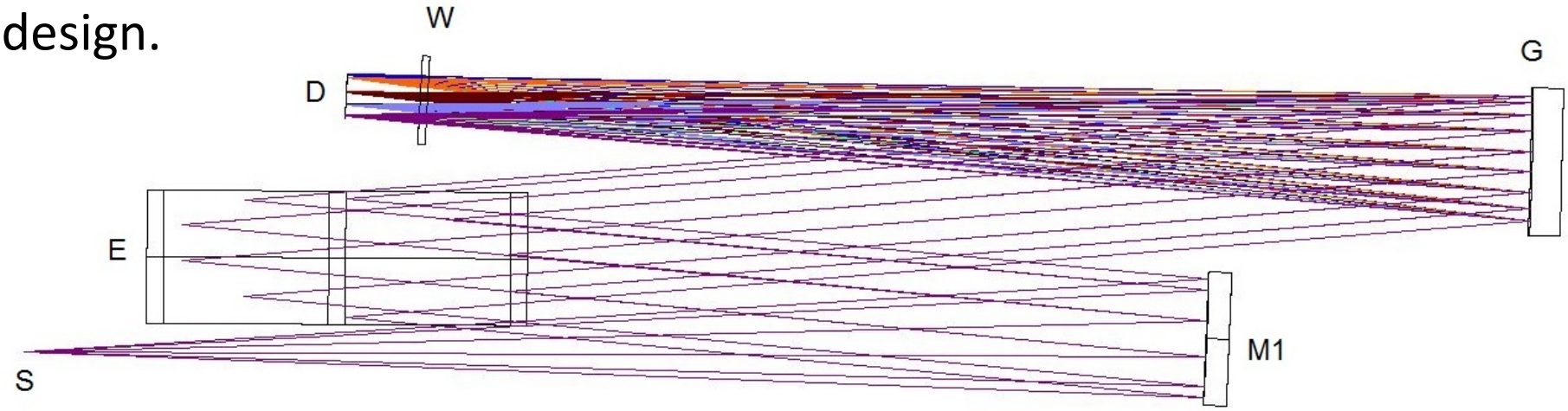
The geometrical stability of spectrograph provided by titanium heap pipes, all heat sources inside spectrographs connected to outer wall by additional heat pipes. Detectors cooling system consists of large external radiator and isolated heat pipe, connecting to detectors cold fingers.





WUVS and NNUVS optical design

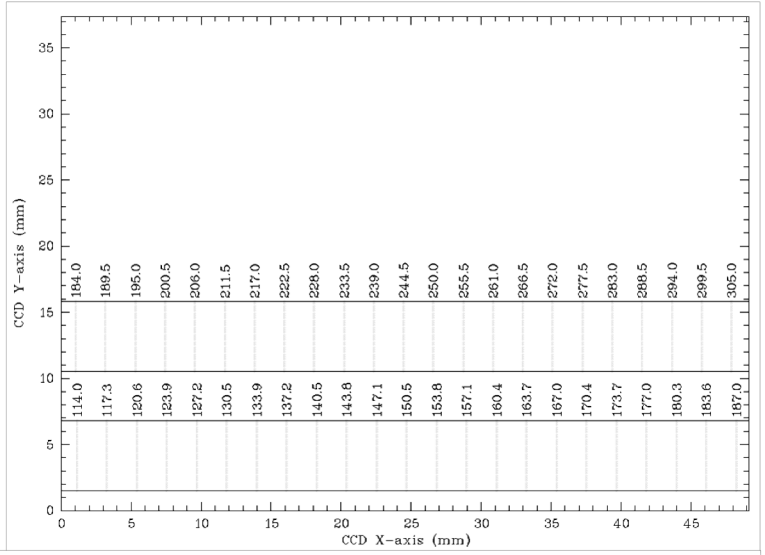
As CCDs were chosen as detectors in all 3 channels new optical design was performed by optical team from Special Astrophysical Observatory of RAS. In the new optical design basic schemes of the VUV and UV spectrographs are quite similar. Instead of UV prism cross disperser in UV spectrograph new design is based on the cross disperser combined with UV camera mirror (identical to the VUV spectrograph). Segmented thoroidal gratings are used in the LSS design.

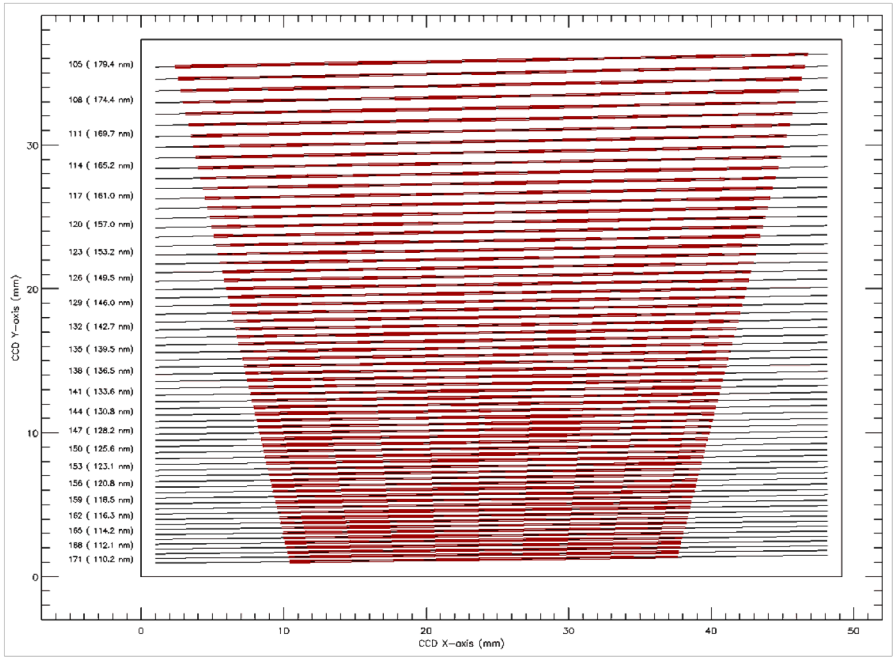


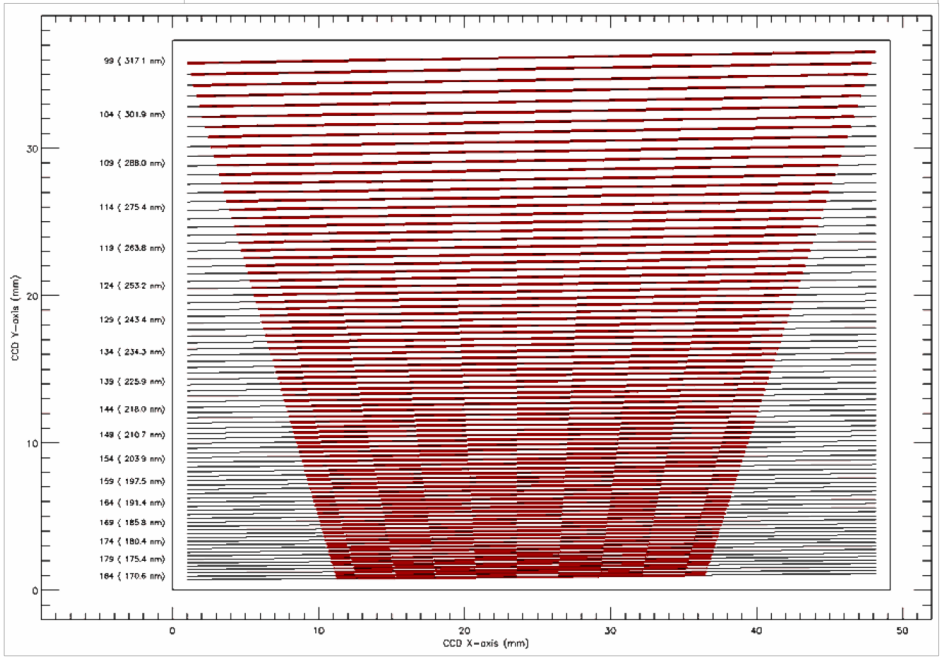
Proposed NNUVS spectrograph must be contain only one NUV channel.

WUVS and NNUVS optical design

Layout of the spectral orders. For NNUVS spectral range is 300 – 400 nm.

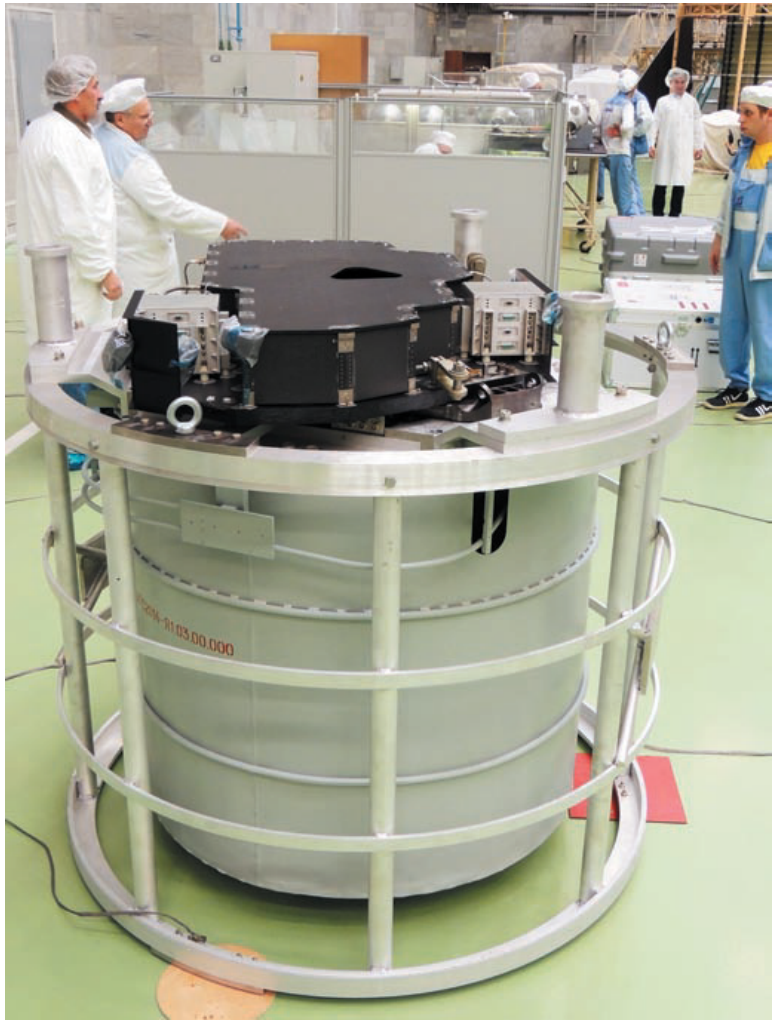






WSO-UV: WUVS spectrograph

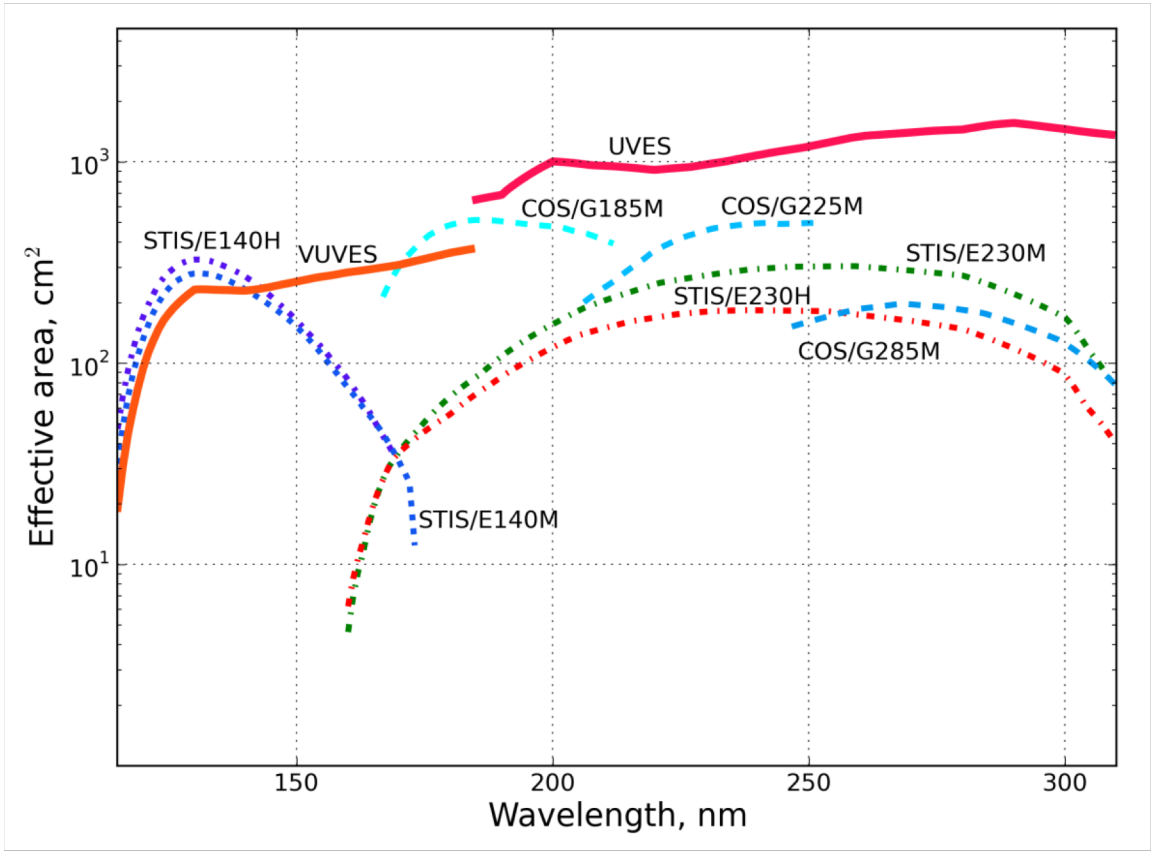
Several photos of launch samples.



WSO-UV: efficiency

WSO-UV as the HST "successor" should has larger aperture but
HST – 2.4 m
WSO-UV – 1.7 m

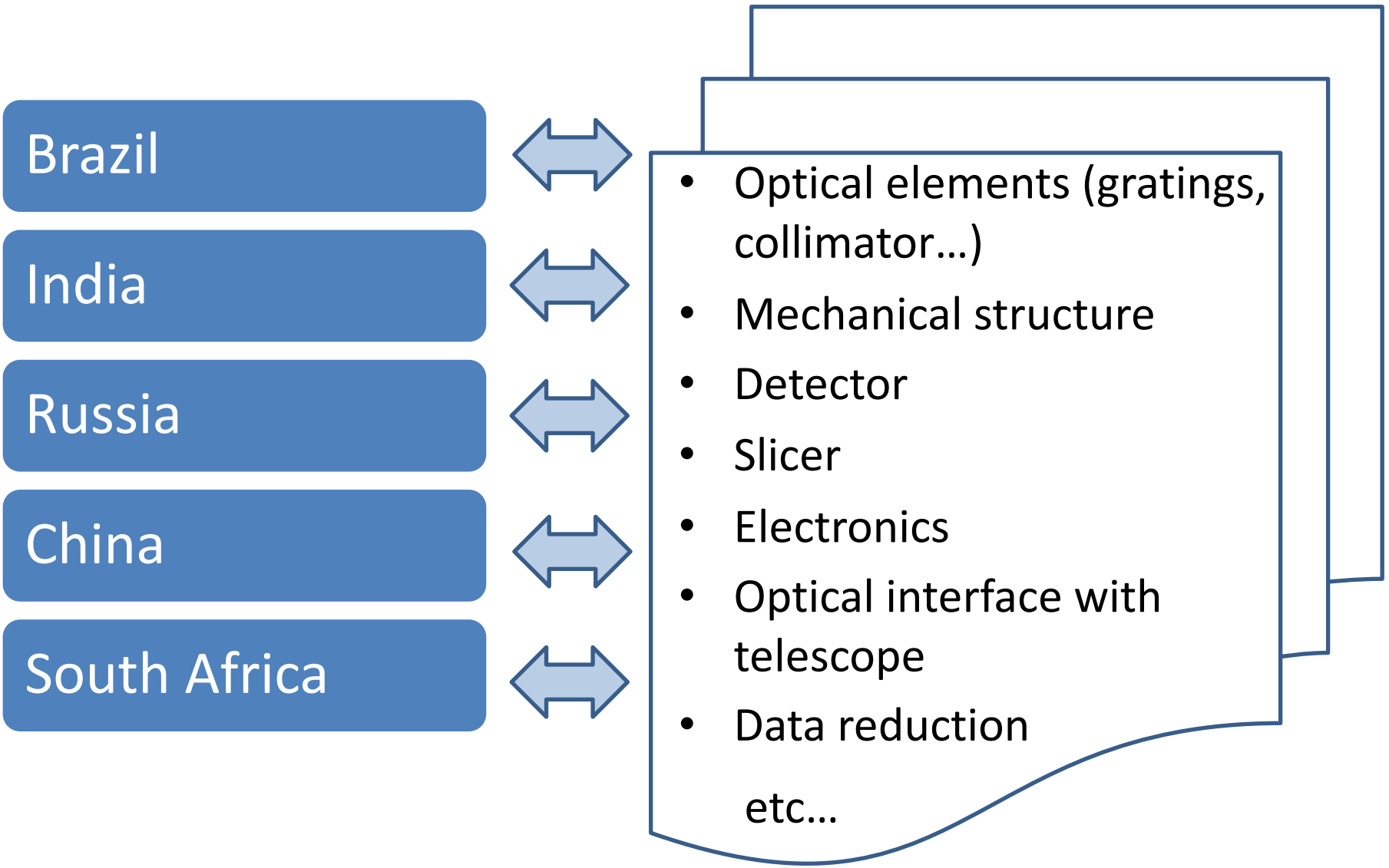
1. Efficient optical system
2. Geosynchronouse orbit
3. Modern detectors



Efficiency of WSO-UV Spectrographs

NNUVS project: preliminary budget

Project executives - TBD



NNUVS project: preliminary budget, TBD

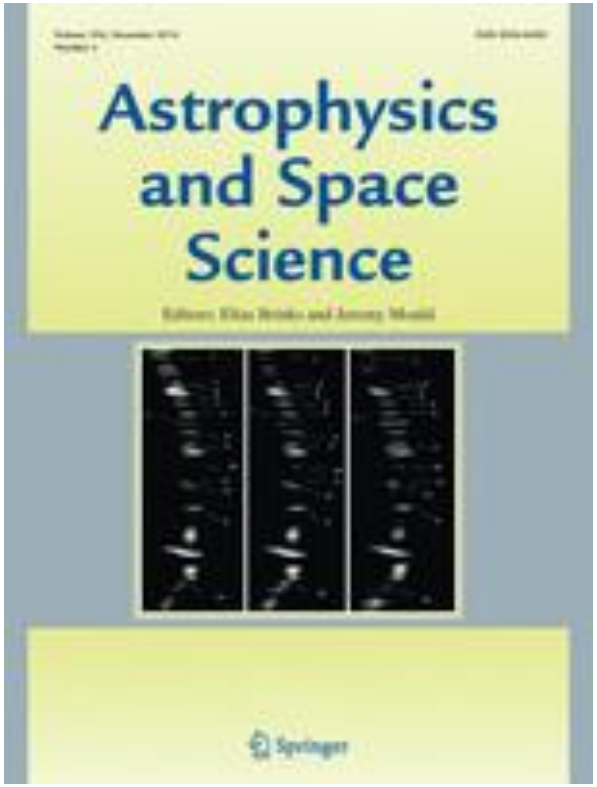
Components & development price (for each spectrograph unit):

- Optical elements - 450K$
- Mechanical structure - 500 K$
- Calibrations unit - 200 K$
- Telescope interface – 100 K$
- Slicer – 150 K$
- Detector - 200 K$
- Electronics - 100 K$
- Software development - 250 K$
- Project management – 250 K$

Subtotal, for each unit – 2.200 K$

Preliminary total budget – 11.0 Million $

BRICS Ground based UV: new meeting offer



ESO/NUVA/IAG Workshop on Challenges in UV Astronomy
ESO Garching, 7-11 *October 2013*

Astrophysics and Space Science
November 2014, Volume 354

Special Issue of Astrophysics & Space Science; “Challenges on Ultraviolet Astronomy 2014”. This volume comes at a crucial time in Ultraviolet (UV) astronomy. The NASA/ESA programms that created the community are reaching completion and future missions, apart from the World Space Observatory-Ultraviolet (WSO-UV), are small-class, some operating from balloons. This volume provides an update on the evolution of the field since our last Special Issue “UV Astronomy 2011”.

New meeting on ground based UV observations in 2019-2020?

Summary

- We proposed the most realizable project of the network of high-resolution spectrographs for ground-based NUV region $\lambda\lambda$=300…400 nm.
- Proposed NNUVS spectrograph is high efficiency and cost effective. **Most of the solutions and technologies were developed at the expense of WSO-UV money!**
- The NNUVS project implementation is very important for research an unexplored physical phenomena and events in UV band.

We invite to active cooperation!