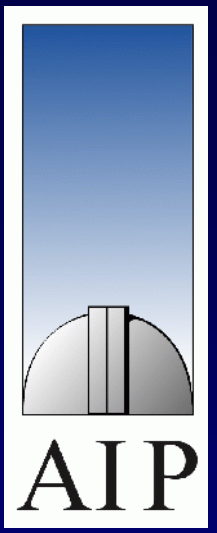
Integral Field Spectroscopy with VIMOS



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Astrophysikalisches Institut Potsdam
[1)] ESO

ESO Instrument Calibration Workshop, January 25, 2007

Overview

I. Introduction

II. Science with VIMOS IFU

III. Data Reduction

IV. Instrumental Considerations, Performance

I. Introduction

Introduction

- VIMOS = Visible Multiobject Spectrograph
- 360 — 1000 nm
- 4-channel, wide-field imager and spectrograph

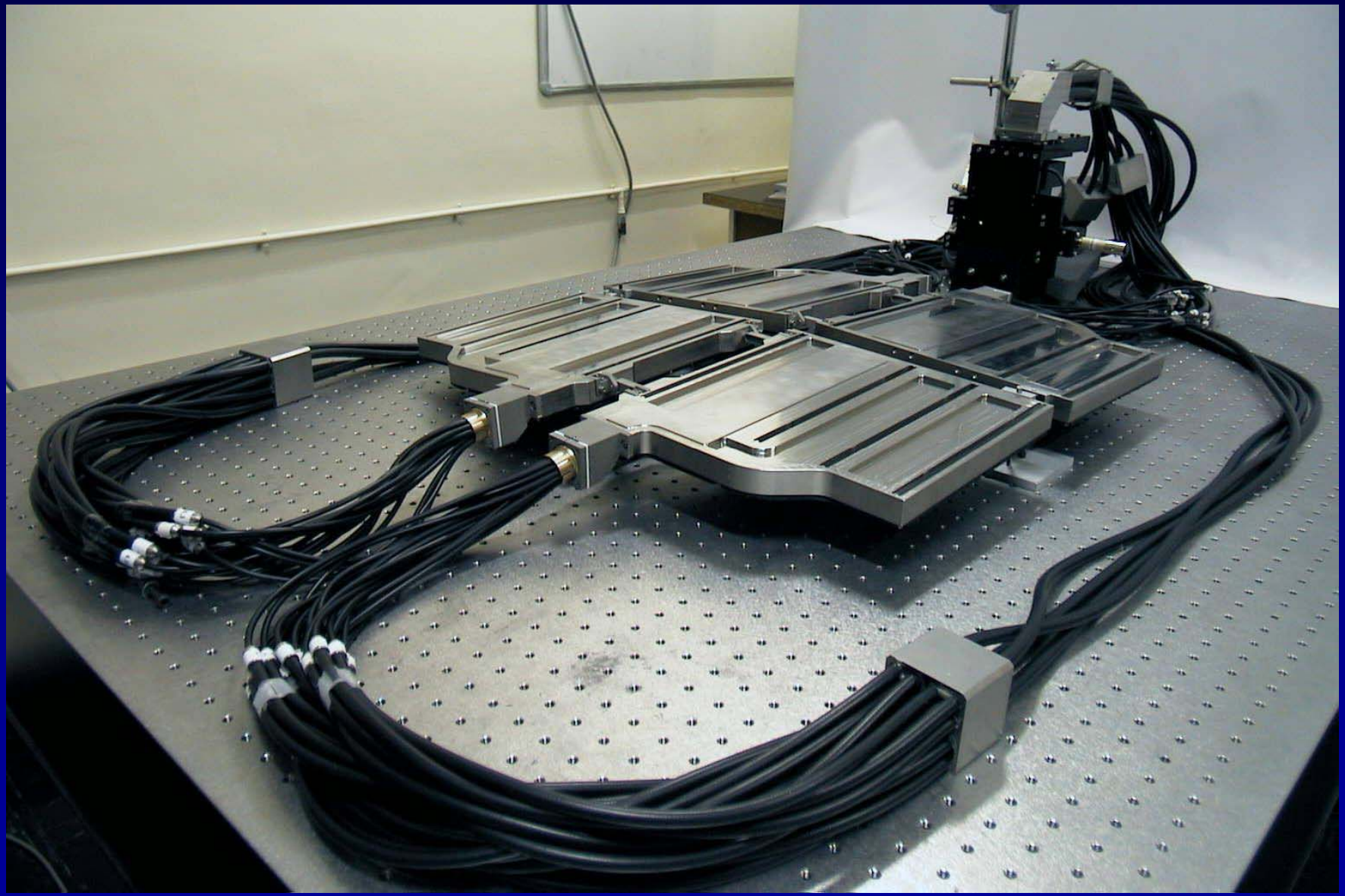
  imaging: 4 fields 7 x 8 arcmin^2
  MOS: 4 fields 7 x 8 arcmin^2, 200…20 slits per field,
  R = 200 … 2500

  IFU: add-on device

  4x 20 bundles of 80 fibers,
  located on 4 deployable masks

  IFU head with total of 6400 fibers (mux = 4)
  1600 fibers (shutter)

Introduction



Introduction

Introduction

Grism	common λ range	R	Å/pix	arcsec/lens	FOV [arcsec^2]
LR blue	400-670 nm	220	5.3	0.67 0.33	54 x 54 / 27 x 27 27 x 27 / 13 x 13
LR red	590-915 nm	260	7.3	0.67 0.33	54 x 54 / 27 x 27 27 x 27 / 13 x 13
MR	490-1015 nm	720	2.5	0.67 0.33	27 x 27 13 x 13
HR blue	415-620 nm	2550	0.51	0.67 0.33	27 x 27 13 x 13
HR orange	525-740 nm	2650	0.6	0.67 0.33	27 x 27 13 x 13
HR red	645-860 nm	3100	0.6	0.67 0.33	27 x 27 13 x 13

Introduction

II. Science with VIMOS IFU

Science with VIMOS IFU

Example 1 :

Mass-loss at AGB measured in Haloes of Planetary Nebulae

Monreal-Ibero, A., M. M. Roth, M.M., Schönberner, D., Steffen, M., Böhm, P. 2005, ApJ 628, L139

"Integral Field Spectroscopy of faint Haloes of Planetary Nebulae"

AGB mass-loss history

Science Case :

- mass-loss history o
  evolution of galaxie
- mass loss rates unc
- no way to directly m

- goal: measure T_e, n_e

- problem: diagnostic
  typically <

- solution: increase S/N significantly through spatial binning over large areas of IFU

AGB mass-loss history

Observations :

- April 17 + 18, 2004
- VIMOS IFU, LR blue
  0.67 " / spaxel
  FOV = 54" x 54"
  λ 3700 – 6700 Å, 5.3 Å/pixel
  R = 180
- mosaic pointings, typically 1800 – 2700 s total exposure times
- photometric nights
- seeing 1.3" / 1.0"

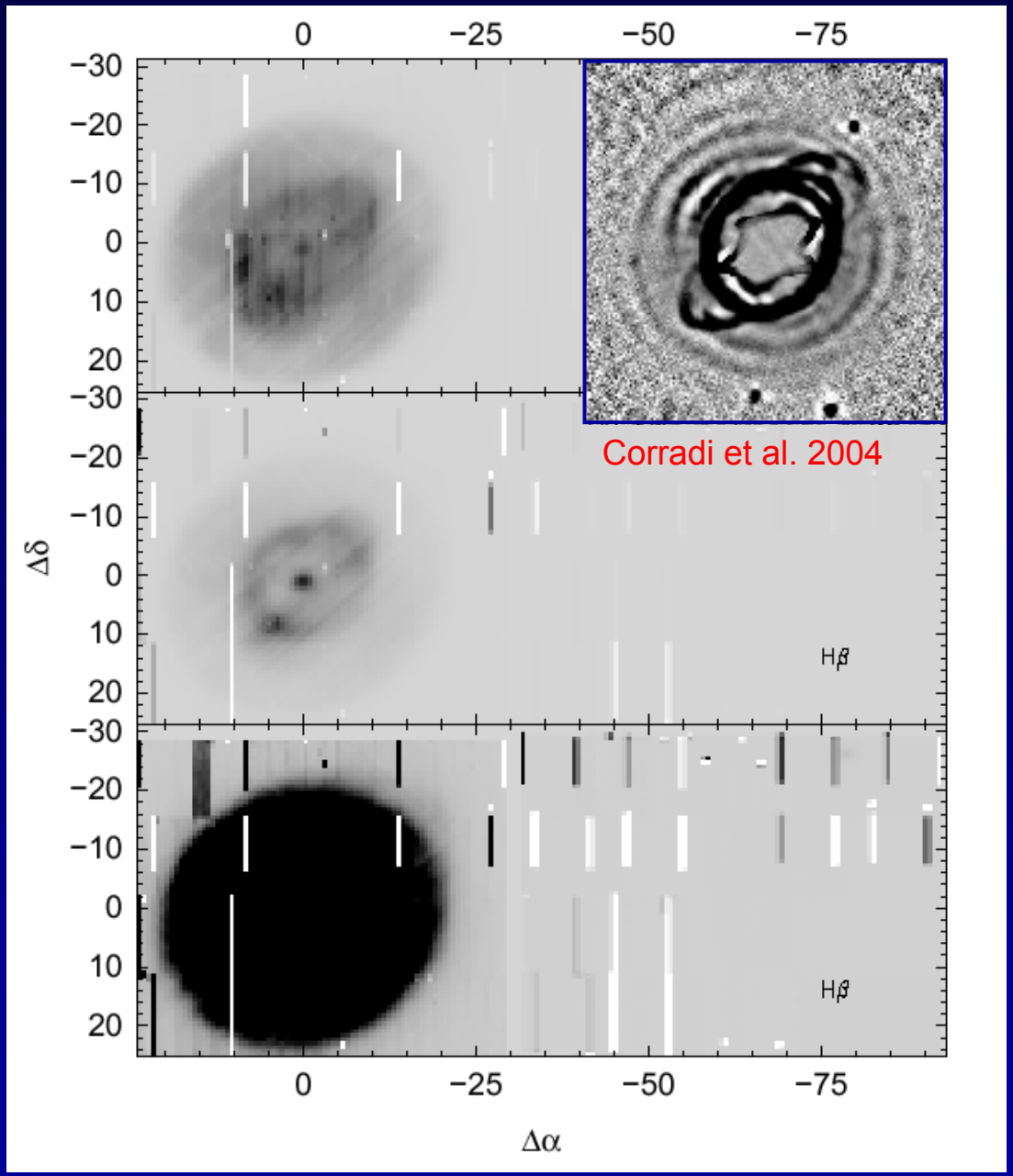
NGC 3242

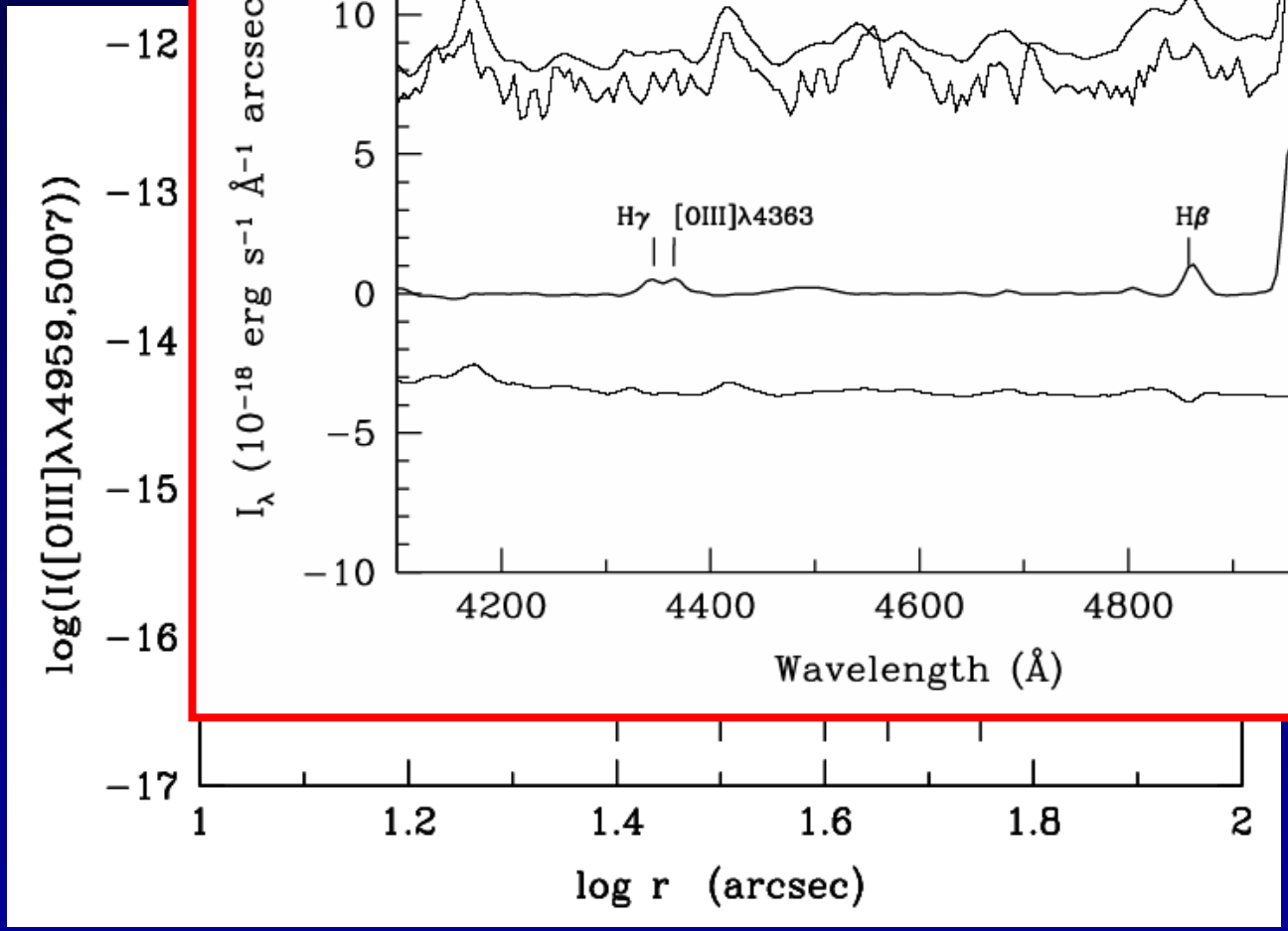
T_{eff} = 68000 K
log g = 4.6
M = 0.65

VIMOS-IFU
54″ x 54″

Mosaic of 3 pointings

Monreal et al. 2005
ApJ 628, L139



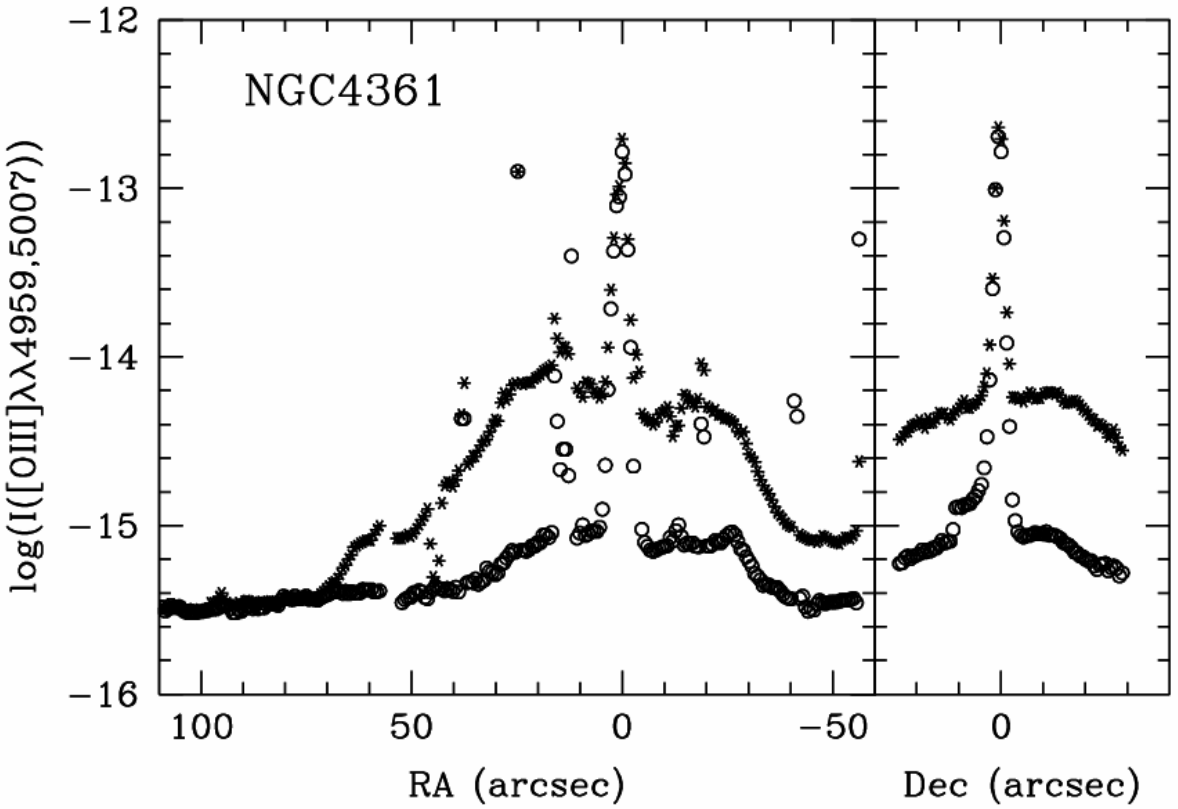


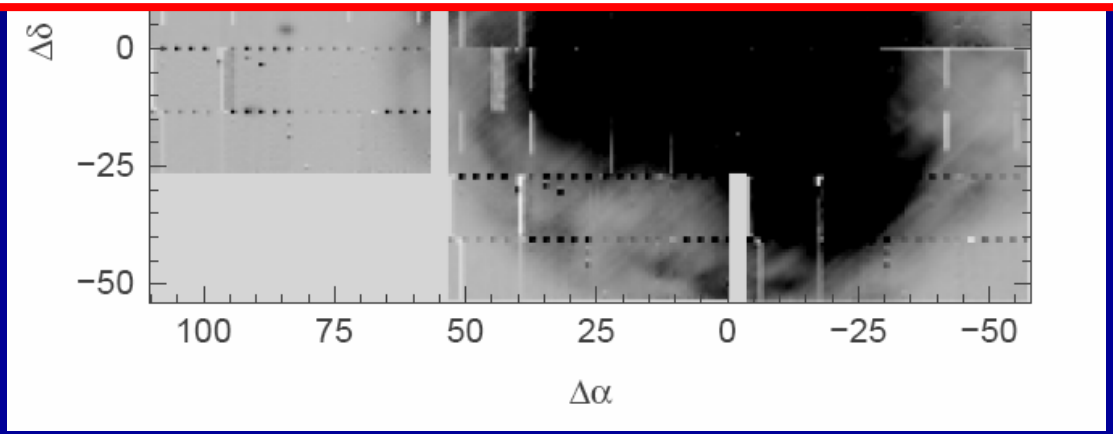
VIMOS data (*Monreal-Ibero et al. 2005*)

NGC 4361

VIMOS-IFU
54″ x 54″

Mosaic of 5 pointi





Monreal et al. 2005
ApJ 628, L139

Science with VIMOS IFU

Example 2 :

Star Formation in merging Galaxies

Bastian, N., Emsellem, E., Kissler-Patig, M., Maraston, C. (2006) A&A 445, 471

"Young star cluster complexes in NGC 4038/39 — Integral field spectroscopy using VIMOS-VLT"

SF in Mergers

Science Case :

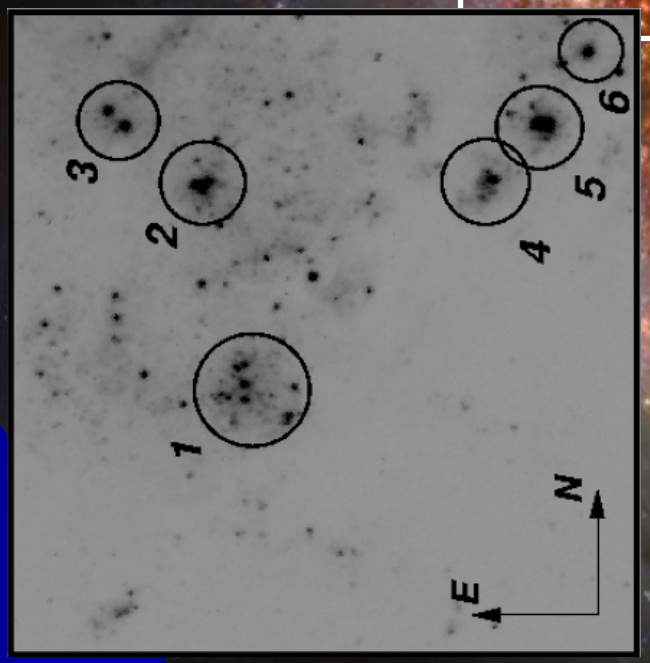
- formation of massive star clusters triggered by mergers
- hierarchical structure formation of clusters ?
- correcting for spatially varying extinction
- measure: age
  metallicity
  velocity/vel. dispersion of gas
  SFR
- target: NGC 4038/39 (Antennae)

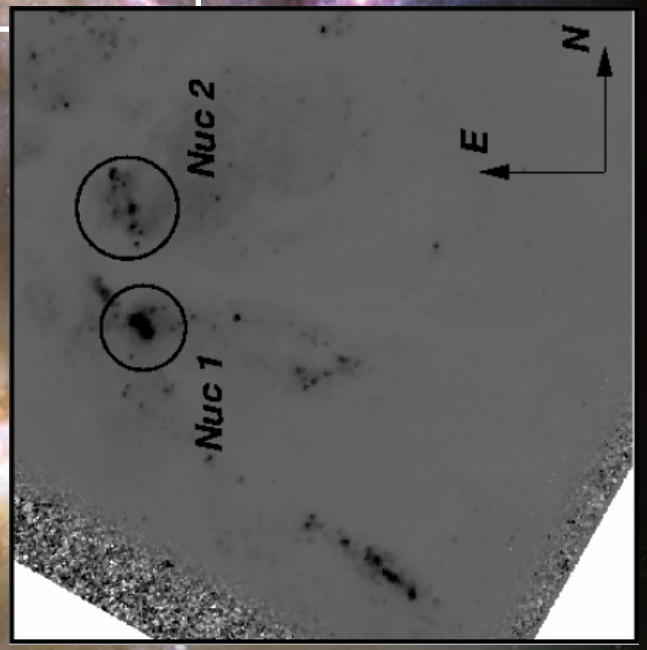
SF in Mergers

Observations :

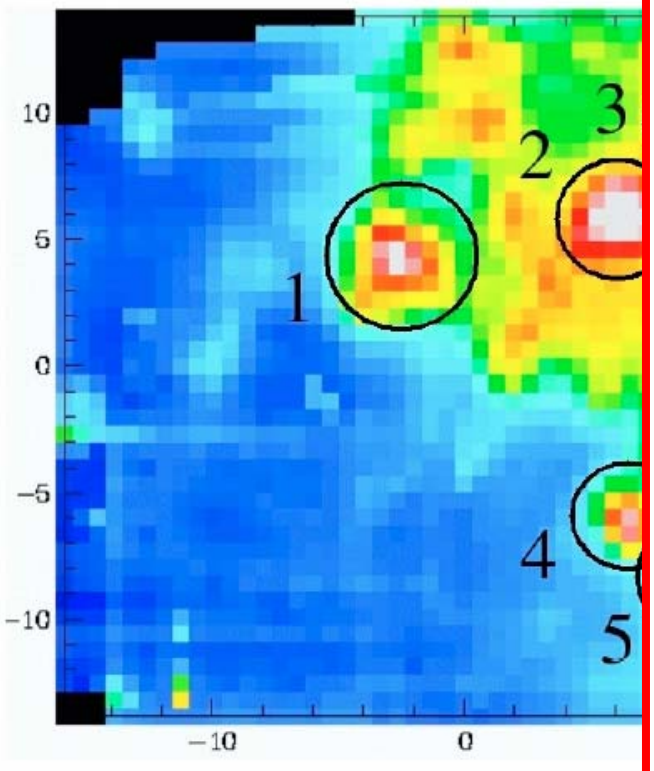
- April 3 - 5, 2003
- VIMOS IFU, HR blue
  0.67 " / spaxel
  FOV = 27" x 27"
  λ 4150 – 6100 Å, 0.51 Å/pixel
  R = 2550
- 2 pointings, 8x 1200 s exposures each
- photometric nights
- seeing 1.3" / 1.0"

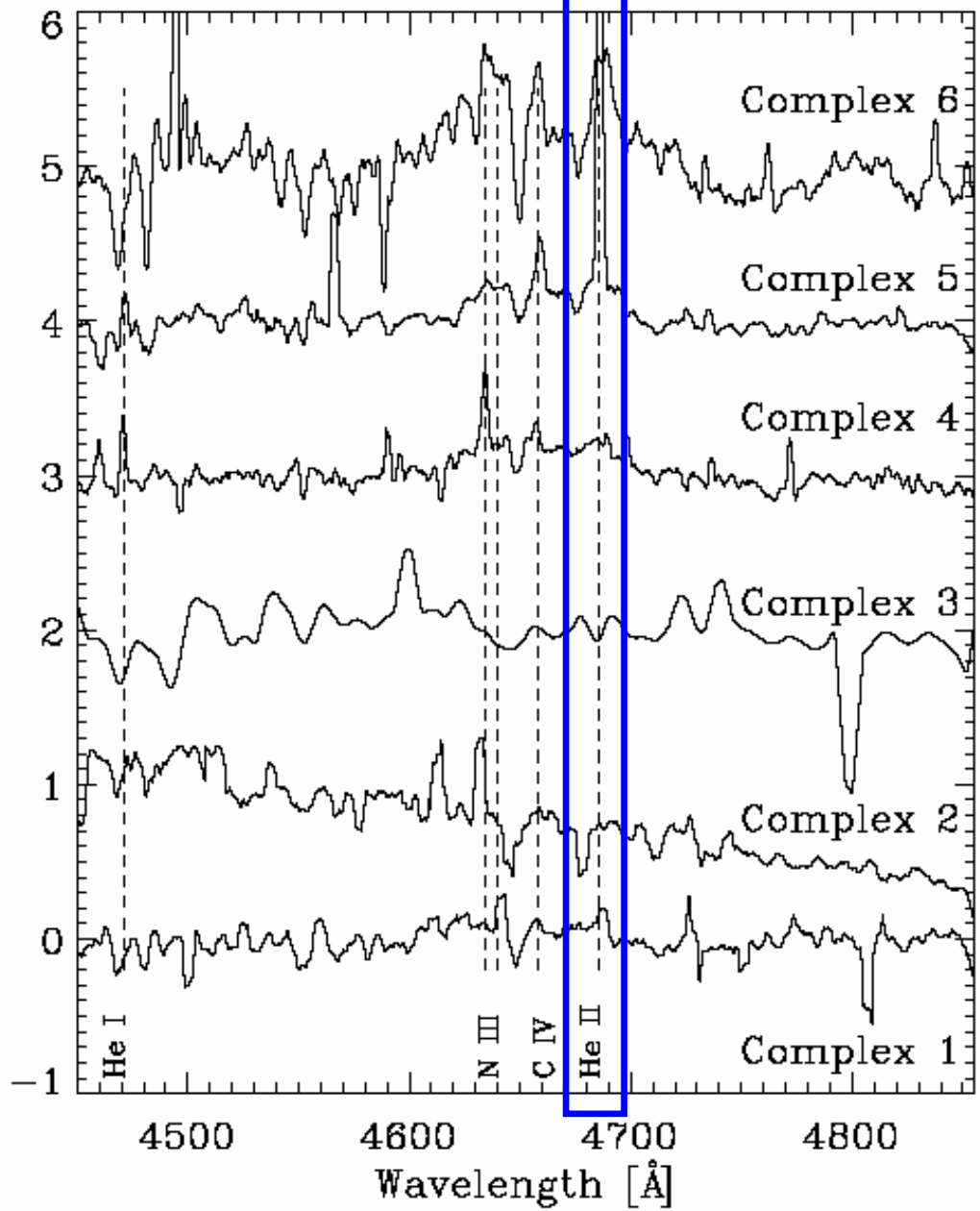
2. Galaxies





NGC 4038/39 (Antennae)





Science with VIMOS IFU

Example 3 :

Ultra-luminous IR Galaxies

Monreal Ibero, A., Arribas, S., Colina, L.

— work in progress

(U)LIRGs

Science Case :

- ULIRGs $L_{IR} \geq 10^{12} L_{\odot}$ ($\sim L_{QSO}$)

  LIRGs $10^{11} L_{\odot} \leq L_{IR} \leq 10^{12} L_{\odot}$ (twice as numerous)

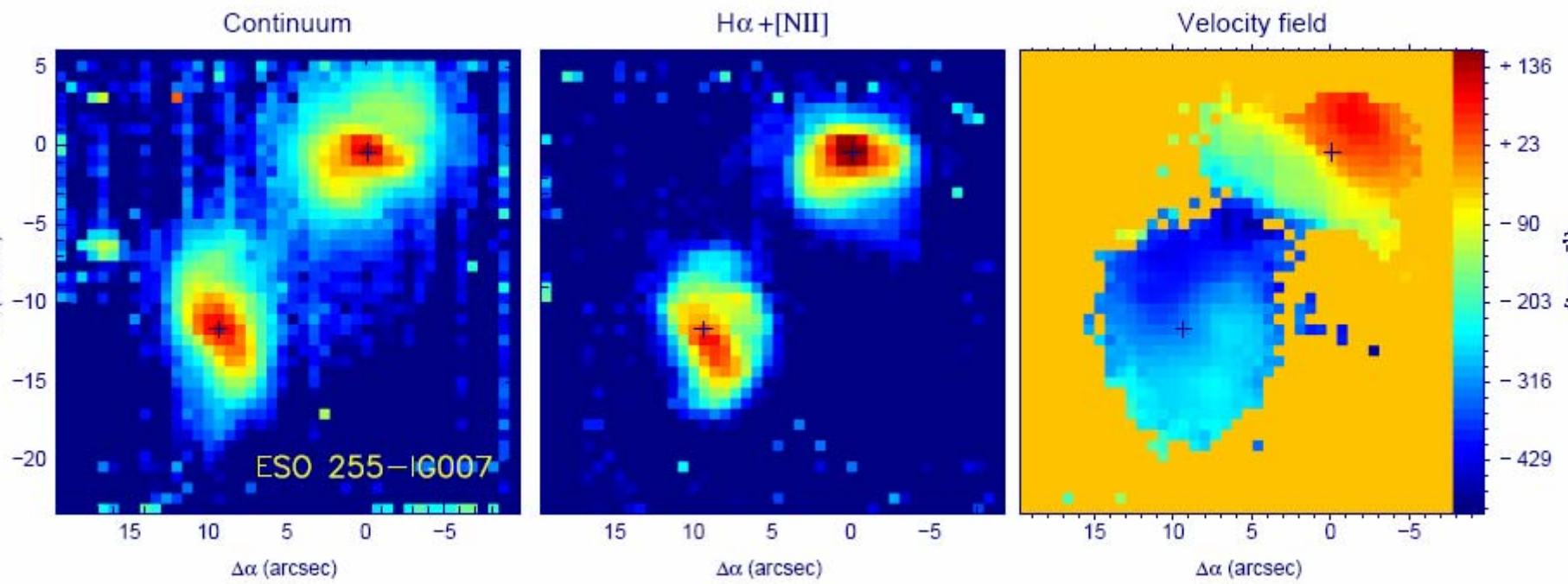
- progenitors of QSOs / or intermediate mass ellipticals ?
- frequency of mergers ?
- kinematics ?
- ionization structure ?

(U)LIRGs

Observations :

- Service in 13 nights, 04 Sep 2005 … 08 Mar 2006
- VIMOS IFU, HR orange
  0.67 " / spaxel
  FOV = 27" x 27"
  λ 5250 – 7400 Å, 0.6 Å/pixel
  R = 2650
- 4 dither pointings, 4x 750 s total exposure times

(U)LIRGs


Continuum
Hα +[NII]
Velocity field
ESO 255−IG007
5
0
−5
−10
−15
−20
15
10
5
0
−5
Δα (arcsec)
+ 136
+ 23
− 90
− 203
− 316
− 429

Science with VIMOS IFU

Example 4 :

Properties of SDSS galaxies

Gerssen, J., Christensen, L., Wilman, D., Bower, R. (2006)
The Messenger 126

"Mapping the properties of SDSS galaxies
with the VIMOS IFU "

mapping SDSS Galaxies

Science Case :

- Quantify bias in SDSS results
  (SDSS data derived from single apertures)
- Map diagnostic properties (metallicity, SFR, etc)
- Map kinematic properties and constrain (dark) mass distribution
- pre-MUSE science

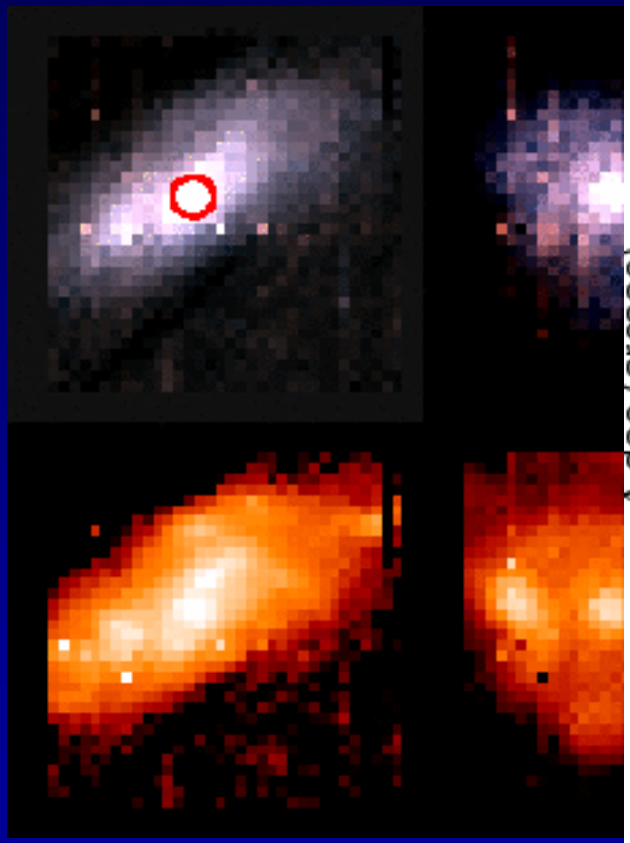
mapping SDSS Galaxies

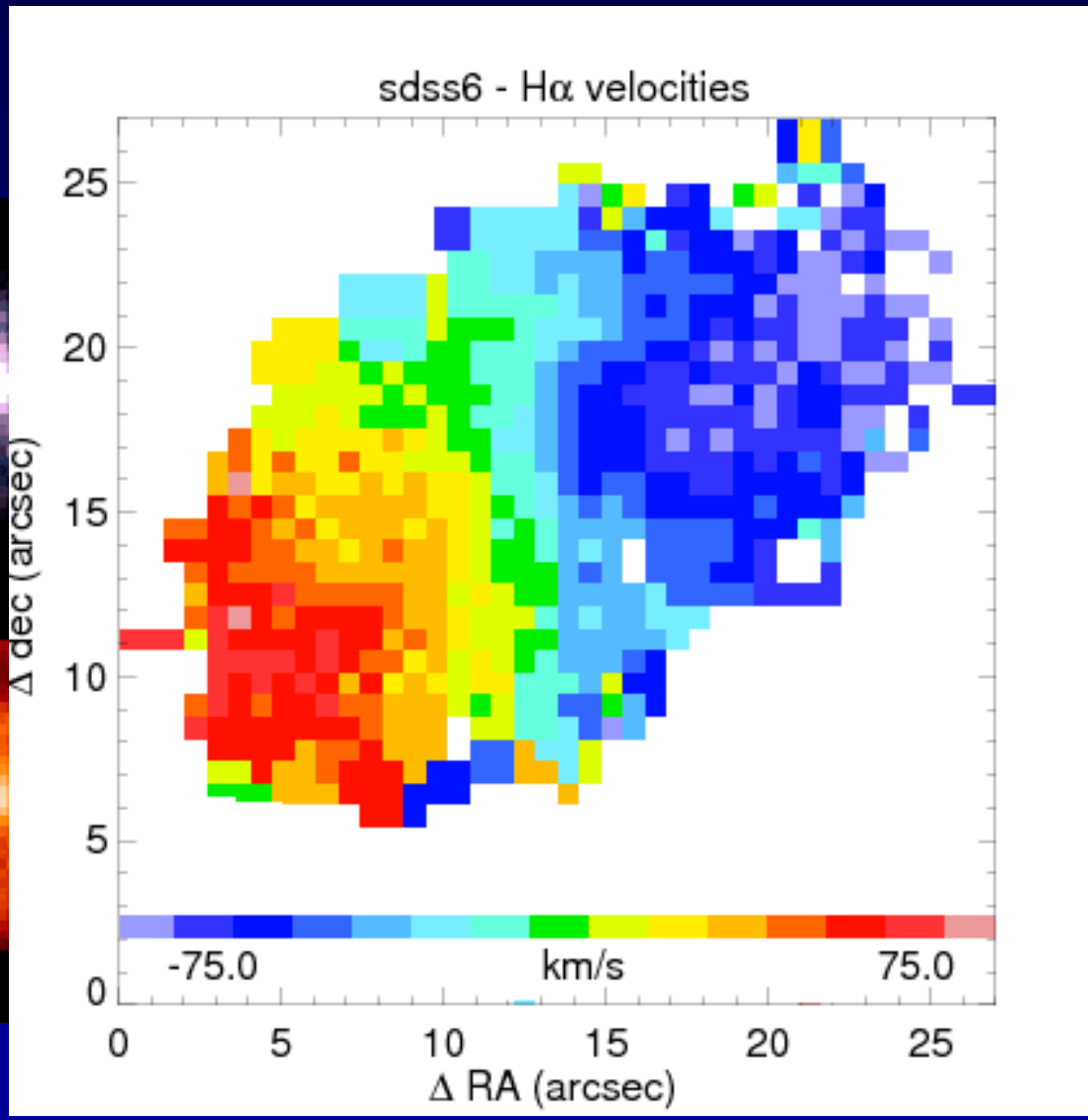
Observations :

- P76 (service), 12 galaxies
- VIMOS IFU, MR blue
  0.67 " / spaxel
  FOV = 27" x 27"
  λ 4400 – 9000 Å, 2.5 Å/pixel
  R = 720
- 3600 s total exposures each

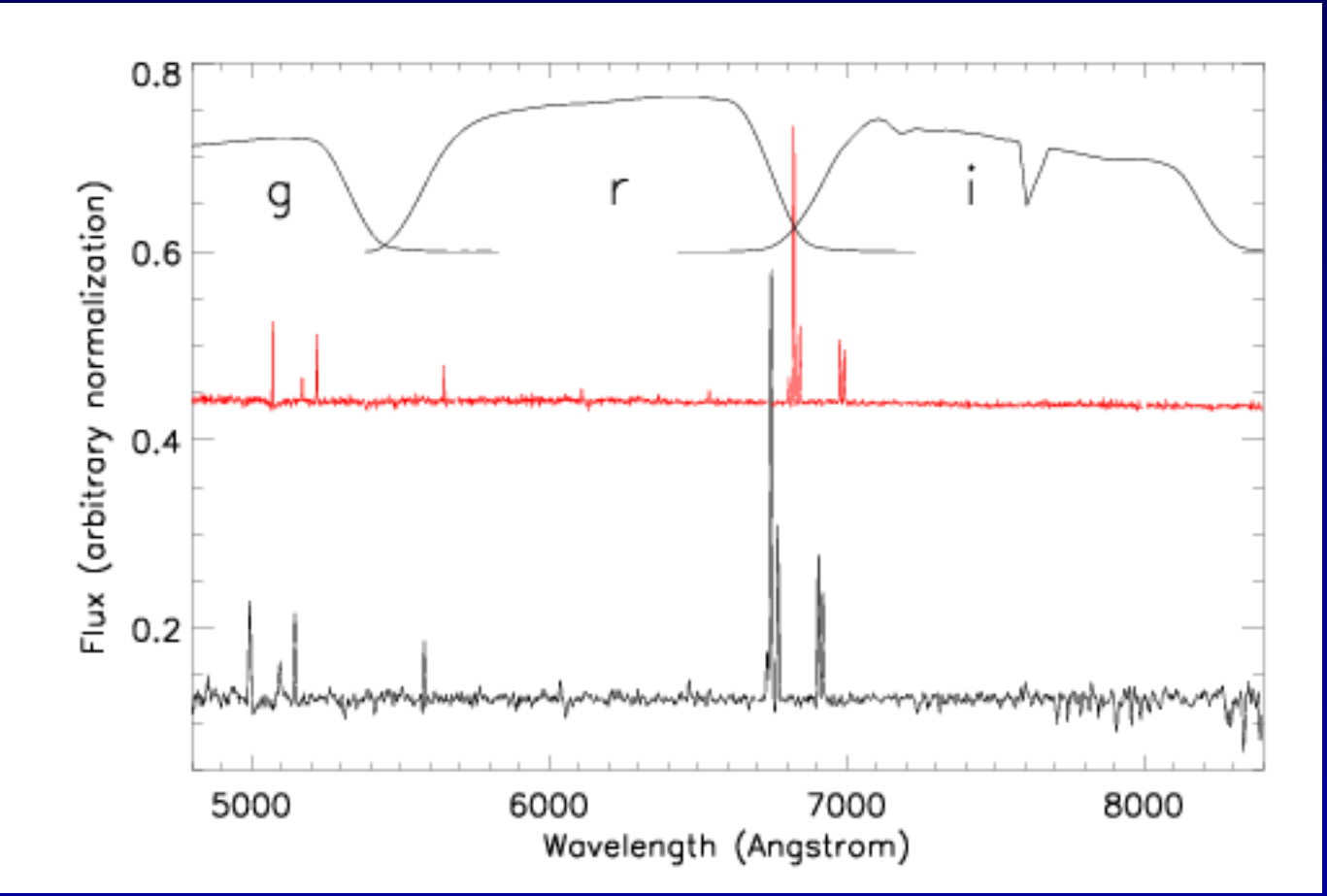
mapping SDSS Galaxies

preliminary results :

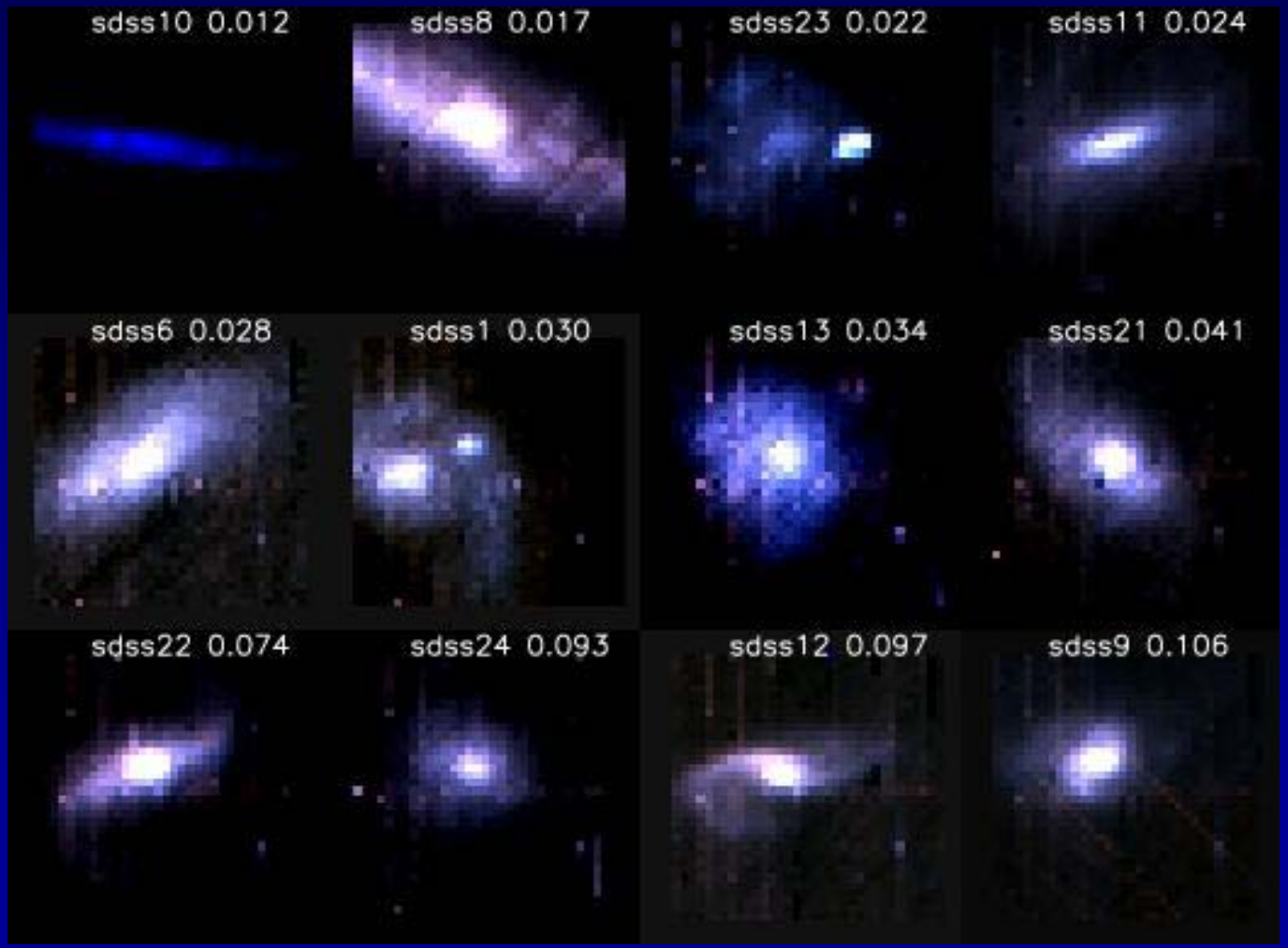




Comparison between a VIMOS IFU spectrum and a SDSS spectrum
The VIMOS spectrum is extracted over an SDSS-sized aperture.
The SDSS spectrum is arbitrarily offset for clarity.



Overview of the first half of the sample obtained in P76.
Observations in P78 will complete the sample.

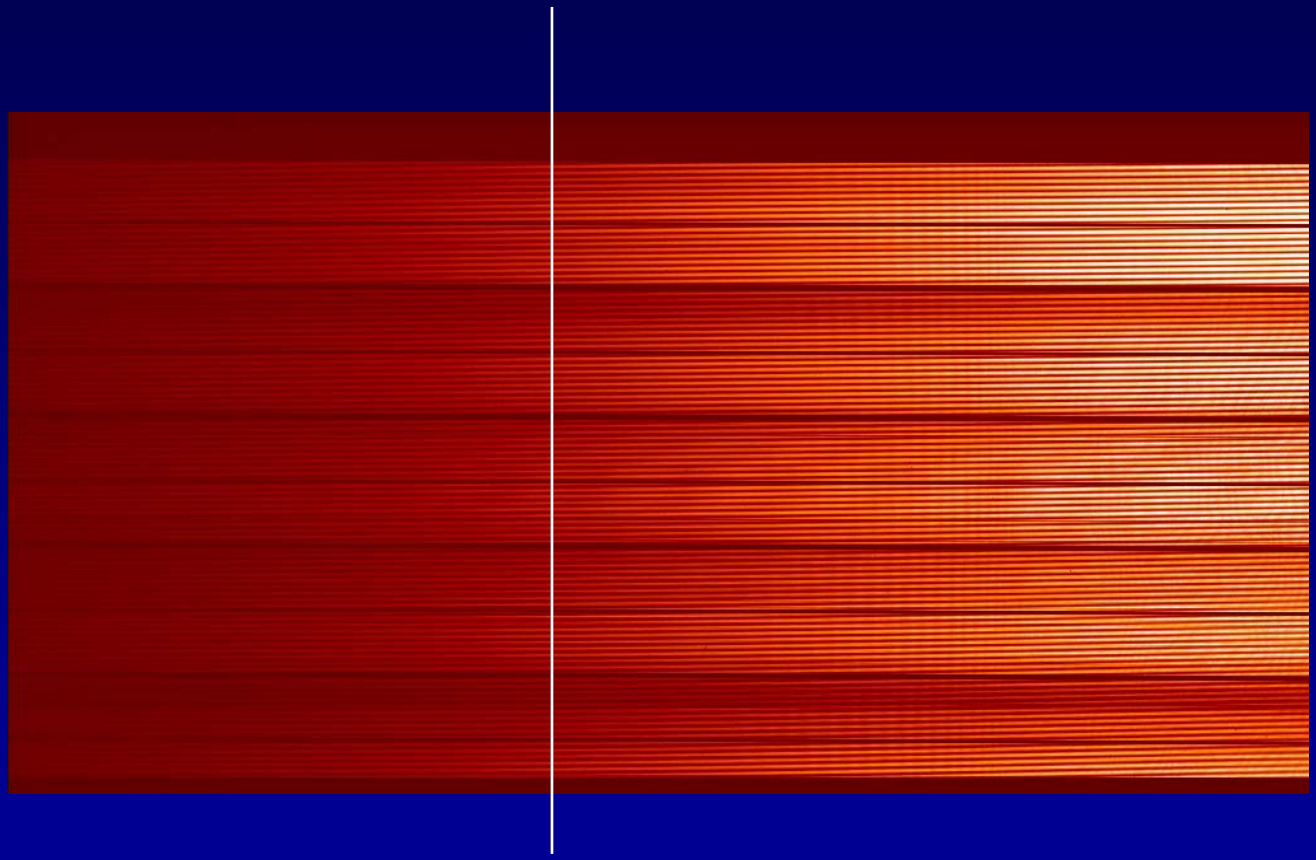


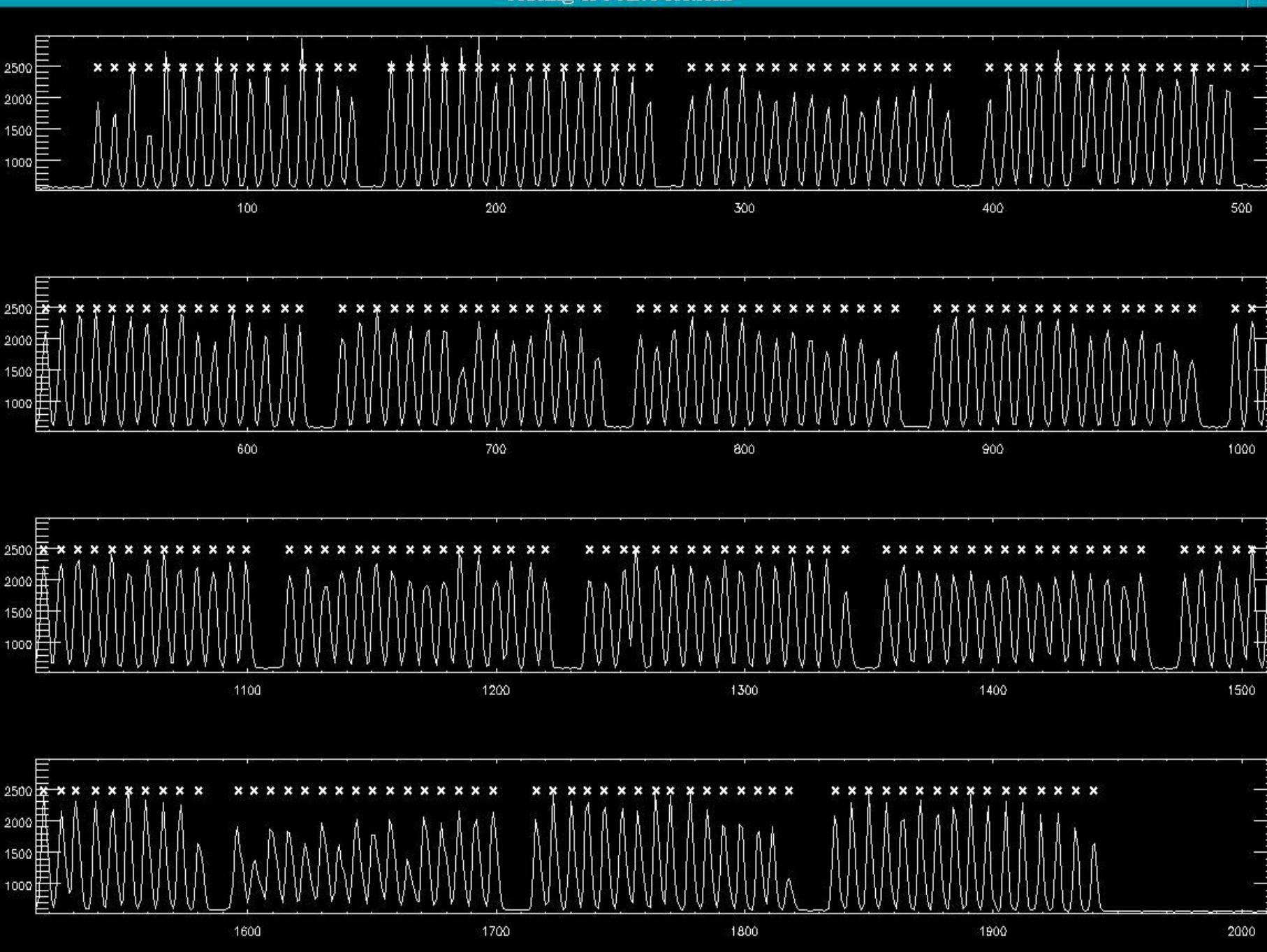
III. Data Reduction

Data Reduction Pipeline

- Pre-reduction (bias,cosmics) → Propagation of Variance
- CCD Response Calibration → Propagation of Variance
- Tracing → Propagation of Variance
- Image Shift → Propagation of Variance
- Straylight Correction → Propagation of Variance
- Extraction → Propagation of Variance
- Wavelength Calibration → Propagation of Variance
- Fiber Response Calibration → Propagation of Variance

Data Reduction

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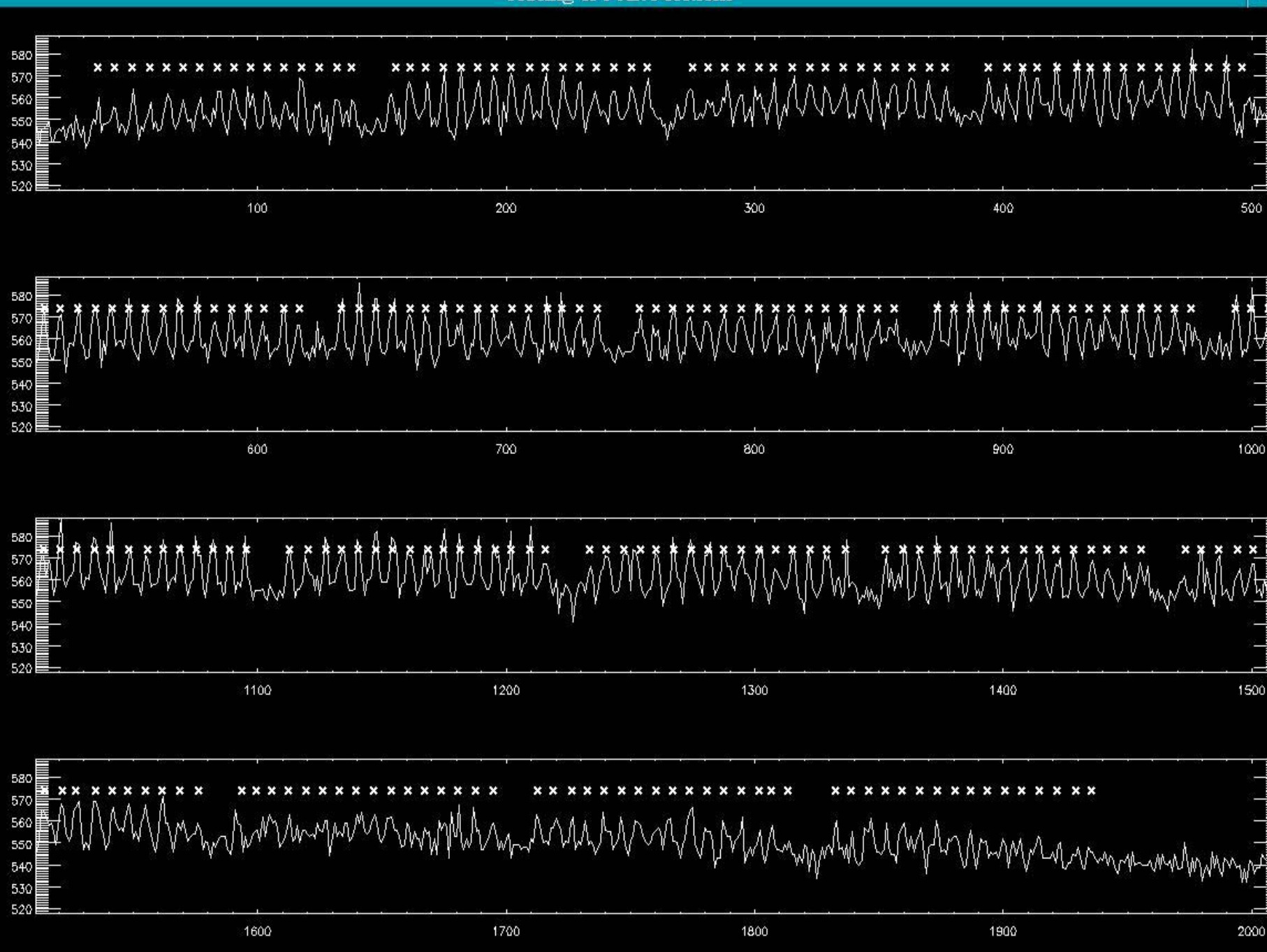
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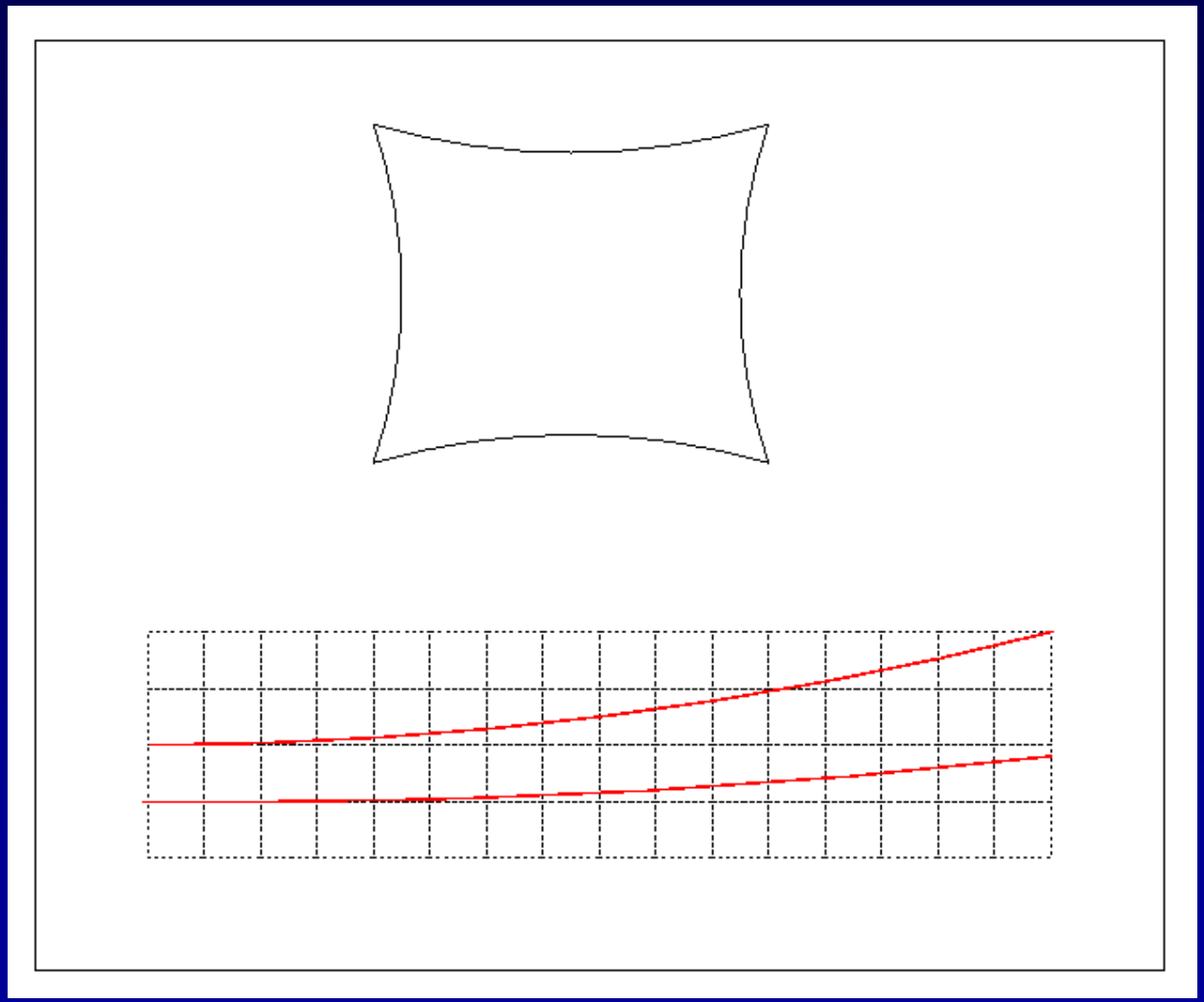
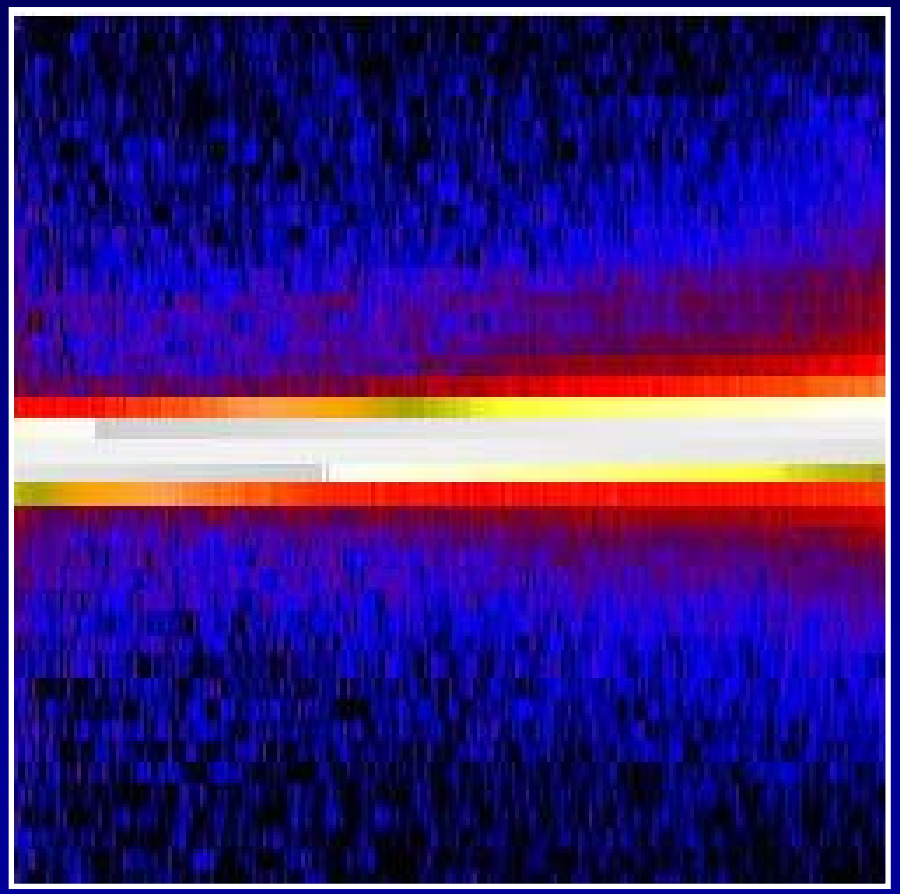
Data Reduction



Data Reduction

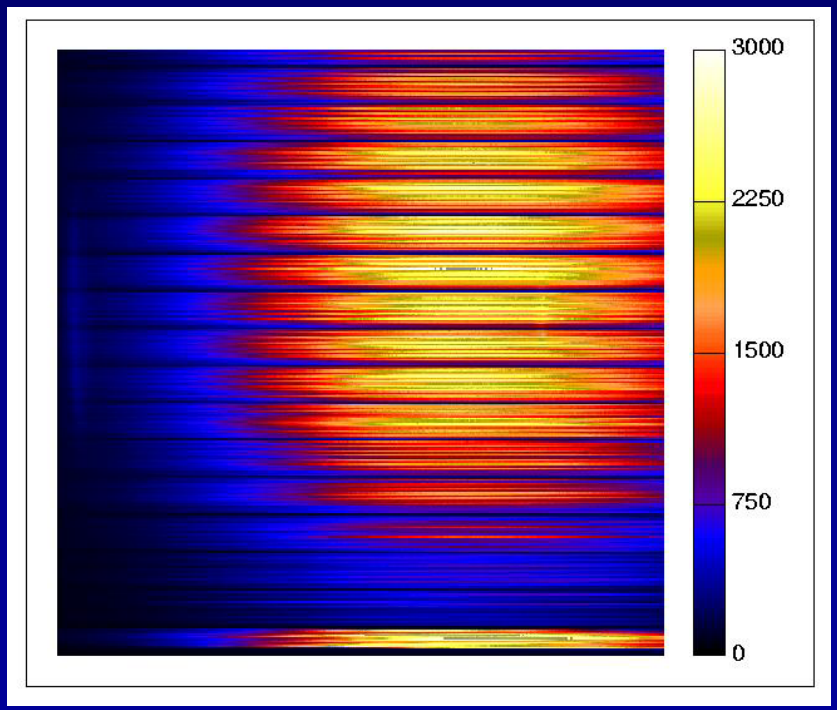
varying profile (spatial direction) along a spectrum :



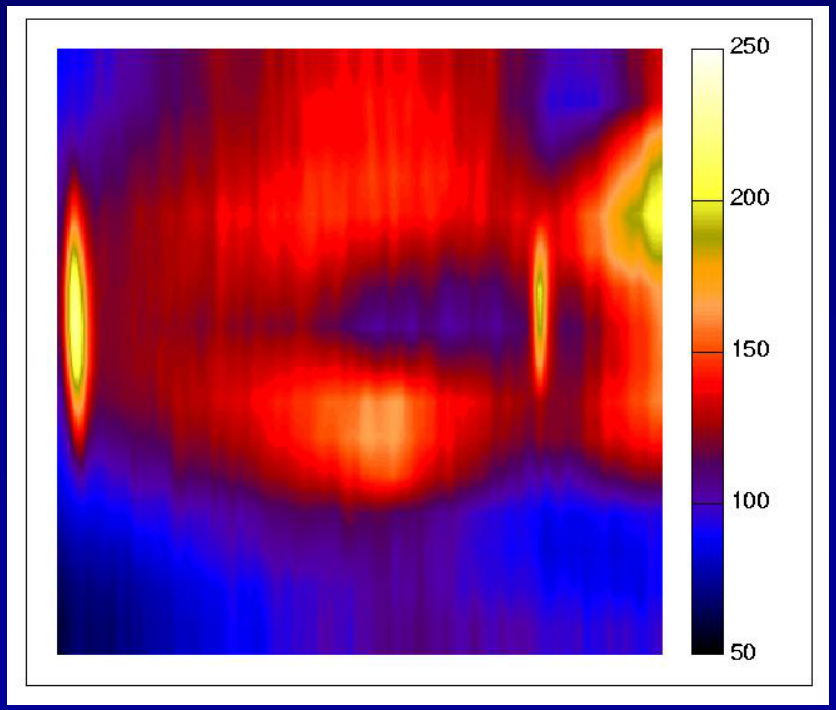
Data Reduction

Straylight Model

MPFS-Flatfield

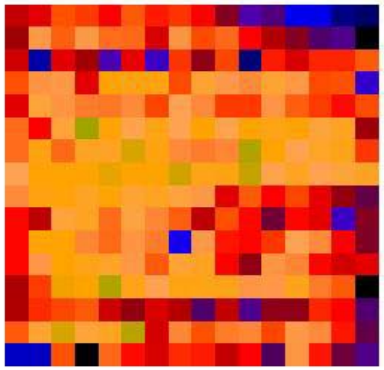


Straylight Map



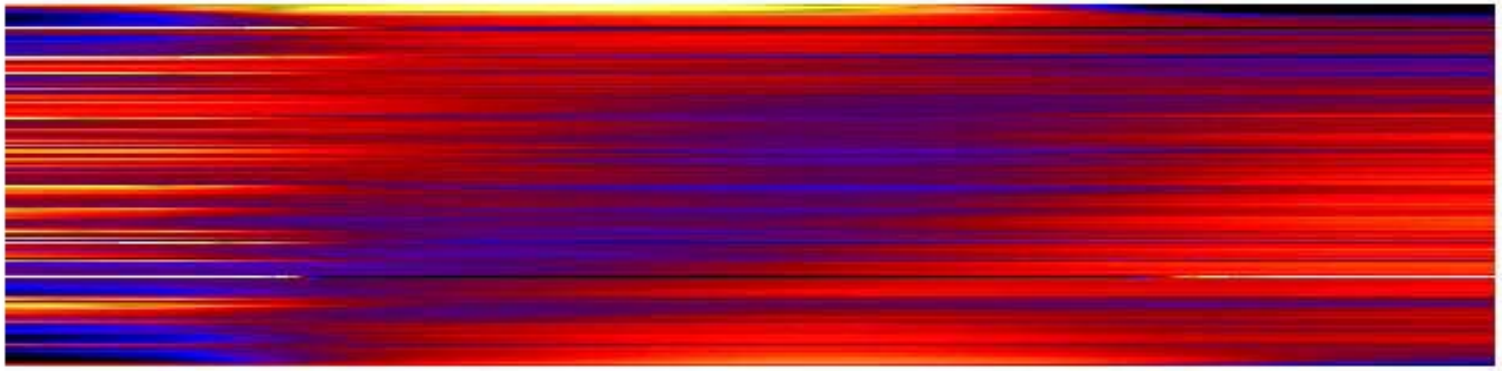
Data Reduction

Fiber Response Calibration („Fiber Flat")



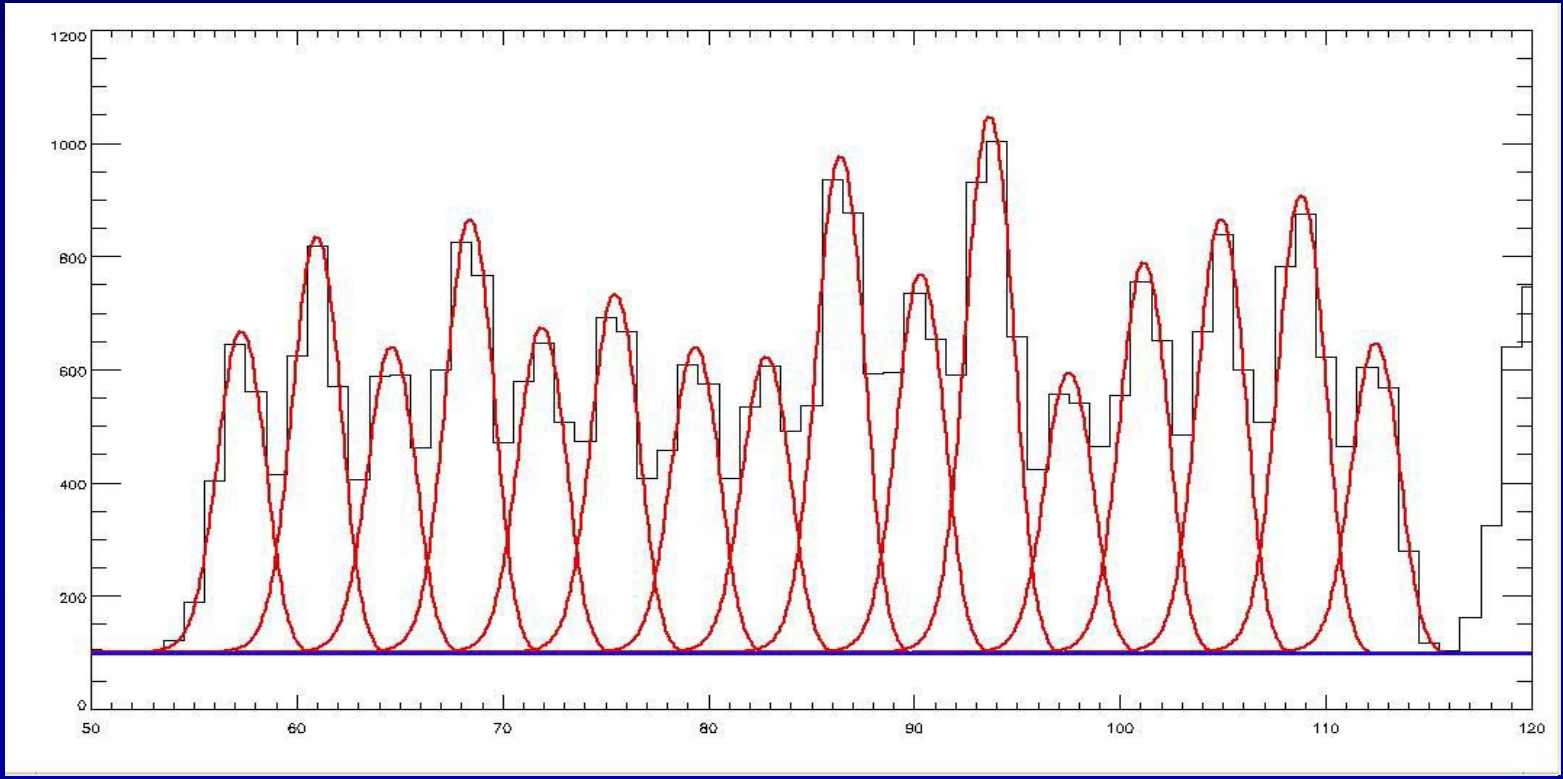
Total Spectra Sensitivity Variation: 8%

Wavelength-dependent Sensitivity Variation: 1-1.5%



Data Reduction

Cross-talk, extraction techniques



Data Reduction

Existing Codes :

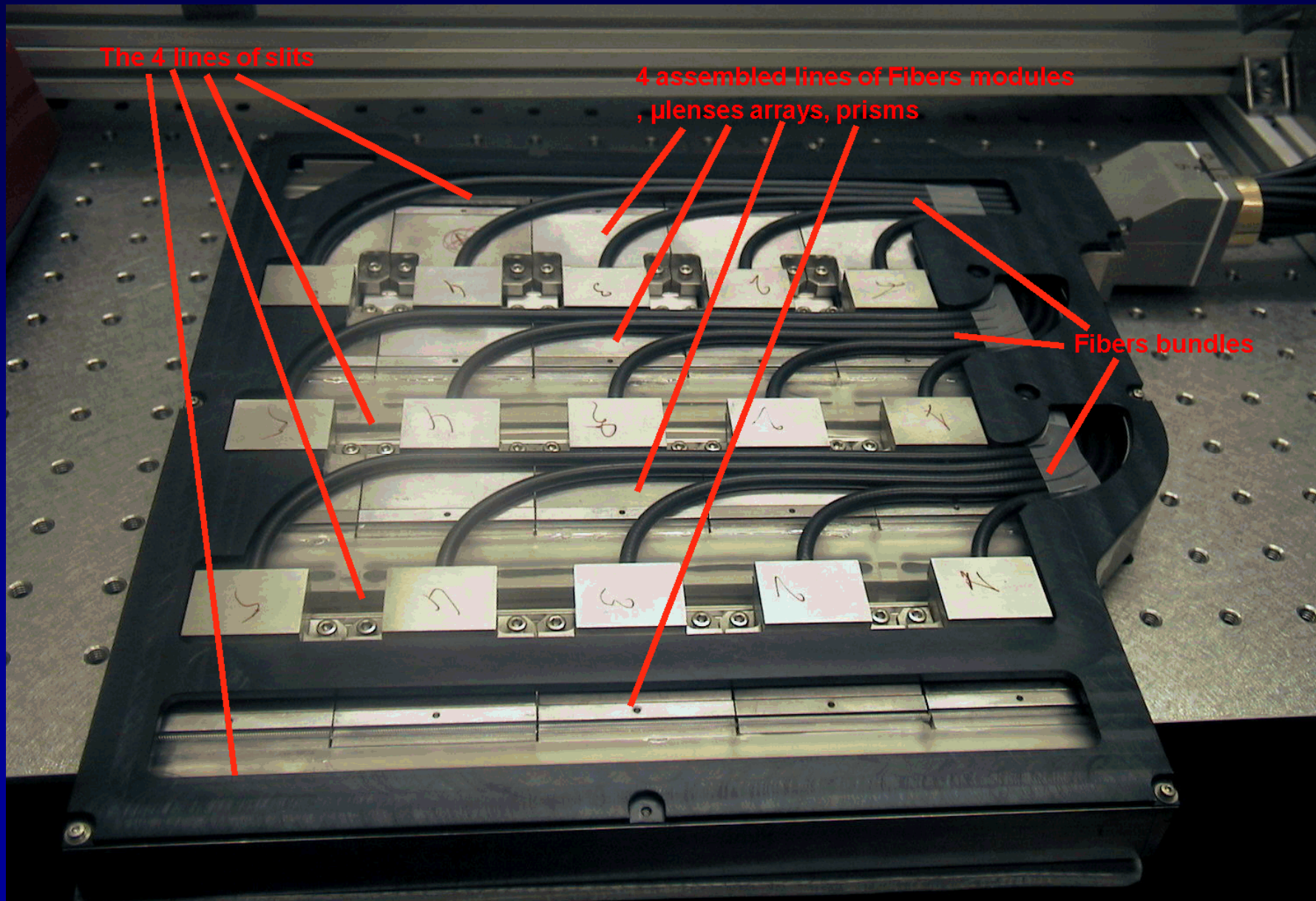
- VIMOS Pipeline
  www.eso.org/projects/dfs/dfs-shared/web/vlt/vlt-instrument-pipelines.html
- P3d
  Becker 2002, Roth et al. 2005, PASP 117, 832
- VIPGI
  Scodeggio, M. et al. 2005, PASP 117, 1284
  Foucaud, S. et al. 2006, New Astr. Reviews, Vol. 50, p. 401
- R3D
  Sánchez, S.F. 2006, AN 327, 850
- IRAF ?

IV. Instrumental Considerations, Performance

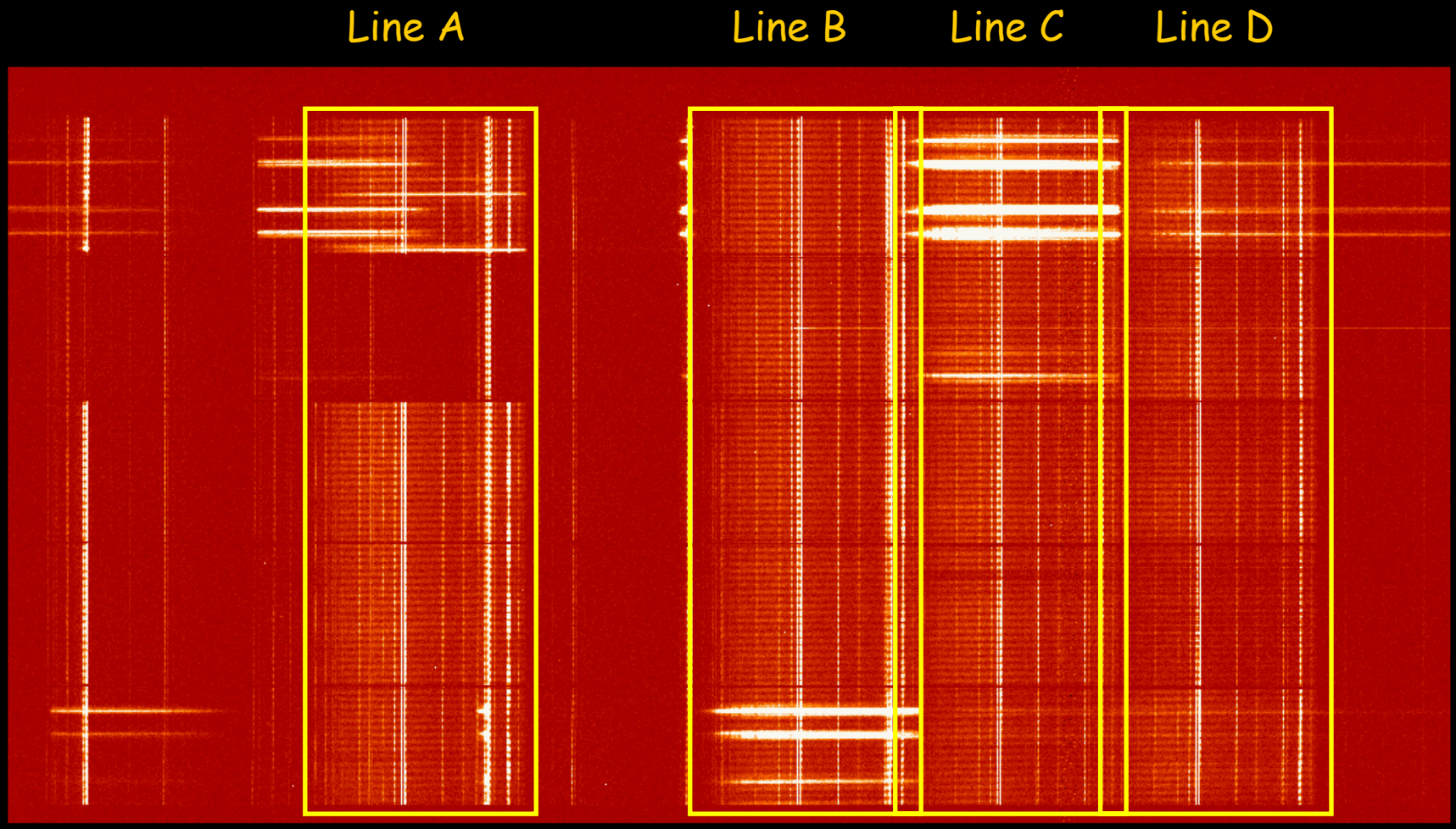
Instrumental Considerations :

- data reduction robustness
- response variations
- flux calibration
- wavelength calibration
- image quality / scattered light

Robustness

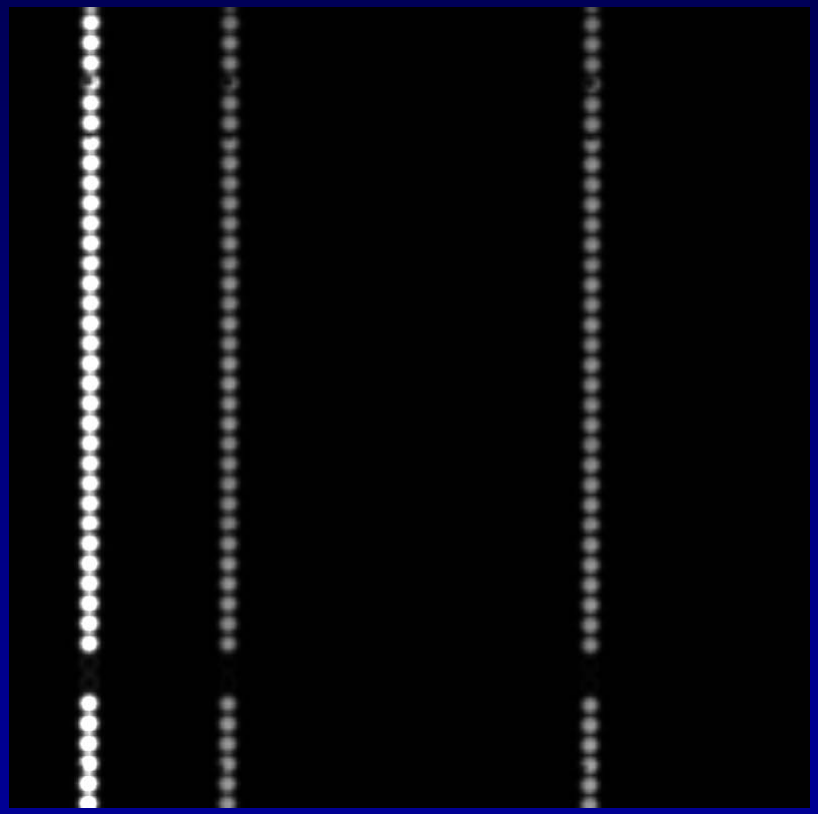

The 4 lines of slits
4 assembled lines of Fibers modules
, µlenses arrays, prisms
Fibers bundles

Robustness



LR blue

Robustness



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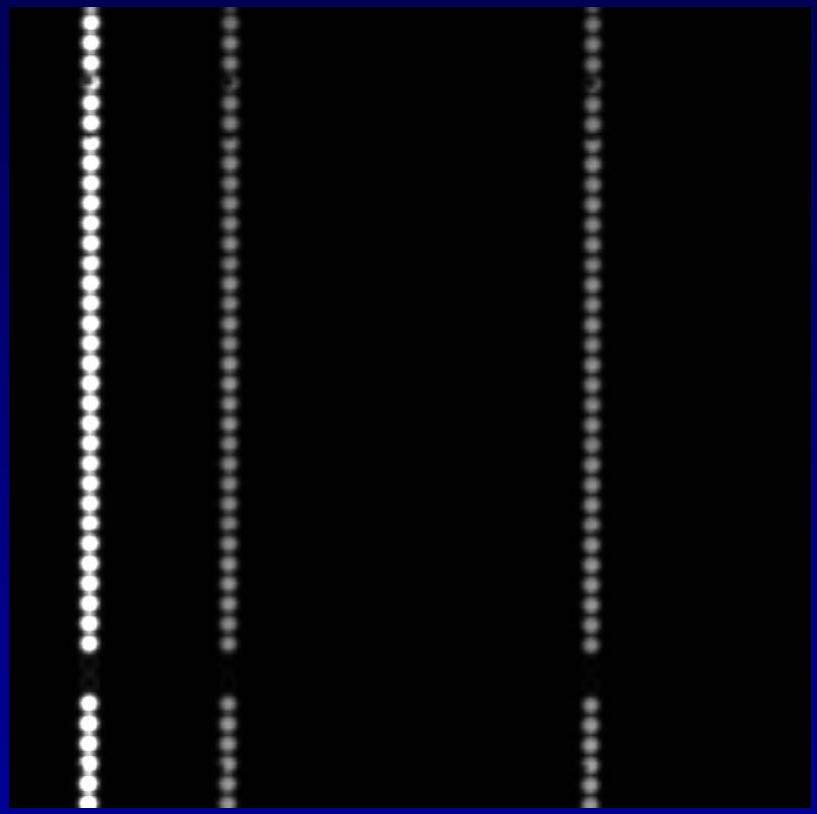

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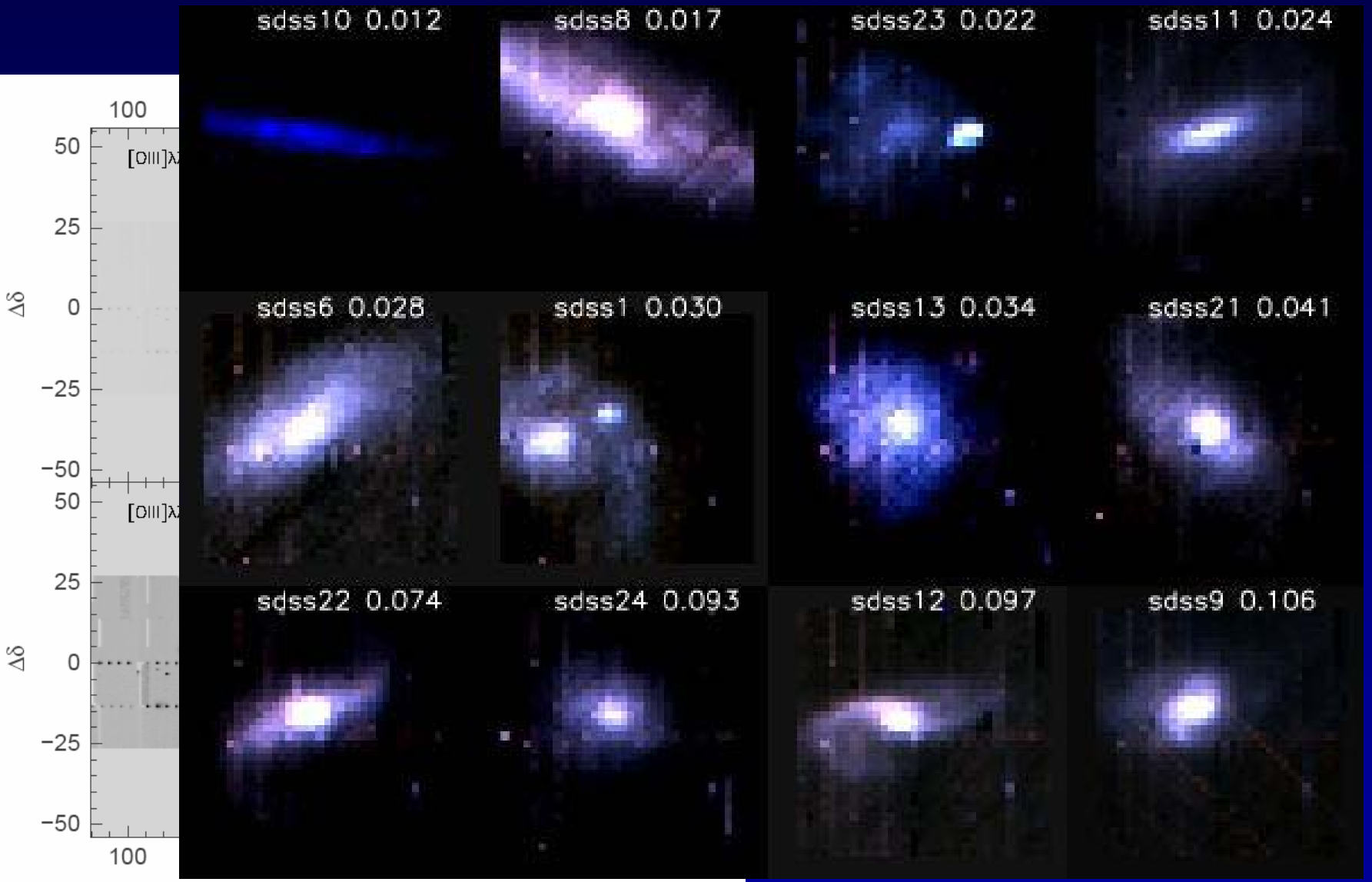
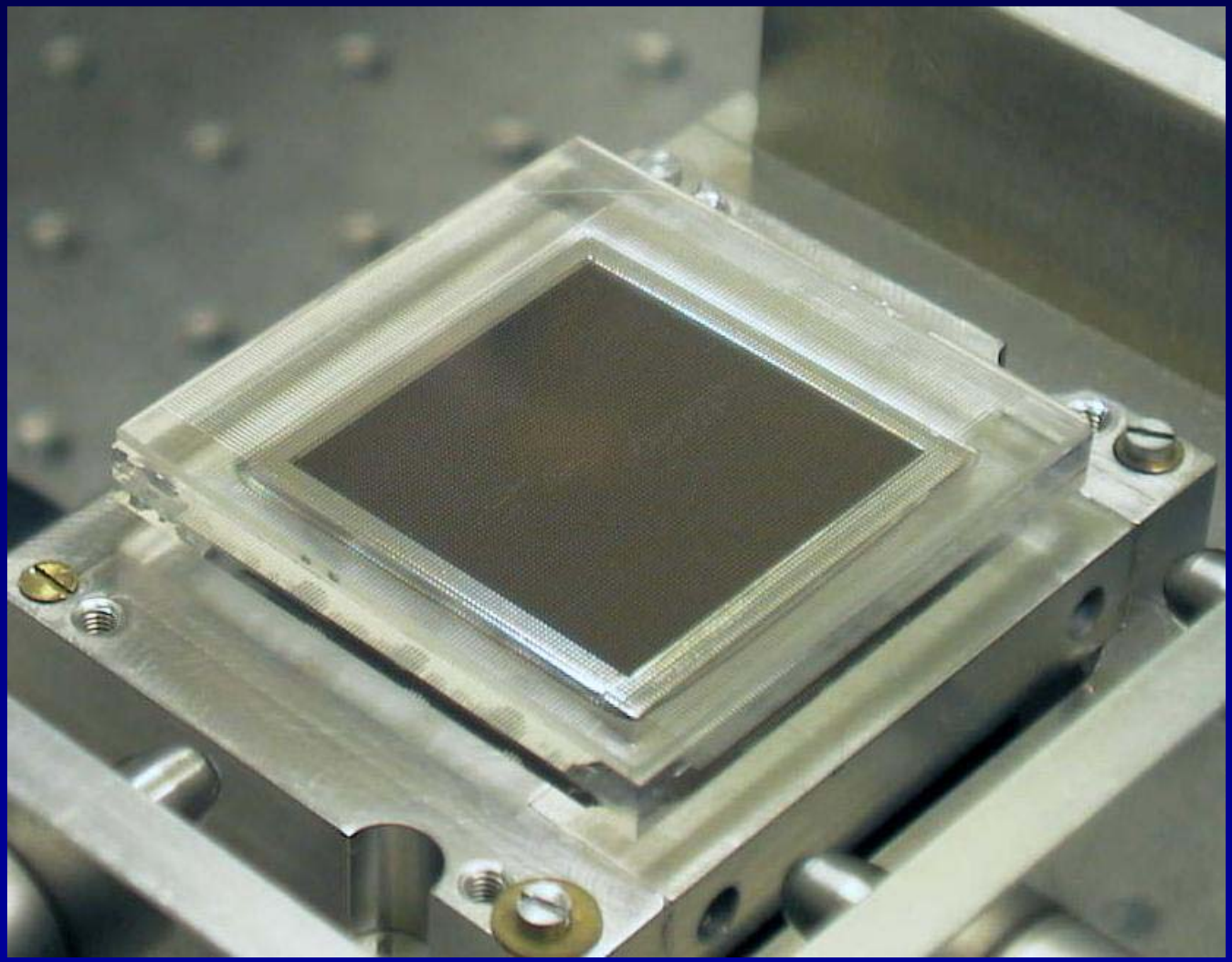
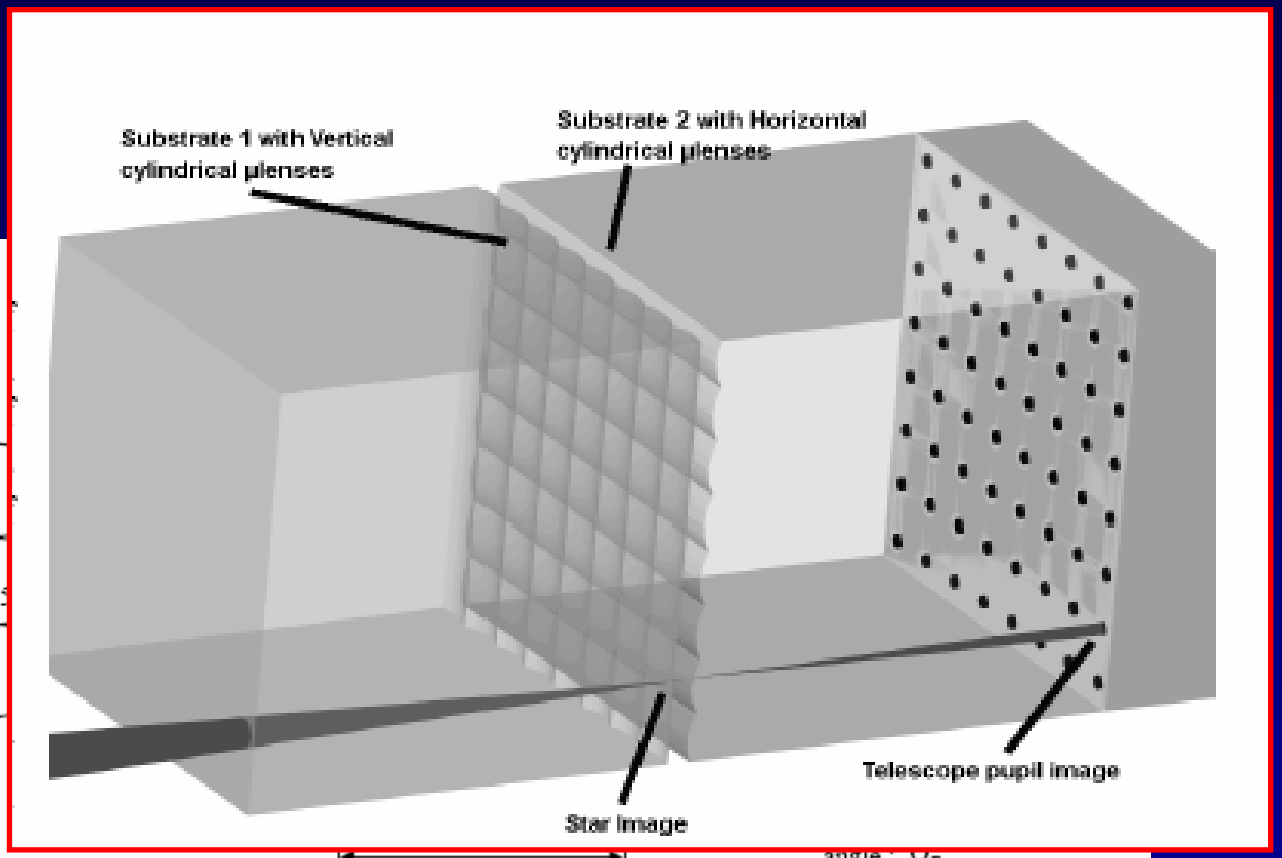
Response Variations



Response Variations, Throughput

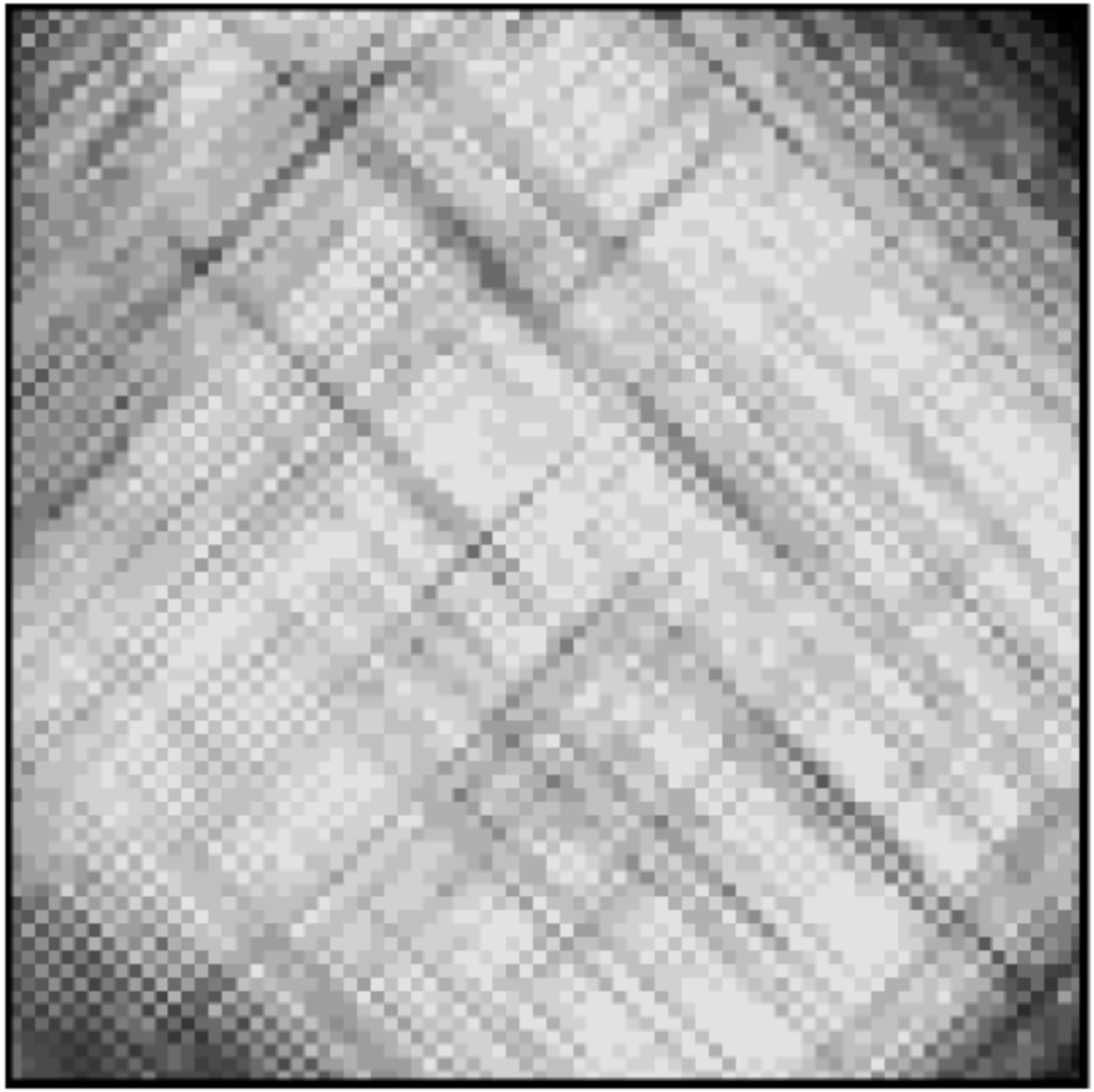


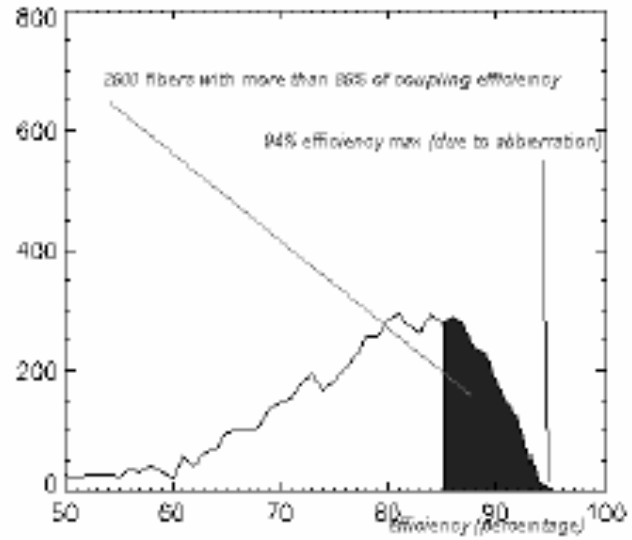
Response Variations, Throughput

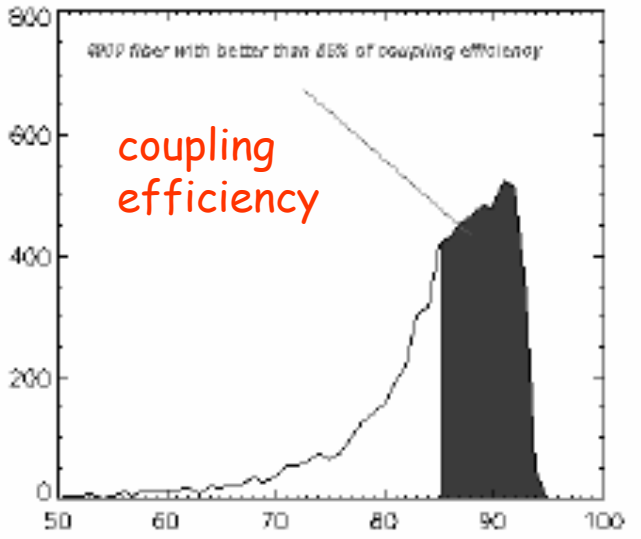


Prieto et al. 2000, SPIE 4008, 510

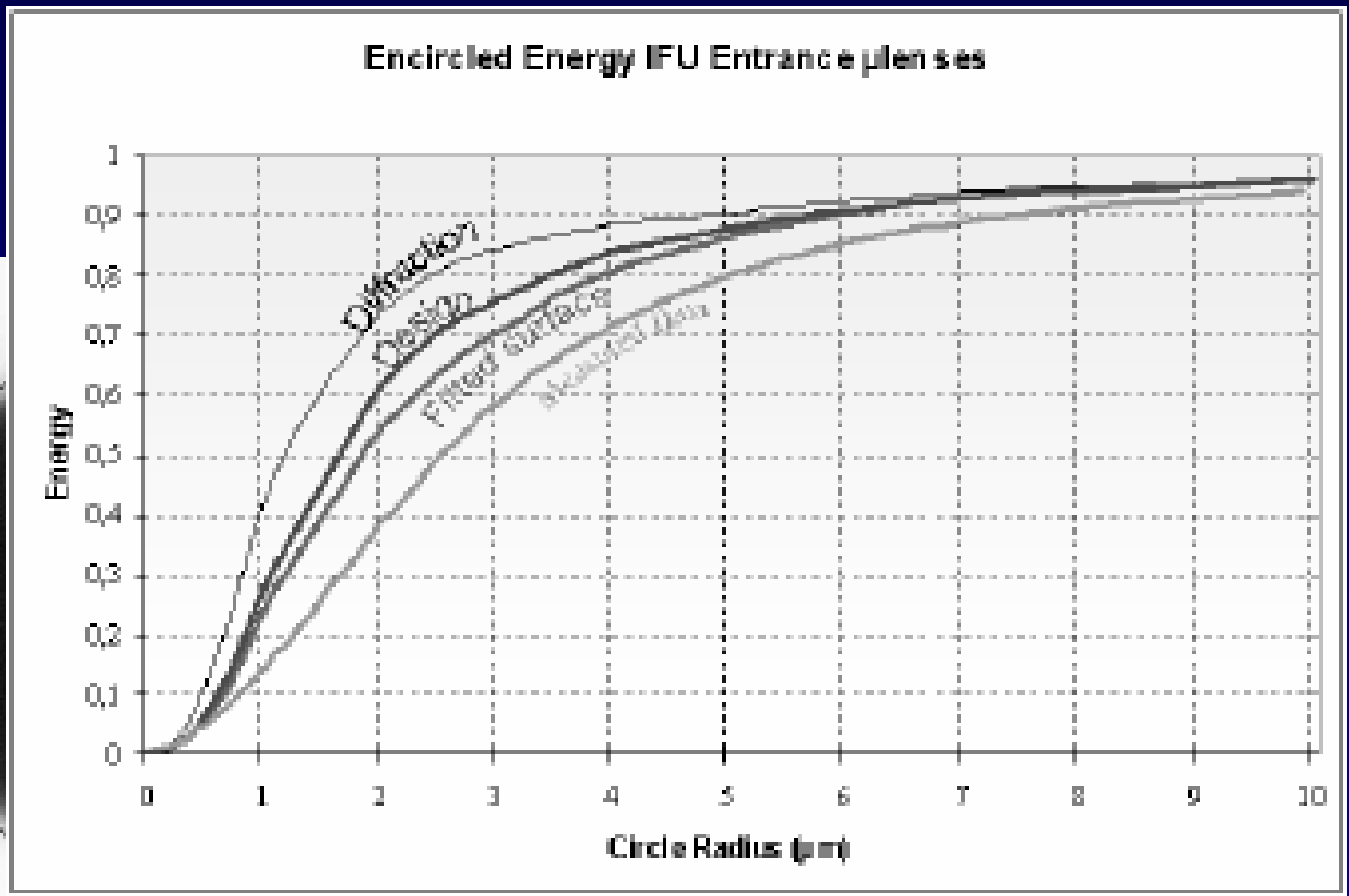
Response Variations, Throughput







Response Variations, Throughput



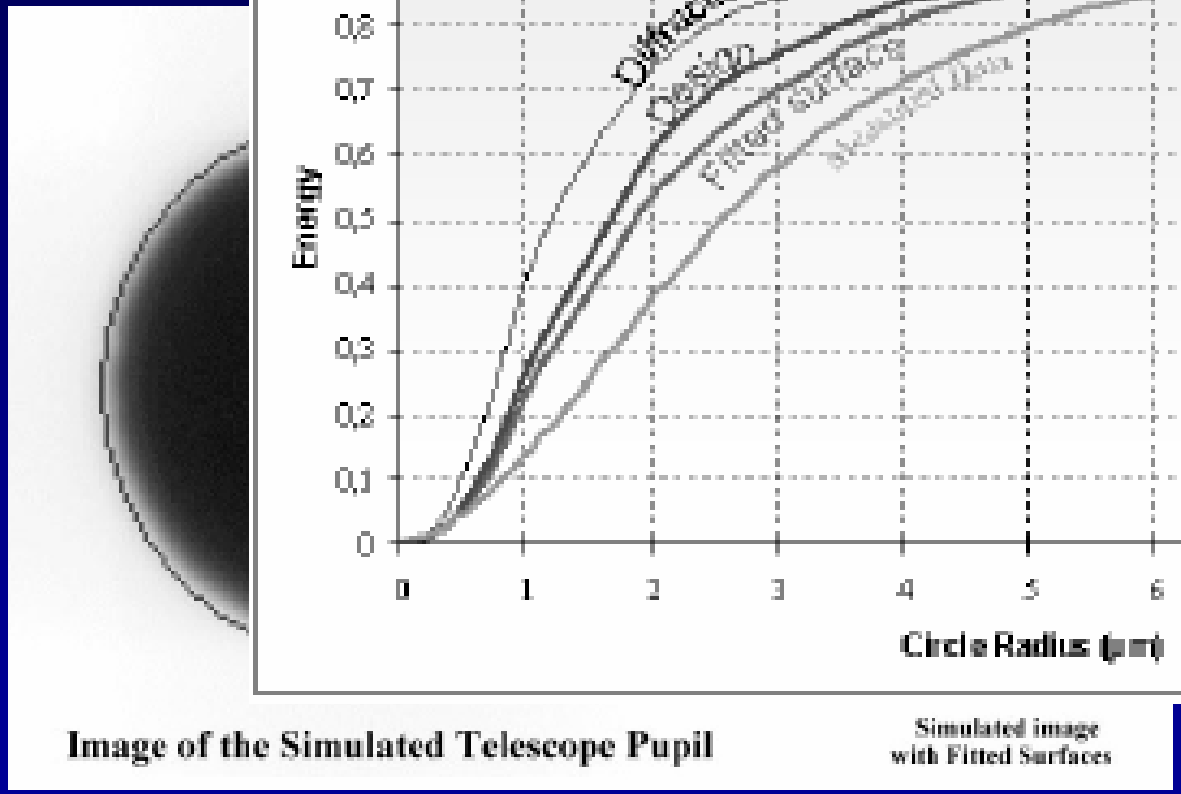
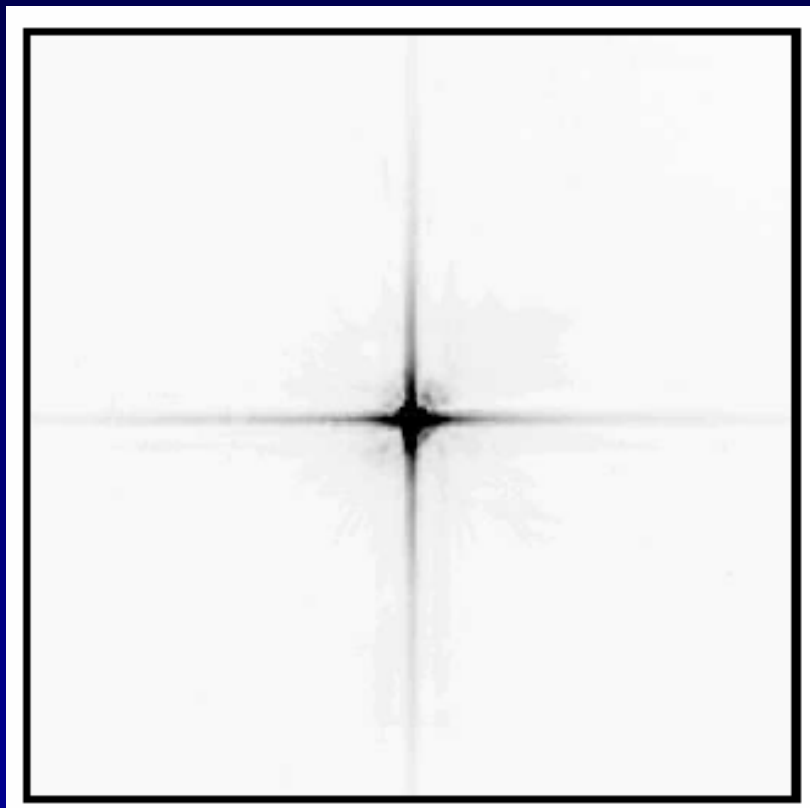


Image of the Simulated Telescope Pupil

Simulated image with Fitted Surfaces

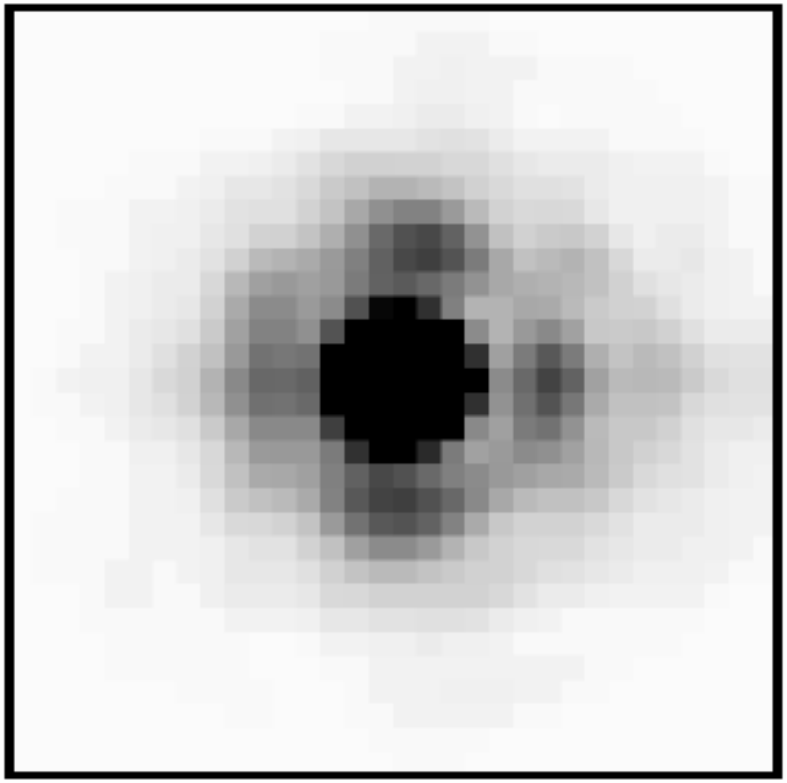
Prieto et al. 2000, SPIE 4008, 510

PMAS lensarray PSF



single lenslet PSF (100 frames)

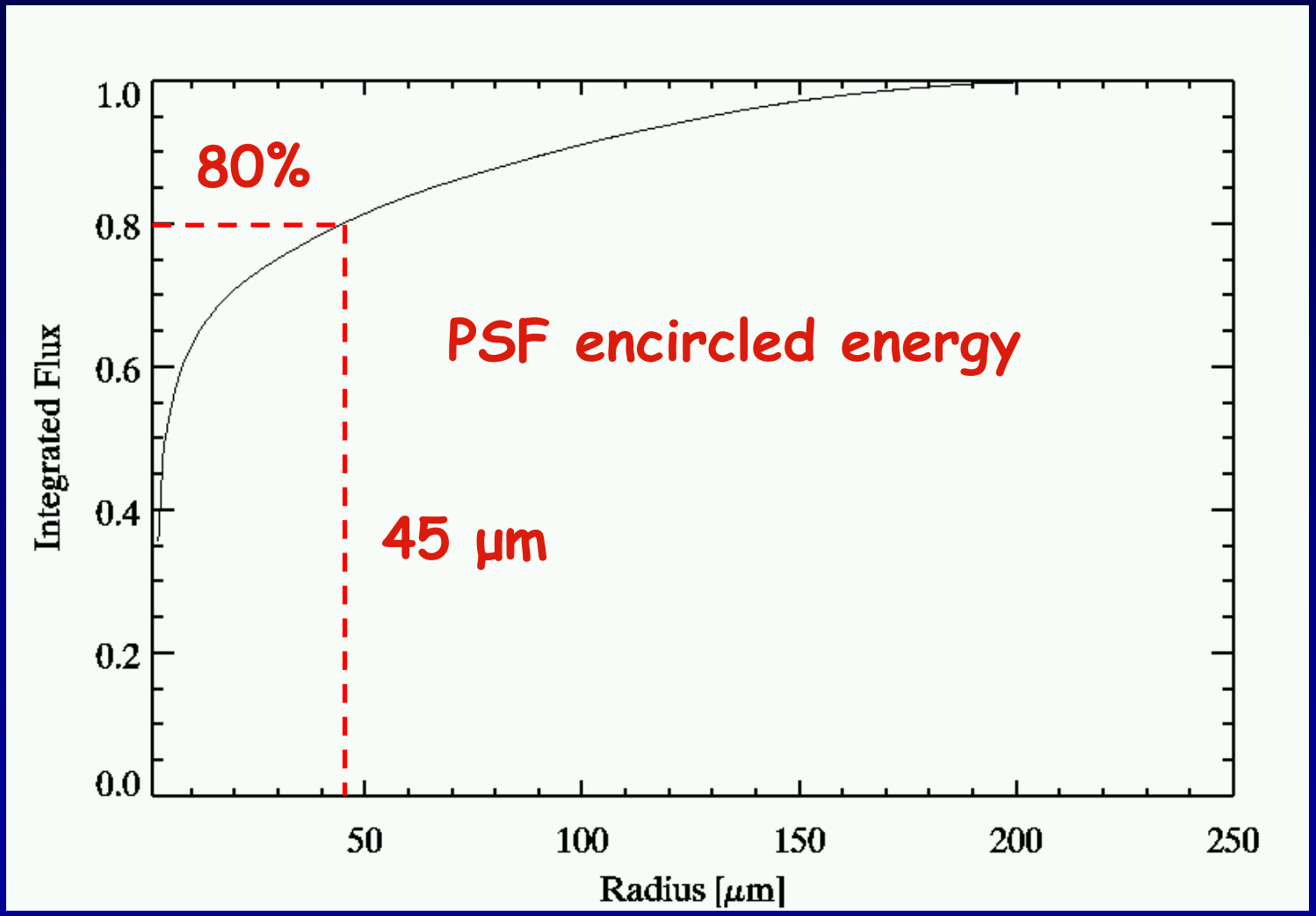
(1% peak scale)



zoom: Airy pattern

Roth et al. 2006, SPIE 6269, 15 (see also Lee et al. 2001, PASP 113, 140)

PMAS lensarray encircled energy



micropupil (43 µm) convolved with PSF
> 70-75% EE within 100 µm

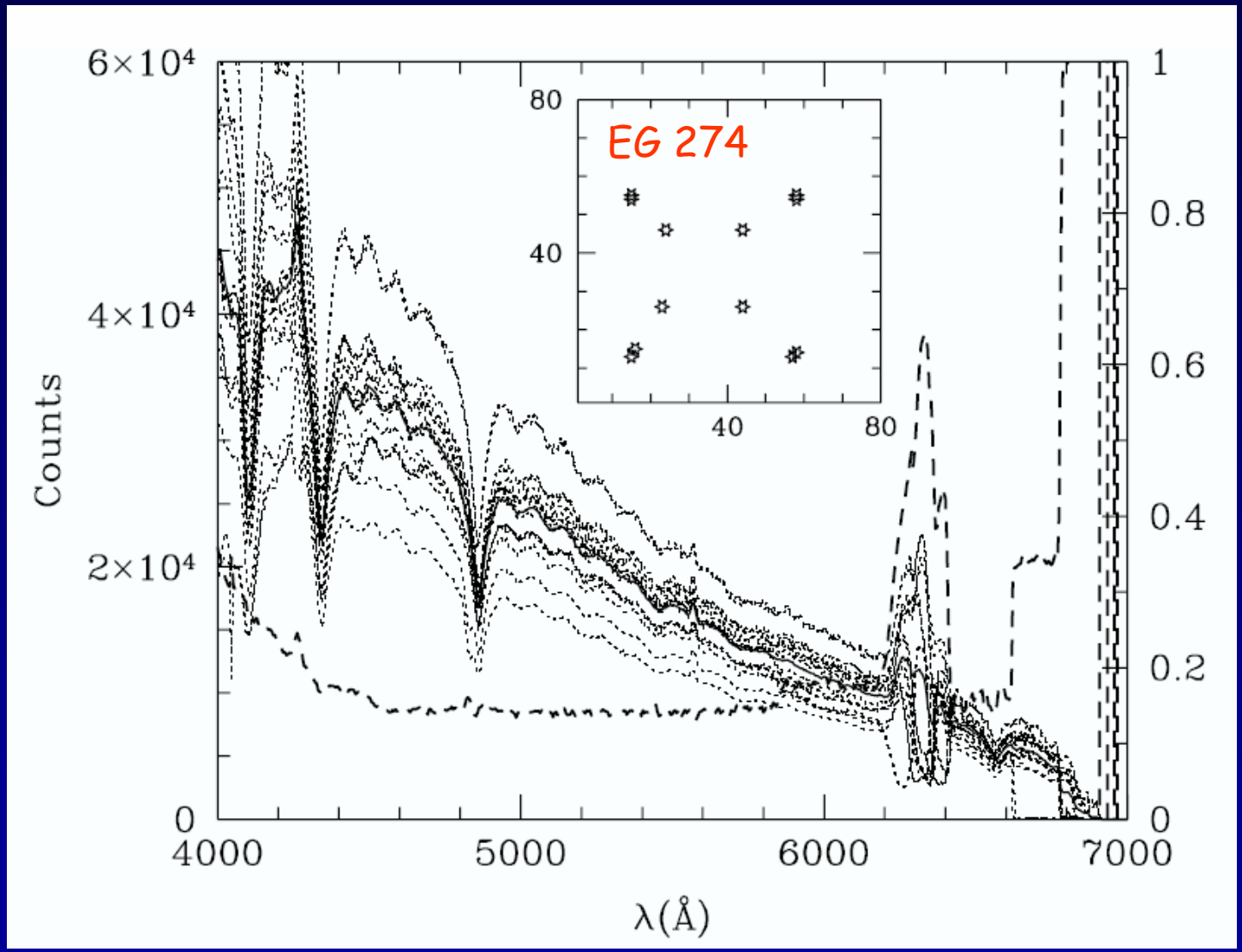
Response Variations

Influence of fiber illumination :

see Schmoll et al. 2003, PASP 115, 854

Response Variations

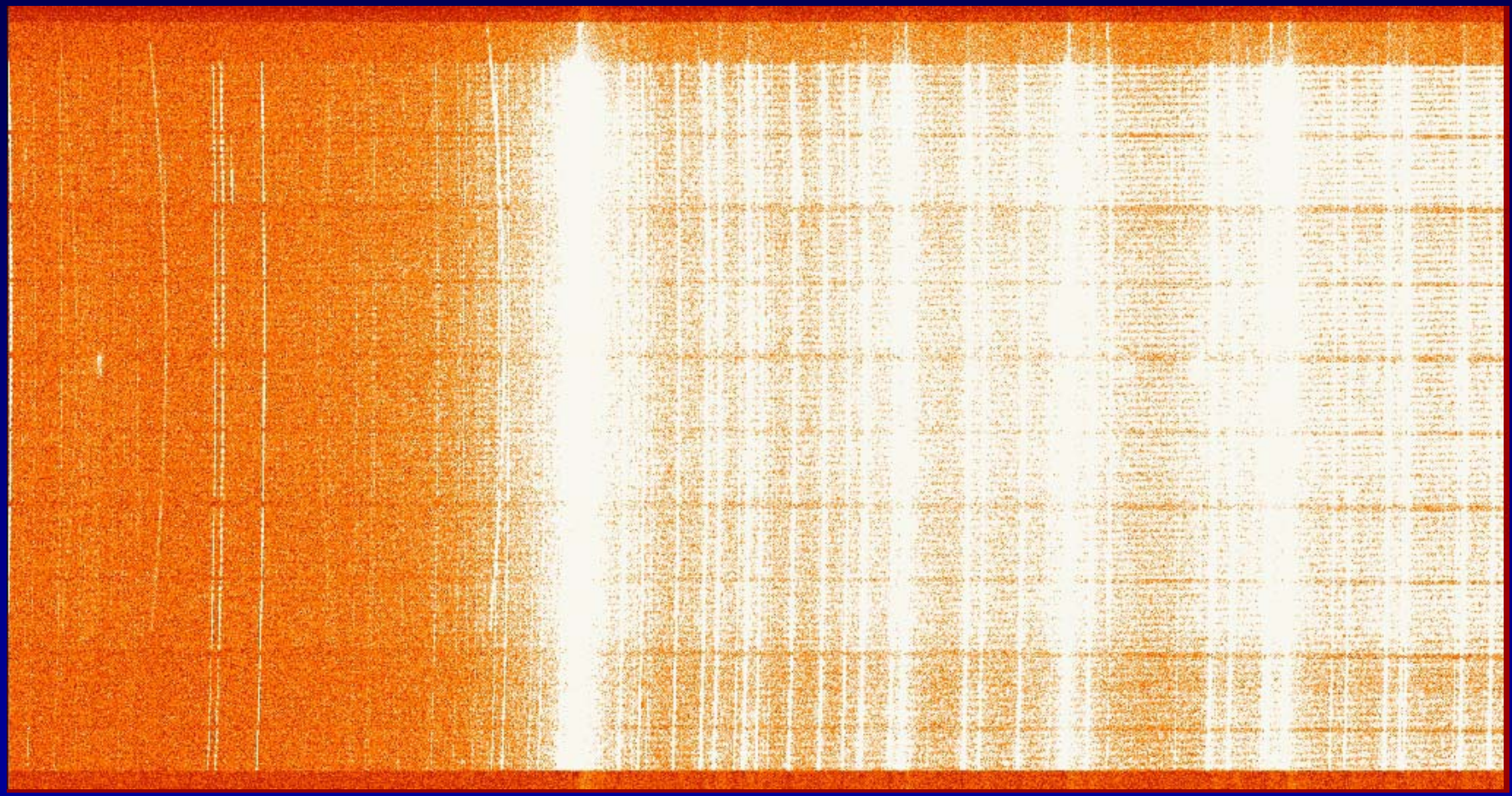
Flux Calibration



15 % rms
flux error
(12 pointings

Monreal et al. 2006, New Astr. Reviews 50, 426

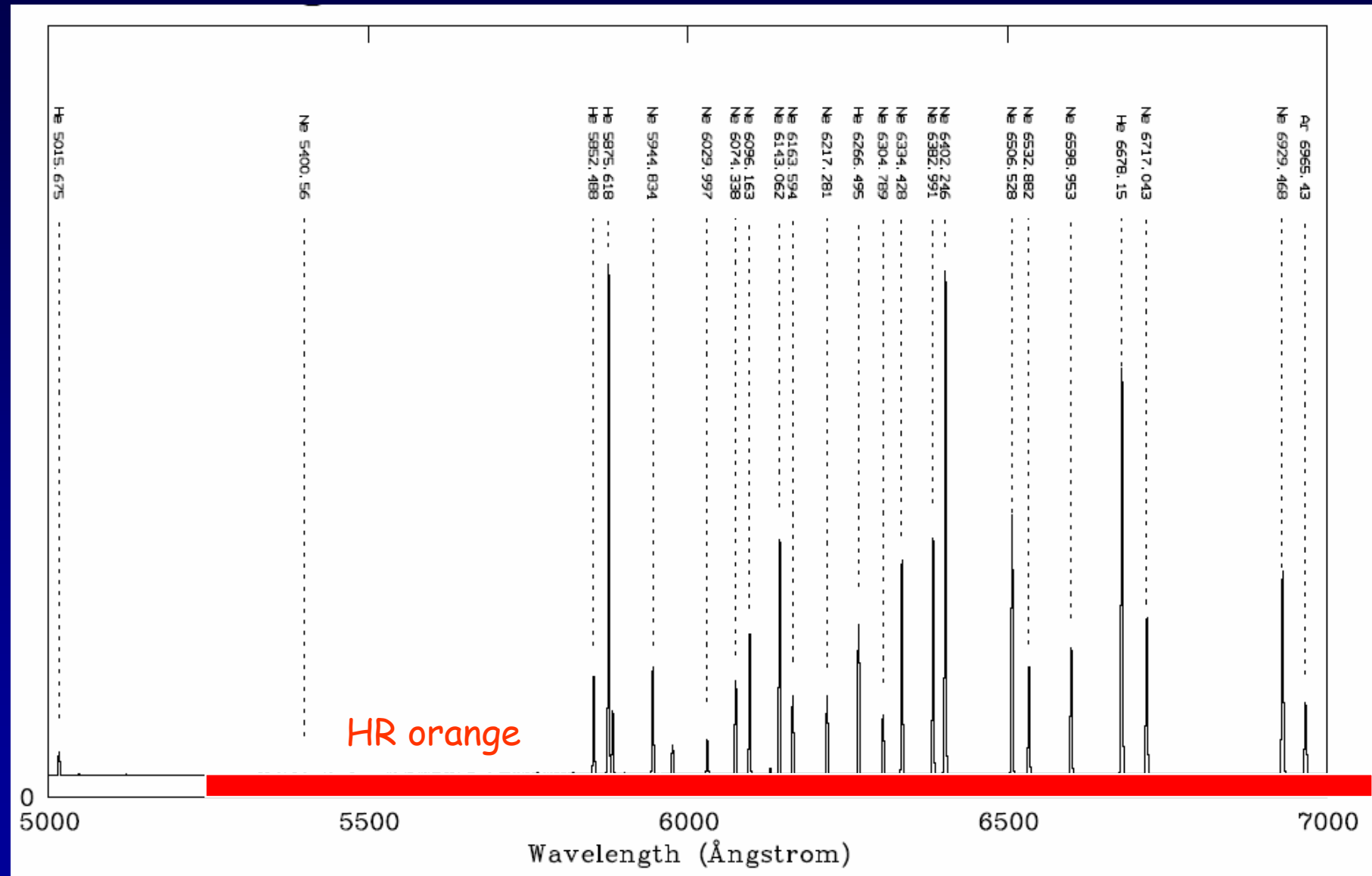
Wavelength Calibration



Ne 5401

HR blue

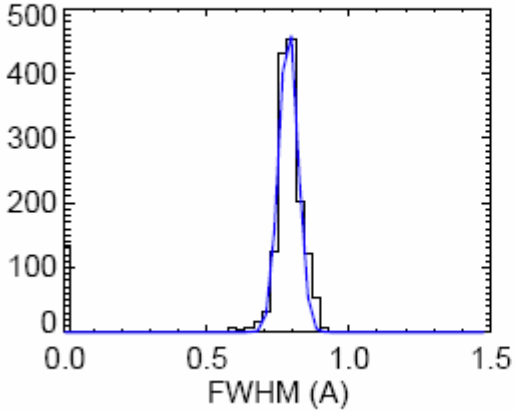
Wavelength Calibration



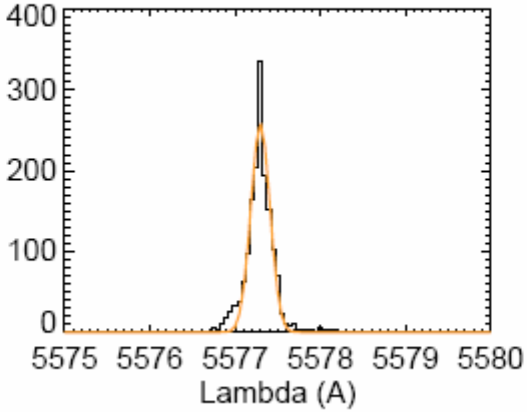
205854

Wavelength Calibration

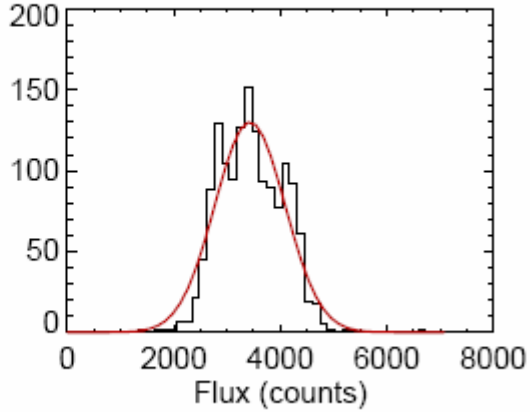
0.79 ± 0.03



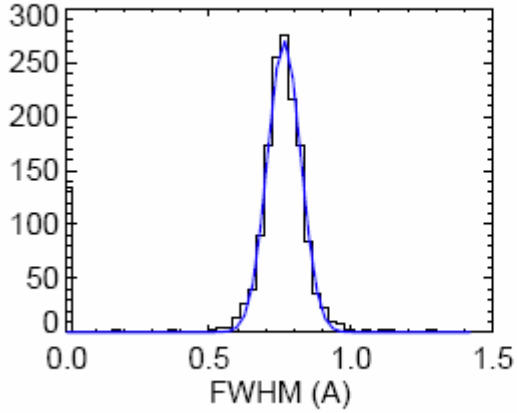
5577.3 ± 0.2



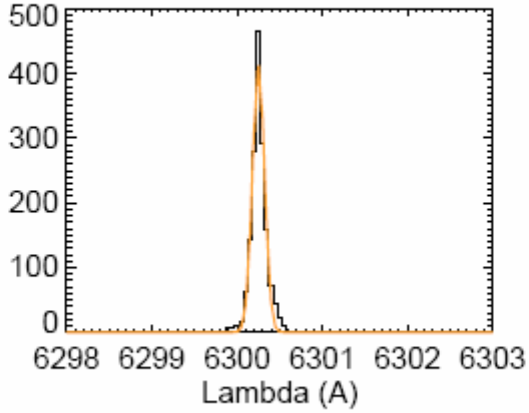
3431 ± 658



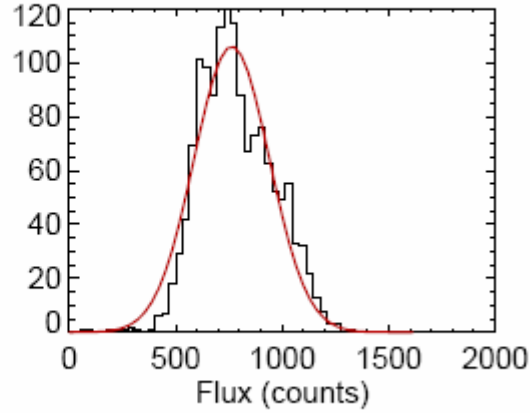
0.76 ± 0.06



6300.25 ± 0.07



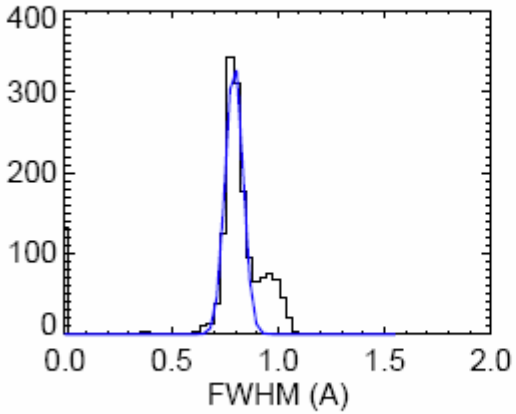
762 ± 176



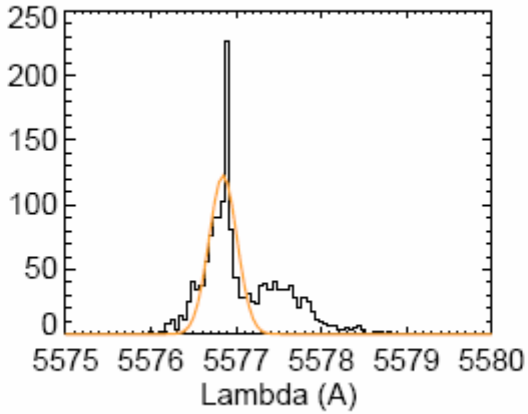
205856

Wavelength Calibration

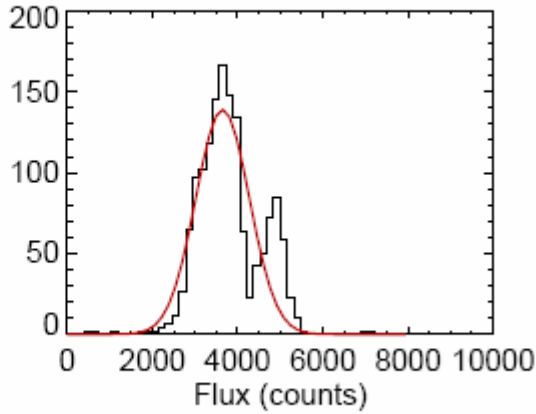
0.79 ± 0.04



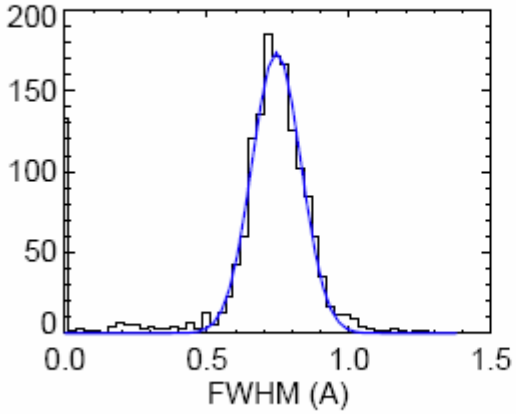
5576.9 ± 0.13



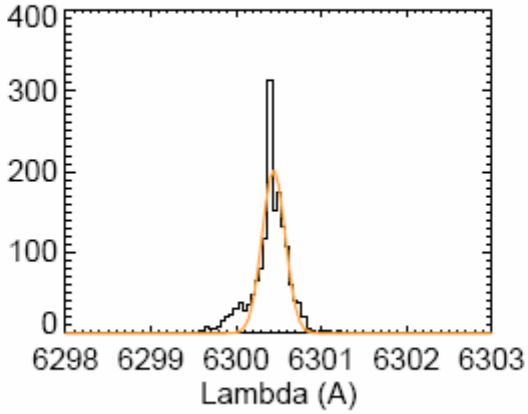
3647 ± 629



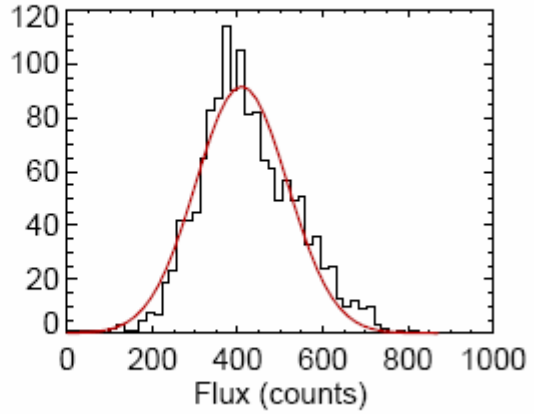
0.74 ± 0.09



6300.44 ± 0.13



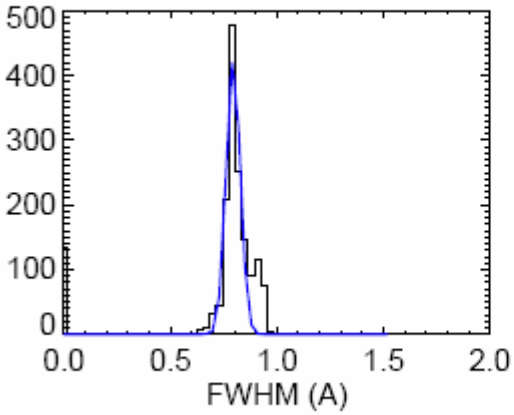
409 ± 107



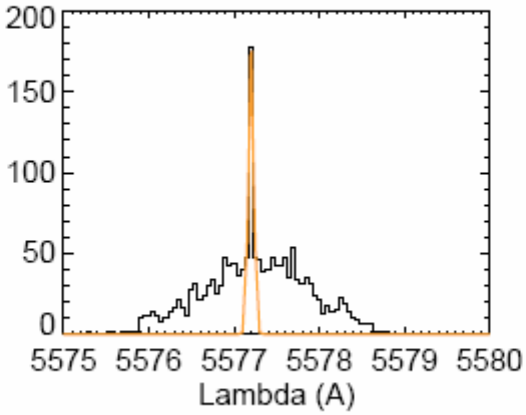
205888

Wavelength Calibration

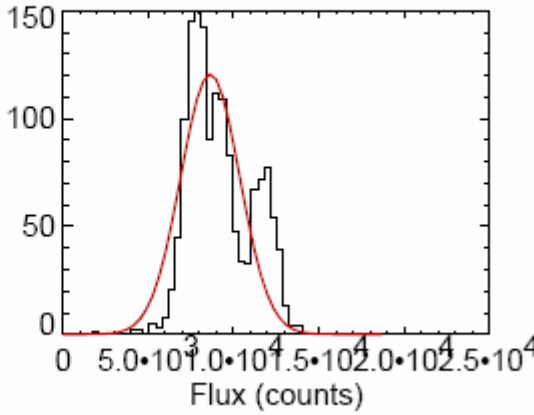
0.79 ± 0.03



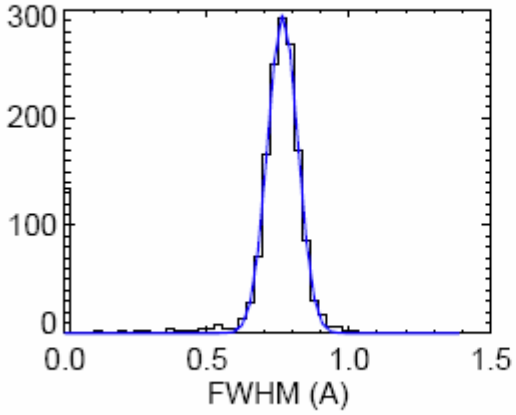
5577.2 ± 0.3



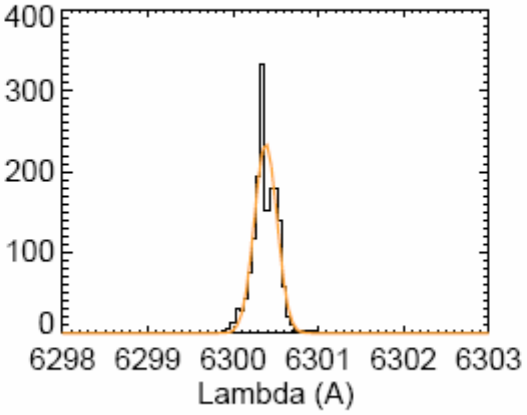
8627 ± 1730



0.76 ± 0.05



6300.38 ± 0.13



812 ± 229

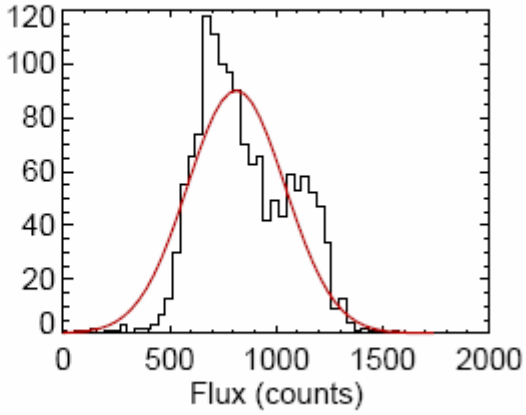
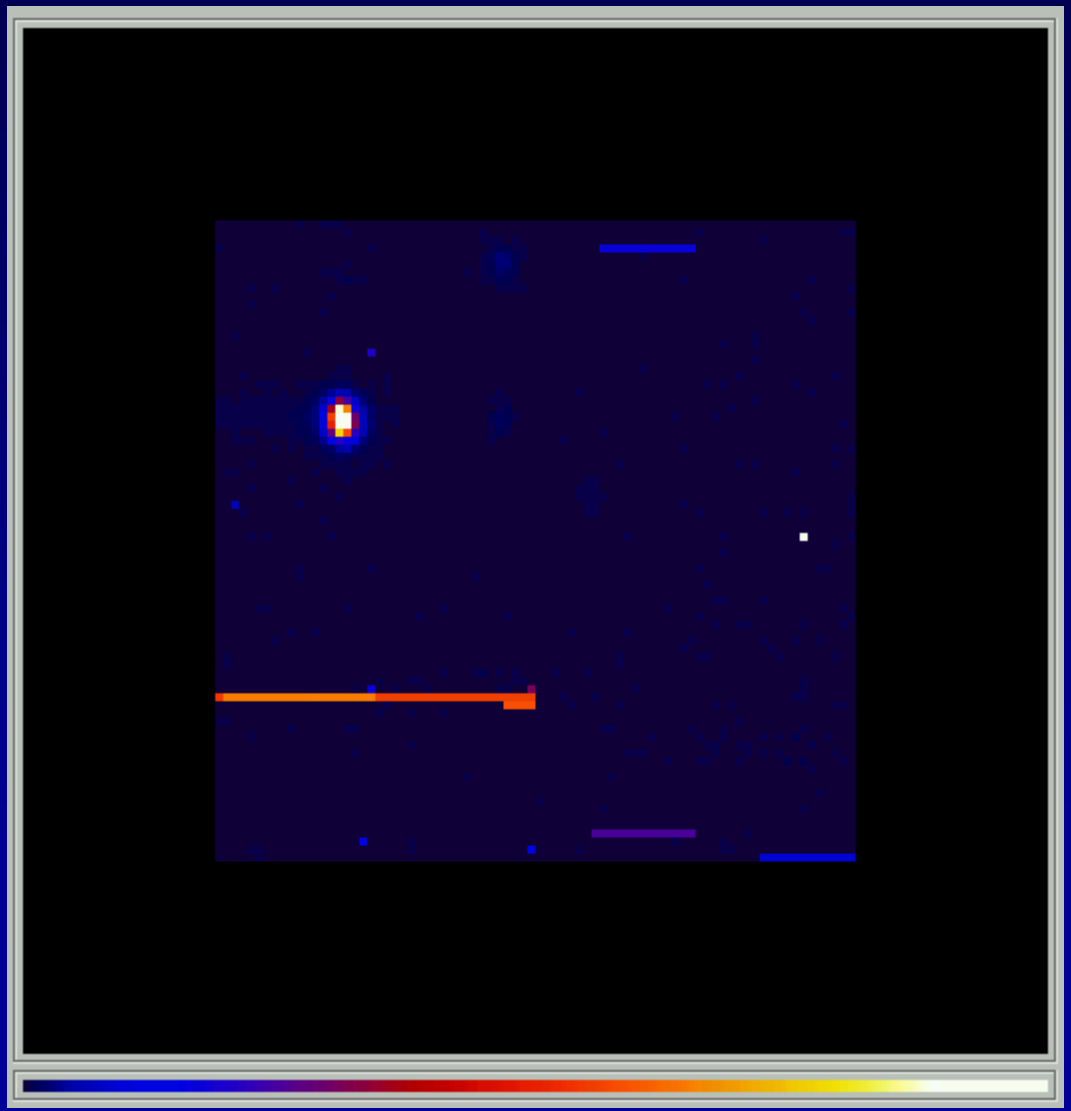


Image Quality



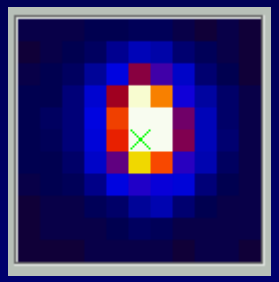


Image Quality

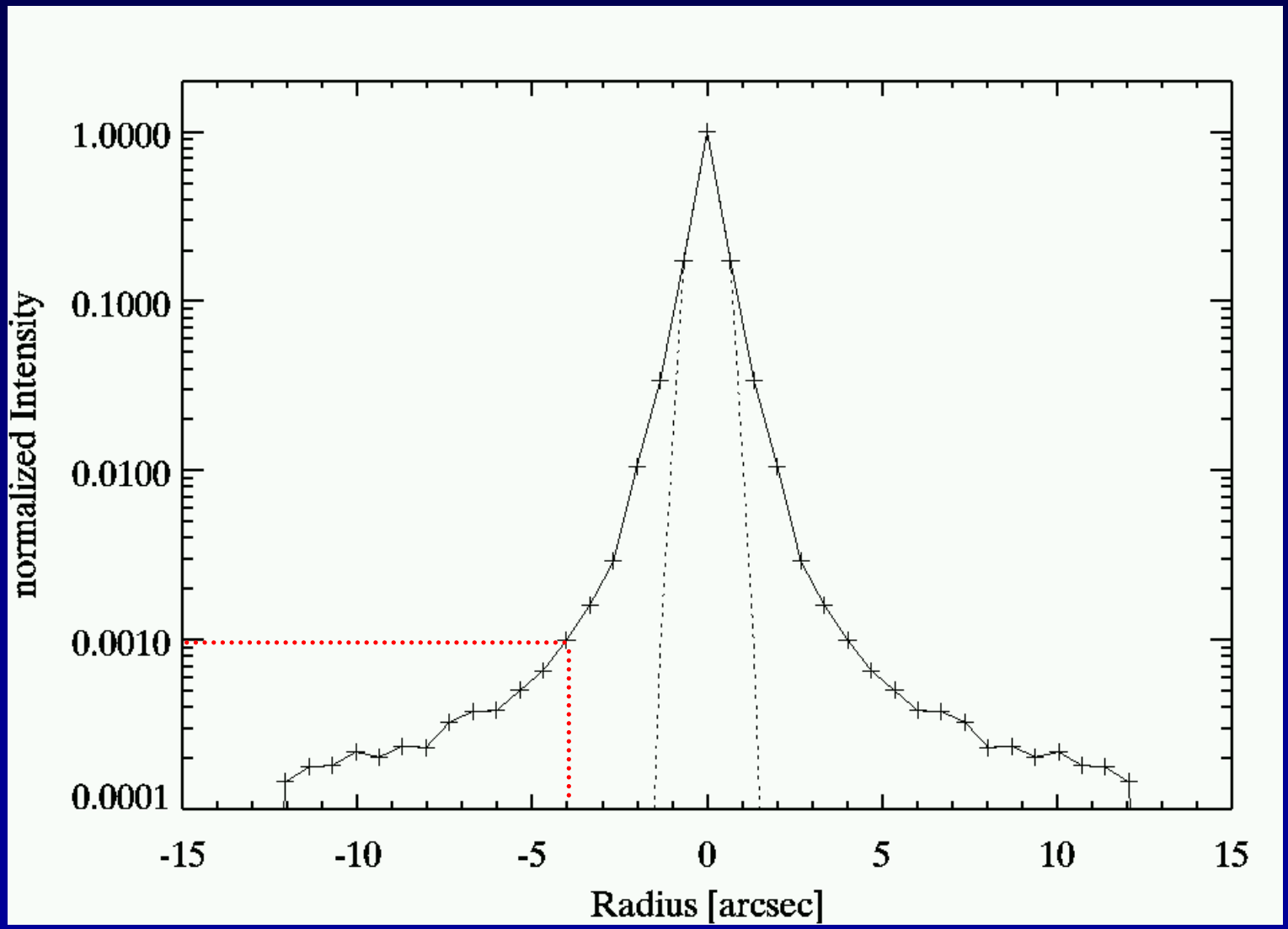


Image Quality

ghost images