Know your SPIRou data!

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You've got some SPIRou data?

- **In 2019A and 2019B, SPIRou is the most requested CFHT instrument.**
- **Lots of PI targets have been observed since February**
- **You want to get started writing papers... but you want to know what the data will looks like.**

The Grand Plan

- **PIs will be provided science-ready data through the CADC archive**
- **The data package includes a number of intermediate**
  - **Single spectrum (all orders merged) from 0.98-2.45μm, CCF and polarization products**
  - **All (known) instrumental effects are removed**
  - **Relevant intermediate products are provided**
  - **Raw and really raw frames are provided**
- **Calibrated data will be re-processed frequently as the DRS improves**
  - **PI-friendly description of the updates on the SPIRou website**
  - **Don't panic when your data is re-released…**

r.fits

[ramp]

- **4096x4096xN**
  - **These are huge files (up to a few Gb each)!**
- **Individual images taken every 5.52s; used to compute the per-pixel time-derivative of flux**
- **The ramp is generally *not saved* by IR instruments**
  - **Not saved in WIRCam**
  - **We save these frames in the hope of improving the per-frame filtering of data in the future**

r.fits

[ramp]

- **Accumulation of signal for a bright A star over 56 frames**
- **Middle of *H* band only**

o.fits

[object]

- Ext 1: The 'slope' image, this is the closest analog to a CCD image
- Ext 2: Intercept of the slope. This is more or less the equivalent of a bias. *Mostly for engineering*.
- Ext 3: Formal error on the slope. To be used for pixel quality assessment.
- Ext 4: Number of unsaturated readouts (normally equal to Nread). To be used for pixel quality assessment.

o.fits

[object]

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e.fits

[extracted]

- **As FITS images:**
- **Ext 1-4: AB, A, B and C extracted spectra, 4088x49 pixels**
- **Ext 5-8: AB, A, B and C wavelength maps, 4088x49 pixels**
- **Ext 9-12: AB, A, B and C blaze maps, 4088x49 pixels**
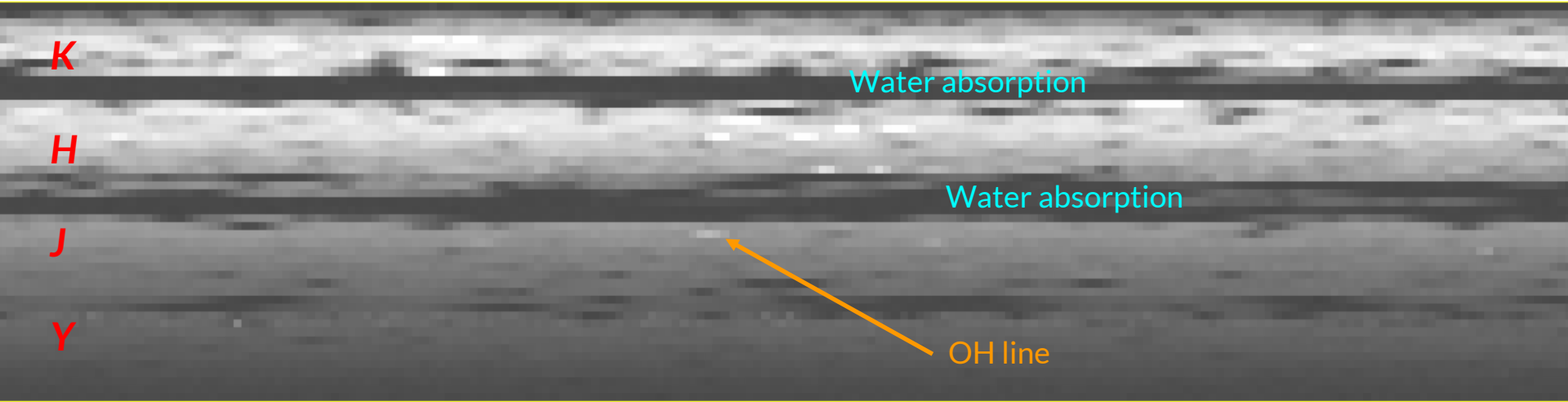
s.fits

- **Stitched spectrum over the entire 0.98-2.45μm domain**
  - **As FITS binary tables**
  - **Extensions for AB, A, B and C fibre configurations**
- **No discontinuity at the edges of order**
  - **Blaze-weighted mean of overlapping orders**
  - **Tapered weight fall-off at the end redder orders**
  - **By construction, cannot create artifacts smaller than 200 km/s**

s.fits

- **Comes into two flavours**
  - **Uniform in wavelength spacing (0.05 nm/pixel)**
  - **Uniform in velocity space (1 km/s/pixel)**
- **Convenient for cross-correlation and convolution over the entire domain**
- **Provided without telluric correction for AB, A, B and C**
- **Provided with telluric correction for AB**
  - **Deep water bands are filled with NaNs**
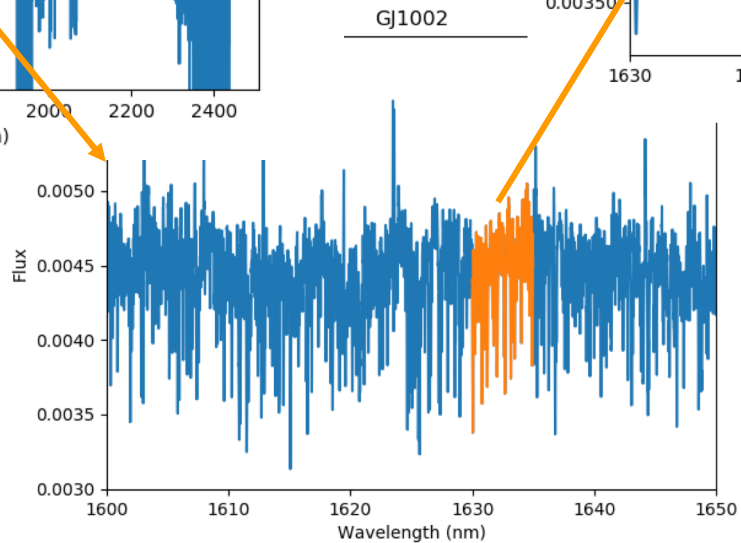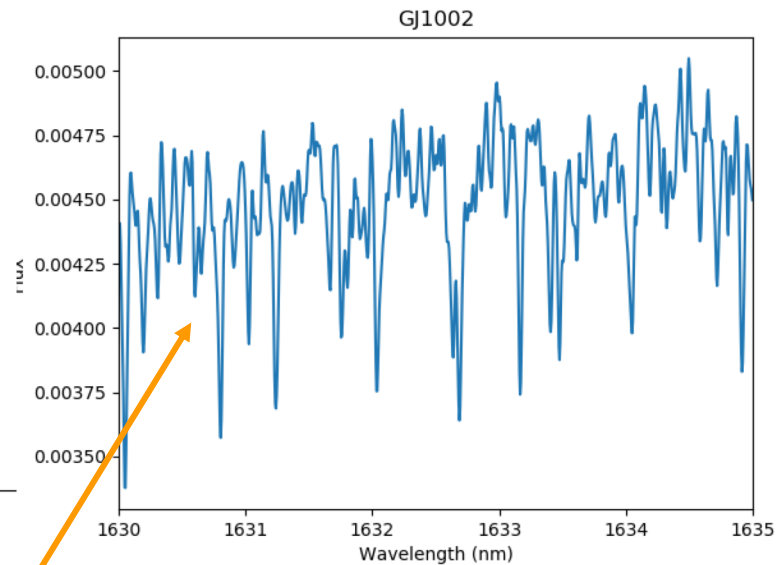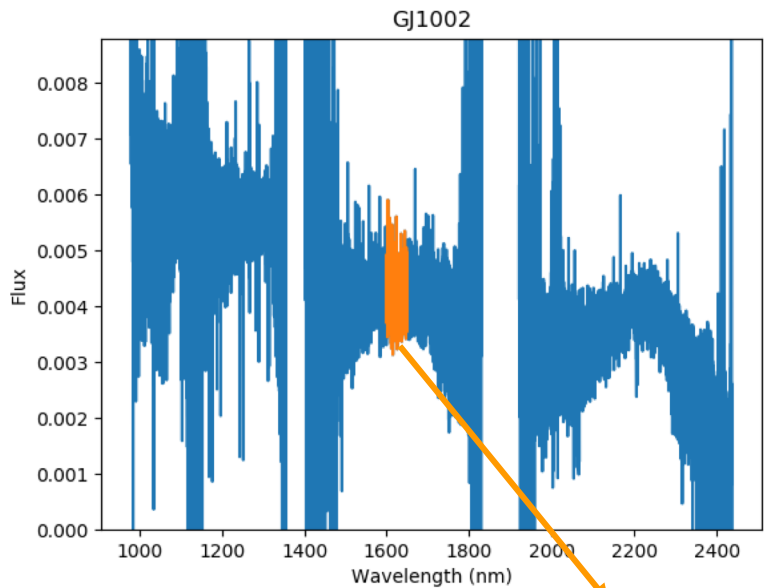
- **A single *s.fits* file provides an impressive amount of information!**

p.fits

[polarimetry]

- **Only available for full polarimetric sequences**
- **Similar to e.fits in format: 4088x49 as a FITS image**
  - **Polarized spectrum and corresponding errors**
  - **Intensity spectrum and corresponding errors**
  - **Null spectrum**
  - **Blaze and wavelength spectra**

v.fits

[velocity]

- **The cross-correlation function of RV data with the CC mask**
  - **CCF line lists are expected to evolve**
    - **Ultimately one per spectral sub-type**
- **Think of it as the mean line profile**
  - **49+1 CCF profiles**

Telluric subtraction
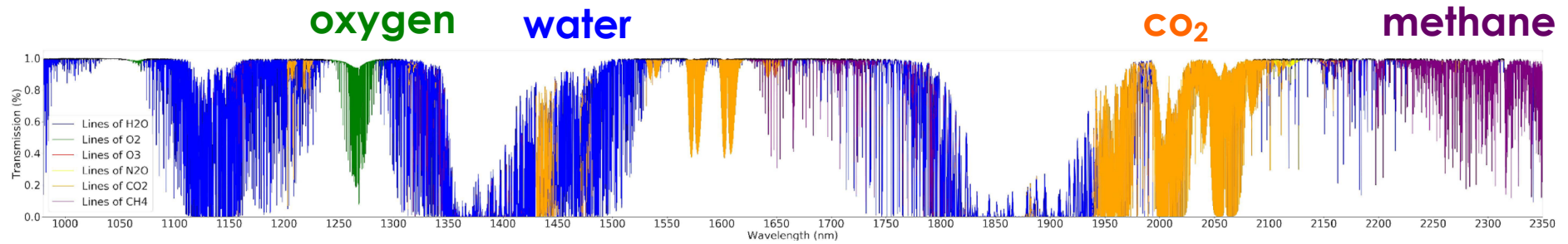
Telluric subtraction

- **Telluric lines are all over the place in the near-infrared**
- **The DRS provides telluric-subtracted spectra**
- **You _must_ check the level of absorption at your favorite wavelength before interpreting the data!**
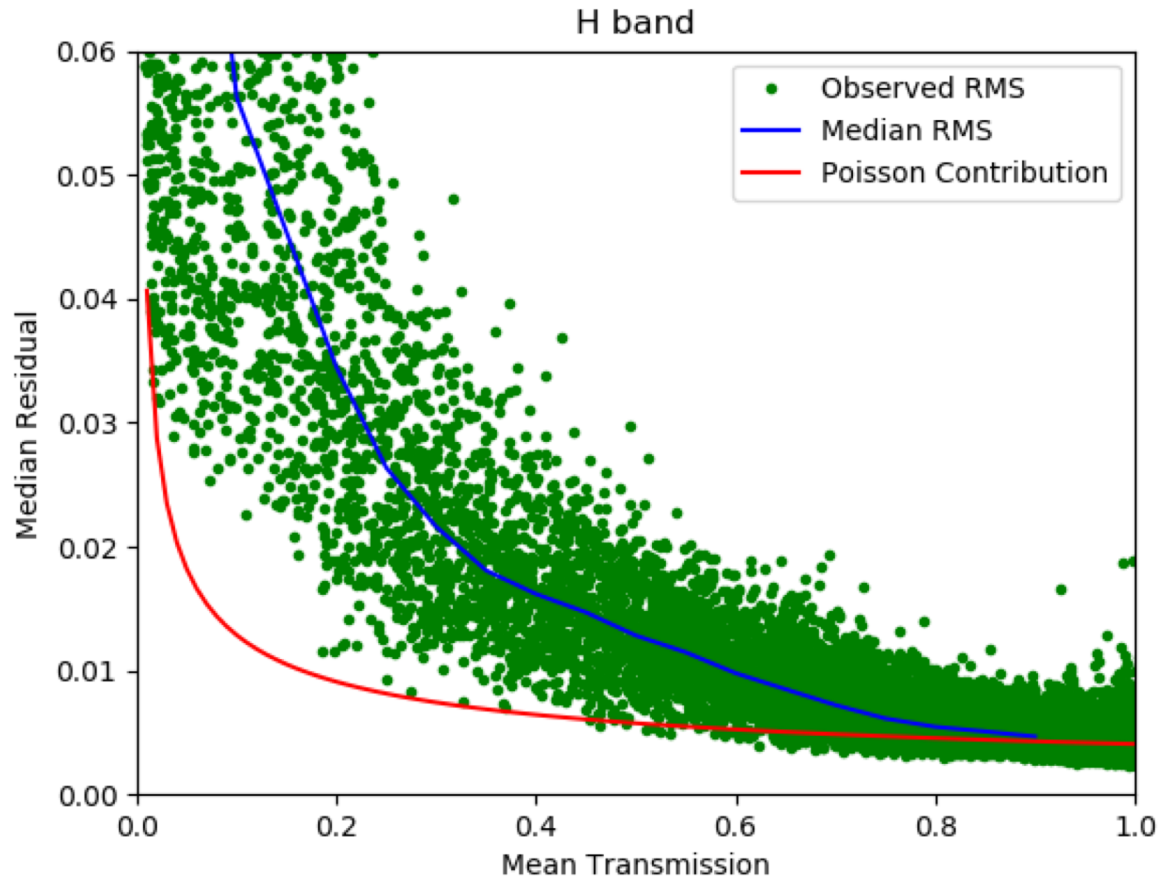
Telluric subtraction

- **Observe ~2 hot bright rapidly rotating hot stars every night**
- **Construct a library of line-of-sight absorbers**
- **Subtract telluric absorption from all science data**
- **… does it work?**
  - **Yes, but it comes with some limitations**

Pa Beta, betSer

Residuals

H band
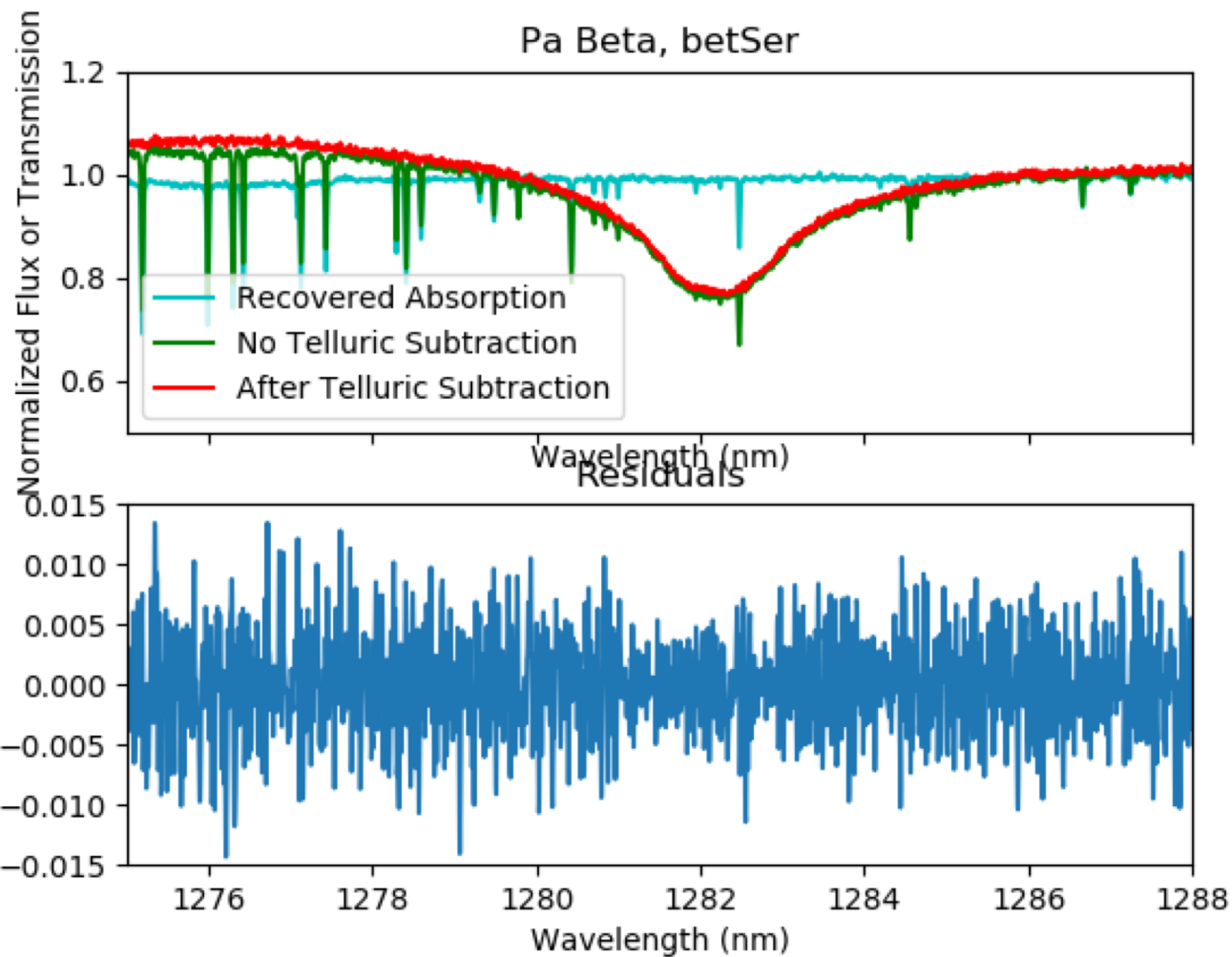
- **Telluric** **absorption residuals increase slowly with absorption**
- **In a perfect world, one would only get an increased Poisson noise due to lower transmission**

H band
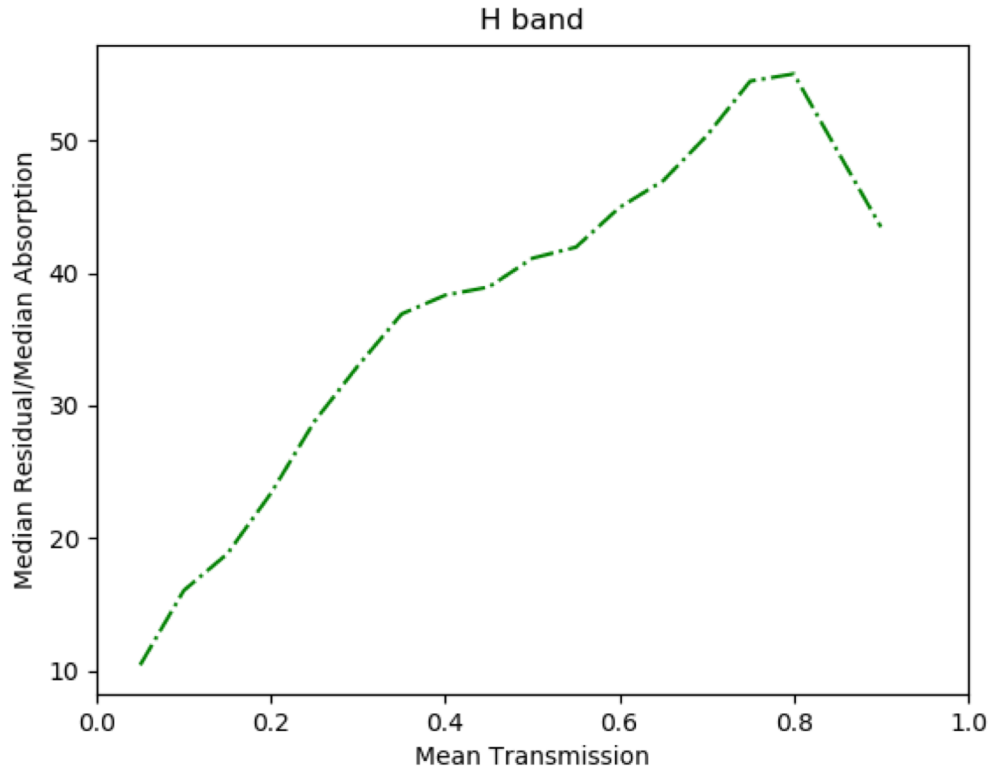
- **The fractional quality of telluric correction depends on absorption**
- **For moderate absorption (0-50%), lines are subtracted to better than 1 part in 40.**
    - **If you have an SNR of 100 and the local absorption is <10%… you are all fine!**
- **Deep absorption (>50%) is more poorly corrected**

t.fits

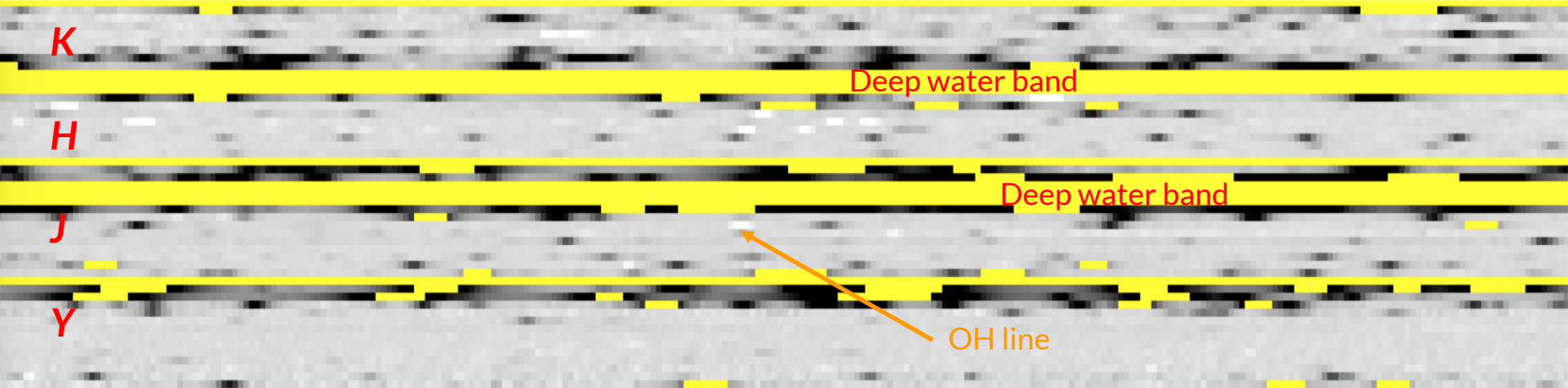[tellurics]

- **Ext 1: Same as *e.fits* but after telluric correction**
  - **Only for AB; we assume that tellurics do not affect polarisation**
- **Ext 2: Recovered telluric absorption**
  - **NaNs where absorption is too strong for proper reconstruction**

K

Deep water band

H

Deep water band

J

Y

OH line

You want to re-reduce your data!

- **Be careful what you wish for!**
- **Unless you have pretty unusual requirements and/or exotic data processing strategies, this is unnecessary**
- **If you think you've found a bug with your SPIRou data (it happens): tell the SPIRou instrument scientist!**

You want to re-reduce your data!

- **Be very sure that your analysis cannot be done with the existing DRS outputs**
  - **e.g.: you do not trust the DRS telluric subtraction (how dare you!) and want to use use your favorite Earth atmosphere model**
    - **Get the merged (*s.fits*) data and start with the extension prior to telluric subtraction**
  - **e.g.: You want to stitch the 49 orders yourself**
    - **Start from the *e.fits* file, there you have the flux, wavelength and blaze data.**

You want to re-reduce your data!

- **The SPIRou DRS is open-source and available on github**
  - **All written in python 3**
    - **Should work on Mac, Linux and Windows**
  - **Contact us for github access**
  - **We are currently testing portability**
- **If you want to reprocess from the *o.fits* or *r.fits* files, you will need to download a large set telluric stars and calibrations**
- **The full reprocessing of calibrations takes >1 week of data-crunching**

What is not *(yet?)* in the DRS

- **Improved telluric subtraction in the deepest water bands**
  - **Should be possible by fitting stellar models for the telluric stars**
  - **Not for pRV, but may be useful for other science**
- **Proper calibration of the SED**
  - **SPIRou is not designed for spectro-photometry… but we'll do our best!**
  - **2MASS photometry could be useful here**
- **Noise propagation all the way to the stitched spectrum**

What is not *(yet?)* in the DRS

- **OH sky line subtraction**
  - **Will use a technique similar to telluric absorption**
- **Detailed line-spread-function calibration**
  - **Important for model convolution and fitting**
- **Convenience tools to manipulate DRS outputs**
  - **Stand-alone examples of read/plot**
  - **Merge a set of *s.fits* files into a single spectrum**
  - **Template-matching PRV**
    - ***Very preliminary* ~1 m/s night-to-night RMS for Barnard with latest DRS version**
    - **Needs to be reproduced over >1 run, various stars**