SWIFT: Studying Galaxy Evolution with Integral Field Spectroscopy

Lisa Fogarty

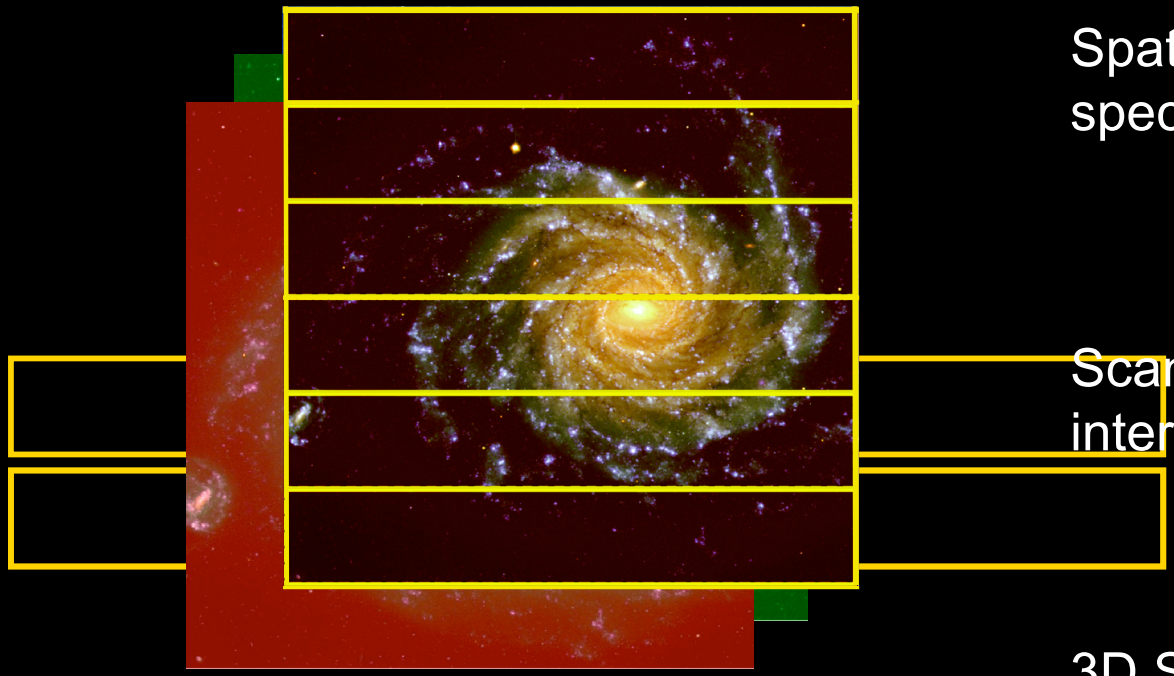
University of Oxford

SWIFT Team: Prof. Niranjan Thatte, Matthias Tecza, Fraser Clarke, Tim Goodsall, Graeme Salter, Susan Kassin

Overview

- The SWIFT Instrument
  - Slicer based Integral Field Spectroscopy.
  - What is SWIFT?
  - SWIFT as a niche instrument.
  - Installation and Commissioning.
- The Scientific Exploitation of SWIFT
  - First Science Results: Arp147
  - Galaxy Kinematics to z~1.4

Integral Field Spectroscopy: Observing a data cube

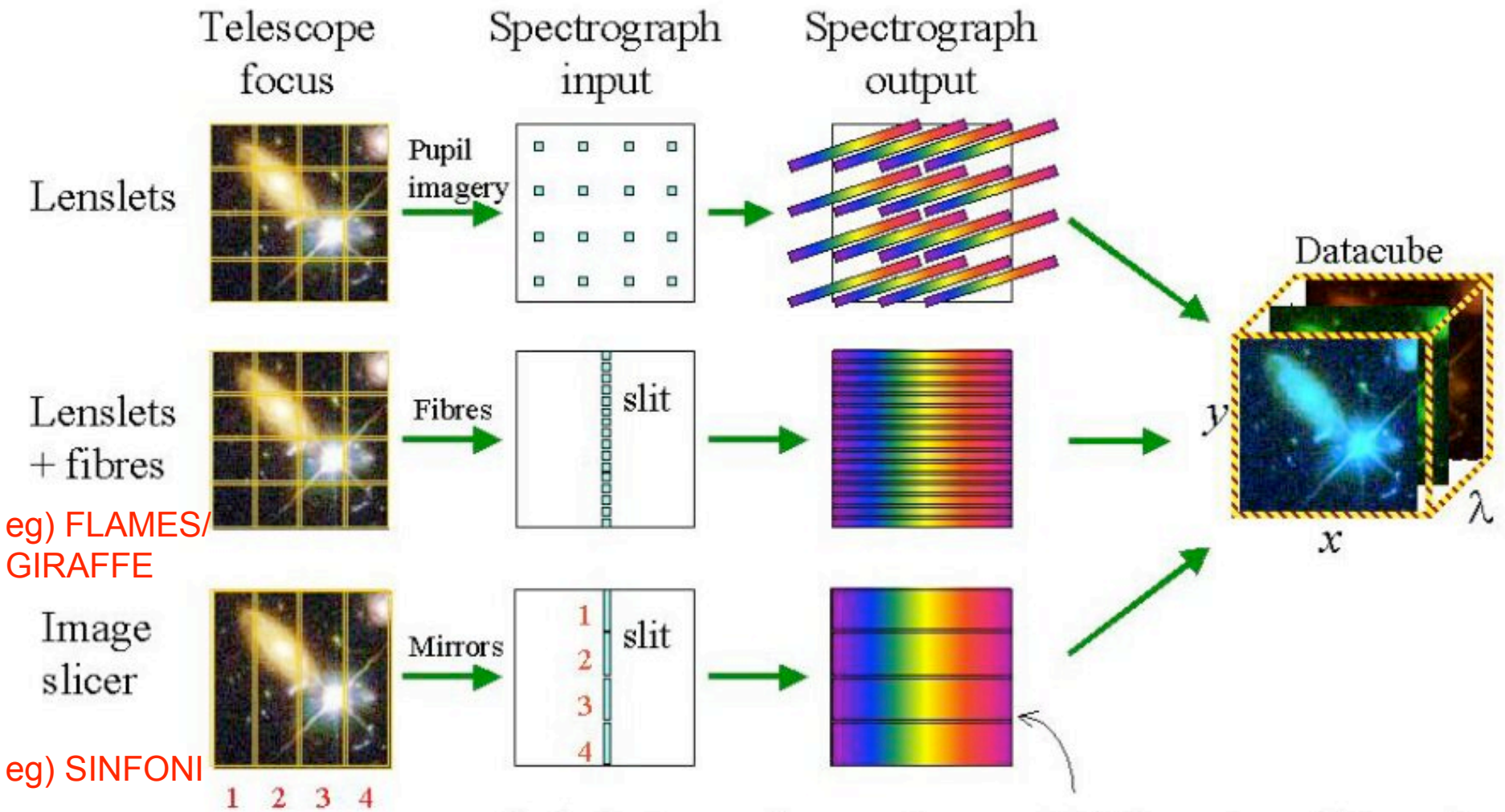


Spatially stepping a long slit spectrometer

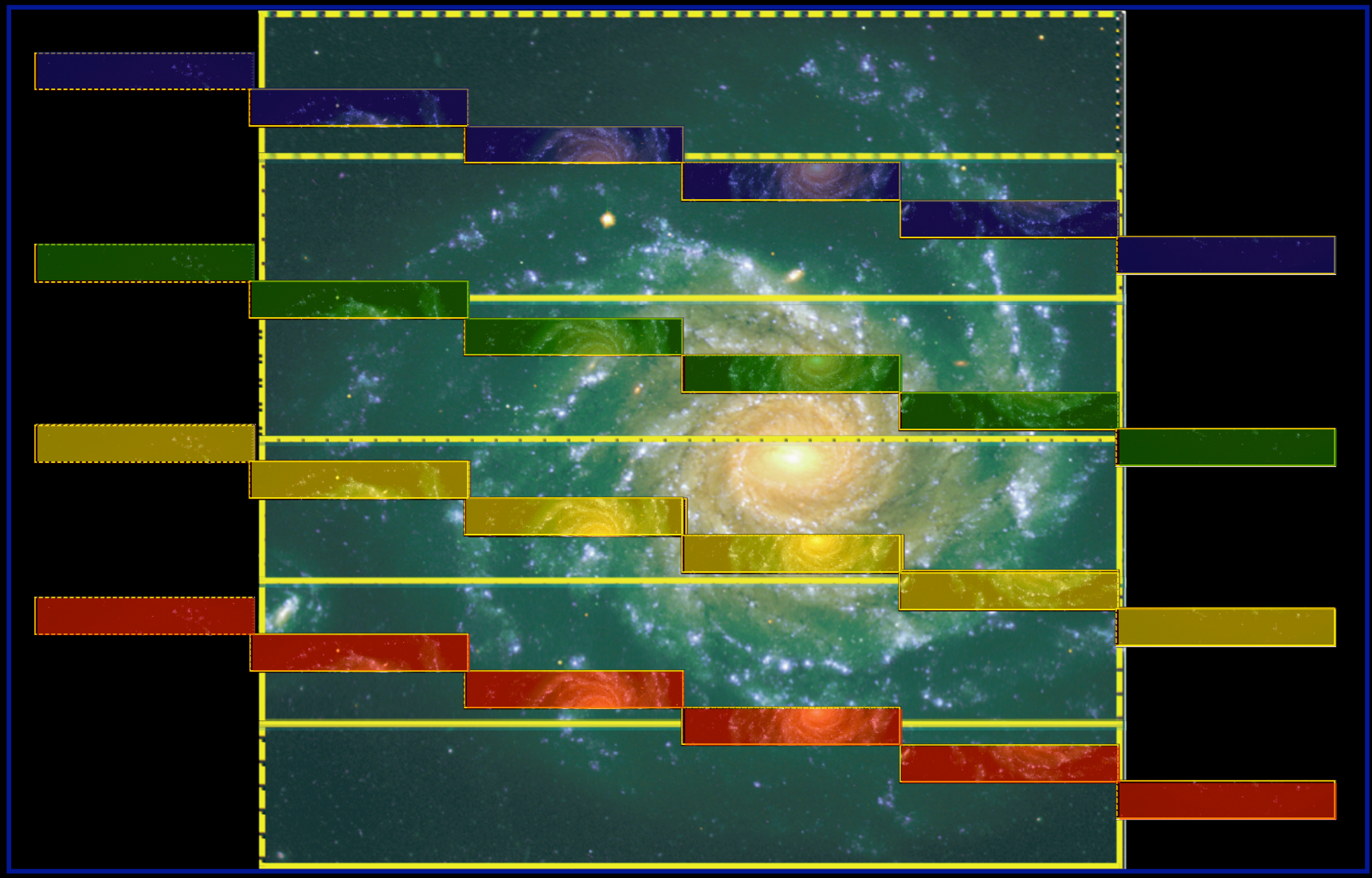
Scanning with a Fabry-Perot interferometer

3D Spectroscopy: Data cube in a single exposure - efficient, homogeneous, large fov.

Different IFS Methods.

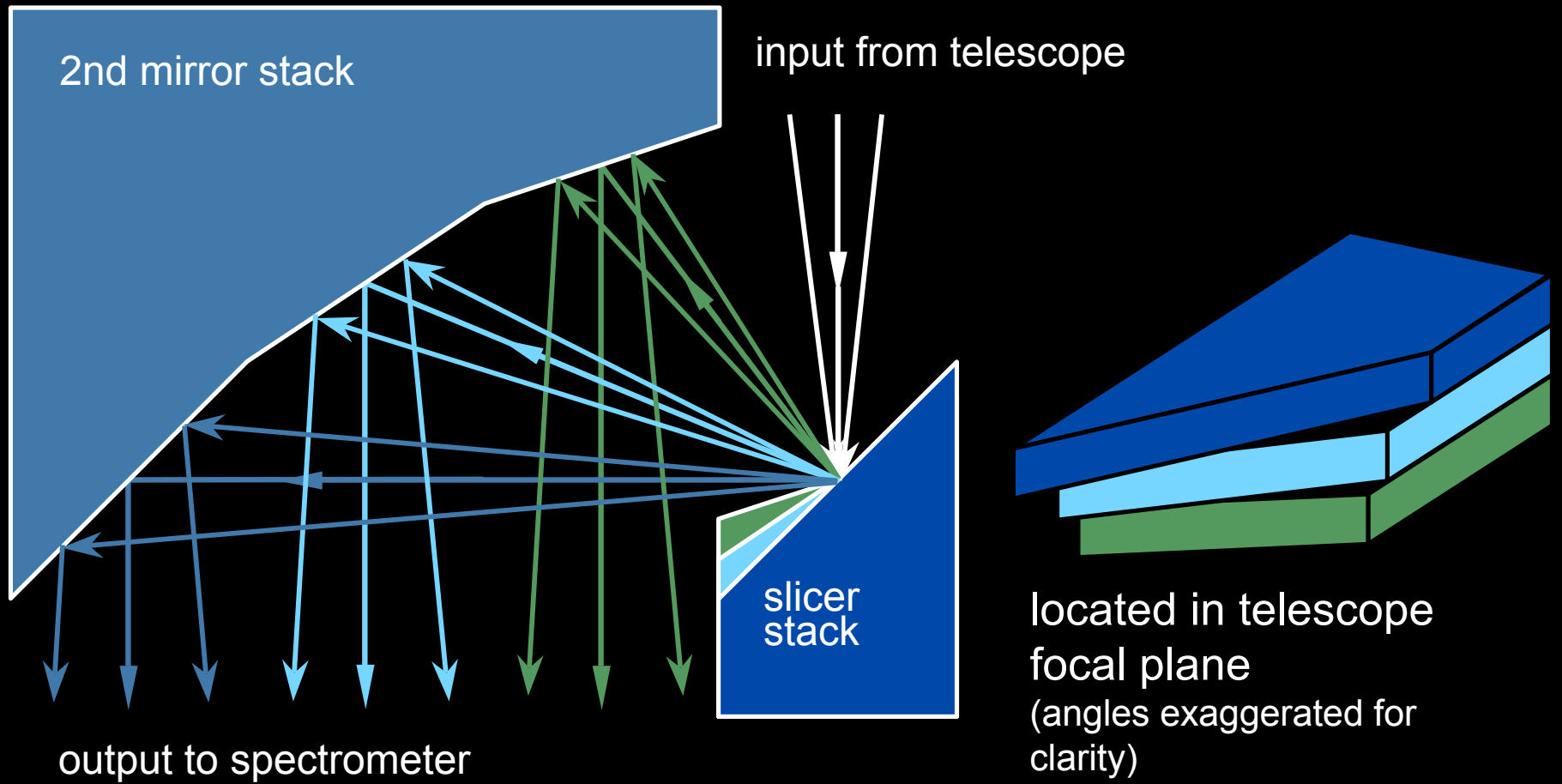


Slicing the Image

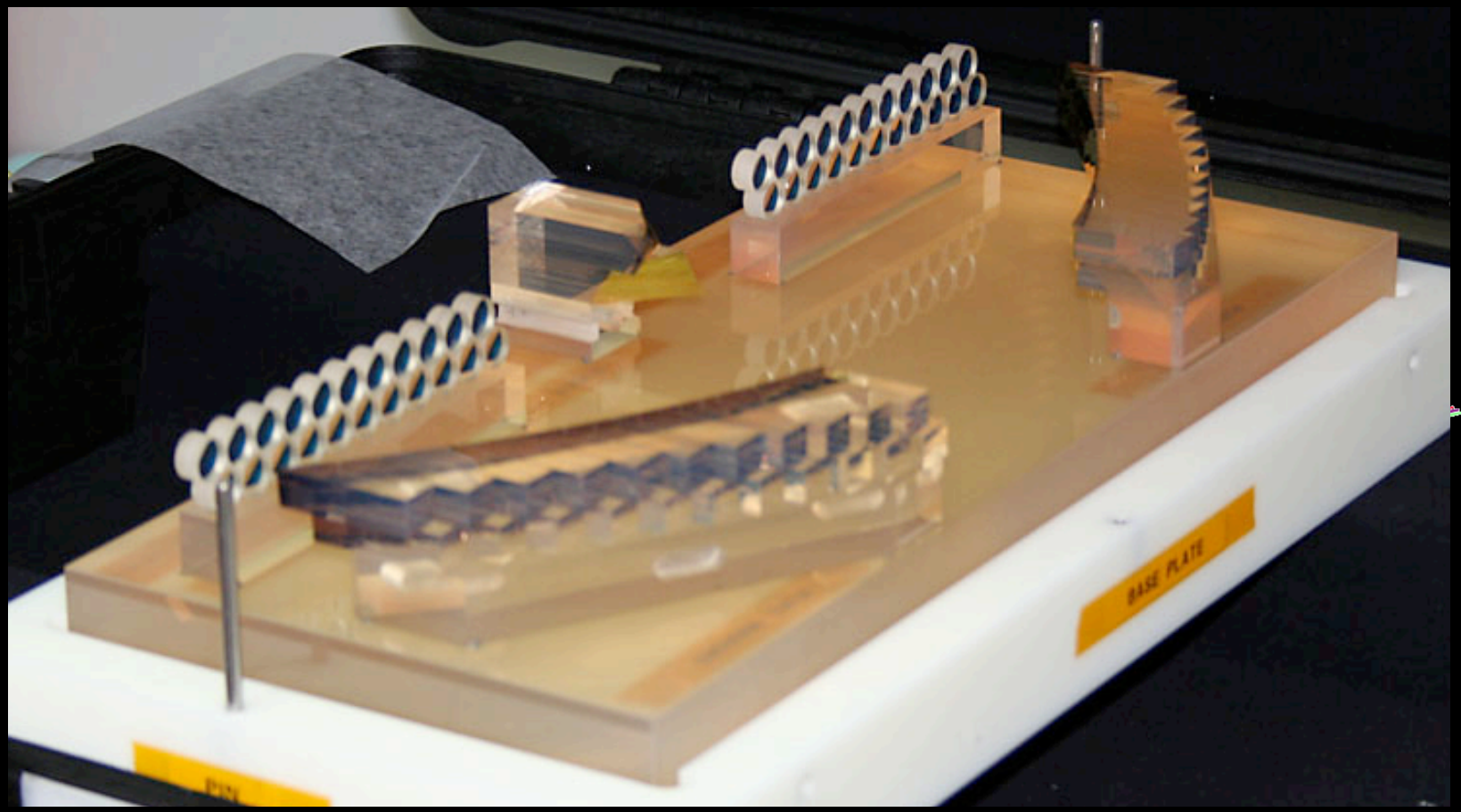


Principle of the Image Slicer

(used in MPE 3D, SINFONI)



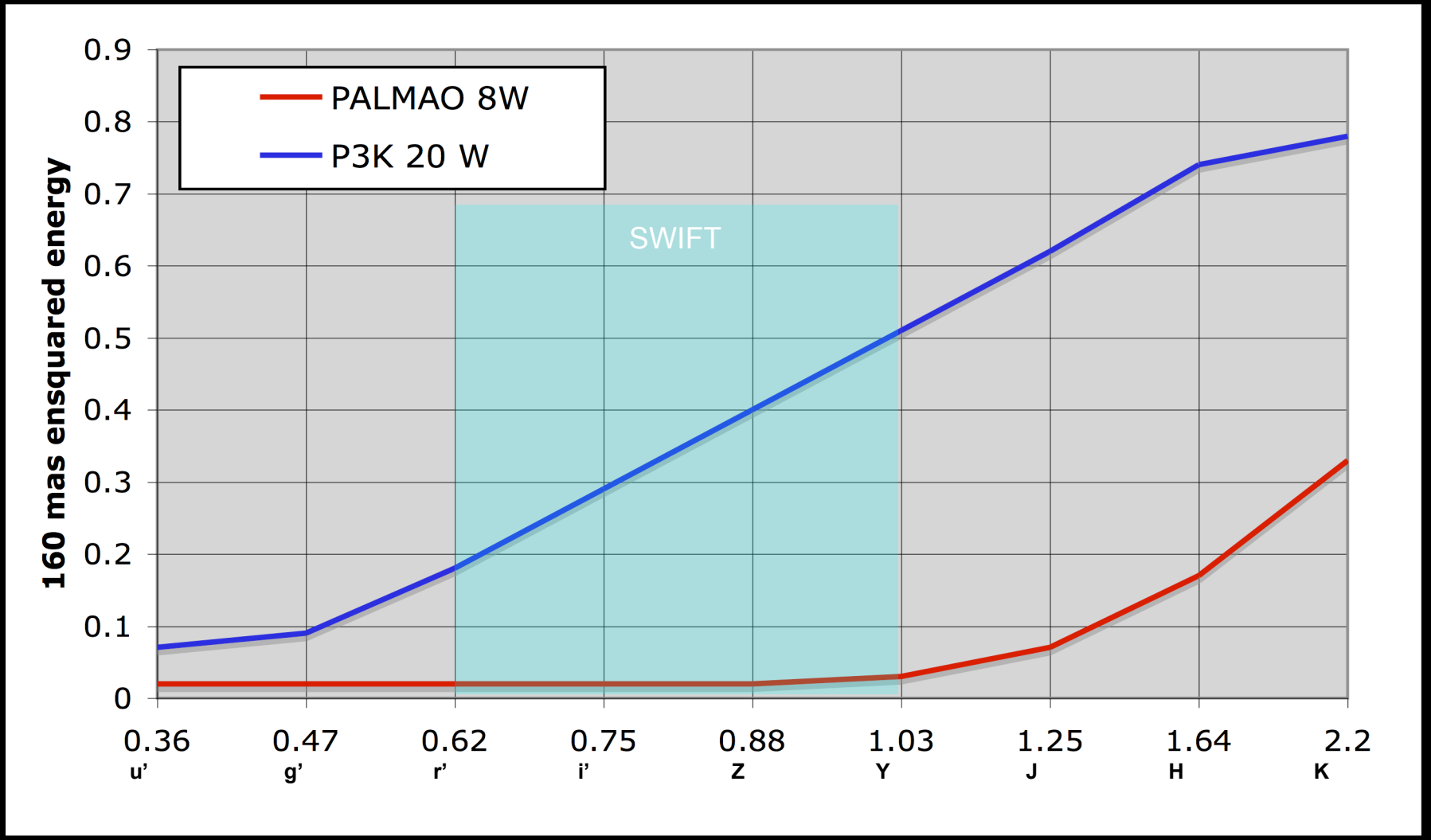
The SWIFT Slicer



SWIFT: Instrument Overview

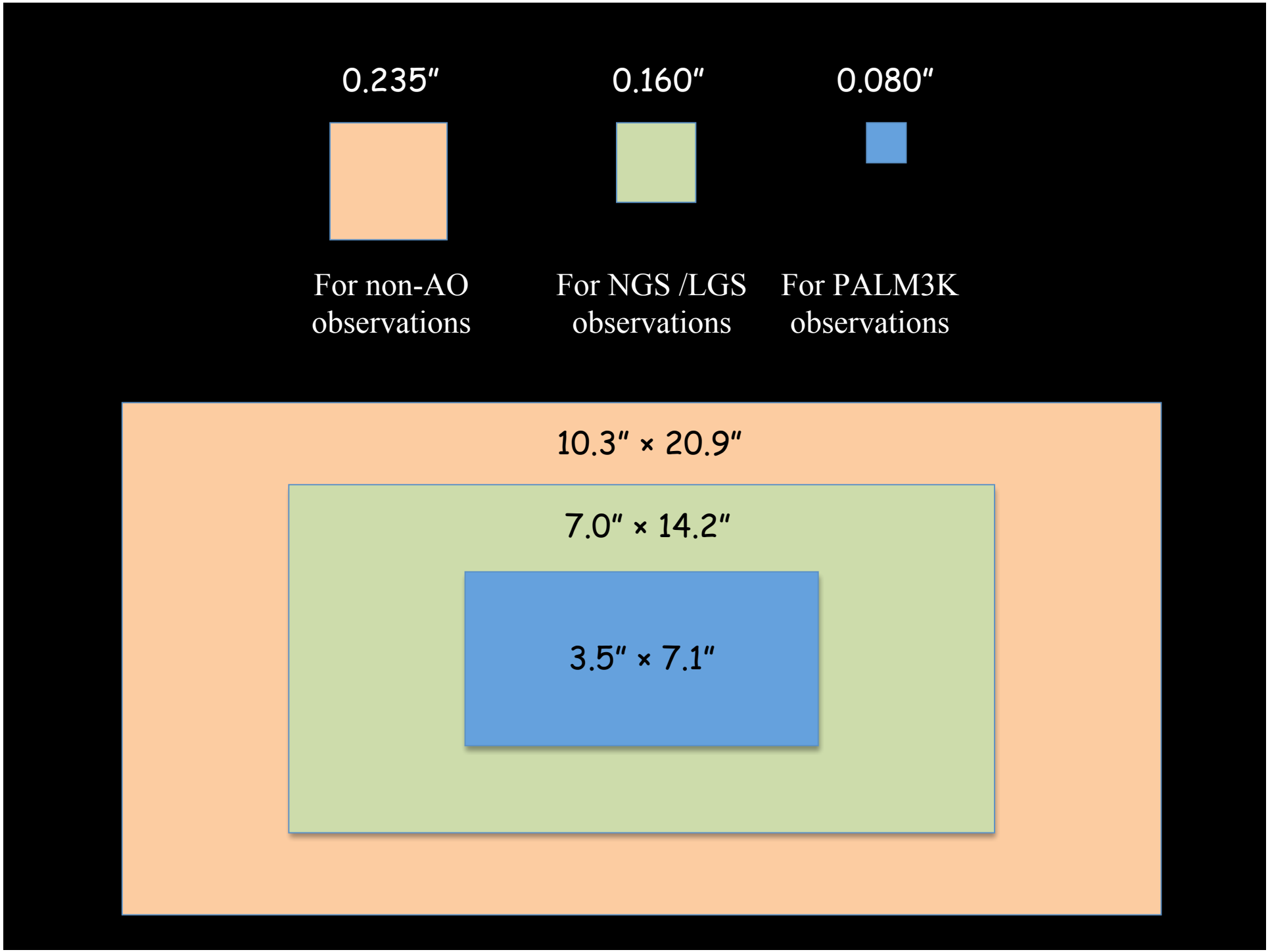
- SWIFT loosely stands for Short Wavelength Integral Field Spectrograph.
- SWIFT is an AO-assisted, I/z band integral field spectrograph.
- Classicaly polished glass image slicer with 44x89 spatial pixels - ~4000 simultaneous spectra.
- Twin spectrographs
  - 650nm-1020nm fixed spectral range
  - Optional 750nm cut-off to enable guiding on fainter stars.
- LBNL CCDs with QE >80% at 950nm
- The instrument has a very high throughtput - 50% (excluding AO and detector).

PALM3000


PALMAO 8W
P3K 20 W
SWIFT
160 mas ensquared energy
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.36 u'
0.47 g'
0.62 r'
0.75 i'
0.88 Z
1.03 Y
1.25 J
1.64 H
2.2 K

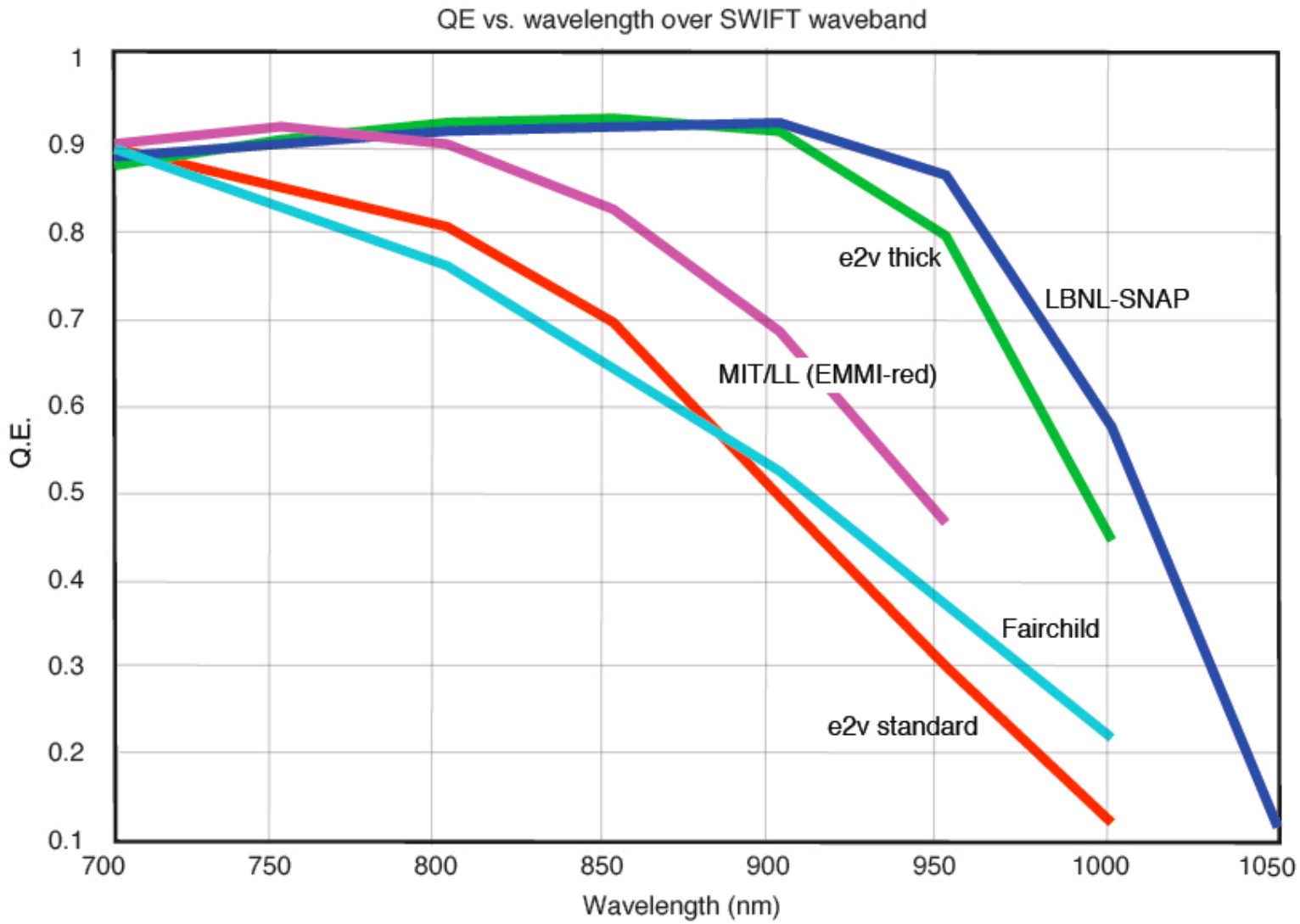
SWIFT: Instrument Overview

- SWIFT loosely stands for Short Wavelength Integral Field Spectrograph.
- SWIFT is an AO-assisted, I/z band integral field spectrograph.
- Classicaly polished glass image slicer with 44x89 spatial pixels - ~4000 simultaneous spectra.
- Twin spectrographs
  - 650nm-1020nm fixed spectral range
  - Optional 750nm cut-off to enable guiding on fainter stars.
- LBNL CCDs with QE >80% at 950nm
- The instrument has a very high throughtput - 50% (excluding AO and detector).


0.235″
0.160″
0.080″
For non-AO observations
For NGS /LGS observations
For PALM3K observations
10.3″ × 20.9″
7.0″ × 14.2″
3.5″ × 7.1″

SWIFT: Instrument Overview

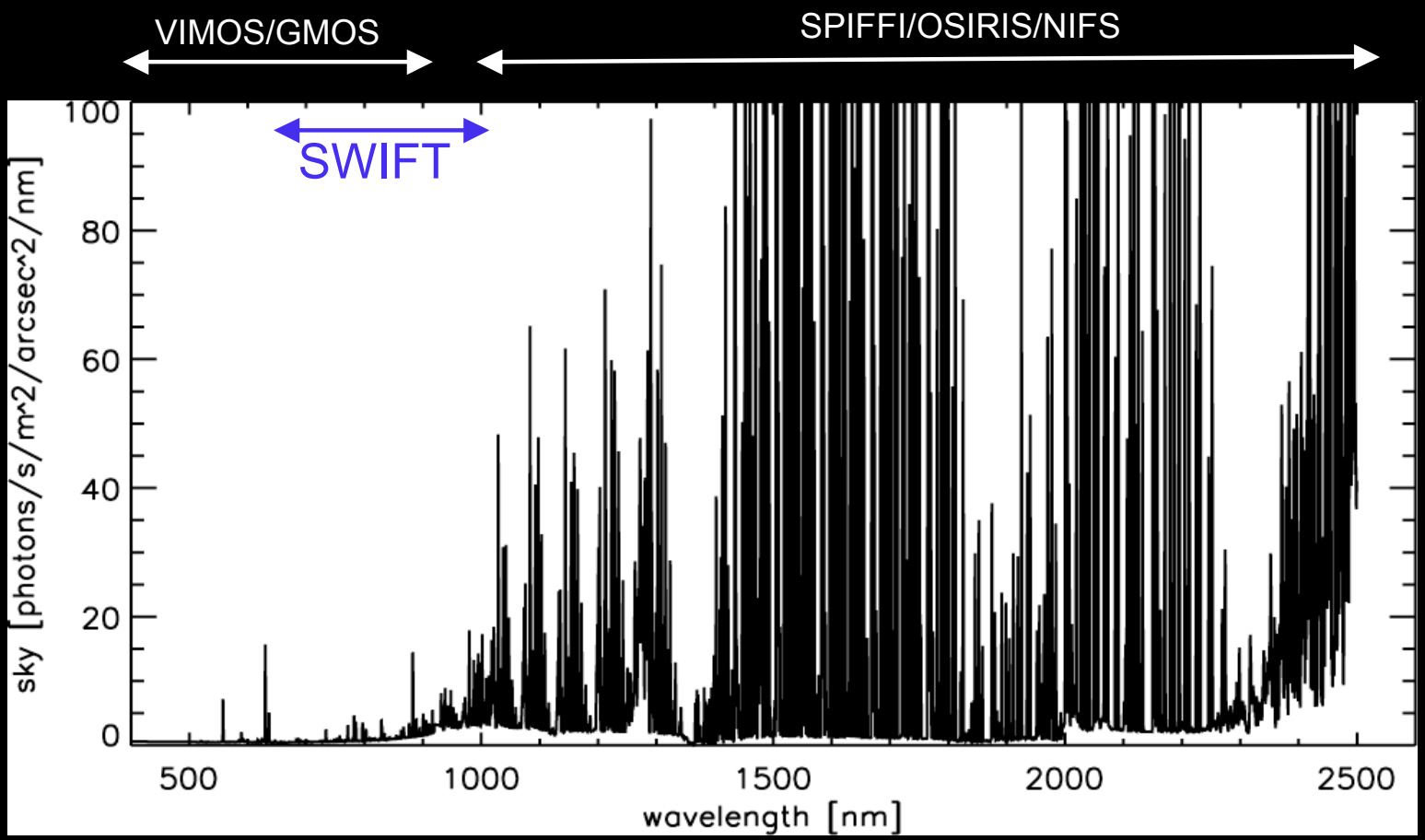
- SWIFT loosely stands for Short Wavelength Integral Field Spectrograph.
- SWIFT is an AO-assisted, I/z band integral field spectrograph.
- Classicaly polished glass image slicer with 44x89 spatial pixels - ~4000 simultaneous spectra.
- Twin spectrographs
  - 650nm-1020nm fixed spectral range
  - Optional 750nm cut-off to enable guiding on fainter stars.
- LBNL CCDs with QE >80% at 950nm
- The instrument has a very high throughtput - 50% (excluding AO and detector).


QE vs. wavelength over SWIFT waveband
Q.E.
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
700
750
800
850
900
950
1000
1050
Wavelength (nm)
e2v thick
LBNL-SNAP
MIT/LL (EMMI-red)
Fairchild
e2v standard

SWIFT as a Niche Instrument

- SWIFT works in the I/z band, thus occupying a spectral niche benefiting from lower sky background.
- SWIFT builds on three new developments:
  - Next generation AO system with good correction shortward of 1000nm.
  - Extremely red sensitive CCDs.
  - A classically polished all-glass image slicer with very high throughput.

SWIFT as a Niche Instrument



SWIFT as a Niche Instrument

- SWIFT works in the I/z band, thus occupying a spectral niche benefiting from lower sky background.
- SWIFT builds on three new developments:
  - Next generation AO system with good correction shortward of 1000nm (PALM3000).
  - Extremely red sensitive CCDs.
  - A classically polished all-glass image slicer with very high throughput.

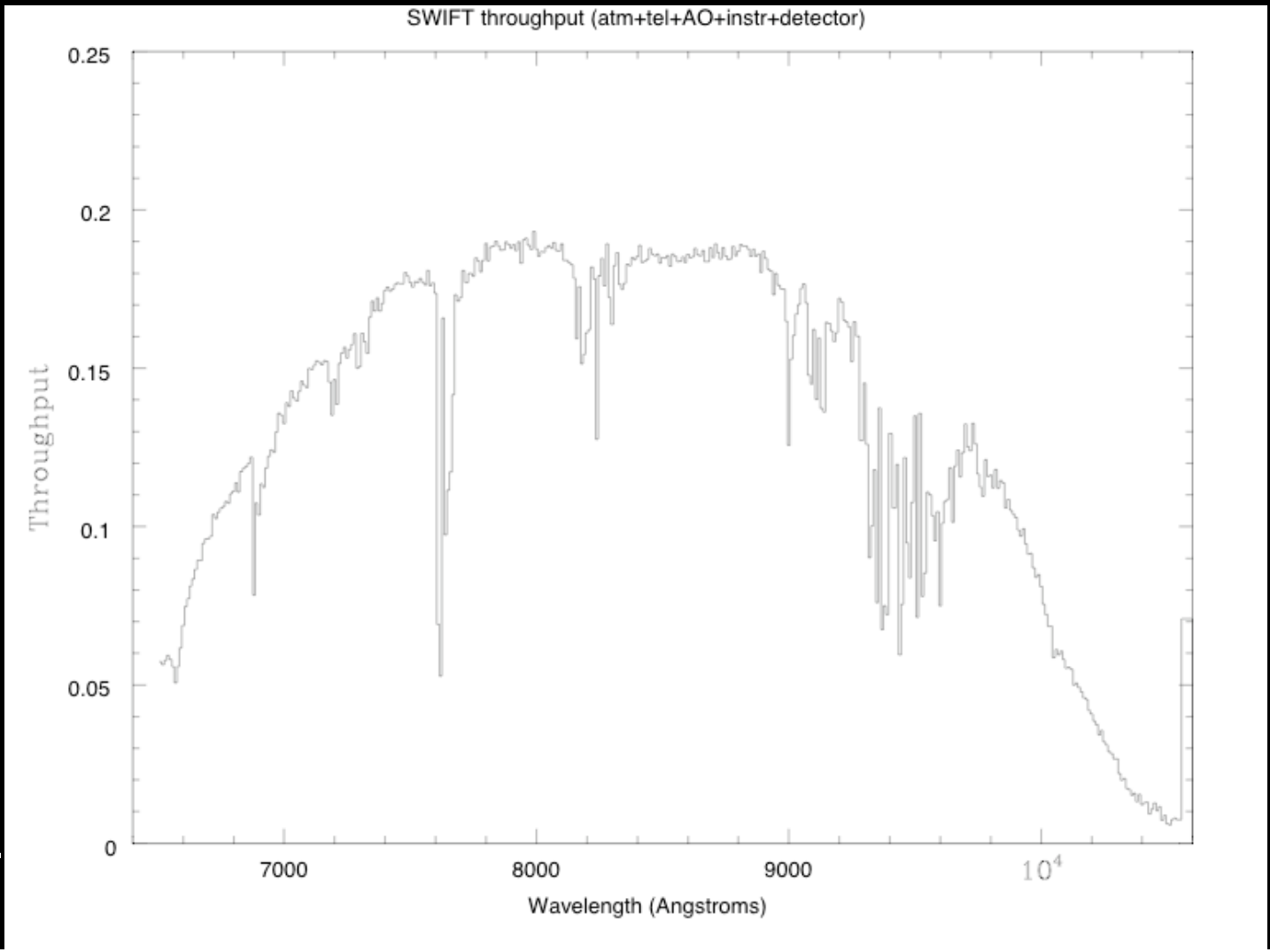
SWIFT as a Niche Instrument

- SWIFT works in the I/z band, thus occupying a spectral niche benefiting from lower sky background.
- SWIFT builds on three new developments:
  - Next generation AO system with good correction shortward of 1000nm (PALM3000).
  - Extremely red sensitive CCDs.
  - A classically polished all-glass image slicer with very high throughput.

SWIFT as a Niche Instrument

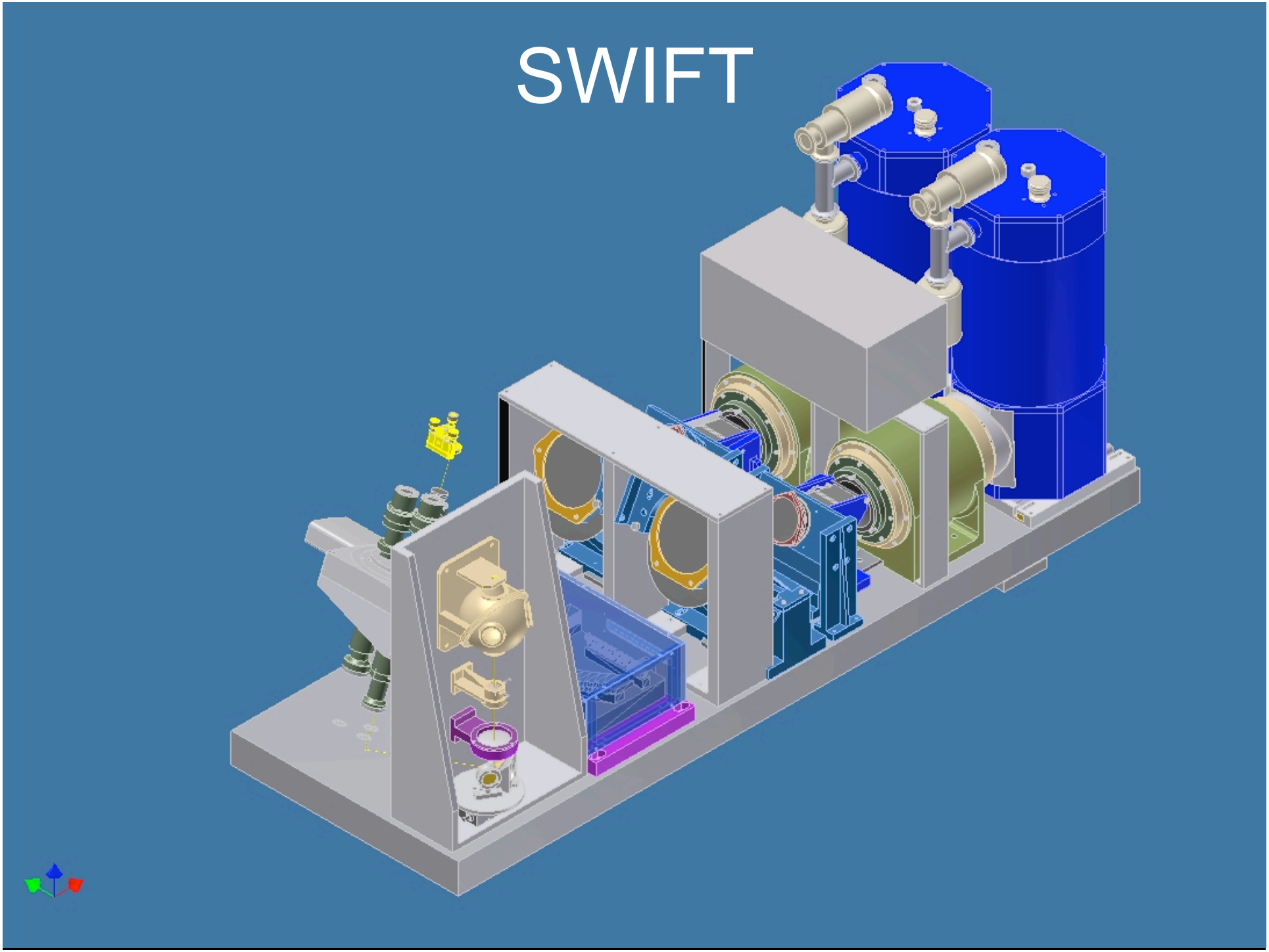
- SWIFT works in the I/z band, thus occupying a spectral niche benefiting from lower sky background.
- SWIFT builds on three new developments:
  - Next generation AO system with good correction shortward of 1000nm.
  - Extremely red sensitive CCDs.
  - A classically polished all-glass image slicer with very high throughput.

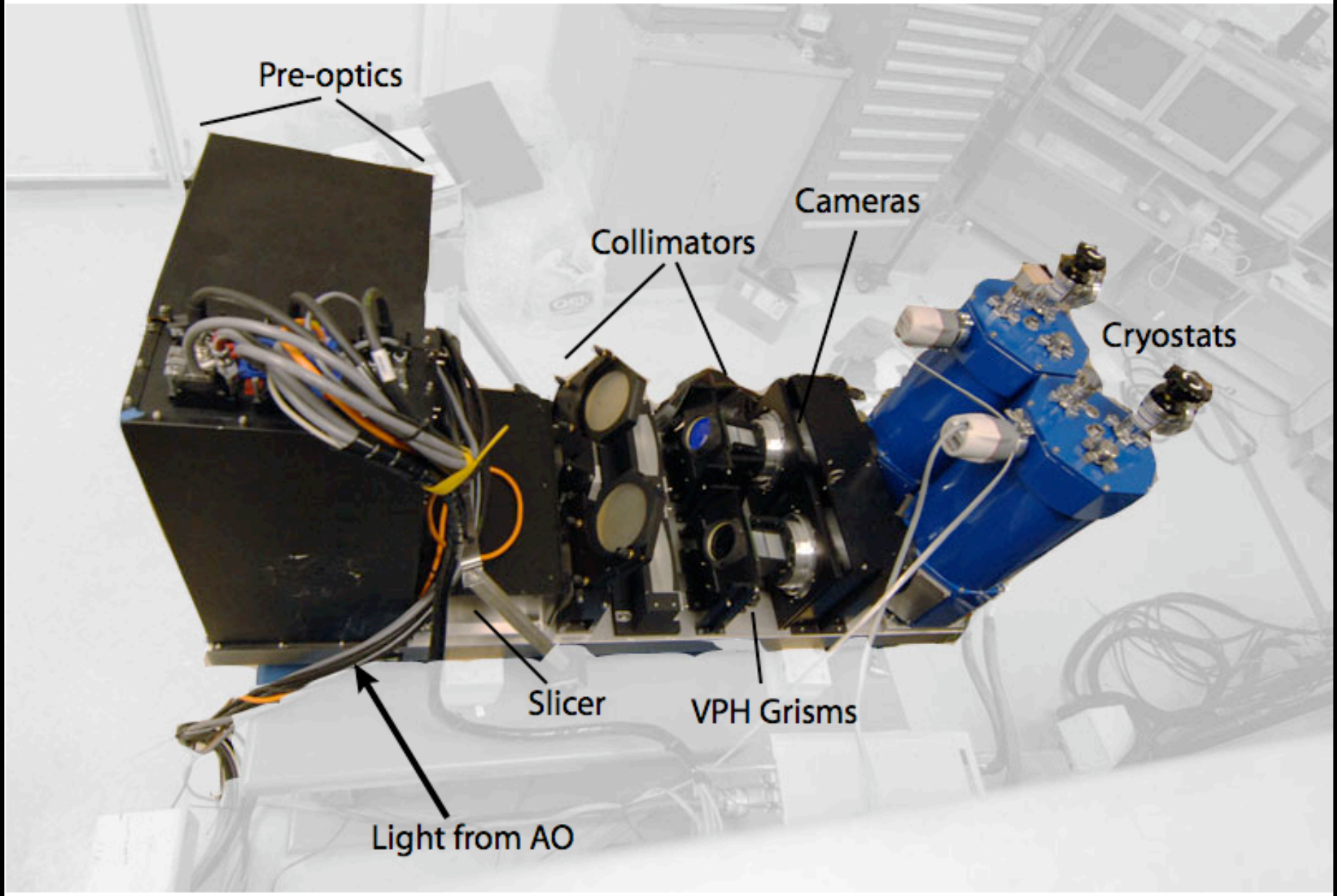
Measured Throughput of SWIFT



Credit: Prof. N. Thatte

SWIFT



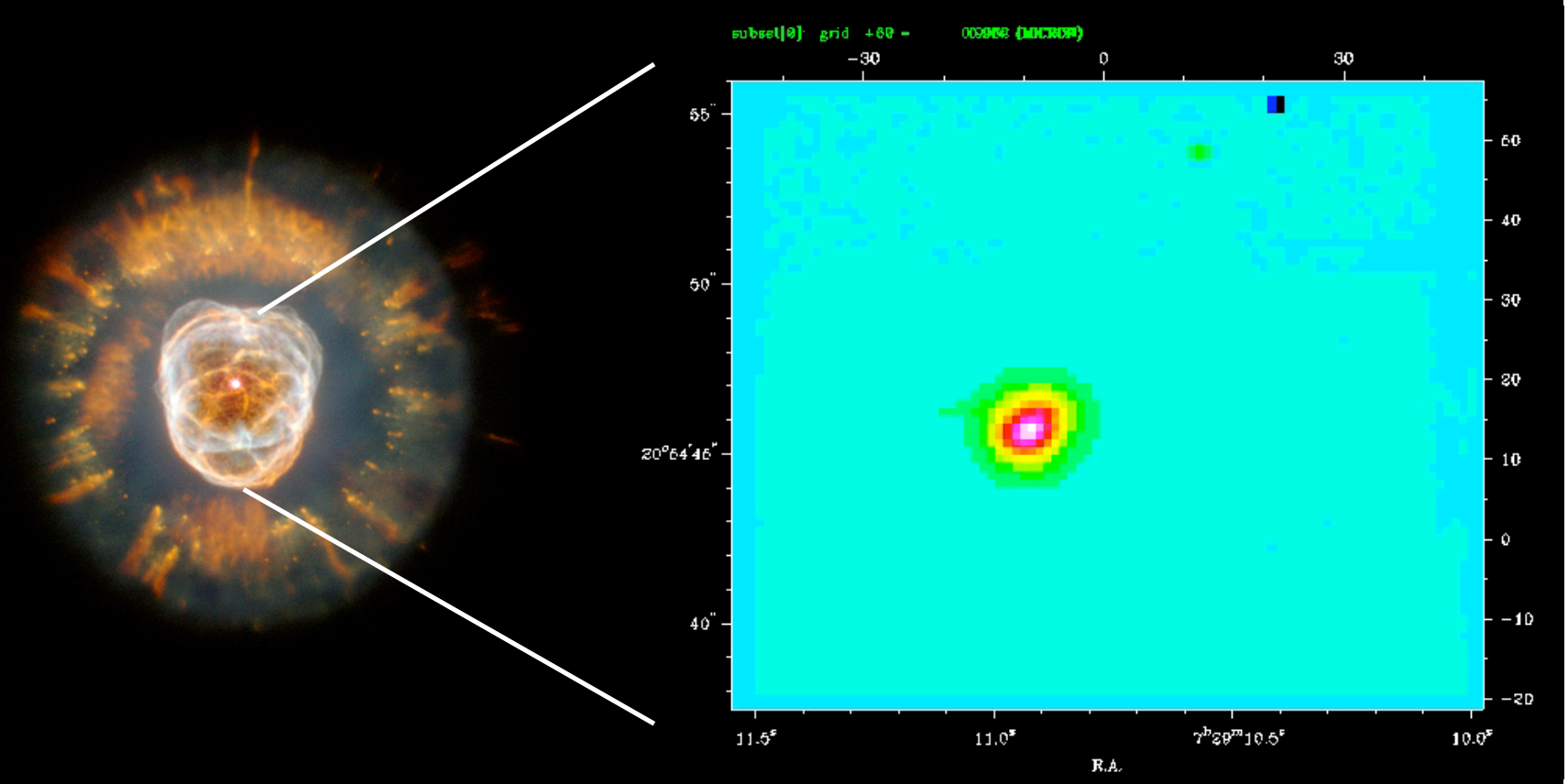

Pre-optics
Collimators
Cameras
Cryostats
Slicer
VPH Grisms
Light from AO

Installation

- SWIFT was installed at the 200” at Palomar on 10th Oct. 2008.

Credit: Scott Kardel, Palomar.

Commissioning (Science) Results.



Credit : Dr. F. Clarke.

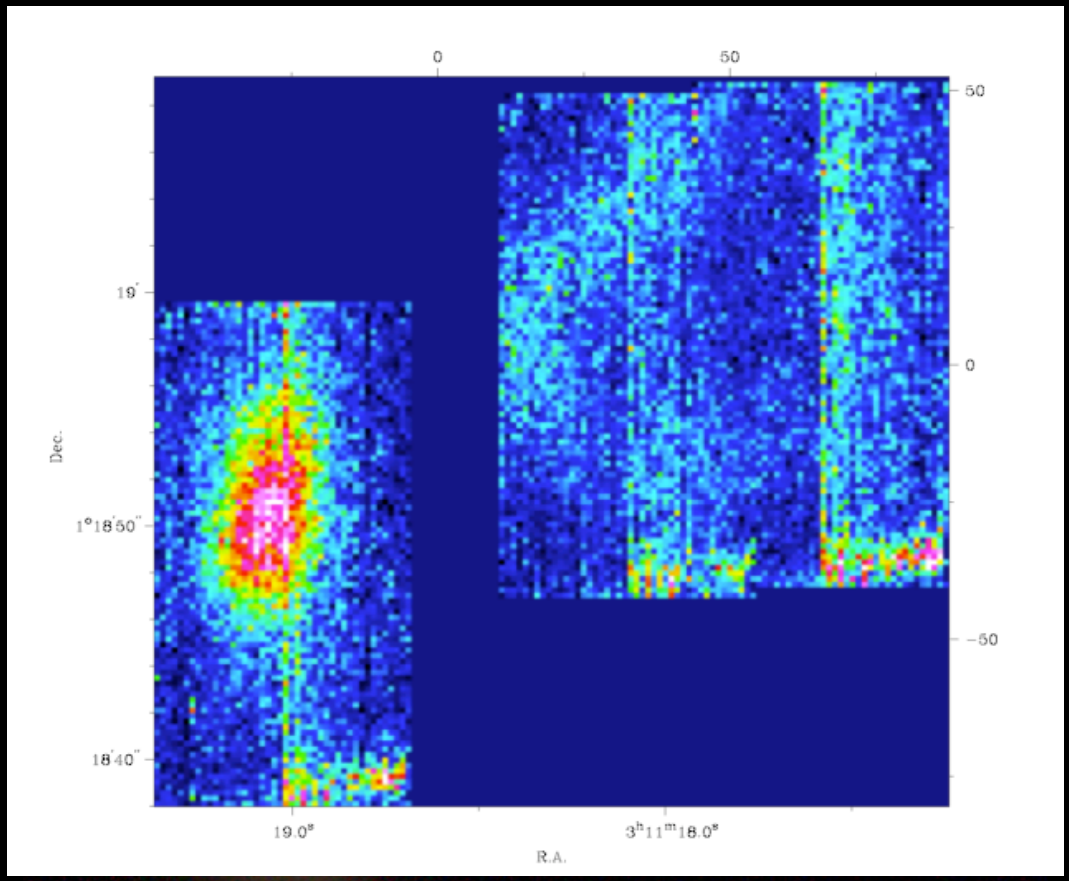
First Science Results: Arp147

- Arp147 is a ring galaxy and companion system.
- Observed as part of the January bad-weather programme.

Credit: NASA, ESA, M. Livio (STSci)

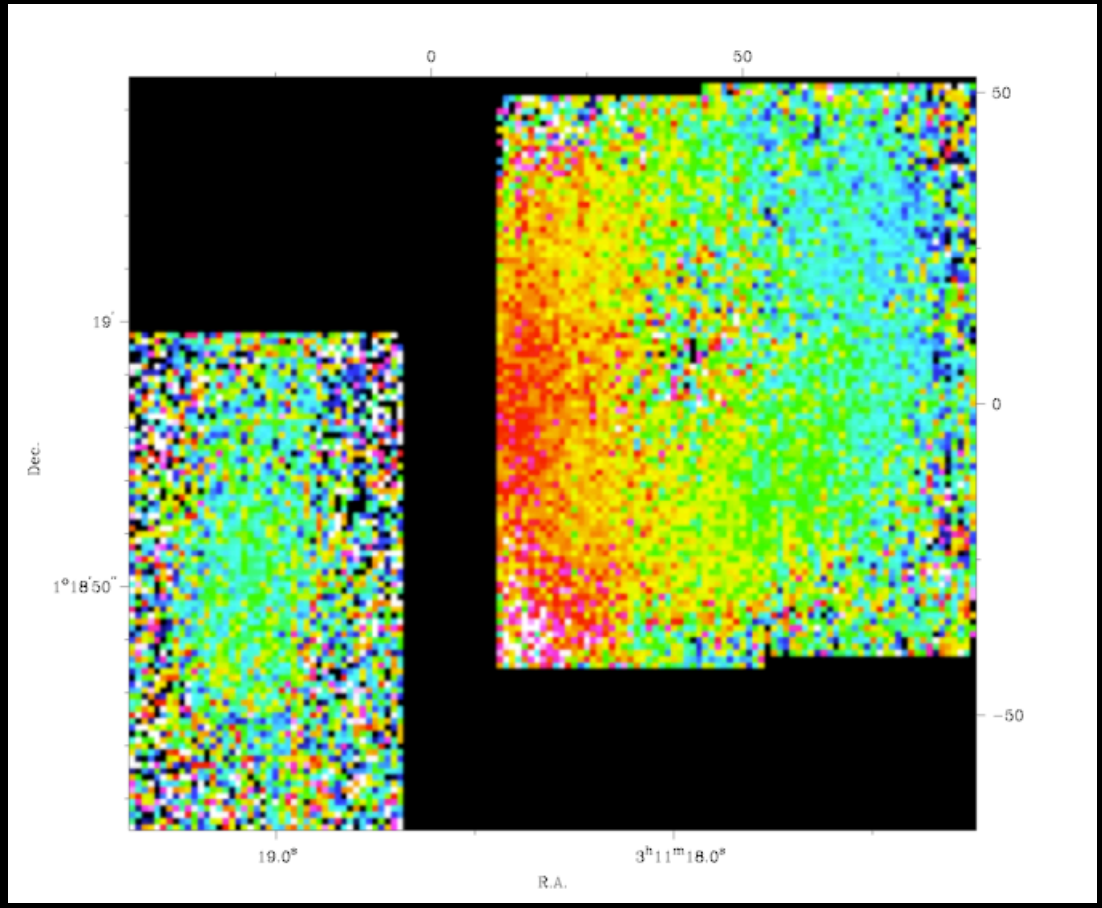
SWIFT Kinematics

- H-alpha line map.
- Strong H-alpha in blue object.



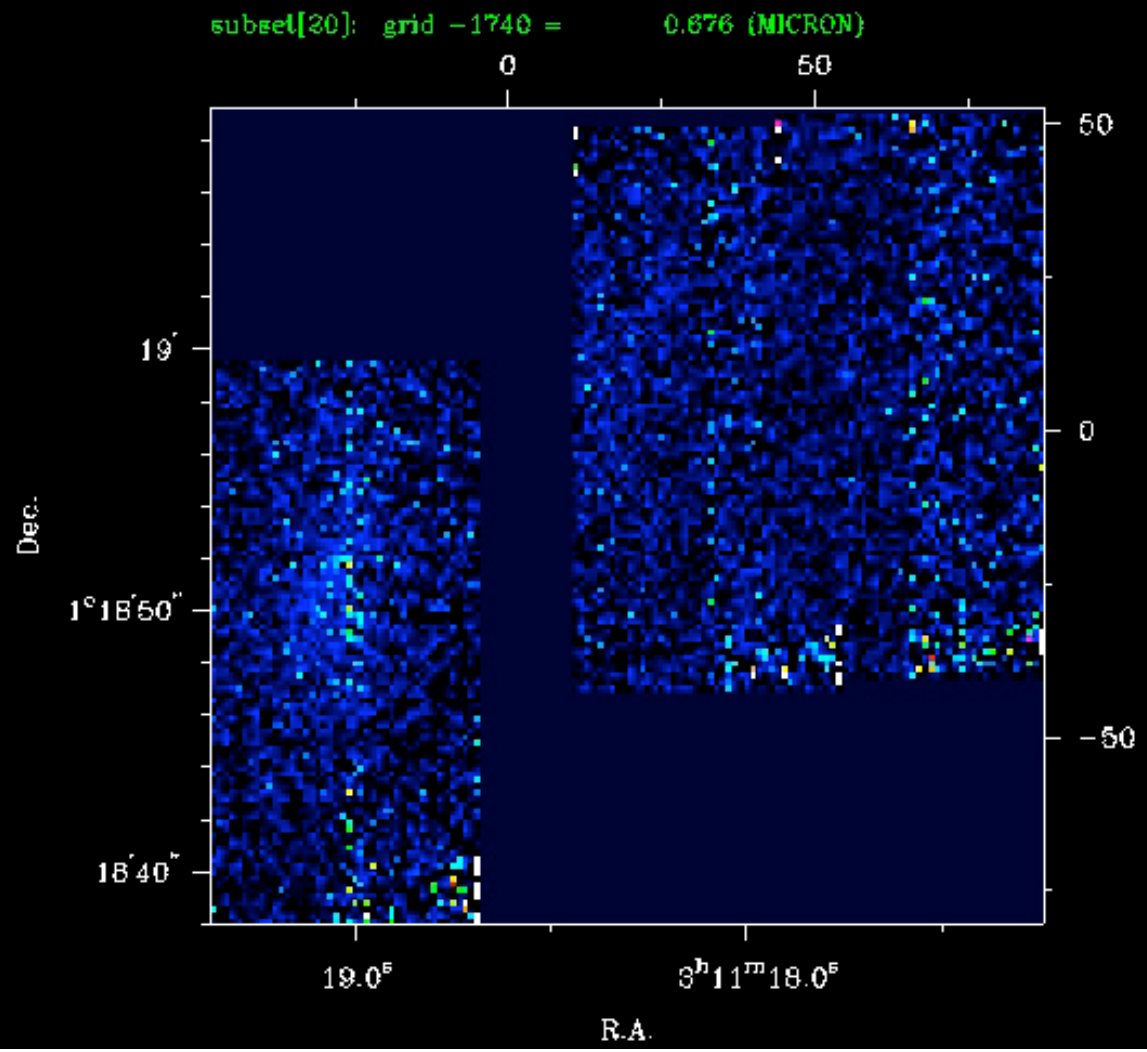
SWIFT Kinematics

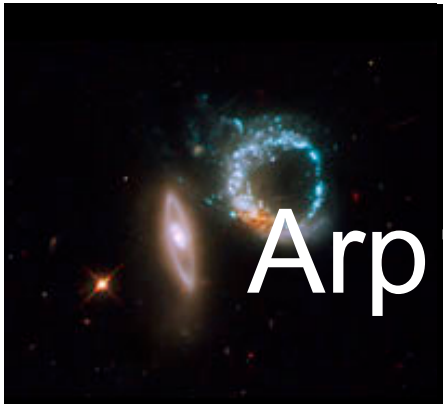
- H-alpha velocity map.
- See strong velocity gradient in the ring.



SWIFT Kinematics

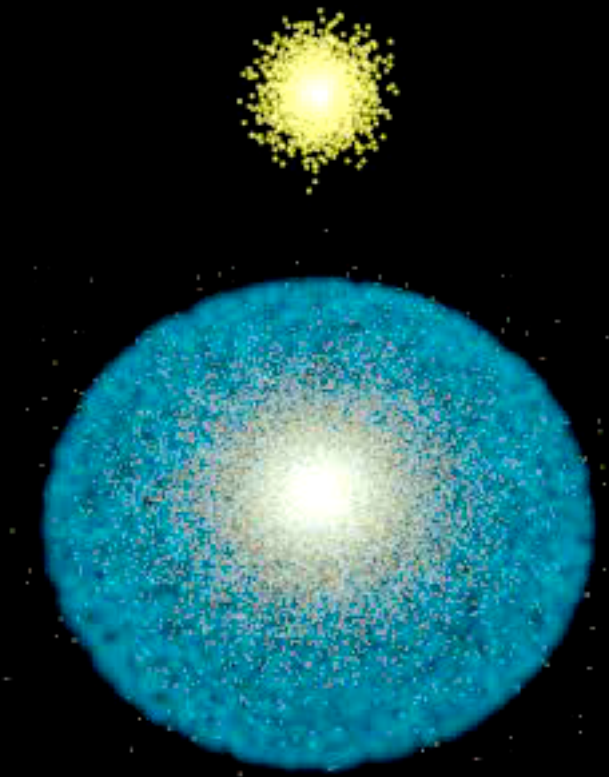
- Easier to see velocity structure in a movie…





Arp147 Formation Scenario

- Collisionally created ring, similar to the Cartwheel.
- But Arp147 has an empty ring.



Refs:Chris Mihos, CWU
Lynds & Toomre, 1976
Gerber et al., 1992

Formation Timescales.

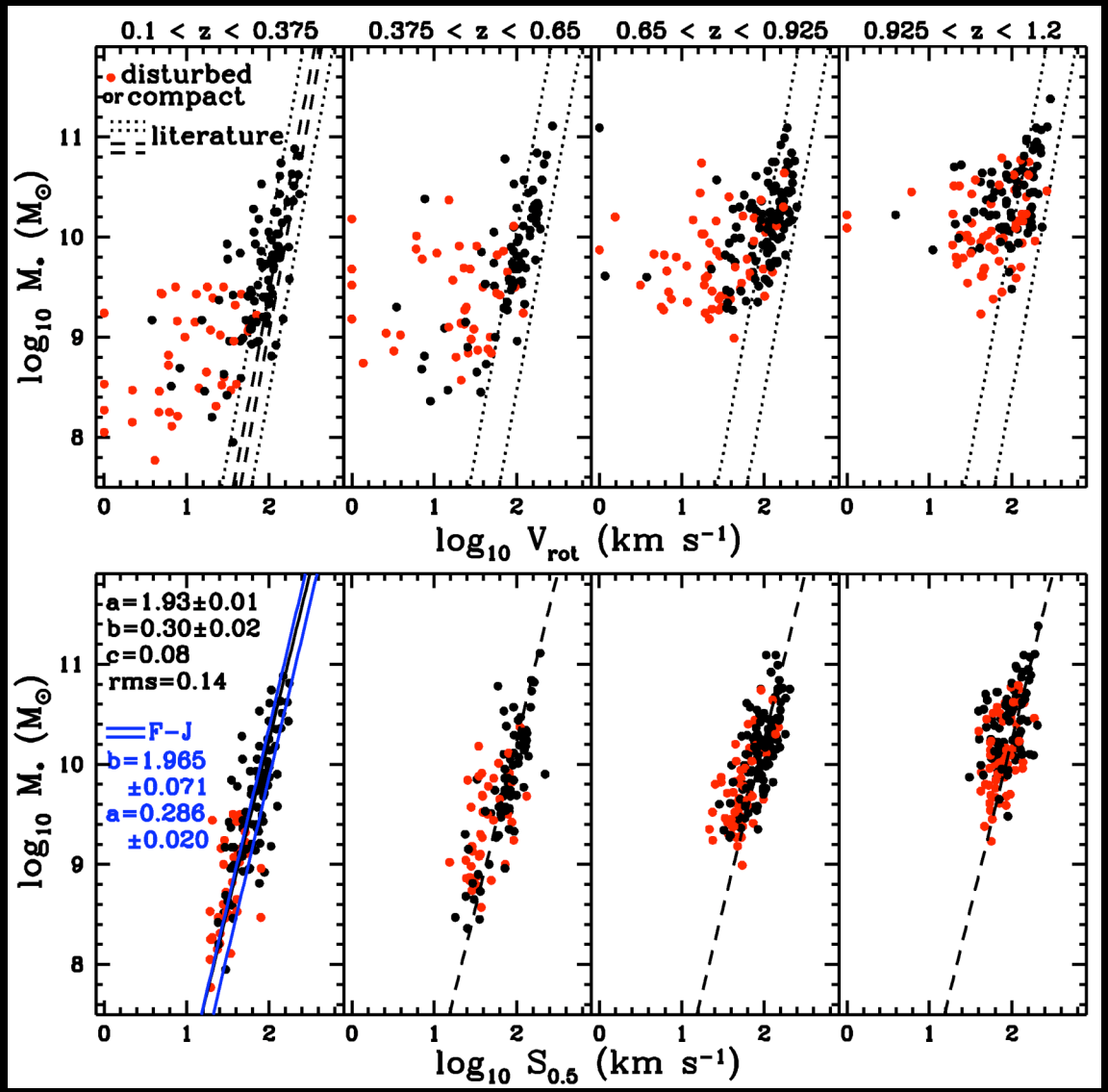
- Expansion Vel: 302.25 kms^{-1}
- Diameter of Ring: 9.25 kpc
- Rough Expansion timescale (from half current size): 7.85 Myrs
- Distance to companion: 12.7 kpc

- Qualitative match to starburst age?
- More - Fogarty et al, 2009 (in prep.)

High Redshift Galaxy Kinematics.

- Complementary to the IMAGES survey
  - Sample of 63 gals
  - Extensive work done on evolution of kinematics, TFR, metallicity etc (e.g. Yang et al 2008, Peuch et al 2008, Neichel et al 2008, Rodrigues et al 2008)
  - Sample from z~0.4-0.75
- The SWIFT sample will look at z~0.8-1.4, looking at OII and/or OIII - perfect for SWIFT.
- I am particularly interested in evolution of galaxy kinematics.

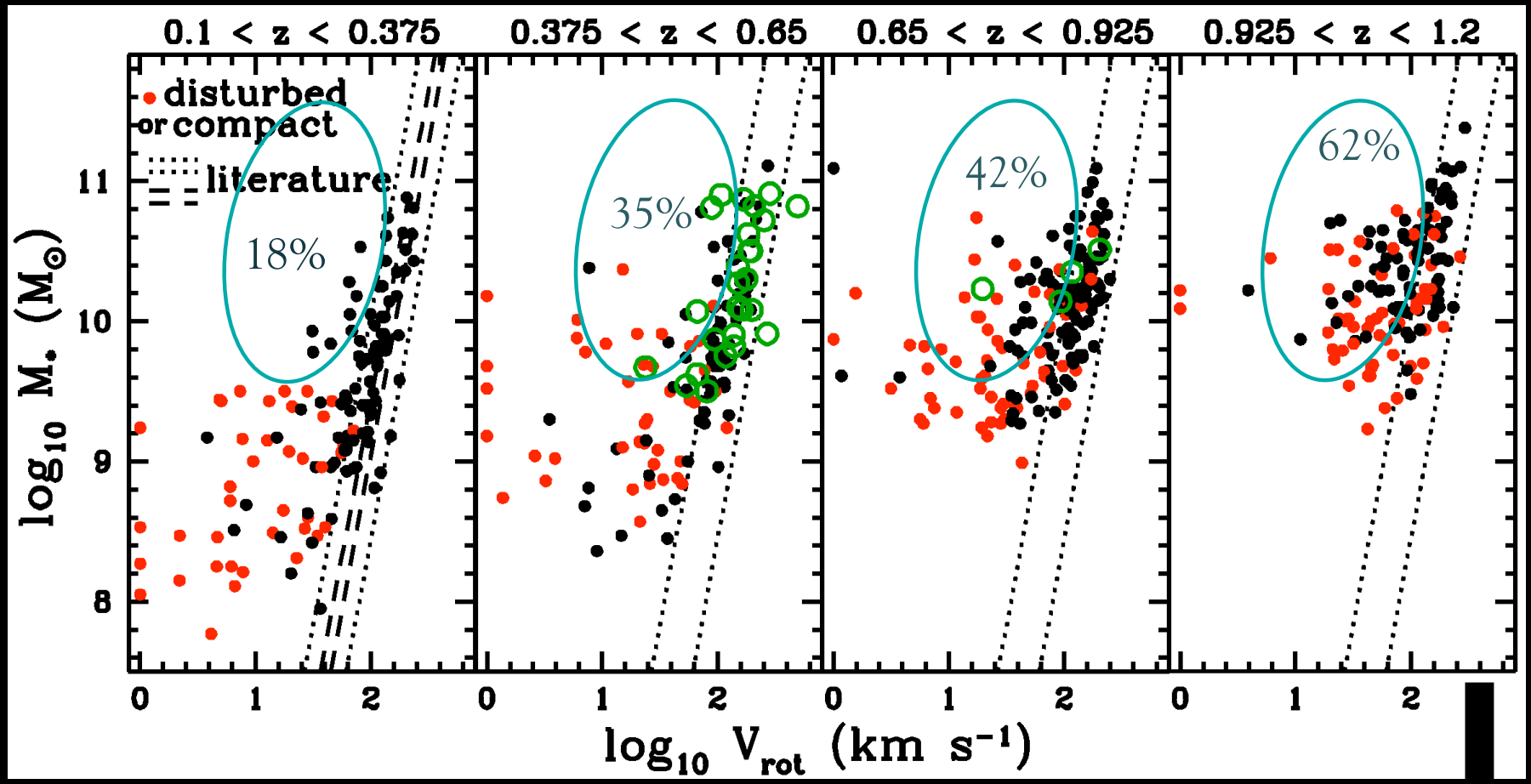
$S_{0.5}$ Kinematic Indicator



Indicator of total KE, in V and σ.

Kassin et al., 2007

Disk Settling?



Flores, Hammer et al. (2006); VLT/GIRAFFE IFU

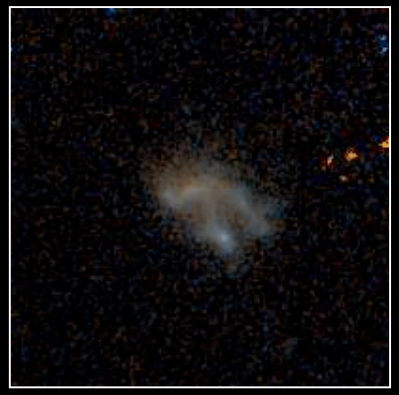
High Redshift Galaxy Kinematics

- Eventually have a large SWIFT sample ~50 galaxies
- Selected kinematically from DEEP2 and GOODS-N surveys.
- HST Imaging.
- Natural seeing/NGS/LGS targets.
- Currently working on 3 galaxies, data collected in May.
- More time in August to expand the sample, complementary SINFONI time.

High Redshift Galaxy Kinematics

Bulge+Disc
z=0.8
SWIFT Obs:
OII at 6755nm
OIII at 9125nm

Ring
z=1.16
SWIFT Obs:
OII at 8106nm



Eagle
z=0.8
SWIFT Obs:
OII at 6592nm
OIII at 8855nm

Future Work

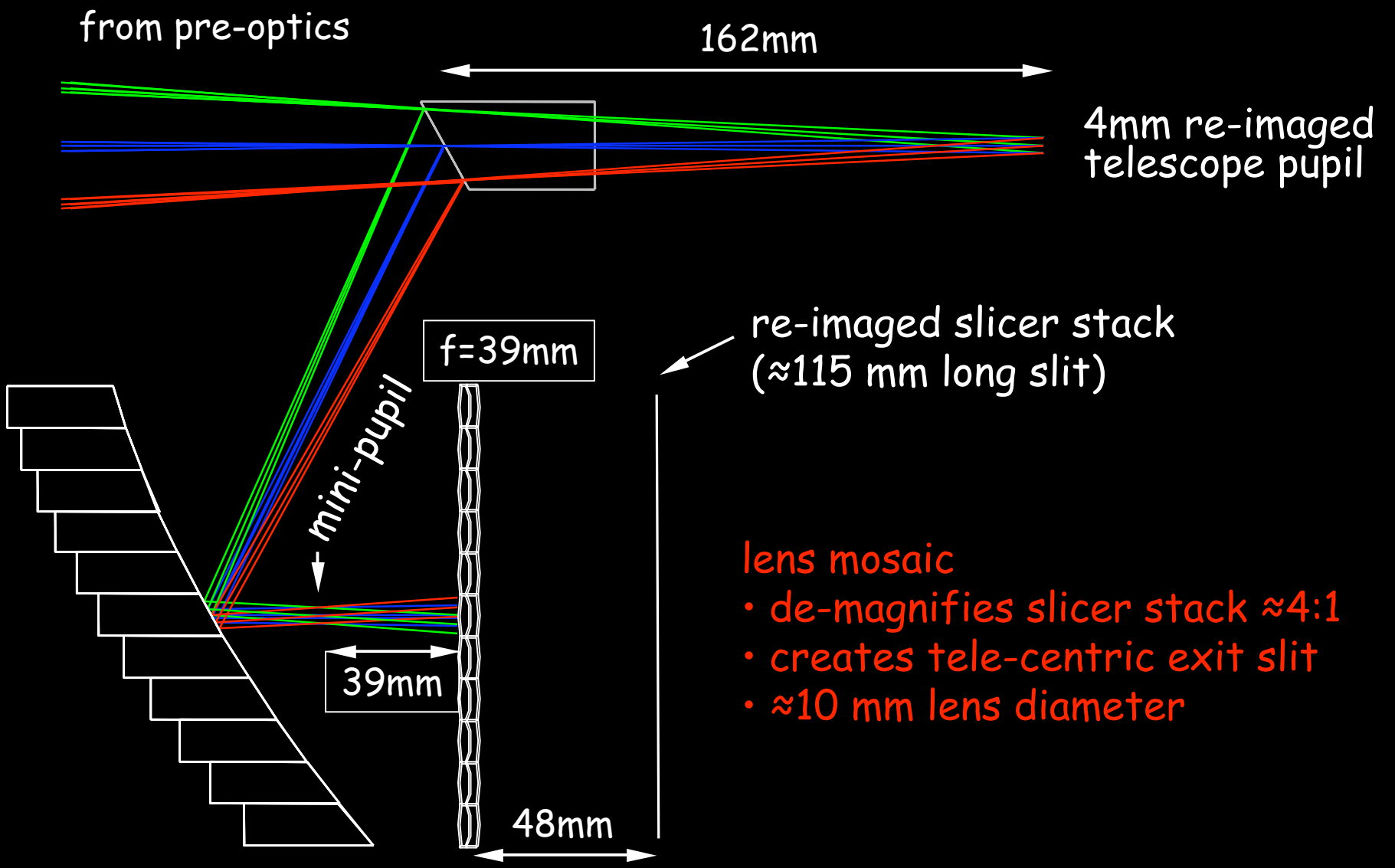
- Expand the current sample.
- Probe the spatially resolved V and σ for each of the galaxies.
- Establish the origin of the σ.
  - Disk settling?
- Study evolution of relation between photometric and kinematic morphology over z~0.8-1.4

Acknowledgements

- The SWIFT Team
- The PALAO and PALM3000 Team
  - Dr. A. Bouchez
  - Dr. J. Roberts

- Questions?

Image Slicer Demagnification



lens mosaic

- de-magnifies slicer stack ≈4:1
- creates tele-centric exit slit
- ≈10 mm lens diameter