LUCI1/2 AO commissioning: status and prospects

AO-image NGC 6543
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The (expanded) team

Arcetri: LBTO: LUCI:

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● the ones mostly at the telescope…

What will LUCI/AO offer?

➢ Diffraction-limited imaging LUCI1/2
  FOV 30" by 30" with 0.015"/pix

➢ Diffraction-limited spectroscopy with LUCI2
  2 gratings: G040/G210, 0.13" slit,
  ~ 5000/25000 spec res @ zJHK-bands

➢ Different optics (aluminium vs zerodur), ie IQ in LUCI1
  somewhat better

➢ Dichroic cutoff: 0.89μm LUCI1, 0.95μm LUCI2

Resolution limit 1.22 λ / D:
0.027, 0.036, 0.048, 0.064" for zJHK

Patrol-field's
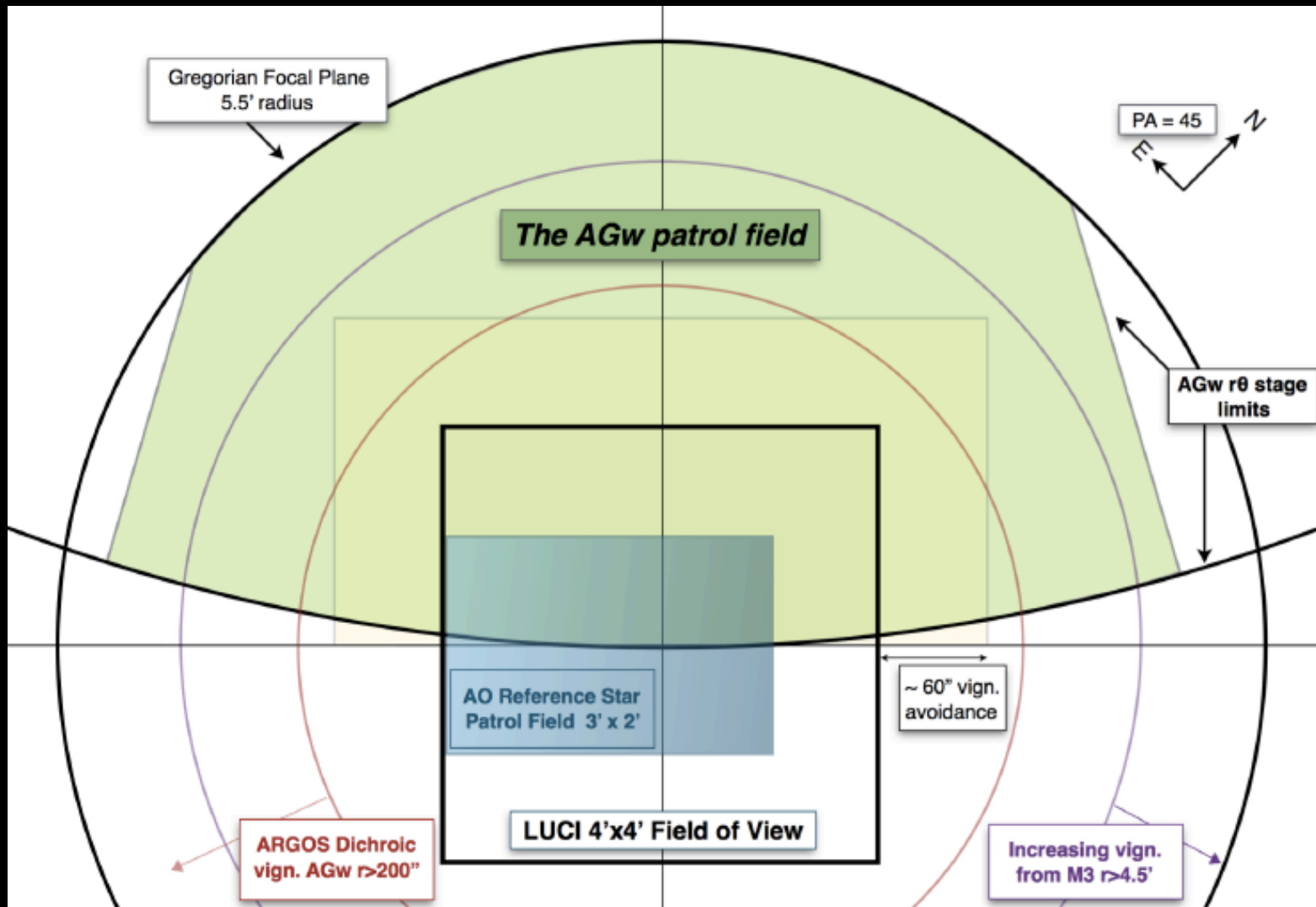
2 stars required: one for pointing & collimation, one for AO FOV for AO RS 2' by 3' centered at detector (30" by 30")

FLAO - capabilities

Table 1. System configuration table as a function of the equivalent star magnitude in R band.

| Equivalent star R-mag M_R	WFS camera (CCD39)		Expected photons / subap. / frame	Num. of controlled modes (n_{mod})	Pyramid modulation ($\pm\lambda_{wfs}/D$)	Acquisition camera (CCD47)	
	Binning mode	f_s (Hz)				Binning mode	f_s (Hz)
7.4	1	990	500	400	3.0	4	4.3
8.4	1	990	213	400	3.0	4	4.3
9.4	1	990	85	400	3.0	16	4.3
10.0	1	990	48	400	3.0	16	4.3
10.0	2	990	192	153	3.0	16	12.6
10.9	2	990	82	153	3.0	16	12.6
11.4	2	990	54	153	3.0	16	12.6
11.9	2	990	34	153	3.0	16	12.6
12.4	2	625	34	153	3.0	16	12.6
13.4	2	400	21	153	3.0	16	12.6
13.4	3	500	37	66	6.0	16	12.6
14.4	3	200	38	66	6.0	16	12.6
14.4	4	300	45	36	6.0	16	12.6
15.4	4	200	27	36	6.0	16	12.6
16.4	4	105	21	36	6.0	16	12.6
17.5	4	105	8	10	6.0	16	12.6

FLAO - capabilities
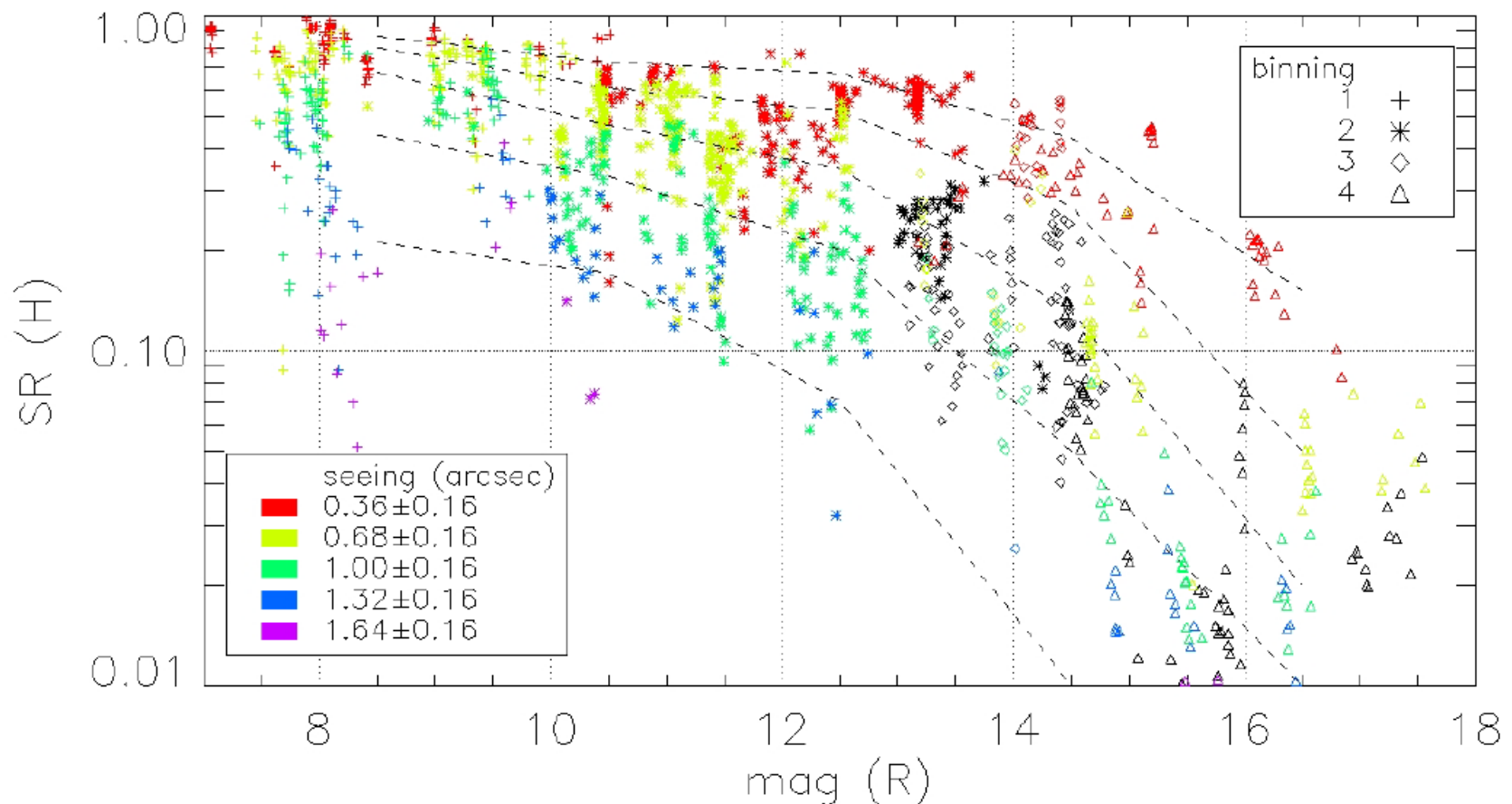
Figure 2. (Color on-line) Summary plot of the commissioning results obtained with the FLAO#1 and FLAO#2 systems. The plot shows the measured Strehl Ratio in H band versus the guide star R-magnitude. The color of the different points gives an estimate of the seeing value (points for which the seeing could not be estimated are shown in black). The symbols indicate the binning mode used. The dashed lines refer to the expected performance values found with numerical simulations for a seeing of (top to bottom) 0.6, 0.8, 1.0, 1.2, and 1.5 arcsec.

FLAO not stable at DIMM > 1.2"

Since 2 ½ years: LUCI1/2 + FLAO commissioning … a painful story…

Commissioning of LUCI1/2 with FLAO in principle simple:

➔ just NIR-light enters the instrument (well, a bit sharper)

BUT:

60n and not yet done…
- Weather losses, 1.2" seeing limit, Glykol leak…
- 3 major issues for optimal performance of system

Issue 1: FLAO not robust and stable at Bin = 1

Bin = 1, 400 modes

Bin = 1, 300 modes,
BW reconstructor
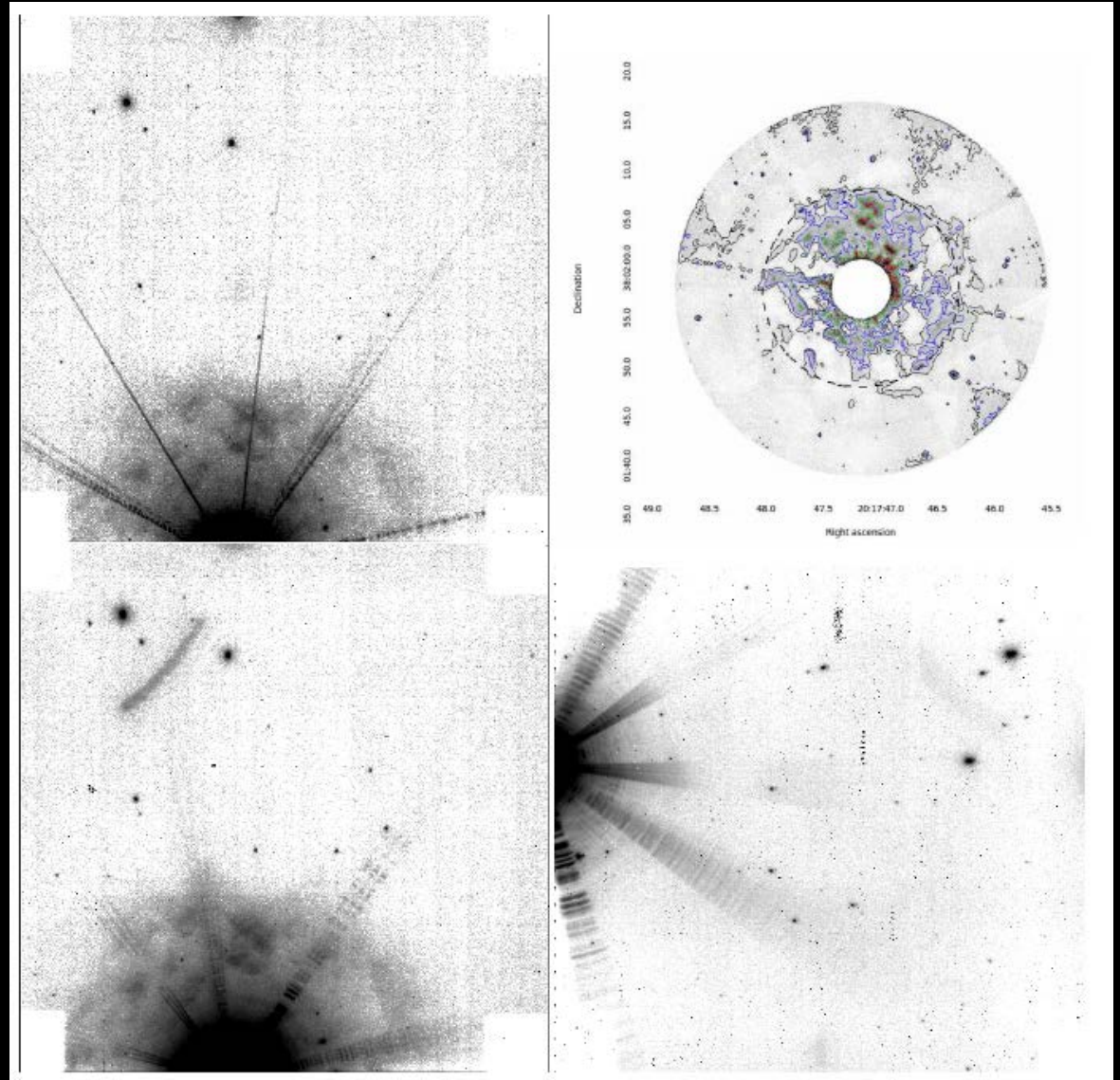
P Cyg, FeII, see also poster by Weis et al.

Issue 2: non-common path aberration

Dichroic splits light in optical (FLAO) and NIR (LUCI)
  ➔ different path's ➔different aberration
Correction as fct. of rotangle and elevation possible but painful.

- Correction matrices via closed dome tests (5 days/instrument)
- Verification and optimization on sky (1.5-2n per instrument)
- Different for LUCI1/2 (Zerodur vs. Aluminium mirrors)

Relevant for Bin = 1 and 2

Seeing-limited   AO w/o NCPA corr   AO with NCPA corr

20150129_033601

LUCI2 +FLAO

Fell filter   1.6μm
exptime 8.5s
NCPA ON
SR=75%

PSF profile
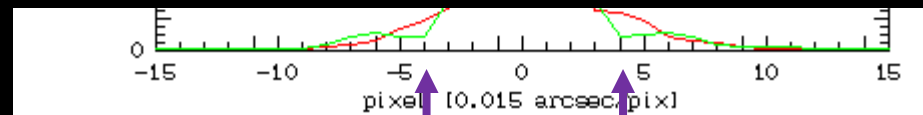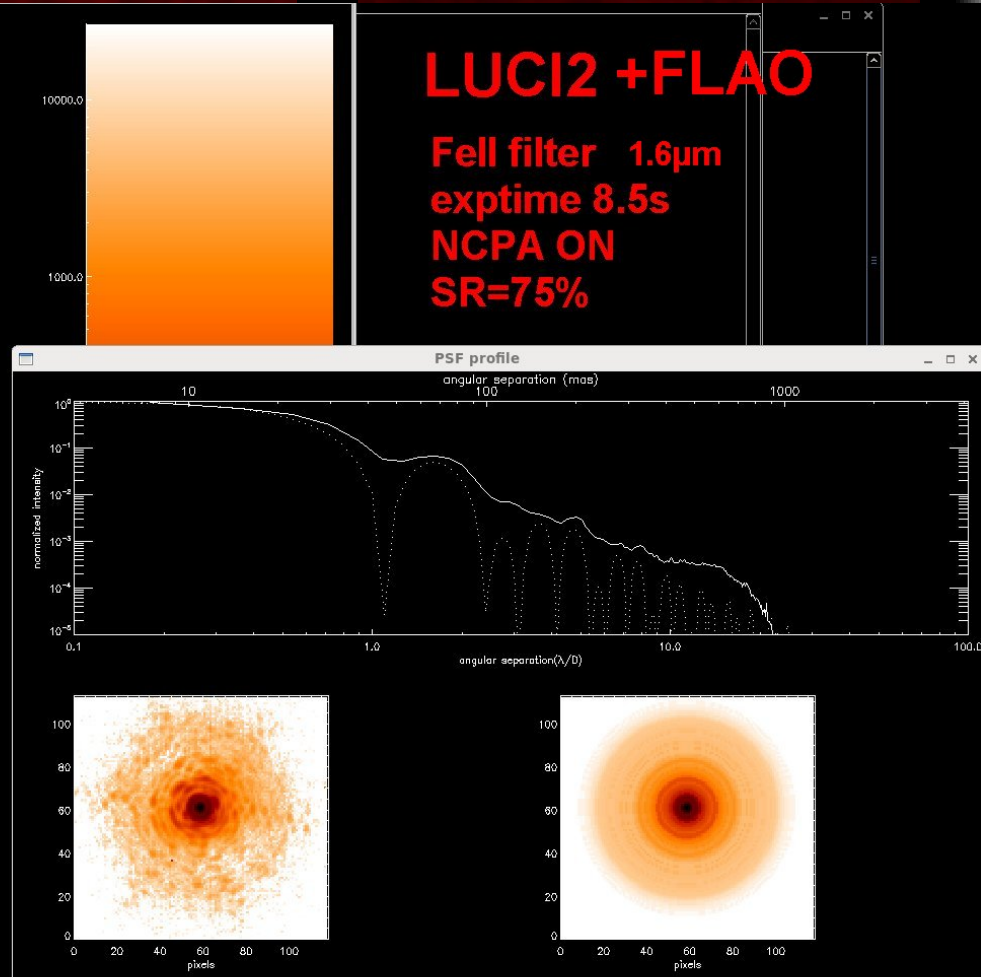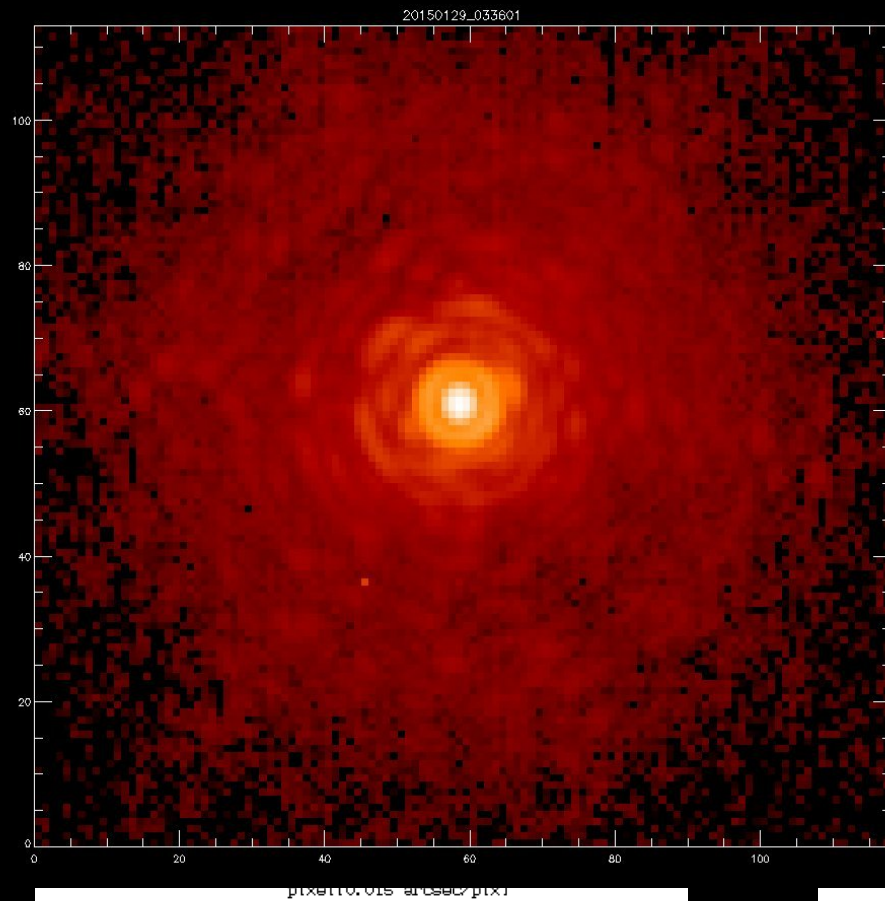
Resolution limit

Issue 3: orientation dependent flexure

Passive compensation for flexure via look-up tables:
0.1" accuracy during 1h at 100deg rotation,
- optimized for seeing-limited operations

AO-observations require:

- Few mas accuracy for long individual narrow-band images
  to be background limited
- AO-slit has 0.13", accuray required 1/10 of slit width, otherwise
  substantial slit losses for spectroscopy (exoplanets)

➡➡ Flexure correction must actively be controlled

Active flexure compensation - principle

- Design field mask with 40 pinholes in the corners for imaging
- Add 25 pinholes to each longslit/MOS mask at upper right and lower left corner to maximize wavelength coverage of the spectra used for the AFC
- Use the night-sky OH-lines as "illumination"
- Use individual images in non-destructive readout mode (sample up the ramp)
- Do image analysis per each sample, ie centroid determination
- Pass the measured dx/dy position to drive fold-mirror 4 for tip/tilt correction

NIR observing (readout)-modes
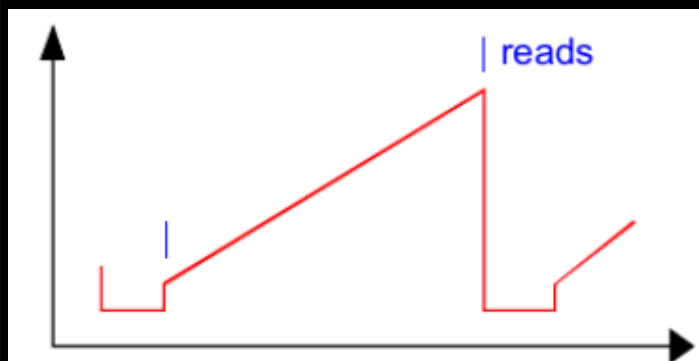
Figure 8: Illustration of the lir-mode (reset-read-read).
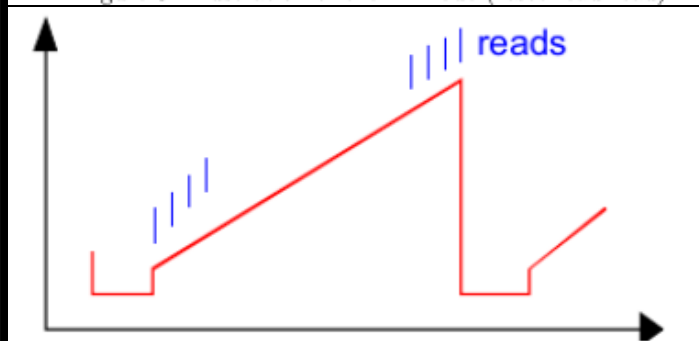
Figure 9: Illustration of the mer-mode (multiple endpoint read).
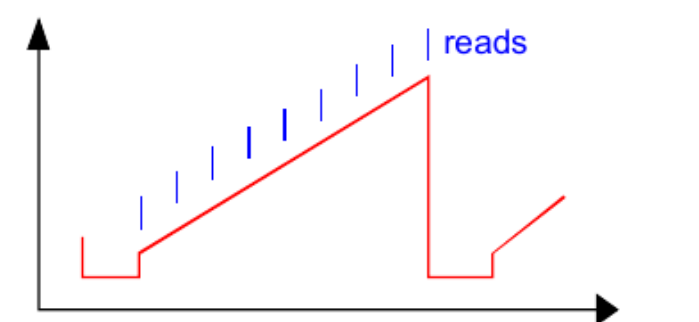
Figure 10: Illustration of the srr-mode (sample up the ramp read mode).

Simplest mode, high RON, suitable for high background (BB-imaging, calibs)

Fowler sampling, RON reduced by SQRT(N), suitable for low-background (nB-imaging, spectroscopy)

MPIA-mode, non-destructive readout, can be stopped at any time, suitable for long individual exposures per dither, pairs of reads are used for centroid determination in AFC

AFC – a powerful tool
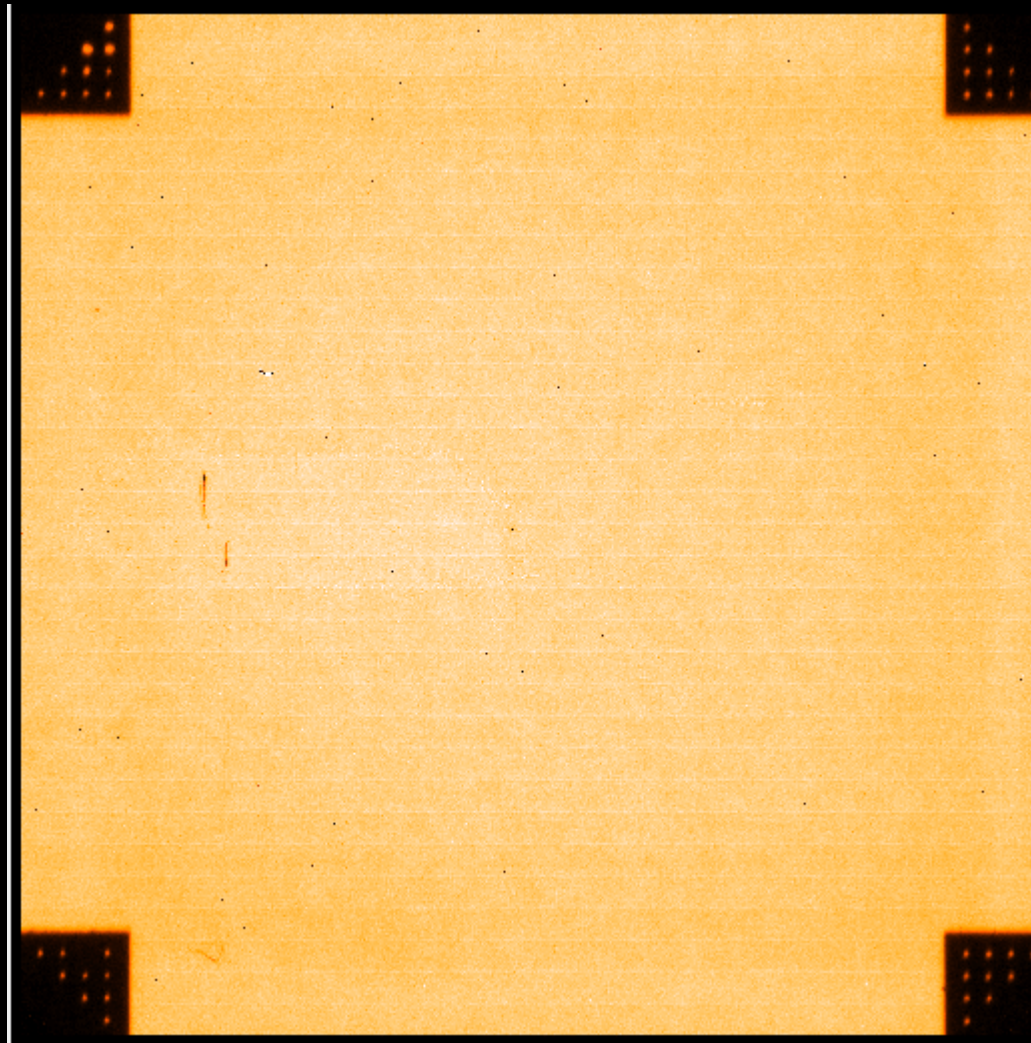
30"

AFC-mask for AO-imaging with 40 pinholes

AFC – a powerful tool
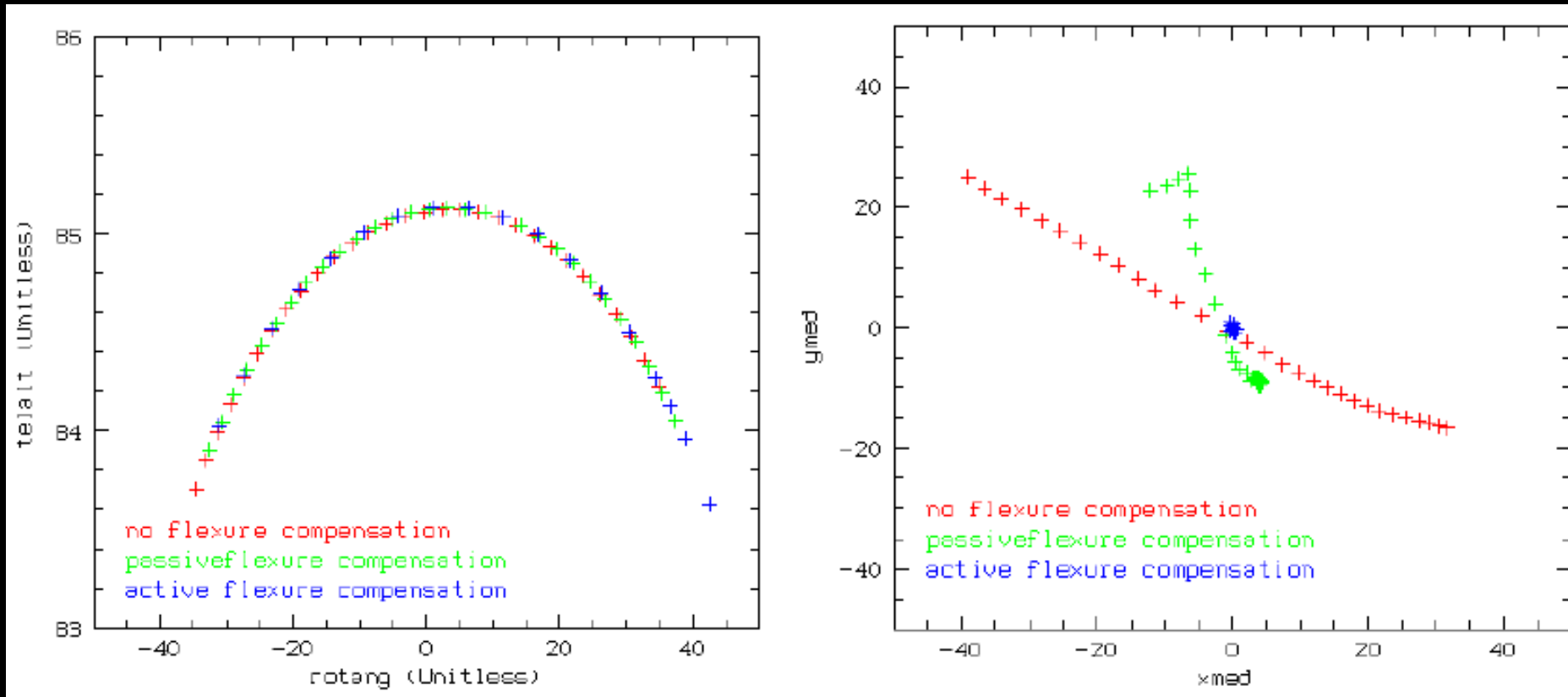
0.5pix rms (0.0075") during 30min at high elevation
Change of rotator angle ~ 80 deg

AFC-spec pretty tricky

Depending on grating and band (order) used, λ-range on detector varies between 80 and 1000 Å
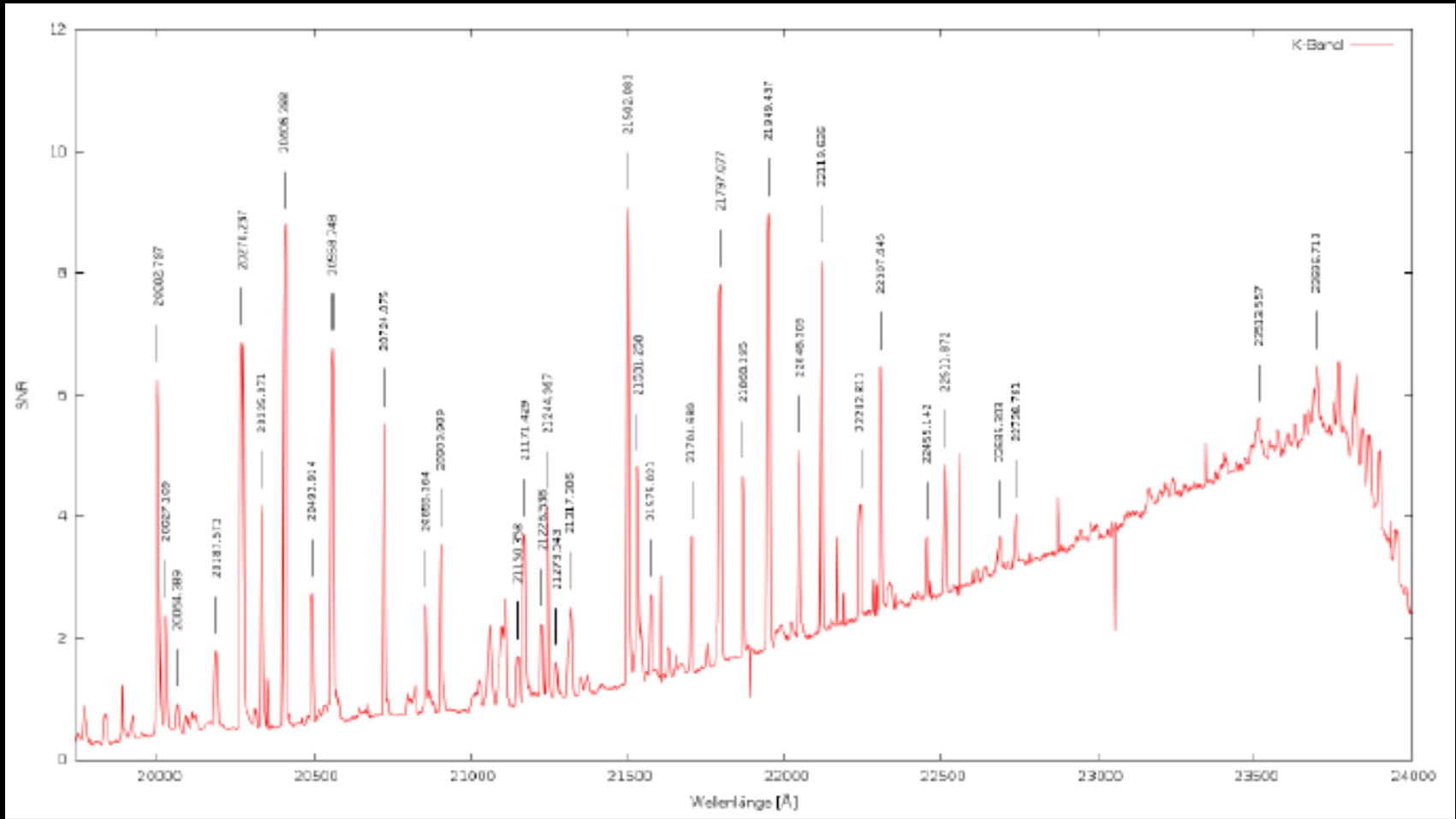
K-band night-sky spectrum @ LBT

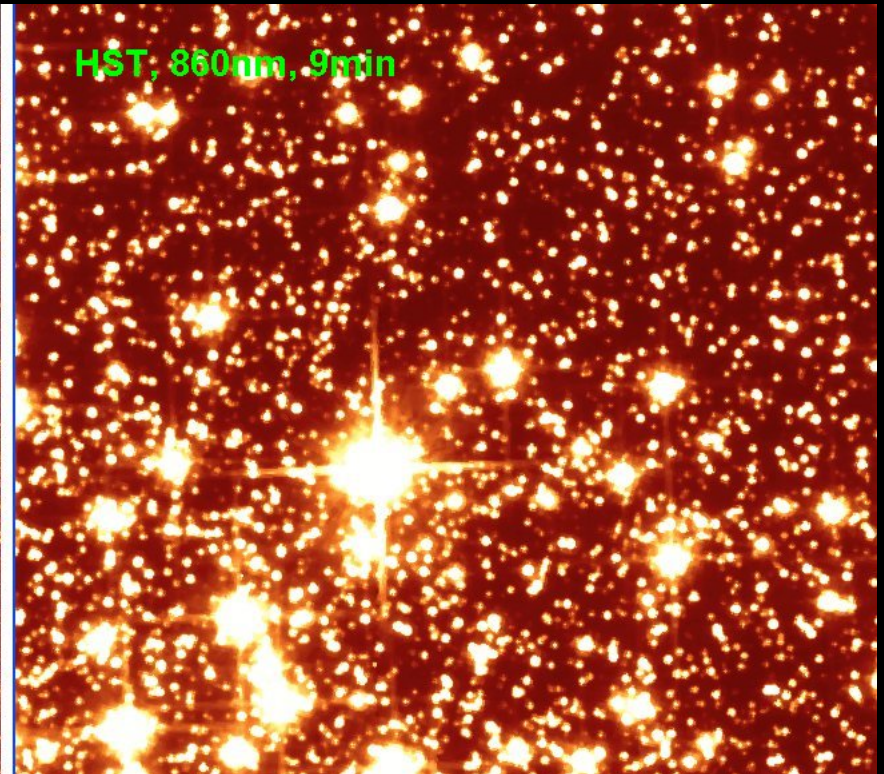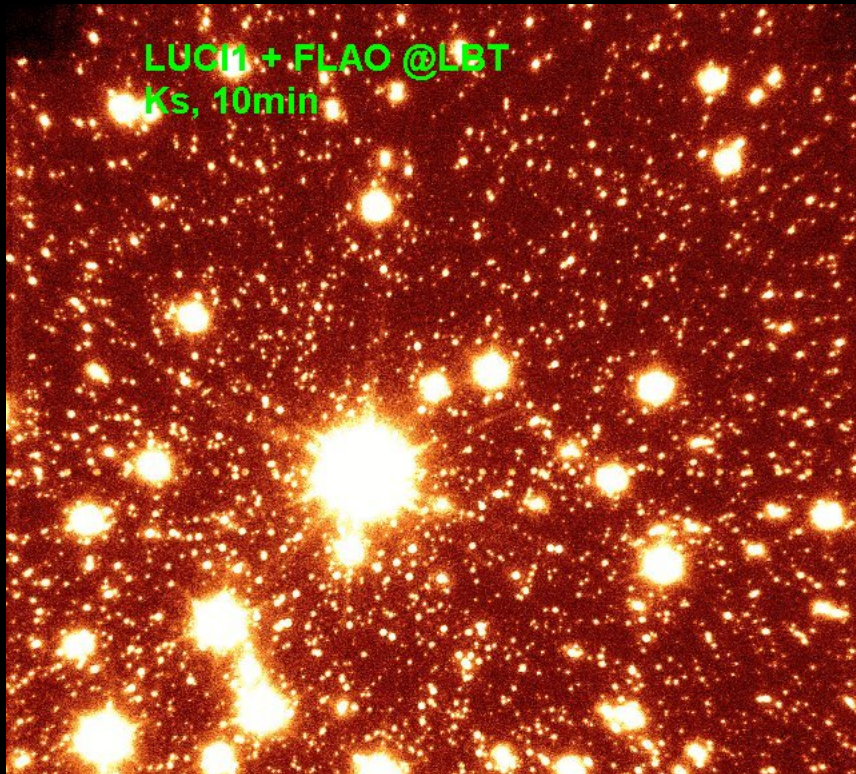# Active flexure compensation – spec-masks

50 holes in the meantime…
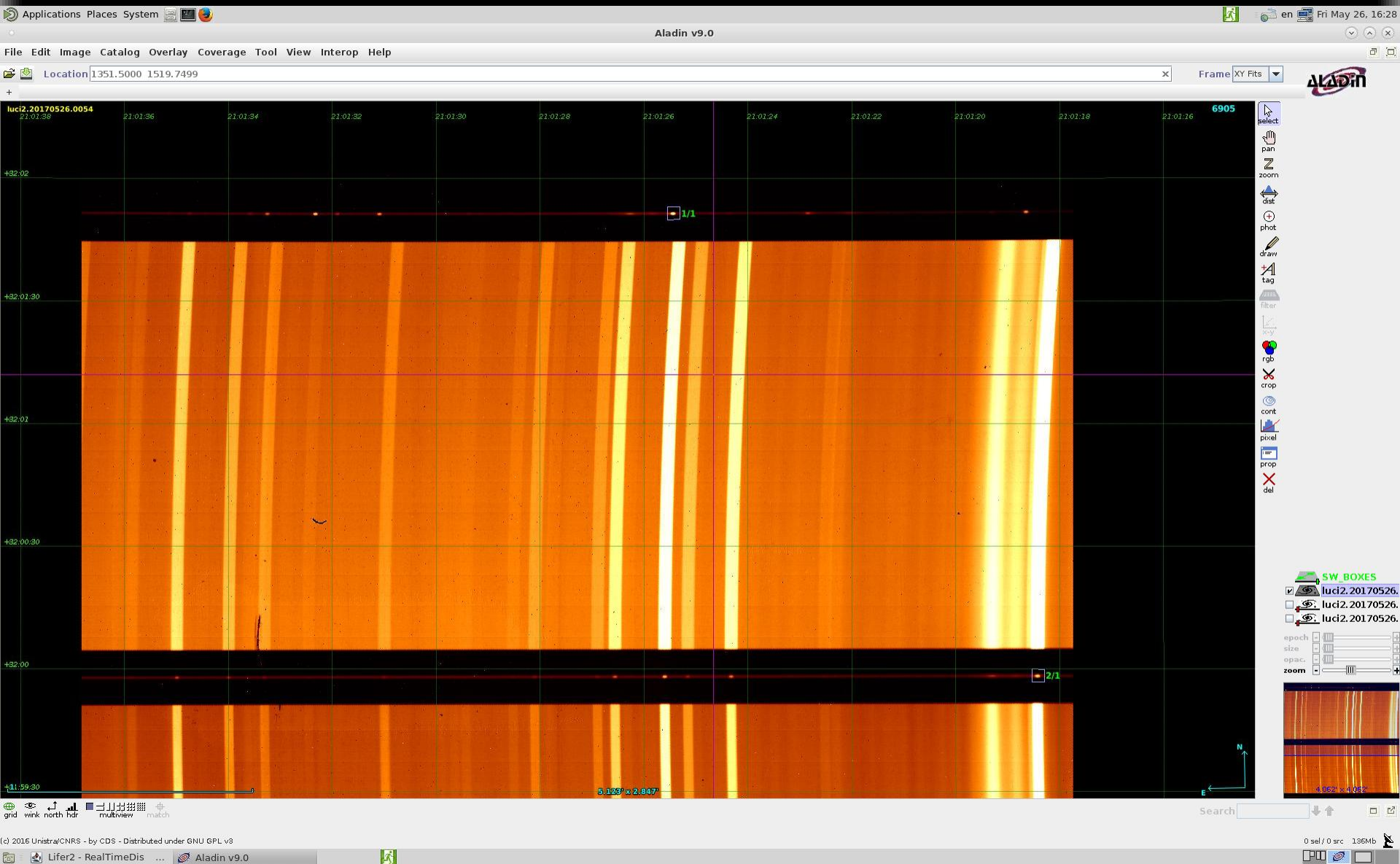
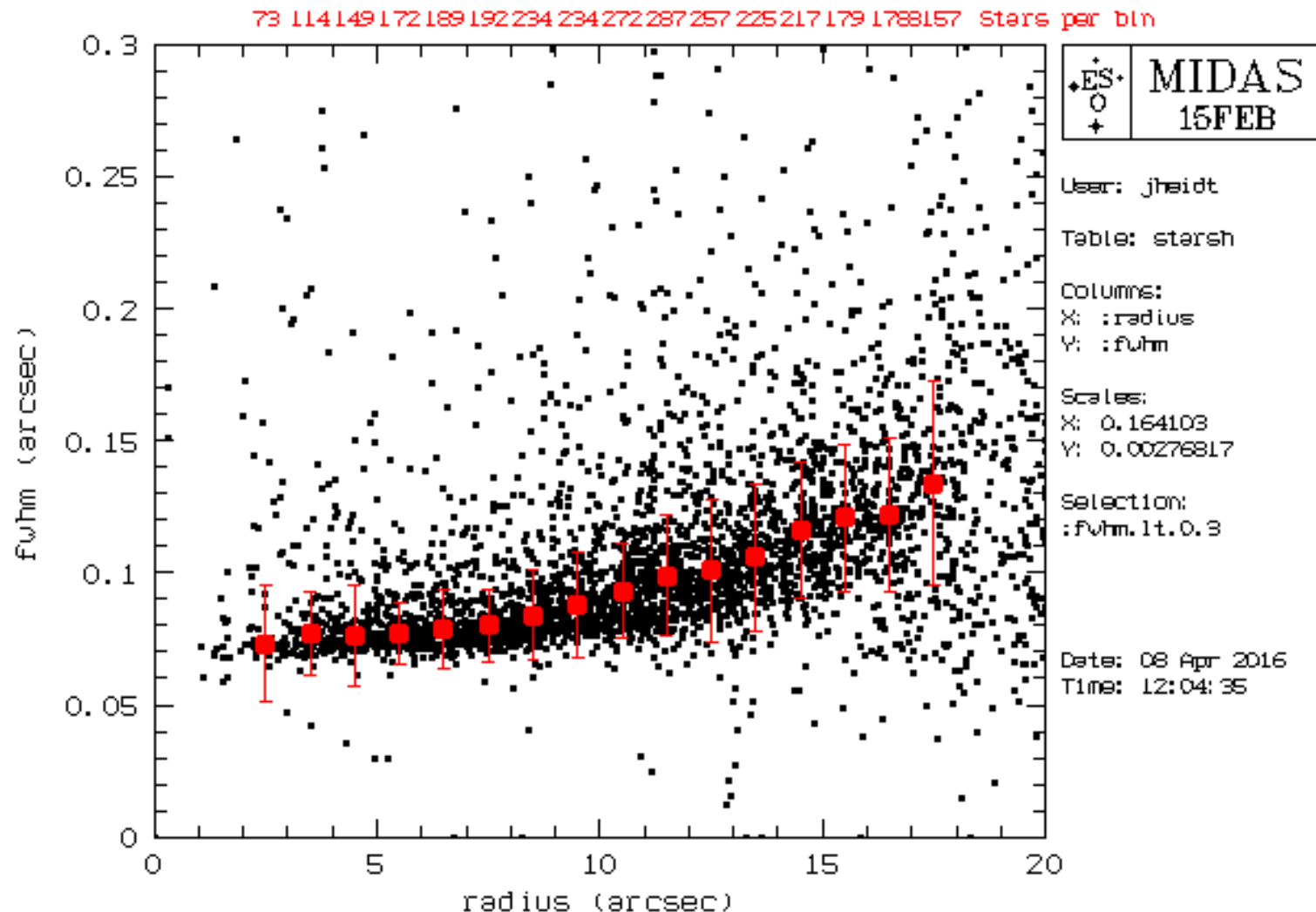Position of line must be known to an accuracy of 1 pix (for blind boxes)
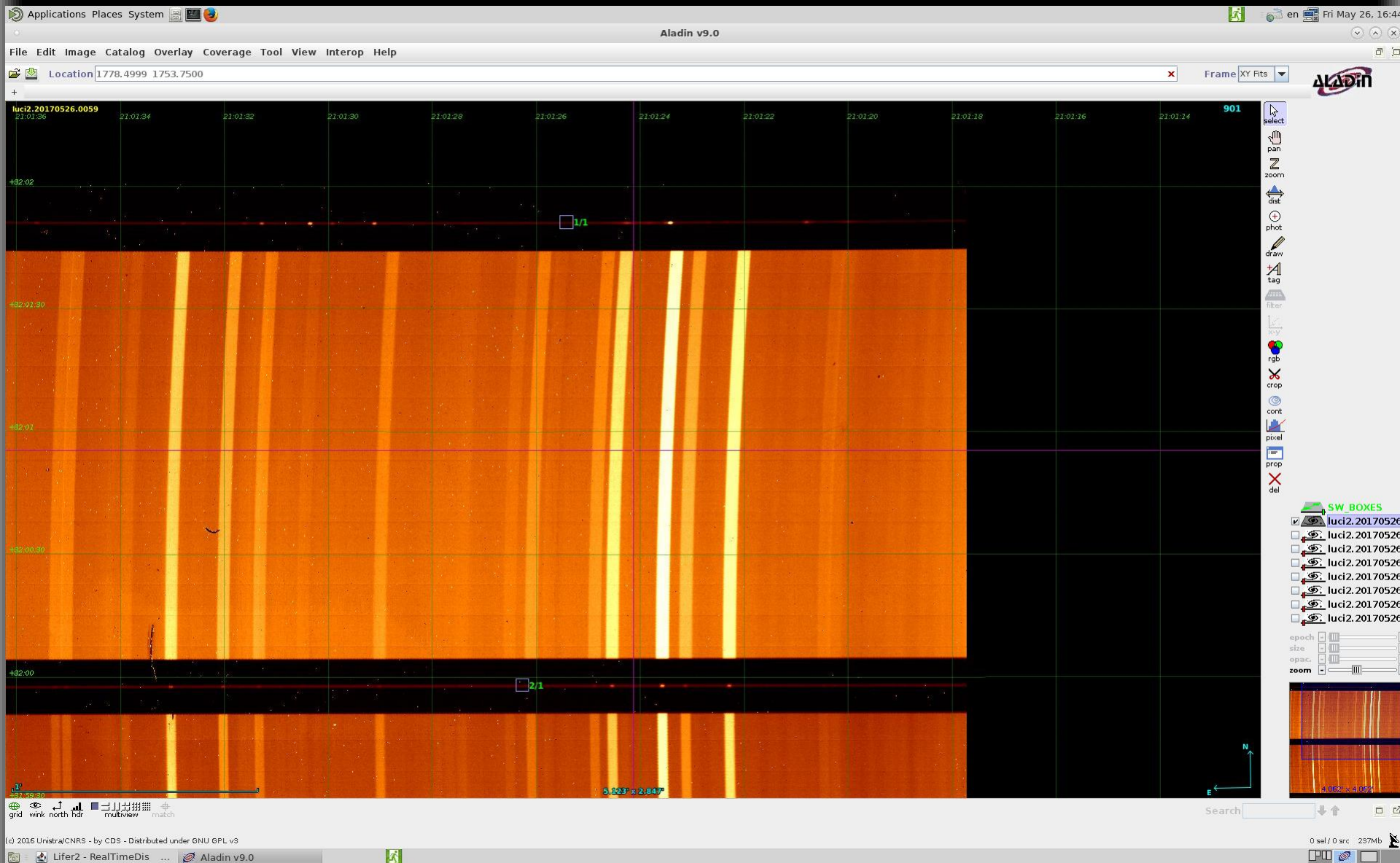
which will be hard given the non-linear dispersion relation…

Globular Cluster M5

The usual comparison: about 3000 stars in 30" • 30" FOV

Globular Cluster M5

RS had 10.7mag, Bin=2
resolution-limited close to reference star where correction is best

Globular Cluster M5

M5 H-band. 1min
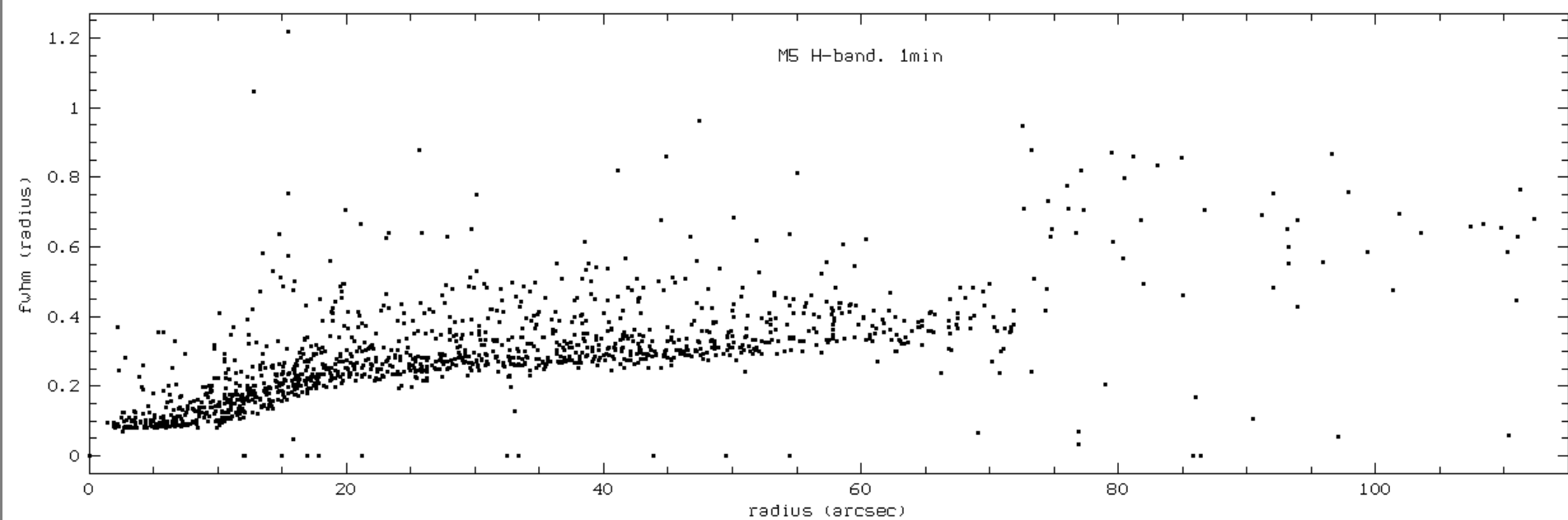
Up to 60" from reference star still good correction !

M71
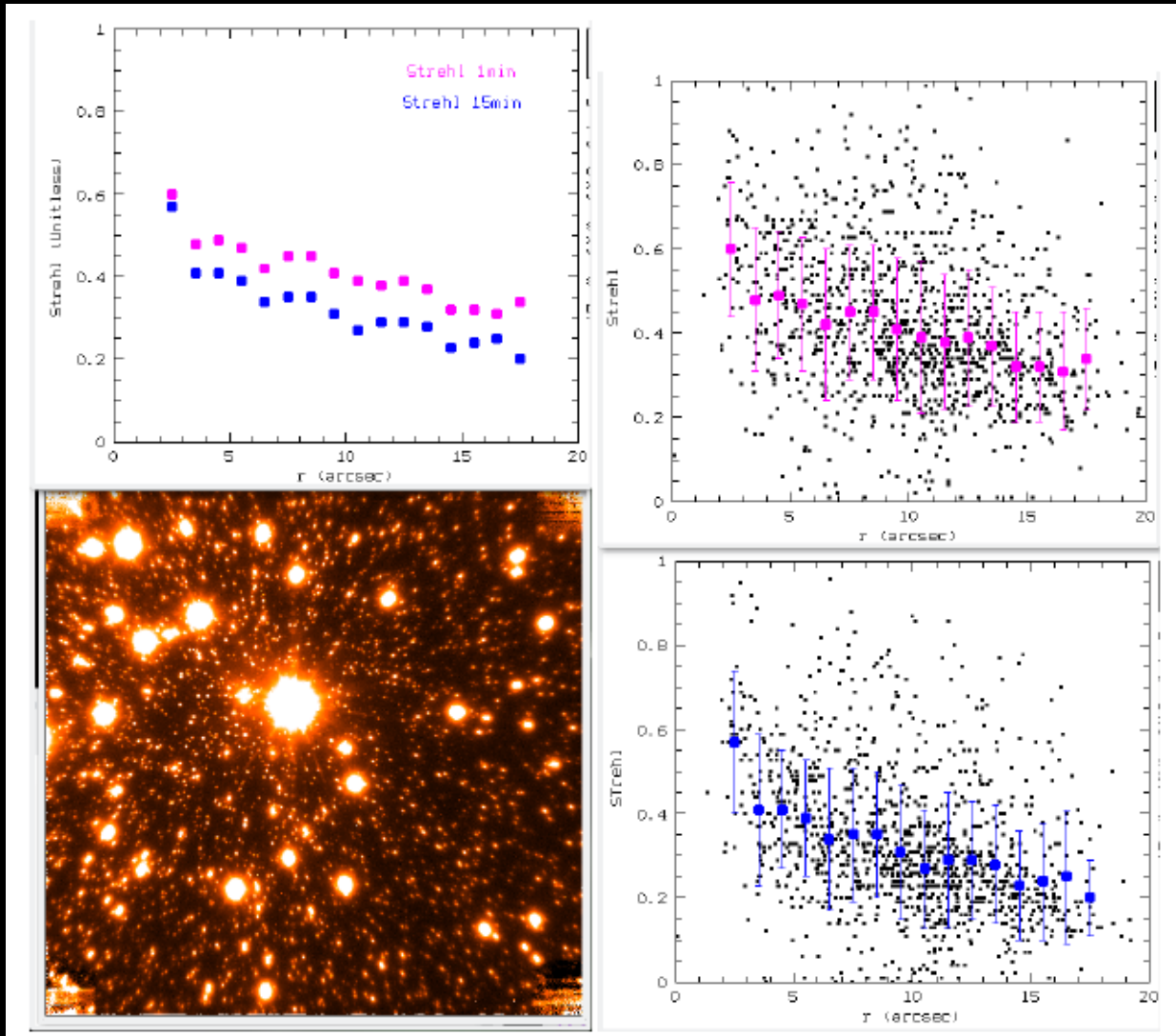
Strehl constant at about 8" radius and declines slowly by 15-20%
Note: Offline Strehl-tool available for observers !

3C 294 (z = 1.786)

3C 294 (z = 1.778), FLAO + LUCI1, KS, 20min

10"

1 arcsec

1"

E N

Figure 1: Left) Ks-image (9 min) of 3C294 taken with Keck in seeing-limited mode. Bottom right) H-band image of 3C294 using the Keck adaptive optics system. Integration time was 100min. Top right) Ks-band image of 3C294 using FLAO + LUCI2. Integration time was 20min. Note the difference in morphology of the western component of 3C294 (north is up and east to the left on the diffraction-limited image). For the FLAO + LUCI1 observations the bright star 10" west of 3C 294 was used as reference star. The KECK images are from Quirrenbach et al. (2001).

RS double with 0.155 arcsec separation

<--------------------->
0.2 arcsec
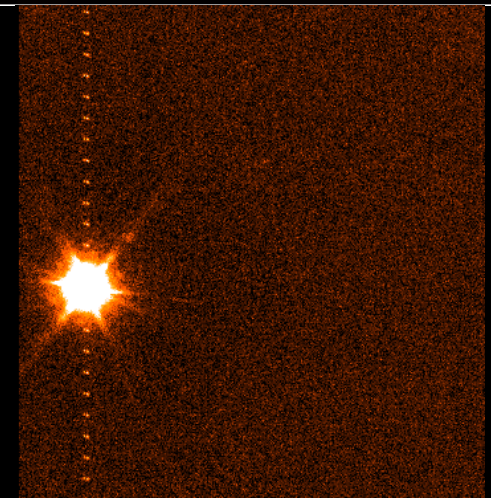
Channel Xtalk

Status & Timeline

- At present: LUCI1/2 offered in shared-risk for (short-DIT) imaging
- Com-run next week: Bin=1 & AFC-ima LUCI2, perhaps AO-spec short images
- Early 2017B: Another AO-com run, AO-checkout, AFC-ima LUCI1, AO-spec AFC LUCI2
- Early 2017B: LUCI1/2 fully available for AO-ima, perhaps AO-spec short images too
- Later in 2017B: full release of LUCI-AO

…now most likely 2 com-runs in 2017B (ideally Sep/Nov) with not much of a further delay…
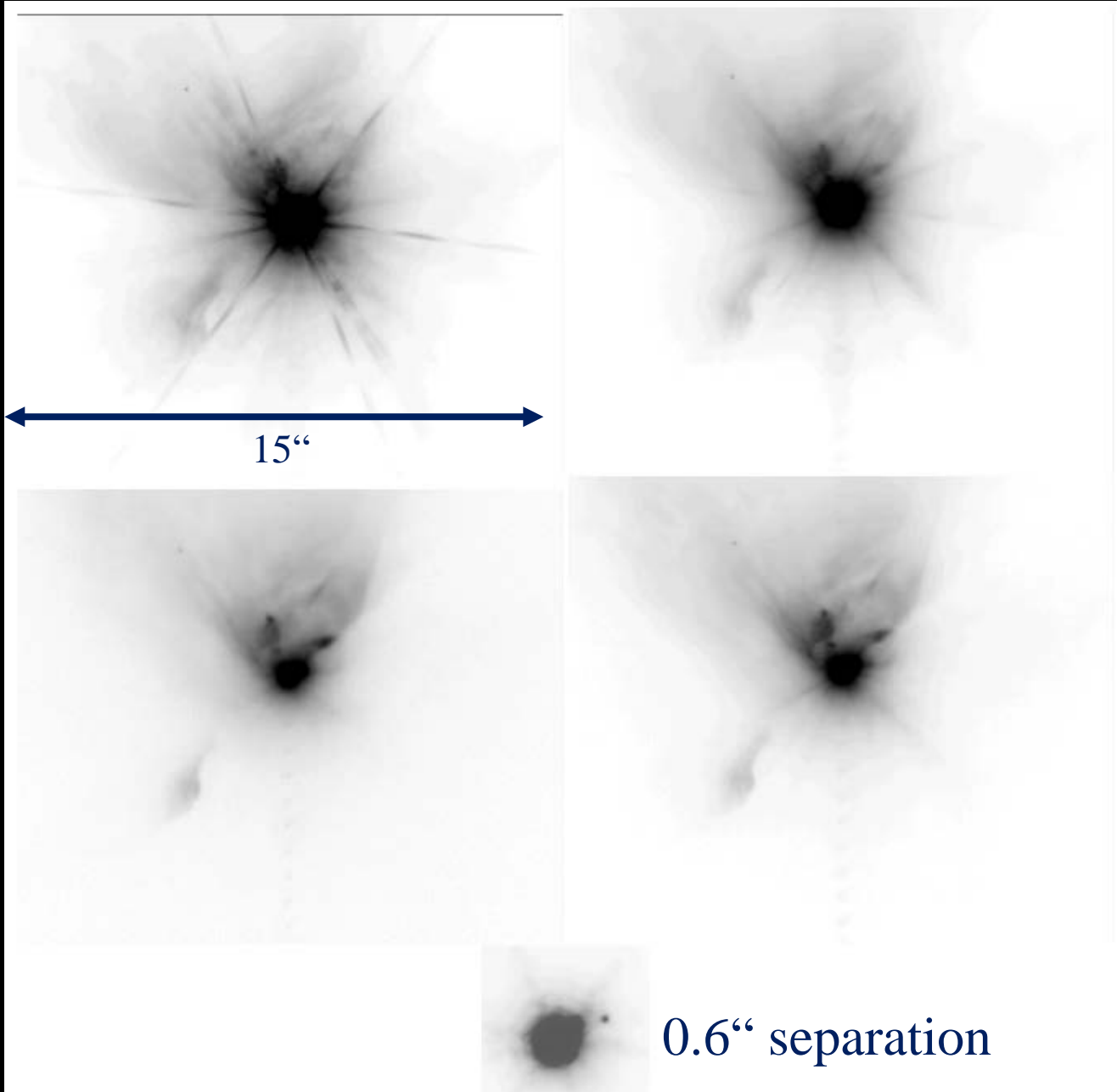
Globular Cluster M5
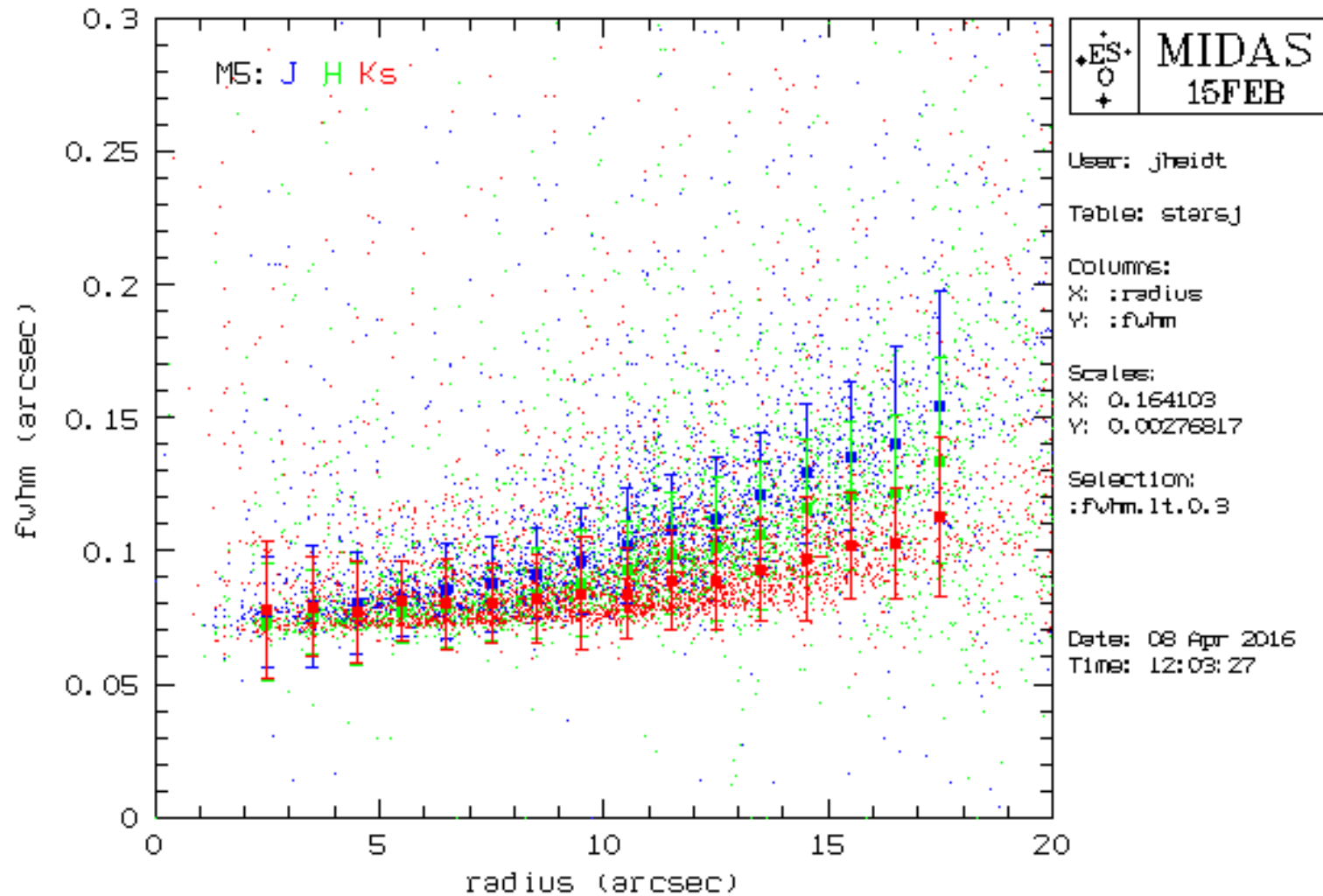
Correction has Lambda-dependence $\propto \lambda / D$

Herbig Be star R Mon

Ks

H

z

J

15"

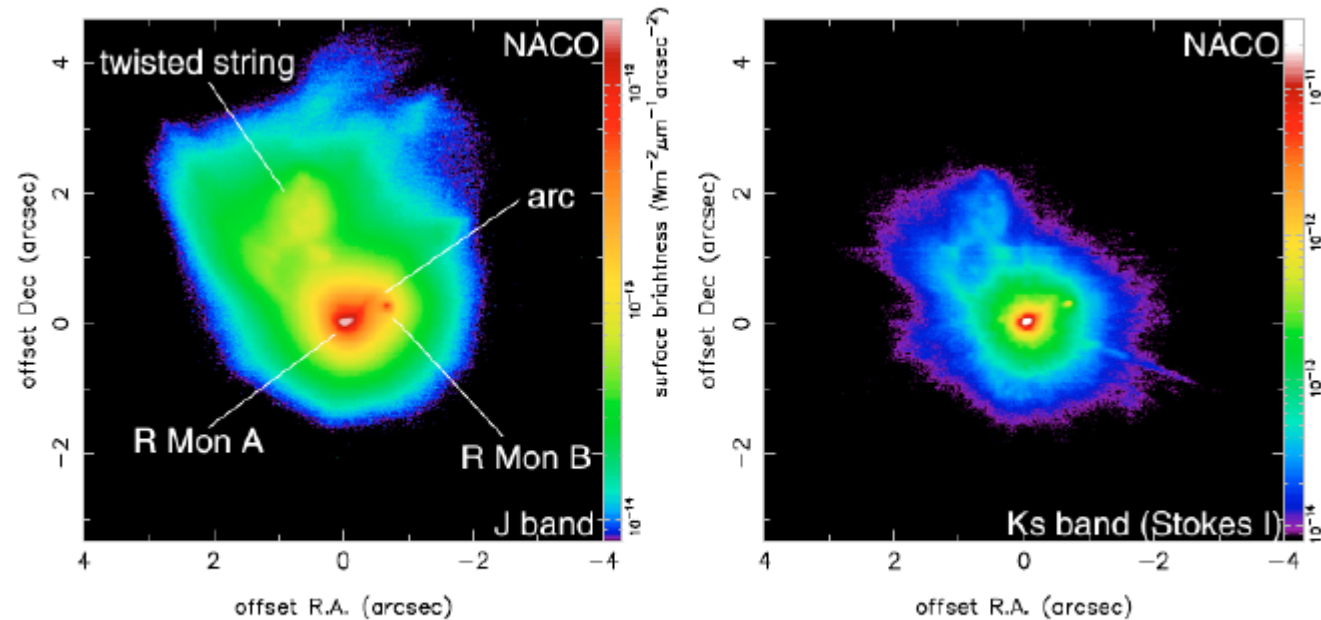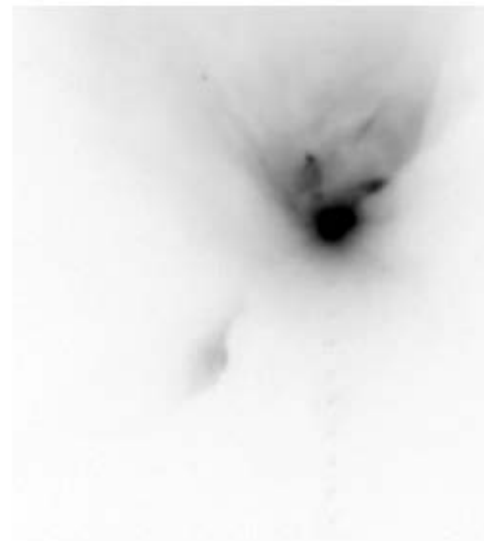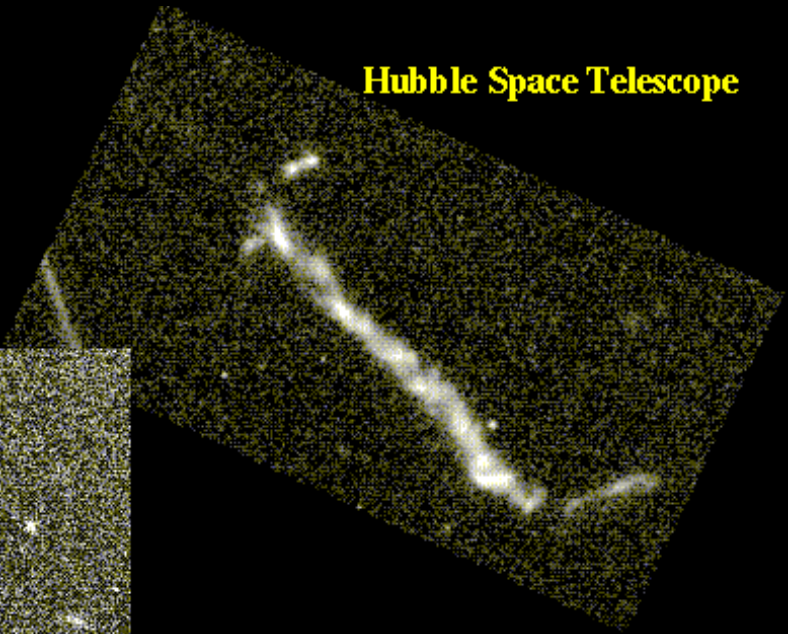0.6" separation

Herbig Be star R Mon

much better!

15"
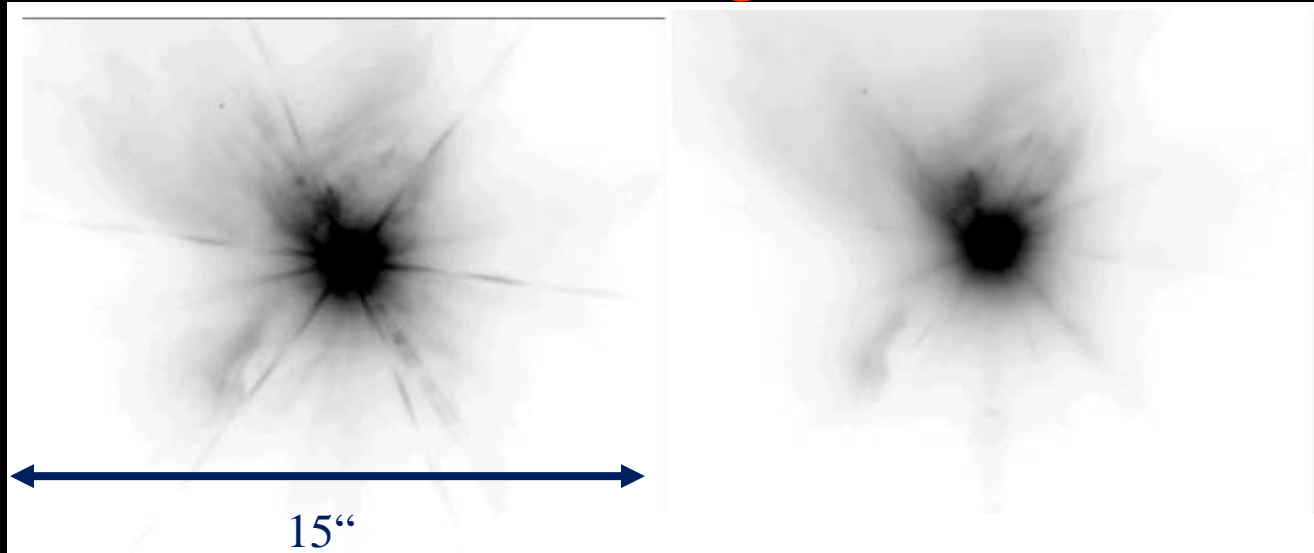
Figure 6: Images of the Herbig Be star R Monocerotis in taken with NACO@VLT in J and Ks for comparison. Adapted from Murakawa et al. (A&A 488, L75 (2008)).
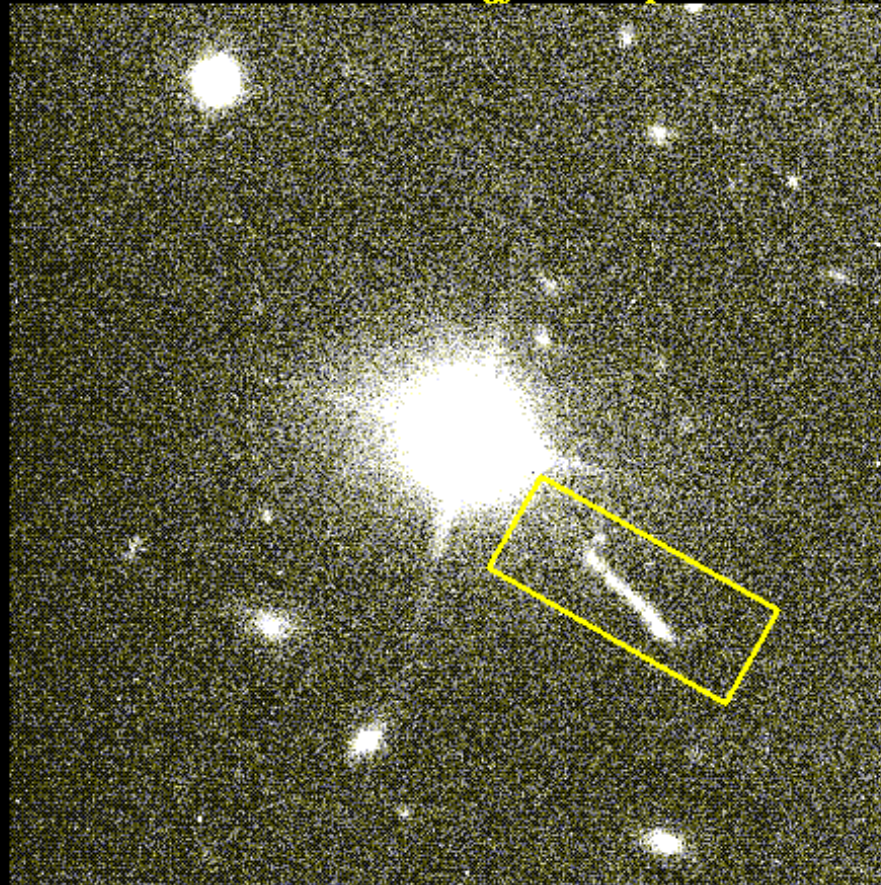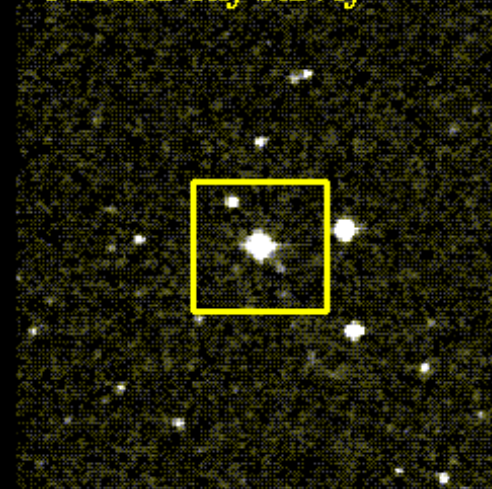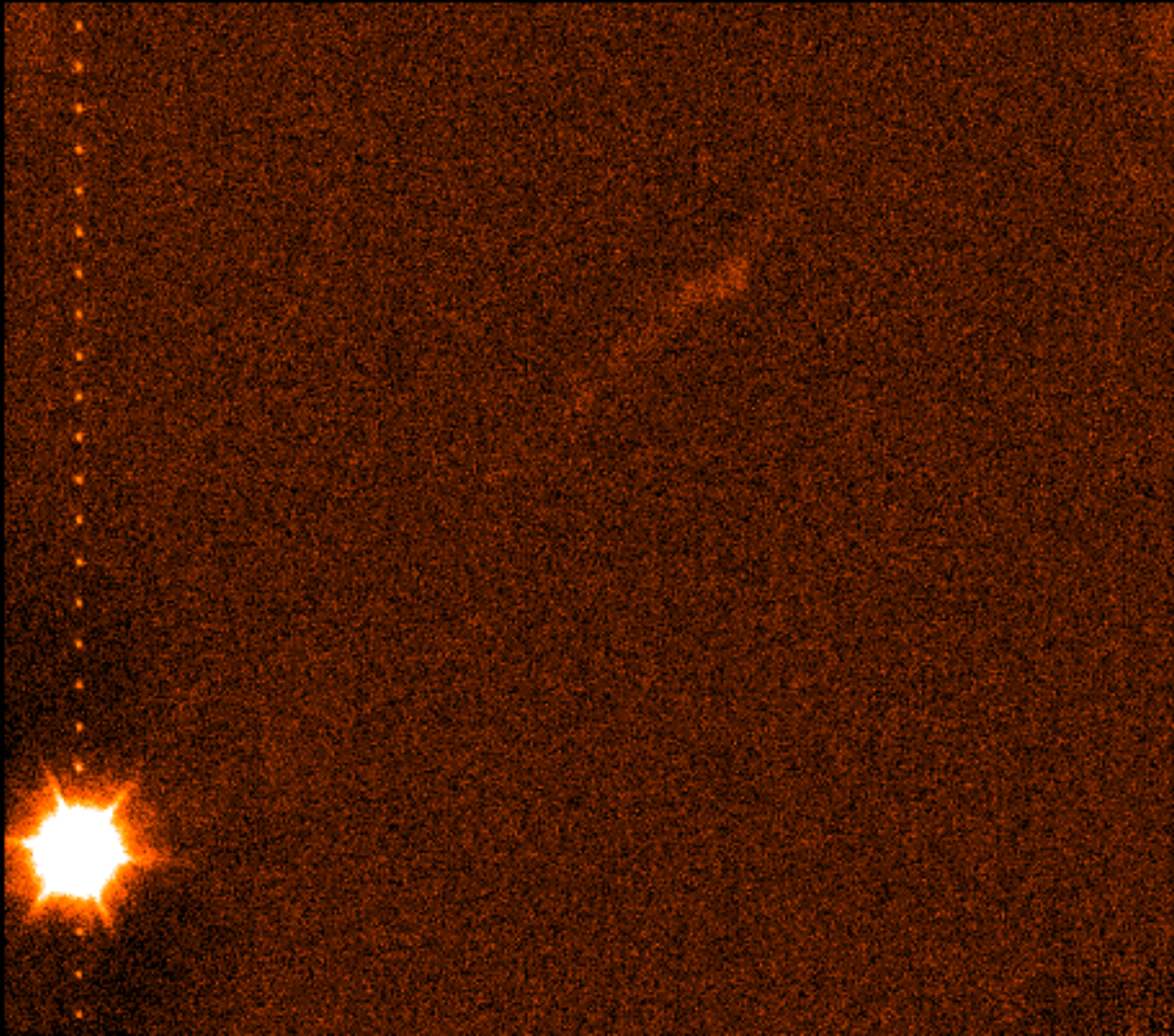
3C 273

3C 273 and its Jet

ESO New Technology Telescope

Hubble Space Telescope

Palomar Sky Survey

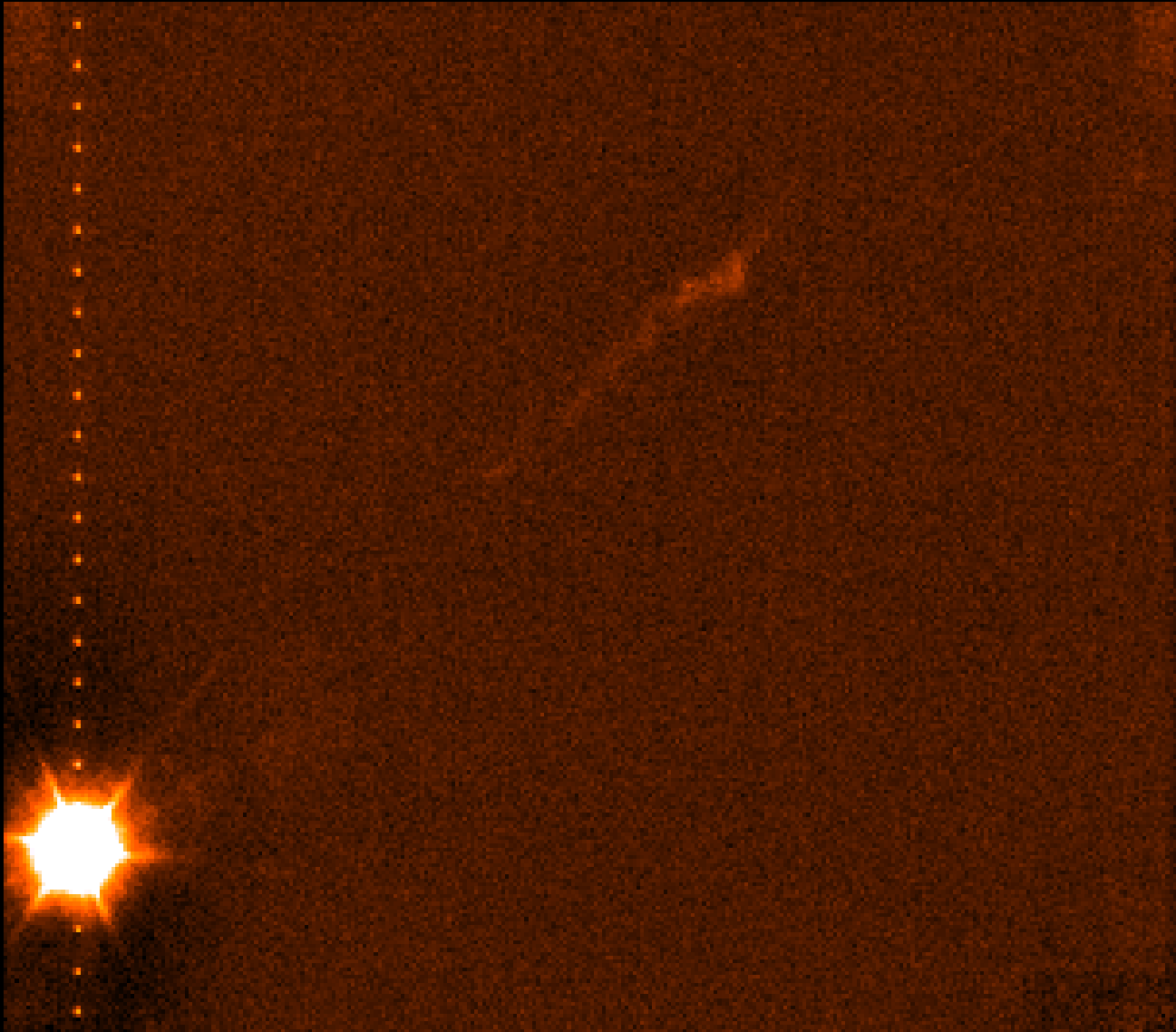# 3C 273

Ks, 35min, doesn't look great – scale is 0.015"/pix!

3C 273

Ks, 35min, doesn't look great – scale is 0.015"/pix!
Rebinning helps…OK as long as images are photon noise limited