CRIRES and CRIRES+ instrument talk

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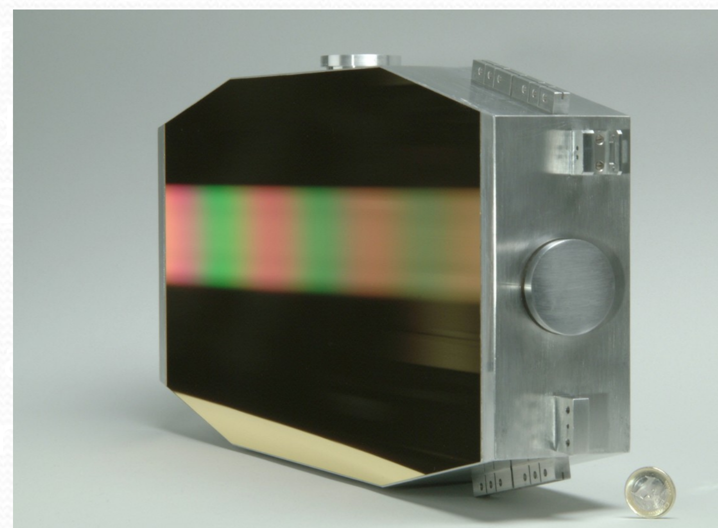
(2017 ESO calibration workshop, January 17th 2017)

Thanks to:

Paul Bristow,
Christophe Dumas,
Maria Eugenia Gomez,
Michael Hilker,
Ulli Kaufl,
Florian Kerber,
Emmanuel Lellouch
Ana-Lea Lesage,
Jared O'Neil,
Jerome Parfique,
Jeff Pirard,
Myriam Rodrigues,
Alain Smette,
Sandy Strunk,
Geronimo Villanova,
Burkhard Wolff



Talk outline

- A little about the CRIRES basics & history.
- Something about the instrument design for CRIRES and CRIRES+.
- The CRIRES calibration plan.
- CRIRES instrument issues/features, and if these problems will be eliminated with the upgrade.
- Science done with CRIRES (offline appendix only).

CRIRES basics

- CRyogenic
- high-resolution
- IR
- Echelle
- Spectrograph

Spectral resolution up to 100,000 with 0.2” slit. One to five microns wavelength range.

CRIRES history

- CRIRES is an ESO instrument. The project scientist was J. Pirard et al., Instrument Scientists: H. Kaufl and R. Siebenmorgen.

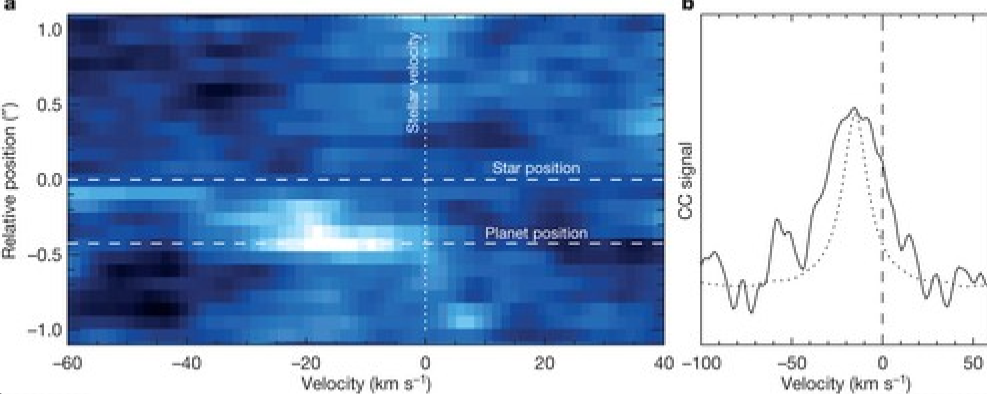
- Science verification was in 2006.

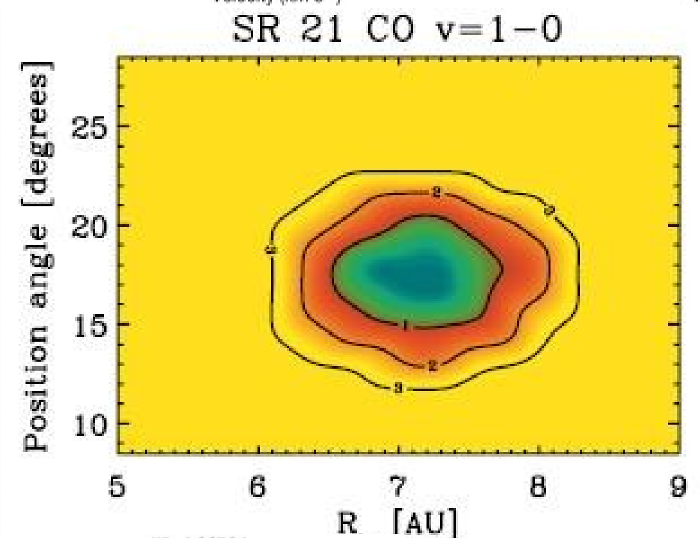
- CRIRES was in regular operation from 2007 to 2014.

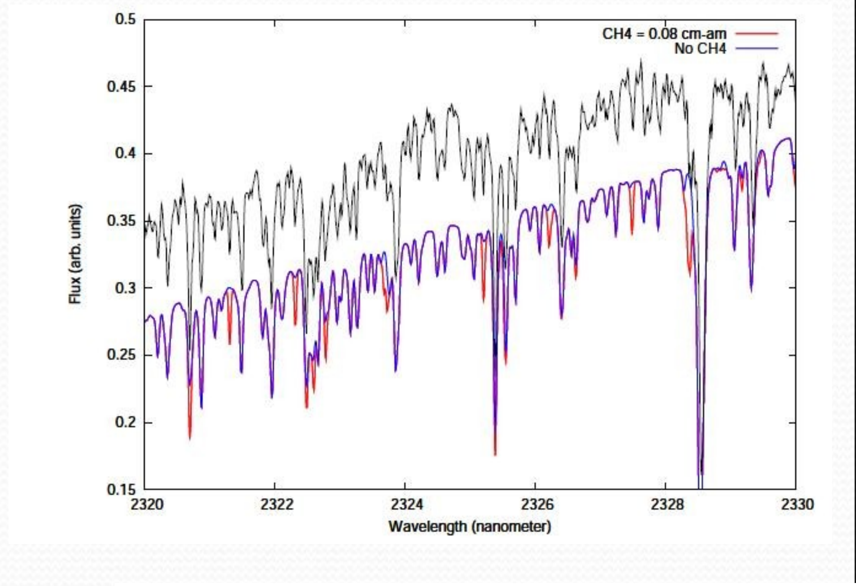
- It is now in Garching being upgraded with new detectors, a cross disperser added, circular polarimitry, new wavelength calibration sources etc. Back in mid-2018 as CRIRES+.

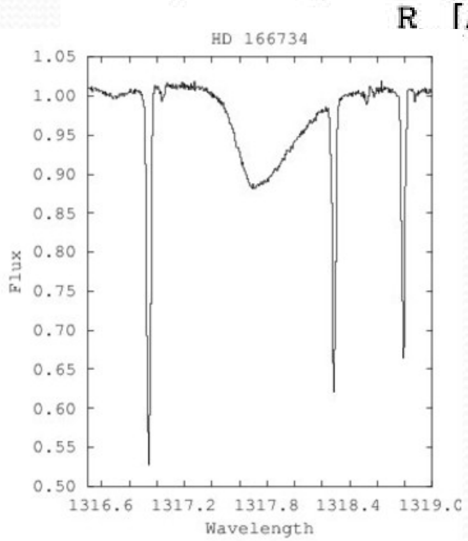
  https://www.eso.org/sci/facilities/develop/instruments/crires_up.html

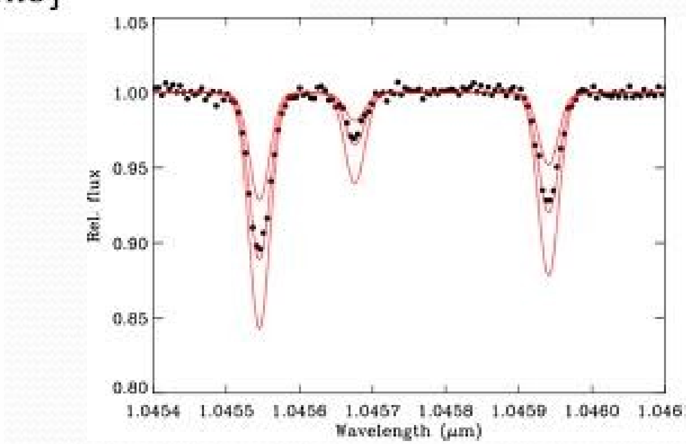
CRIRES science

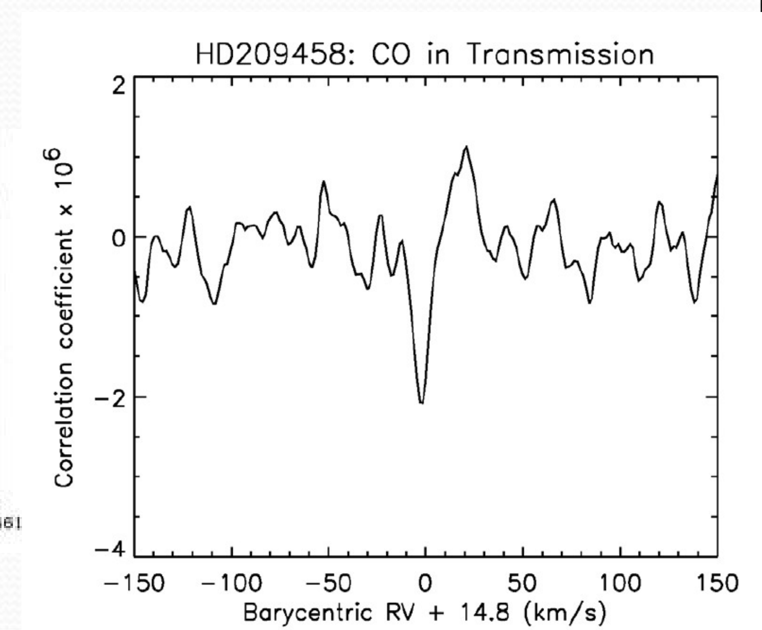






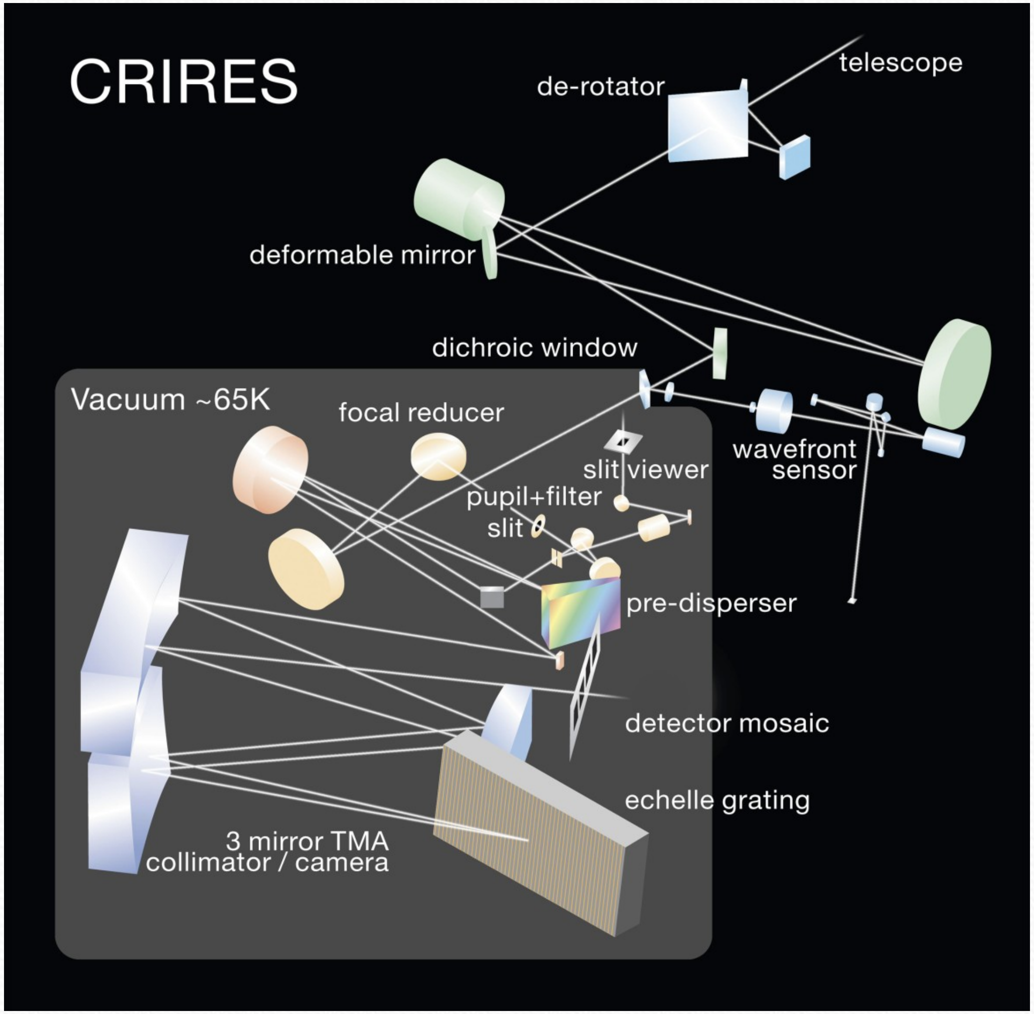


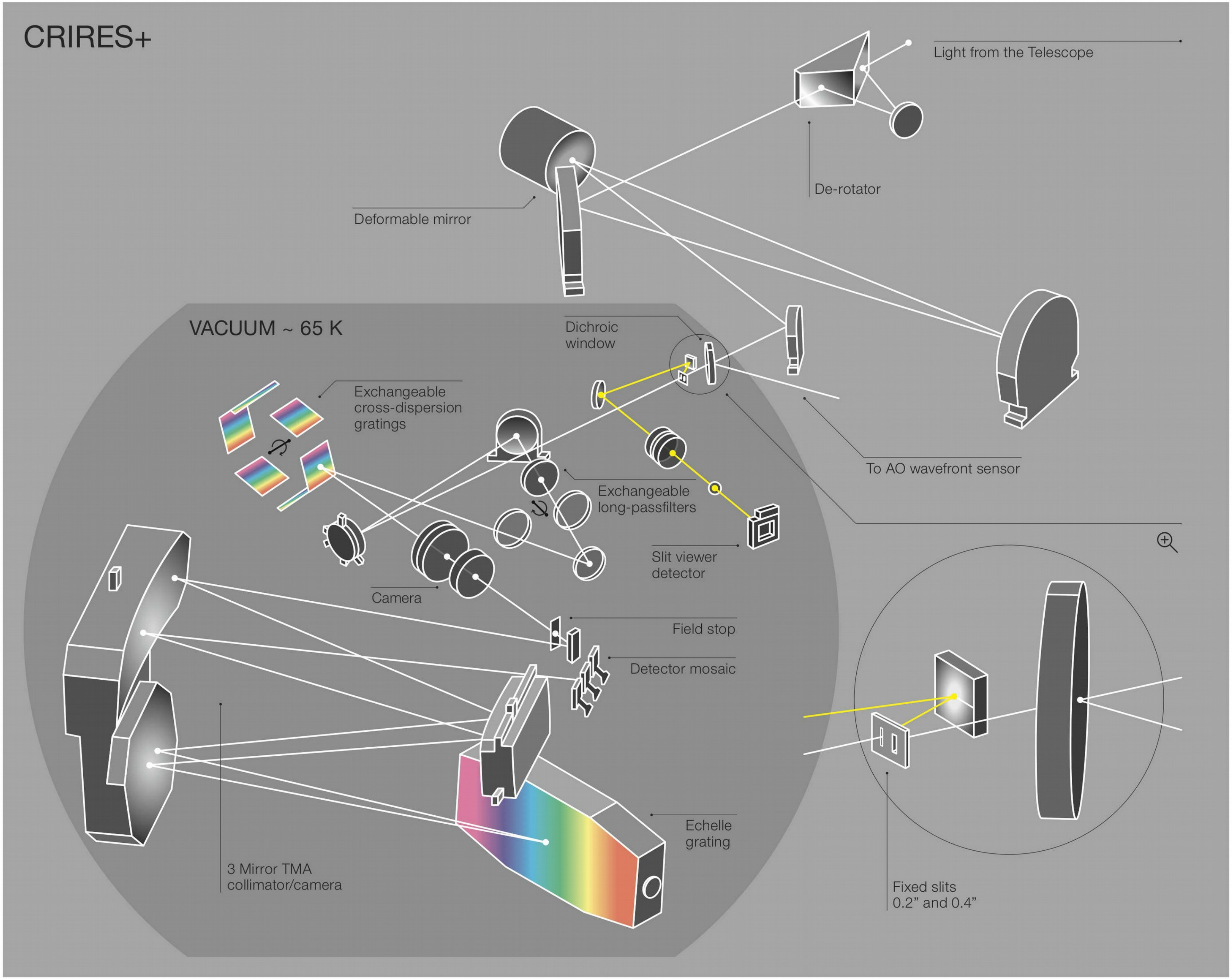




CRIRES and CRIRES+ optical layout

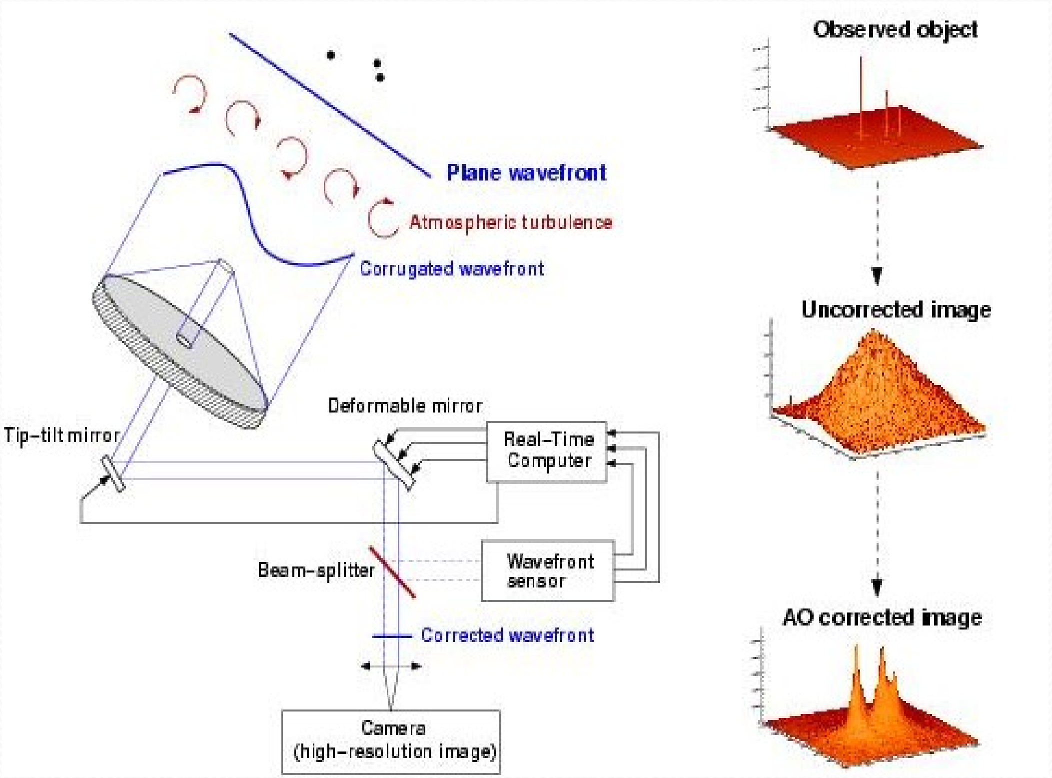
- CRIRES is complex! It comprised a warm part containing the adaptive optics and a cold part with the spectrograph.
- CRIRES plus adds other optical elements........




CRIRES+
Light from the Telescope
De-rotator
Deformable mirror
VACUUM ~ 65 K
Dichroic window
Exchangeable cross-dispersion gratings
To AO wavefront sensor
Exchangeable long-passfilters
Slit viewer detector
Camera
Field stop
Detector mosaic
Echelle grating
3 Mirror TMA collimator/camera
Fixed slits 0.2” and 0.4”

CRIRES warm part – AO system similar in CRIRES and CRIRES+

- The Adaptive Optics system of CRIRES enables the light from the astronomical source to be concentrated in a much smaller area by applying corrections to the incoming wave-front c.f. NACO, SINFONI.

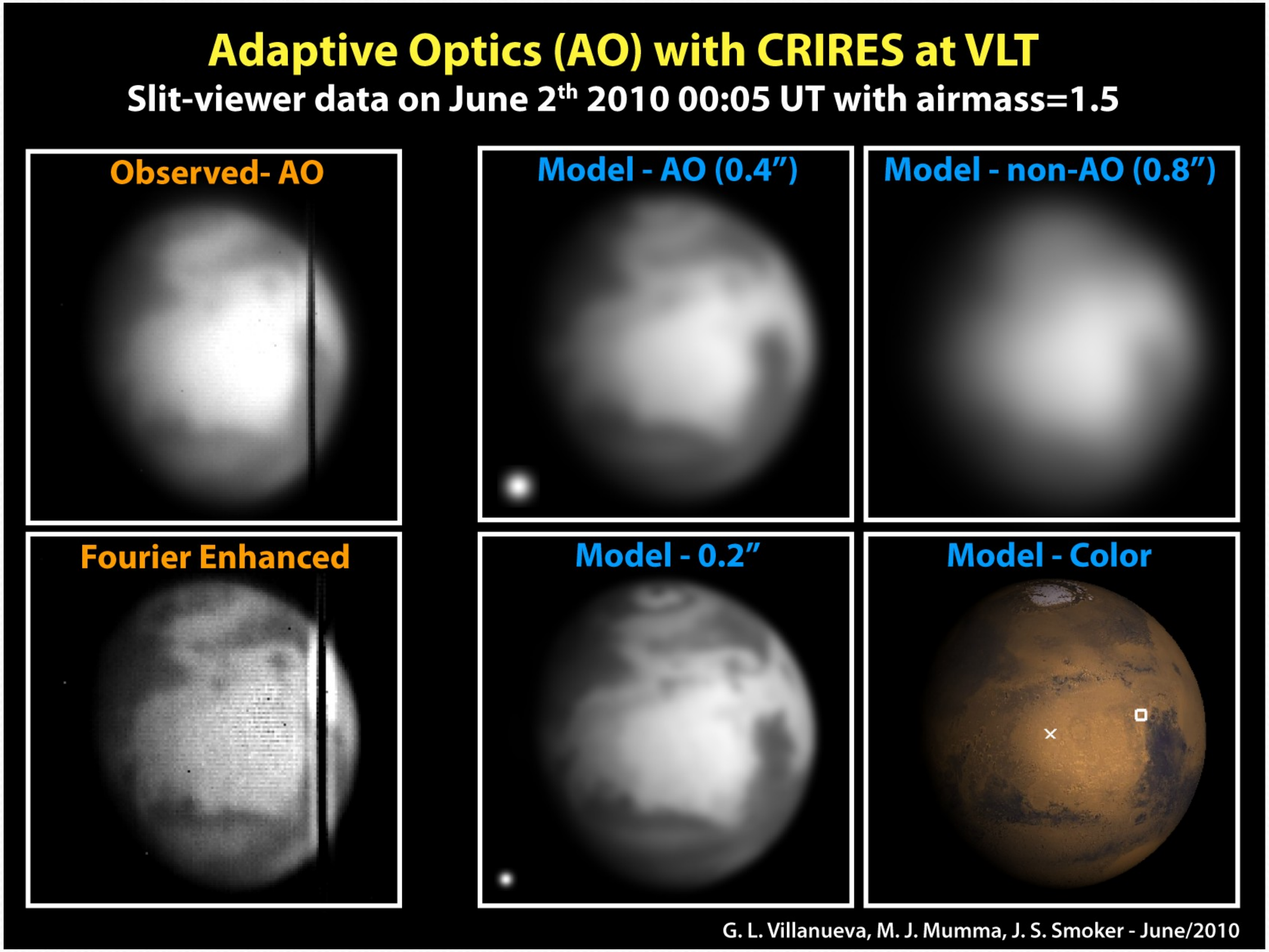


Why do we need AO?

- With AO we get better spatial resolution (slit viewer pixel scale was slightly less than 0.05 arc seconds per pixel), so we can separate close binaries for example.

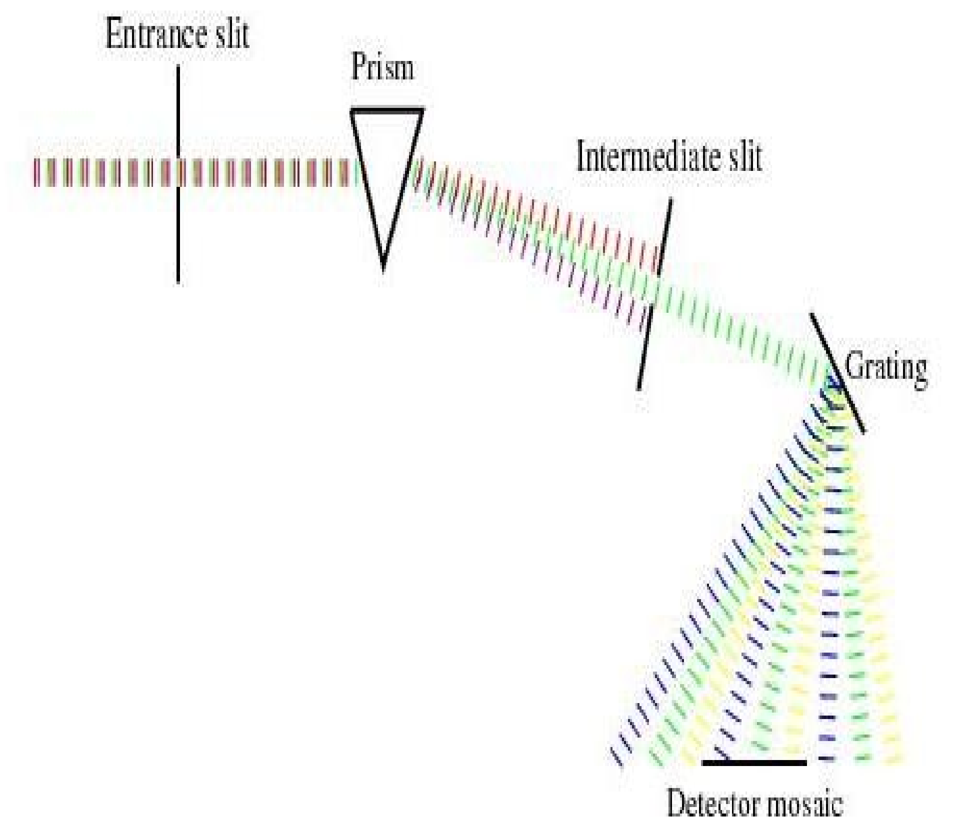
- With AO we can concentrate the light on the slit better (remember slit width typically 0.2 or 0.4 arcseconds), so we can have a narrower slit and obtain high spectral resolution with fewer slit losses.

Mars with and without AO

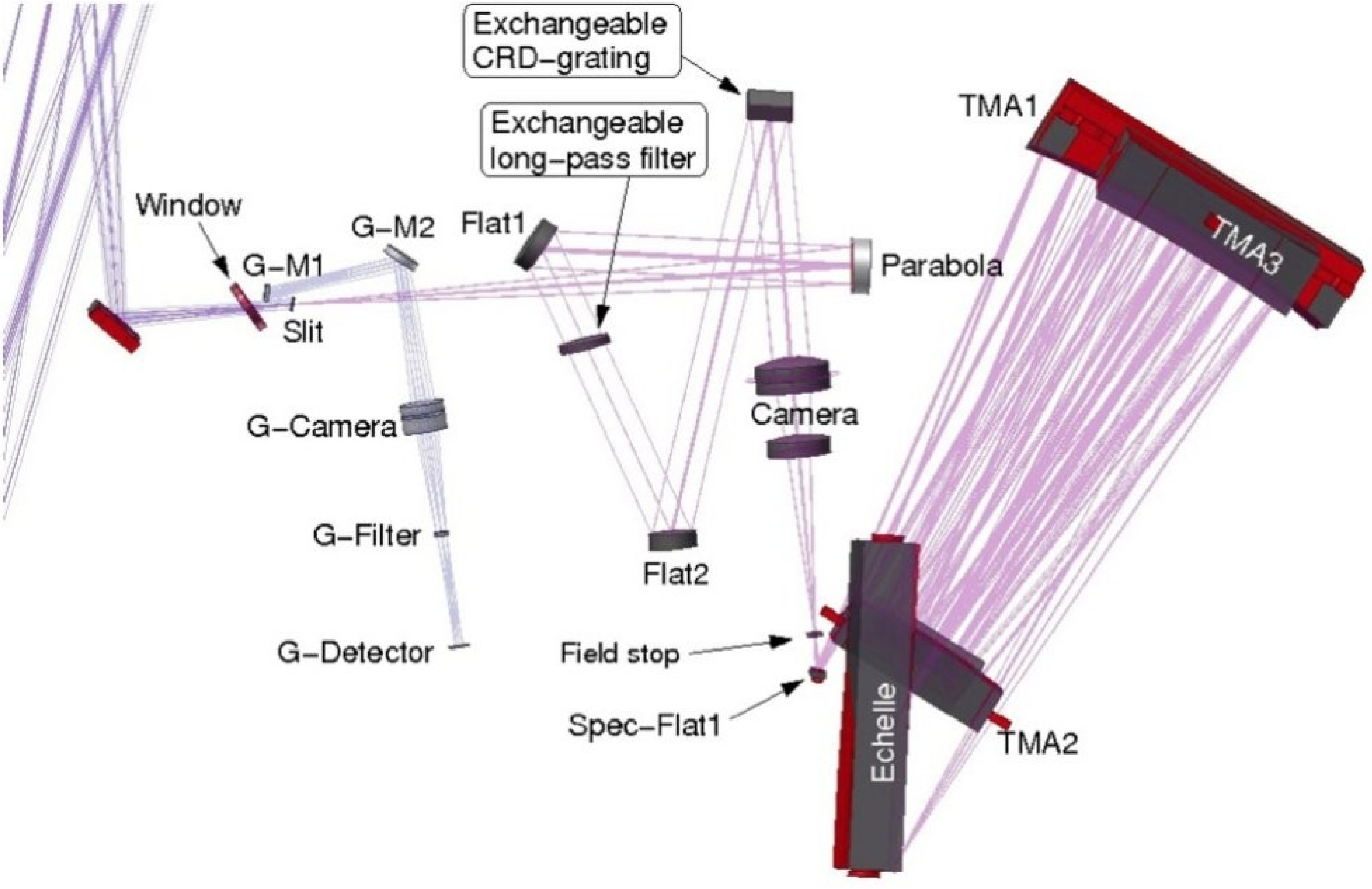


oCRIRES Cold part - spectrometer

- Temperature of detectors is about 24-27 K.
- Temperature of structure (prism etc) is about 70 K.
- Wavelength range from 0.95 to 5.2 microns.
- Resolution l/dl = 100,000 with a 0.2 arc sec slit (now you see why we need AO). Also 0.4” slit.
- Slit length 40 arc sec (FOV similar).
- We only have ONE order at a time! Wavelength range is lambda/50 @5 microns to lambda/70 @1 microns c.f. UVES on a future slide.



CRIRES+ Cold part - spectrometer



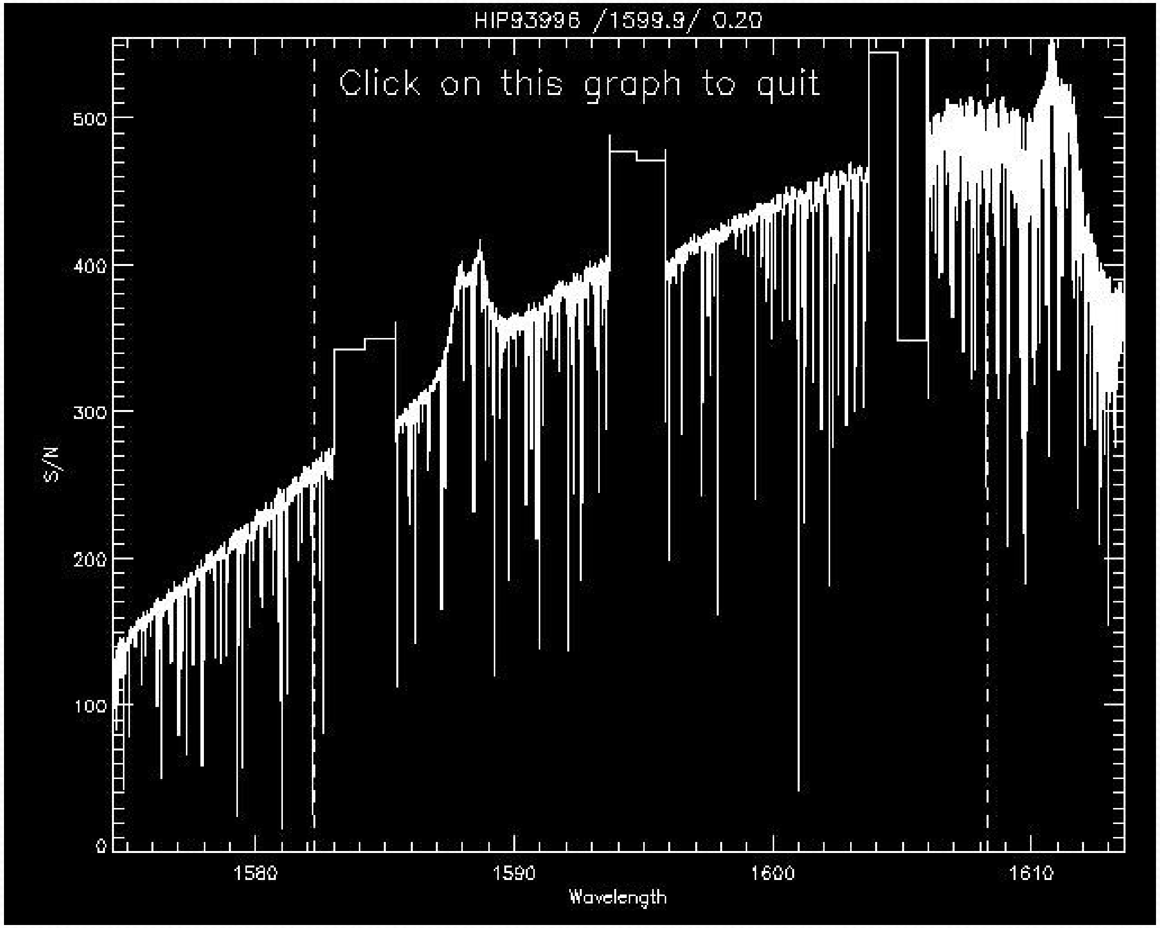
CRIRES in action: spectral resolution

- First-light spectrum from CRIRES showing a doublet at 1706-nm:

- The high spectral resolution of CRIRES allows one to separate closely-separated lines (for example produced by the source and the Earth's atmosphere), waiting for the right time if necessary using the Doppler motion of the Earth. Following slide shows why this is important:

CRIRES in action: reduced data

- Often we will have telluric lines present in our science spectrum.
- Often therefore we observe a telluric standard close in time and airmass, or use an atmospheric model such as molecfit.
- We also include the water vapour as a constraint as we have this value in real time via a radiometer.



CRIRES calibration plan

Daily:

– Three darks with the same DIT as the observation.
– Three flatfields (daily).
– Three wavelength calibration frames for settings less than 2400-nm (daily).
– Measurement of the precipitable water vapour.
– Radial velocity standard.

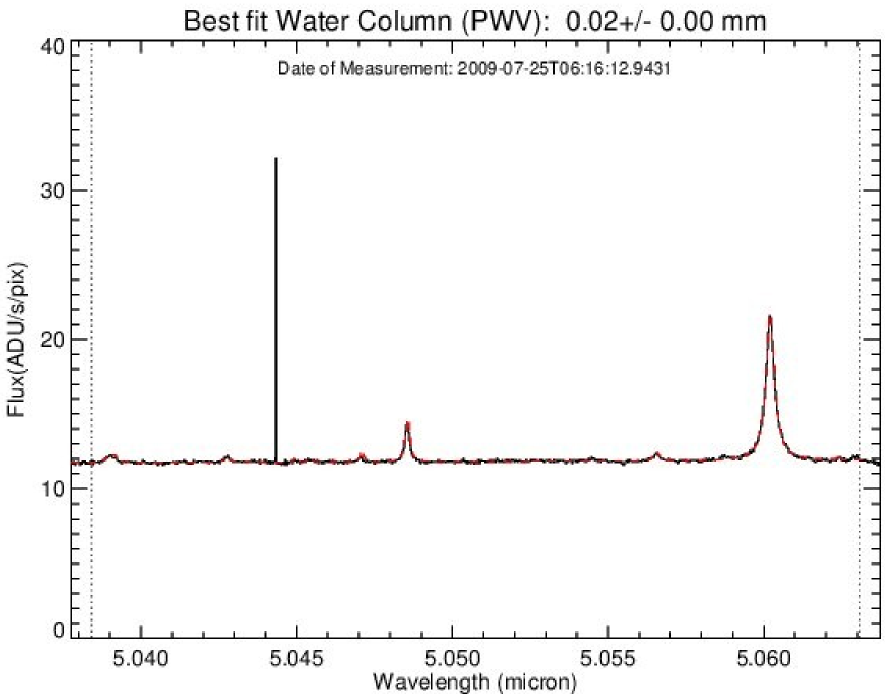
Monthly:

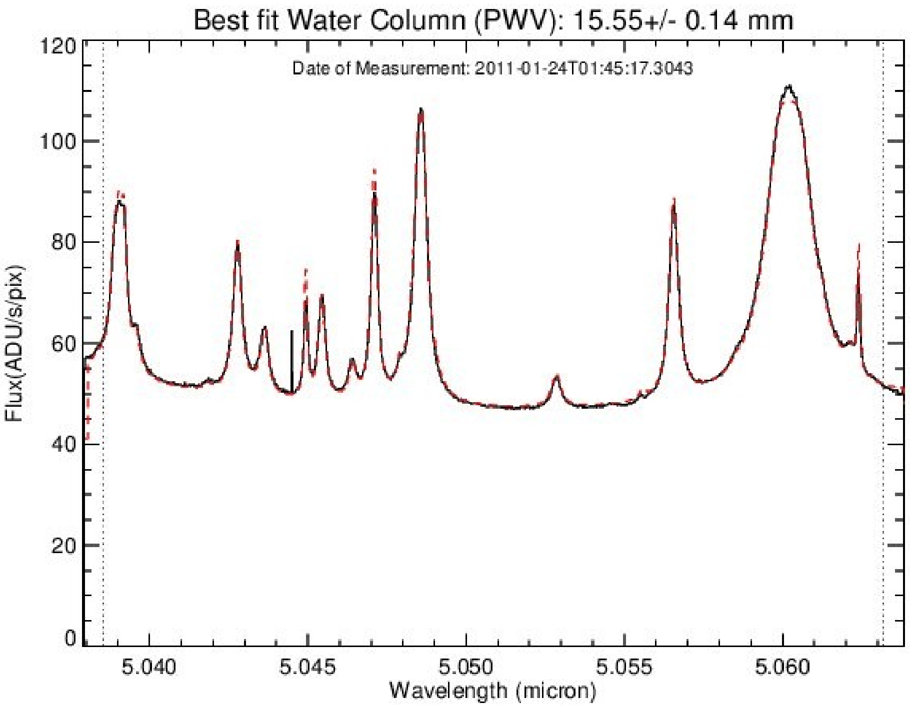
– Detector non-linearity (detector monitoring).

NOT taken by default for CRIRES (under discussion for CRIRES+):

– Telluric standards (package molecfit often does a good enough job), Spectrophomometric standards.

CRIRES aside: low and high PWVs





Left plot: Very low Precipitable Water Vapour (0.02mm in July)

Right plot: Very high PWV (15.6mm in January)

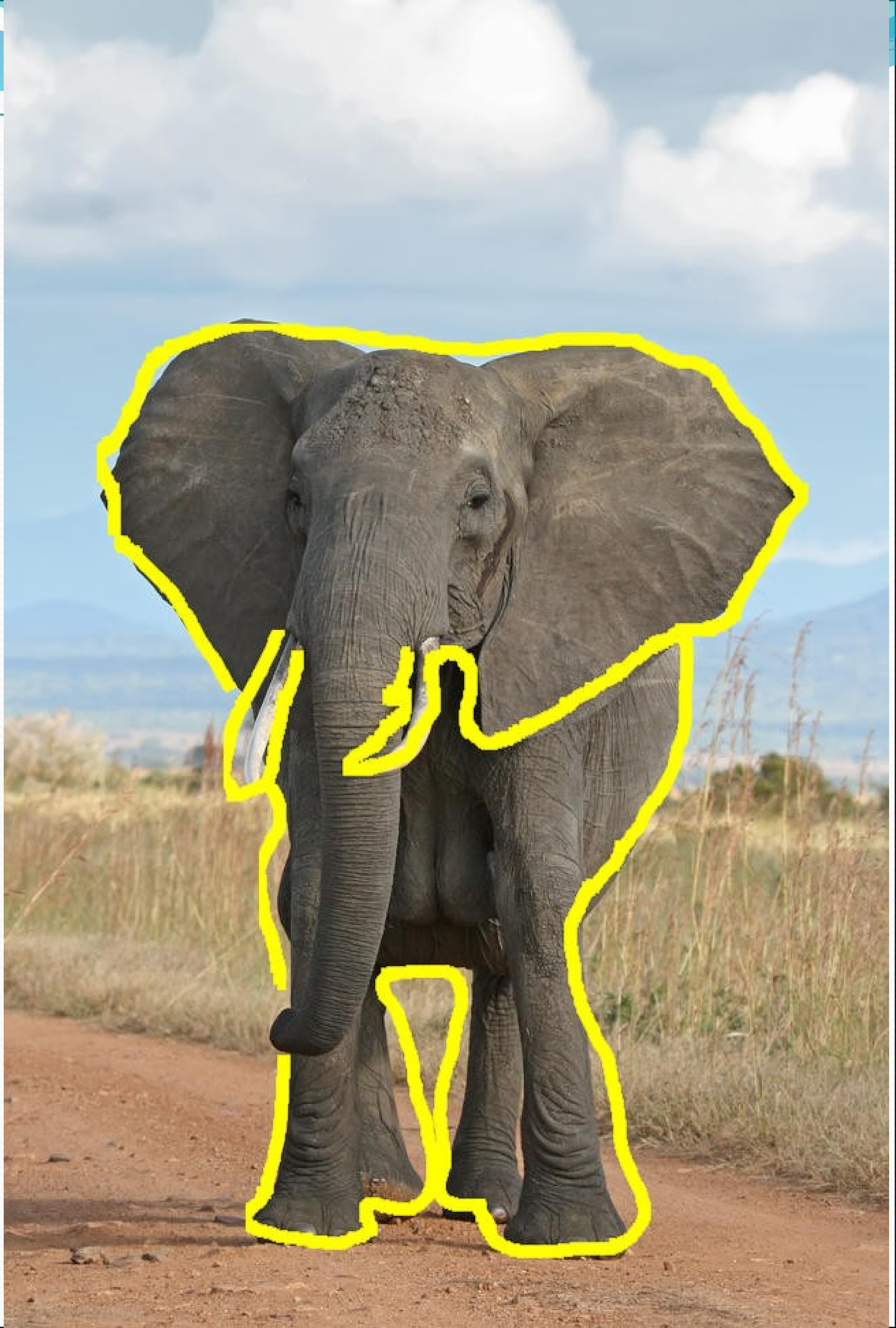
CRIRES issues – mainly solved in CRIRES or will be/maybe in CRIRES+

– Wavelength calibration; few ThAr lines in many settings.
– Flatfielding (poor repeatibility of moveable entrance slit).
– Detector persistance and closed cycle cooler problems.
– Performance of Adaptive Optics system under high humidity conditions.
– No calibrations with upper lights on in the dome.
– Bad detector cosmetics.
– Order contamination esp. on detectors 1 and 4.
(– Limiting RV precision; not filling slit, Pipeline issues)
(– Telluric contamination in calibrations, Long cooldown times and low shutter open times.)

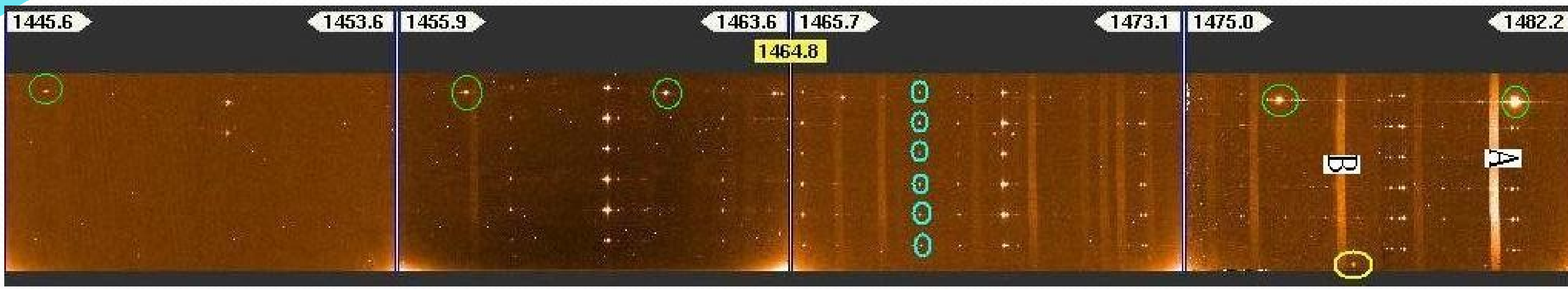
CRIRES issues: wavelength calibration

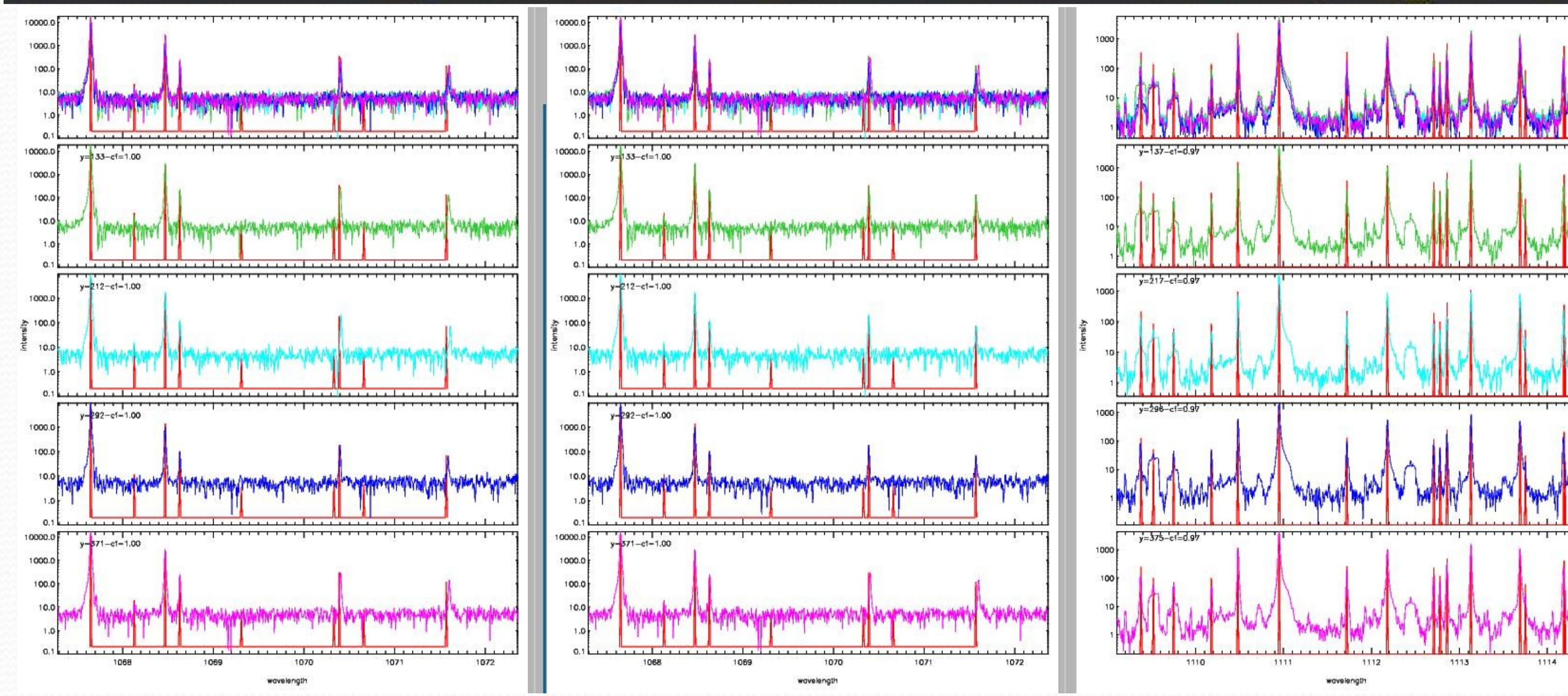
Many settgings only had a handful of ThAr lines available (next slide). Additionally the repeatibity was of the order 2 pixels peak to peak.

In CRIRES plus this will be less of an problem as (1) there will be other wavelength calibration sources (this slide+2, also talk by Paul Bristow) and (2) a metrology system to achieve sub-pixel repeatibility (Paul Bristows talk). The instrument model for CRIRES plus never quite achieved accuracies high enough.



CRIRES issues: wavelength calibration





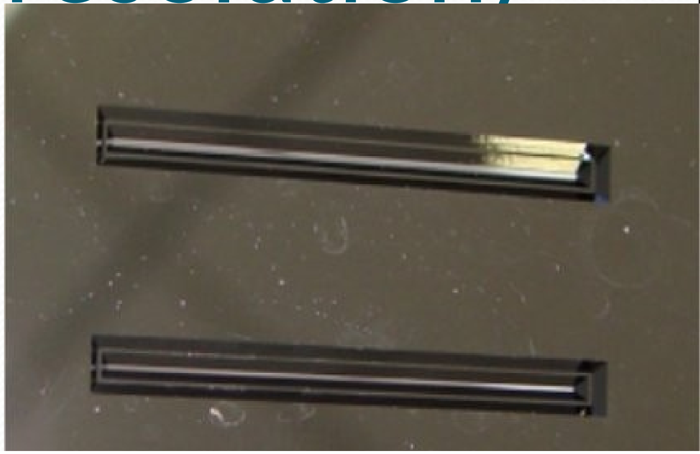
Top figure: Example of the four detectors during a wavelength calibration.
Bottom figure (Daniel Asmus): example of wavelength calibration (good & bad).

CRIRES and CRIRES plus calibration sources – also talk by Paul Bristow

6.1.1.1 Summary of available calibration sources for CRIRES+. New sources are indicated in green.

Type	Principal use	Location	Notes
(Atmospheric lines)	Wavelength calibration	Sky	L & M band where the lamps have few lines and continuum
Halogen lamp	Flat Fields	IS	Extended spectrum/black body, temperature: 3000-3100K
IR black body source	Flat Fields	IS	Extended spectrum/black body, temperature: 1100-1150K
Krypton pen-ray	Wavelength calibration, alignment	IS	Sparse spectral features
Ne pen-ray	Wavelength calibration	IS	Sparse spectral features
He-Ne Laser	Alignment, health checks on resolution	Feeds IS	Dual wavelength 1.15258984µm and 3.392235µm. Coupled to an IR fiber that will transmit both lines that feeds the IS.
U/Ne HCL	Wavelength calibration	On carriage	Dense spectral features up to K-band. Illuminates the entrance slit uniformly and feeds the metrology fibres.
Metrology fibre source (U/Ar HCL)	Metrology	Under warm optics table, near IS (location of and assembly of oCRIRES Th/Ar)	U/Ar HCL feeds a fibre that passes to the cryostat. Provides ≥2 isolated high S/N reference features in a narrow wavelength range see RD8 and RD11.
Fabry Perot Etalon	*Wavelength calibration*	*Under warm optics table, Feeds IS*	*Frequent, regularly spaced, reference wavelength features with uniform dynamic range from Y- to K-band.*

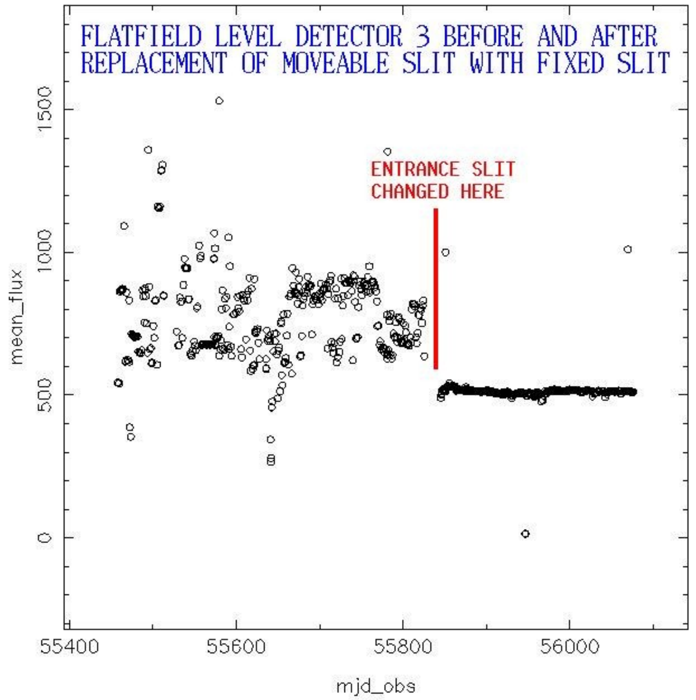
CRIRES issues – slitwidth repeatibility (variable flatfield level & resolution)



Until October 2011 we had many problems with setting the slit to the required width (10-20% variation for 0.2” slit).

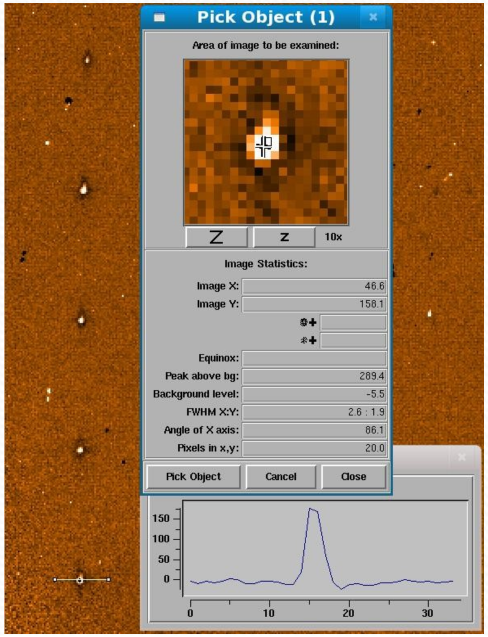
→ Meant flatfield levels were not stable and resolution variable. This was fixed by changing from a movable slit to fixed slits with widths of 0.2” and 0.4” (upper plot), giving much improved flatfielding repeatibility (lower plot).

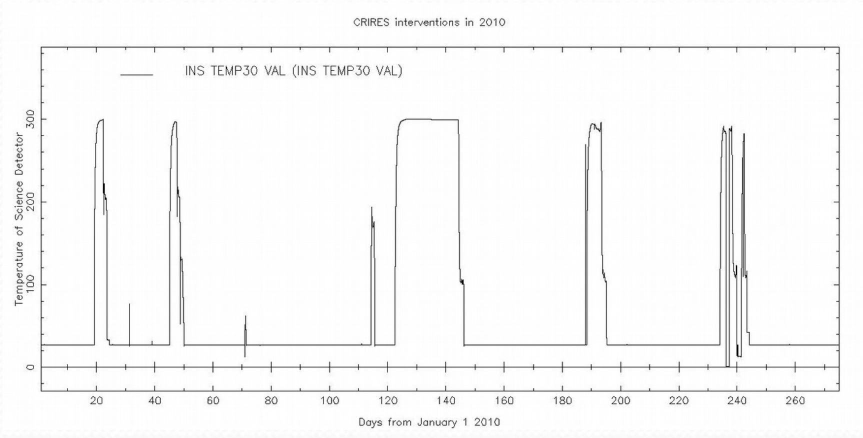
CRIRES plus will also have fixed 0.2” and 0.4” slits.

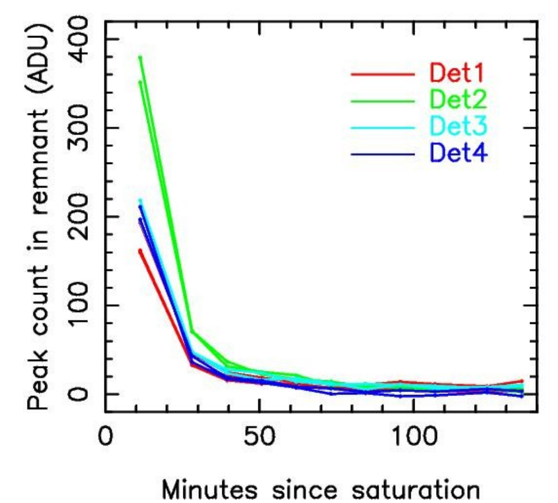


CRIRES issues: Persistance/CCC

- Saturation of the detectors left remnants that could last an hour or so, hence no saturation was allowed in service mode; right hand figures. Not clear if this will still be an issue in CRIRES plus.
- We had many problems with the closed cycle coolers that were fixed.

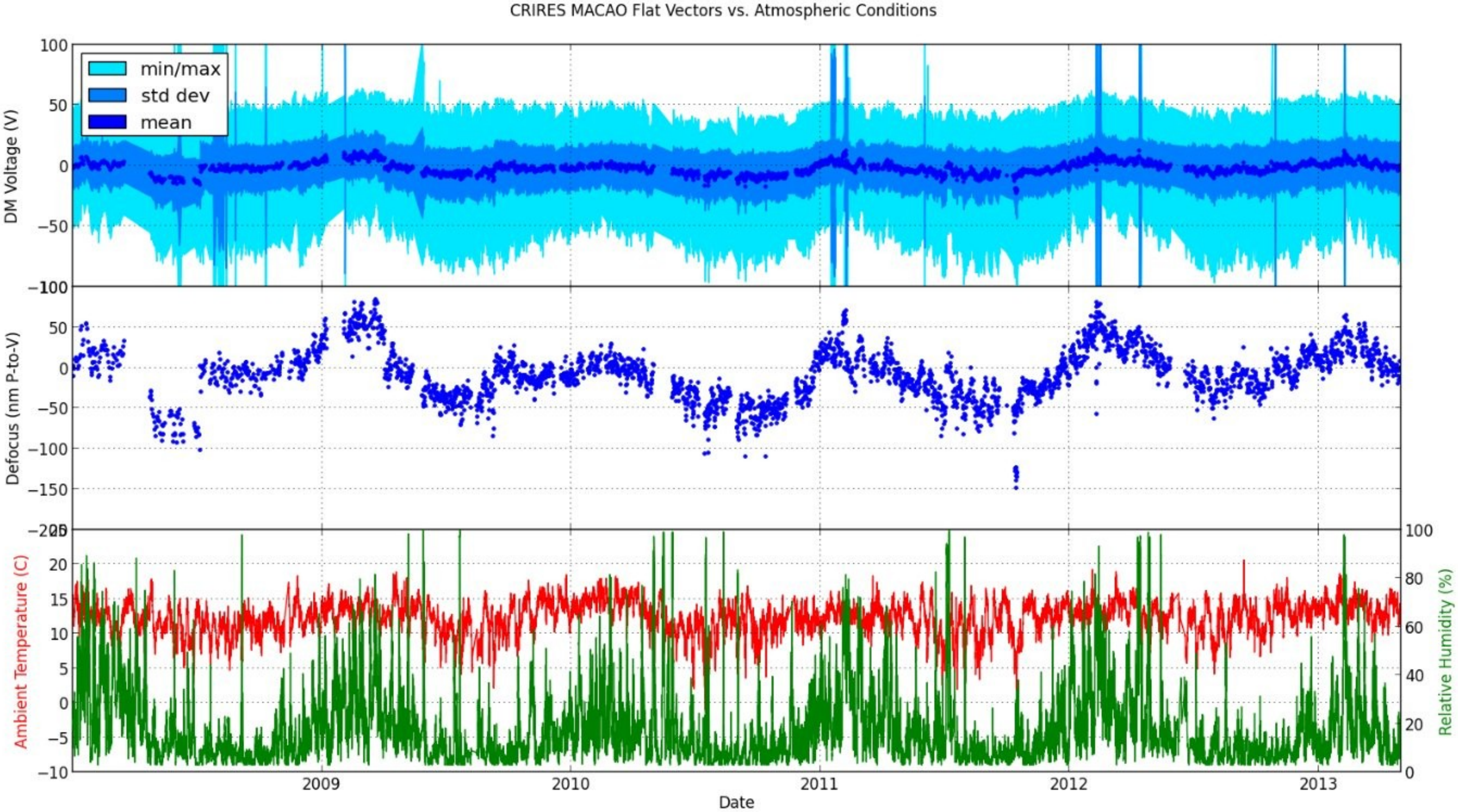






CRIRES issues: AO in high humidity

- **Prolonged** high-humidity and high-temperatures lead to instability



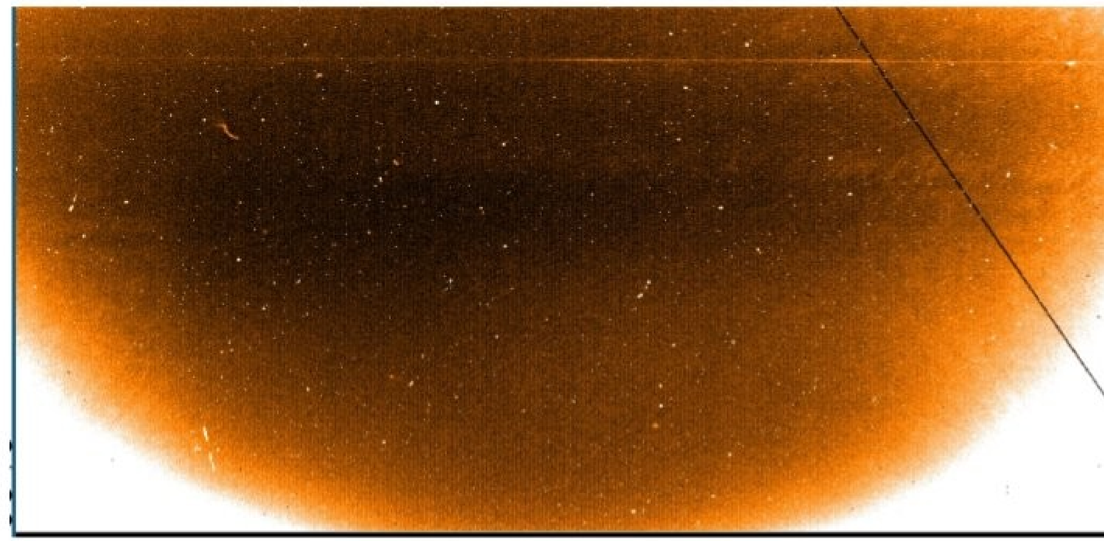
Plot by J. O'Neil for CRIRES. For CRIRES+ it is hoped to be able to remove water vapour from the system.

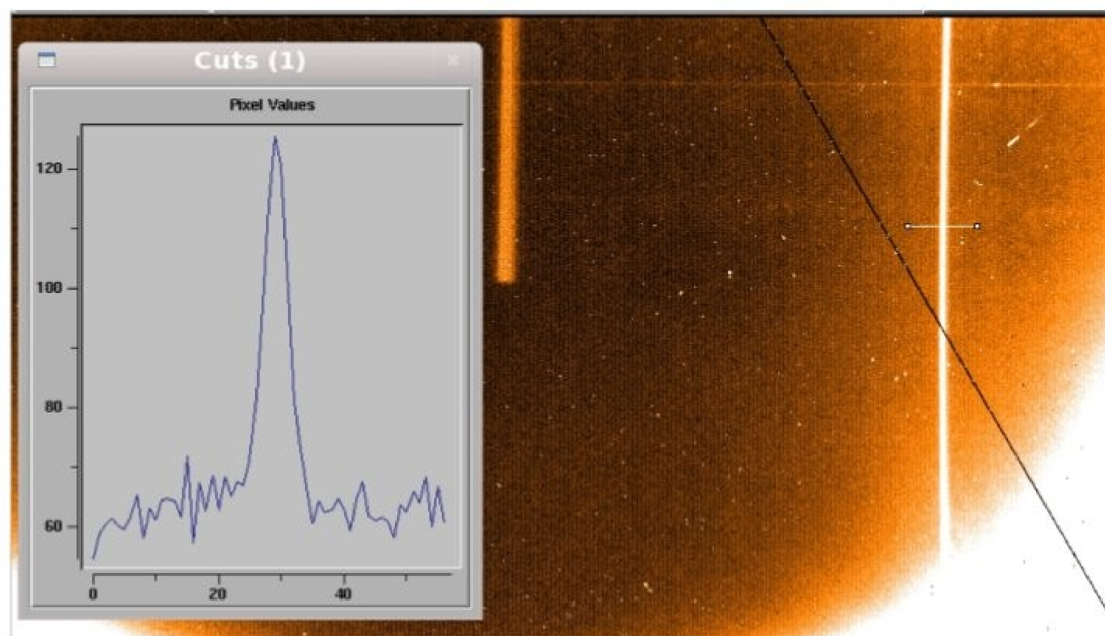
CRIRES issues: Calibrations were not possible with the upper lights and calibration times were long if many settings observed in the previous night. AO system not light tight either.

In CRIRES+ there will be a new cover so hopefully we will be able to calibrate with all lights on.

Screenshots of Darks and "Flats" with all lights ON (1)

Top frame: 600-s dark at 1018.6-nm, detector 2 (slit 0.0") - no light from Hg seen.
Bottom frame: 300-s flat at 1018.6-nm, detector 2 (slit 0.4") - Hg line at 1014.30 clearly seen.

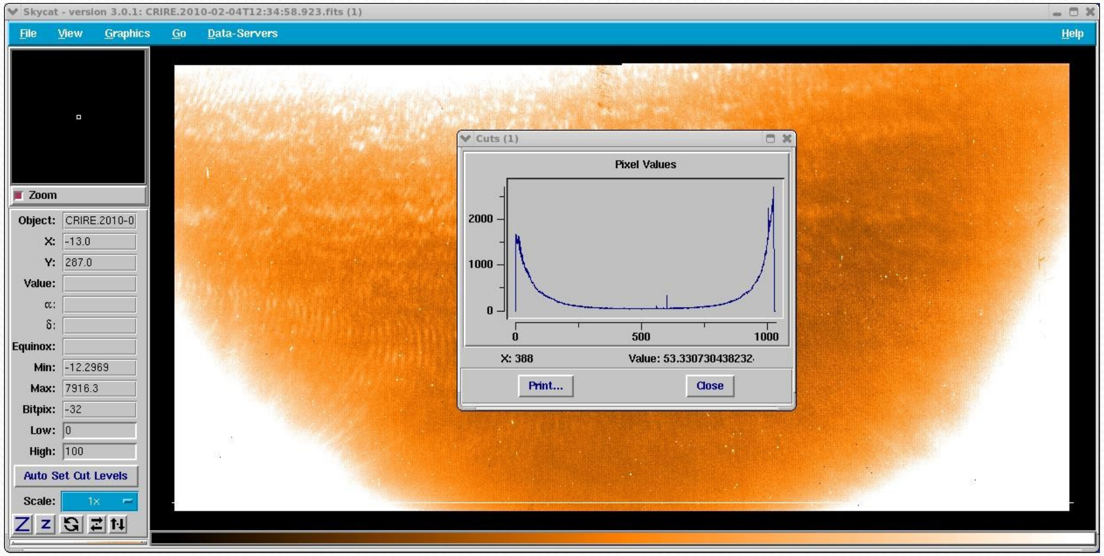


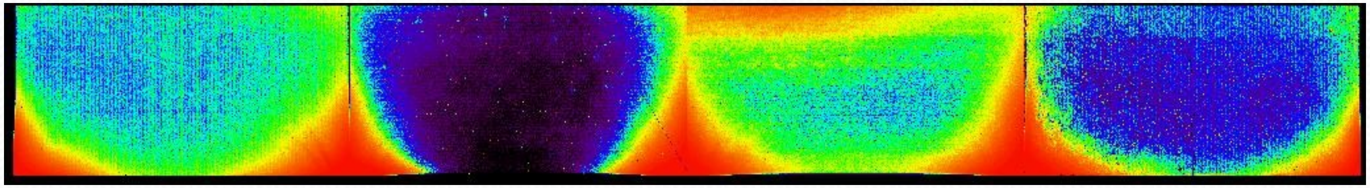


CRIRES issues: Detector cosmetics

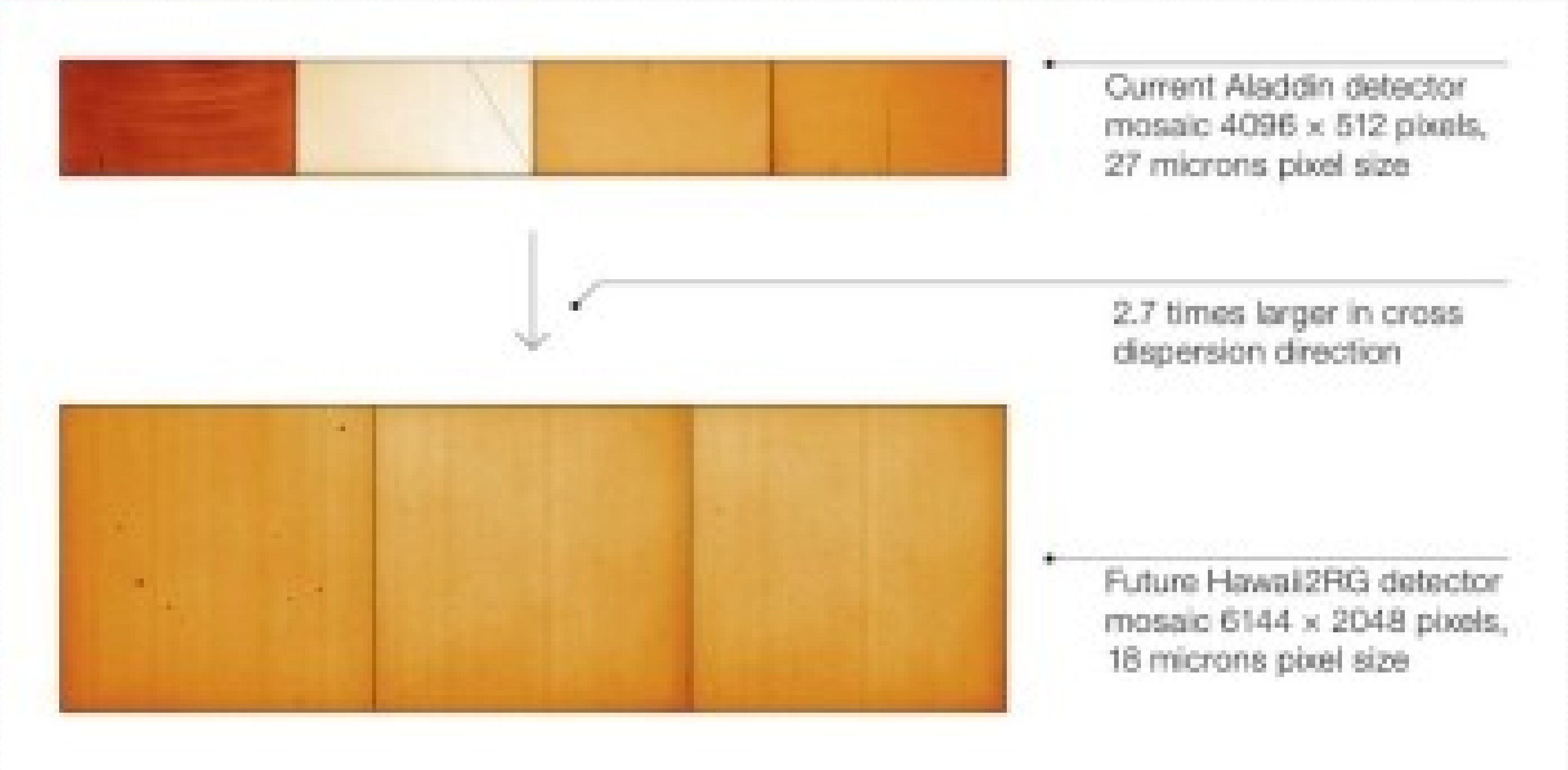
- The four detectors of CRIRES are not of perfect quality and suffer from glow with long DITs as well as scratches and bad pixels. The new detectors in CRIRES+ show much better quality.

Right figure: Detector 3 only, 600s dark frame with glow of 2000+ ADU. Bottom frame all four detectors shown.



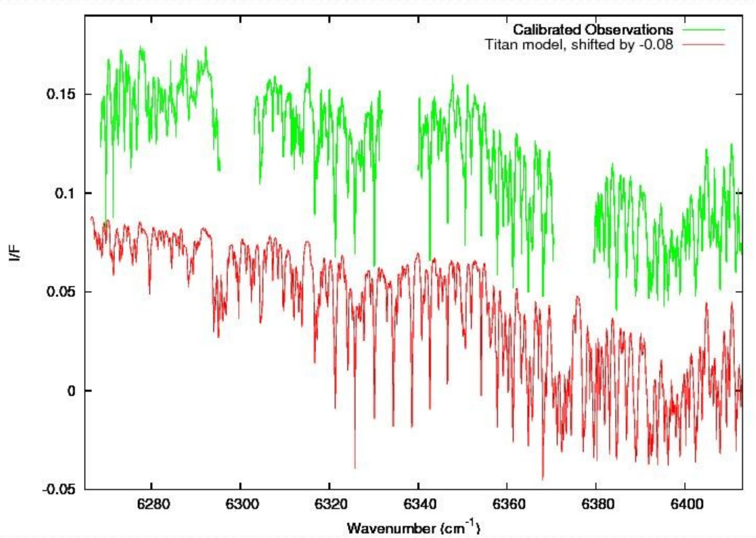


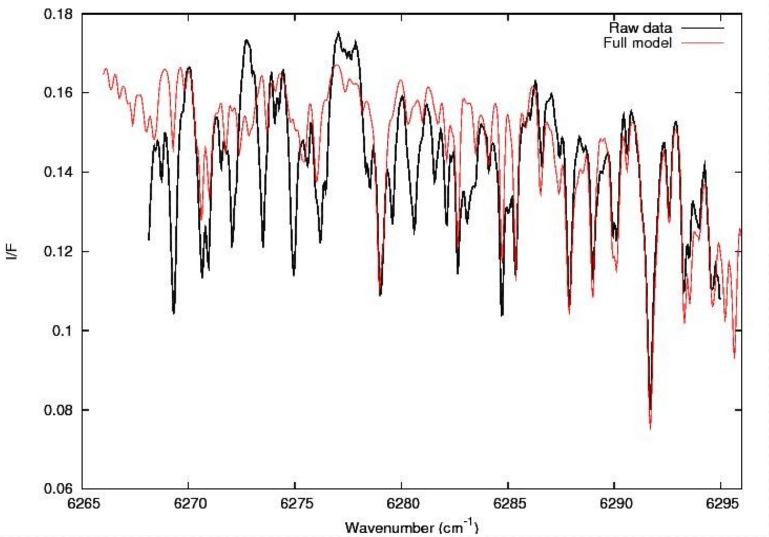
oCRIRES to CRIRES+



CRIRES issues: contamination of different orders.

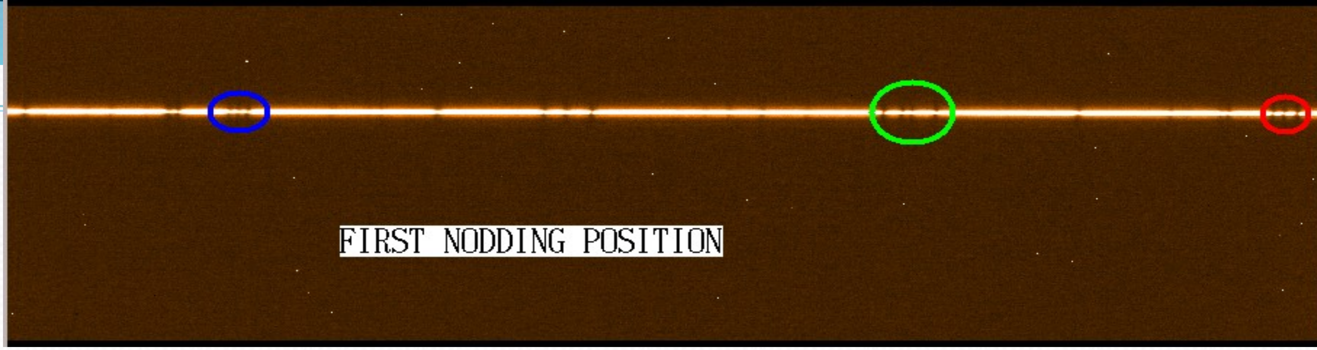
At short wavelengths the orders could overlap and affect detectors 1 and 4. CRIRES plus will not have this problem as it has a cross disperser.



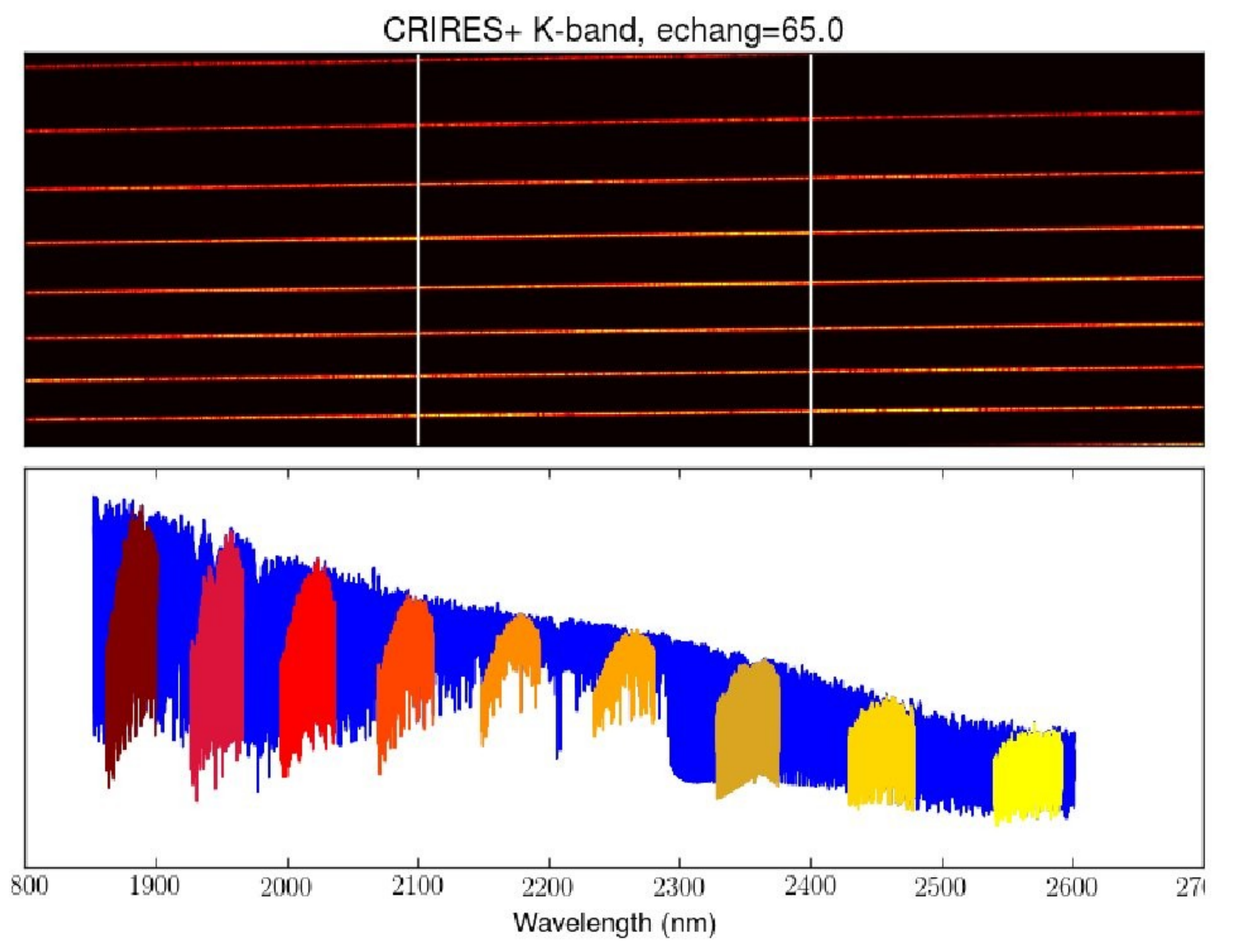


(Figures courtesy E. Lellouch)

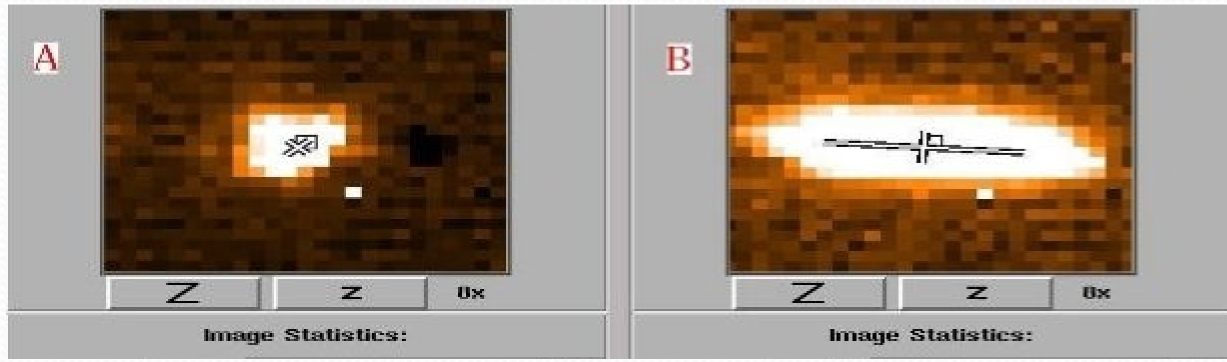
CRIRES issues: only one order was observed at a time.



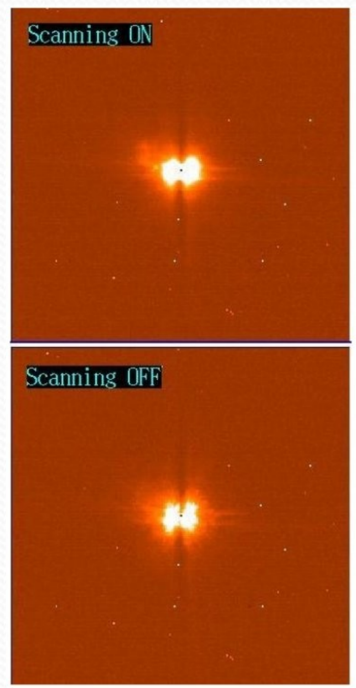
Fixed in CRIRES plus with the cross disperser (simulated data)

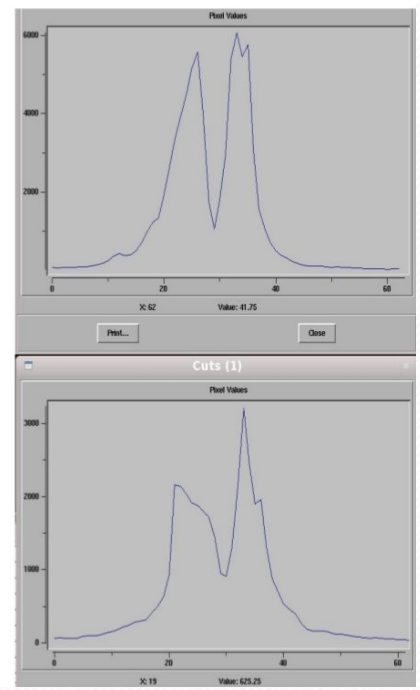


CRIRES issues: Limiting radial velocity precision



With CRIRES we were limited to a RV precison of about 5-10 m/s. It is hoped we may improve on this by rapid scanning (60 Hz) of the star across the slit using the field selector (Fig B) to have a more uniform photo centre (fill the slit), plus better calibration sources and bigger lambda coverage.





CRIRES issues: Pipeline

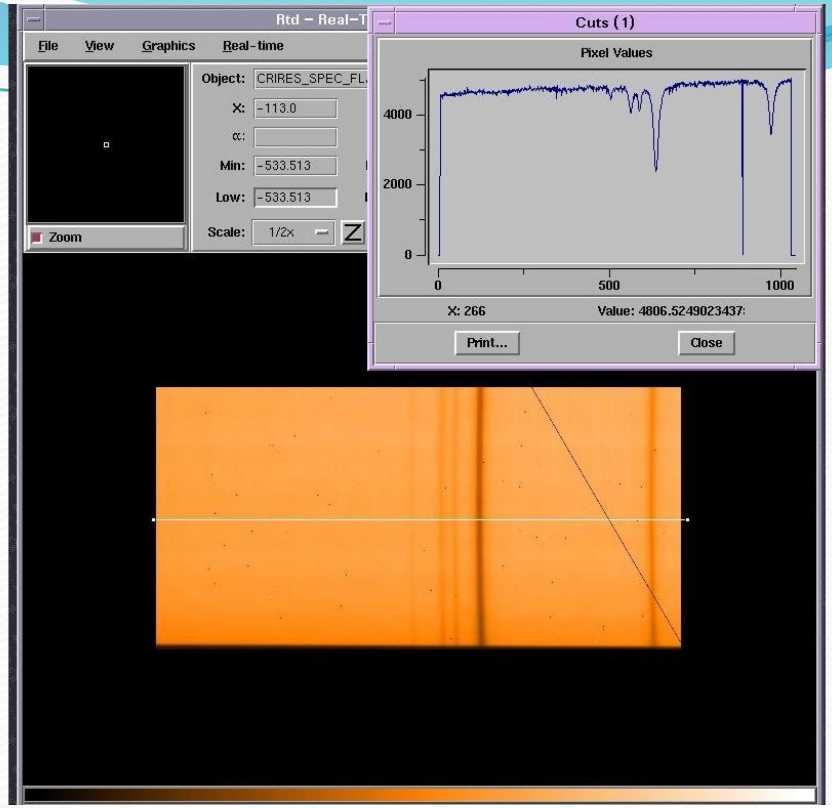
There were some pipeline issues e.g.

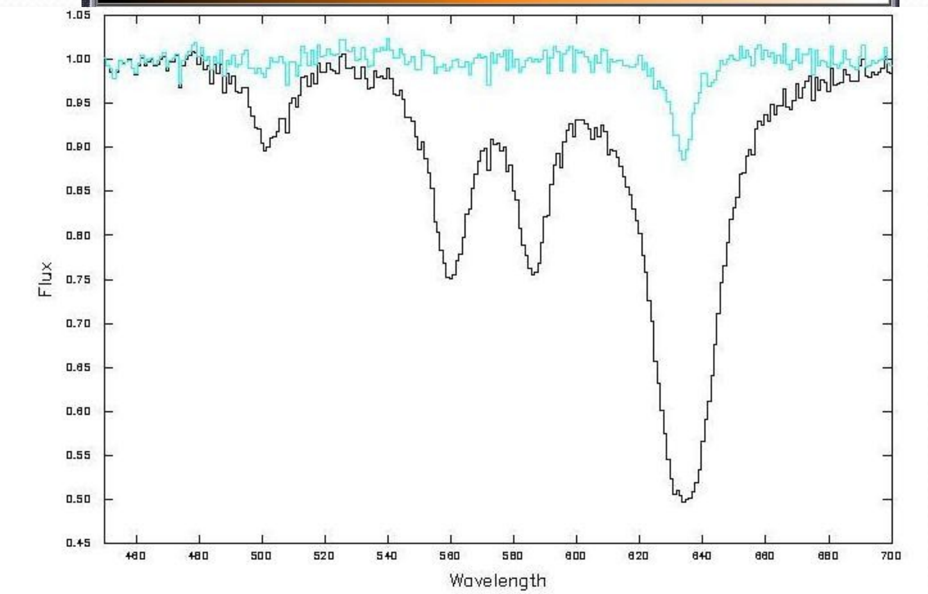
– Insufficient number of decimal places in wavelength atlas.
– Non-ideal tracing for low S/N spectra.
– Removal of residuals in the background.
– Windowing and generic offset support.
– Wavelength calibration supports optical distortion.
– Support for UNe calibration lamp.
– No reflex support.

Many of these were fixed by the pipeline developer.

CRIRES issues: Telluric lines

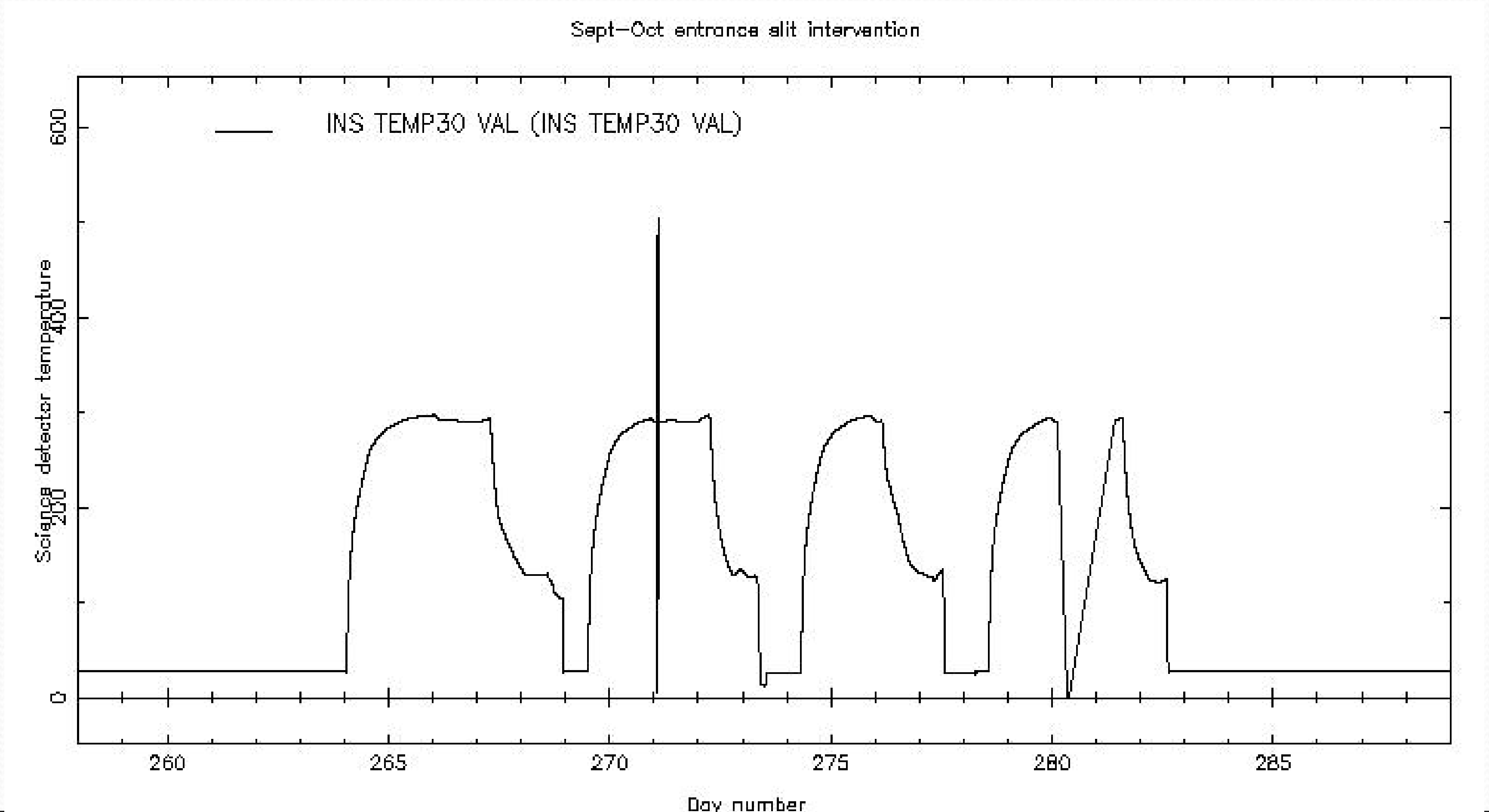
- Water vapour in the atmosphere causes many telluric features that have to be removed. Such features are sometimes present in calibration spectra taken using the instrument only.





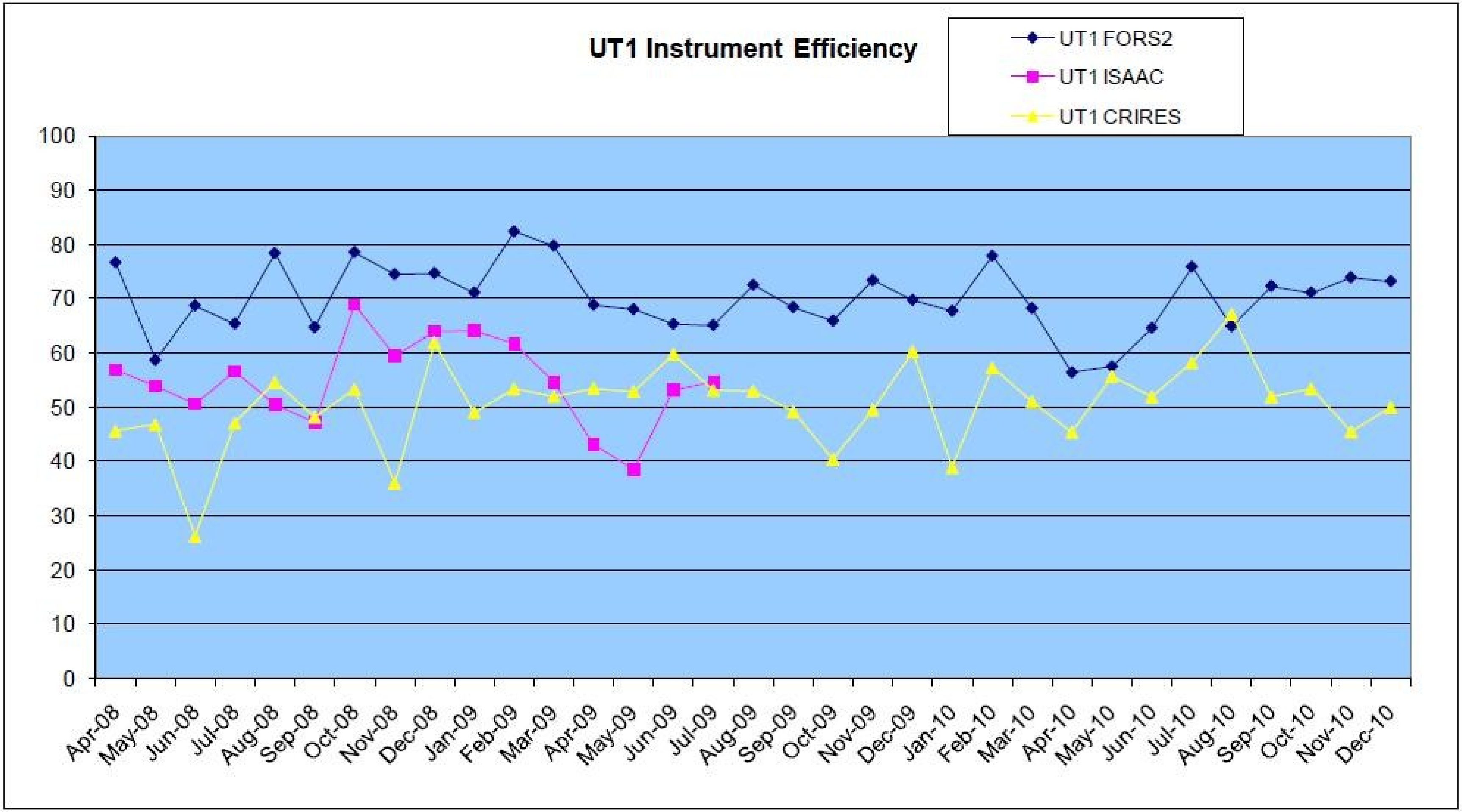
CRIRES issues: cooldown time

When interventions happen they were often long with multiple openings. Cooldown takes several days.



CRIRES issues: shutter open time

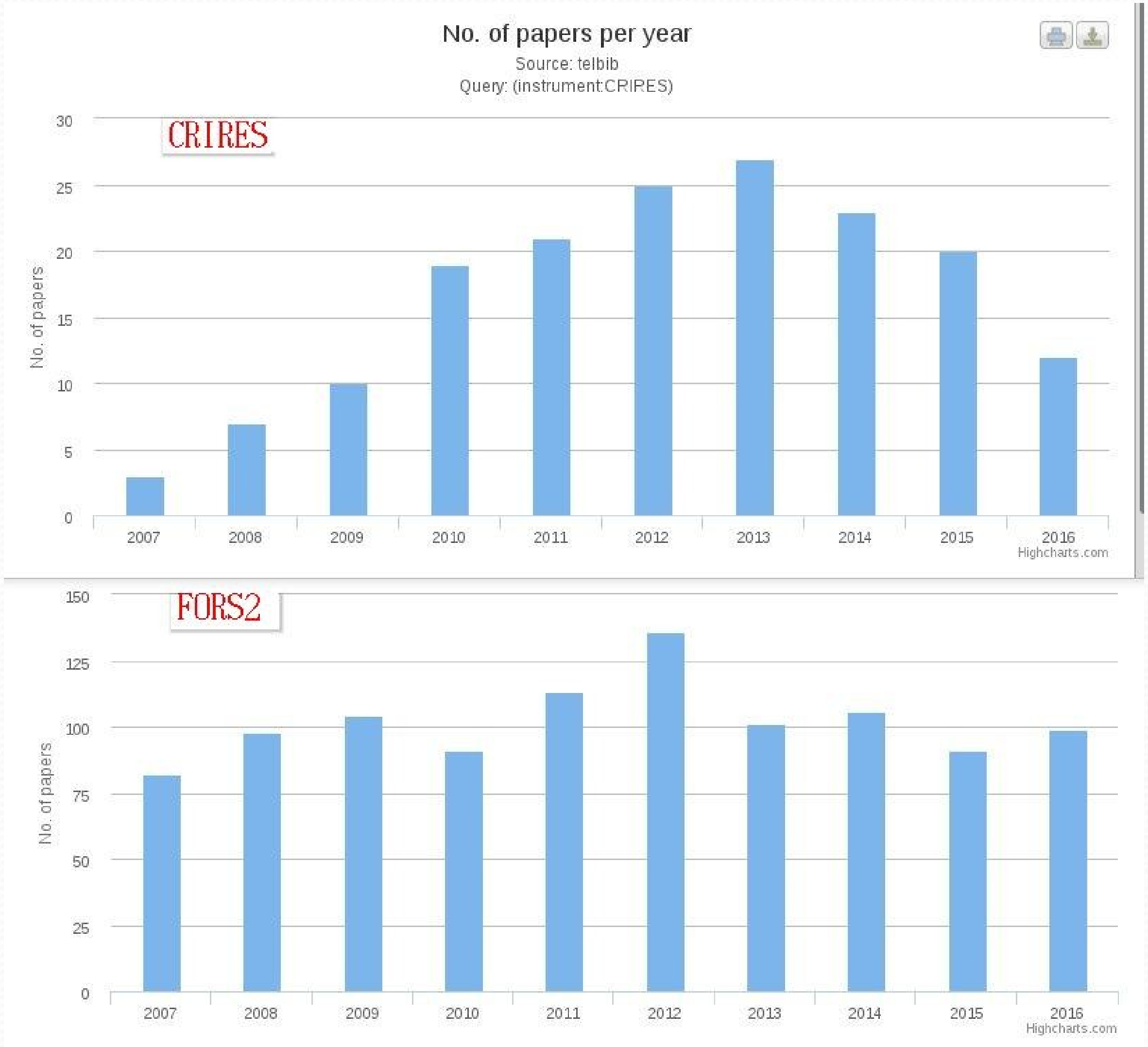
- The "shutter open" eff. for oCRIRES was typically only 50%, due to higher overheads in acquisition, nodding and typically short DITs (blue=FORS2, yellow=CRIRES). Likely will be similar in CRIRES+.



In spite of these issues, CRIRES still did a lot of science!

CRIRES paper count vs. time

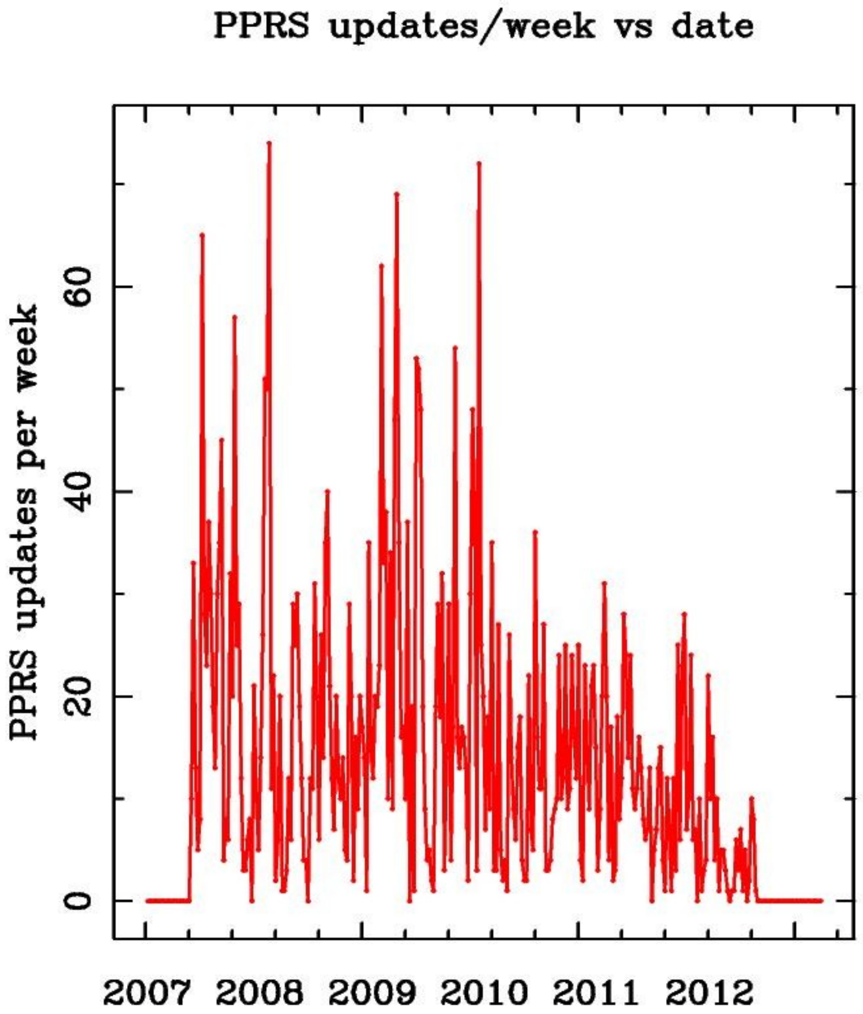
via telbib.eso.org

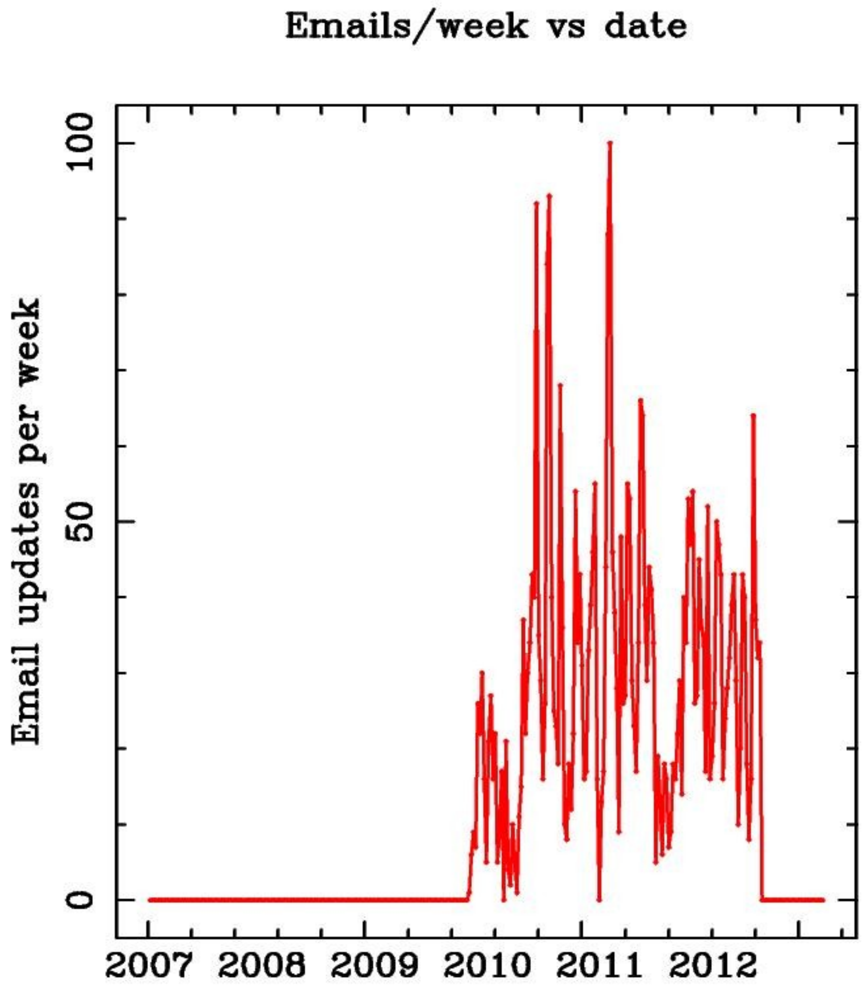


(Thanks to Maria Eugenia and Uta Grothkopf for link telbib.eso.org)

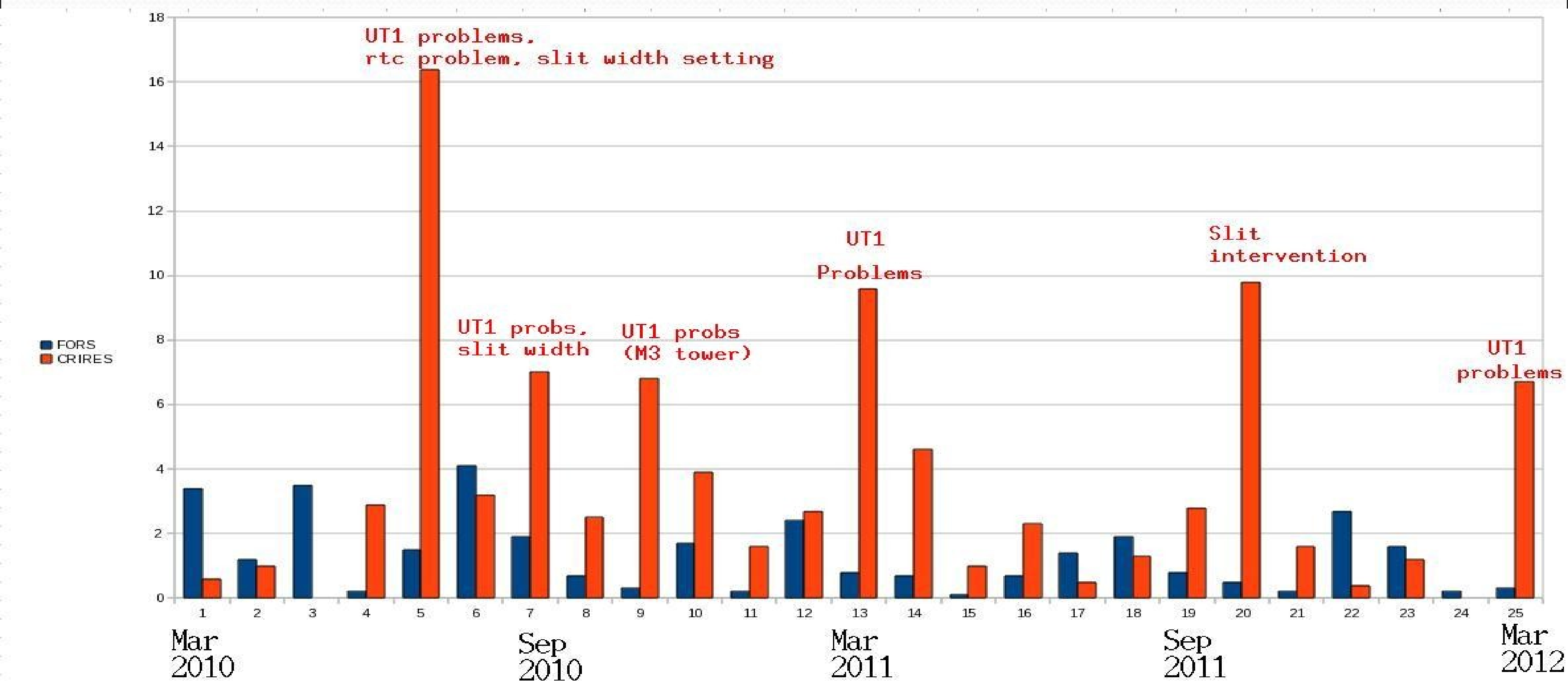
The End

CRIRES PPRSs and emails





CRIRES technical losses (%)



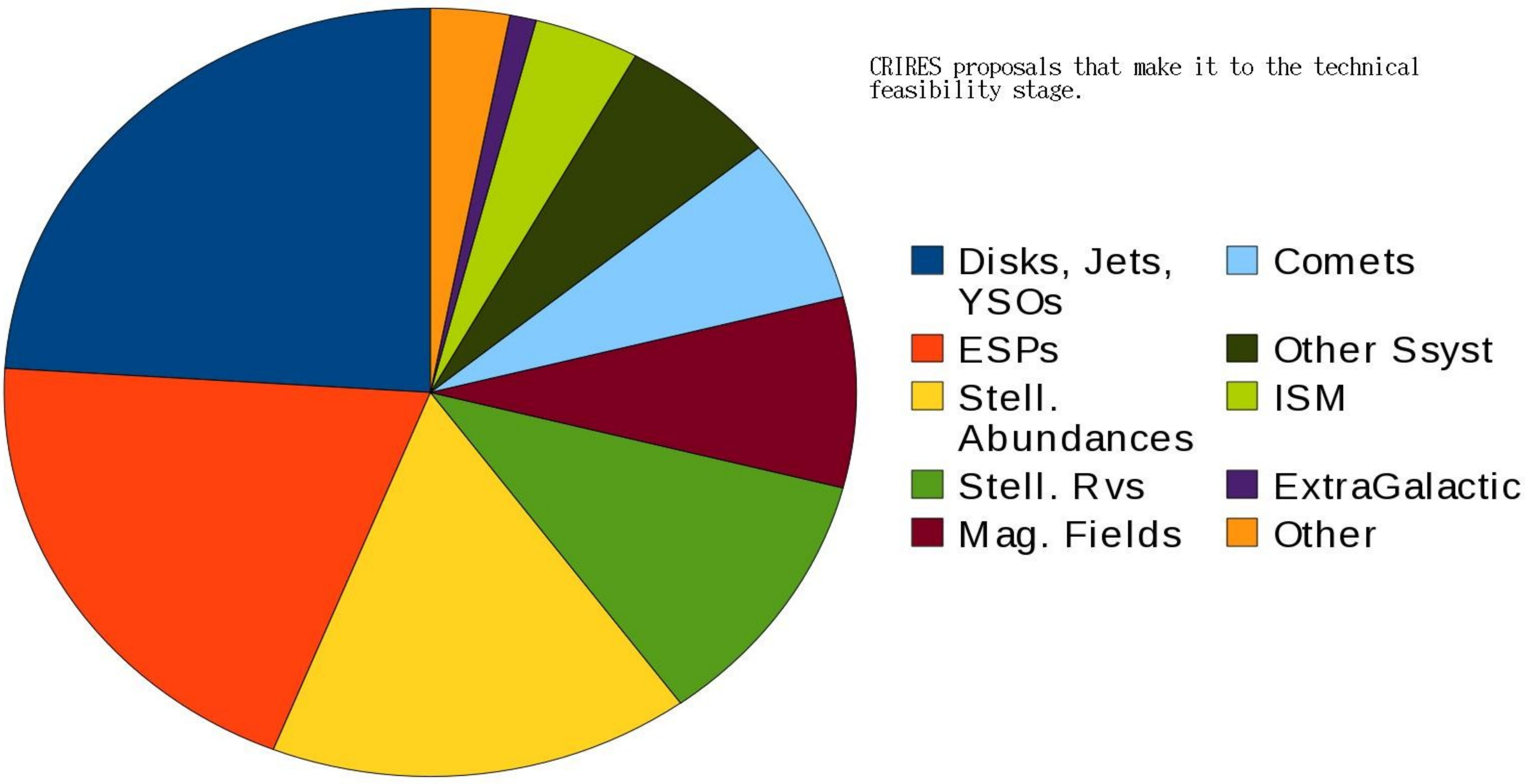
(Figure based on data from C. Dumas and S. Strunk)

CRIRES science

- Because CRIRES cannot go to very faint magnitudes, most science done with it tends to be in the Galactic domain.

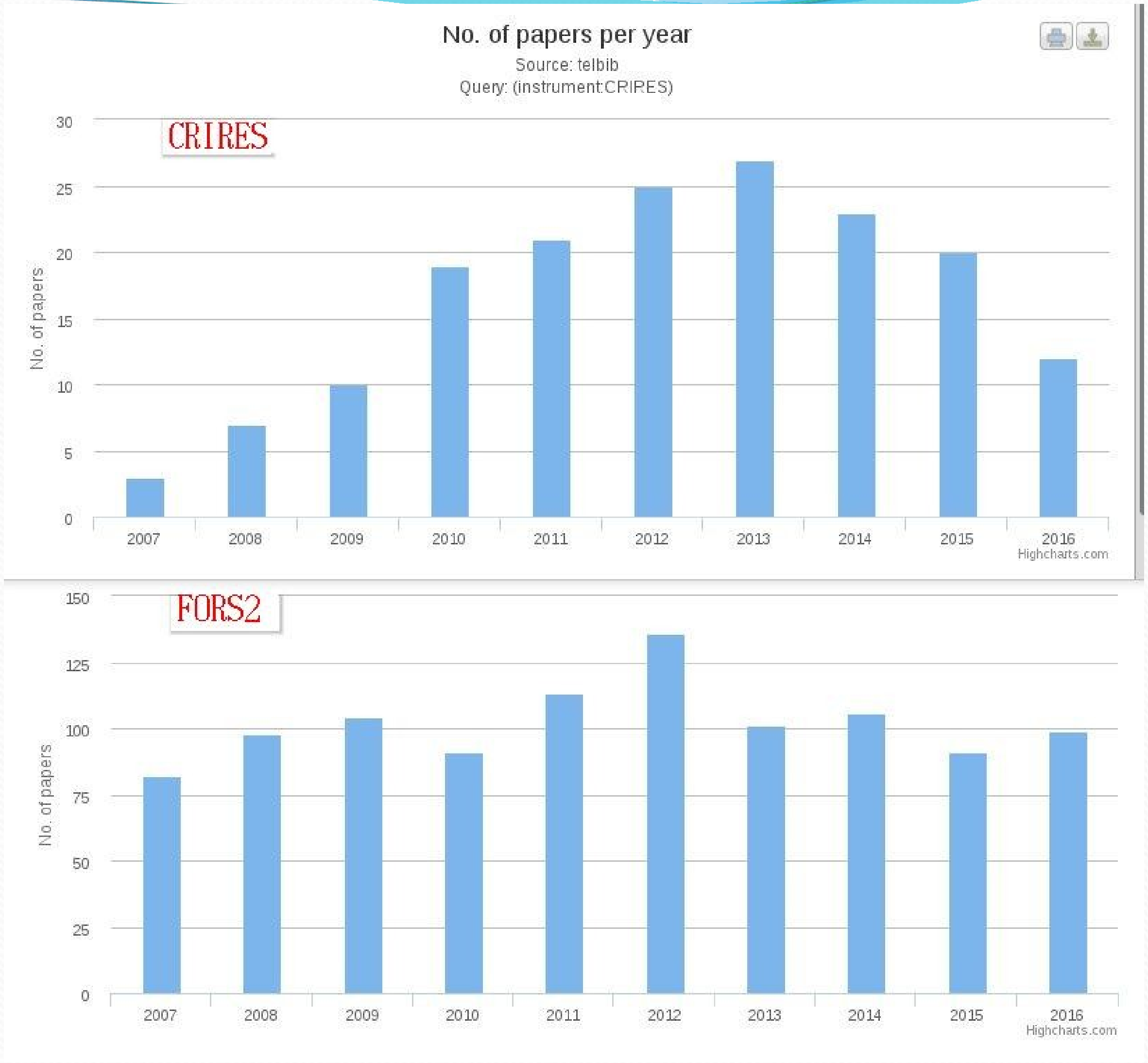
- You have to take a lot of care with the position of telluric lines from the Earth’s atmosphere and avoid them if possible by observing at another time of year, if lines from the gas-cell exist in your wavelength region etc etc

CRIRES science cases (2013)



CRIRES paper count vs. time

via telbib.eso.org



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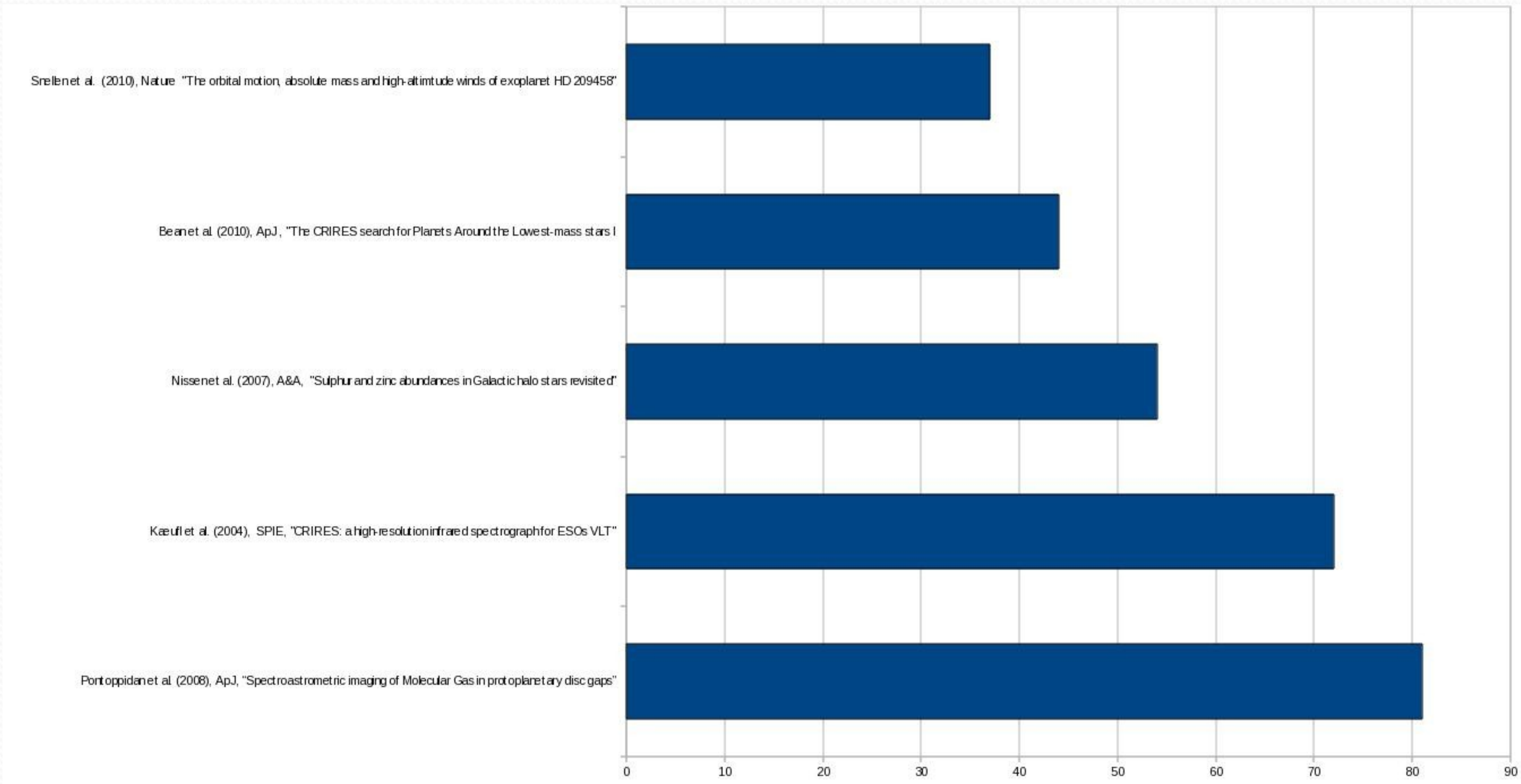
CRIRES highest-cited papers



(From ADS / eye testing services at no charge)

1) Methane and CO on Triton

- First observation since Voyager in 1989
- First observation of CO in its atmosphere
- Seasonal variability

Lellouch et a
(2010)

Also Mars…

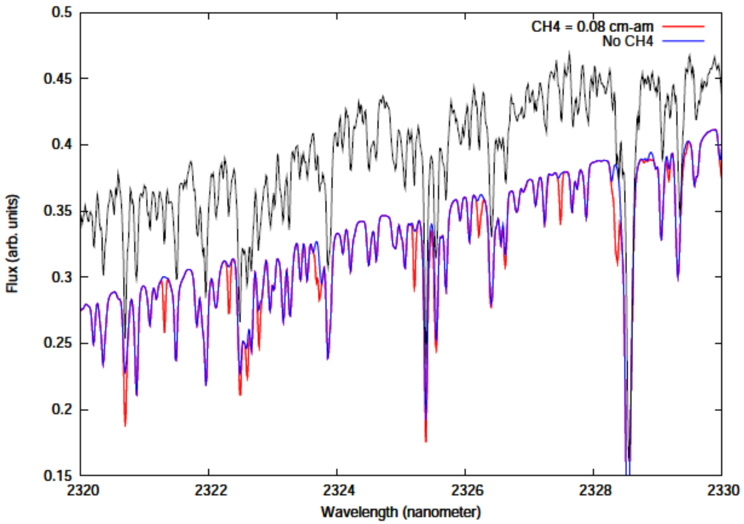


Fig. 1. Black: Triton spectrum at 2320 - 2330 nm observed by CRIRES/VLT. The spectral resolution is 60,000. Red and blue curves show synthetic spectra, including telluric and solar lines. Red: methane column density in Triton's atmosphere = 0.08 cm-am. Triton's thermal profile, based on Voyager measurements, is taken from Krasnopolsky (1993) and a Voyager-like vertical distribution is used for methane (Herbert and Sandel 1991, entrance profile). Blue: no methane. The continuum slope is due to the red wing of the $\nu_3 + \nu_4$ band due to solid methane. Here, as in Fig. 3, the vertical unit approximately represents the geometric albedo (but uncorrected for telluric and solar lines). Models are shifted vertically by -0.07 for clarity.

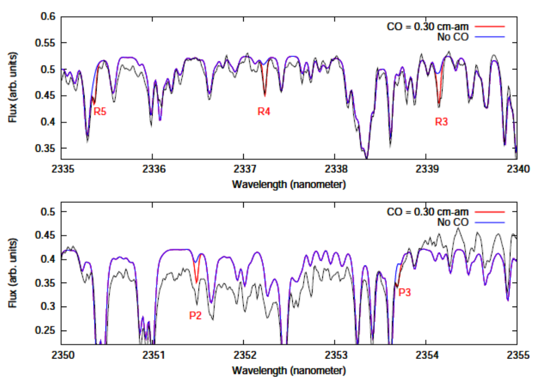
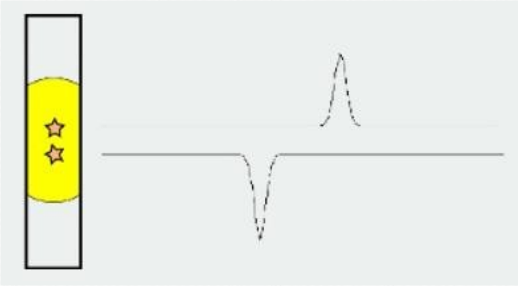
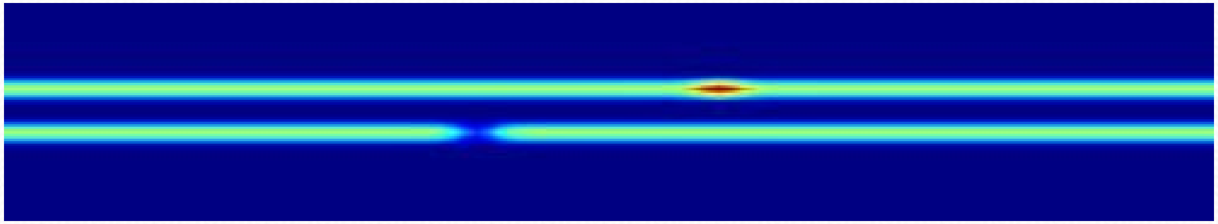


Fig. 3. Black: portions of the Triton spectrum at 2335 - 2340 nm and 2350-2355 nm. Five CO lines (R5, R4, R3, P2 and P3) are present in these spectral ranges. Red and blue curves show synthetic spectra, including telluric and solar lines, as well as Triton's methane. Red: CO column density in Triton's atmosphere = 0.30 cm-am. Blue: No CO. The mismatch in the "continuum" level over 2351-2354 nm is due to the absorption of the (2-0) band of CO ice (see e.g. Quirico et al. 1999, Grundy et al. 2010), not included in models.

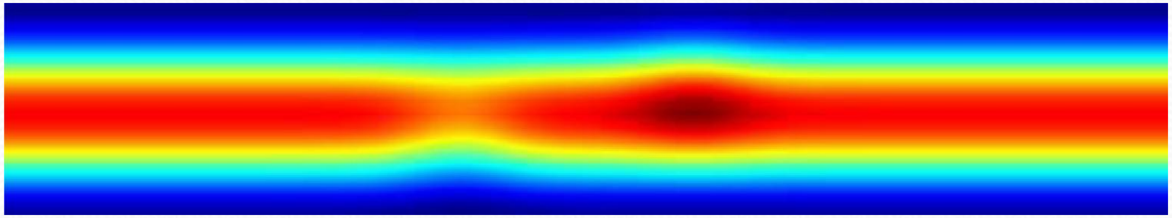
2) Spectro-astrometry (A)



Left image: imagine we observe two stars very close together on the sky (bottom star with absorption line, top star with an emission line. If we have perfect spatial resolution we would see one trace for each star (image below):

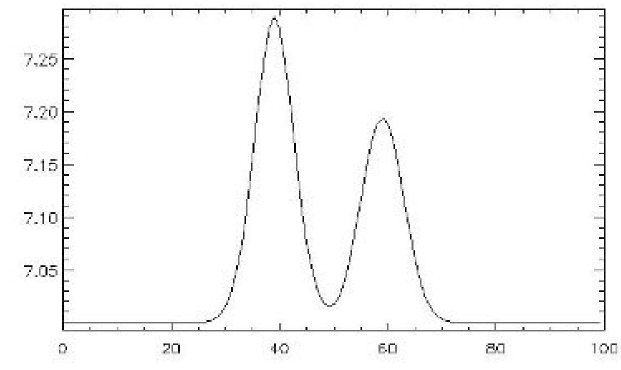


With the atmosphere we see a spectrum that is a “mix” of the two stellar spectra (image below):



If we take a cross-cut as a function of wavelength (right image), we can determine the CENTRE position of the trace very accurately and see that it moves. This is spectro-astrometry.

(Figures courtesy Ana-Lea Lesage)



2) Spectro-astrometry (B)

- Study CO gas at 4.7 microns at different slit position angles for protoplanetary discs.

- This technique can give PAs of inner disc to 2 degree accuracy and spatial resolutions 0.1-0.5 AU in this case.

Pontoppidan et al. (2008) – see next slide

Spectro-astrometry using CO

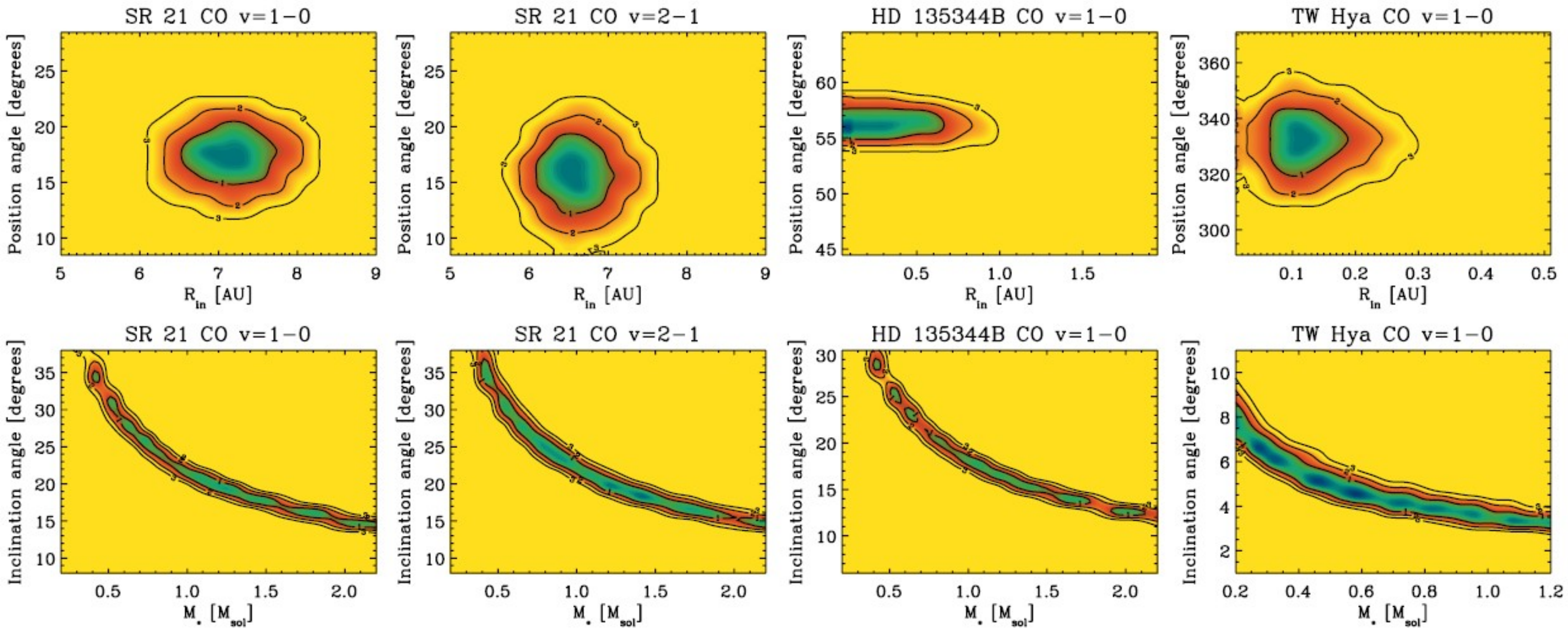
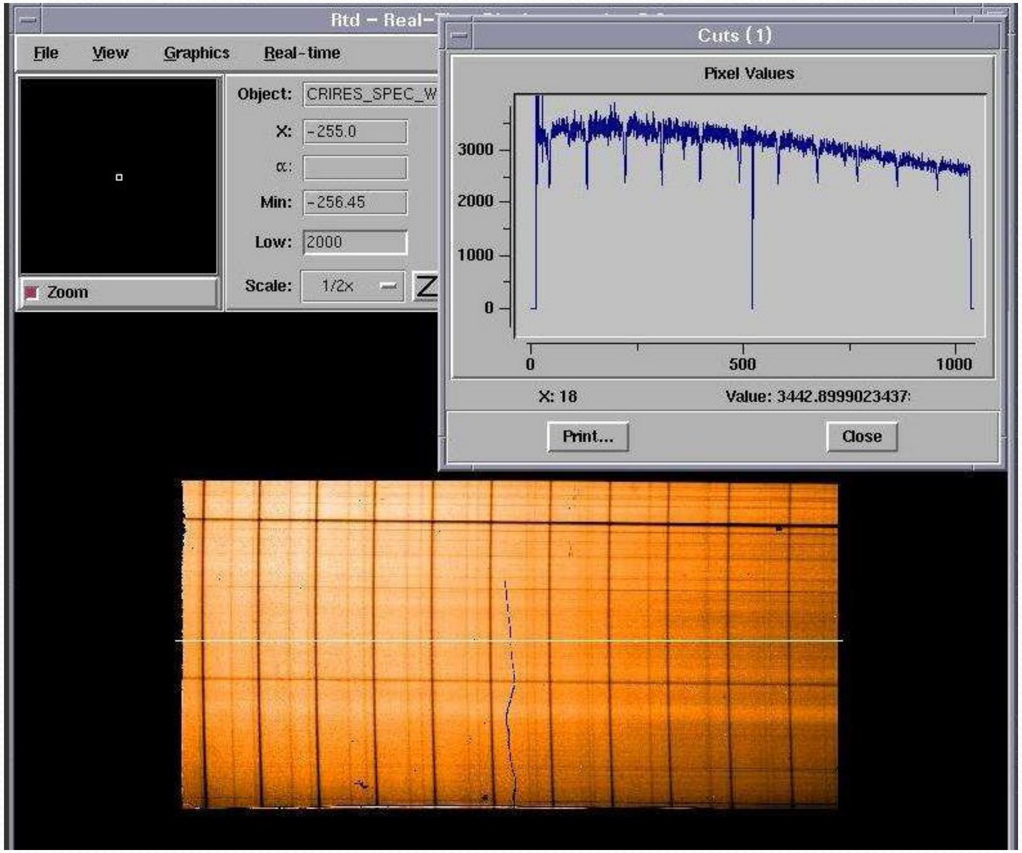


FIG. 3.—χ^2 surfaces for the best-fitting Keplerian disk models. The contours are at 68%, 95%, and 99% confidence levels, corresponding to 1, 2 and 3σ.

3) Radial velocities

- Partly because the temperature of the system is very stable, RV accuracies using CRIRES have got down <10 m/s level over long timescales (or <5 m/s over a week; Bean). One can either use NoAO with telluric and stellar lines or AO/NoAO



3) Radial velocity papers

- ‘TW Hya under CRIRES light: evidence against the presence of a hot Jupiter’ (Figueira et al. 2010; NoAO without gas cell)
- ‘The Proposed Giant Planet Orbiting VB 10 Does Not Exist’ (Bean et al. 2010; Ammonia gas cell).
- With CRIRES we can get down to better than 10 m/s.

Both papers above postulate that RV variations seen in

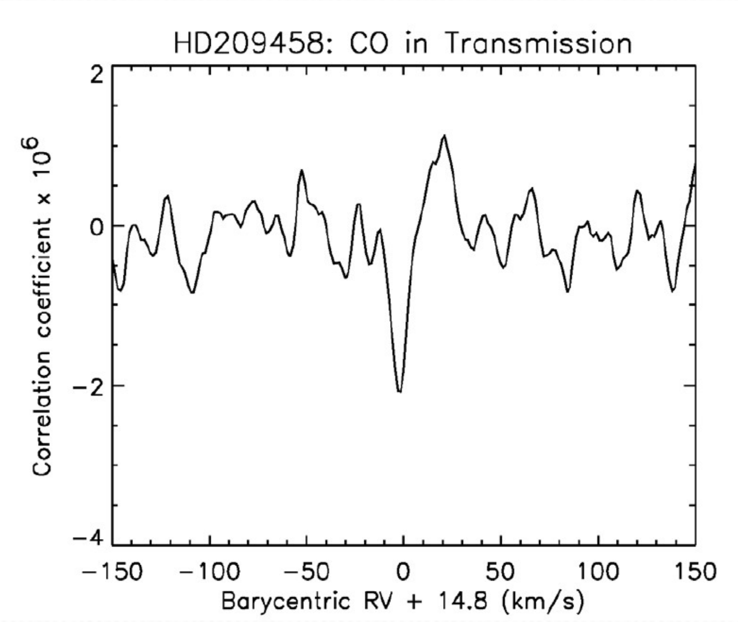
the optical are caused by star spots and not

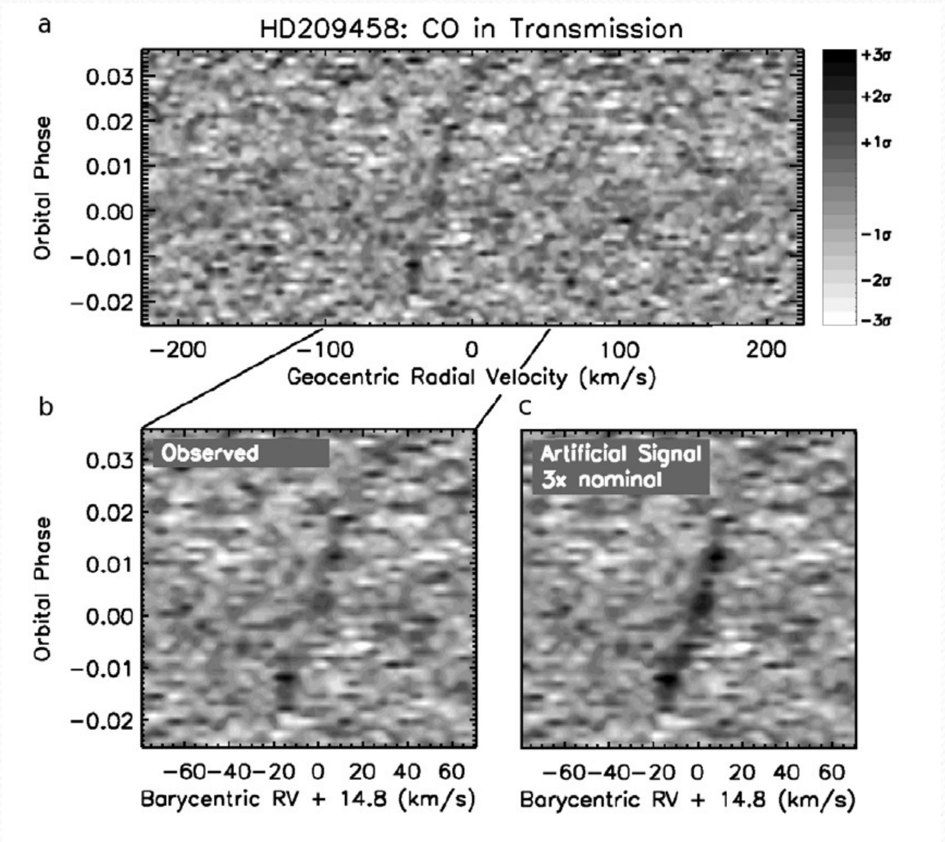
4) Exo planet atmospheres

- Long observing sequence of transiting system
- CO detected in emission (but really at the limit of what
  can be done!)
- A 2 km/s blue shift of CO signal with respect to the systemic velocity of the host star suggests the presence of a strong wind flowing from the irradiated dayside to the non-irradiated night side of the planet within the 0.01-0.1 mbar atmospheric pressure range.

Snellen et al. (2010)

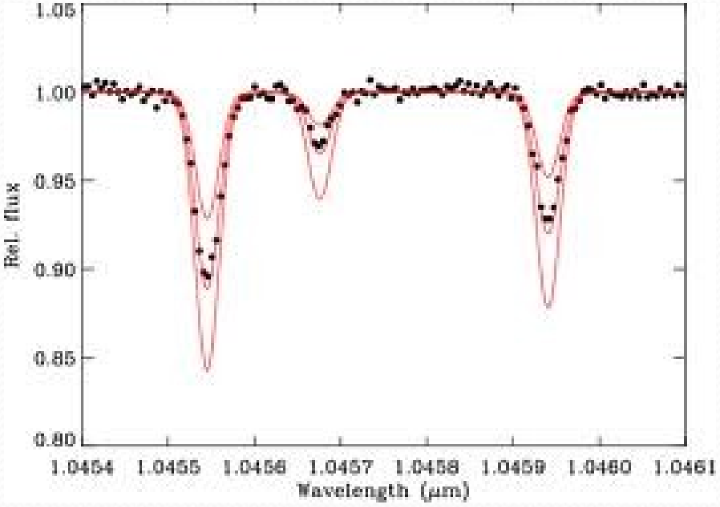
4) Exo planet atmospheres





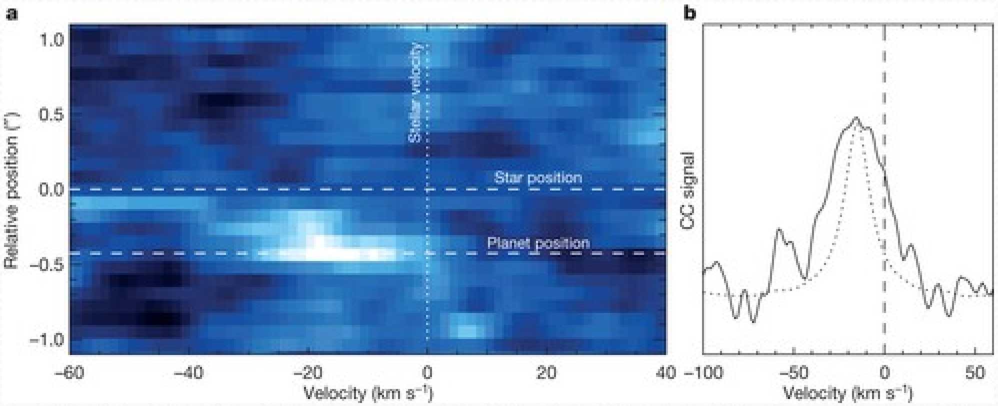
5) Stellar abundances

- Galactic abundance gradient of B-type stars (infrared towards GC better due to much less extinction).
- Sulphour abundance of metal-poor stars (Nissen et al):



6) Doppler imaging

Beta Pic – Snellen et al. (2014).



CRIRES IoT work

- Determination of how CRIRES works at low and high light levels (DIT*NDIT constant).
- See how the detectors react to over-saturation.
- Improve the pipline /write a data-reduction cookbook.
- Measure the position of the ThAr lines for the metrology – this will improve the ThAr repeatability and hence the wavelength calibration.
- Start thinking on how we could use CRIRES as an imager, at least save the SV images.
- Close loop on Jupiters Great Red Spot etc etc.
- In total 30+ mini-projects, see next slide:

CRIRES IoT work

CRIRES Projects

Highest-priority items are:

- Metrology
- SV camera characterisation
- Data reduction cookbook
- Windowed mode characterisation
- Linearity correction
- Data enhancement proposal

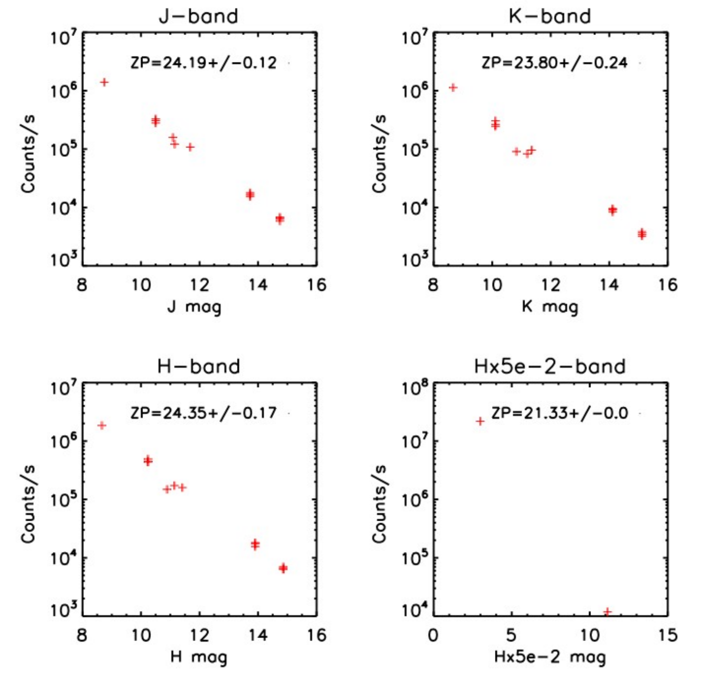
http://sciops.pl.eso.org/wiki/index.php/CRIRES_Projects

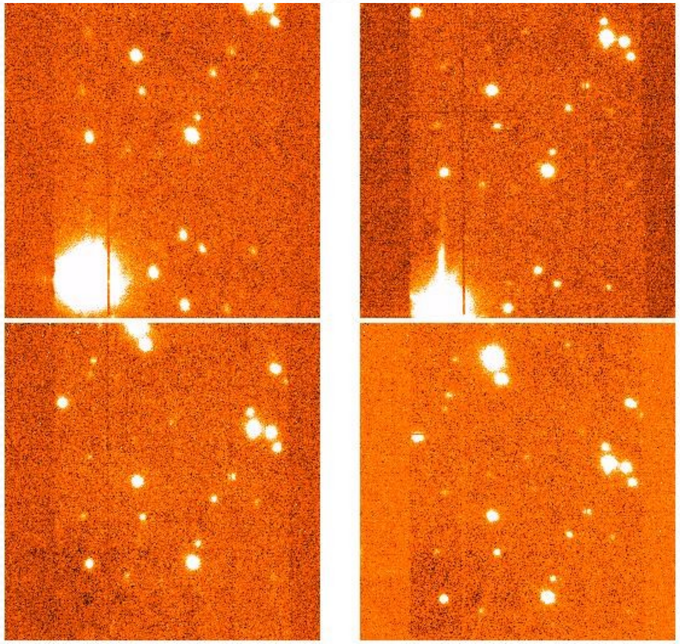
These have been chosen as high priority as they are all projects that have advanced somewhat.

Project	Responsible	Report location and comments	Status
Calibrations with upper lights on	JSm, JVa, UKa, JPi	http://sciops.pl.eso.org/ody5/team_only/CRIRES/docs/CRIRES_Calibrations_Upper_Lights.pdf - conclusion is that flat and wave calibrations are not possible at the moment with upper lights on	
Entrance slit replacement	JPi, UKa, JLi, JSm, NSl	http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/CRIRES_Slit1_Intervention_October_2011.pdf completed but under monitoring. Last checked April 15th 2012.	
Entrance slit repeatability	JSm, JVa	Under monitoring - last data taken 15th April 2012. PPRS to be written to take this image every day in calobBuild if not already done.	
ETC verification	JSm, MHi, JVi		
ETC with windowed mode	JSm, MHi, JVi	Waiting on report for Windowed mode characterisation	
Data reduction cookbook	JSm, EVa	In progress - last worked on April 2012 (script to reduce data written). Sent around to a subset of IoT April 20th.	
Data enhancement proposal	YJu, JSm, ASm, BWo	Deadline June 2012. To be worked on in JSm April turno. Will go ahead at this point with or without firm results from the UNe lamp.	
FITS headers FWHMLIN FWHMLINOBS	ASm		
Flatfield stability with new slit	JSm, BWo	Much improved stability. Possibly reduce calibration frequency in P90.	Completed
Flatfield absorption features	JSm	Visitors were asking what the absorption features on the flatfields were and how stable they were. Features are just water vapour absorption and their strength correlates well with humidity measured on the ASM. Report written and placed here: http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/WaterVapourInFlats.pdf - user manual has been updated for phase II P90	Complete
Functional check at startup	JSm, NSl	PPRS-22377. Last updated May 2011.	
Galactic centre observations with AO	ASm, HBo, RSi	Data taken and sent to Jerome for analysis. Will be part of SV camera characterisation	Completed
Gas cell (new model)	FKe, JSm	http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/CRIRESH-BandCalibrationJustification.doc - input asked from FKe what needed for Paranal for technical tests at start of April 2012.	
Linearity correction	SGu, ASm, JSm	Some on-sky data and flatfields taken with and without the gas cell.	
MACAO AO scanning with field selector	JSm, JPa, JOn, JVa	Daytme and night-time tests taken January 2012. Report written; waiting for feedback from Pedro Figuera: http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/AO_Scanning.pdf	
MACAO memrane to ROC a0 average	NSl, JOn, JVa, JSm	Night-astronomers made aware of Membrane to ROC changes by PSO. CCB-0000114 written and waiting implementation.	
MACAO interaction matrices	JOn, FGo, JPa	All IMs have been sent to Jerome who will analyse them in parallel with Jared to see how they have evolved with time.	
MACAO membrane scan	JOn, FGo	Memo written by Jared. Any other action neeed?	
MACAO skipping opening/close shutter	JPa, JOn, JVa, JSm	http://sciops.pl.eso.org/ody5/team_only/CRIRES/docs/ND_Wheel_Data_Reduction.doc - tests indicate that skipping the open/close shutter in the acquisition is a good idea. It is pending to see if we go ahead in implementing this in CRIRES to improve shutter life and slightly decrease overheads. Will be a Garching-based initiative to change the RTC software.	
MACAO Sthrell Ratio	GCa, JSm	Rationalise the calculation of the Sthrell Ratio on CRIRES, NACO, SINFONI, VLTI	
Maintenance plan	JPi, JSm	http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/CRIRES_Maintenance_Plan_PLA5027_1_1_FINAL.pdf	
Metrology	NSl, JPi, JSm, ASm	Ticket last updated January 2012 by Nicolas and Jonathan.	
OH atlas (DGDF)	DAs, ASm, MRo, CLi, JSm	DGDF again aproved for 2012 for Daniel to work on this.	
Operations manual	JSm, ASm	http://www.eso.org/paranal/sciops/team_only/CRIRES/documents/VLT-MAN-ESO-14500-4725_v89.pdf - updated in March 2012 as the slit was replaced and radiometer now exists in ASM	Completed
Physical Model	PBa, JSm, YJu, BWo	On-going to take physical model data and include in pipeline.	
Polarimitry	UKa, SGu, JSm, ASm	Polarimiter slide inserted and tested in January 2012 by Ulli and Sylvain. Pending is the report from them.	
Radial velocity stability	???	Volounteer needed to reduce all the RV data we have taken.	
Radiometer to plan observations	MVa, FKe	Incorporated in ASM. Tickets sent to UT1 group to let them know how to use it. In use.	Completed
Remnant duration after saturation	JSm, ASm	http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/CRIRES_Saturation_Remnants.pdf	Completed
RTC data saving as on SINFONI	FGo		
Scattered light via OH	UKa, JSm	Data taken sent to UKa for analysis	
Sky model for tellurics (Austrian IK)	ASm, UKa, BWo		
Survival Guide	KAu, JSm	Guide written, pending JSm to get document number	
SV camera characterisation	MRo, JSm, JPa	Slit viewer characterisation. Deadline end of June 2012	
Technical templates for CRIRES	NSl, JSm		
Telluric check script	FSe, MRo, JSm	CRIRES Programmes that do/do not need tellurics	Completed
UNe lamp	UKa, FKe, JSm, ASm, JVa	Lamp inserted in January 2012. Further tests needed.	
Wavecal with 0.2 and 0.4" slit	JSm, BWo	The conclusion is that wavelength calibration with a 0.2 or 0.4" slit gives reasonable results. We will offer attached calibrations with both slit widths in P90. Manual updated.	Completed
Windowed mode characterisation	SGu, JSm	Darks and flats taken with both readout mode. Results presented by Sylvain in: http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/Darks_Normal_Readout_Mode.pdf http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/Darks_Windowed_Readout_Mode.pdf http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/Flat_Ratio_Windowed_Normal_x.pdf http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/Flat_Ratio_Windowed_Normal_y.pdf Some observations taken with a 2.0" slit in windowed and non-windowed readout mode. These were not useful and we will have to repeat, perhaps with the pinhole. Very rough draft of what we have done so far written here: http://sciops.pl.eso.org/ody5/team_only/CRIRES/documents/Reports/CRIRES_Normal_And_Windowed_Mode_Comparison.pdf	

CRIRES IoT work example (1)

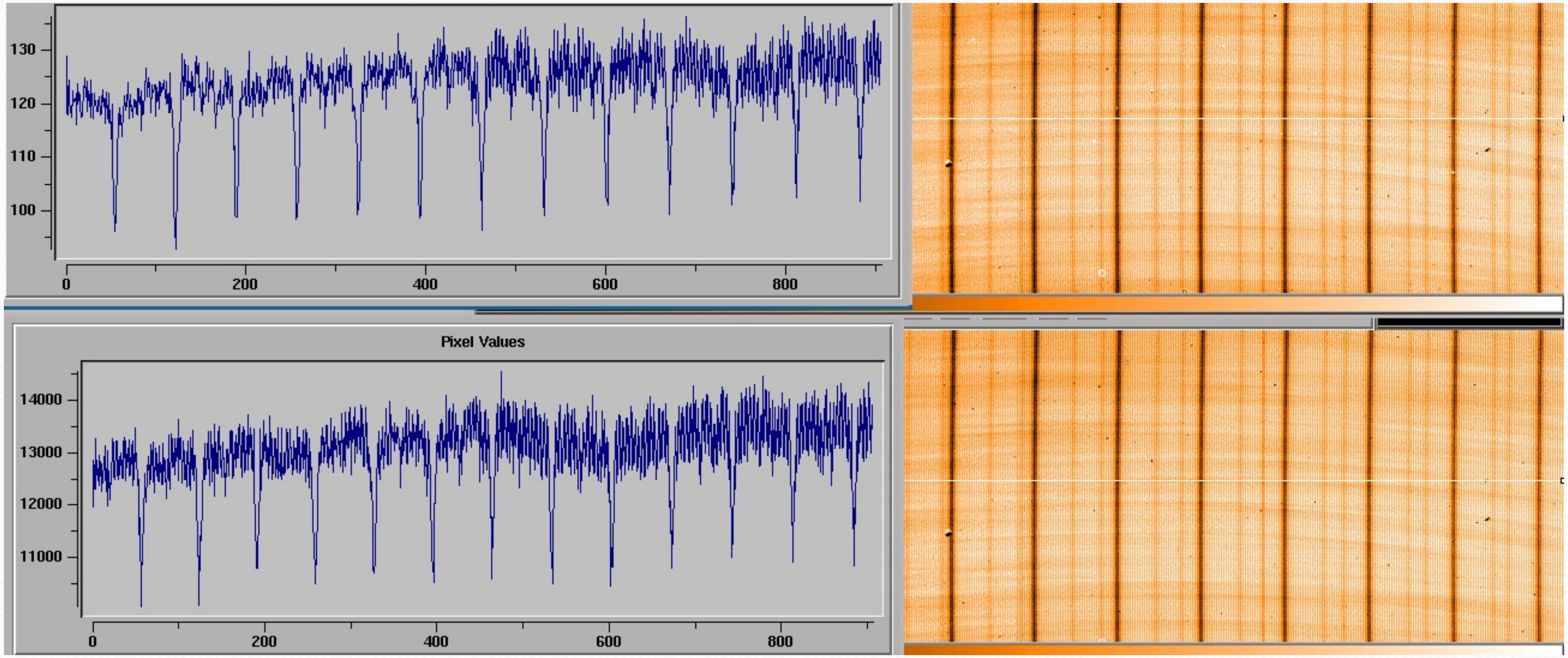
- Determine the zero-point of the CRIRES slit viewer camera, compare with NACO and determine the Sthrell ratio (Myriam, Jerome, Jonathan).
- Rediscover the Southern Cross.





CRIRES IoT work example (2)

- Determine how CRIRES and its pipeline acts at low and high count levels (Jonathan, Alain, Sylvain).
- Use the gas-cell and take observations of different DITs but with the same DITxNDIT

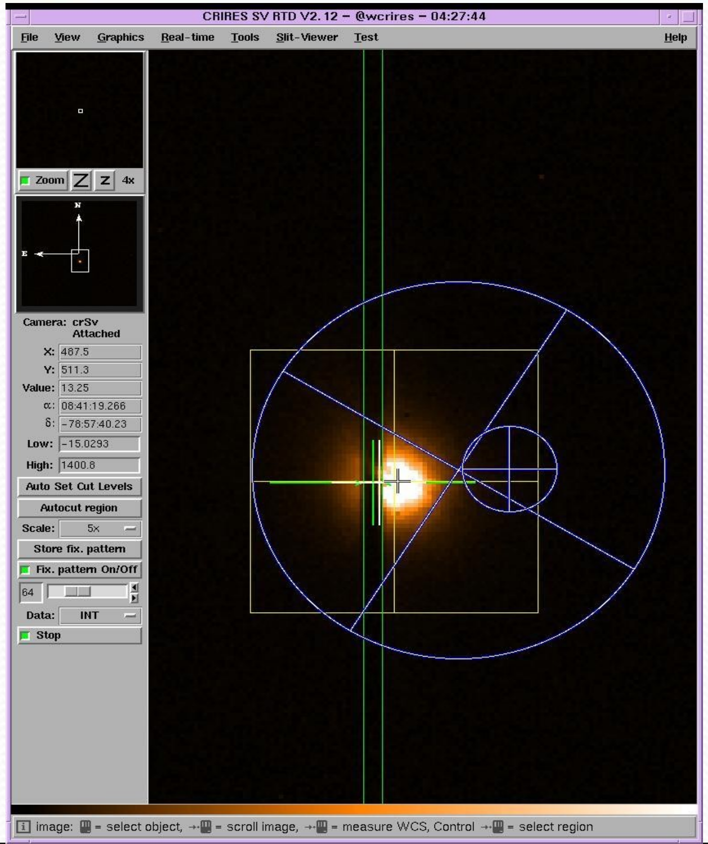


oCRIRES Detectors

- CRIRES used an array of four Aladdin IR detectors (spectrometer) (4096x512), two readout modes.

- We use another IR detector for acquisition and secondary guiding (slit viewer camera):

- Note that here the entrance slit is shown in green and the light from the star is actually passing through the slit.



Really the End