The Oxford SWIFT spectrograph: First commissioning and on-sky results

Niranjan Thatte[a], Fraser Clarke[a], Matthias Tecza[a], Timothy Goodsall[a], Lisa Fogarty[a], Ryan Houghton[a], Graeme Salter[a], Nicholas Scott[a], Roger L. Davies[a], Antonin Bouchez[b], Richard Dekany[b]

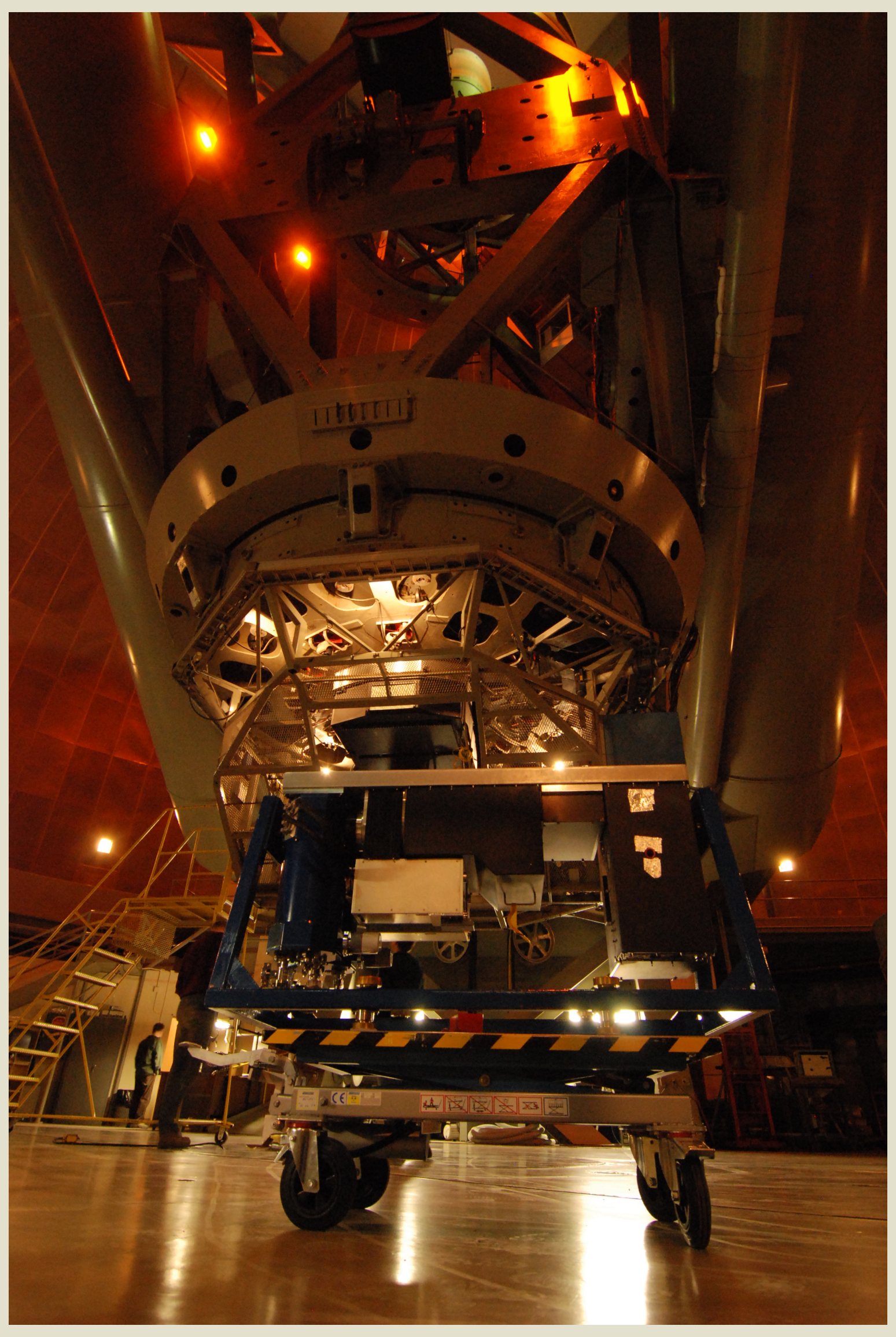
[a]Dept. of Astrophysics, University of Oxford, Keble Road, Oxford, OX1 3RH, U.K.;[b]California Institute of Technology Optical Observatories (COO), 1200 E. California Blvd., Pasadena, CA 91125, U.S.A.

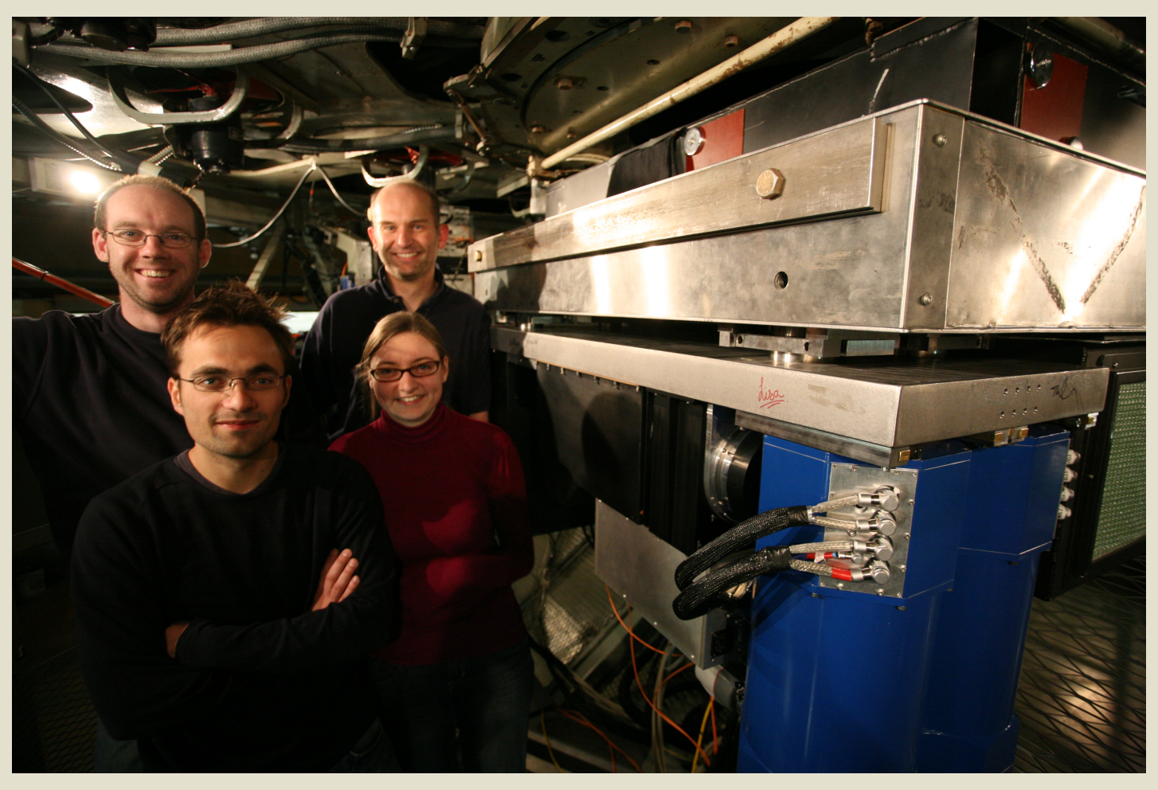
The SWIFT integral field spectrograph

SWIFT is an I & z band AO assisted integral field spectrograph. It provides ~4000 simultaneous spectra, arranged in 2:1 aspect ratio field of view (44 × 89 spaxels), so as to optimally allow "nodding-on-IFU", enabling almost perfect subtraction of the night sky background (although the sky emission at the SWIFT wavelengths (650 – 1050 nm) is substantially lower than in the near-infrared). SWIFT has a fixed spectral format, dispersion is achieved by high performance volume phase holographic gratings (VPHGs) in the twin spectrographs, each using a thick (250 μm), fully-depleted, 4k × 2k LBNL CCD detector, with unprecedented red sensitivity and extremely low fringing, especially valuable longward of 900 nm. SWIFT observations can use one of three spaxel (spatial pixel) scales, selectable "on-the-fly". These spaxel scales are 0.235", 0.16" and 0.08", corresponding to fields of view of 10.3" × 20.9", 7" × 14.2", and 3.5" × 7.1" respectively. The spectral resolution is ≈4000 across the spectral range, covering the entire wavelength range in a single exposure.

SWIFT has four unique features: (1) *very high throughput* (23% from photons above the atmosphere to detected electrons, including telescope and AO), combined with an IFS format allowing point-and-shoot of faint targets, whilst yielding 2D morphological, kinematic and dynamical information on extended objects (2) *very high red sensitivity and very low fringing* almost out to the silicon band edge, thanks to thick, fully depleted LBNL CCDs, (3) *an LGS AO system that can dramatically improve sensitivity* by concentrating the light within each spaxel (≥2 compared to seeing), while providing almost complete sky coverage, (4) *low sky background* compared to other instruments working at near-infrared wavelengths.

Commissioning


A view of the SWIFT spectrograph on its handling cart, just prior to mounting it at the 200inch Cass focus.

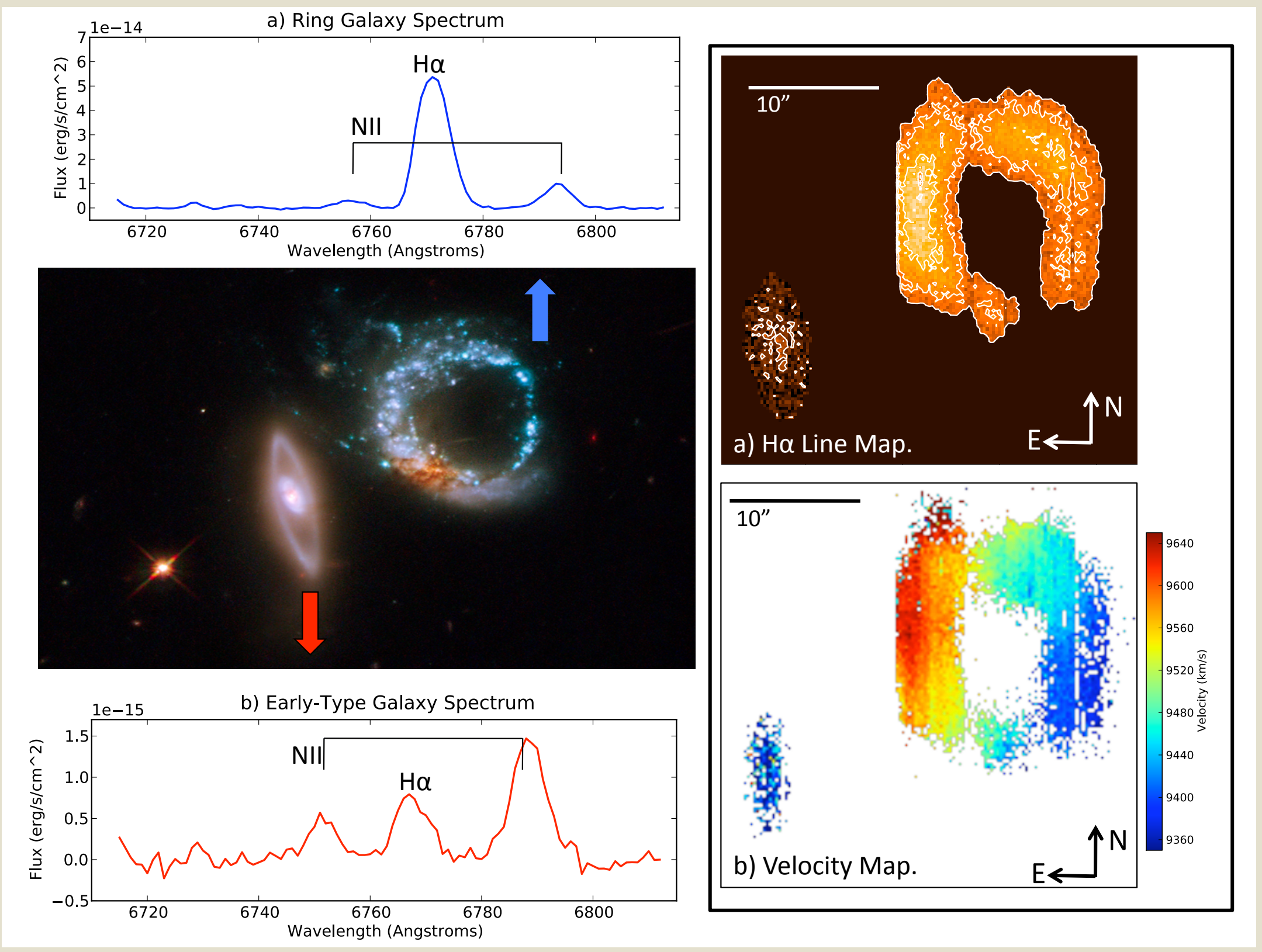

Some SWIFT team members next to the instrument mounted to the AO bench The blue cryostats house the LBNL CCD detectors.


The Palomar sodium LGS in operation. SWIFT was commissioned in both NGS and LGS AO modes.

SWIFT First Science Results

The interacting galaxy pair Arp 147

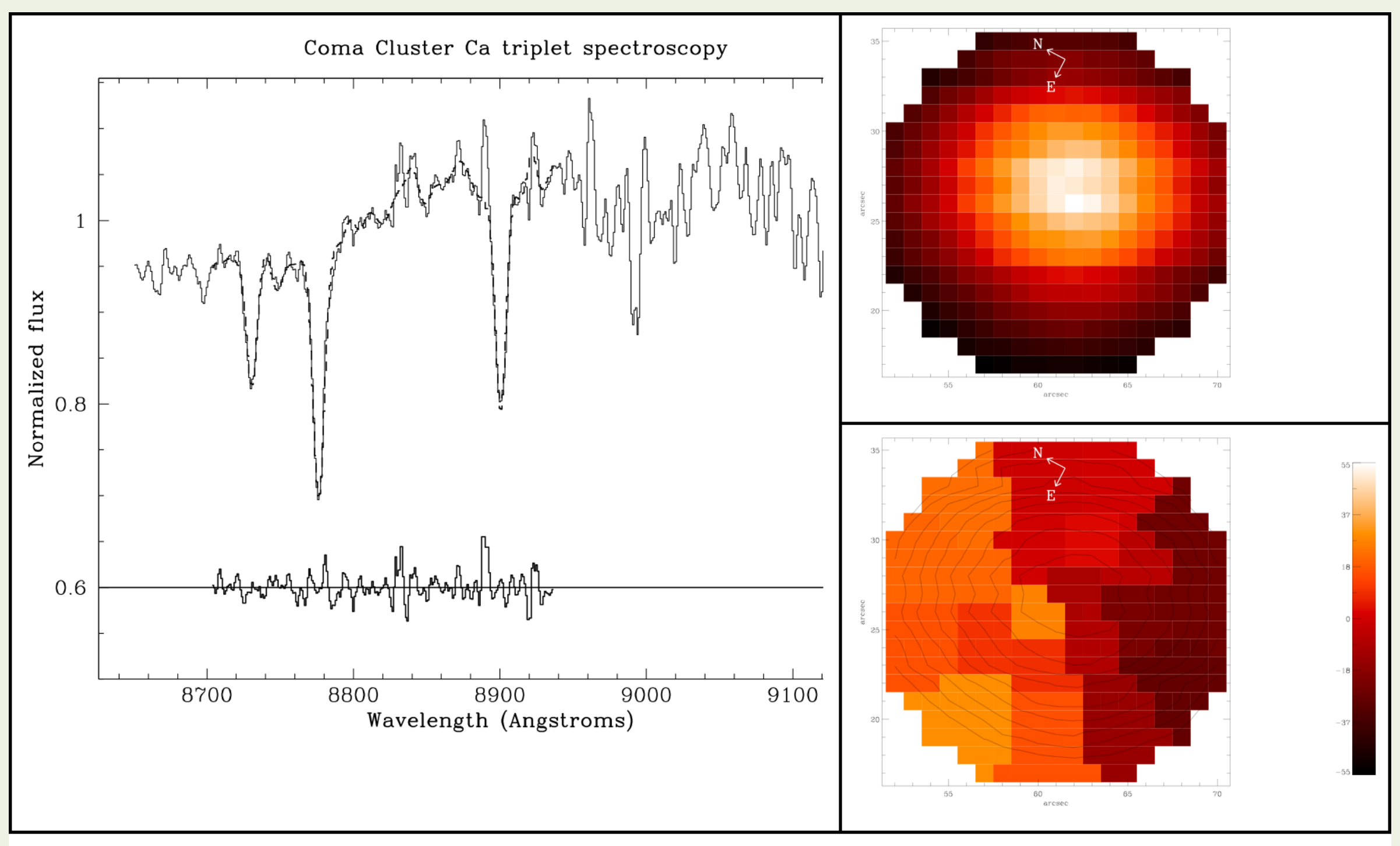
Arp 147 is a spectacular interacting galaxy system comprising of a collisionally-created ring galaxy and an early type companion galaxy, that was recently imaged by HST. It was observed as part of a bad weather backup SWIFT program to study the kinematics of interacting galaxies. The coarsest scale was used, as seeing was ~2.5″, and no AO correction was possible. Three different pointings were mosaicked together to form the data cube, from which line maps in the emission lines of Hα, [NII], [SII] and [SIII], as well as line free continuum images were extracted. Sky subtraction was performed using exposures of blank sky interleaved with the object exposures.



The kinematics observed with SWIFT show a clear signature for an expanding ring, and the expansion can be disentangled from the rotation using the spatially resolved kinematic data. The equivalent width of the Hα line conclusively indicates that a young starburst is occurring in the ring, consistent with the HST colours. It is probably triggered by the collision. Other line ratios (Hα/[NII], [SII], and [SII]/[SIII]) allow us to deduce that the eastern half of the ring is more metal rich than the western half, and that the redder region in the south-east corner of the ring is likely to be the nuclear bulge of the disk galaxy that formed the ring.

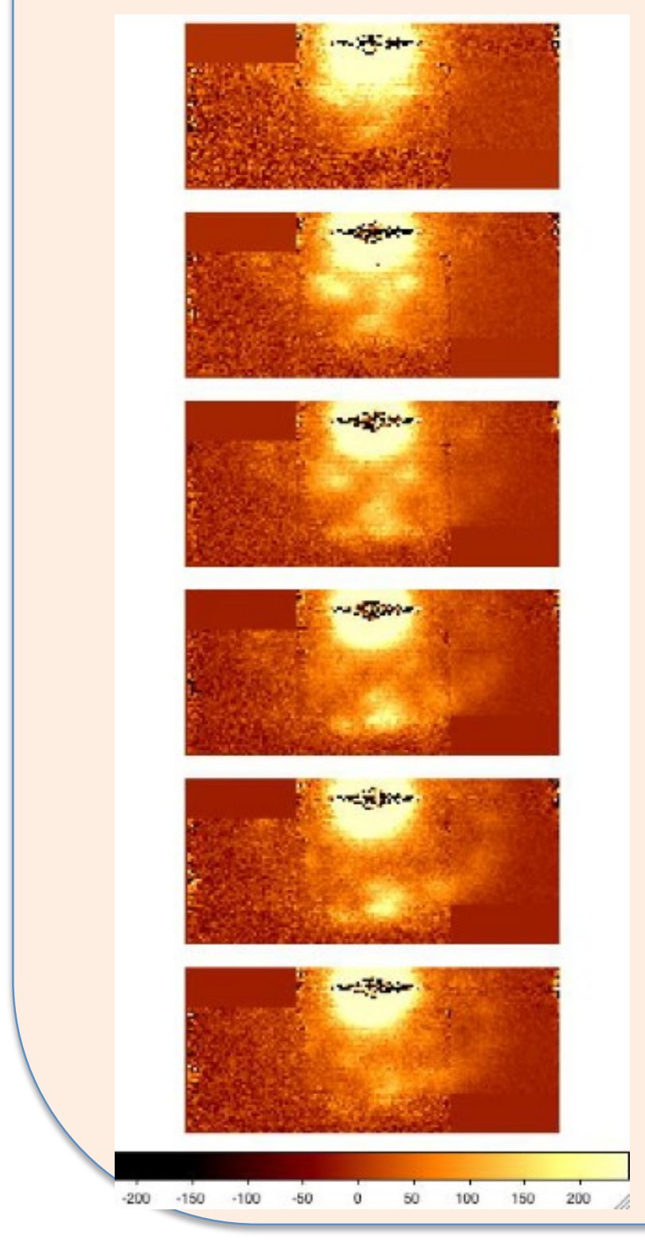
The fundamental plane of the Coma cluster

The program aims to measure the kinematics of early type galaxies in several well-defined luminosity bins spanning the entire luminosity range of early type galaxies in the dense Coma cluster. The SAURON survey indicated that the specific angular momentum of early type galaxies (ETGs) provides a physical classification that relates much more closely to the assembly history of galaxies than the traditional morphological classification of E and S0. By measuring the specific angular momentum of the early type galaxies in a well studied rich cluster we aim to establish their merger history. Coma is the richest nearby cluster and is the local comparator for studies of the evolution of galaxies in clusters.



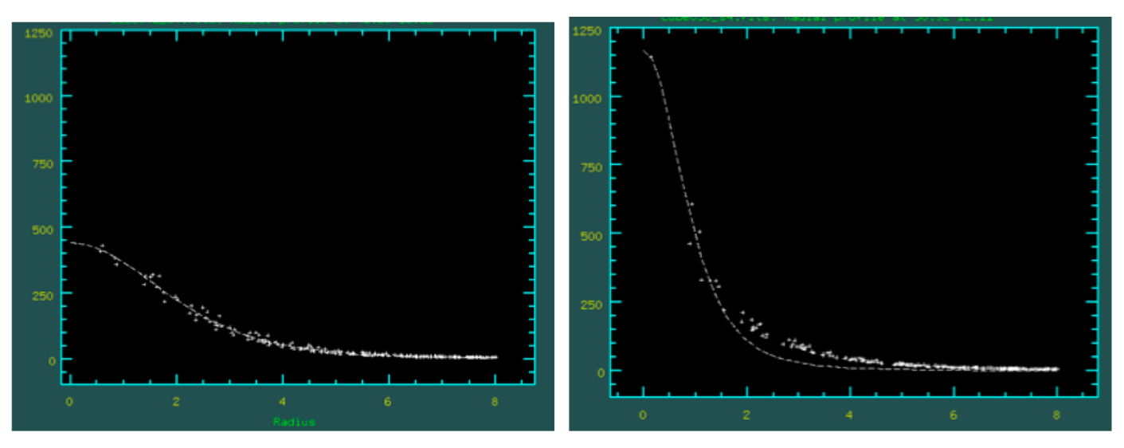
Coma has extensive HST imaging from which we can derive accurate effective radii and surface brightness. Combining these with SWIFT kinematic measurements (σ_e – the velocity dispersion within the effective radius), we can place these galaxies on the Fundamental plane, and derive a dynamical mass-to-light ratio for comparison with that determined from the stellar populations.

Observing P Cygni

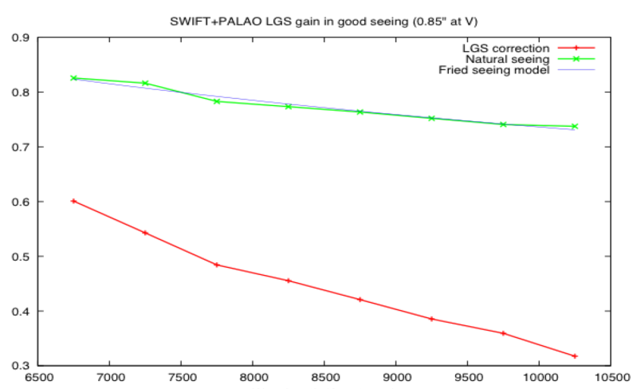


P Cygnus is a luminous blue variable synonymous with circumstellar material - it gives its name to characteristic 'P Cygni' line profile caused by the shell of material ejected from the star.
P Cygni is surrounded by a several shells of material from previous ejections of material. The set of images show the velocity structure of the NII line in P Cygni's inner nebula from 7374A (top) to 7379A (bottom).
Several structures and clumps at different LOS velocities can be seen, and presumably correspond to the front and back of the expanding shell of material.

Performance with LGS

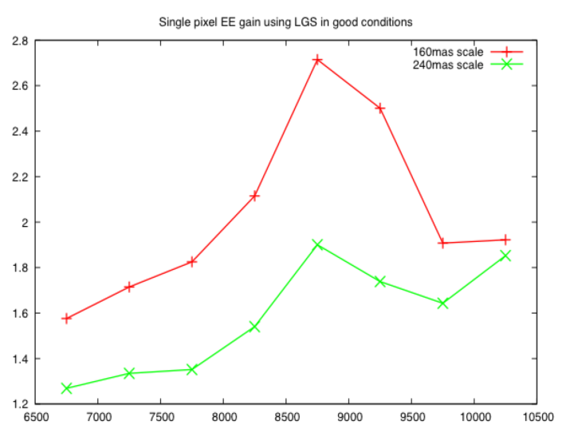


Comparison of LGS off (left) and LGS on (right) radial profiles at 850nm. The sharp core in the LGS image is obvious. Both profiles are plotted on the same scale. 1 spaxel is 0.16″ on the sky.



FWHM as a function of wavelength for natural seeing (green upper line) and LGS AO correction (red lower line).

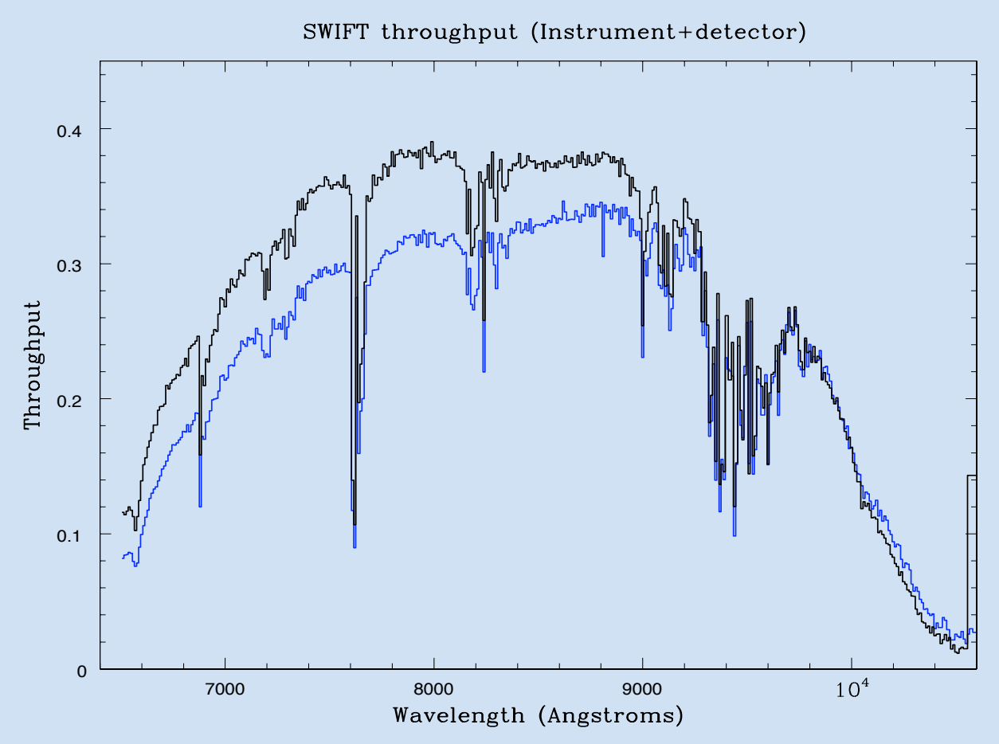
The natural seeing behaviour is a good match to a Fried seeing model (FWHM ∝ $\lambda^{-1/5}$; blue line).



In the 160mas scale, we gain a factor of 2 in ensquared energy over a seeing limited PSF over much of SWIFT's wavelength range

single pixel (1×1) ensquared energy gain with LGS compared to natural (0.85") seeing.

Instrument throughput



Note that the sensitivity stays high at very long wavelengths, up to 10000 Å. Beyond 9000Å, SWIFT is at least twice (and probably thrice) as sensitive as a typical observatory spectrograph with a standard CCD detector array

The plot shows the measured throughput of the instrument, including the detector. The assumed throughputs for the telescope and the AO system are 0.75 and 0.8 respectively, with the latter including a 0.9 dichroic transmission. The black curve is for the master chip (science grade detector), the blue curve is for the slave chip (engineering grade detector) . Note that the atmospheric transmission profile has **not** been removed from the throughput plot. .