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A MAGELLAN IMACS-IFU SEARCH FOR DYNAMICAL DRIVERS OF NUCLEAR ACTIVITY

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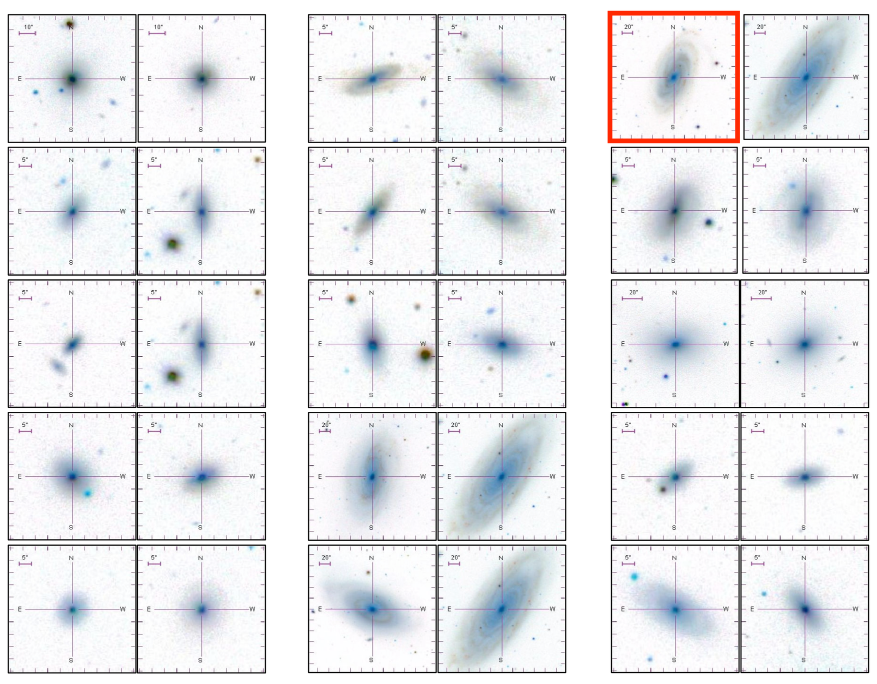
Introduction

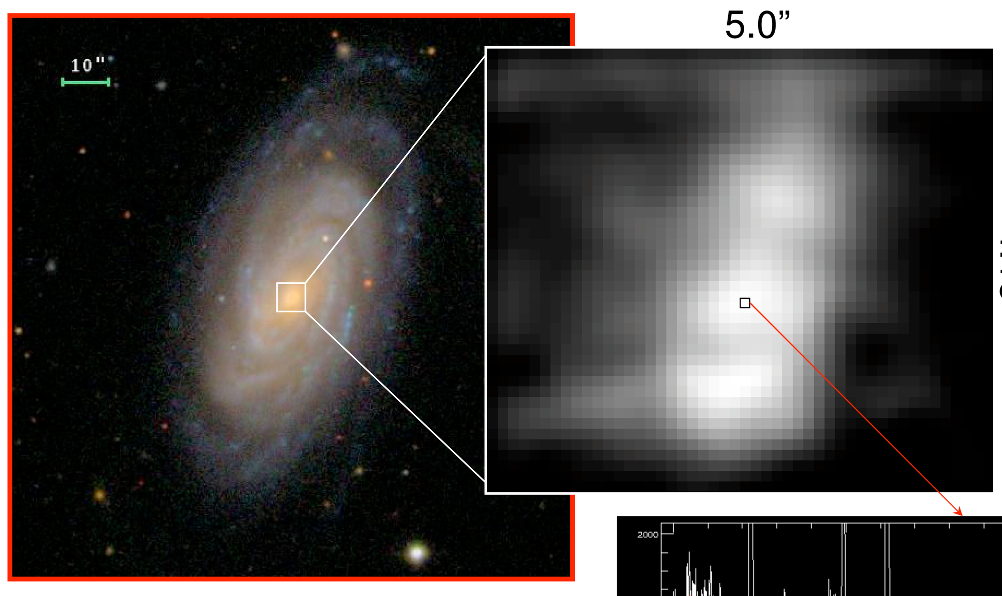
One of the main challenges surrounding active galactic nuclei (AGN) physics is constraining the origin and transportation of fuel to the nucleus. Assuming the material (gas) in the galaxy is undergoing rotational motion, then to transfer the material inwards it must lose a significant amount of its angular momentum. The nature of the physical processes that can remove such large amounts of angular momentum is then key to our understanding of AGN fuelling. We have therefore designed the first statistically-significant investigation of the two-dimensional distribution and kinematics of ionised gas and stars in the central kiloparsec regions of a well-matched sample of Seyfert and inactive control galaxies selected from the Sloan Digital Sky Survey (SDSS; York et al. 2000), to search for dynamical triggers of nuclear activity in the central region where AGN activity and dynamical timescales become comparable. Here, we present the first results of the 2-D kinematic survey using the 6.5-m Magellan telescope in IFU-mode.

IMACS-IFU Sample and Observations

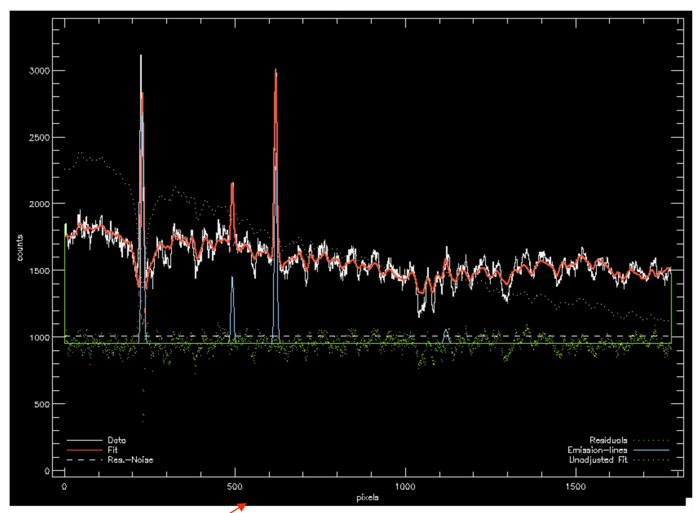
- Magellan-I telescope, Las Campanas Observatory, Chile
  - IMACS-IFU FOV: 4.15" x 5.00"
  - Wavelength range: 3975 - 7097 Å
- Observations made in December 2005, April 2006 and August 2007.
  - Typically 4 x 1800 sec exposures
  - Sub-arcsecond seeing
  - Resolution: ~40 km.s^{-1} at 5000 Å
- Galaxies selected from SDSS
  - z < 0.05
  - Controls matched to Seyferts on:
    - Redshift
    - Absolute magnitude, M_r
    - Aspect ratio (in r-band)
    - *petroR90*
- Currently 15 active-inactive pairs



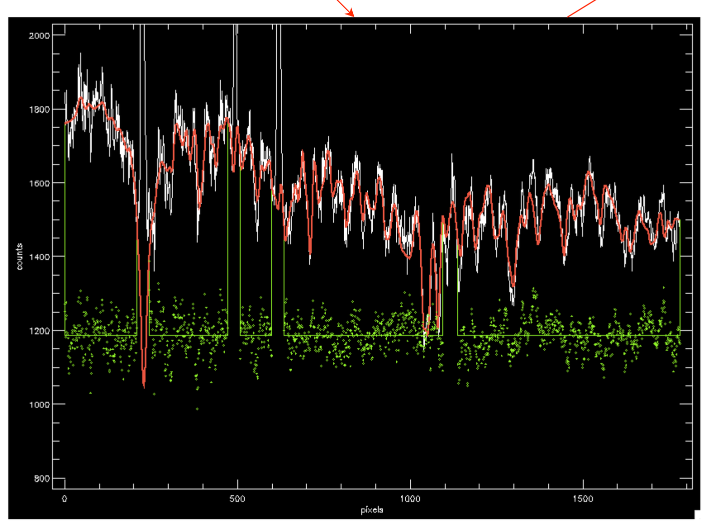
Images from SDSS



NGC 5740

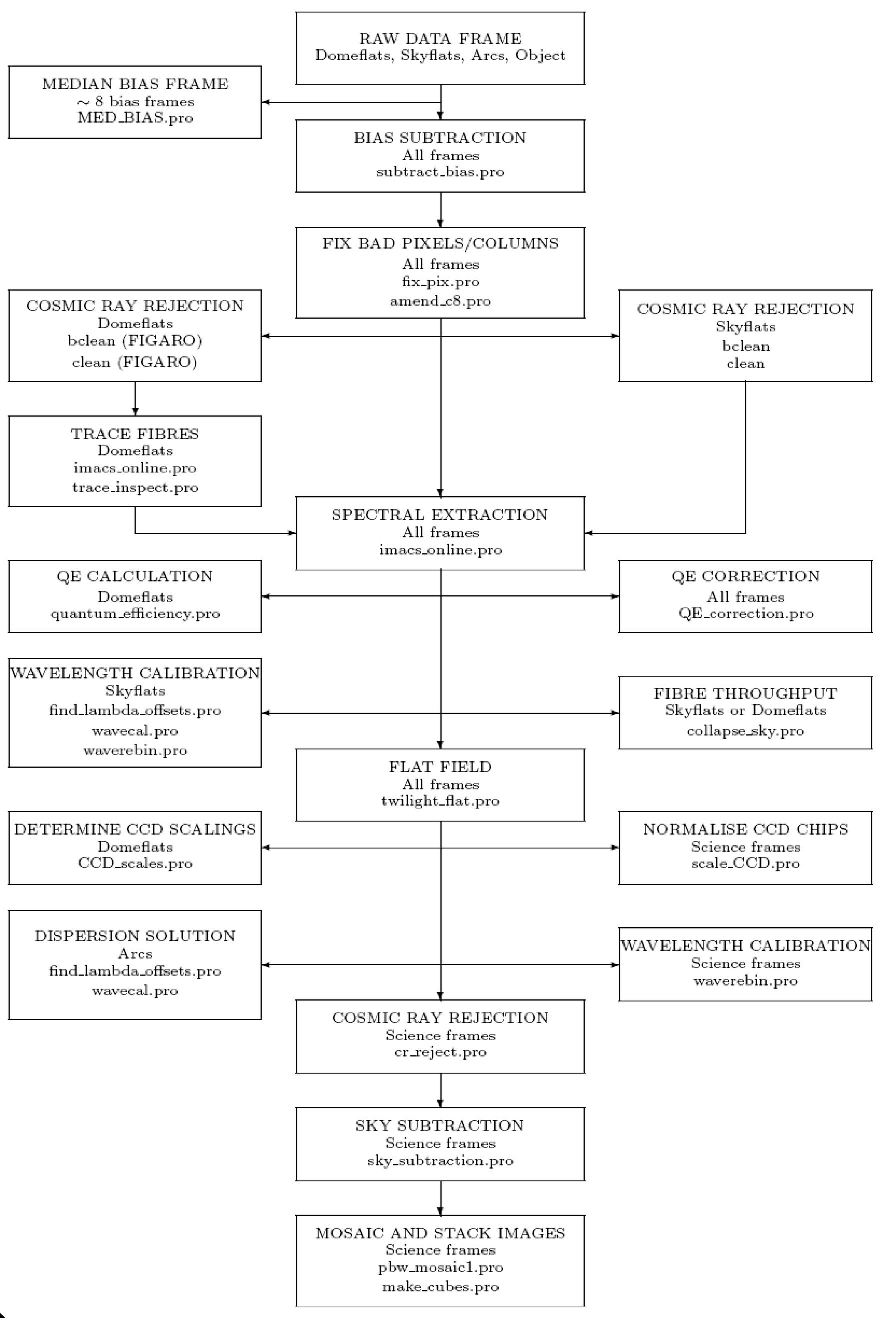


Gas kinematics



Stellar kinematics

Data Reduction Pipeline



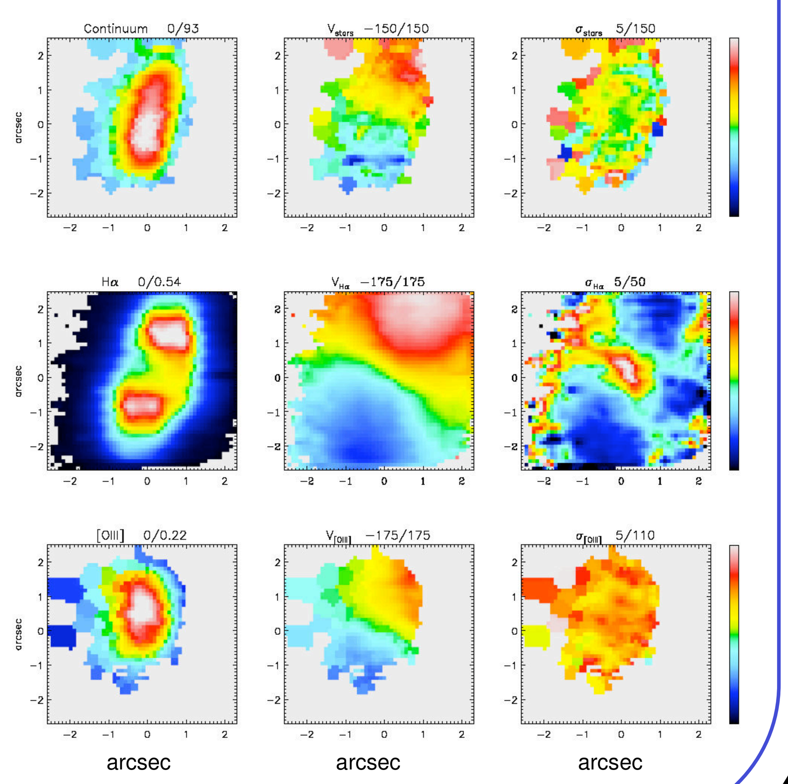
- Developed full reduction pipeline
  - IMACS-IFU `long-mode'
  - IDL code
  - P3d (Roth et al. 2005)
    - imacs_online
  - Process summarised in the flowchart on the left
- Derivation of stellar kinematics
  - Absorption-line fitting
  - pPXF (Cappellari & Emsellem 2004)
- Derivation of gas kinematics
  - Emission-line fitting
  - GANDALF (Sarzi et al. 2006)
    - Hβ
    - [OIII]
    - [NI]
  - Independent single Gaussian fits
    - Hα
    - [NII]
    - [SII] doublet

Stellar and Ionised Gas Distributions and Kinematics

- Stellar distributions
  - Majority axisymmetric distributions
  - 3 strongly barred (e.g. NGC 5740, right)
- Ionised Gas distributions
  - [OIII] emission in active galaxies only
    - Compact and centrally concentrated
  - Hα in active and inactive galaxies
    - Extended emission (e.g. NGC 5740)
    - Star-forming rings
- Kinematics
  - 18 galaxies show rotation in gas or stars
    - 8 show rotation in both
    - Kinematic PA's of gas and stars offset
      - In both Seyferts and controls
  - Velocity dispersions generally increase towards the centre
    - One potential `σ-drop' galaxy
      - NGC 5750
  - Evidence for gas streaming in Seyferts
  - Ionised gas outflow found in 4 Seyferts

Example: NGC 5740

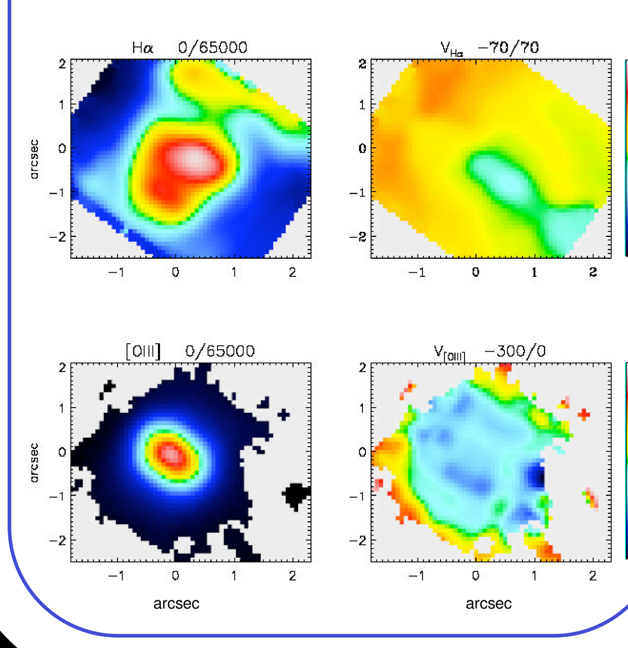
- SABb Seyfert 2 galaxy
  - z = 0.0052 (Cosmology scale: 118pc/arcsec)
- Nuclear stellar bar
- Bimodal Hα distribution
- [OIII] distribution extends NE
- Stellar and ionised gas rotation fields similar
- [OIII] rotation field deviates in NE corner
  - Evidence for gas streaming



Detection of outflow components

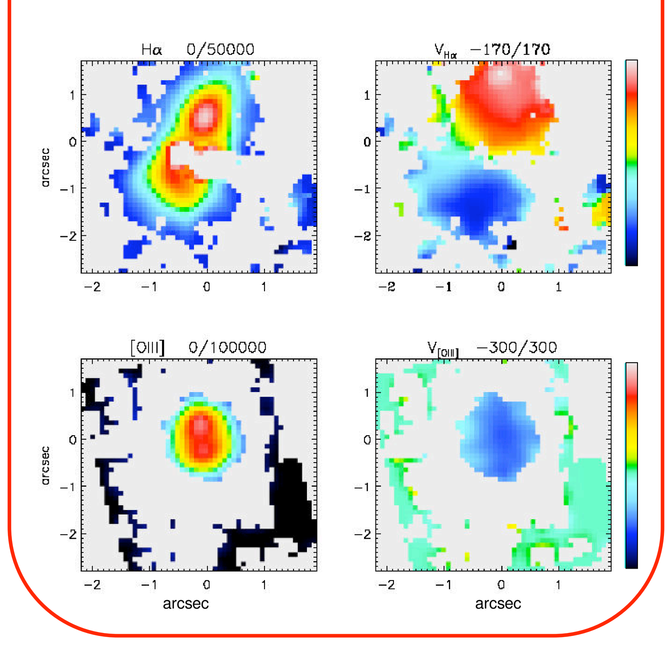
Mrk 609

- S0 galaxy (almost face-on)
- Broad-line AGN
- z = 0.034
  - Cosmology scale: 650 pc/arcsec
- Possible low-level Hα rotation
- [OIII] outflow
- [OIII] gas mass ~ $5 x 10^5 M_\odot$



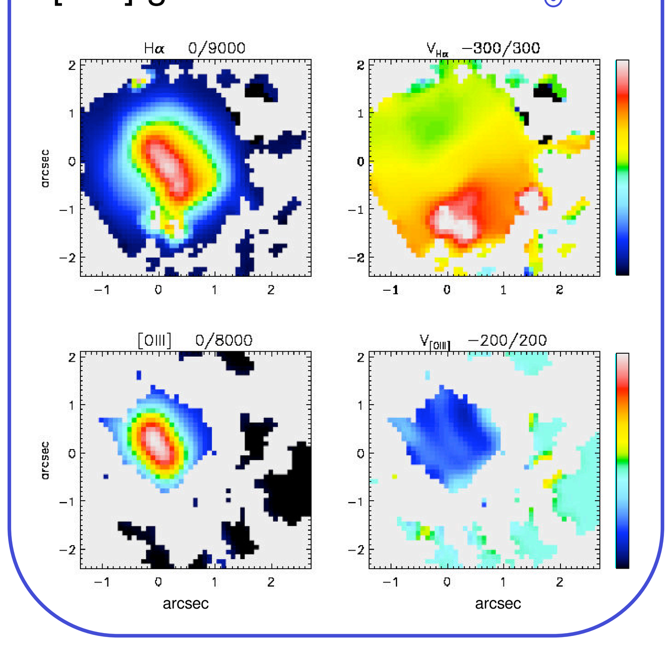
SDSS J033955.68-063237.5

- Narrow-line AGN
- z = 0.031
  - Cosmology scale: 592 pc/arcsec
- Unperturbed Hα rotation
- [OIII] outflow
  - Perpendicular to rotating gas disk
- [OIII] gas mass ~ $1.9 x 10^5 M_\odot$



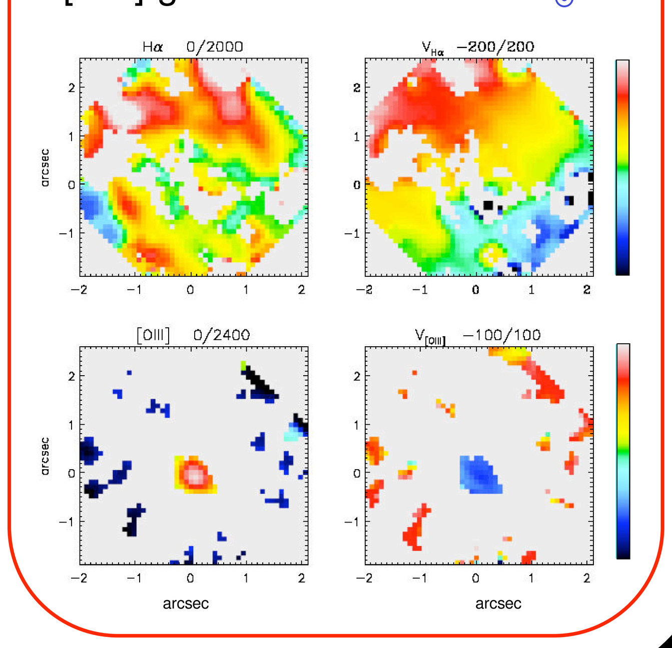
SDSS J03457.53-000047.3

- Narrow-line AGN
- z = 0.036
  - Cosmology scale: 679 pc/arcsec
- Hα rotation - slightly perturbed
- [OIII] outflow
  - At an angle to rotating gas disk?
- [OIII] gas mass ~ $2.8 x 10^7 M_\odot$



SDSS J090040.66-002902.3

- Sab Narrow-line AGN
- z = 0.041
  - Cosmology scale: 788 pc/arcsec
- Circumnuclear star-forming ring
- [OIII] outflow
  - Disturbing the rotating gas disk
- [OIII] gas mass ~ $1.1 x 10^5 M_\odot$



Notes

The work presented here is from a corresponding series of papers (Westoby et al. 2010, *in prep*).

The IMACS kinematic maps are displayed such that North is up and East is left. Only pixels with S/N > 3 are plotted. The range of values plotted are given above each map. [OIII] in these figures refers to the [OIII] λ5007 emission-line. Flux units of the figures to the left are in data-counts only. For NGC 5740 (above), flux units are x10^{16} ergs/cm^2/s/Å.

Ionised gas masses were estimated based on the [OIII] λ5007 luminosity in the outflow region, and an estimate of the electron density from the [SII] doublet ratio. These values are summarised in the table below.

IONIZED GAS MASSES OF OUTFLOW COMPONENTS

Galaxy (1)	[O III] flux (2)	[S II] ratio (3)	e^- density (4)	Gas mass (5)
Mrk 609	2.86	1.09	500	5.0×10^5
SDSS J033955.68–063237.5	0.66	1.20	300	1.9×10^5
SDSS J034547.53–000047.3	25.95	1.38	80	2.8×10^7
SDSS J090040.66–002902.3	0.61	1.03	500	1.1×10^5

NOTE. — (1) Galaxy name. (2) Integrated [O III] flux. (3) Mean [S II] ratio in outflow region. (4) Electron density derived from [S II] ratio. (5) Mass of ionized gas in outflow region.

References

Cappellari, M., & Emsellem, E. 2004, PASP, 116, 138

Roth, M. M., et al., 2005, PASP, 117, 620

Sarzi, M., et al., 2006 MNRAS, 366, 1151

York D. G. et al., 2000, AJ, 120, 1579