AKARI IRC Spectroscopy data reduction and calibration for PHASE 3

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On behalf of IRC spec calibration team
2008/10/24

What's NEW in Phase 3?

- New telescope PSF
  - Tuned M2 position for re-focusing
  - But degraded a bit from pre-phase-3
- New array settings
    - Same clock, with tuned voltage settings
      - Due to increased temperature environment (for *T*=42 K)
  - Change in dark images
    - Increased effect of bad pixels
    - AOTZ4 has introduced.
  - Change in linearity/saturation
  - Change in response

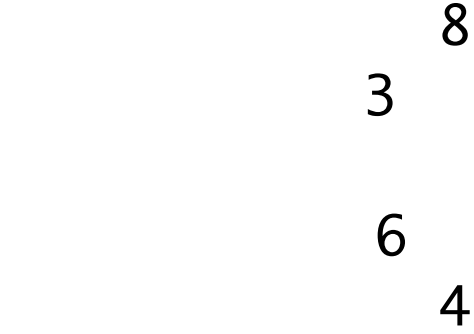
What's NOT new in phase 3?

- Spectral distortion?
  - NP: No detectable changes
- Wavelength solution?
  - dispersion curve:
    - NP/NG: No detectable changes
    - NG: Zero-th order light position unchanged
  - Wavelength zero-point:
    - NP/NG slit (Ns/Nh): Slight modification necessary.
      - But the change seems NOT due to phase-3 environment

AOT: IRCZ4 (a or b)

- 5 darks + 4 spec + 1 ref-imag + (4+alpha) spec + 5 darks
- Automatic position “shift” among pointings
  - For better hot-pix removal
  - Done by operation side (Oyabu special)
  - Slit-less
    - Np: one step = 3 arcsec in X or Y
    - Nc: one step = 6 arcsec in X or Y
  - Ns/Nh: one step = 4 arcsec in X

<Np/Nc (slitless)>



<Ns/Nh (slit)>

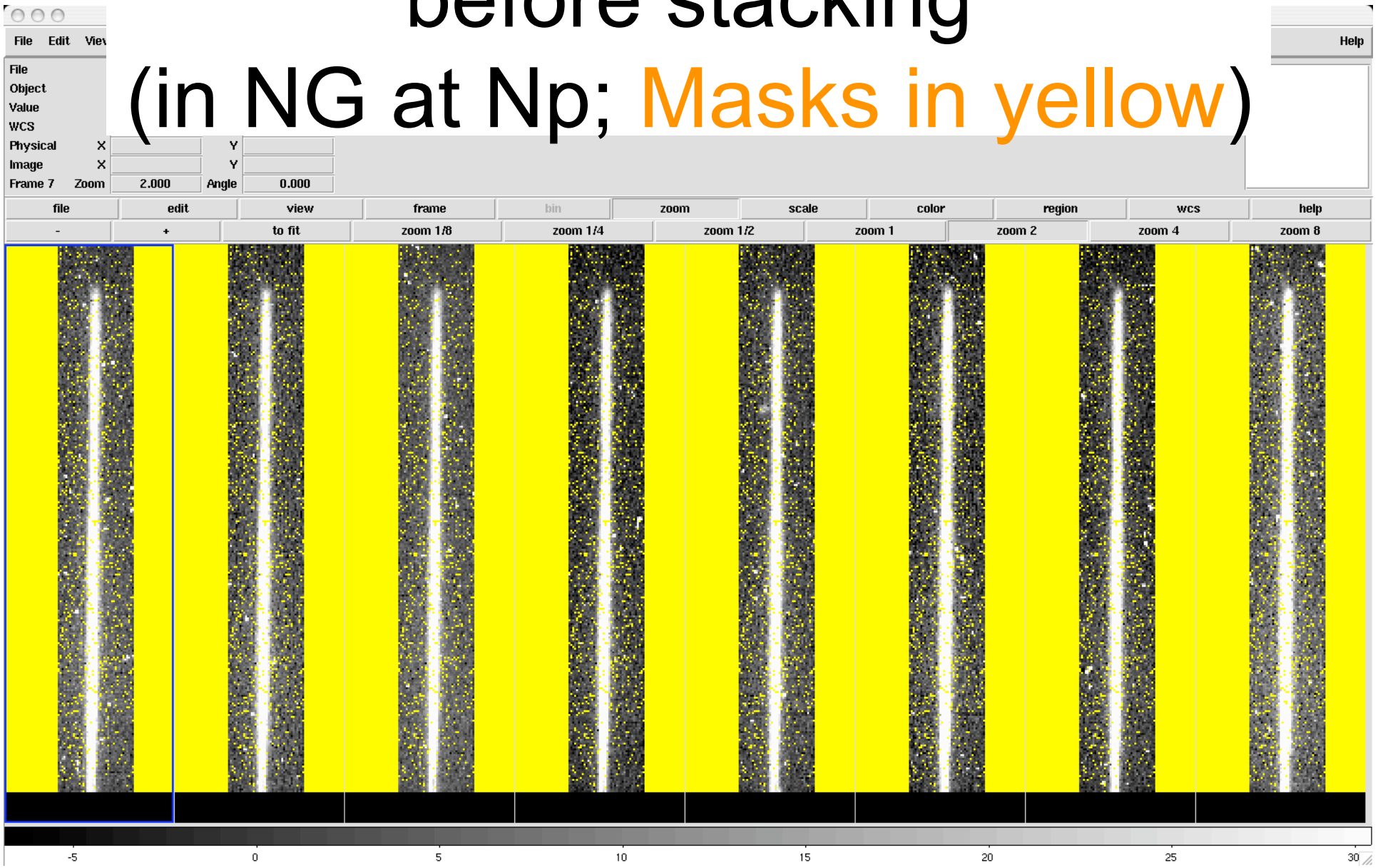
Telescope PSF issues

- Updated aperture-correction table (NP/NG)
- No change in NP ‘spectral’ response so far.
  - Needs more investigation to characterize the PSF
- Extra PSF degrading due to insertion of dispersers seems negligible.
  - Imaging PSF = Spectroscopy PSF

Dark/hot-pixel issues

- Increase in dark level/number of hot pixels
- Super-dark does not work fine
  - Probably due to temporal change in hot pixels.
- 10 dark images taken in AOTZ4 are combined for subtracting dark/hot pixels.
  - The same procedure adopted for imaging pipeline.
- Some bad pixels are masked, not subtracted.
  - Bad=Too bright or too much flickering (among ten dark frames)
  - Masking threshold values seem need to be tuned.
  - For slit-less data, most of the pixel masks should be removed during shift&add-ing sub-frames.

Typical hot-pixel situations before stacking (in NG at Np; Masks in yellow)



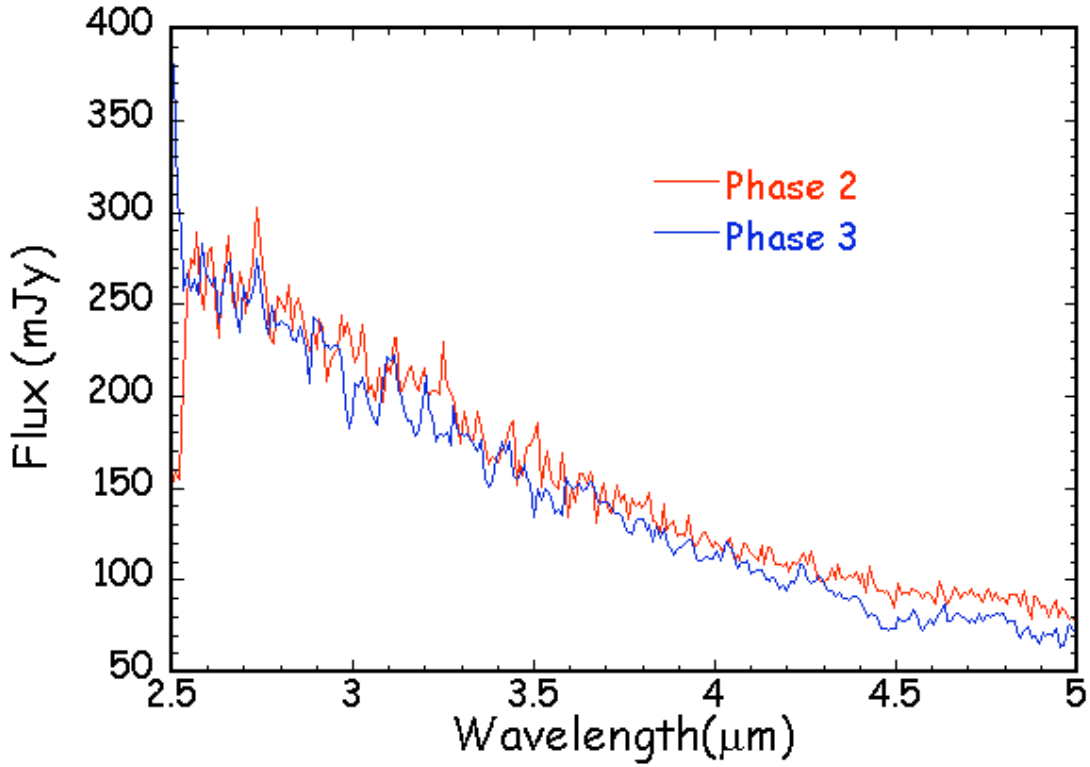
‘median’: New option in plot_spec_with_image

- Hot-pixel masked pixels often remain in the final stacked image:
  - For slit-less data, most of the pixel masks should be removed during shift&add-ing sub-frames.
  - For slit data, since no shift&add-ing is possible, larger number of hot pixel masks might damage the spectra.
- New option ‘median’:
  - When set as, e.g., median=3, image will be median-averaged only along spatial direction before extracting one-dimensional spectrum for plotting over specified median running-box size (3 for the example).
  - This could be helpful for slit spectra of extended sources.
  - But use this option with your own risk
    - Median could destroy your results.

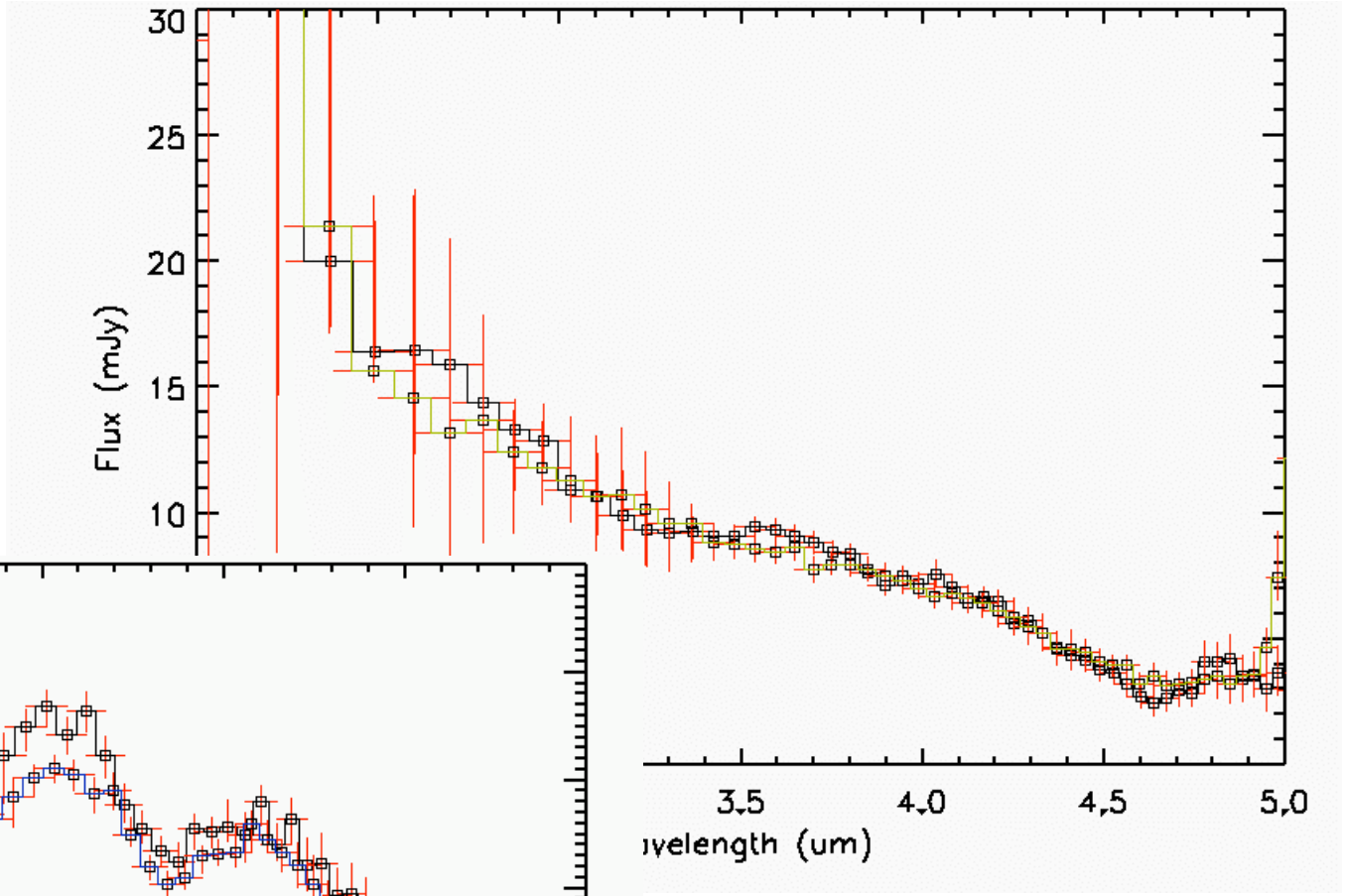
Response issues

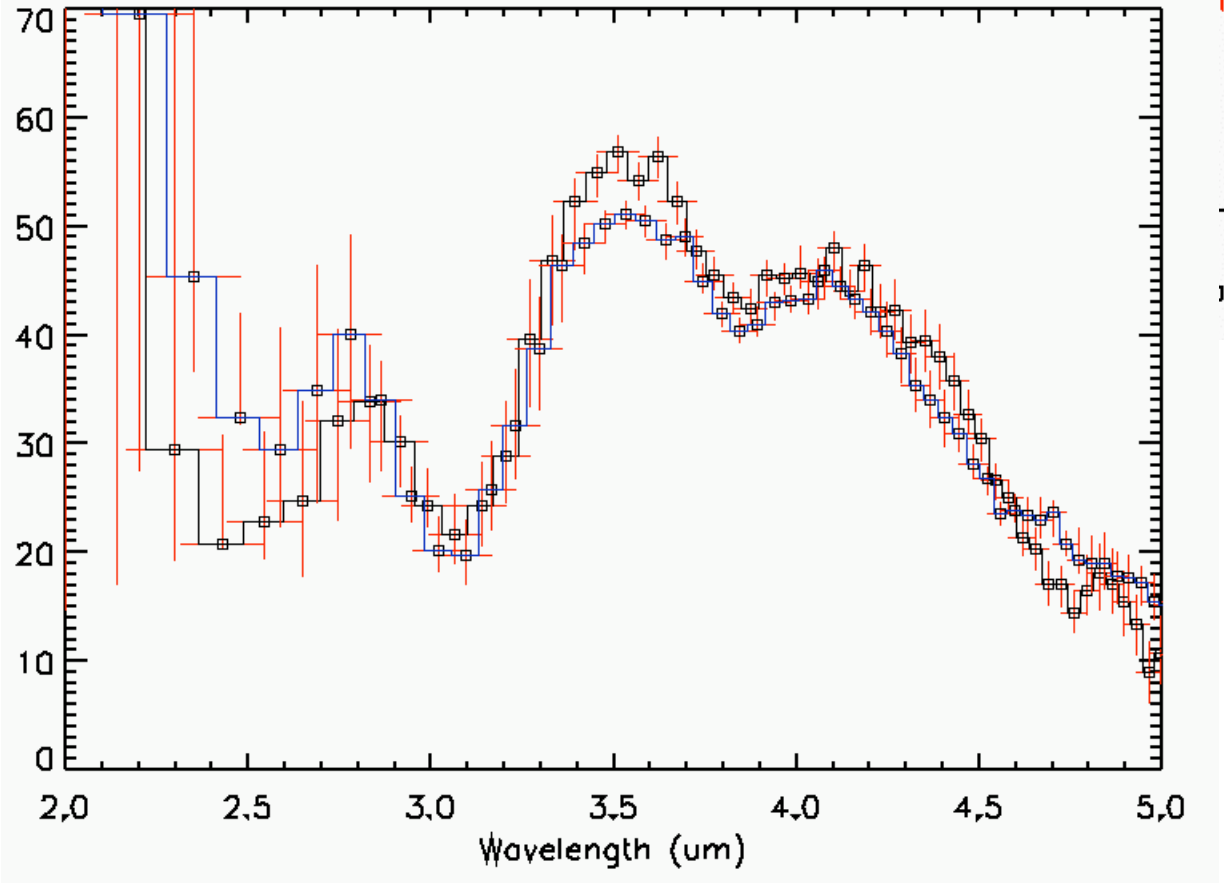
- Less response (ADU/photon) in phase 3
  - ADU (pre-phase-2) = 0.7 ADU (phase-3)
    - Based on imaging data,
      - Check Ita san's talk.
    - Spectroscopic flux calibration studies agree well with imaging results.
    - Regardless of the color (wavelength).
- Simple scaling (x0.7) gives good enough results in most cases.

Standard star (NG)
phase-2 vs. phase-3 calibration

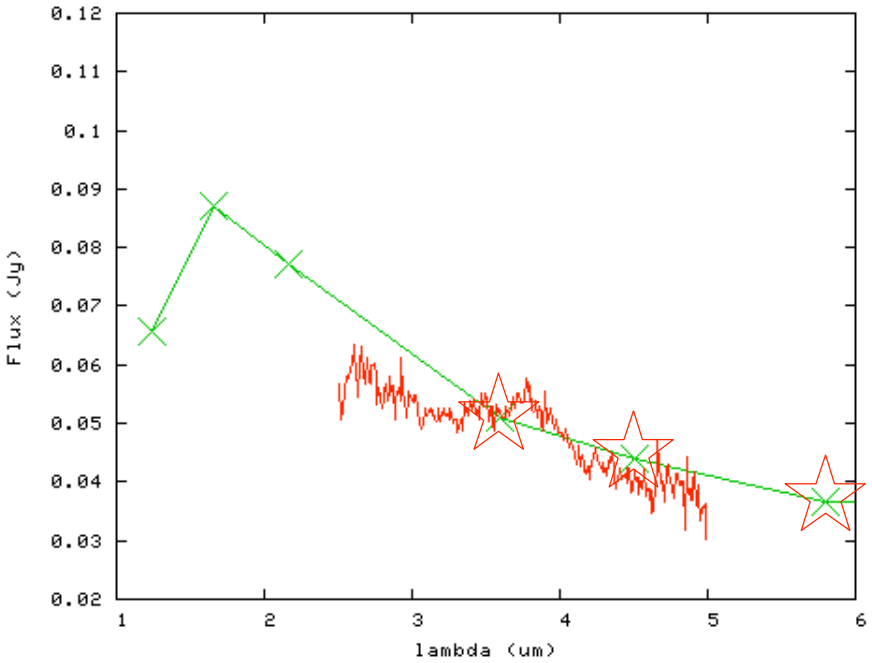


phase-2 vs. phase-3 at NP



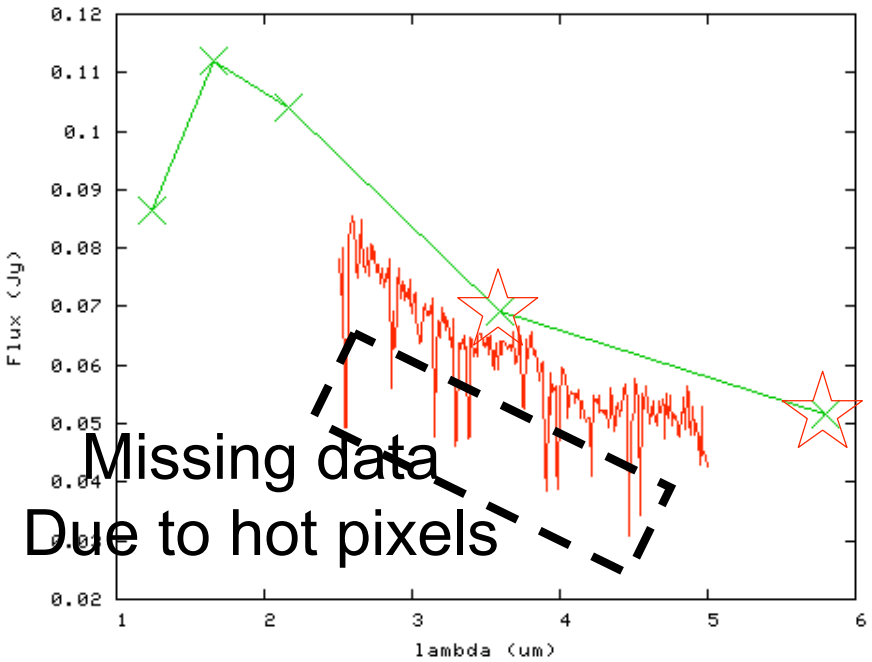


Slit-less Example



Absolute flux?

NG at Np vs. 2mass+IRAC☆



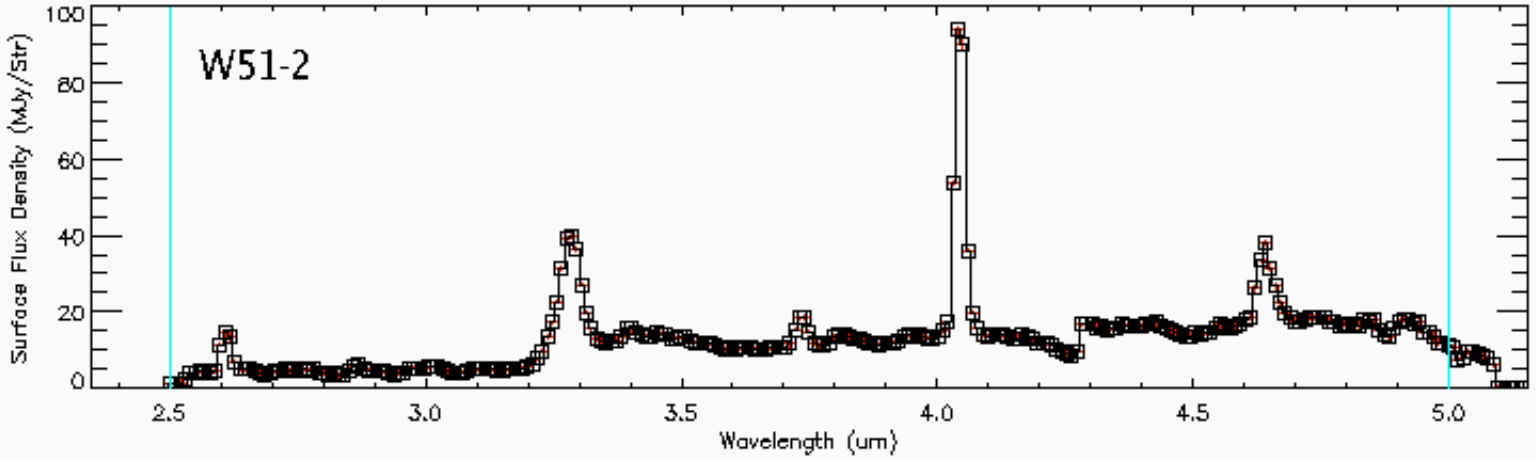
Wavelength Solution: Changed from pre-phase-3 relation?

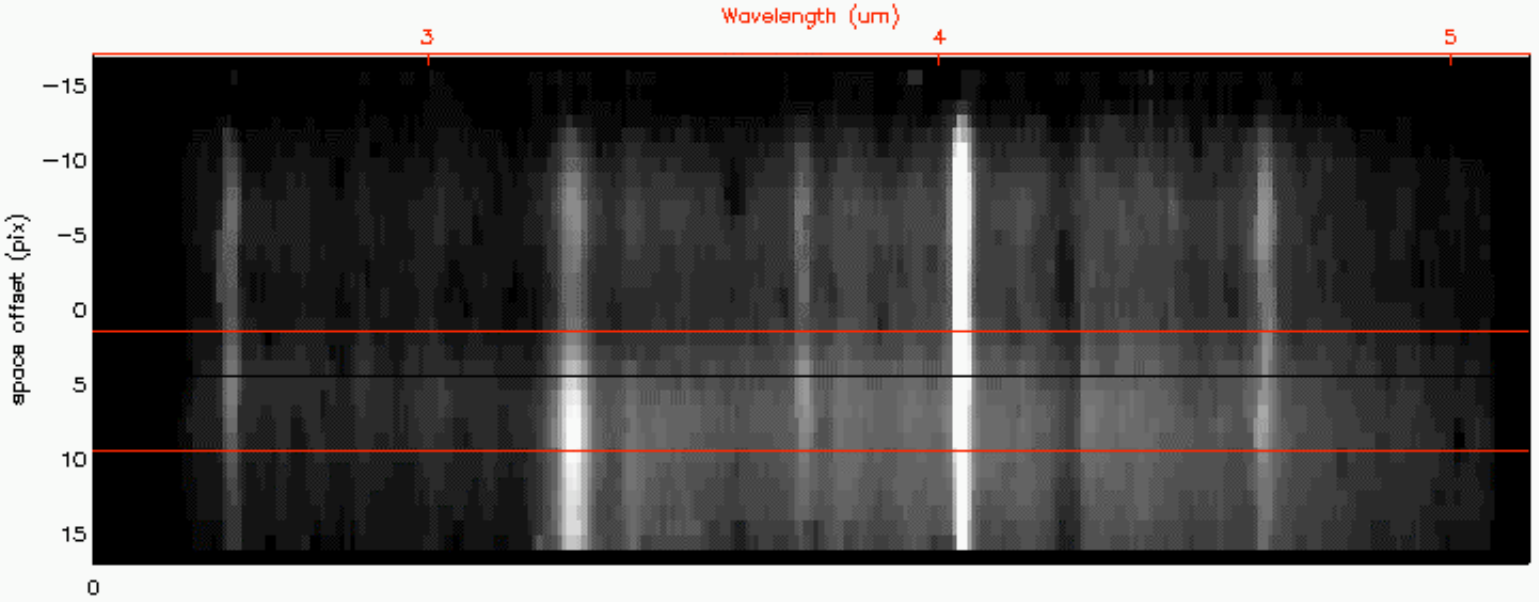
- NP
  - Wave_Offset at Slit (Ns/Nh):
    - -1.4 pix
  - Dispersion relation:
    - No significant change
- NG
  - Wave_Offset at Slit (Ns/Nh):
    - -1.0 pix
  - Dispersion relation:
    - unchanged from pre-phase-3 at ~0.1% level.

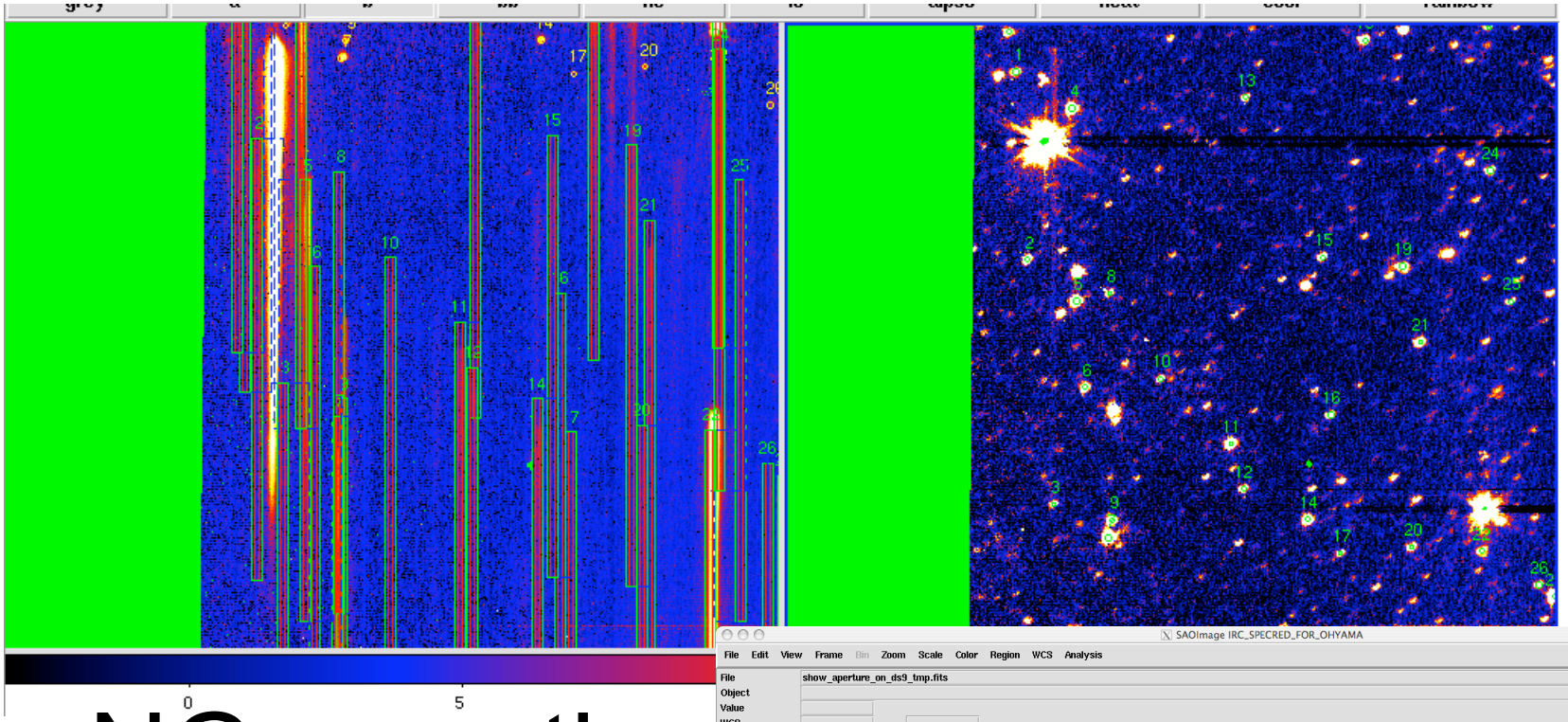
Wavelength Issues

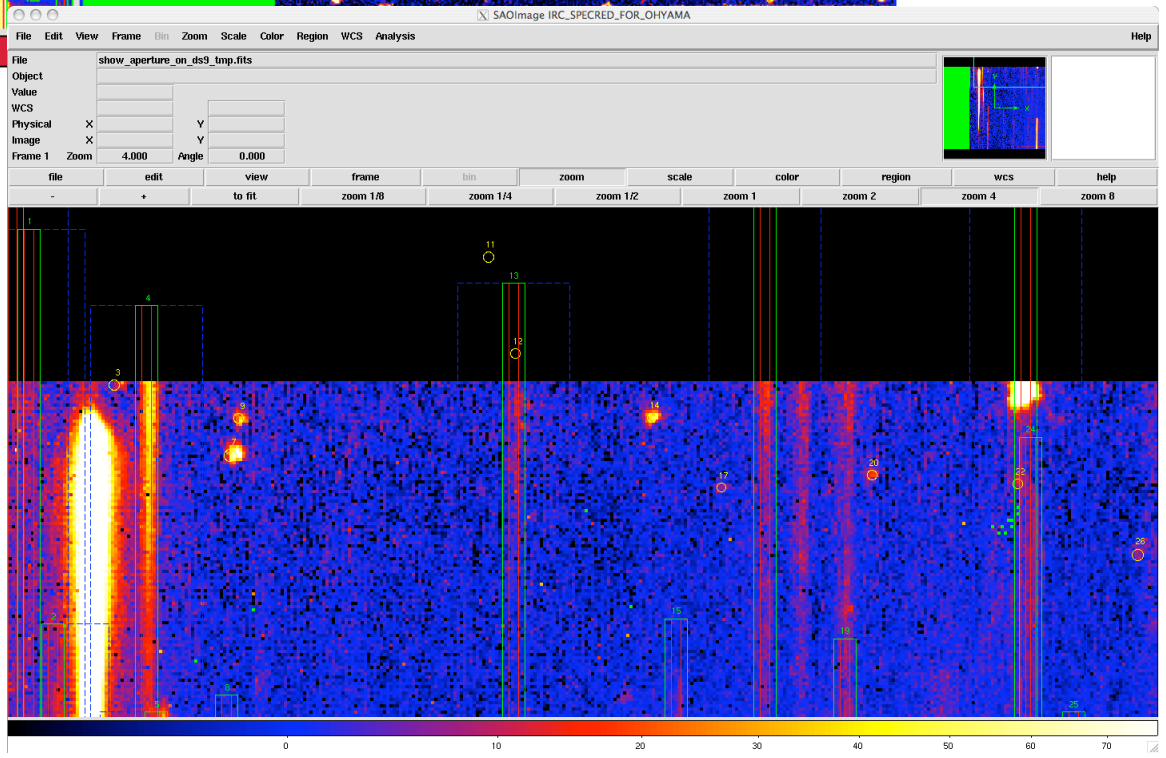
HII NG@Ns

Example 2



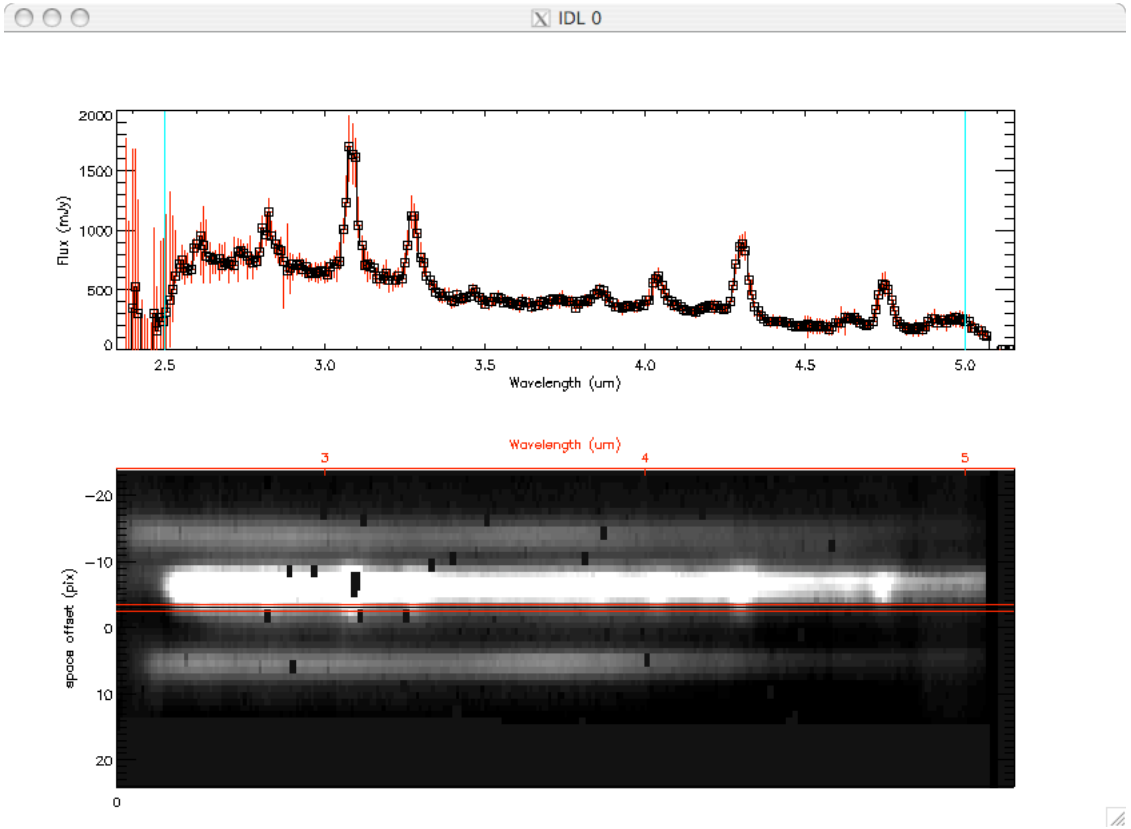






NG zero-th order light images are still useful in phase 3

Slit-less Example WR111 NG@Np

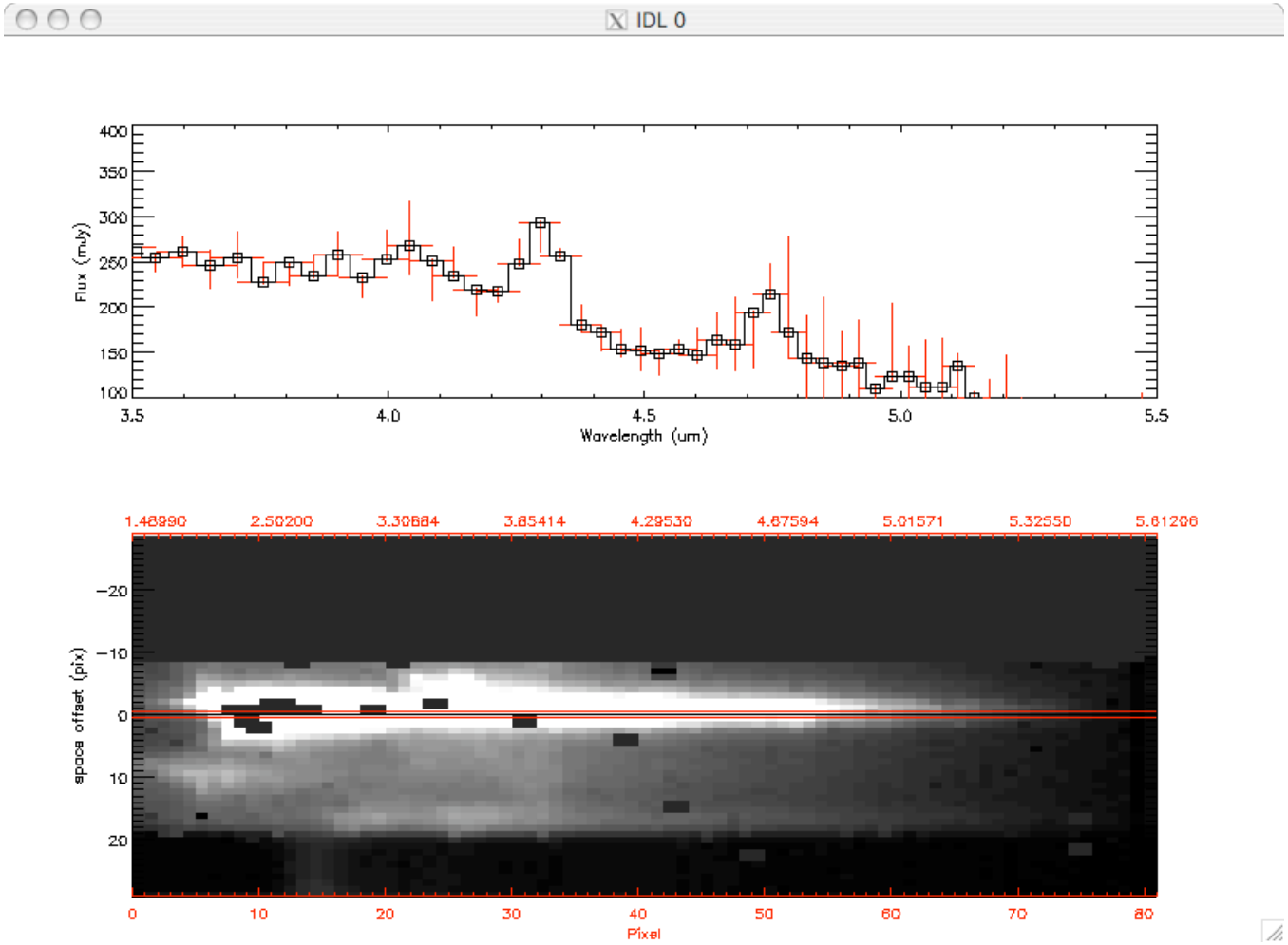


- 2.8273 HeII 9-7
- 3.0912 HeII 7-6
- # 3.297 HeI 5-9 (or CIV 11-10)?
- 4.0495 HeII 10-8
- # 4.2959 HeI 3P-3S,3Po-3S (or CIV 12-11)?
- 4.7642: HeII 8-7

- Offset: ~1/4 pix, dispersion: ~0.4%

Slit-less Example

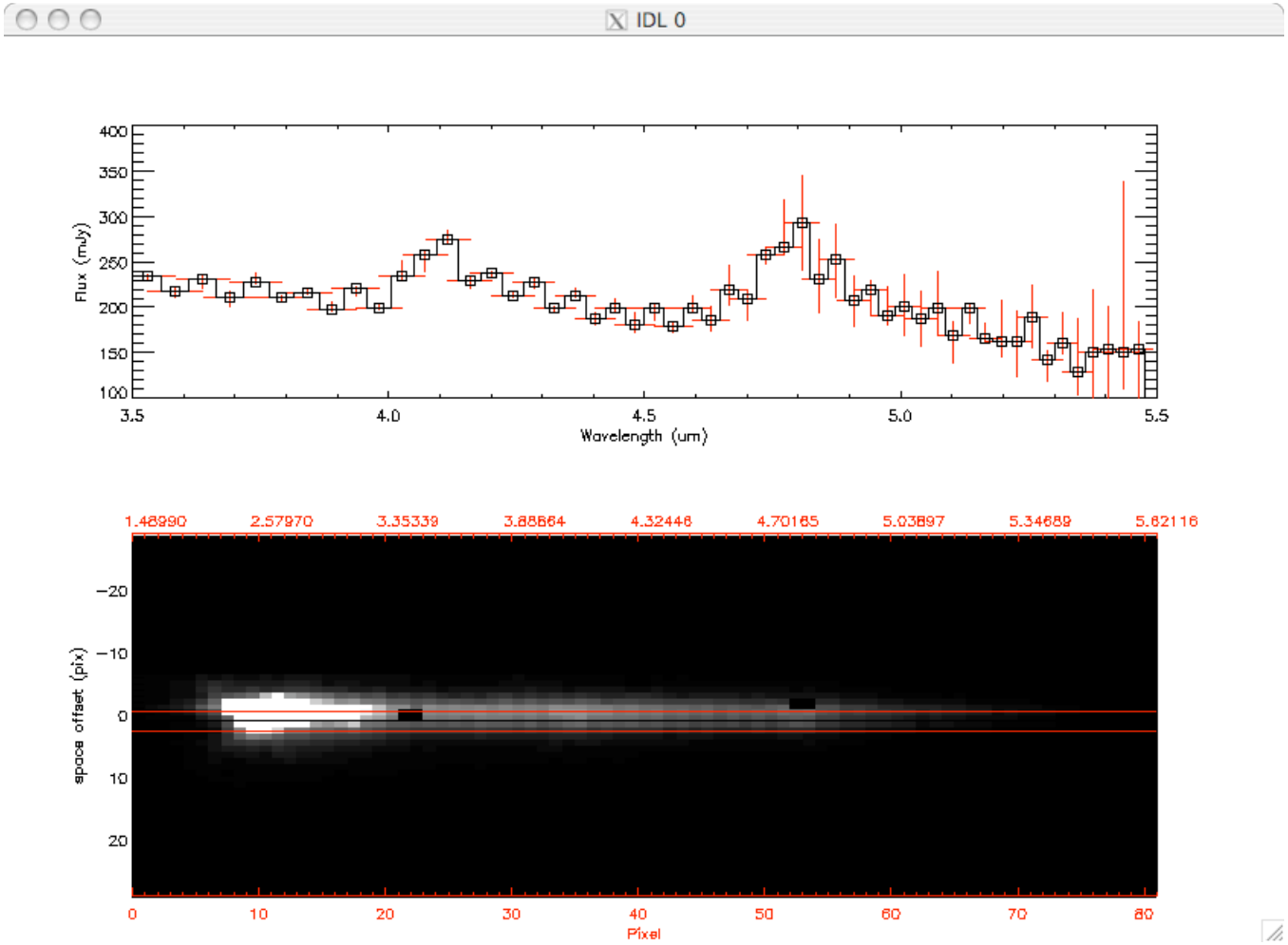
NP@Np: WR45



- 4.0495 HeII 10-8
- # 4.2959 HeI 3P-3S,3Po-3S (or CIV 12-11)?
- 4.7642: HeII 8-7

Example 6

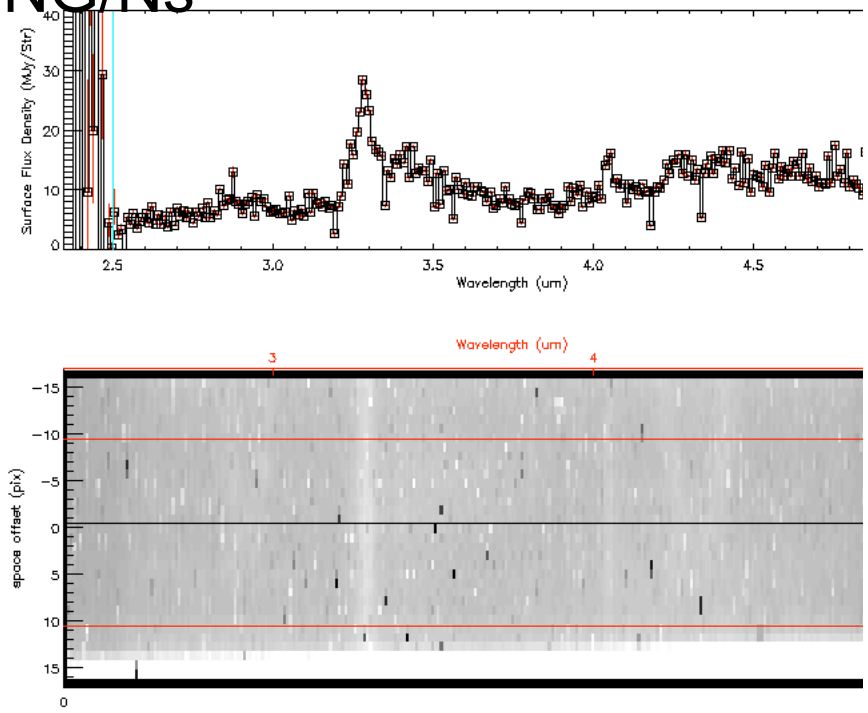
NP@Np: WR1



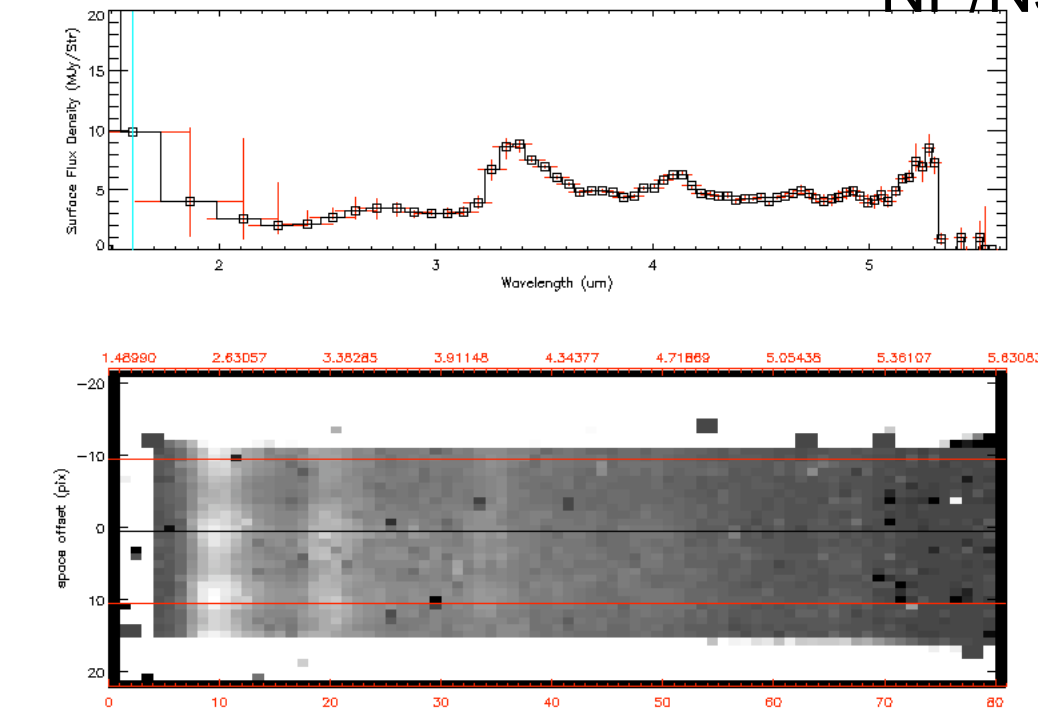
- 4.0495 HeII 10-8
- # 4.2959 HeI 3P-3S,3Po-3S (or CIV 12-11)?
- 4.7642: HeII 8-7

Extended HII regions, observed at 2 slits, 2 dispersers

NG/Ns



NP/Ns



Saturation/Linearity issues

- Linearity: new linearity correction table is implemented.
  - The same correction as for imaging pipeline.
- Saturation: Decreased saturation depth causes troubles in some observations:
    - In phase 3, just 1/6 of pre-phase-3 value
    - New saturation value are implemented for masking, etc.
  - This causes not only damages your science spectra, but also
  - Troubles in processing frames with IRC_SPECRED (see the followings).

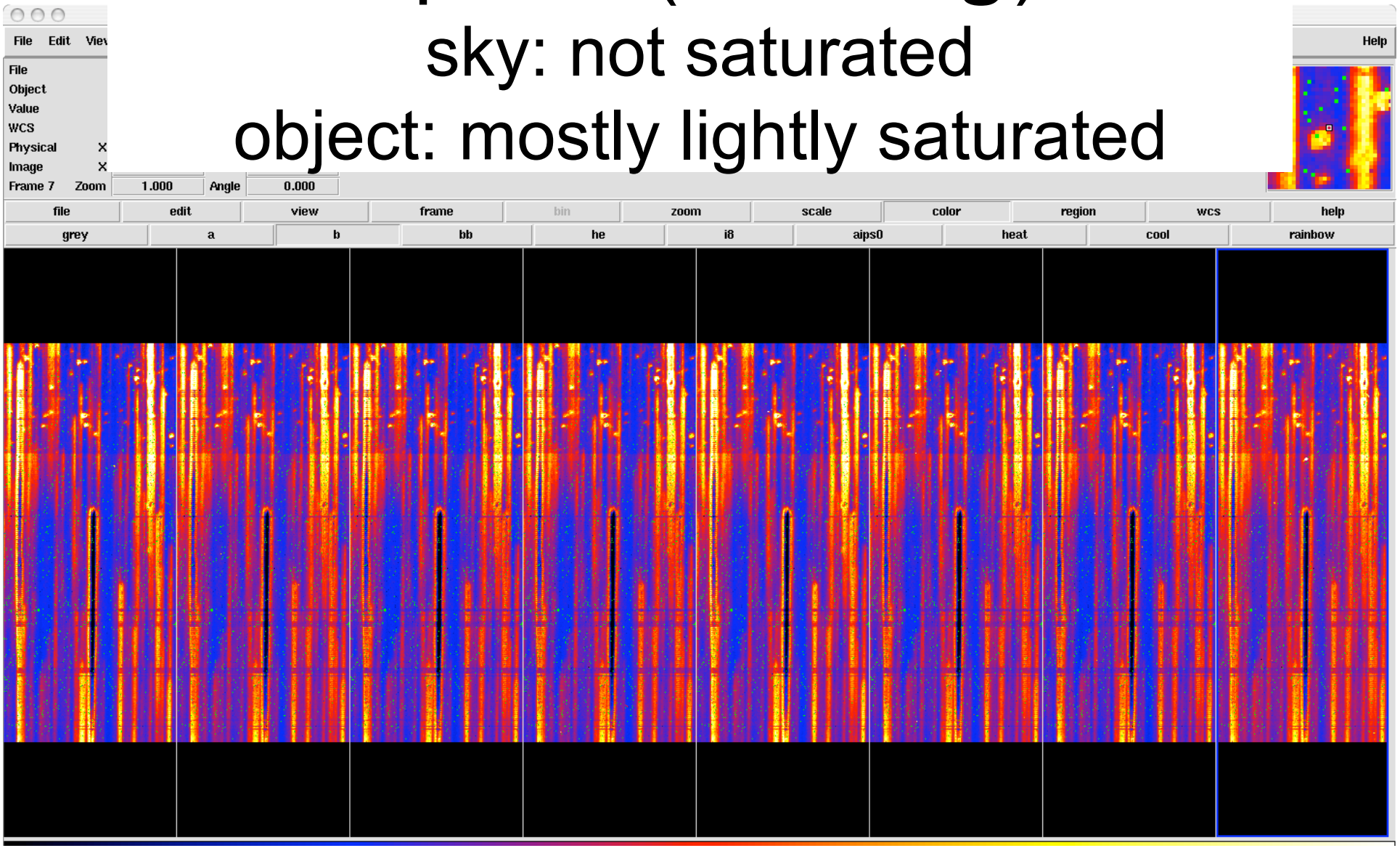
Saturation issues and Some Special Tricks for IRC_SPECRED

- Too-much saturation in long frames causes some troubles in IRC_SPECRED processing, since
- **Bright sources in long frames** serve as reference points in:
  - Finding shift (dX, dY) among sub-frames
  - Finding shift (dX) among spec_ and ref_image
  - Finding wavelength zero-point (Y_lamda_0)
    - Short frames basically follow changes/reference points in found in long frames.
- For phase 3, short frames should be used for these purposes,
  - instead of using long frames.

Example at near ecliptic equator (NG/***long***):

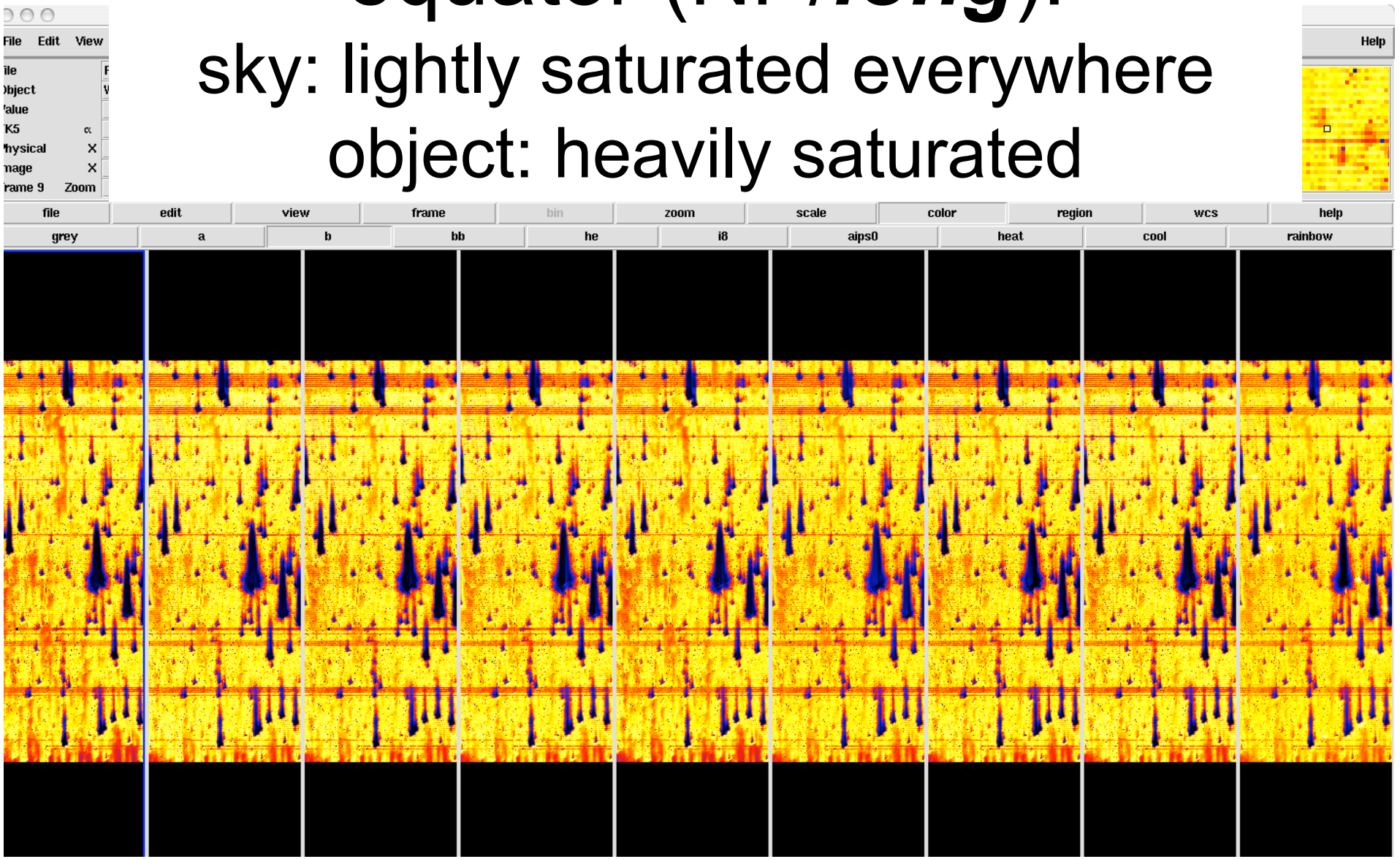
sky: not saturated

object: mostly lightly saturated



Example at near ecliptic equator (NP/***long***):

sky: lightly saturated everywhere
object: heavily saturated



Some new processing options are added for avoid saturation-related troubles.

Descriptions of new options (1)

- Source detection on ref-image:
  - /use_short_refimage: as before, use short reference image for detecting sources when their counterparts in long frames saturate.
- Finding shift among sub-frames:
  - /no_long_saturation_mask: applying saturation mask for long frames is dismissed.
    - When the background level is very high, significant fraction of the FOV is masked out, and frame-to-frame shift measurement fails.
    - When users notice strange offset values either in X or Y, or in both, try this option.

Descriptions of new options (2)

- Finding wavelength zero-point:
  - /use_short_for_wave_offset: Wavelength zero-point will be measured with short frame.
    - This works in a similar way in spectroscopy images as /use_short_refimage works for reference image.
    - When users find warning message showing that the software can not measure the wavelength zero-point offset (because no useful spectra are available), try this option.
  - /short_saturation_mask: Saturation mask for short spectroscopy frames is applied, to make proper calculation of the wavelength offset.
    - Saturation masks were applied only for long frames with software for phase 2 and before.

Note on /short_saturation_mask

- The short frame mask is only active for spectroscopy images.
- We can not apply similar saturation mask for short reference image, since interpolations over hot-pixel (NaNs) masks will also "correct" the saturated pixels, leading troubles in locating sources.
  - This limitation comes from the fact that we have only one mask image in the current software framework, and both hot-pixel mask and saturation mask are stored in the same mask image.

Descriptions of new options (3)

- Finding X shift between spec and ref_images
  - /use_short_for_calc_x_shift: Software measures the spatial shift (dX) based on short frames.
    - With too much saturation in long frames, one can not measure its peak position to find spatial shift between reference and spectroscopy images.

(Tentative) Guideline of option usages with IRC_SPECRED

- First, run the pipeline without any new options,
  - i.e., follow the same way as for the pre-phase-3 data.
- When your sources are bright and are saturated in long ref_image, use
  - /use_short_refimage
    - in a similar way for the pre-phase-3 data.
- When you find too much saturated area in the long frames in spectroscopy images, try
  - /use_short_refimage,/no_long_saturation_mask,/short_saturation_mask,/use_short_for_wave_offset,/use_short_for_calc_x_shift
    - i.e., all new options should be set at once.

Known problems (1)
Absolute flux calibration of short-exposure frames

- Phase-3 data apparently show strange short/long exposure ratio.
  - Before phase 3, the source count ratio is consistent with the ratio predicted from array clock.
  - However, the ratio changed in a strange way in phase 3, and this is true even before spectral response calibration.
- So far the problem is not well understood in terms of operation/array settings, and absolute flux calibration of the short frames are not correct at all.

Known problems (2): New flats are **NOT YET** ready

- So far old (pre-phase-3) spectroscopy flats are applied.
- We will update and provide new flats with the updated software distribution in the future.
- For slit flat, it is still advised to use /no_slit_flat option due to worse quality of the slit flats.
  - This condition may not change in the future since it is even difficult to construct slit spectroscopy flats in phase 3.
- New phase-3 imaging flats color correction are already included in the current software distribution.

Known problems (3):
NP calibration at ~<2.5um

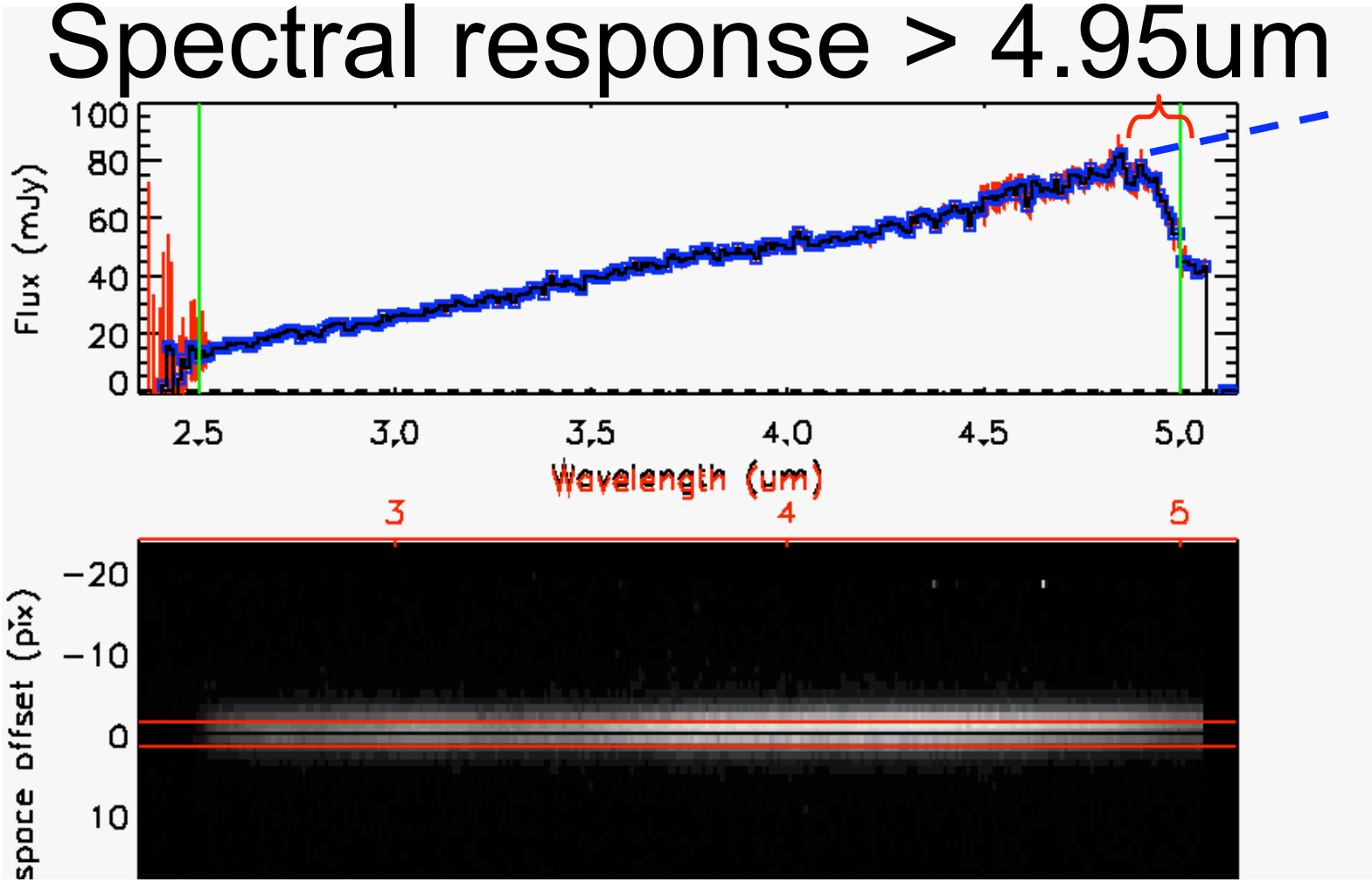
- The response curve closely follows the telescope's PSF below ~2.5um,
  - where response shows its peak and one can see bright pseudo-point-like 'peaks' in the dispersed spectral images.
  - So, it is obviously not a good idea to use the scaled old response for phase-3 data because the telescope's PSF got worse in phase 3.
- However, scaled pre-phase-3 response is still used in the current software release.
  - Users who are interested in spectra below ~3um should be careful in interpreting the flux calibrated spectra.
  - More information may be provided if calibration progresses.

Known problems (4): Wavelength calibration of NG (both for slit/slit-less)

- At shortest 2.5um~2.6um, calibrated NG wavelength shows a systematic error (shift) of
  - ~-0.05um, or ~-1 pixel
    - Wavelength assigned by the software (lambda_obs) is slightly shorter than expected value (lambda_true).
  - This is true even after applying new wavelength offset.
  - At long-ward (2.6um-5.0um), no such systematic deviation is so far observed.
  - If you notice similar wavelength deviation only around 2.5um-2.6um, this could not be a true shift but a calibration error.
- Needs more investigation.

Known problems (5)

Spectral response > 4.95um



- For red sources, error in response causes significant error in flux calibration.
  - Red: much redder than typical stellar color

IRC_SPECRED for phase 3
IRC_SPECRED_P3

- Latest beta release: on 2008/10/15
- More beta releases will follow,
  - After your reports/requests,
  - With updated calibration.
- The IRC_SPECRED_P3 is designed to work both for pre-phase-3 and phase-3 data.
  - But *no full-test has been made for pre-phase-3 data processing*.
  - Use previous release for phase-2 for cold-phase data processing.
- The toolkit automatically recognizes AOTZ4 data on FITS header information.

IRC_SPECRED_P3 Usage basically no change

- Installation:
  - no change from predecessor.
  - New sub-directory (irc_spec_toolkit_p3) will be created, and everything will be stored under it.
- Irc_specred.pro
  - Basically no change from predecessor.
    - With some new options.

```
IDL> irc_specred,1xxxxxx,1,'','N3.lst','NG.lst','N3_NG',root_dir='<somewhere>'
      Information (get_aot_info_irc): This is warm mode data processing.
      Information (get_aot_info_irc): This is AOTZ4 mode data processing.
      Information (get_aot_info_irc): This is 04B operation mode.
```

- Plot_spec_with_image.pro
  - Basically no change from predecessor.
    - New 'median' option.

Questions? Suggestions? (for ***beta***)

- Send your comments to
  - Irc_red_usr@ir.isas.jaxa.jp
- while it is in *beta* status.

ENJOY!