Oxford Astrophysics

SWIFT - Iz-band Integral Field Spectroscopy for PALAO

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MARIE CURIE ACTIONS

Oxford Astrophysics SWIFT Short-Wavelength Integral Field Spectrograph

The Project

- Conceived as a niche instrument that complements near-IR integral field spectrographs (SINFONI, OSIRIS, NIFS)
- Builds on three new developments
  1. The availability of a second generation A.O. system that provides partial correction at wavelengths shortward of 1000 nm.
  2. Extremely red sensitive CCD detectors, available in large formats at a fraction of NIR detector cost.
  3. An all glass, classically polished, image slicer that provides high throughput even at visible wavelengths.

  ++ lower sky background than in the NIR

Vital Statistics

- R~4500 spectra from 650 to 1000+nm
- 89 x 44 spatial pixels (3916 spectra)
- High throughput (>45%) and QE (>80% at 950nm)
- 3 plate scales
  - 0.24″ FoV 21″x10″
  - 0.16″ FoV 14″x7″
  - 0.08″ FoV 7″x3.5″
- Operation with PALAO/PALM3k NGS/LGS

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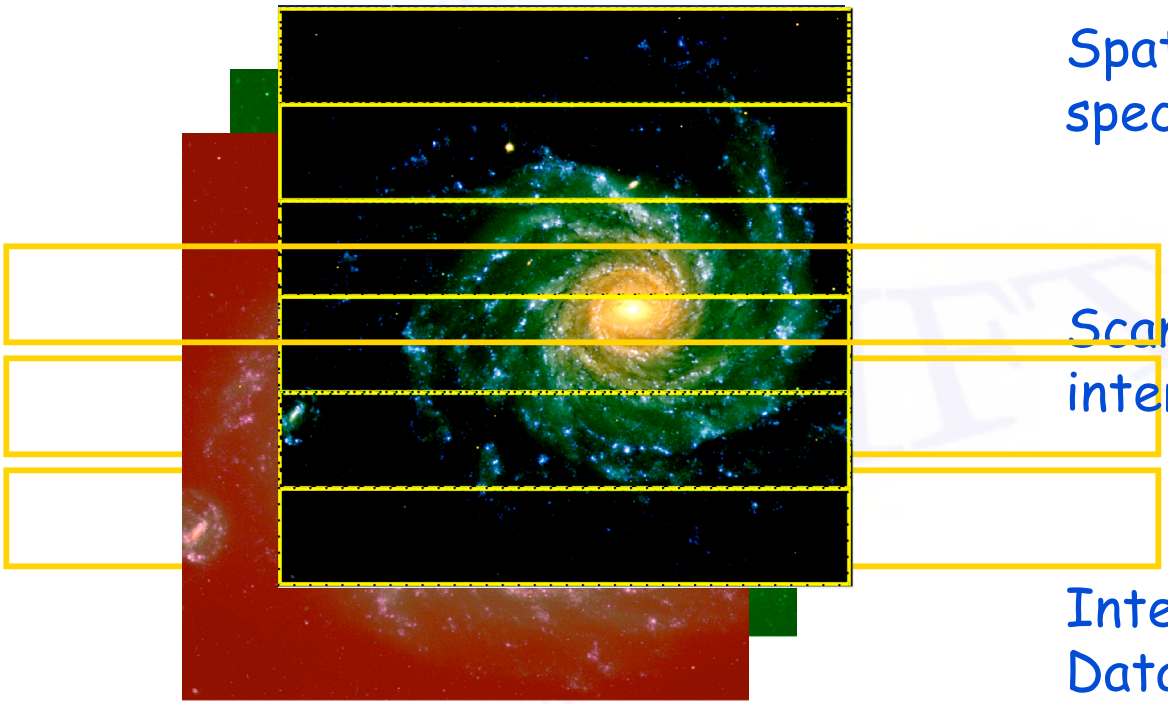
Integral Field Spectroscopy: Observing a data cube



Spatially stepping a long slit spectrometer

Scanning with a Fabry-Perot interferometer

Integral Field Spectroscopy: Data cube in a single exposure.

- Microlens array
- Fibre bundle
- Image Slicer

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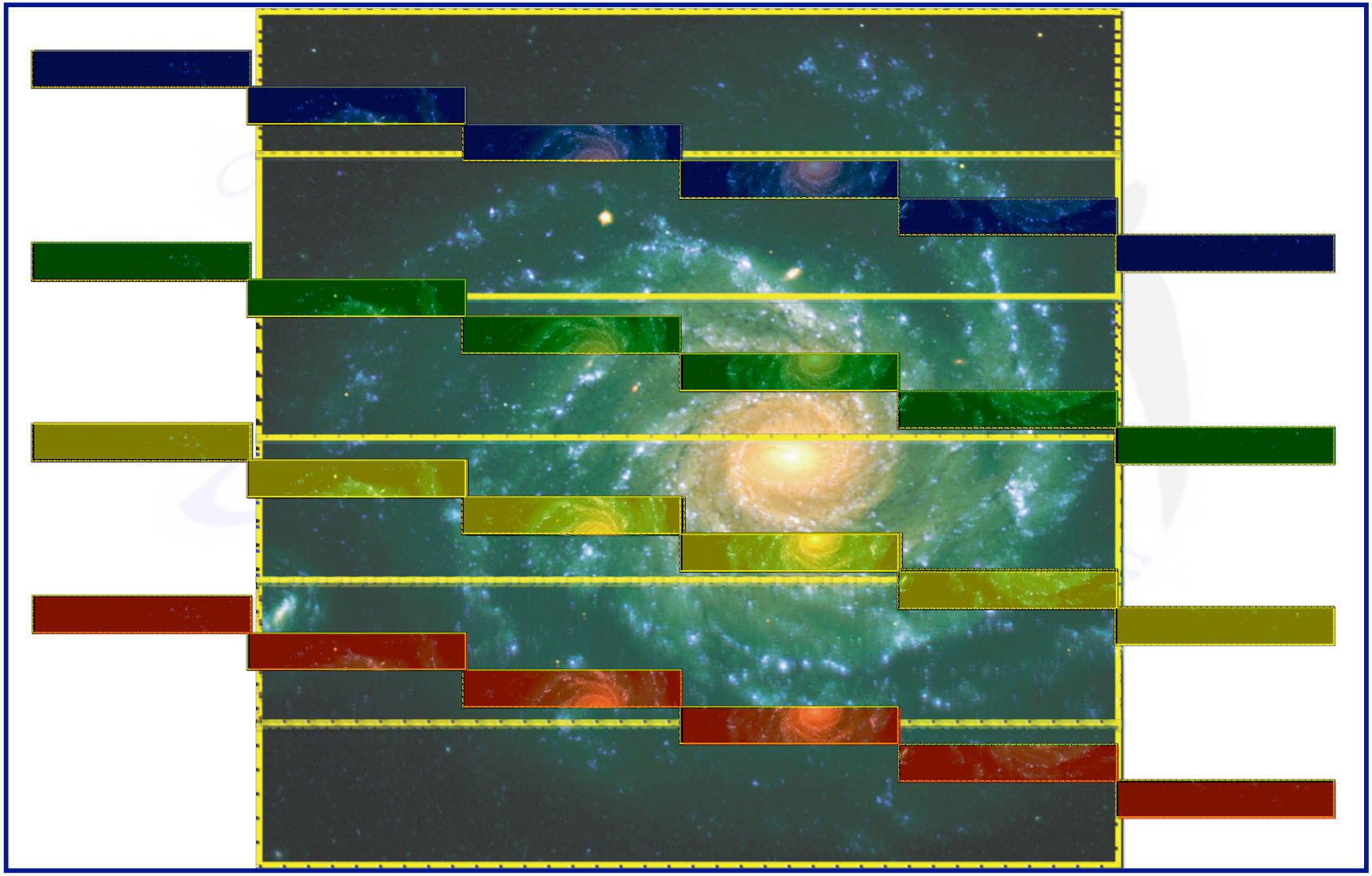
Slicing the Image



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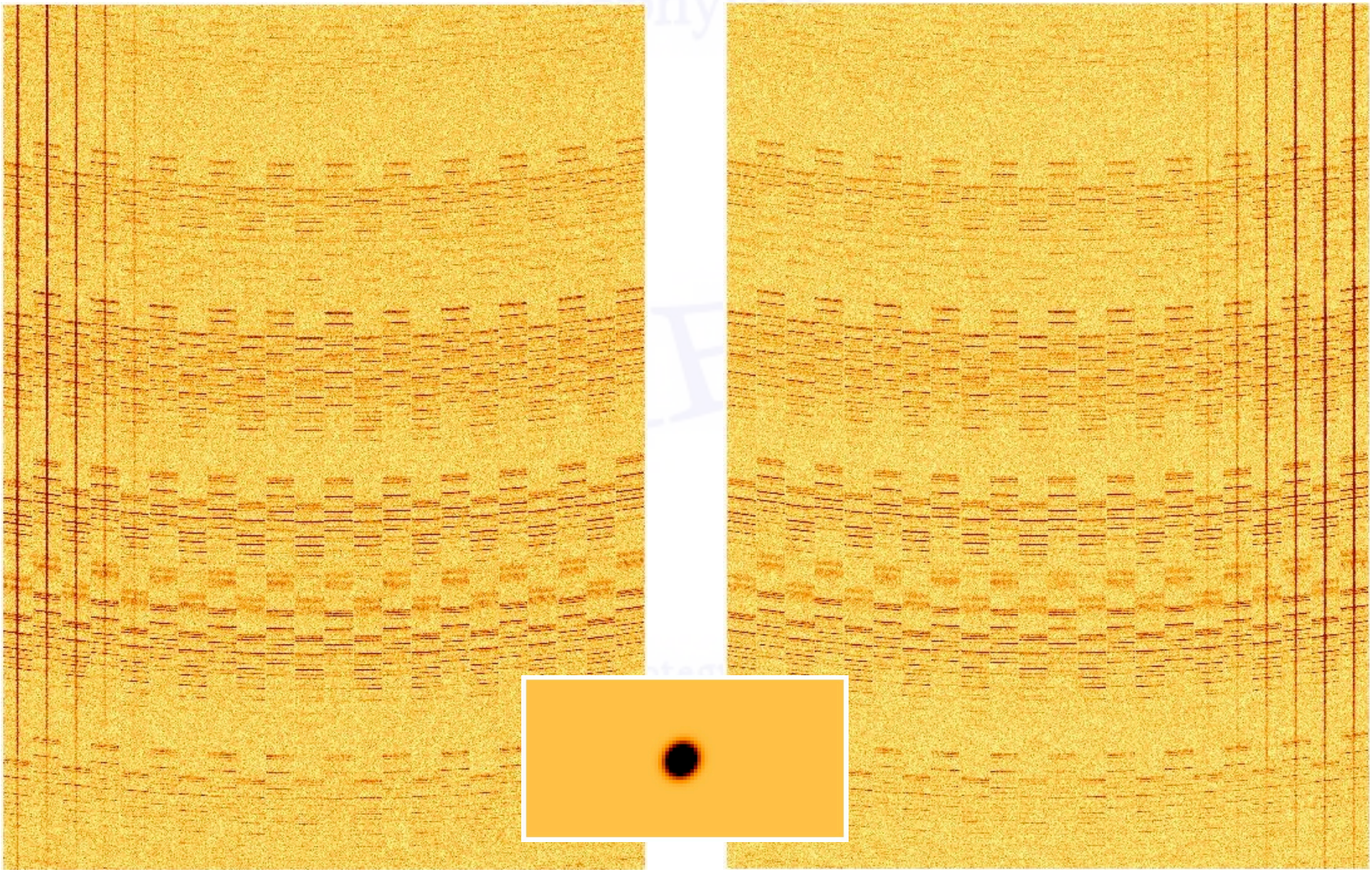
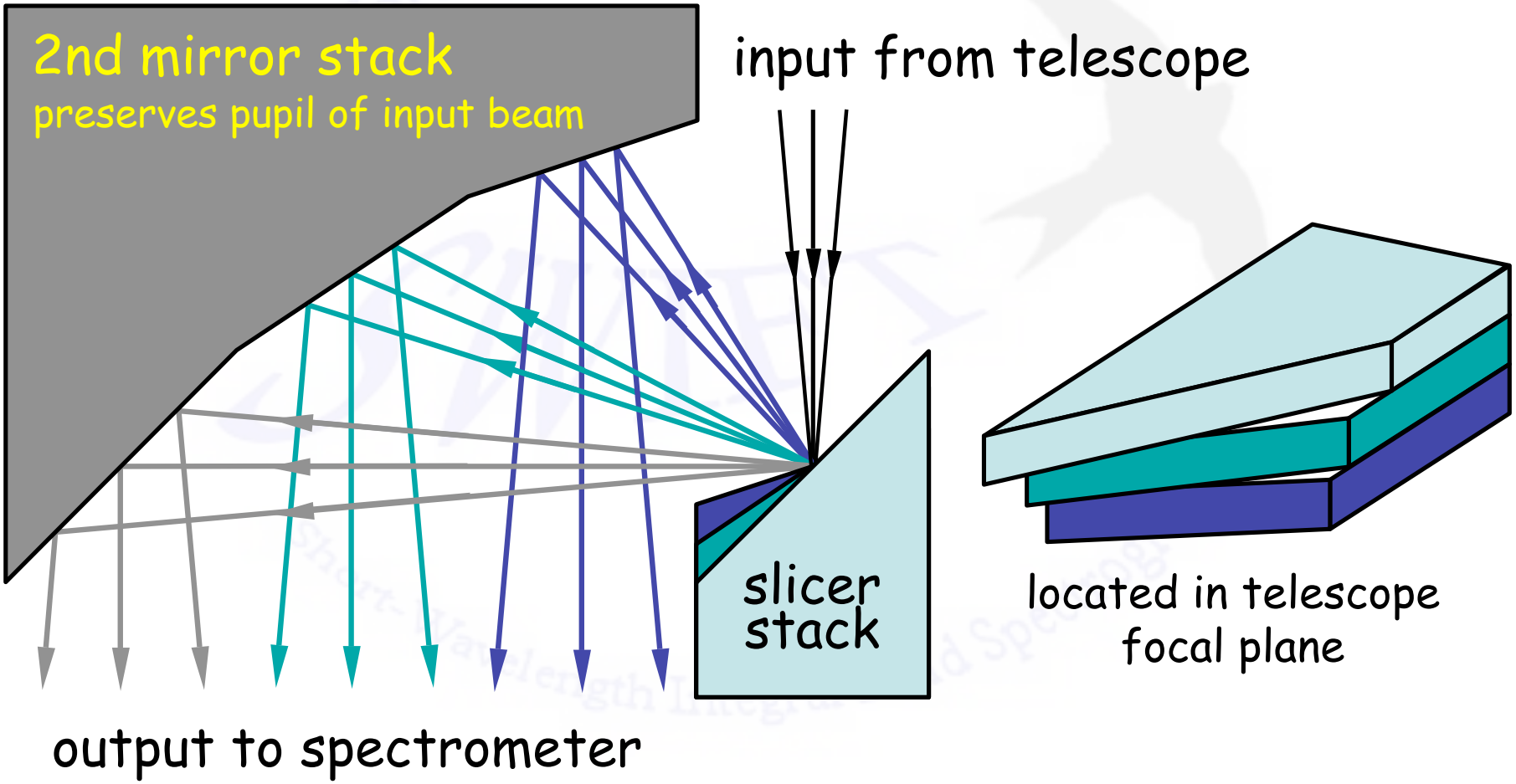
Raw SWIFT image of a star



Principle of the Image Slicer

(used in SPIFFI, GNIRS, NIFS)



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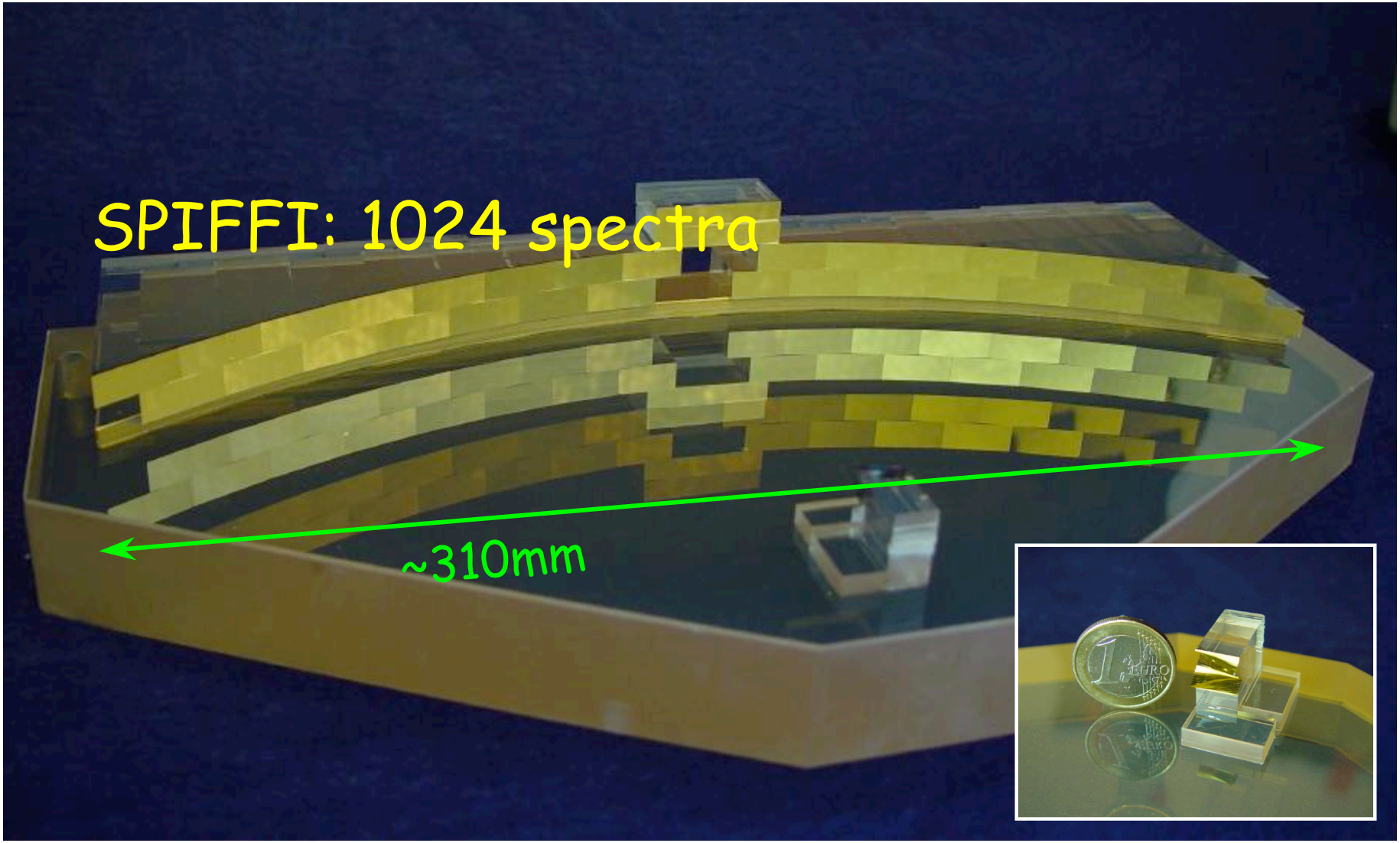
SPIFFI Image Slicer



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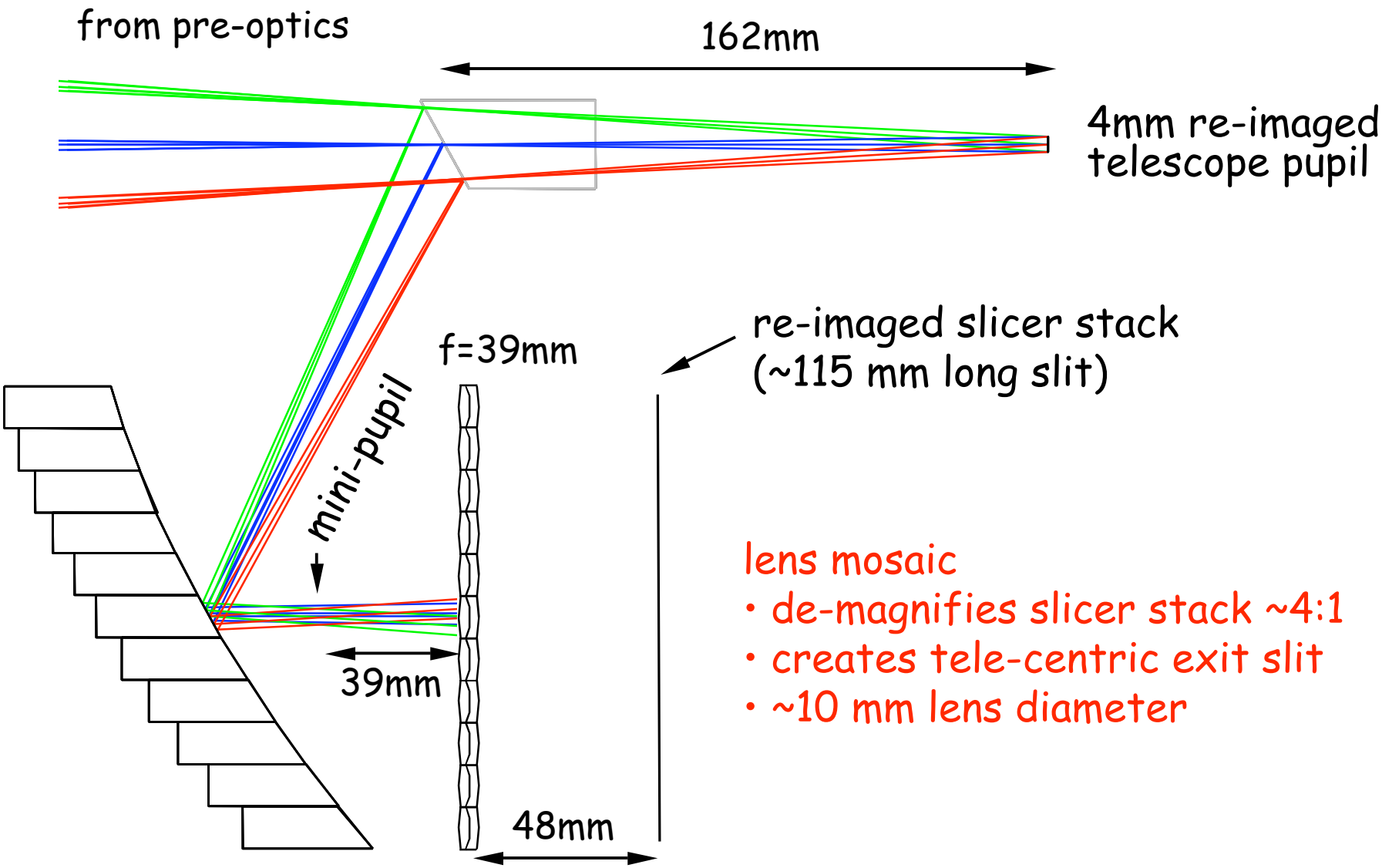
Demagnifying Image Slicer



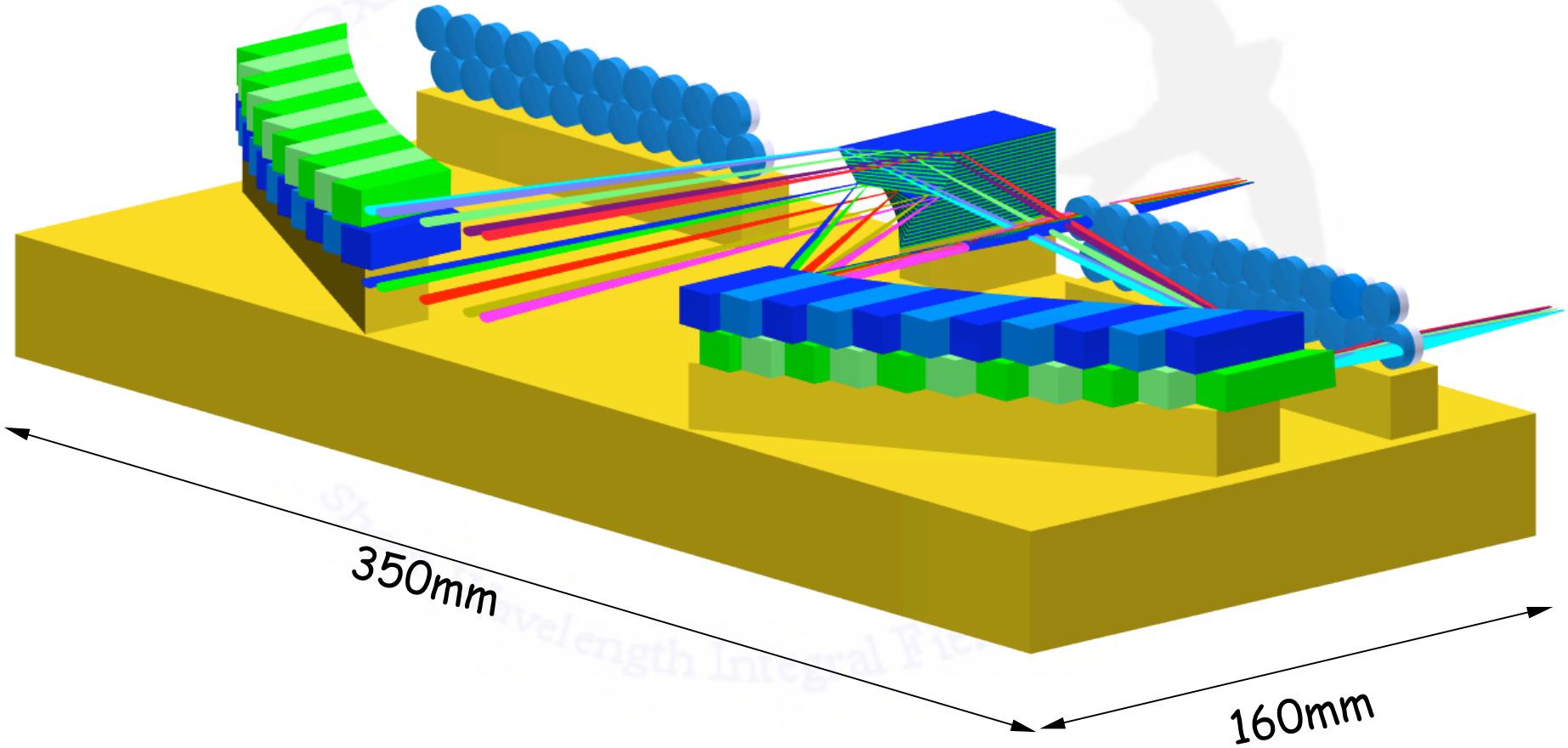
lens mosaic

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

The SWIFT image slicer

- Classically polished all-glass image slicer
  - Splits field into 44 “slitlets”, each 89 pixels long
  - Slitlets arranged into 2 symmetric psuedoslits feeding 2 spectrographs
  - Novel design using lenslet array to give 4:1 demagnification of slit length
  - Protected silver coating
  - 97% throughput

Perspective view of Slicer



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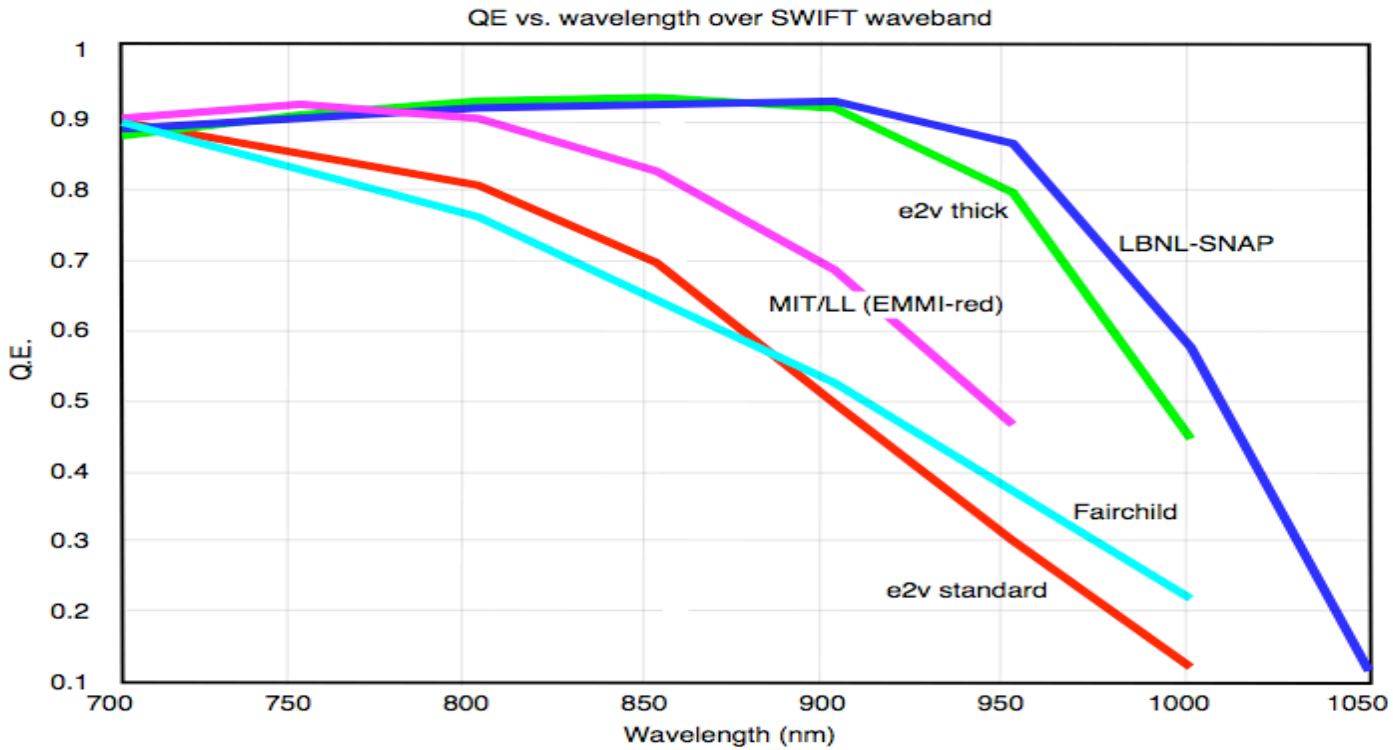
SWIFT spectrographs

- After the slicer, SWIFT is a standard spectrograph
  - Catadioptric collimator
  - VPH/prism sandwich providing high throughput and quasi-constant resolution with wavelength
  - F/2.8 five element camera
  - 4k x 2k 15um detector

Red-sensitive CCDs

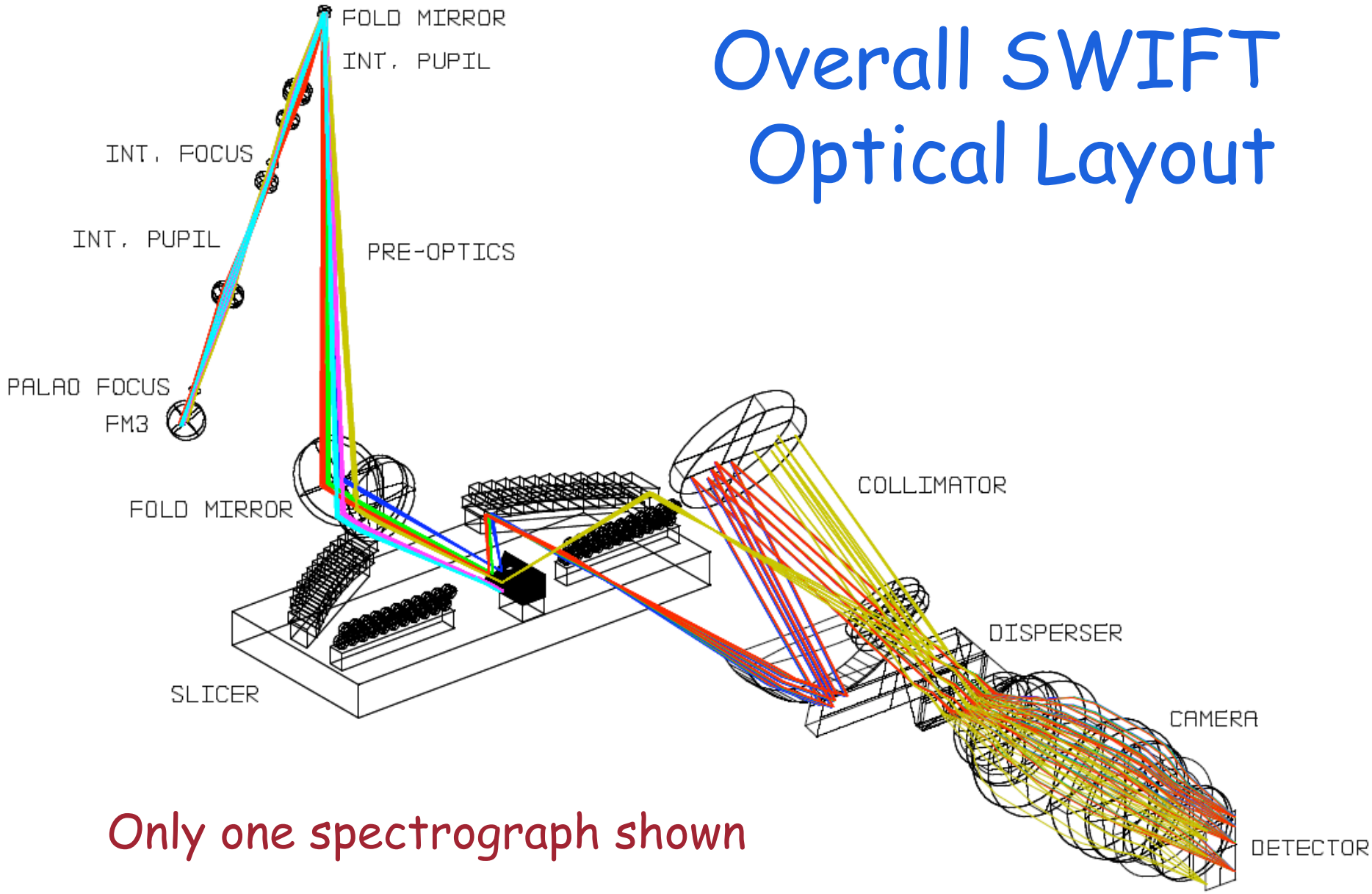


- » **E2V** & **Fairchild** available off-the-shelf
- » **MIT/LL** chip has excellent Q.E. and low measured fringing
- » **LBNL** develops SNAP chip with thick deep depletion technology
- » **E2V** is developing thick deep depletion chips with Q.E. predicted to be similar to SNAP detectors

SWIFT CCDs

- Caltech (Roger Smith) leading effort to procure LBNL CCDs for SWIFT
  - Devices currently in foundry run
  - Custom 4k x 2k mask design to allow nod-and-shuffle with SWIFT
  - Aiming for QE > 80% at 950nm

Overall SWIFT Optical Layout



Only one spectrograph shown

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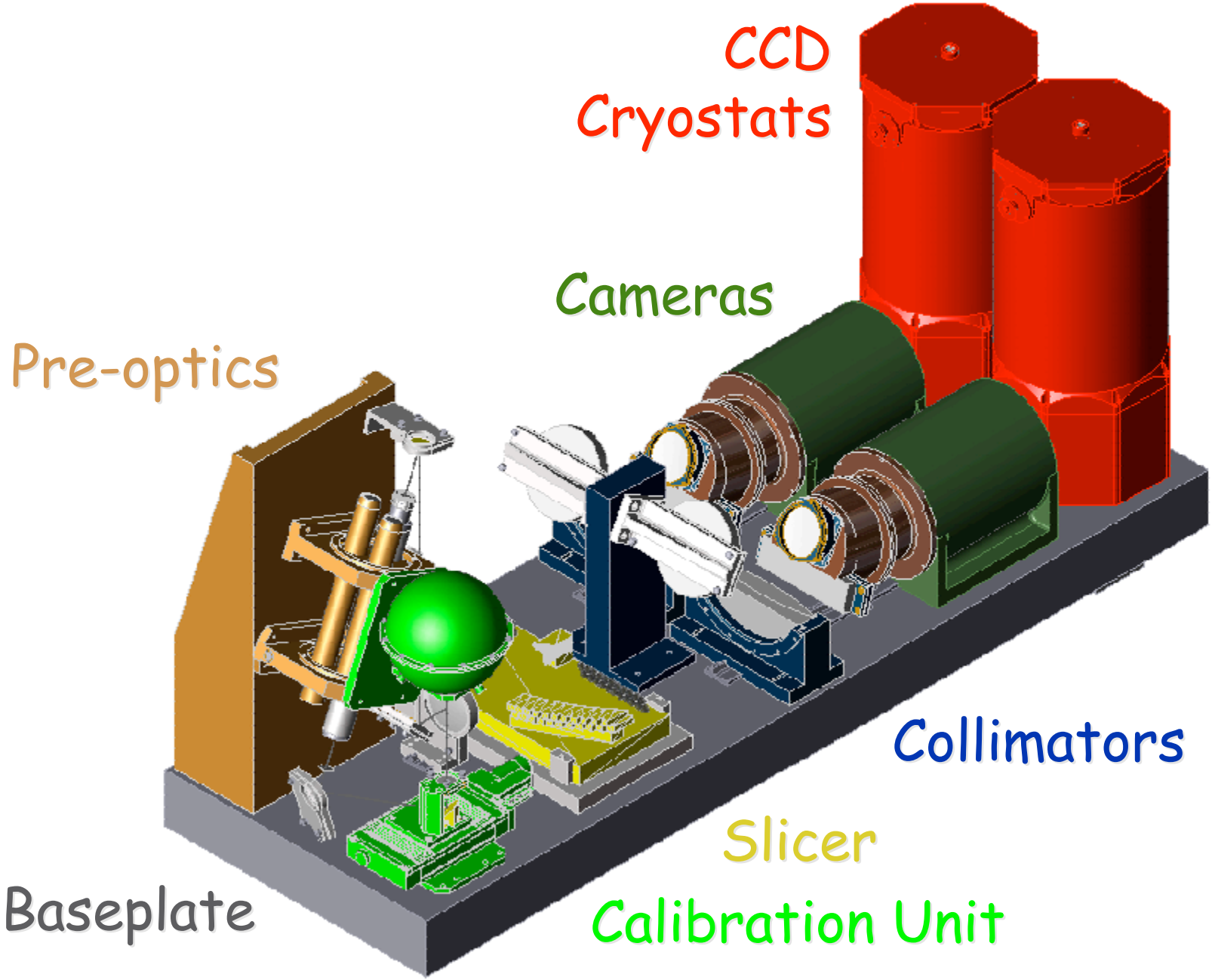
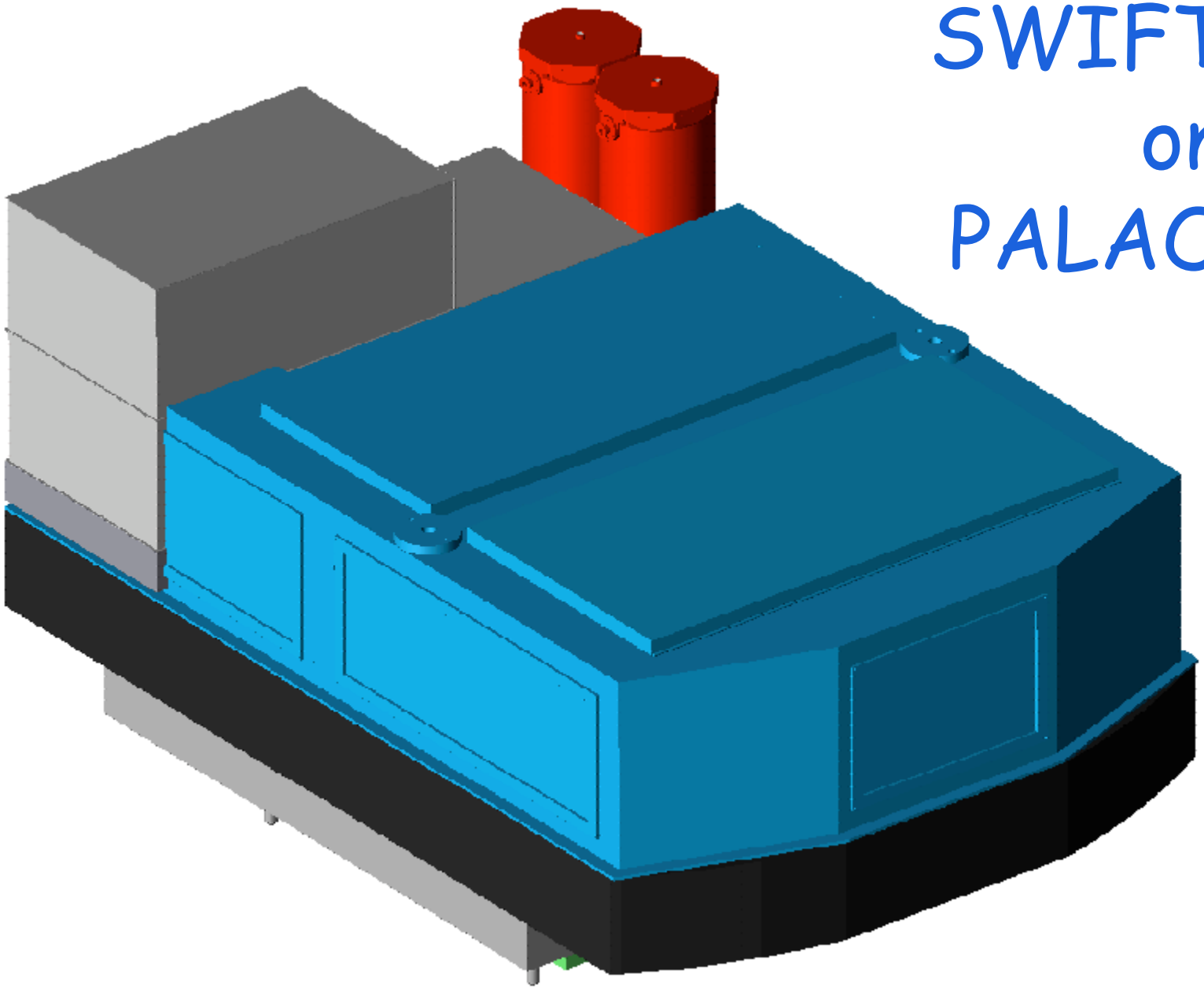
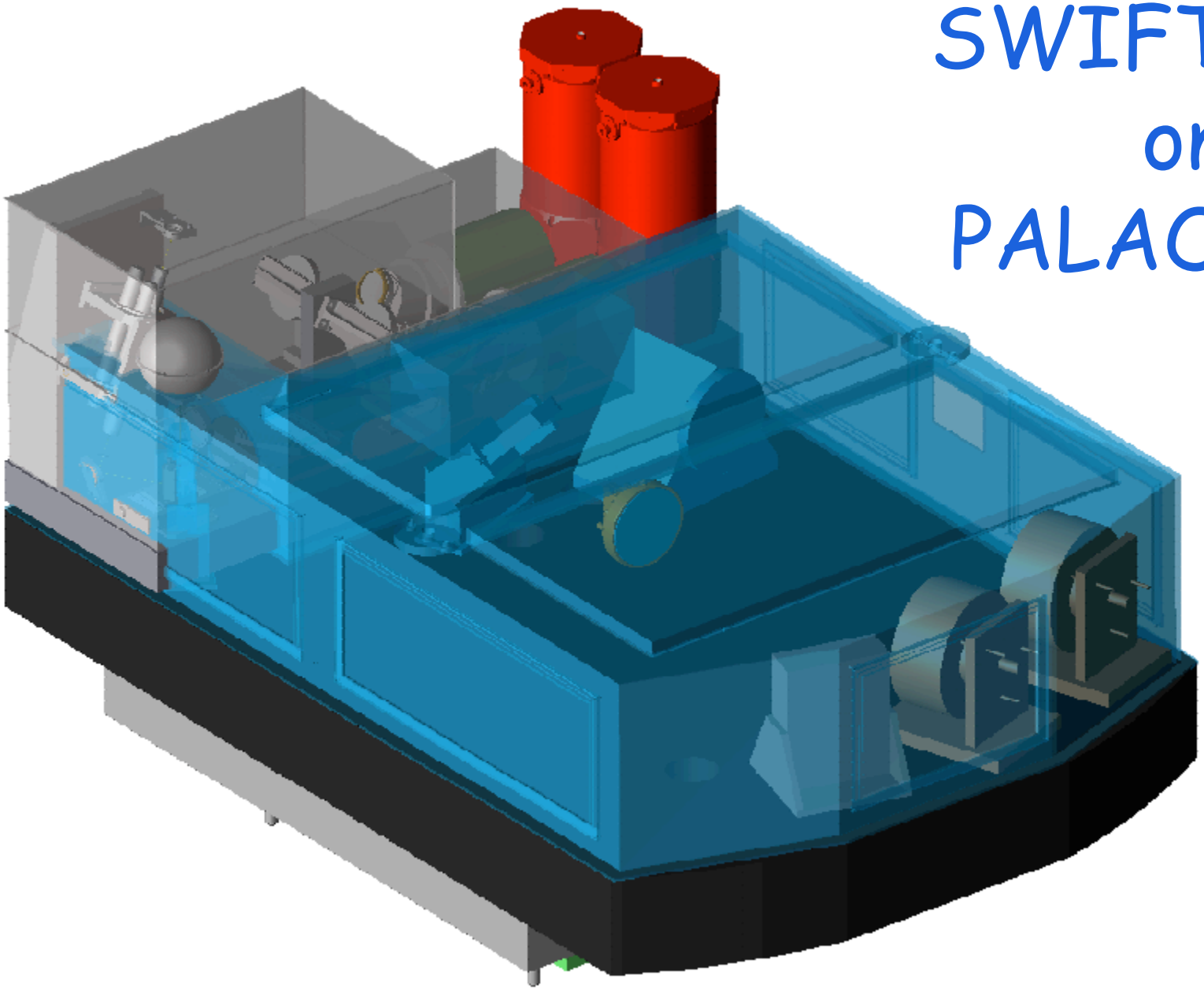

CCD
Cryostats
Cameras
Pre-optics
Collimators
Slicer
Calibration Unit
Baseplate

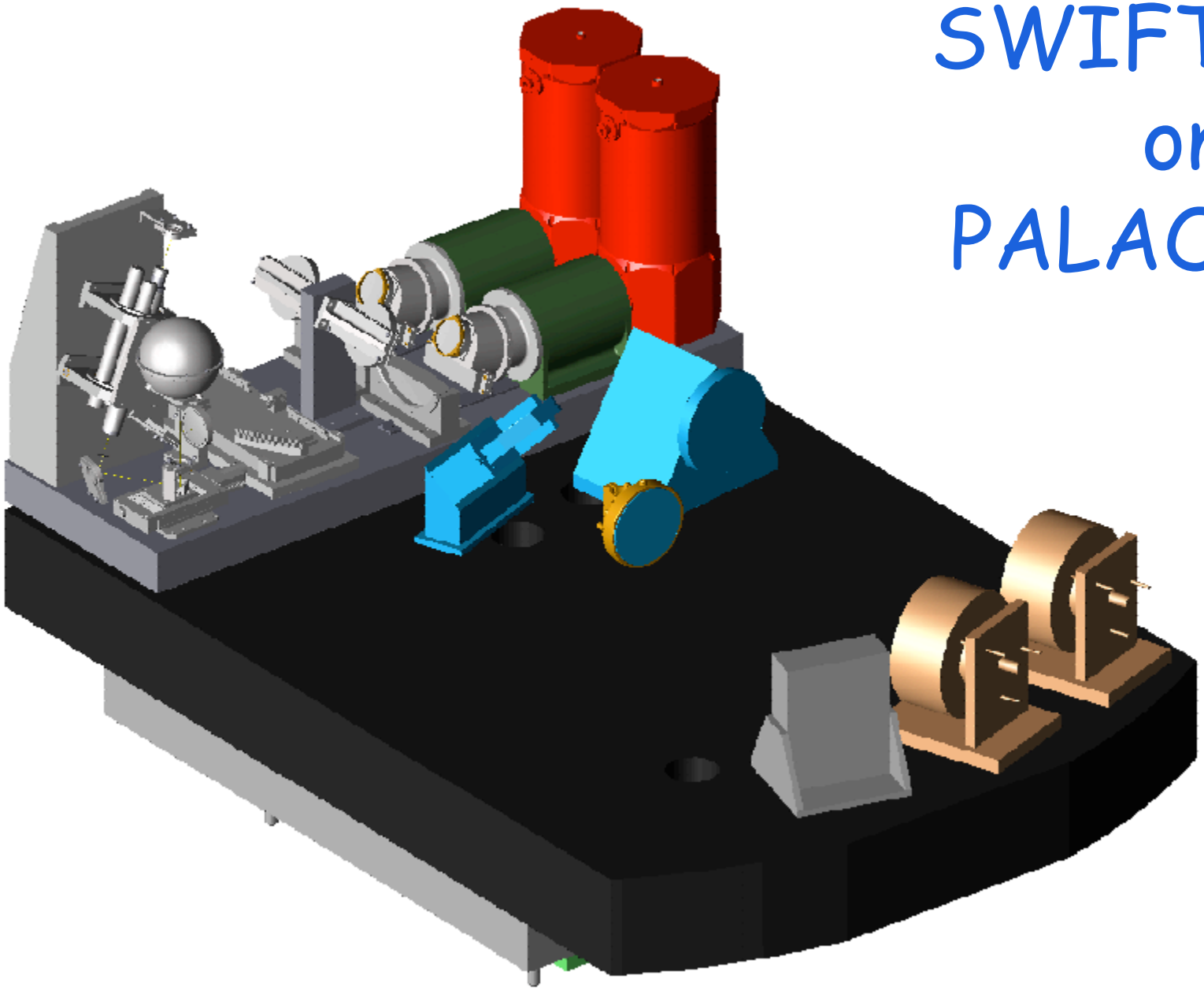
SWIFT on PALAO



SWIFT on PALAO



SWIFT on PALAO



Sensitivity

- Assumptions
  - AO delivering 50% EE in 0.5"
  - 0.24" pixel scale
  - S:N=5 in 3600s (3x1200s exposures) per spectral bin

Point source Summing four 0.24" spaxels	**I=21.0** @ 8000Å
Surface brightness per 0.24" spaxel	**1.3E-17** erg/s/cm^2/□" @ 9500Å

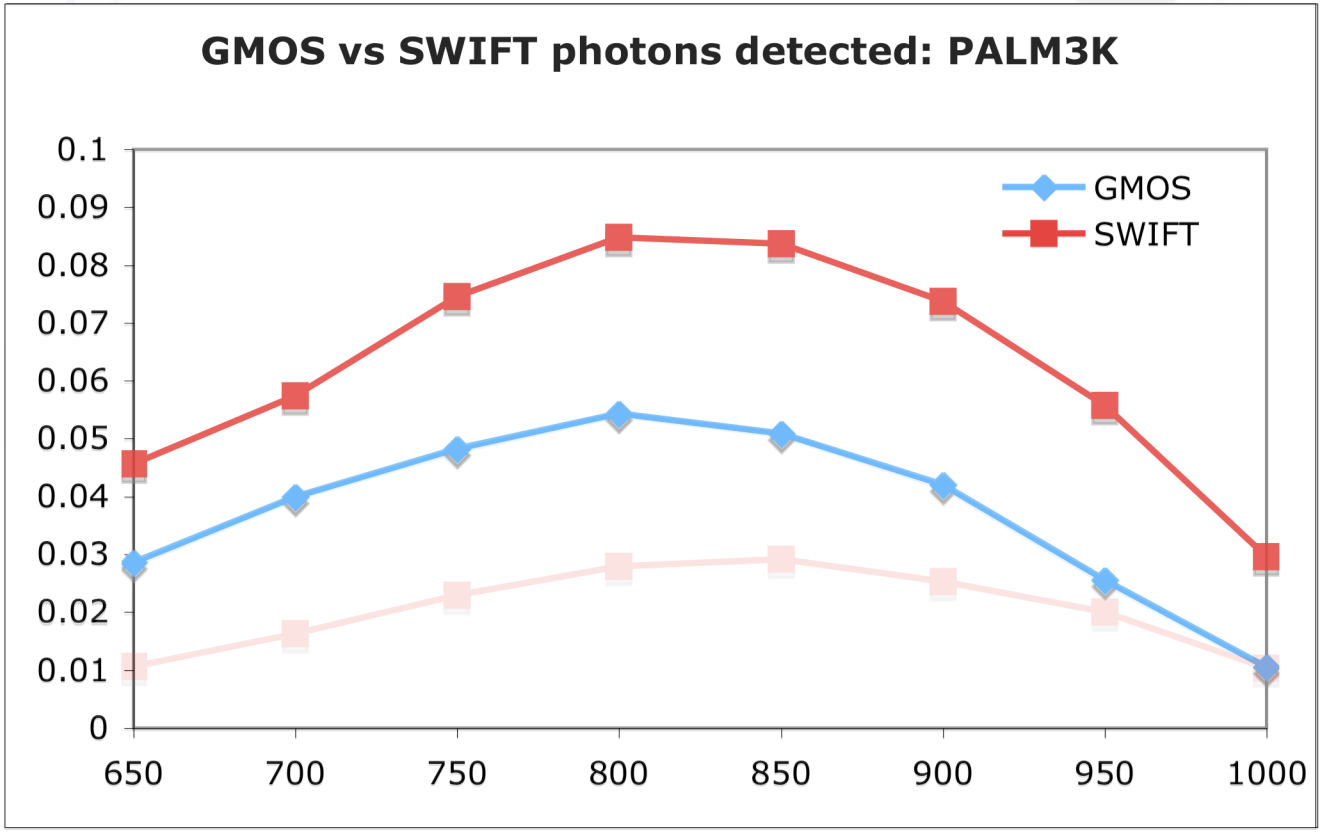
Example observation

- Lyman-alpha galaxy at z=6 (8500Å) (c.f. Stanway et al 2004, "GLARE" galaxies)
  - 1E-17 erg/s/cm^2
  - 15A width
  - 0.5" size (4 spaxels)
- Peak S:N=14 per pixel in 3600s (3x1200s)

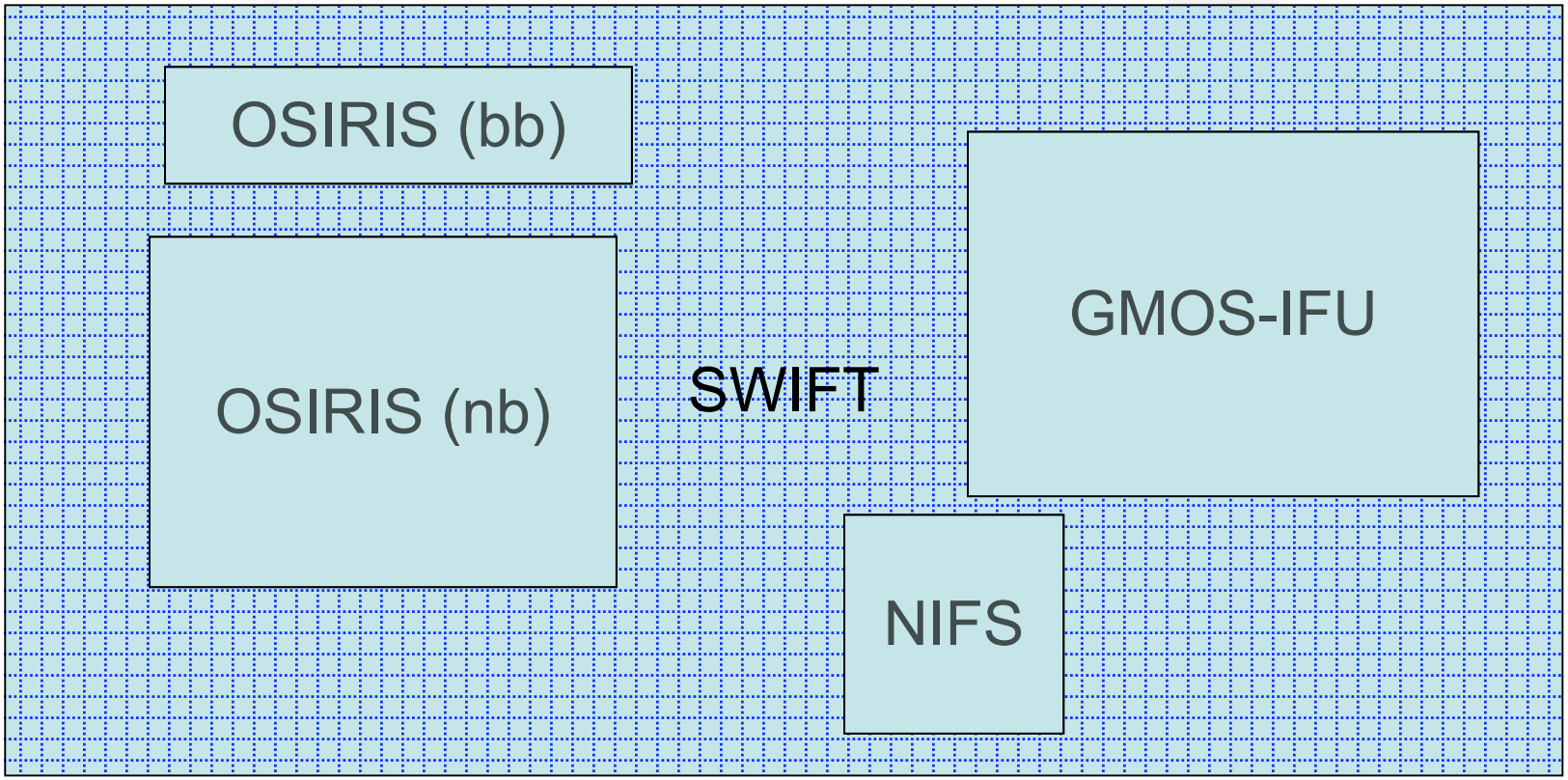
SWIFT vs 8--10m

- Can SWIFT on a 5m compete with instruments on 8--10m telescopes?
- Four advantages
  - High instrument throughput (>45%)
  - High red QE (should be one of the first instruments to have LBNL CCDs)
  - Large Field of View
  - PALAO and potential of PALM3K

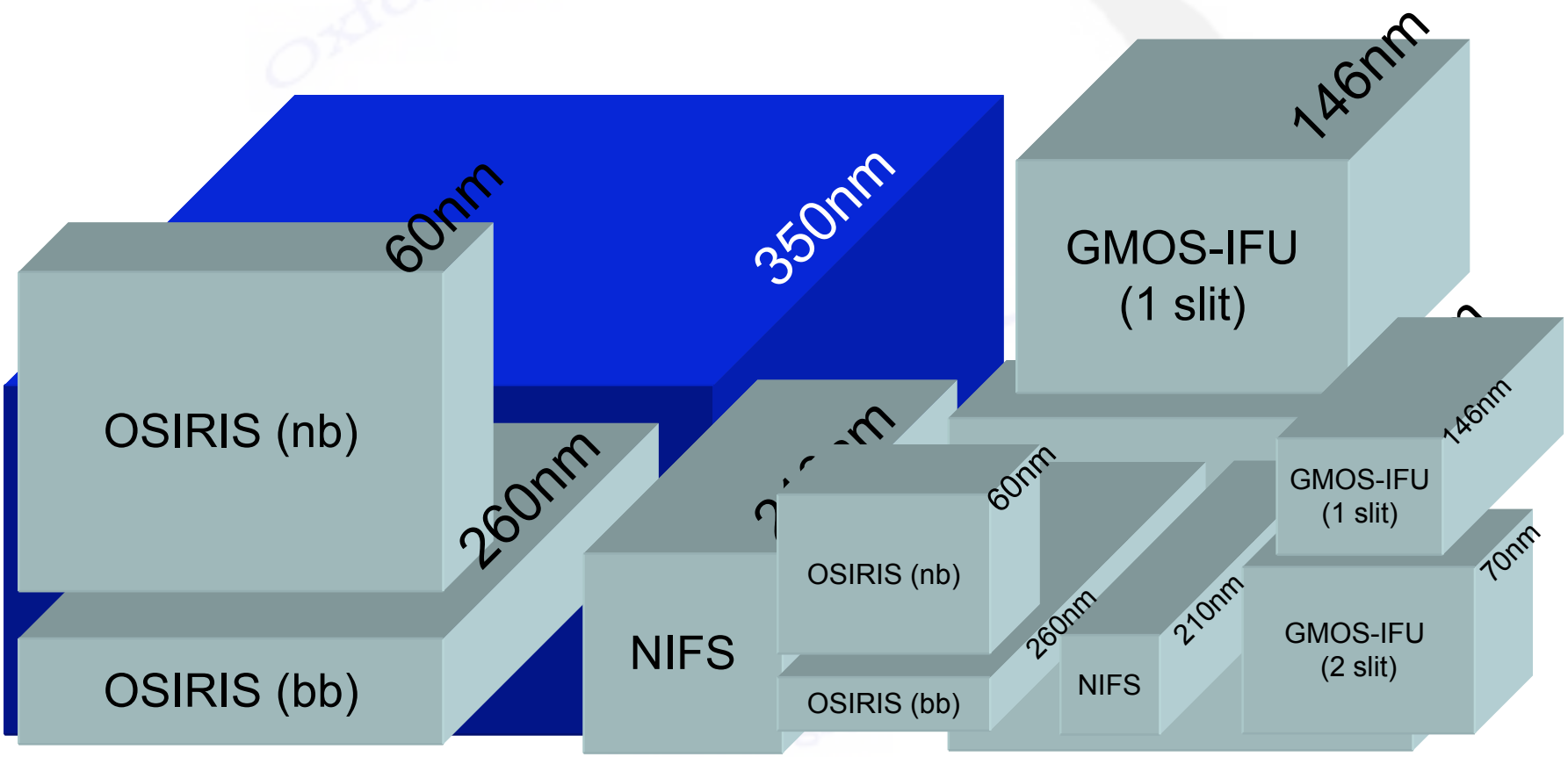
Photons detected



Field of View



Survey Volumes



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SWIFT vs 8--10m

- SWIFT on Palomar can be competitive with 8--10m facilities
  - Particular strength for programs requiring field of view and/or wavelength coverage
  - Unique capability for faint spectroscopy in the 900--1000nm region
  - Very complimentary to existing near-IR IFUs

Key Science Cases

- Morphology & Dynamics of Ly-α emitters at z=5--7
  - Several Ly-α sources known to be spatially extended
  - Kinematics distinguish between infall and superwind outflow in Ly-α halos.
- Dynamics and Tully-Fisher in the redshift desert
  - No a-priori knowledge of dynamic axis required
  - Accurate slit placement not required
- SMBH masses with Ca triplet
  - Stellar dynamics of inner most regions of nearby galaxies => mass estimates for nuclear super-massive black holes

Other Science Cases

- Probing QSO lines of sight and their environments out to the highest redshifts
- Using strong gravitational lensing to study detailed morphology and kinematics of a few special objects at high redshifts
- Characterise stellar populations out to z~1 (spatially resolved ages and metallicity) using well understood features (Mg b, Hβ, Fe), instead of bluer (less reliable) indicators
- Hα morphology and kinematics of jets in young star forming regions, HH objects
- SNe (SNAP followup, removal of galaxy light)
- Brown dwarf companions (TiO, VO bands, NaI)

Access

- Common user 650--1000nm IFS for PALAO/PALM3k
- Due to be commissioned at Palomar in Q1/2 2008, likely available for general use 2nd semester 2008
- Minimum five year lifetime at Palomar

Software

- Oxford will provide data reduction software;
  - Real-time display, used for acquisition
  - Data reduction software can be run in two modes;
    - Automatic "quick-look" pipeline
    - Offline interactive full science reduction
- Control software based on ArcVIEW (cf DBSP)

Technical Specifications

- I/z band integral field spectrograph, covering 650 – 1000 nm in 1 exposure
- ~4000 simultaneous spectra, arranged in a 44 x 89 spatial format
- 0.08", 0.16" and 0.24" pixel scales, with FoV of 3.5"×7.1", 7.0"×14.2" and 10.6"×21.4" respectively.
- R~4500 Nyquist sampled spectra
- Two 2048 × 4096 red-sensitive CCD detectors (15 μm pixels)
- A.O. assisted (PALAO → PALM3K)
- 50% throughput (avg.) excl. A.O. and detector, 45% including detector.
- Available on Palomar in Q3 2008