The Smoking Gun of AGN Fuelling - new clues from multi-scale stellar and gaseous kinematics

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Gas and Stars in Galaxies –
A Multi-Wavelength 3D Perspective
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Fuelling the AGN

- Most of nearby galaxies host a central SMBH
- Correlations between SMBH mass and the host galaxy properties
- only ~5 % of nearby galaxies are active
- QSO epoch at z~2 – 3
- Nuclear activity lifetime ~ 10^{7} - 10^{8} yr: recurrent phenomenon?

Need to study the dynamics

- Fuelling the AGN: dynamical phenomenon

- Previous imaging studies:
  - No global photometric difference between Seyfert and non-active galaxies
  - Circumnuclear regions: recent correlation between photometric features and nuclear activity (Hunt & Malkan, 2004; Simões Lopes et al. 2007)

→ Identifiable dynamical differences in the circumnuclear regions?

Goals

- Search for dynamical differences between Seyfert and non-active galaxies at different spatial scales
- Identify fuelling mechanisms
- Quantify the role of the host galaxy and its environment

- What do we need?
  - Well-matched samples of Seyfert and non-active galaxies
  - 2D kinematics and morphology
  - Large scales and circumnuclear regions

The surveys

- IFS optical data:
  - Stars + ionised gas
  - circumnuclear regions

} SAURON/Seyfert Survey

- Radio synthesis imaging data:
  - HI emission line
  - Large scale disk & environment

} VHIKINGS Survey

- Kinematics and morphology from the outskirts of the galaxies down to a few 10s pc
- Multiwavelength data

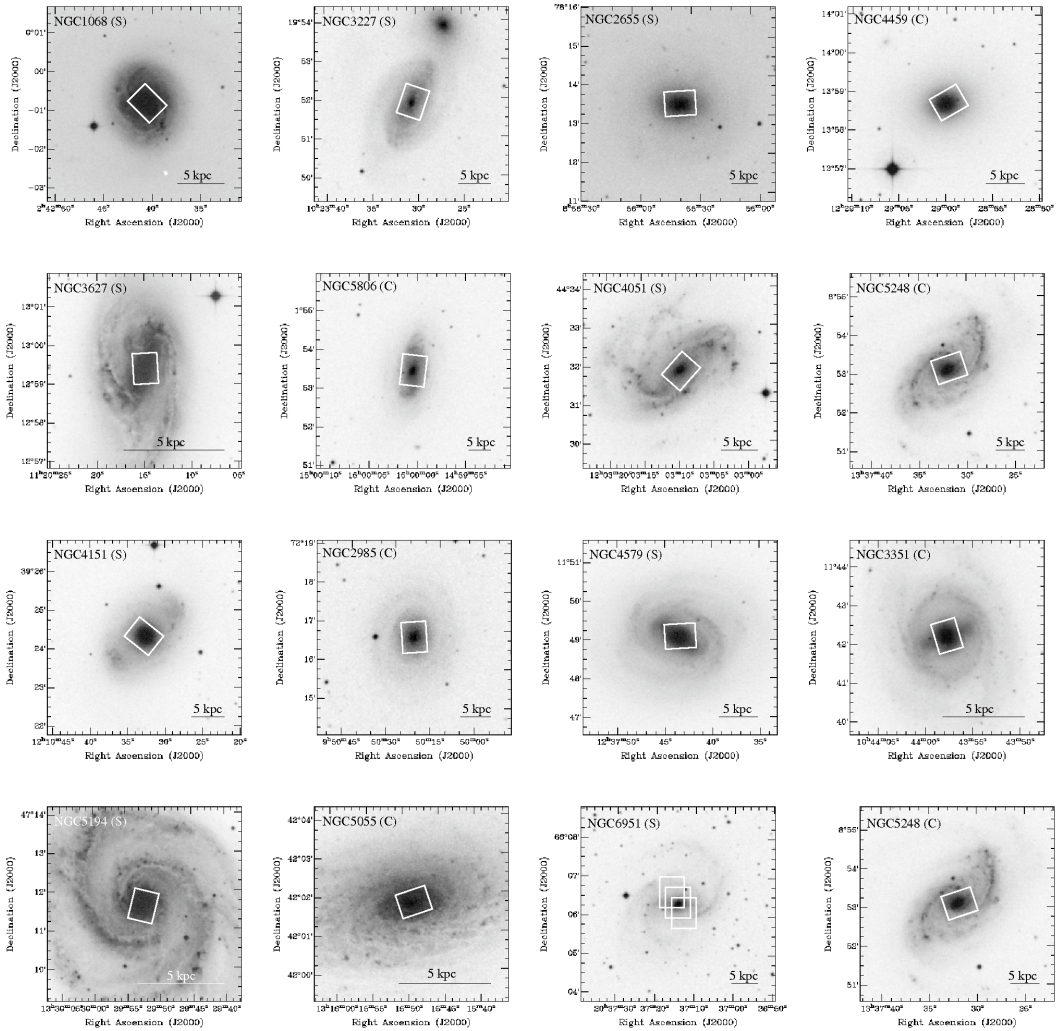
The surveys

VHIKINGS (Mudell et al. 2007)

- 28 Seyferts + non-active galaxies
- HI emission line
- VLA data
- Ongoing data reduction

SAURON/Seyfert (Dumas et al. 2007)

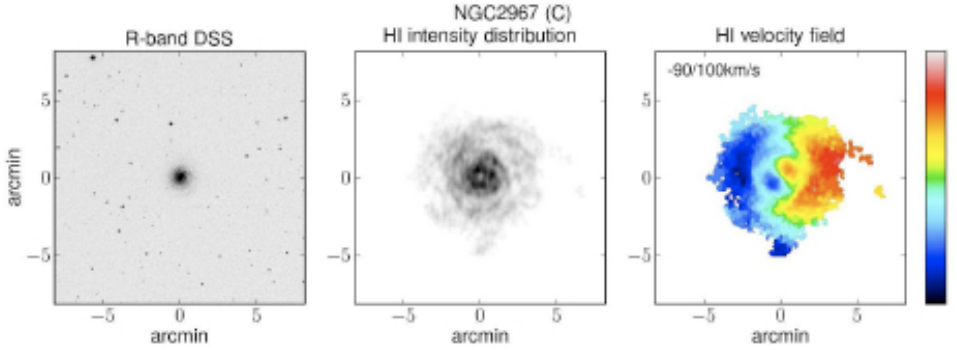
- 7 pairs + 2 Seyferts
- FOV 41”x33”
- 2 kpc to 20 pc

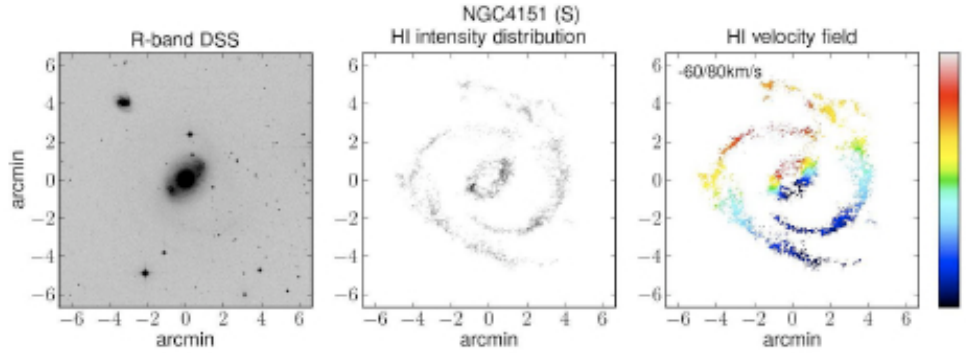


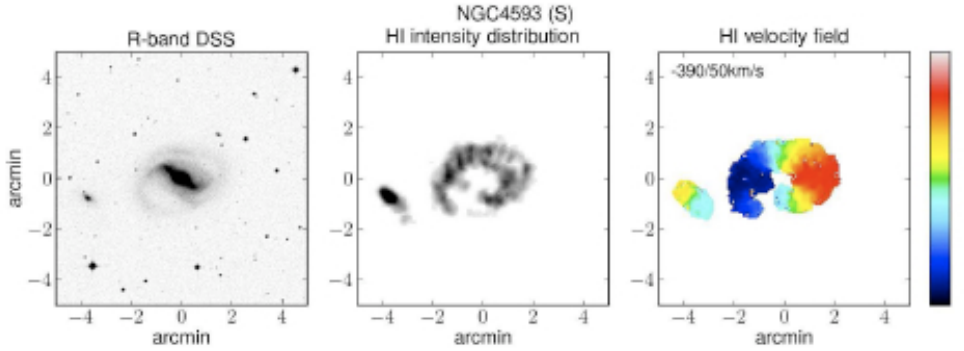
HI moment maps

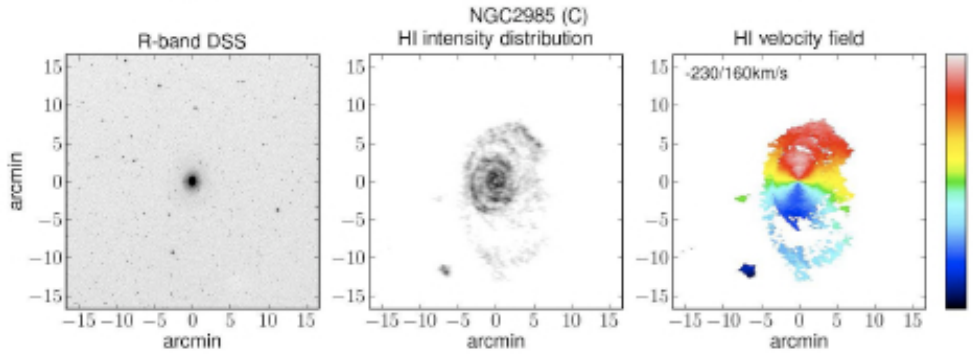
- Large extent, outer features
- Central depression

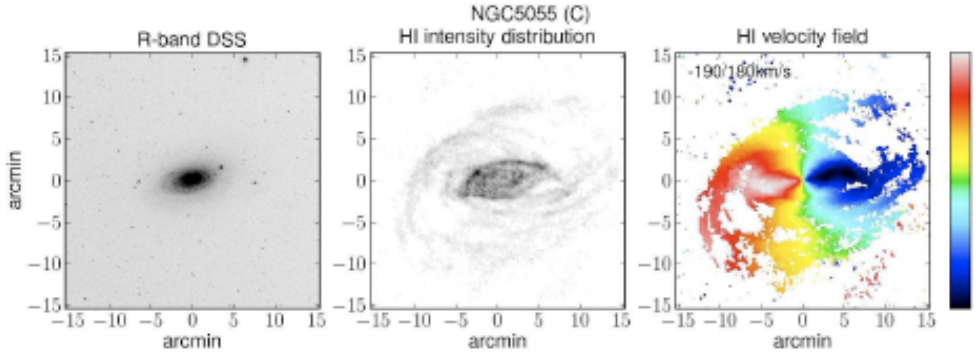
- Regular velocity fields
- Twists and wiggles



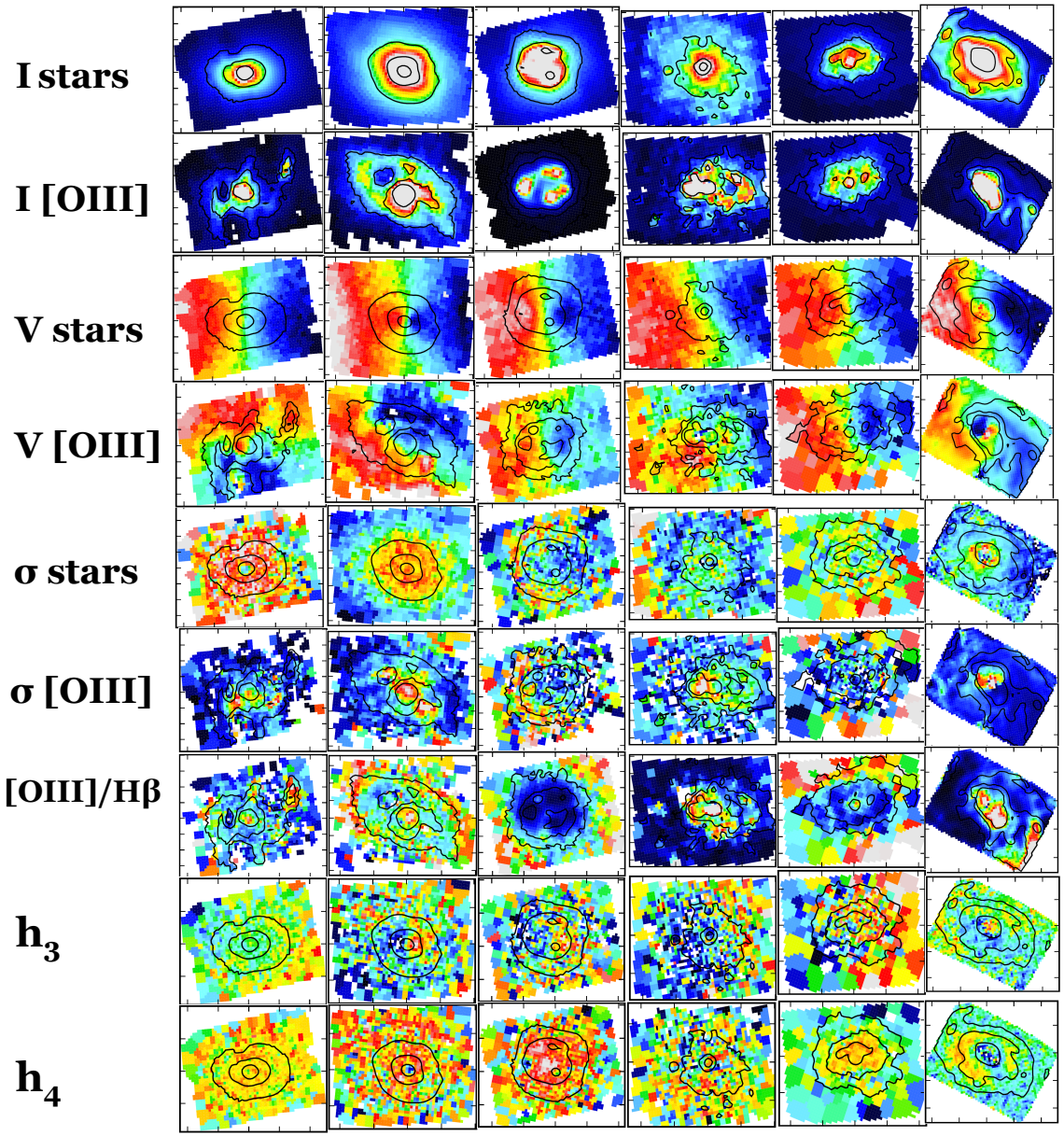








SAURON Maps (dumas et al. 2007)

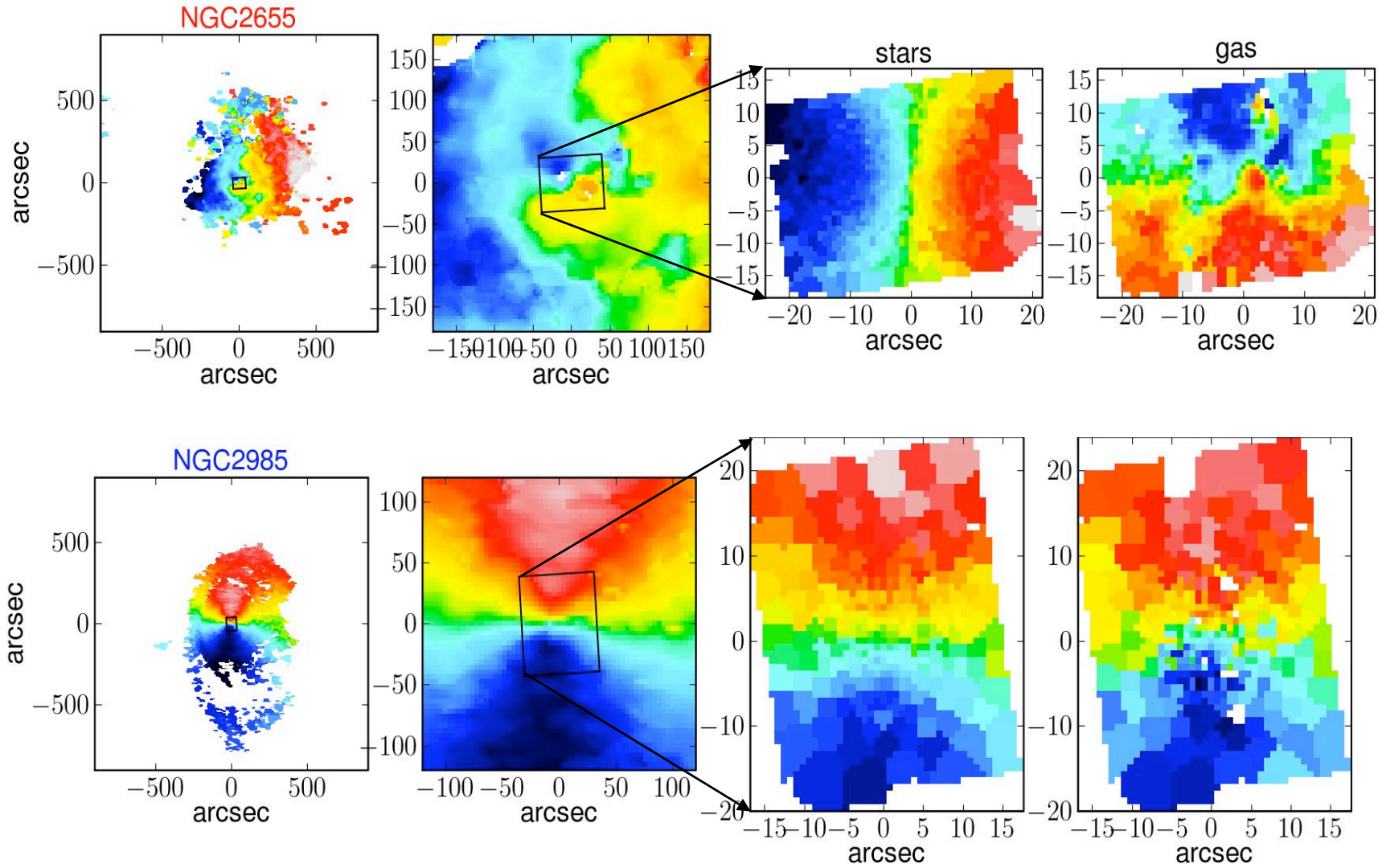


- Numerous maps:
  - Stellar maps: I, V, σ, h3, h4
  - Ionised gas maps: [OIII] & Hβ (I,V,σ), [OIII]/Hβ
- Complex and varied structures

Velocity Maps

Radio; large-scale disk

Optical; circumnuclear regions



Kinematics Analysis

Quantifying and interpreting the observed kinematic perturbations

Link circumnuclear regions/large-scale disk

1. Kinematic misalignments (Dumas et al. 2007)
   Seyferts have larger kinematic misalignments in the circumnuclear regions
2. Kinematics parameter as function of radius: **PyRing**
3. 2D Fourier analysis

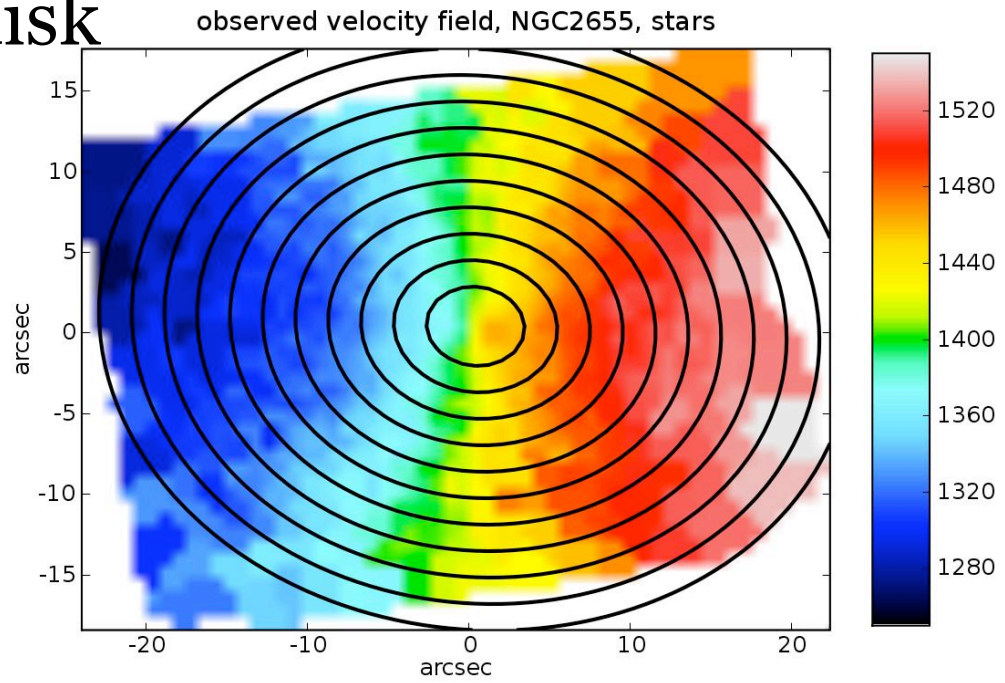
Kinematic Analysis PyRing

$$V_{LOS} = V_{sys} + V_{\phi}(R,\phi)\cdot\cos(\phi)\cdot\sin(i) + V_{R}(R,\phi)\cdot\sin(\phi)\cdot\sin(i)$$

$$\begin{cases} \cos(\phi) = \dfrac{-(x - X_c)\cdot\sin(PA) + (y - Y_c)\cdot\cos(PA)}{R} \\ \sin(\phi) = \dfrac{-(x - X_c)\cdot\cos(PA) - (y - Y_c)\cdot\sin(PA)}{R\cos(i)} \end{cases}$$

- Kinematic parameters: V_{sys}, i, PA, X_c, Y_c, V_R, V_φ
- 2D infinitesimally thin disk
- Tilted-ring method

- Python code
- Robust & friendly-user
- Optical & radio data

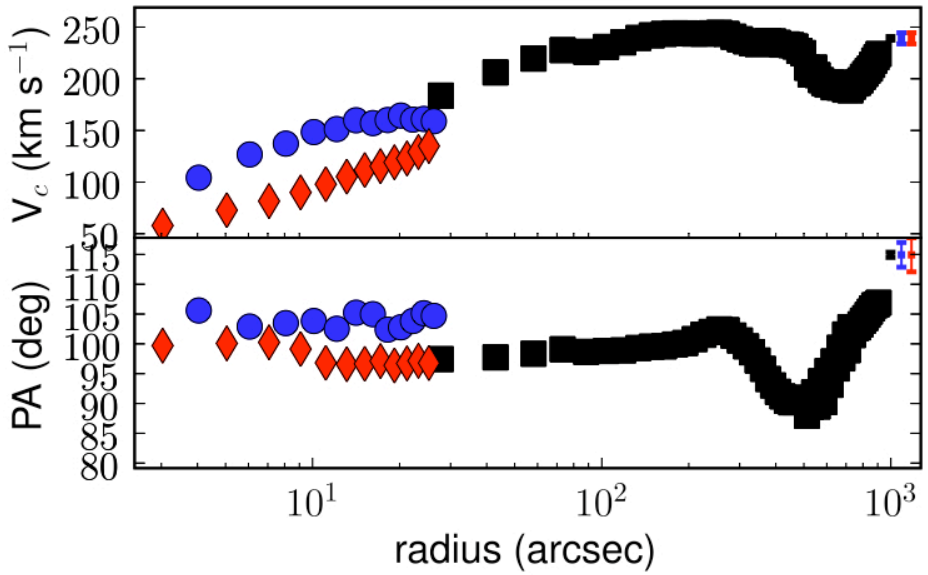


Kinematic Analysis
Circular velocity

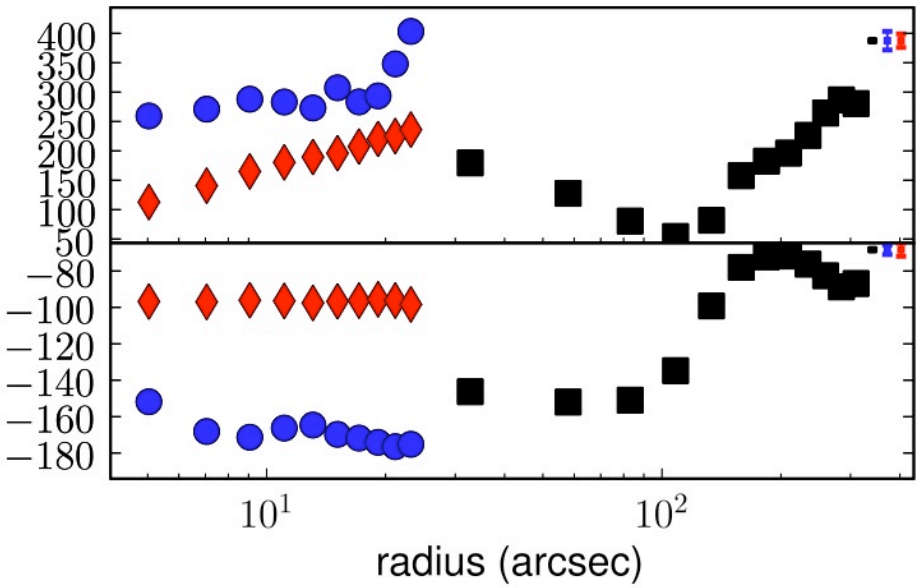
$$V_{LOS} = V_{sys} + V_c(R) \cdot \cos(\phi) \cdot \sin(i)$$

- Global variations: PA and velocity curves
  - ● Ionised gas
  - ◆ Stars
  - ■ HI

NGC5055



NGC2655



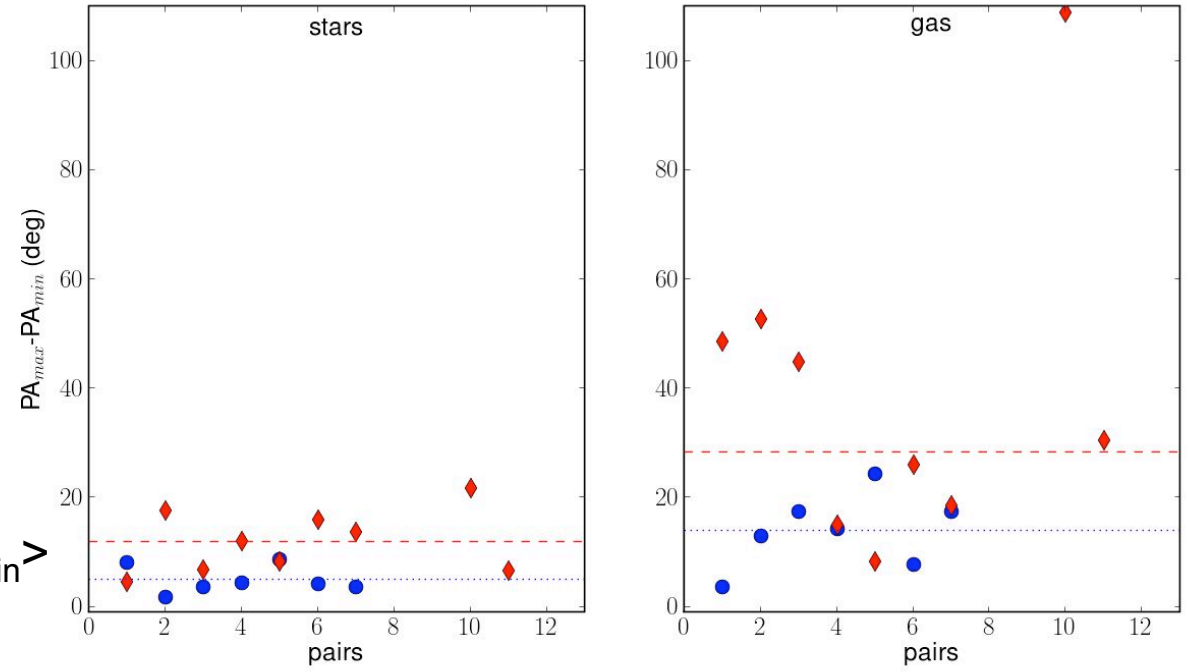
Kinematic Analysis
Circular velocity

Circumnuclear regions

- Stellar kinematics more regular
- Radial variations of gaseous PAs ~ 2.5 times greater in Seyfert

● Non active
◆ Seyfert

<PA$_{max}$ –PA$_{min}$>



Kinematic Analysis Harmonic Decomposition

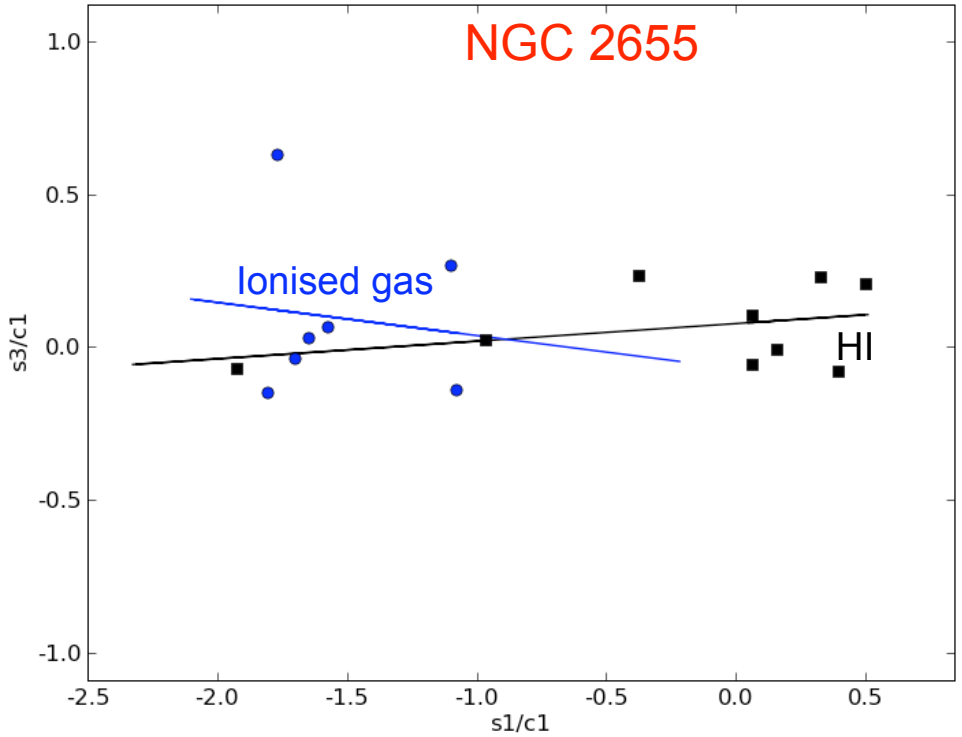
from Schoenmakers et al. 1997, Wong et al. 2004

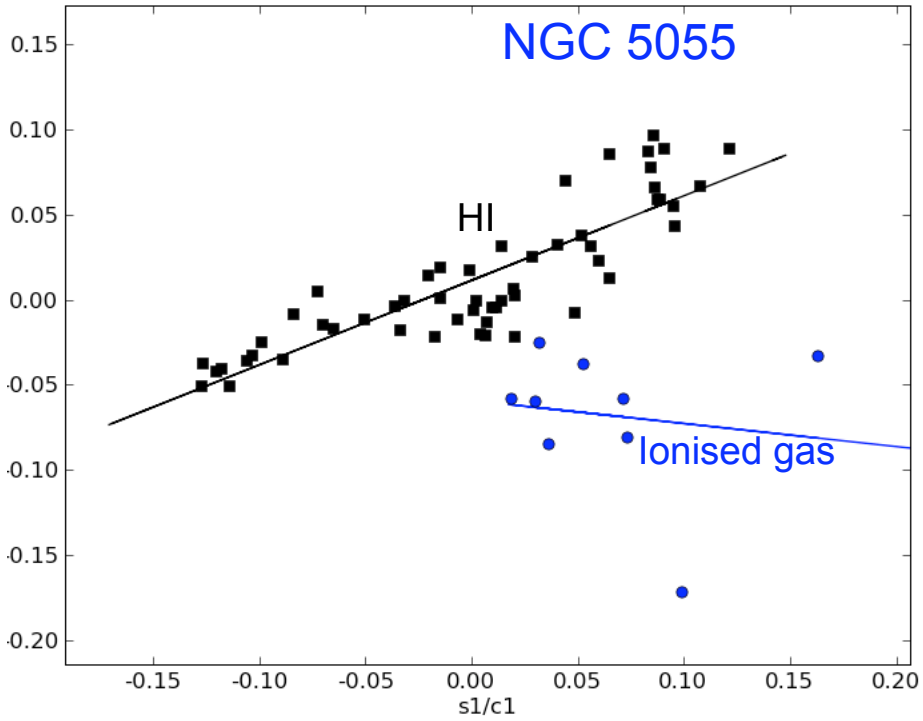
$$V_{LOS} = c_0 + \sum_{n=1}^{k} c_n(R) \cdot \cos(n\phi) + s_n(R) \cdot \sin(n\phi)$$

- Quantify the non-circular motions
- Fourier coeff in term of dynamical perturbations
  - Non-axisymmetric perturbation, order m => m-1 & m +1 coeff (Schoenmakers et al. 1997)
  - Distinguish between barred potential, spiral waves, pure radial streaming (Wong et al. 2004)

Kinematic Analysis
Harmonic Analysis

- Harmonic coefficients
  - ● Ionised gas
  - ■ HI





Conclusion

- Evidence of weak gravitational perturbations in the circumnuclear regions of Seyferts
- PyRing analysis
  - Link circumnuclear regions/large-scale disk
  - Identify the dynamical processes

- What's next?
  - Modelling the underlying potential to interpret the non-circular motions in term of dynamical structures
  - Global dynamical picture
  - Physics of the gas: ionised + neutral (+ molecular, NUGA)