

# CRIRES+ at the Very Large Telescope

– what to expect?

## Alexis Lavail

Uppsala University &  
the Swedish Collegium for  
Advanced Study

## the CRIRES+ consortium

- \* University of Göttingen
- \* INAF Arcetri
- \* Tautenburg observatory
- \* Uppsala University
- \* European Southern Observatory

## Useful CRIRES+ resources

Slides available at:  
[aalex.is/presentations](http://aalex.is/presentations)

- **User manual:** <http://www.eso.org/sci/facilities/paranal/instruments/crires/doc.html>
- **CRIRES+ page at ESO:** <http://www.eso.org/sci/facilities/paranal/instruments/crires.html>
- **Exposure time calculator:** <https://etc.eso.org/observing/etc/crires>
- **ESO Call for Proposals:** <https://www.eso.org/sci/observing/phase1/proposals.html>
- **ESO Phase 1 tool:** <https://www.eso.org/p1>
- **GTO protected targets:** <https://www.eso.org/sci/observing/teles-alloc/gto.html>
- **Overheads:** <https://www.eso.org/sci/facilities/paranal/cfp/overheads.html.html#UT3>
- **astroquery . eso:** <https://astroquery.readthedocs.io/en/latest/eso/eso.html>
- **ESO science archive:** <http://archive.eso.org/cms.html>

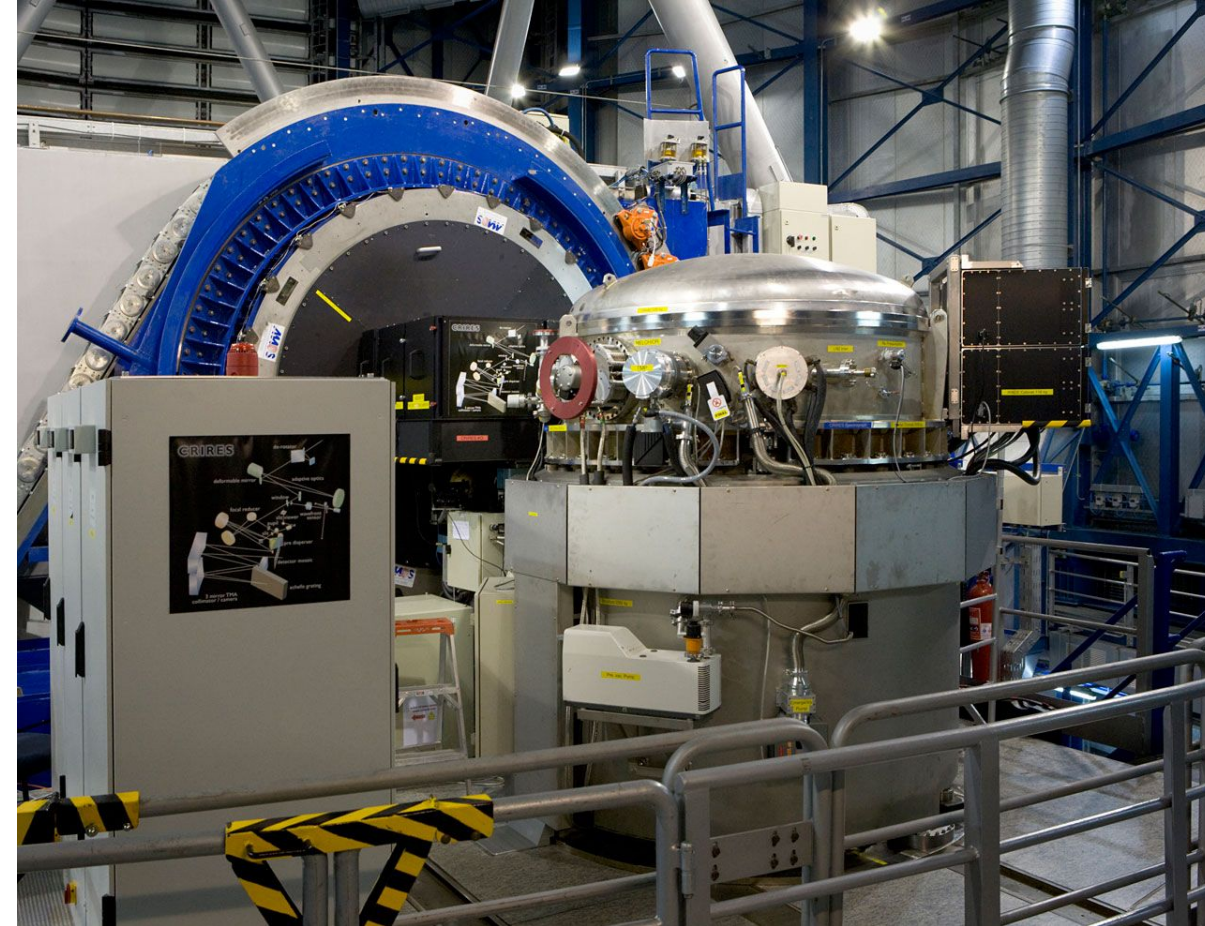
# oCRIRES

Slides available at:  
[aalex.is/presentations](http://aalex.is/presentations)

Old CRIRES (oCRIRES) in a nutshell:

- high-resolution ( $R \sim 10^5$ ) near-IR spectrograph
- located at Nasmyth focus of 8-m VLT UT 1
- adaptive optics fed
- wavelength range from  $\sim 950$  to  $\sim 5200$  nm
- single-order spectrograph
- long 40 arcseconds slit

More info in the CRIRES paper: [Kaufl et al. 2004](#)



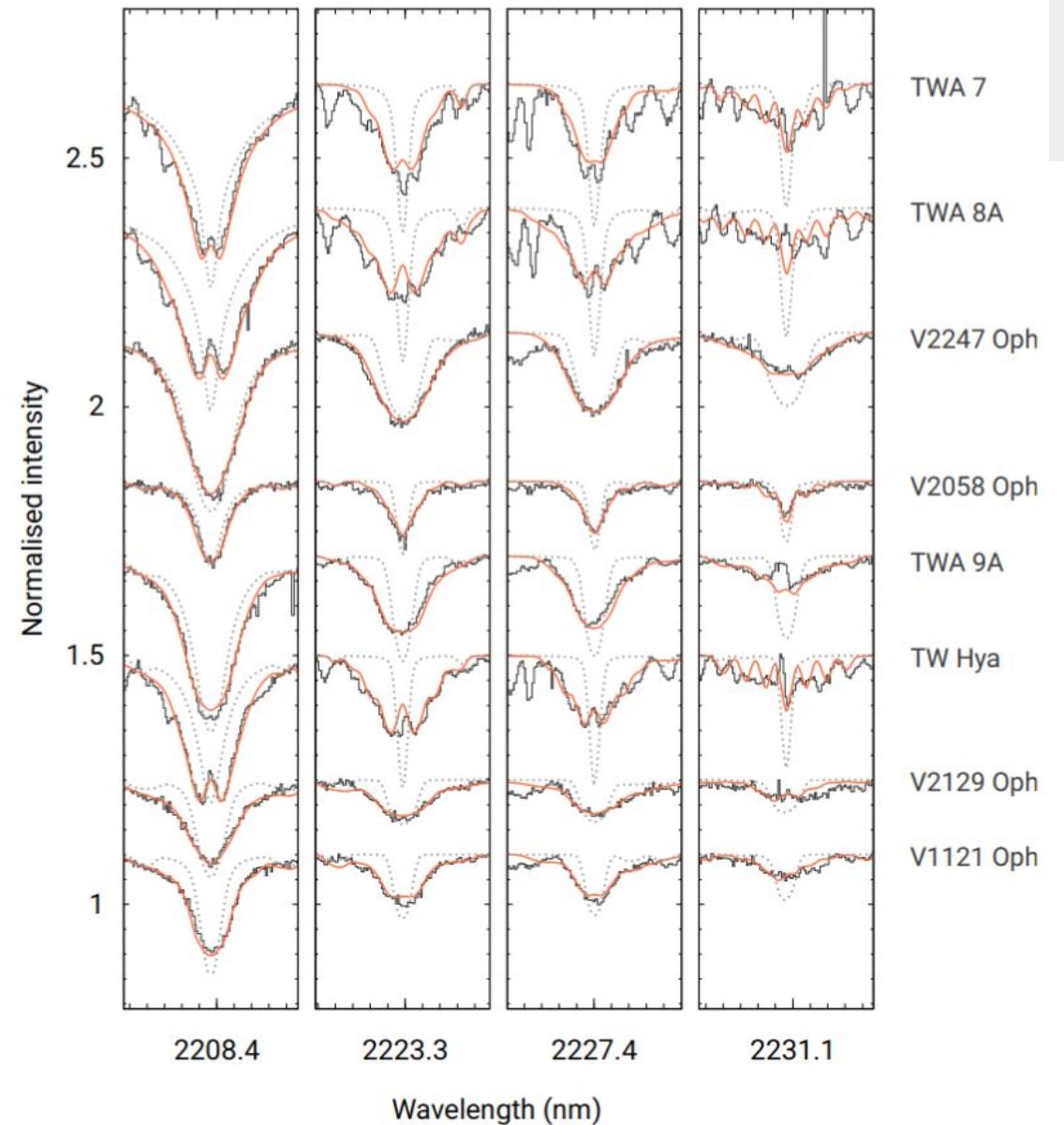
† The CRIRES Instrument, located on the Nasmyth-platform of VLT Unit Telescope 1, Antu. Credit: [ESO](#)

# oCRIRES

Old CRIRES (oCRIRES) in a nutshell:

- high-resolution ( $R \sim 10^5$ ) near-IR spectrograph
- located at Nasmyth focus of 8-m VLT UT 1
- adaptive optics fed
- wavelength range from  $\sim 950$  to  $\sim 5200$  nm
- single-order spectrograph
- long 40 arcseconds slit

More info in the CRIRES paper: [Kaufl et al. 2004](#)



Zeeman broadening in CRIRES K-band spectra of T Tauri stars. From [Lavail et al. 2019](#)

**CRRES+**



Bcool 2021 meeting | 2021-04-12

# CRIRES+

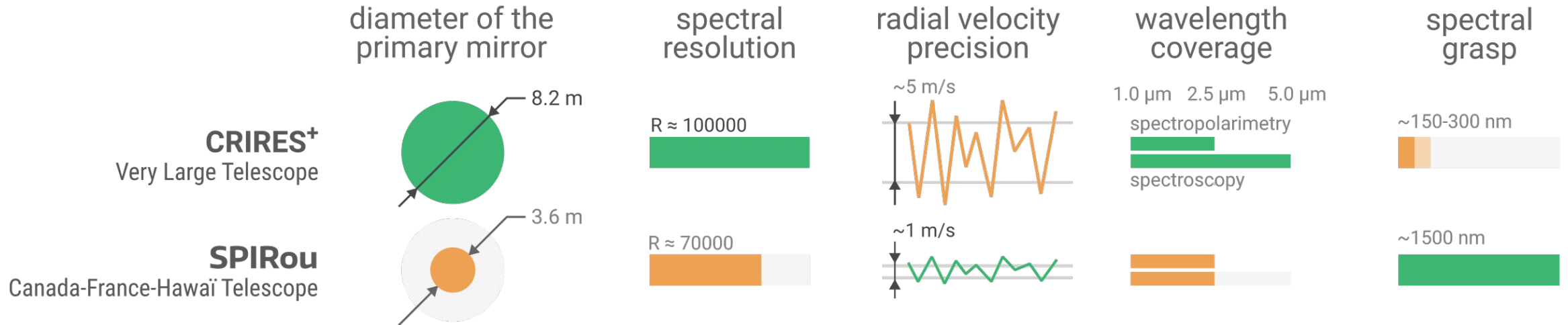
New CRIRES+ in a nutshell:

- high-resolution ( $R \sim 10^5$ ) near-IR **spectropolarimeter**
- located at Nasmyth focus of 8-m VLT **UT 3**
- Adaptive optics fed
- wavelength range  $\sim 950 \rightarrow \sim 5200$  nm (spectroscopy) |  **$\sim 950 \rightarrow 2500$  nm (polarimetry)**
- **Cross-dispersed** spectrograph: **larger spectral grasp**
- **10 arcseconds** slit

# CRIRES+ and SPIRou

Slides available at:  
[aalex.is/presentations](http://aalex.is/presentations)

CRIRES+ complements existing instruments such as SPIRou.



## Improvements from the upgrade

- Increased throughput (most mirrors replaced)
- Better calibration capabilities (new RV gas cells, Une lamp, Fabry-Perot étalon, metrology)
- Powerful DRS rewritten entirely, based on REDUCE ([Piskunov et al. 2021](#))
- Larger spectral grasp (new detector array, cross-dispersed design)
- Spectropolarimetry (Stokes *IQUV*) in YJHK bands

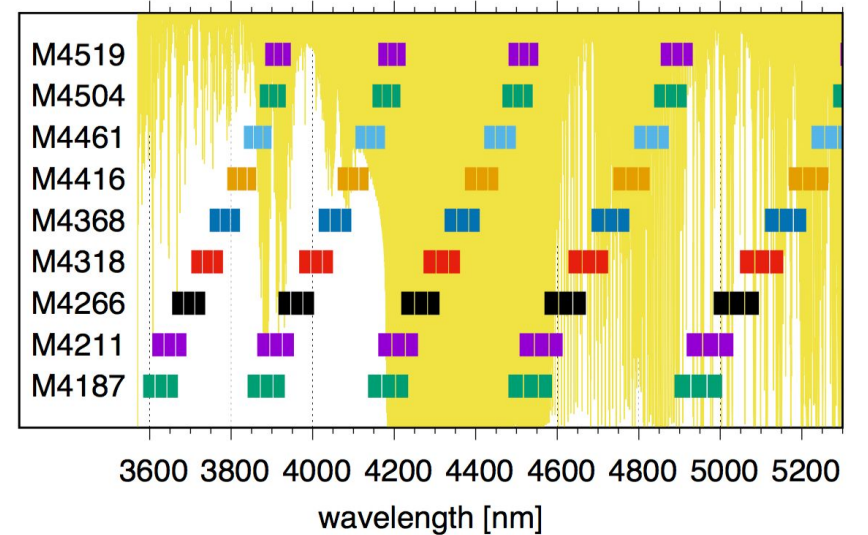
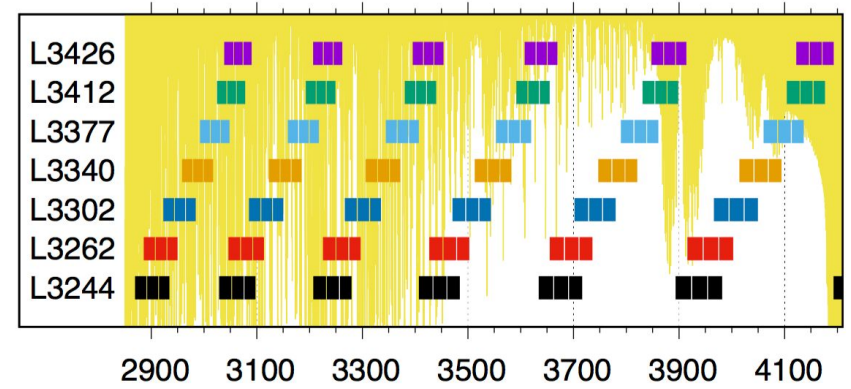
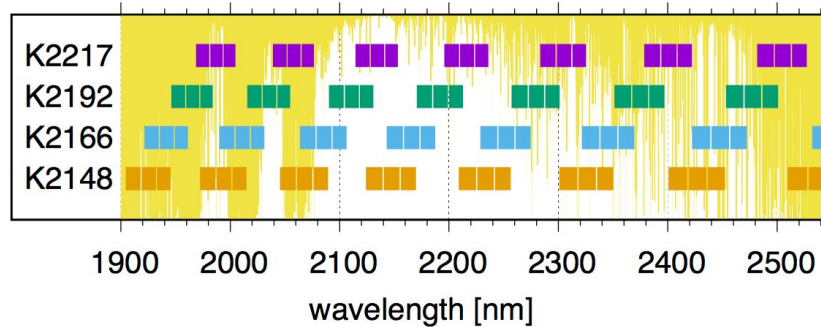
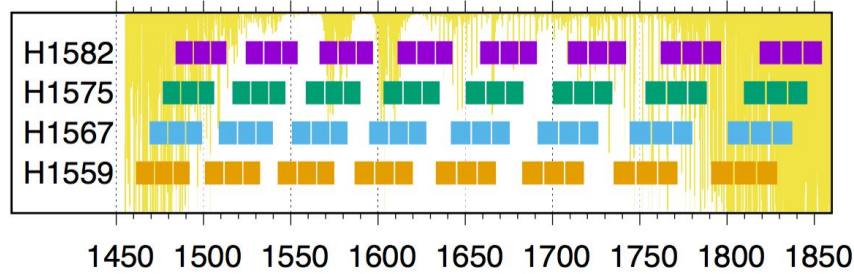
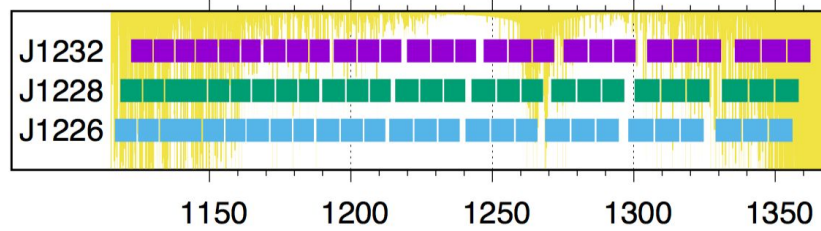
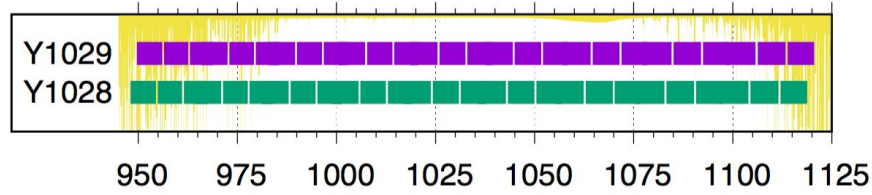


## CRIRES+ current status

- 2 commissioning runs done
- 2 more commissioning runs in May and August 2021
  - spectropolarimetry performance
  - observing modes (offset, extended objects etc ...)
  - RV performance: ~5 m/s is expected, to be demonstrated
- Science verification tentatively in August, with CfP tentatively early May
  
- CRIRES+ offered in ESO Period 108: Oct 2021 → Mar 2022 in limited mode
- CRIRES+ normally offered in full swing in P109 (including polarimetry)

# CRIRES+ in practice

→ Wavelength coverage of all standard wavelength settings. From the [CRIRES+ user manual](#) (Fig. 31). Hi-res figure available at [this link](#).



## [TIPS]

Make sure lines of interest are covered in the wavelength setting you choose.

Use the ETC.

This you can start doing now, wavelength settings should not change.

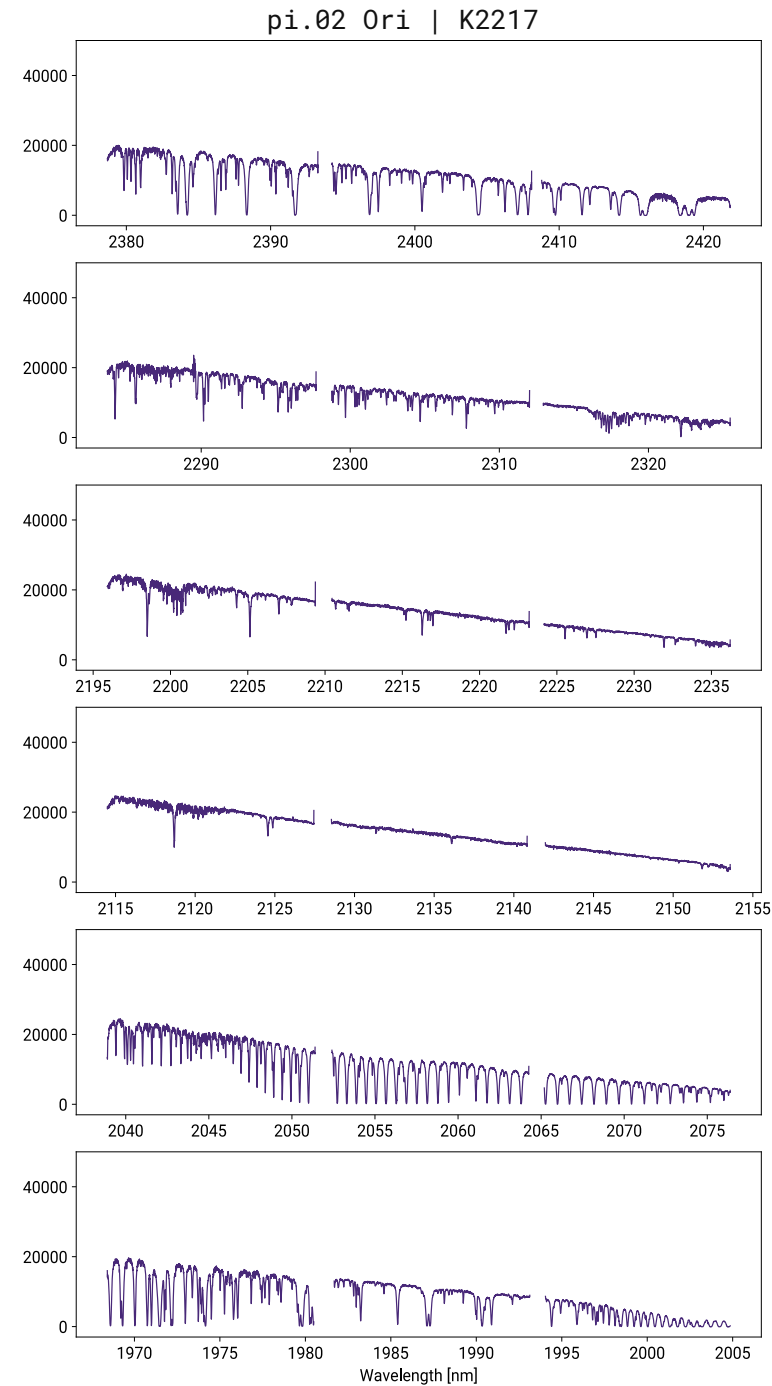
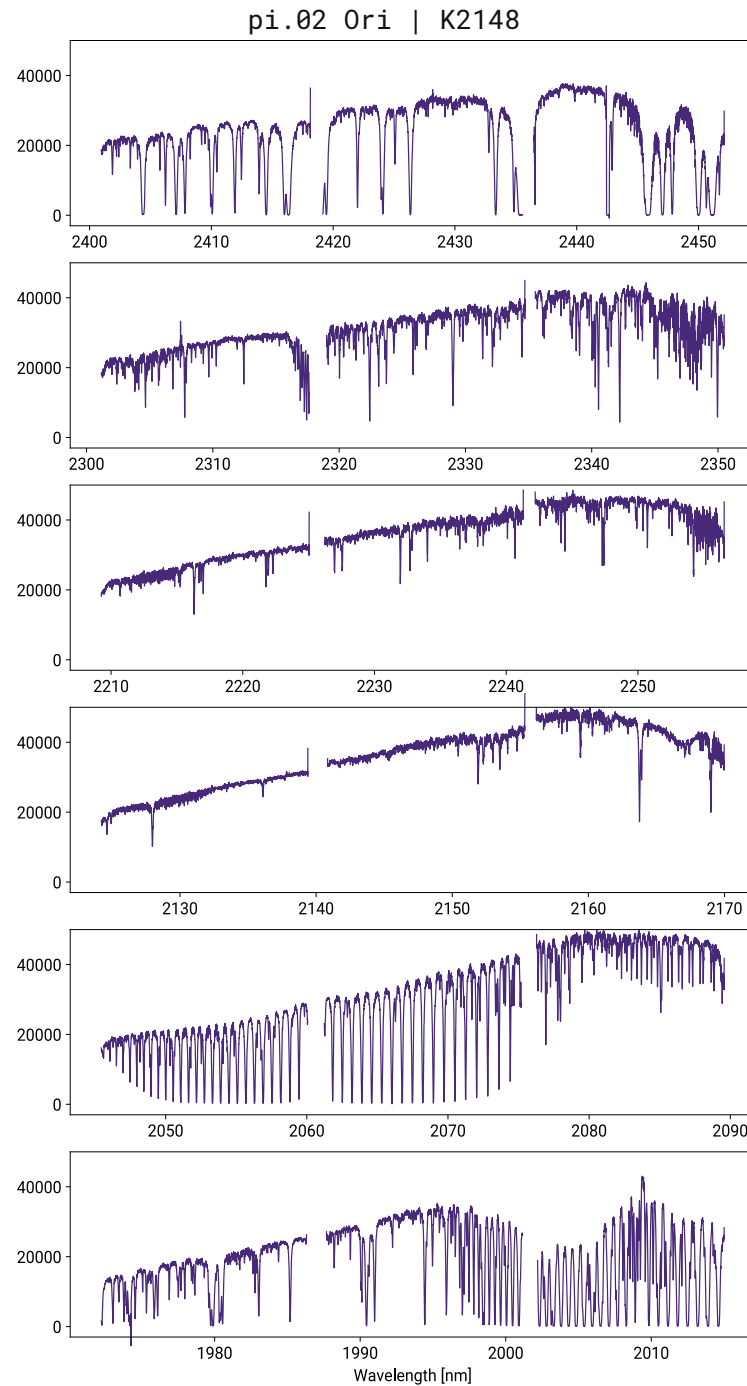
# CRIRES+ in practice

→ Extracted spectra of Pi.02 Ori in two wavelength settings: K2148 and K2217

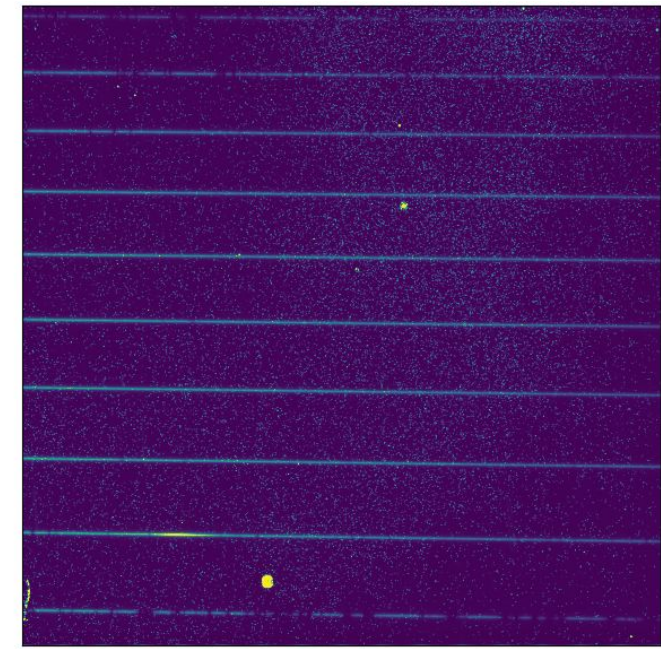
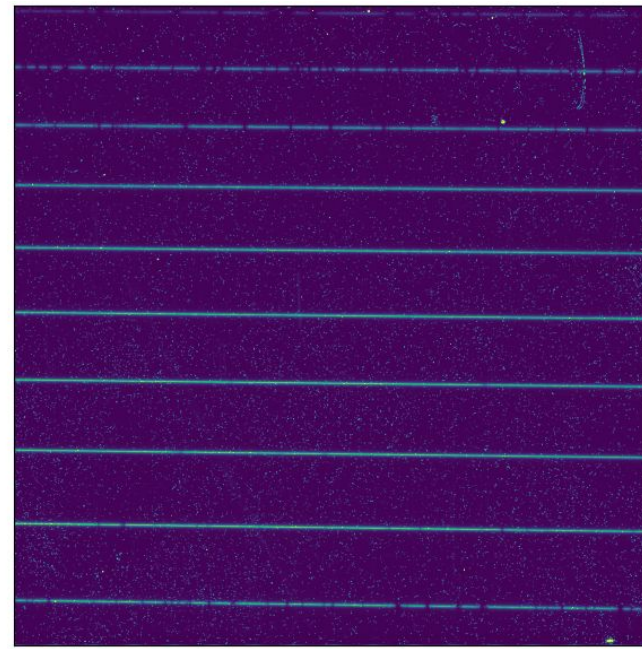
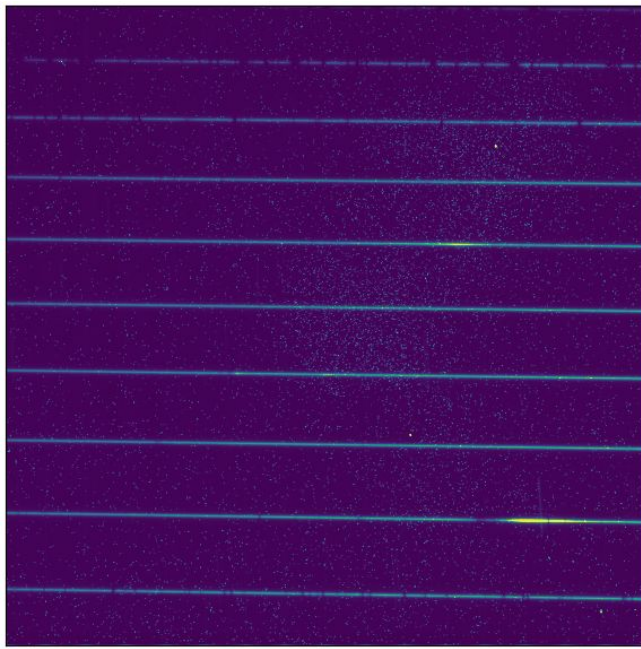
[TIPS]

If you have a choice, choose the wavelength setting with the best blaze.

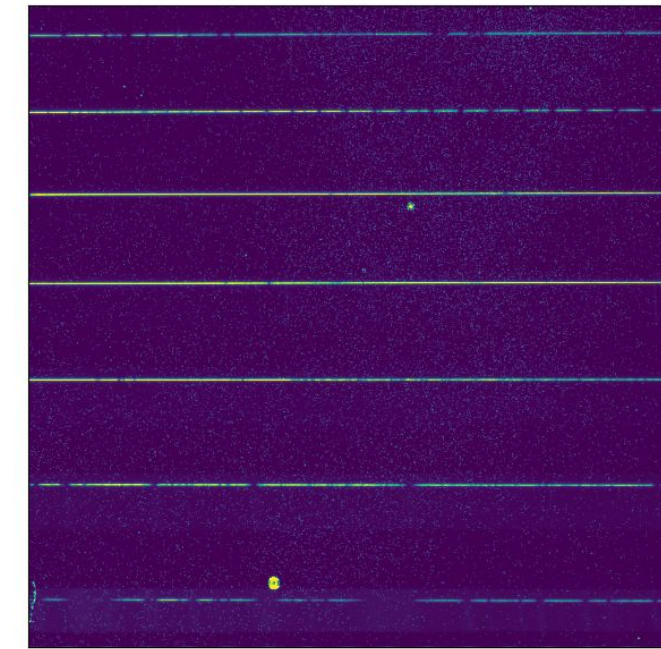
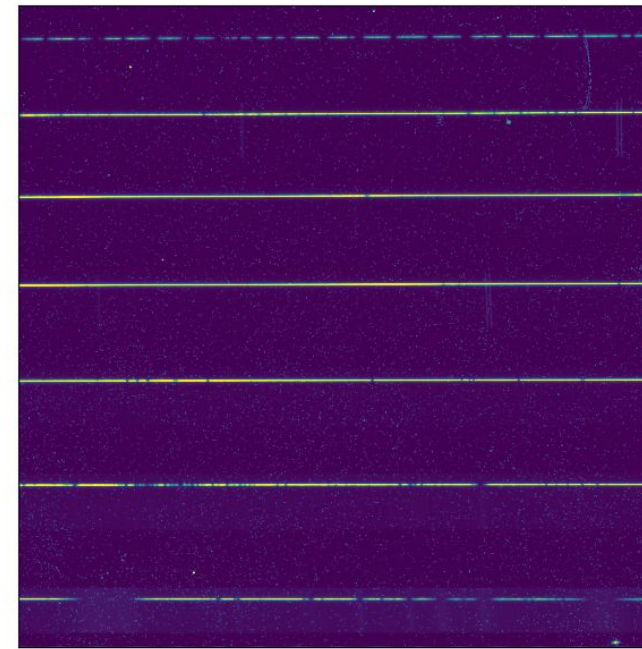
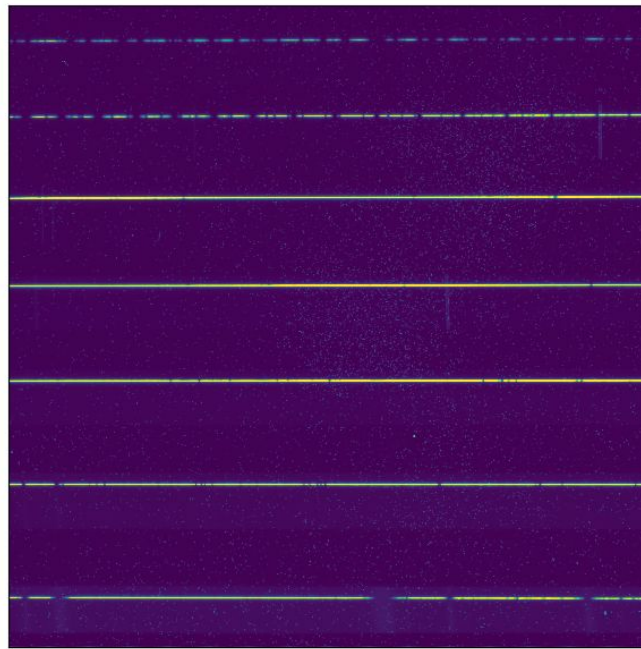
→ use the ETC



→  
TW Hya  
Y band  
raw frame

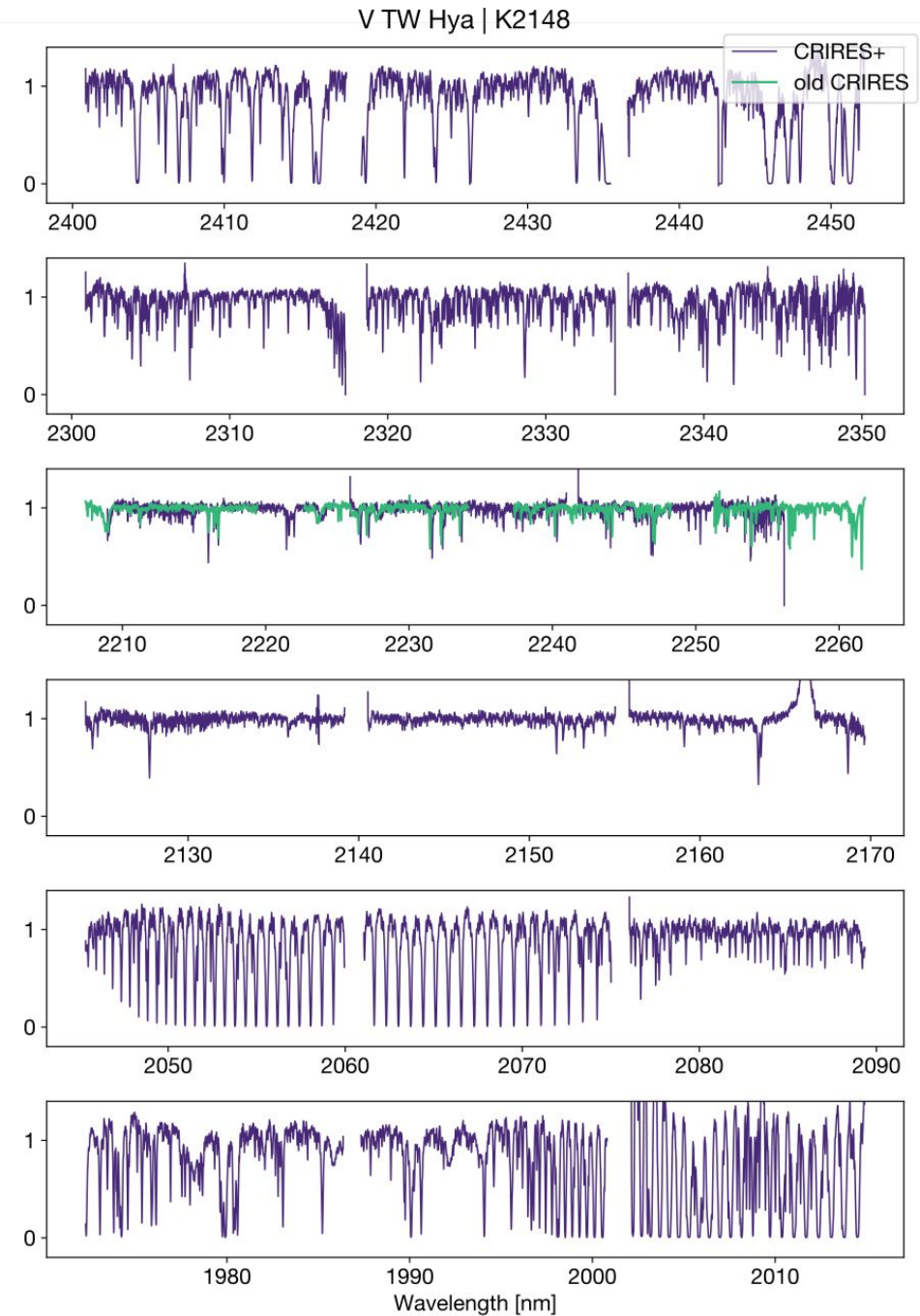


→  
TW Hya  
K band  
raw frame



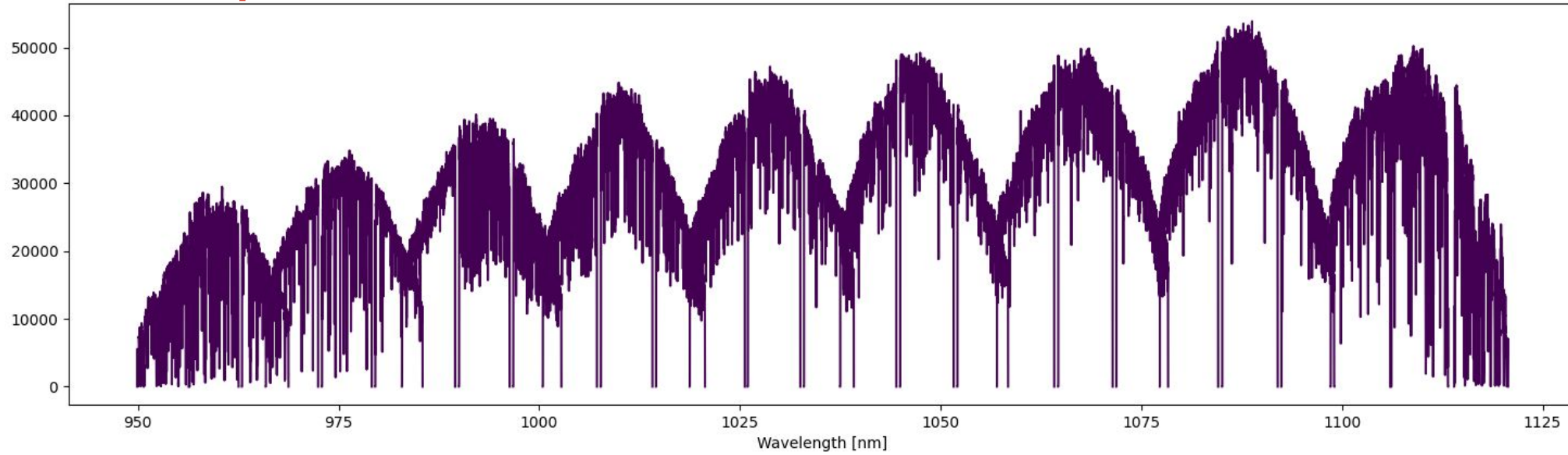
# CRIRES+ in practice

→ Quick comparison between oCRIRES and CRIRES+. TW Hya observed then and now

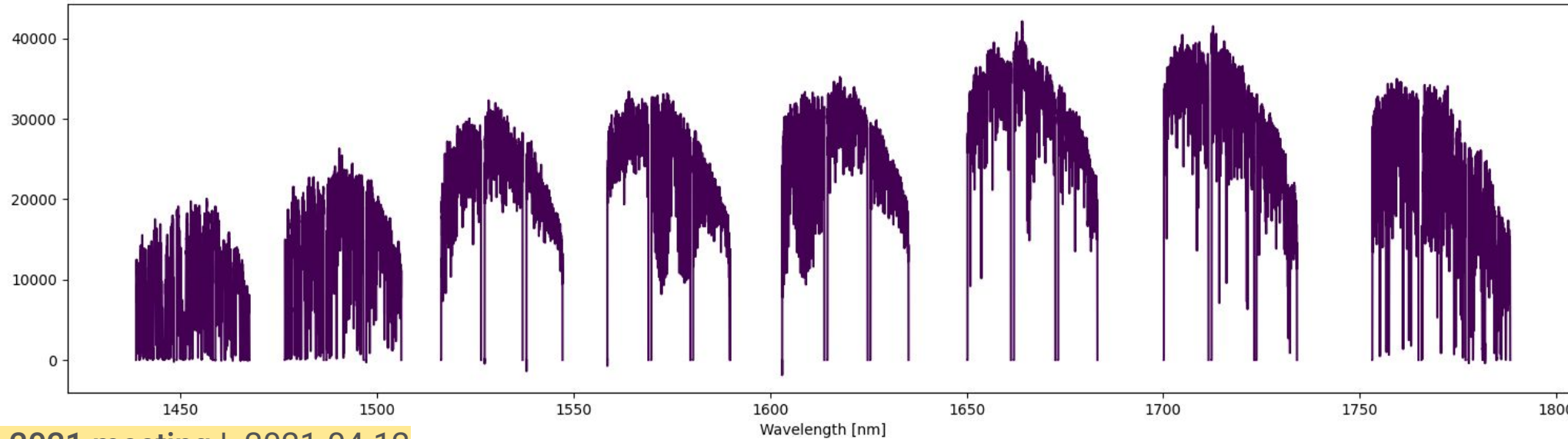


# CRIRES+ in practice

NAME Proxima Centauri | Y1029 | 2021-02-24T06:32:20

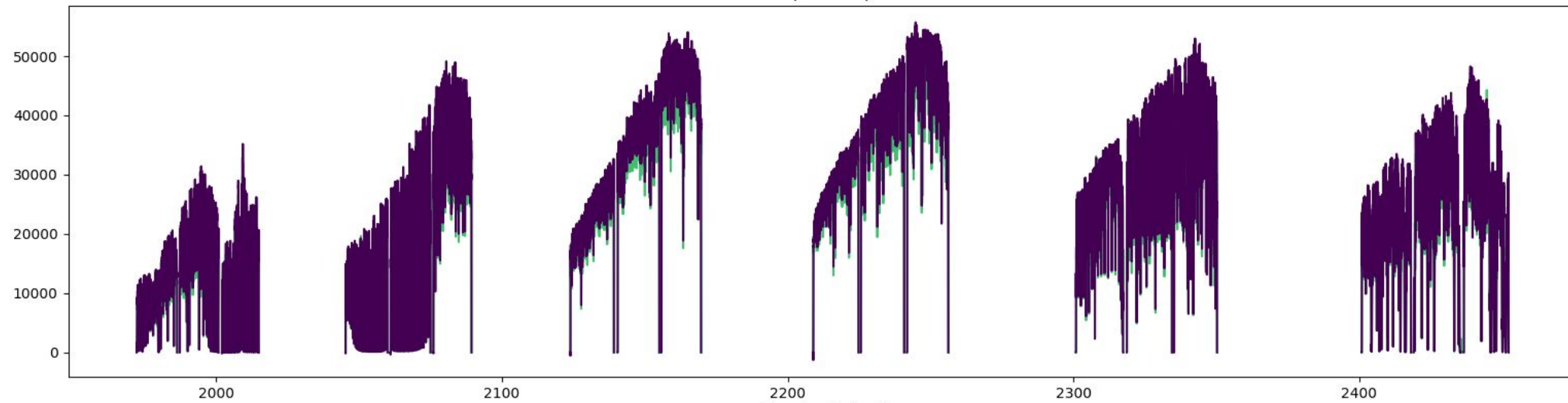


NAME Proxima Centauri | H1575 | 2021-02-24T06:52:32



# CRIRES+ in practice

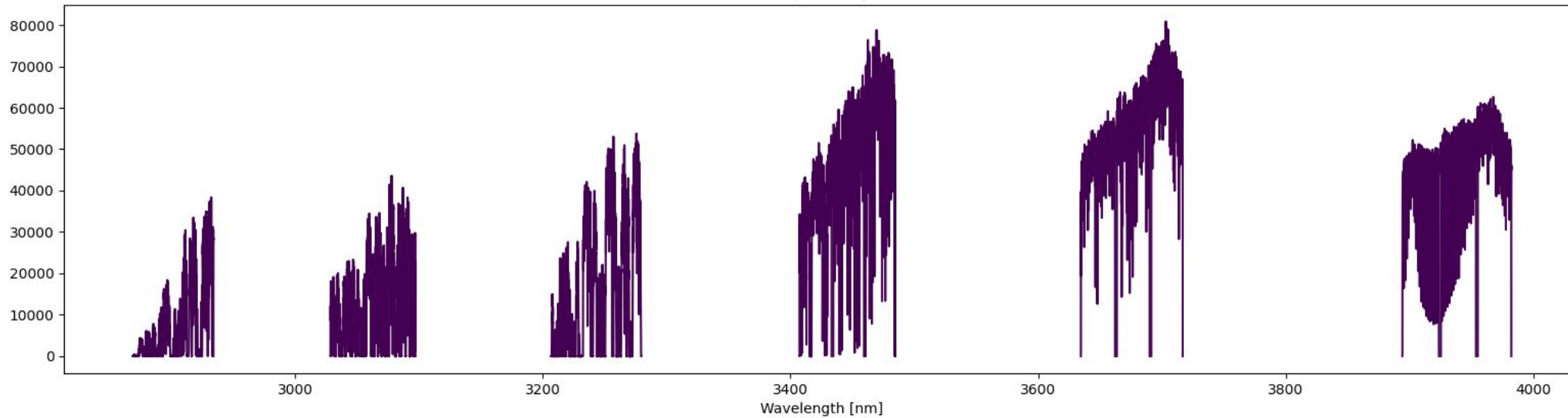
NAME Proxima Centauri | K2148 | 2021-02-24T06:05:29



**K-band**

EXPTIME: 870 s

NAME Proxima Centauri | L3244 | 2021-02-24T07:02:01



**L-band**

EXPTIME: 360 s

# CRIRES+ in practice

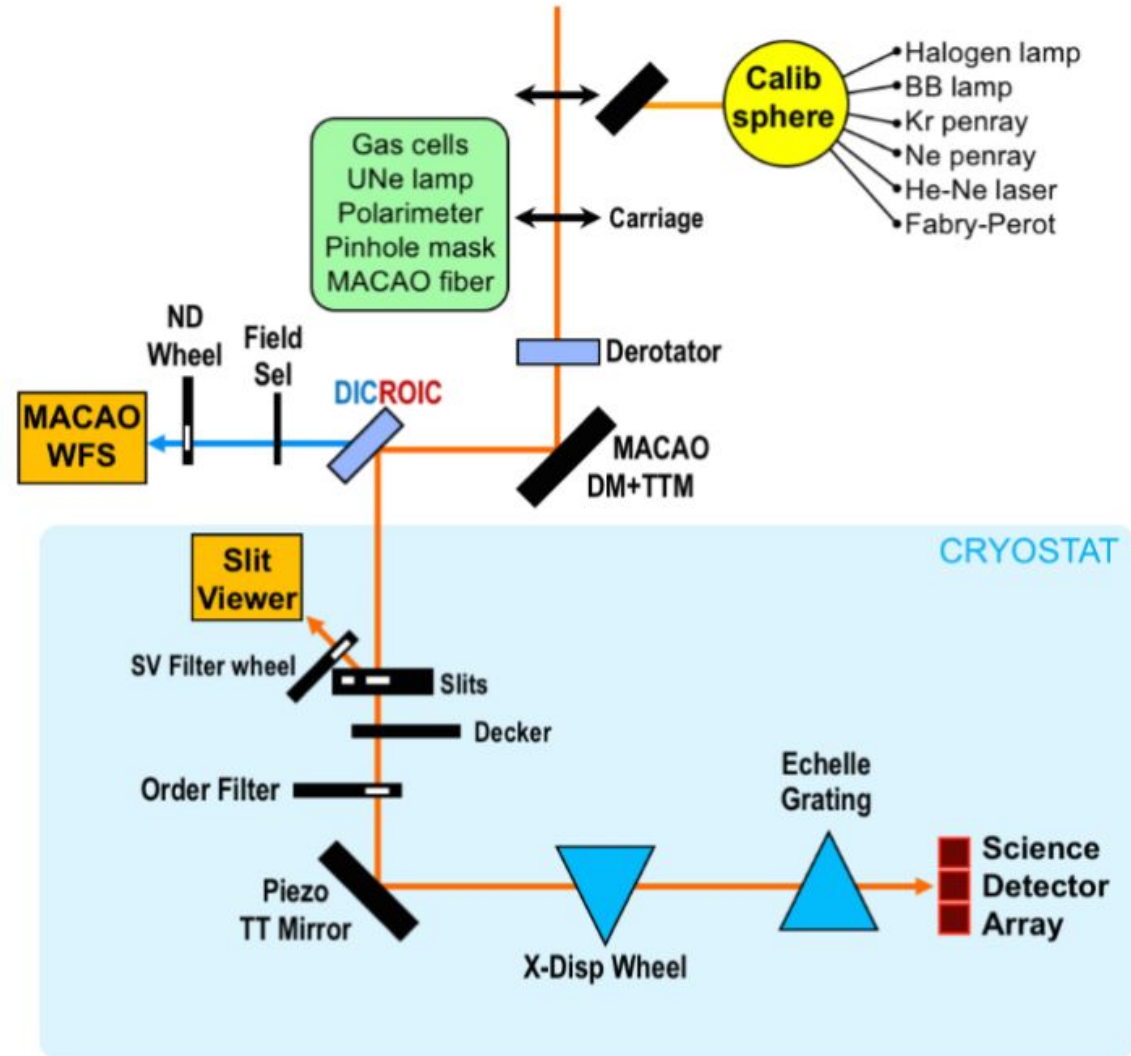
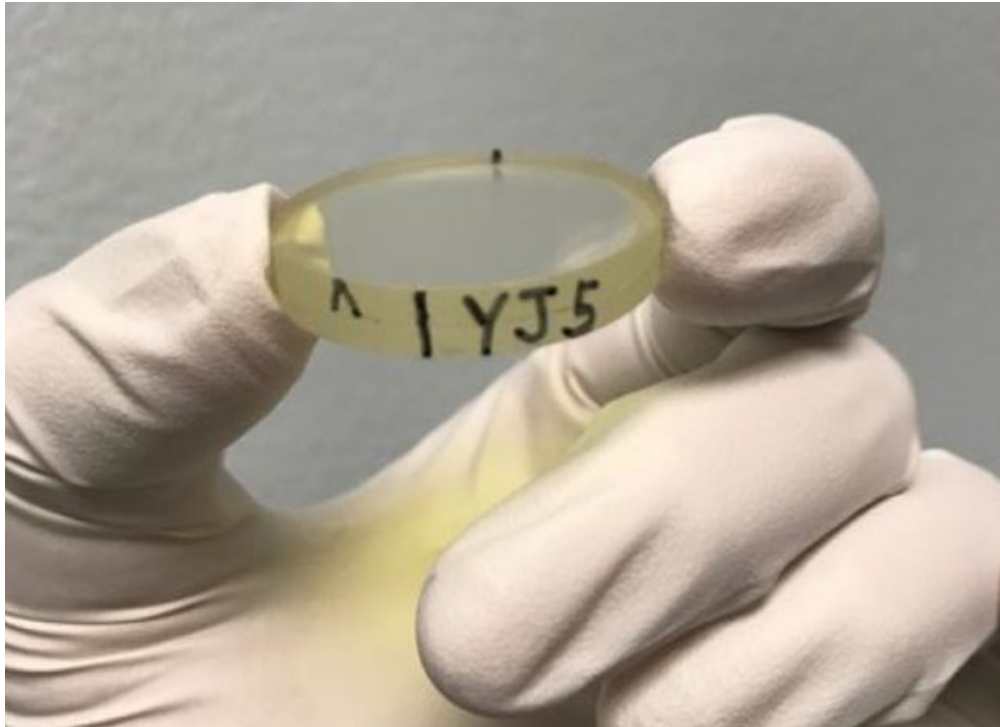


Figure 2: Light path sketch of the upgraded CRIRES.

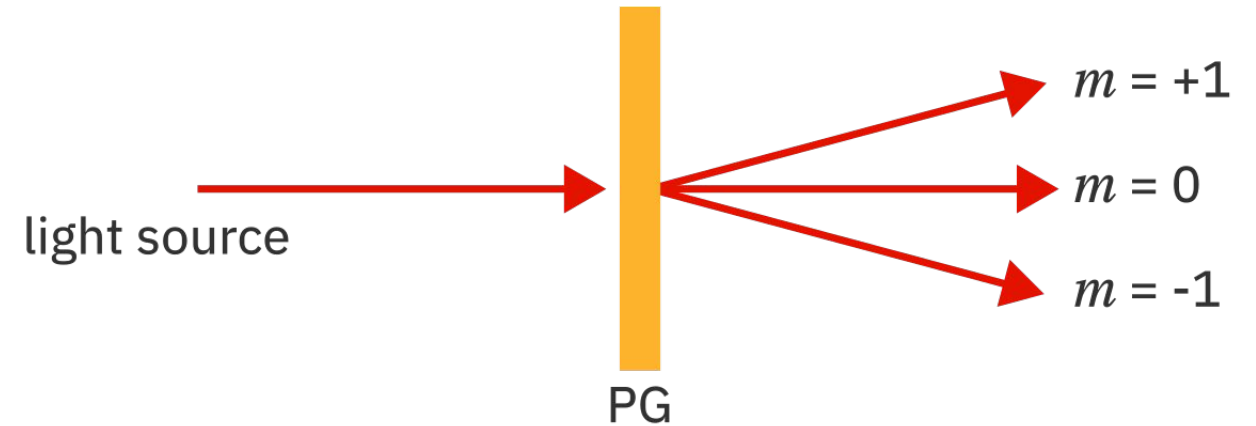


# Spectropolarimetry unit

Different design than NARVAL/ESPaDOnS/SPIRou: based on pairs of polarization gratings



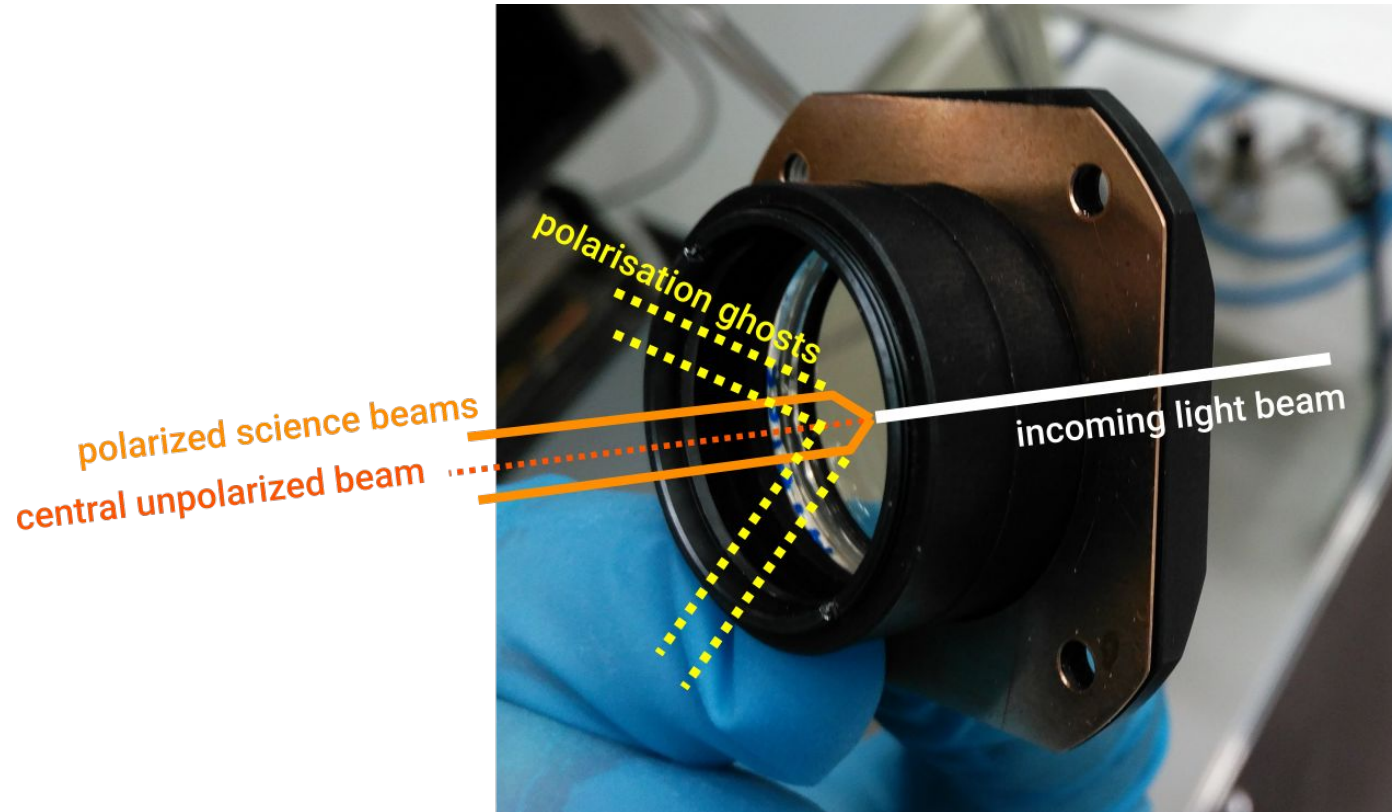
† A single polarisation grating for YJ bands. From [Piskunov et al. 2018](#)



**PGs are designed to:**

- Let light through  $m=0$  below cutoff wavelength
- Split light into  $m=\pm 1$  above cutoff wavelength

# Spectropolarimetry unit



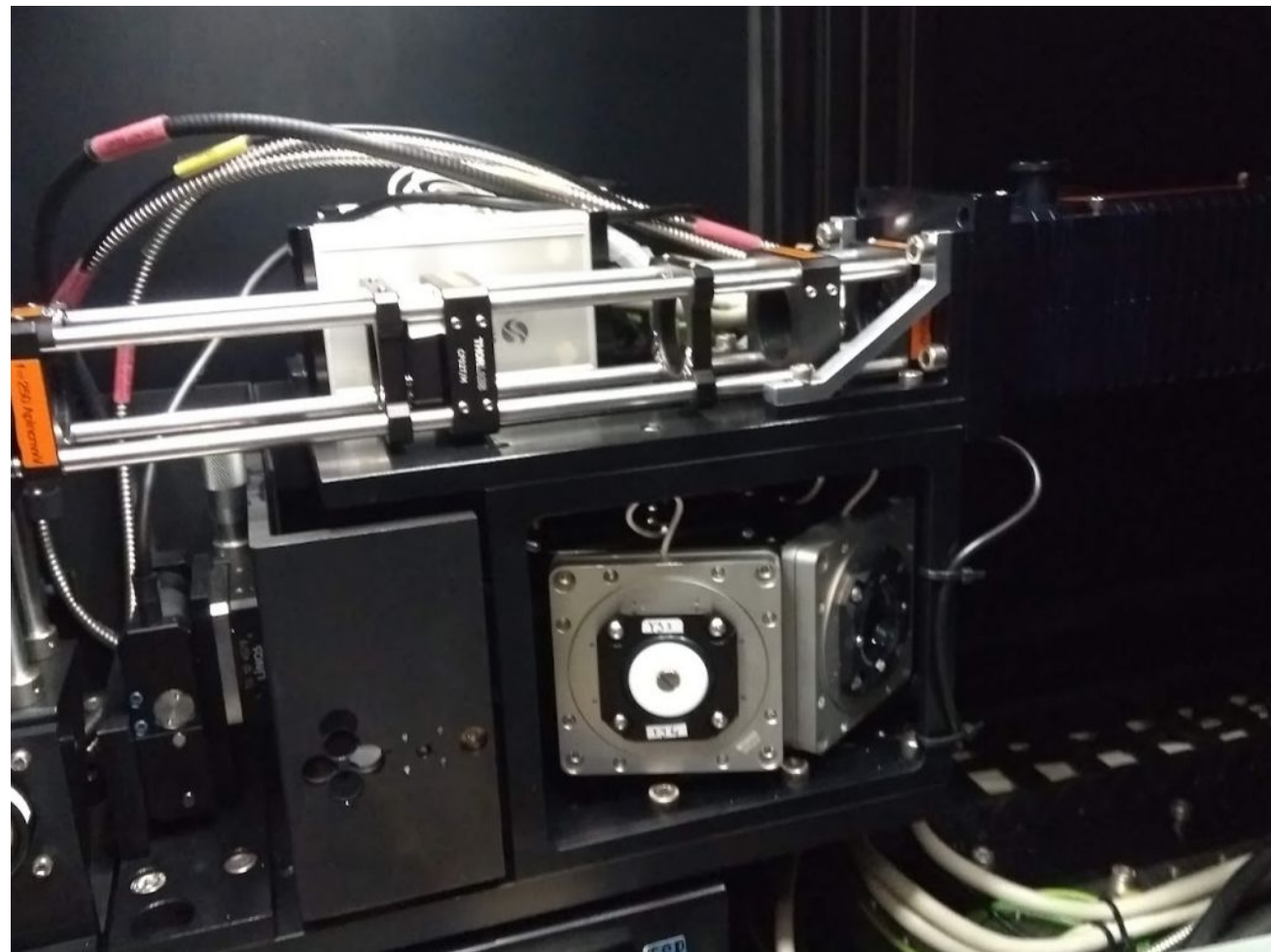
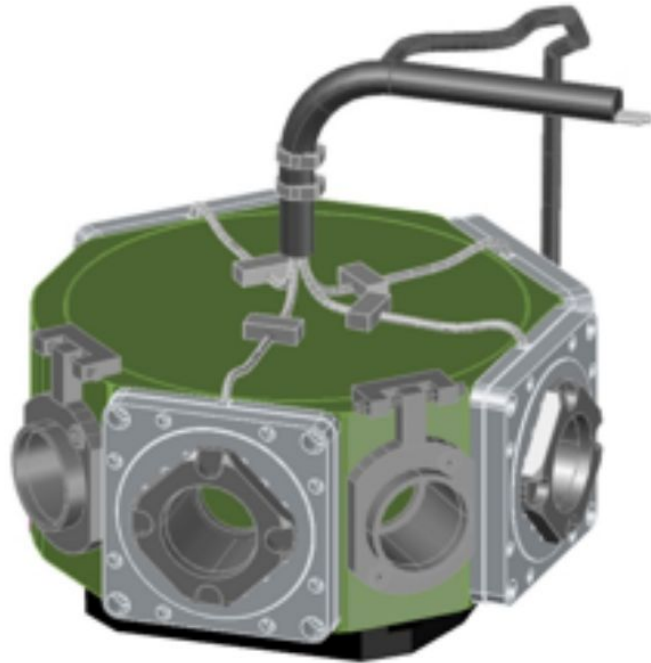
↑ Picture of a beam-splitter with schematic ray-tracing

## 4 beam-splitters in total:

- YJ circular
- YJ linear
- HK circular
- HK linear

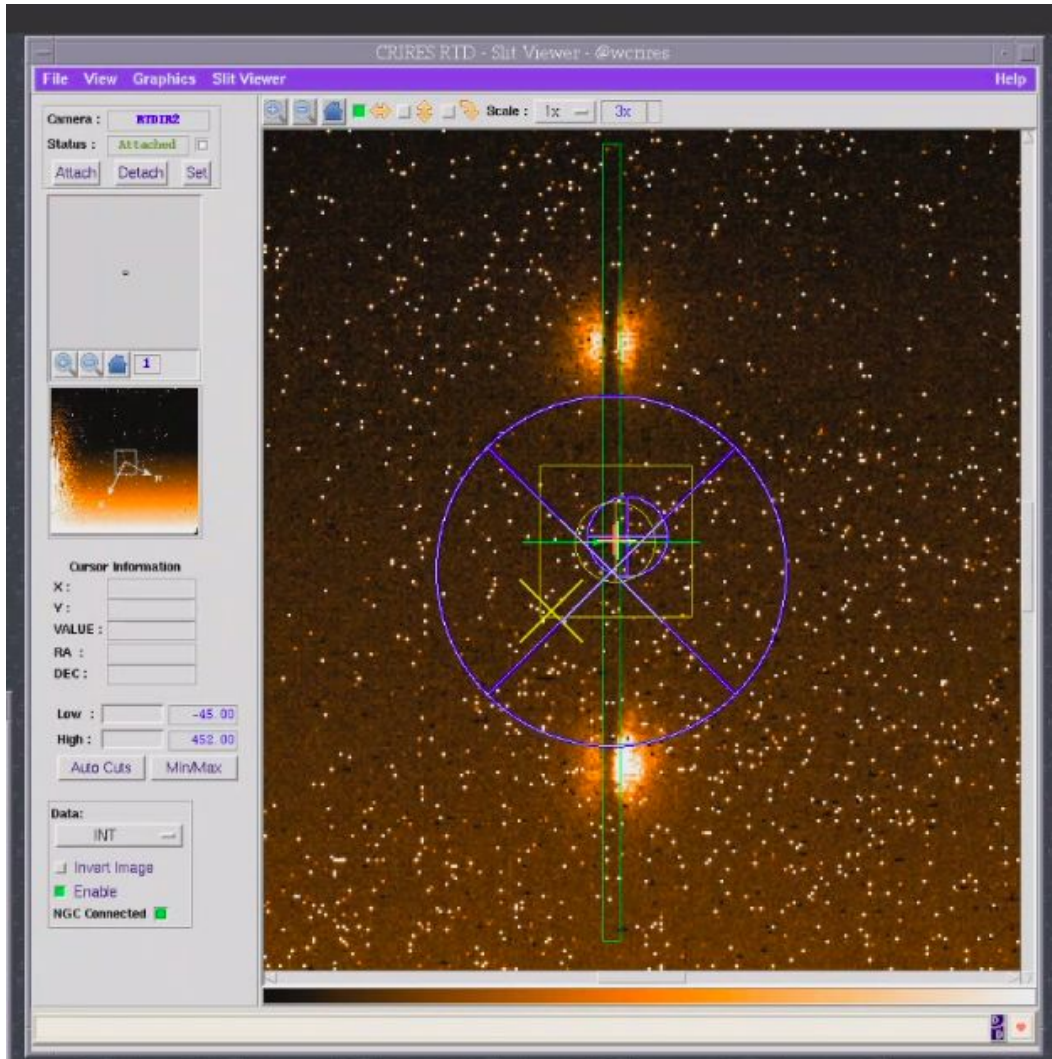
Beam splitter act on circular polarisation: for linear-polarisation, beam-splitters have an extra quarter wave plate.

## Spectropolarimetry unit



↑ Spectropolarimetry unit with the 4 beam-splitters

# Spectropolarimetry unit



← Sneaky spectropolarimetry test during the previous commissioning. These are the two polarized beams landing on the slit. Full spectropolarimetry commissioning happens in May 2021

## Take away messages

- CRIRES+ will enable exciting new science
- Hi-res spectroscopy up to M-band / spectropolarimetry up to K-band
- RV precision should be ~ 5 m/s
- Already offered at P108 in limited mode – offered in nominal mode in P109. **Apply!**
- Science verification should happen soon → call for proposal open to community. **Apply!**
- Start playing with the Exposure Time Calculator already now
- **Get in touch** if you have questions :-)
- Additional exciting project: [HiRISE](#) (PI: Vigan; coupling SPHERE with CRIRES+)