Oxford Astrophysics

SWIFT

Short-Wavelength Integral Field Spectrograph

PALM3K Review

Caltech

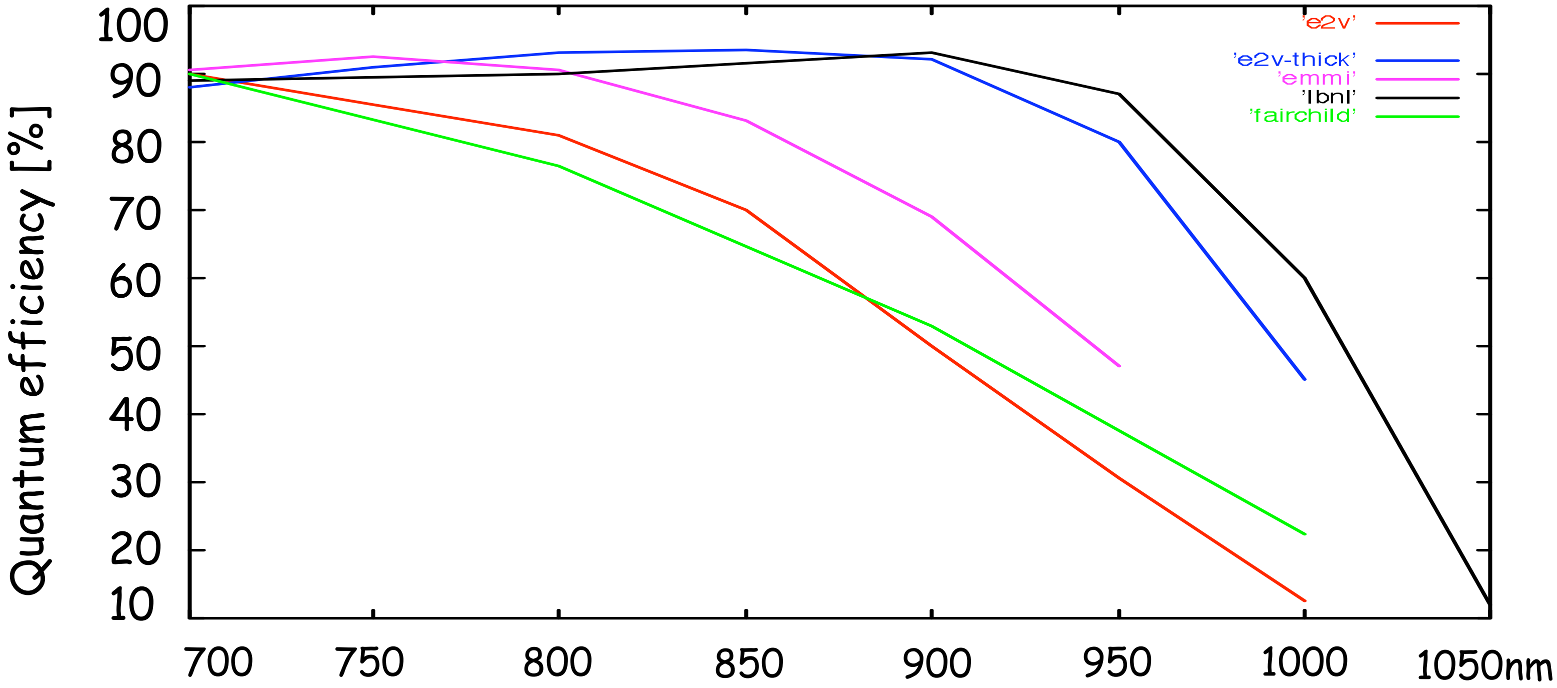
Feb 27th, 2009

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 good 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.

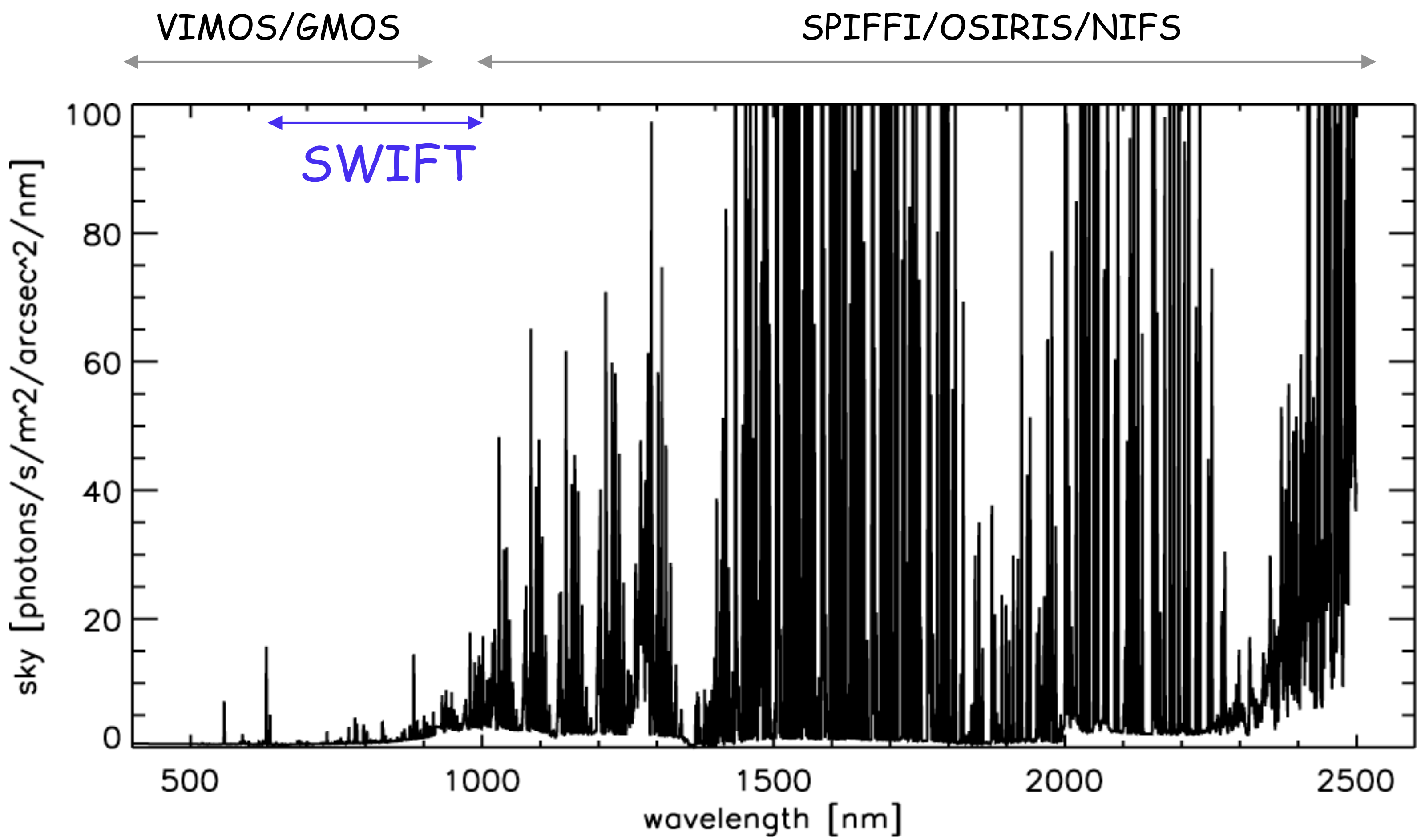
  ++ lower sky background than in the NIR

Red-sensitive CCD



- **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

Sky background



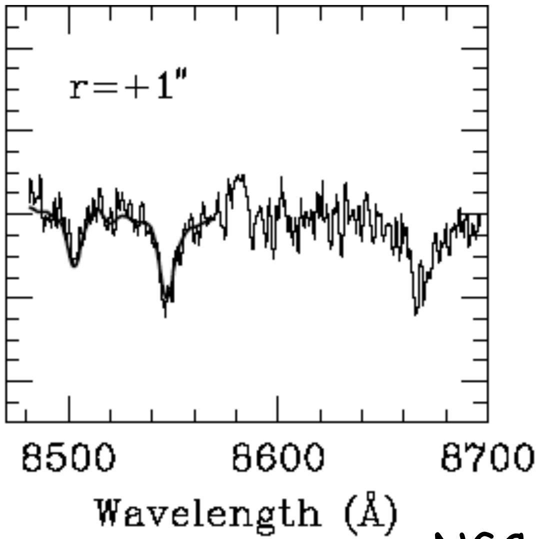
» **SWIFT will occupy a niche between the NIR and the visible**

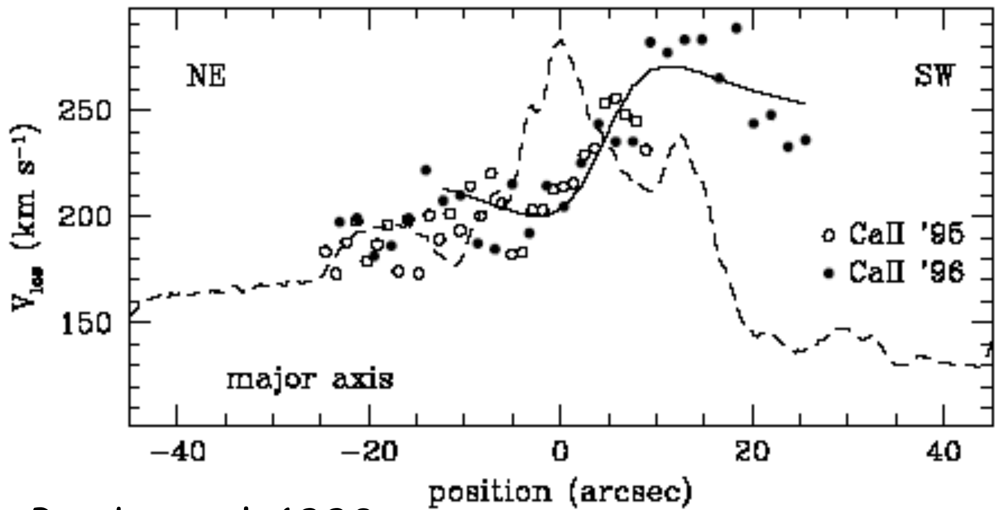
PALM3K Science Cases

- Weighing supermassive black holes in the local Universe
- Resolved stellar populations using the Lick indices at substantial redshift
- High contrast imaging spectroscopy through spectral deconvolution
- Galaxy dynamics at $z < 1.7$
- Properties of QSO host galaxies

Almost all PALM3K science cases are for extragalactic objects, and need the LGS!

SMBH masses with Ca triplet

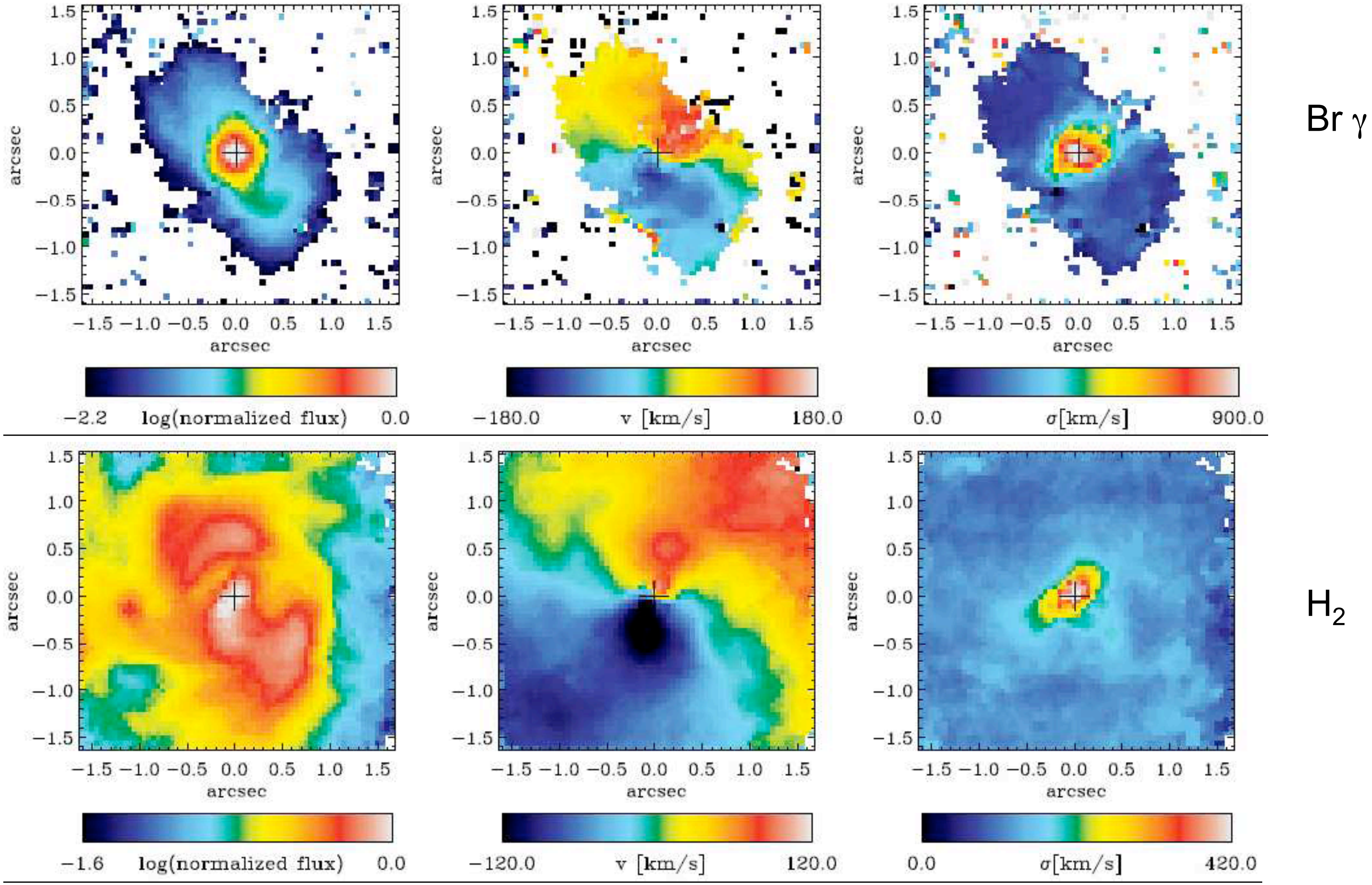




NGC 253: Prada et al. 1998

- Stellar dynamics in the innermost regions of nearby galaxies (Ca II triplet) ⇒ mass estimates for nuclear super-massive black holes
- Palomar 5 m at 0.87 μm ≡ 36 mas, compared with 59 mas for the ESO VLT (8 m) at 2.29 μm
- Can study objects out to z = 0.15

The black hole in Cen A with SINFONI

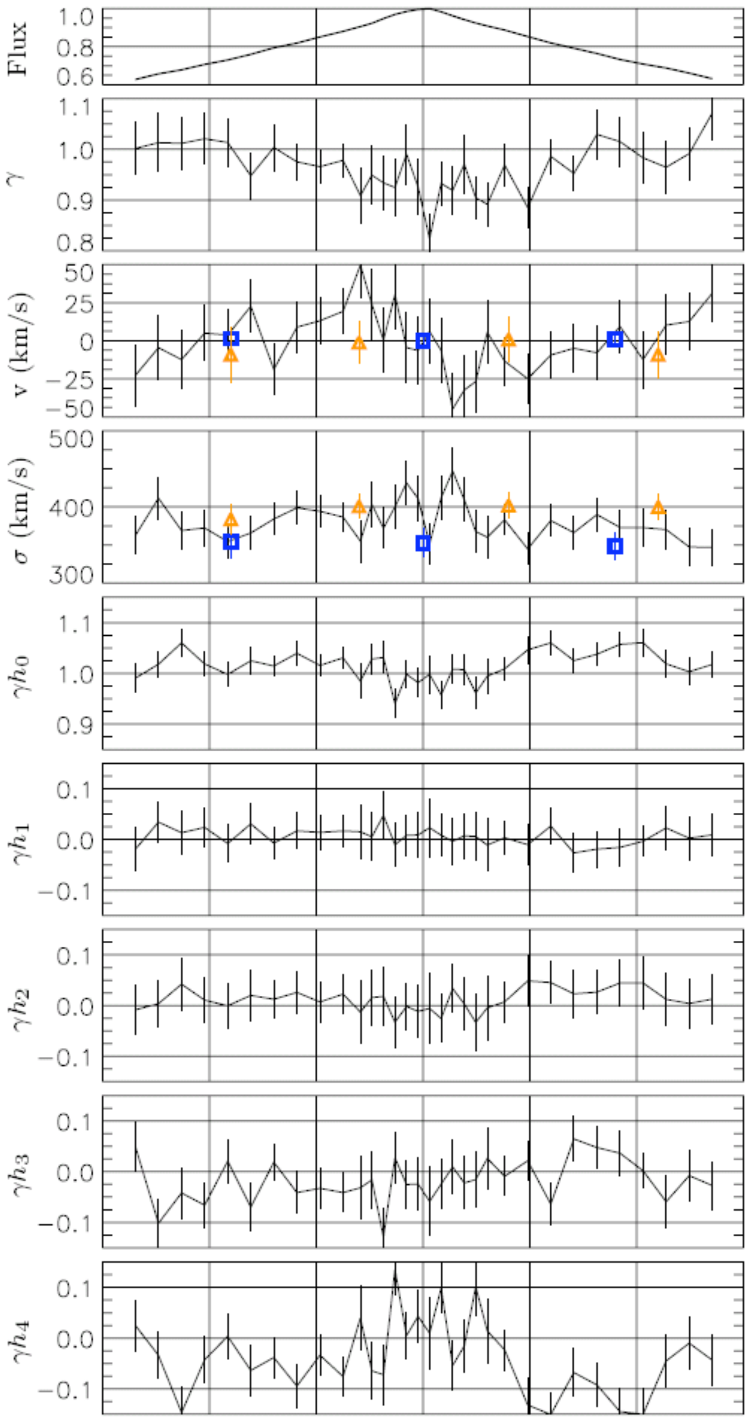


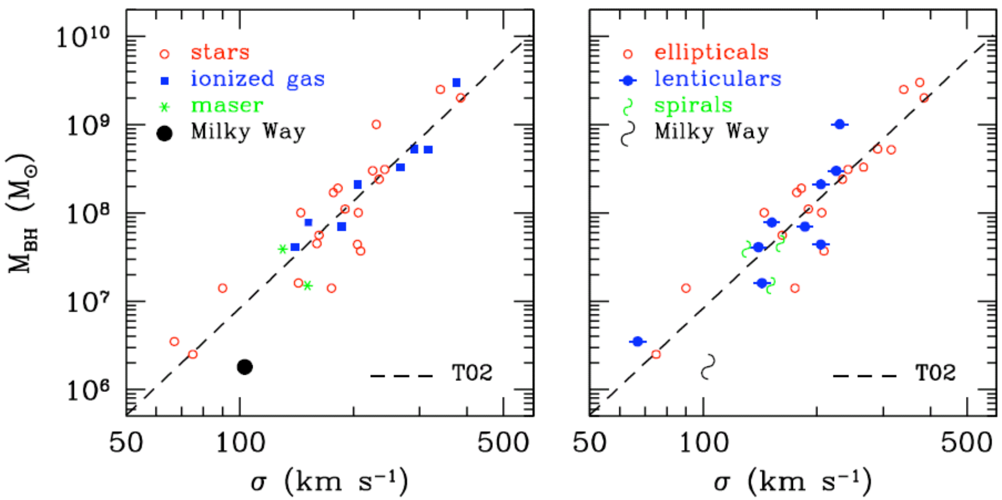
4.5×10^7 solar masses

- Neumayer et al. 2008.

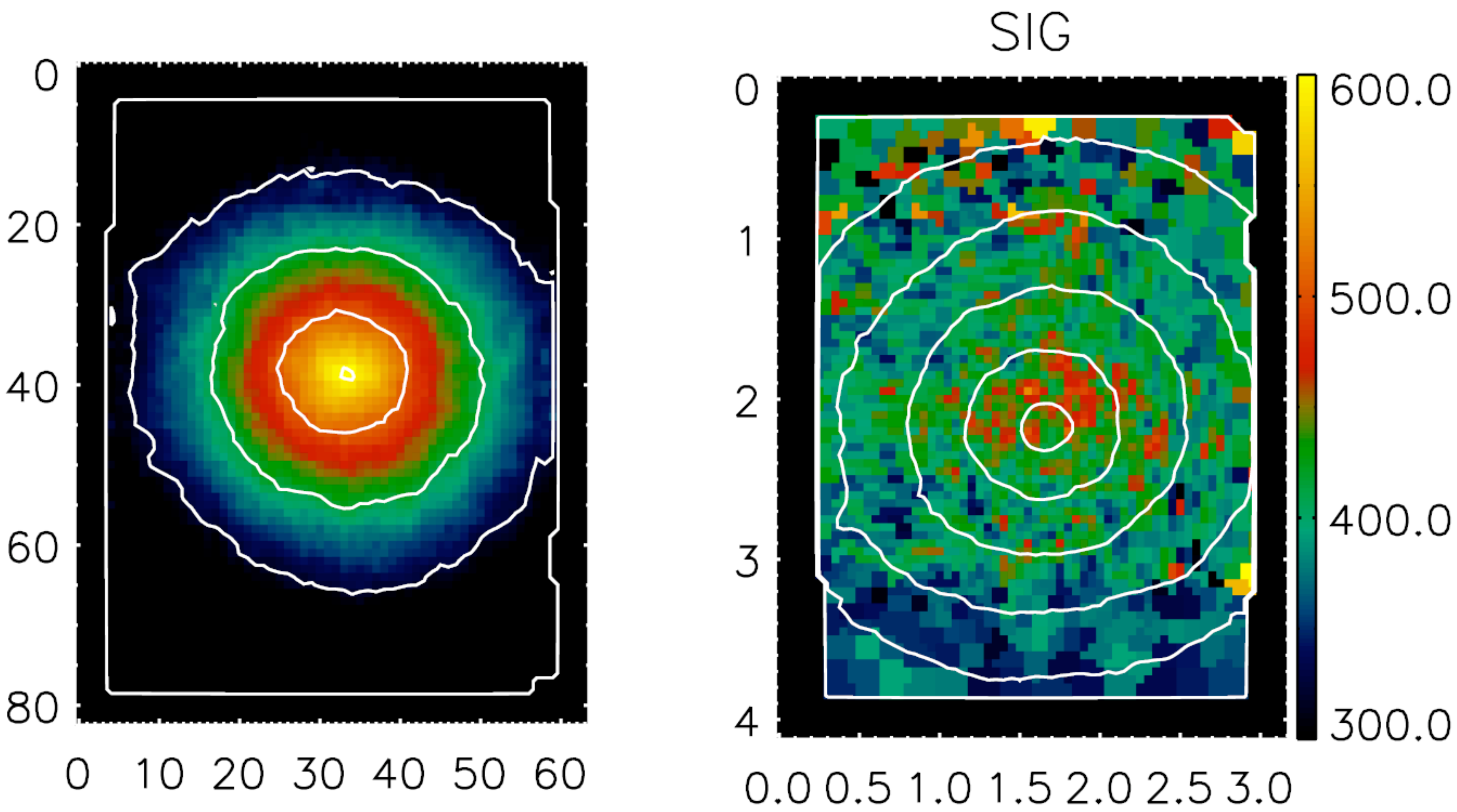
AO assisted NIR spectroscopy of the nuclear region of NGC 1399

Houghton, Thatte, Davies et al. (2005)



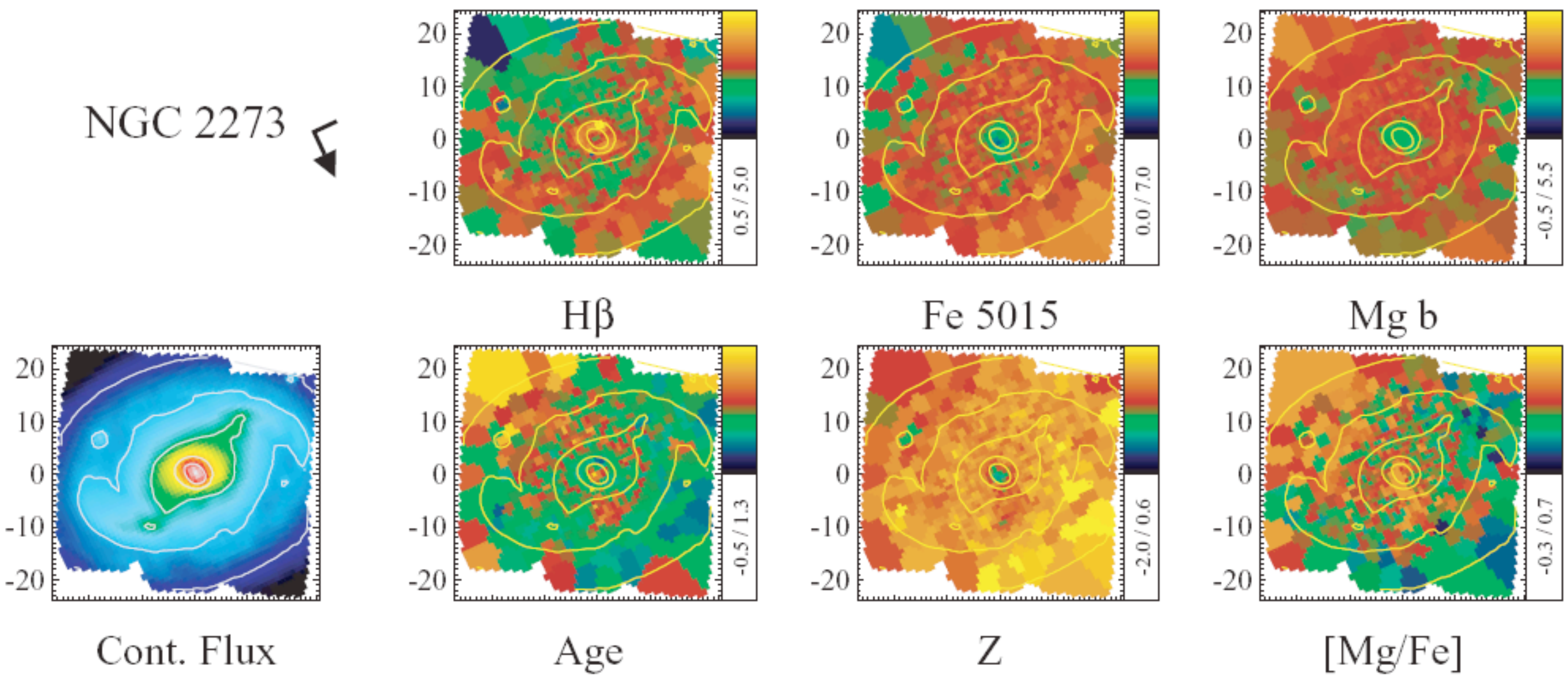


SINFONI IFS data on NGC 1399



- Houghton et al. (in prep)

Resolved stellar populations with SAURON



- Peletier et al., MNRAS, 2007

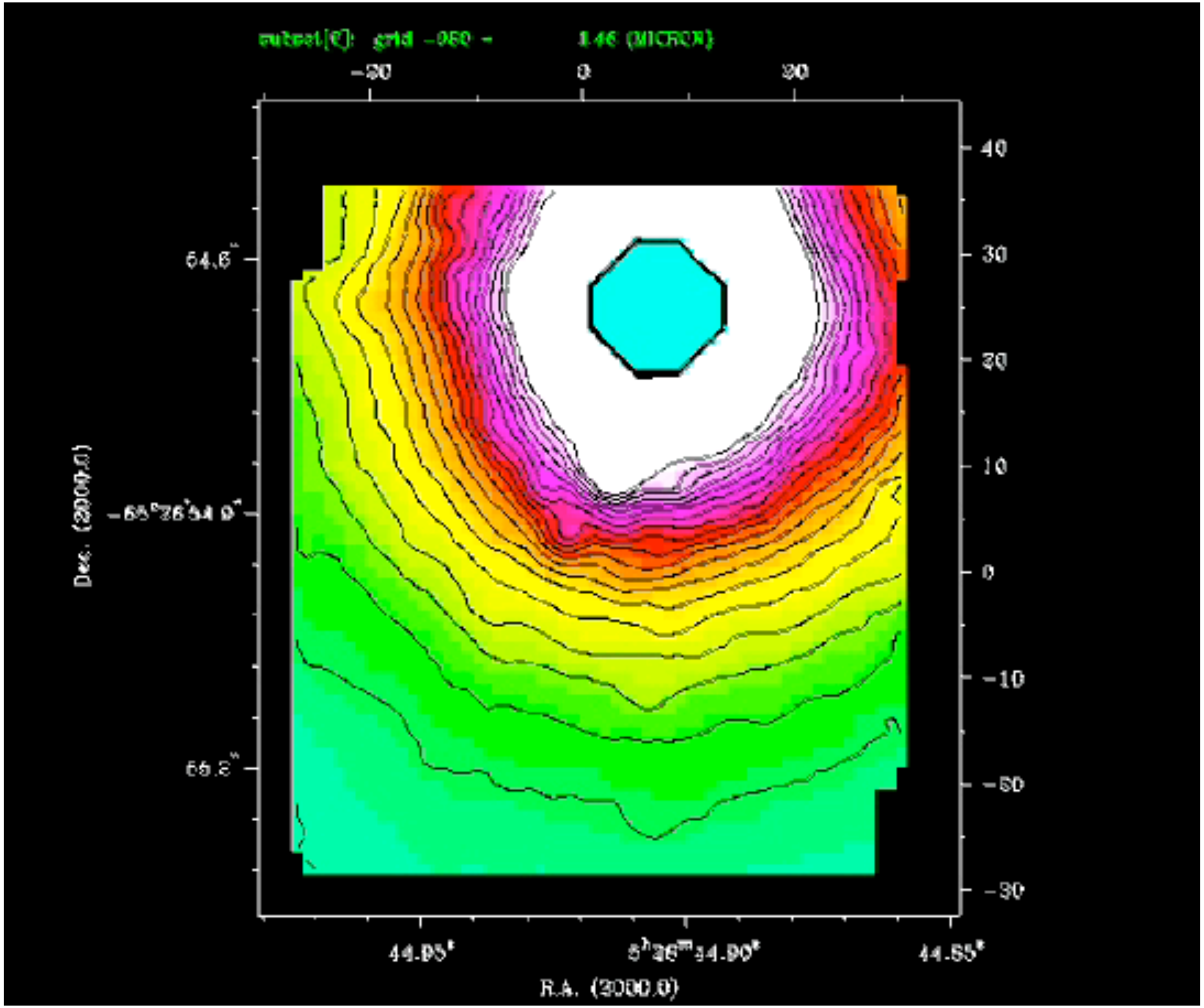
Resolved stellar populations at intermediate redshift

- Stellar populations (age, metallicity) usually studied using lines of Fe, Mg b, H β at ~5000 Å
- However, at intermediate z, lines shift out of instrument bandpass, necessitating use of bluer indices (e.g. Thomas et al.)
- SWIFT can observe well-understood indices out to z~1
- Improved spatial resolution offered by PALM3K means we can study stellar age and metallicity gradients in galaxies out to z~1 in a robust and reliable way.
- Age and metallicity gradients are the fossil record of galaxy formation & evolution, thus tracing formation history out to z~1.

PALM3K high contrast imaging

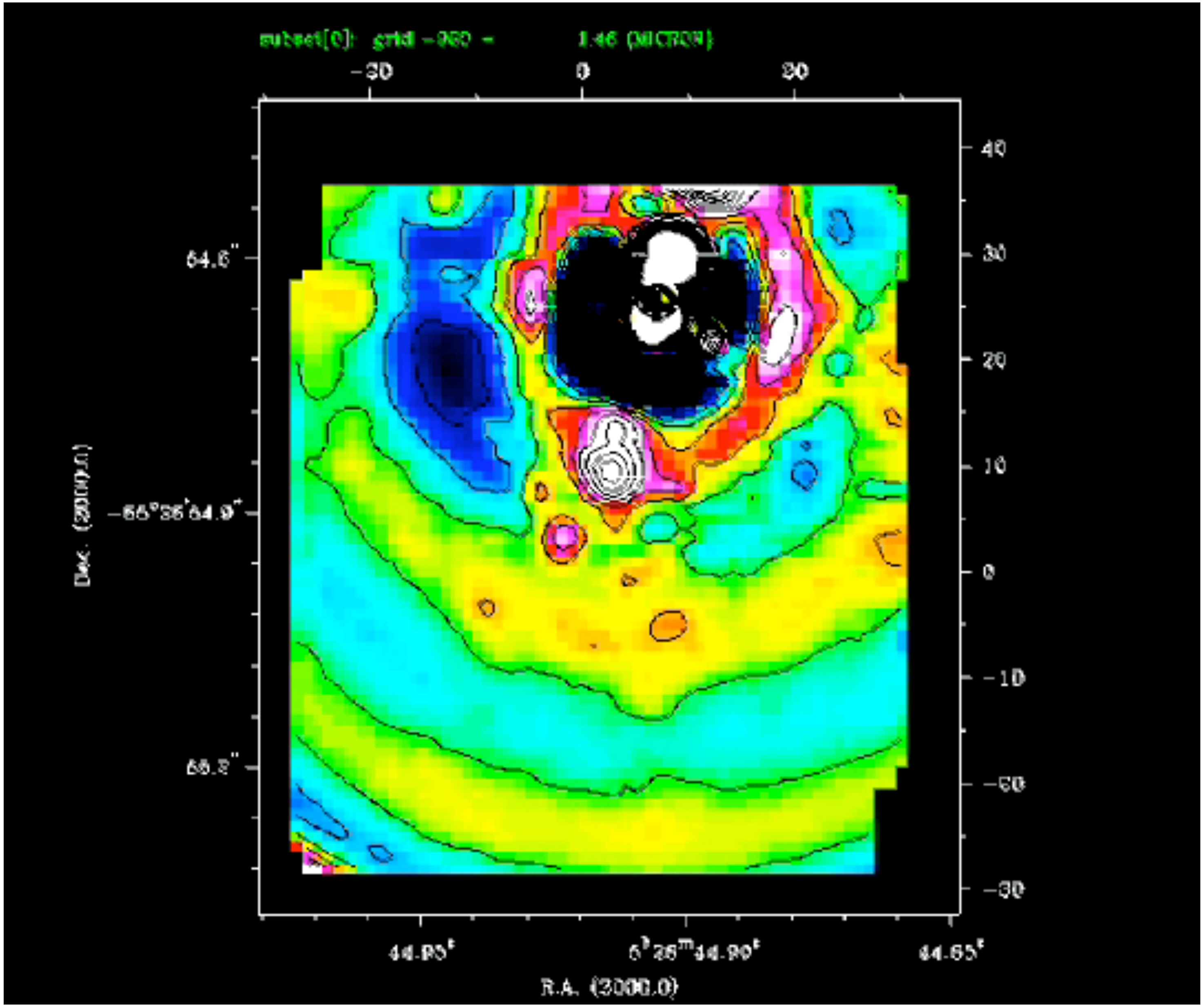
- Experiment carried out with SINFONI to prove spectral deconvolution works, even at moderate Strehl ratios
- AB Dor system, 5 mag fainter companion AB Dor C, located 200 mas away.
- 20 mins on-source, H+K bands, ~30% Strehl.

Spectroscopy at the diffraction limit



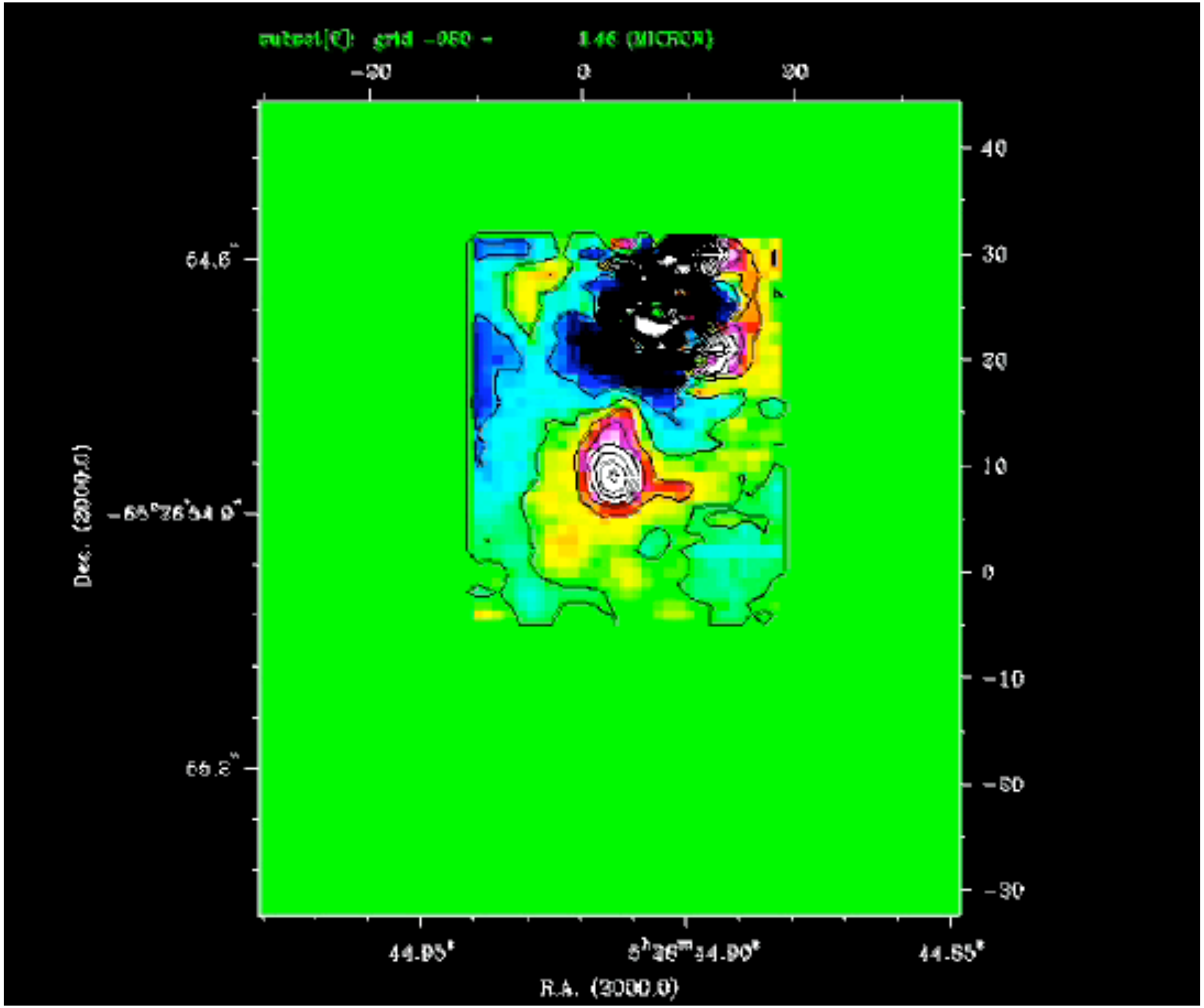
Input data cube (normalised)

Highlighting super-speckles



Radial profile (azimuthally symmetric component) fitted and removed.

The clean data cube



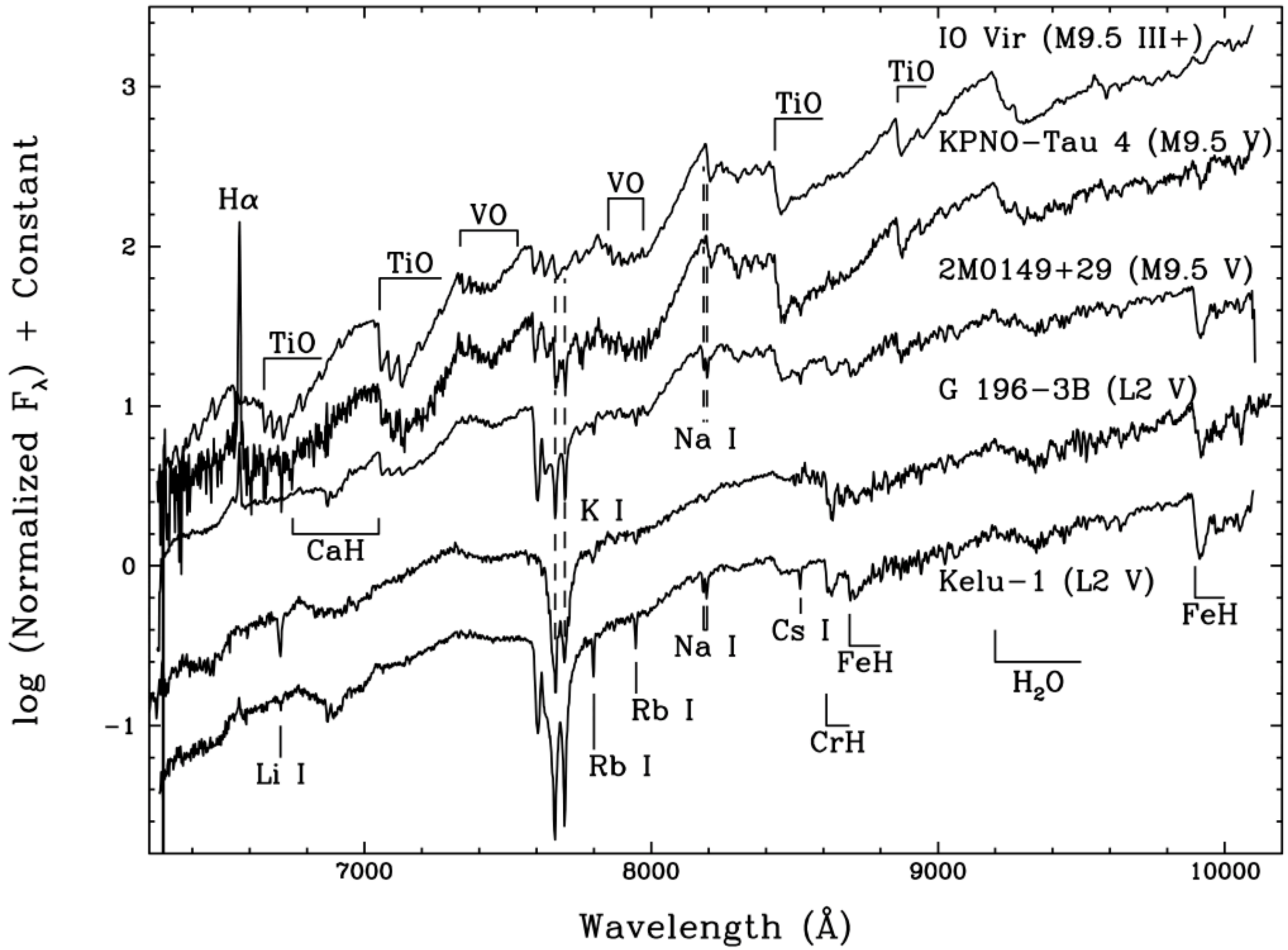
Radial profile (azimuthally symmetric component) fitted and removed.

High contrast w/o a coronagraph

SWIFT+P3K: substellar atmospheres

- SWIFT's wavelength range (6500-10000Å) covers many key features in L/T dwarf atmospheres
  - TiO & VO bandheads - key spectral markers of M/L change
  - FeH & CrH lines - temp sensitive lines in L dwarfs
  - Na, Rb, K, Li, Cs neutral alkali lines - gravity markers
  - K line - key marker below 700K ?
- Whilst low resolution spectroscopy is ideal for identifying substellar objects through molecular features (e.g. CH_4), higher resolution observations with an instrument like SWIFT open up more detailed studies of these objects. Key gravity features, for example, are only available at R>2000
- Combined with P3K, SWIFT would be the ideal tool to study these features in low-mass companions to bright stars (presumably found with another instrument; P1640, for example)
  - SWIFTs unique red-sensitivity makes it attractive for this science even for field objects

SWIFT: substellar atmospheres

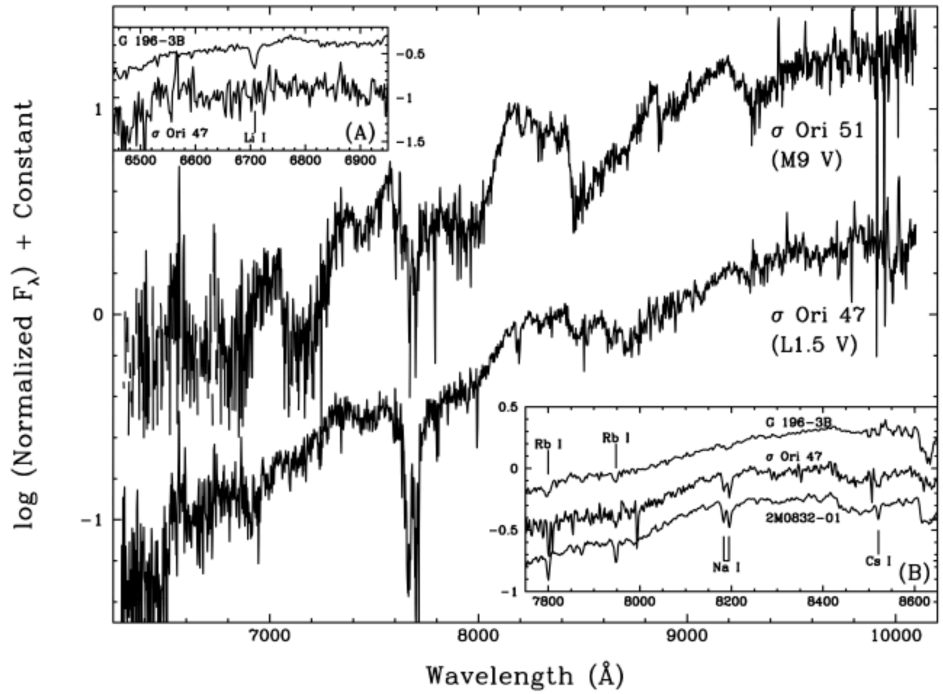


LRIS spectra of M & L dwarfs showing the wealth of features seen in SWIFT's wavelength range (from McGovern et al, 2005, ApJ, 600, 1020)

Substellar gravities with SWIFT & P3K

- Luminosities of substellar objects are degenerate with mass and age
  - Old and heavy, or young and light?

- Either need to know age of object independently (not always possible), or be able to measure gravity
- For M/L/T dwarfs, there are several gravity sensitive features in the 7000-10000Å range. They are typically narrow atomic lines, so require low/ medium spectral resolution (R>500)
- SWIFT+P3K could measure (low) gravity of potential young planet and brown dwarfs

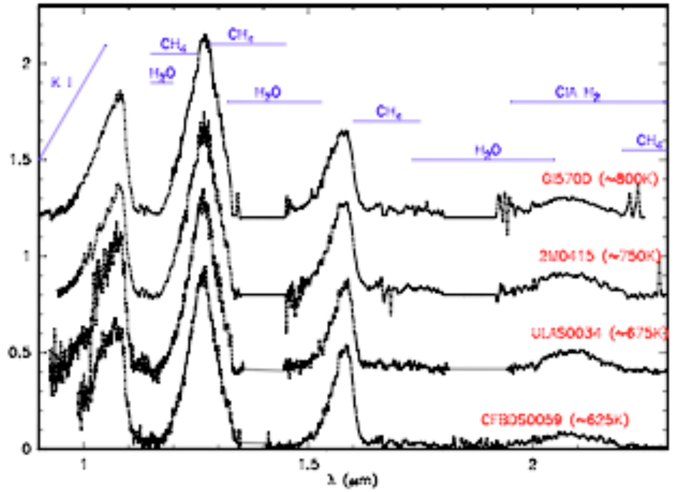


Comparison of spectra of low (top) and high (bottom) gravity objects. The narrow alkali lines (inset) are particularly sensitive to gravity. From McGovern et al 2005

SWIFT+P3K: confirming Y dwarfs?

- The coolest objects found to date (650-700K) are on the boundary of the T & Y spectral types
  - No true Y dwarfs have yet been found

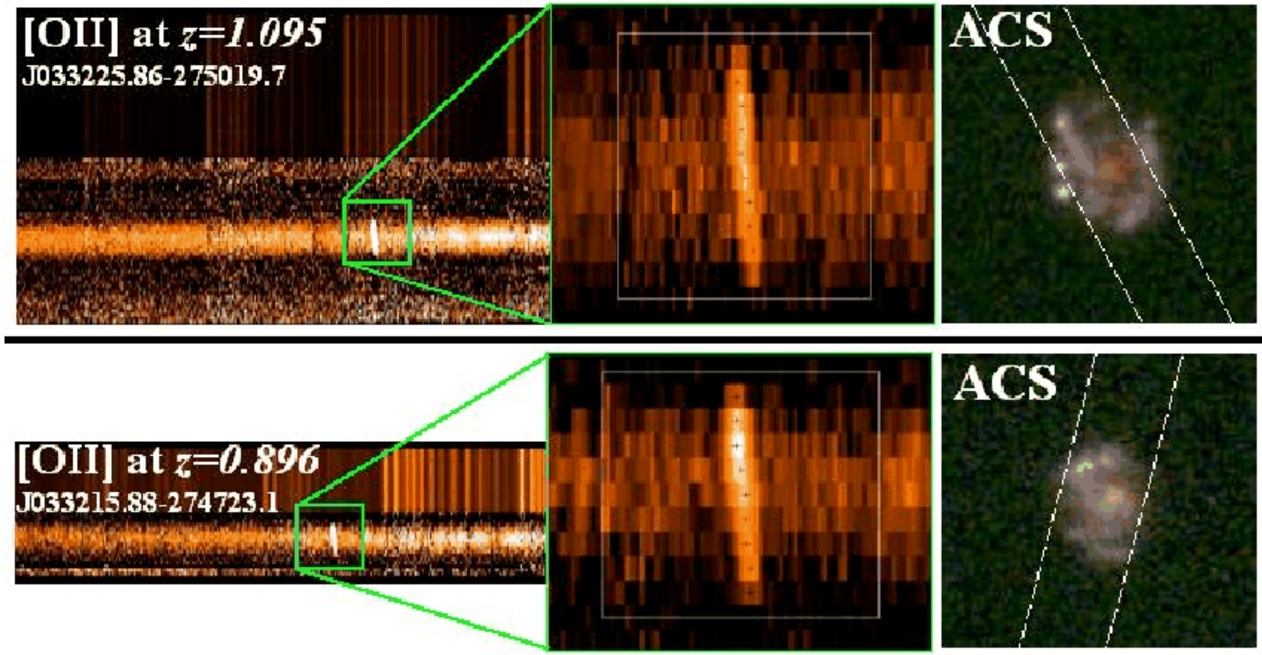
0.9-2.5um spectra of the coolest objects known to date (Delmore et al 2008). The continuum shape around and below 1.0μm is a key diagnostic below 700K



- One discriminator of the change from T to Y type is the slope of the continuum from 7000-10000Å. This is dominated by the red wing of the (pressure broadened) Potassium (K) line at 7000Å. Around 6-700K, K becomes depleted in the gas phase, forming KCl. This effects it's absorption strength, and the slope of the 0.7-1.0 micron region could therefore be a key temperature indicator for objects below 700K (e.g. Leggett et al 2007, APJ, 667, 537). SWIFT and P3K could be the ideal combination to confirm potential Y dwarf candidates found in near-IR surveys.

Probing the redshift desert

Project being pursued with PALAO, to be expanded with PALM3K



Rotation curves and dynamical masses out to z = 1.7 (probing the redshift desert)

Vanzella et al. 2005

Small source size needs P3K to increase number of resolution elements across disk

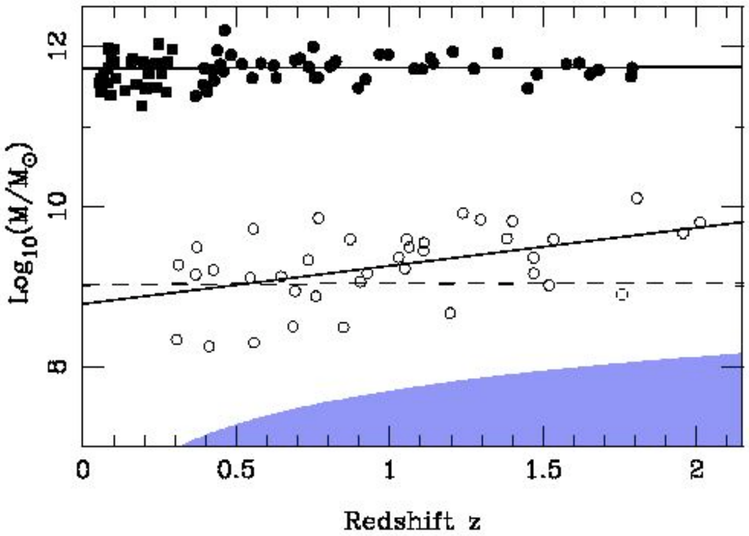
Advantages of using IFS

- No a-priori knowledge of kinematic major axis, inclination, etc. required
- Accurate slit positioning not required
- Azimuthal mean has high SNR and insensitive to HII regions

Black holes at high z

- Wish to determine both the black hole mass and the galaxy velocity dispersion to look at evolution of black hole mass v/s bulge mass relation.
- Additional information about QSO host galaxy (e.g. age of stellar component) also vital.

Evolution of stellar mass/black-hole mass relation

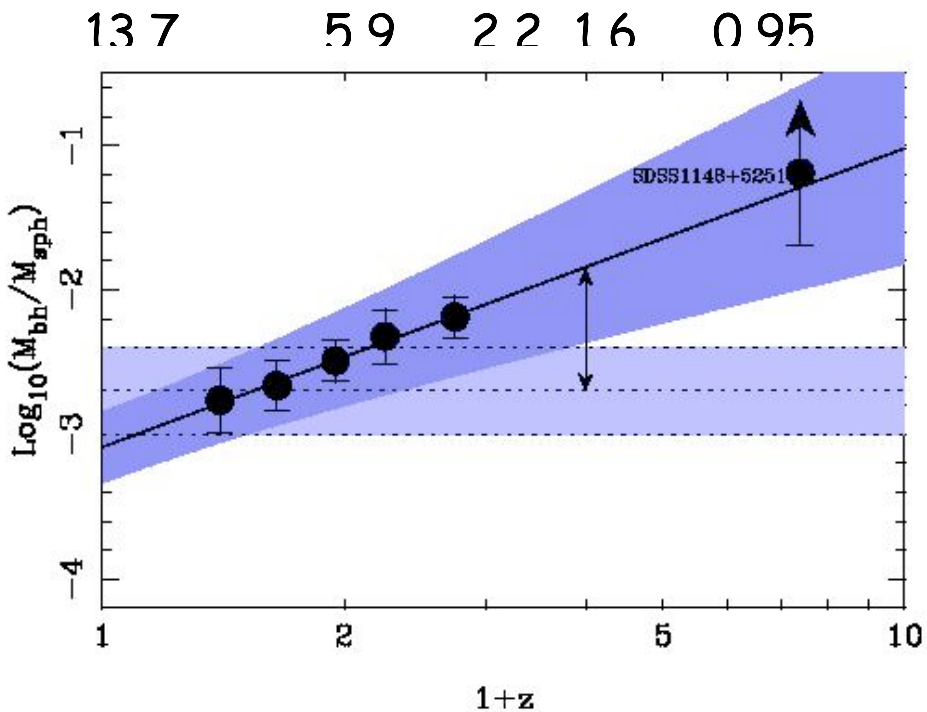


McLure, Jarvis et al. 2006

Use MgII (2800 Å) line width as a measure of black hole mass. Shown to be a robust indicator.

The black-hole mass – host galaxy relation

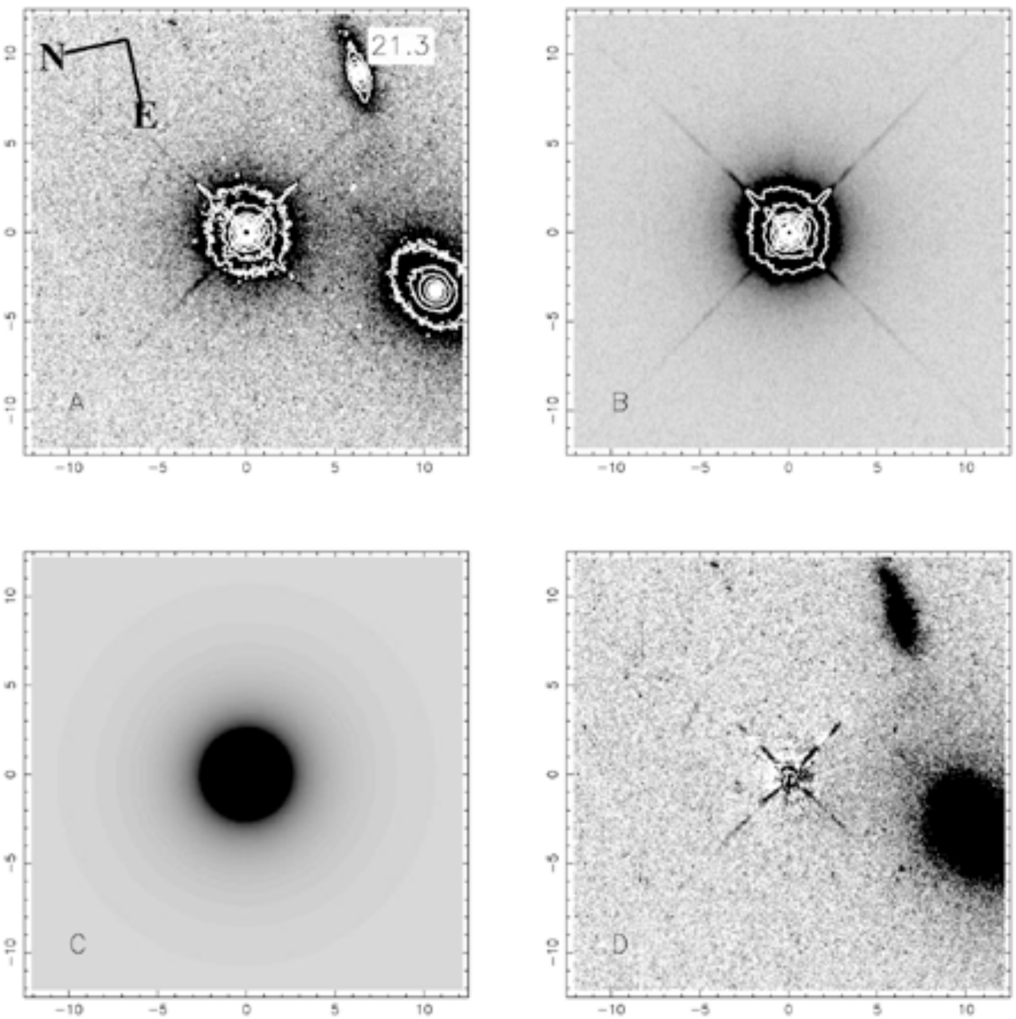
Time since Big Bang/ Gyrs



Ratio BH mass - Stellar mass

Redshift ⟶

First the black hole or first the galaxy?



With SWIFT we could subtract the QSO nucleus from the IFU data, leaving the host galaxy component. Therefore we can measure stellar mass and stellar velocity dispersion.

With the nuclear spectrum we can measure the Black Hole mass!

Other Science Cases

- Ly α observations of galaxies out to z ~7
- Ha 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)