Identifying Seyfert AGN Fueling Mechanisms

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Goal: Trace inflow mechanisms on scales of 1kpc down to tens of parsecs.

Potential Seyfert AGN fueling mechanisms:

i. Major merger

ii. Minor merger

iii. Galaxy interactions

iv. Accretion of gas streamers

v. Secular evolution

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Several studies suggest *__not__* major mergers:

- Over 50% of z~2 AGN in undisturbed host galaxies (Koceviski et al. 2012)
- AGN at z~2 *not* in galaxies with enhanced star formation (Rosario et al. 2013)

Goal: Trace inflow mechanisms on scales of 1kpc down to tens of parsecs.

Potential Seyfert AGN fueling mechanisms:

i. Major merger

ii. Minor merger

Minor mergers perhaps associated with low and intermediate luminosity AGN (Neistein & Netzer 2014)

iii. Galaxy interactions

iv. Accretion of gas streamers

v. Secular evolution

Detailed Kinematics Required

- ✧ Imaging studies cannot differentiate between the relative roles of minor mergers, gas accretion (due to interactions or streamers), or secular evolution
- ✧ Detailed studies of the kinematics are needed to do this
- ✧ Also need to look at spatial scales with relevant timescales:

✓ AGN duty cycle is 100 Myrs with flickering on scales of **1-10 Myrs** (e.g. Hickox et al. 2014)

✓ At r=100pc v=100-150 km s^{-1} (Hicks et al. 2013)

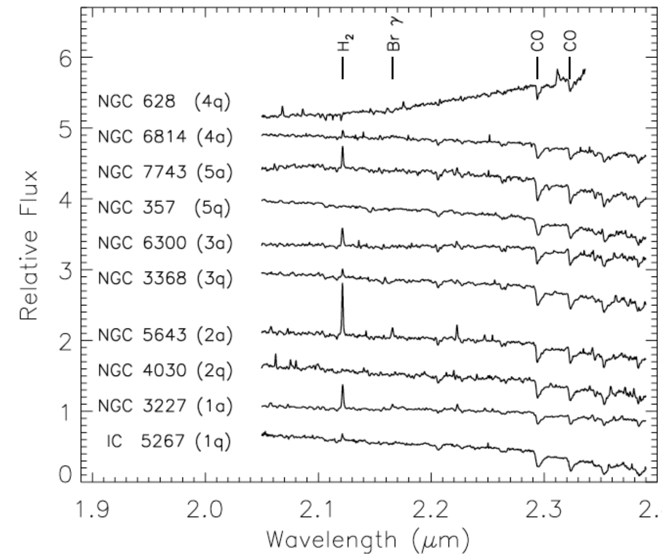
→ Dynamical timescale of **2-3 Myrs**, comparable to duty cycle

With local galaxies we can probe the central few hundred parsecs at the resolution needed to accurately measure the nuclear gas and stellar kinematics

Matched Sample: Seyfert & Quiescent Galaxies

- Galaxy pairs (from Martini et al. 2003) matched in large scale (>kpc) host galaxy properties:

  galaxy type, optical luminosity, angular size, inclination, and distance



- 5 galaxy pairs
- VLT SINFONI *K*-band data
- Average resolution 54 ± 24 pc

Summary of Observations

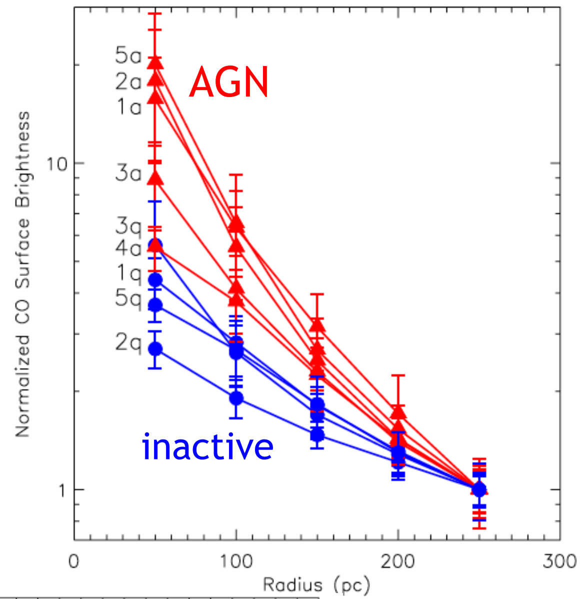
ID	Galaxy	D (Mpc)	Ref.[b]	pc/″	T_{int} (minutes)	PSF FWHM (″)	PSF FWHM (pc)
1a	NGC 3227	21.1	1	102	50	0.55	56
1q	IC 5267	30.3	2	147	140	0.61	90
2a	NGC 5643	16.9	3	82	140	0.49	40
2q	NGC 4030[a]	27.2	4	132	50[a]	0.66[a]	87[a]
3a	NGC 6300	17.1	4	83	140	0.48	40
3q	NGC 3368	10.5	5	51	40	0.58	30
4a	NGC 6814	22.8	3	111	140	0.51	57
4q	NGC 628	9.9	6	48	100	0.59	28
5a	NGC 7743	19.2	7	93	140	0.54	50
5q	NGC 357	32.1	3	156	90	0.62	97

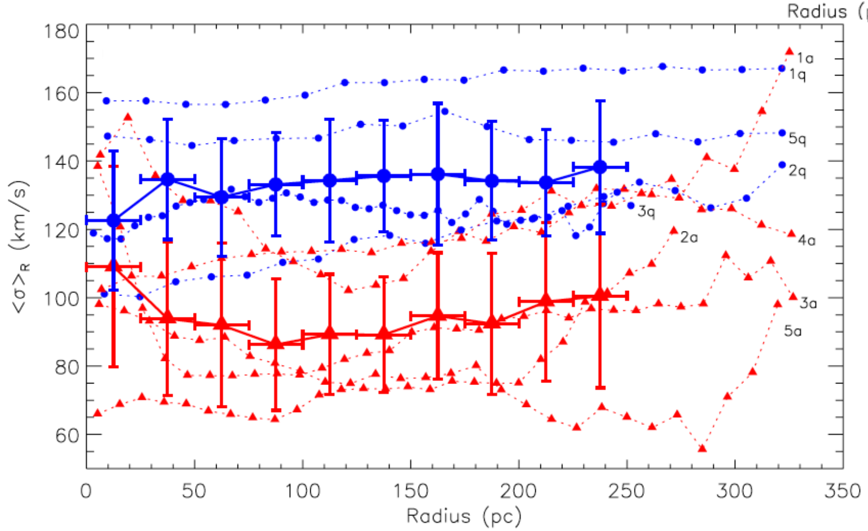
Comparison of Integrated Properties

Seyferts systematically have:

(1) a more centrally concentrated nuclear stellar surface brightness

(2) a lower central stellar velocity dispersion (r < 200 pc)





Stars traced by CO 2.3μm bandheads

Comparison of Integrated Properties

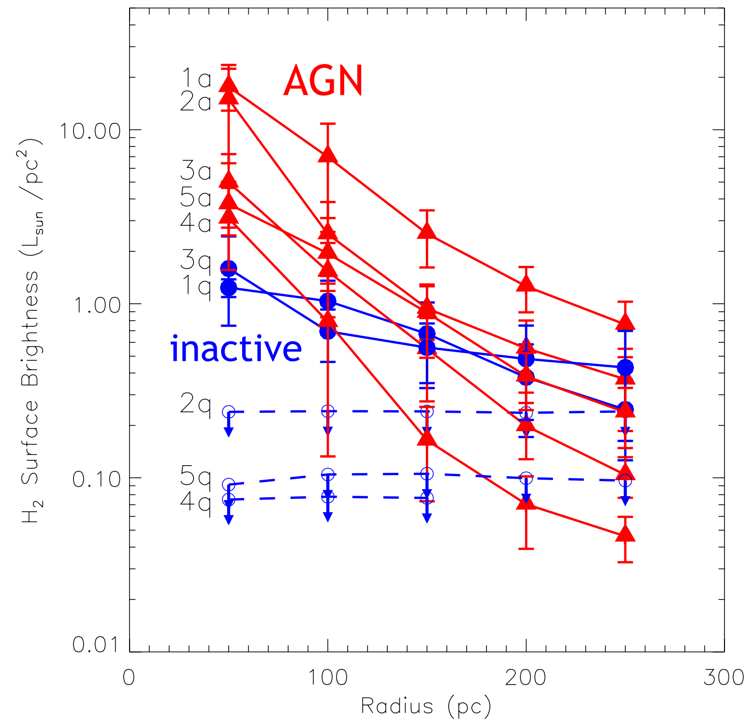
Seyferts systematically have:

(1) a more centrally concentrated nuclear stellar surface brightness

(2) a lower central stellar velocity dispersion (r < 200 pc)

(3) more centrally concentrated H_2 surface brightness profiles

(4) elevated central H_2 1-0 S(1) luminosity (r < 250 pc)



Molecular gas traced by H_2 1-0 S(1)

Comparison of Integrated Properties

Seyferts systematically have:

(1) a more centrally concentrated nuclear stellar surface brightness

(2) a lower central stellar velocity dispersion ($r < 200$ pc)

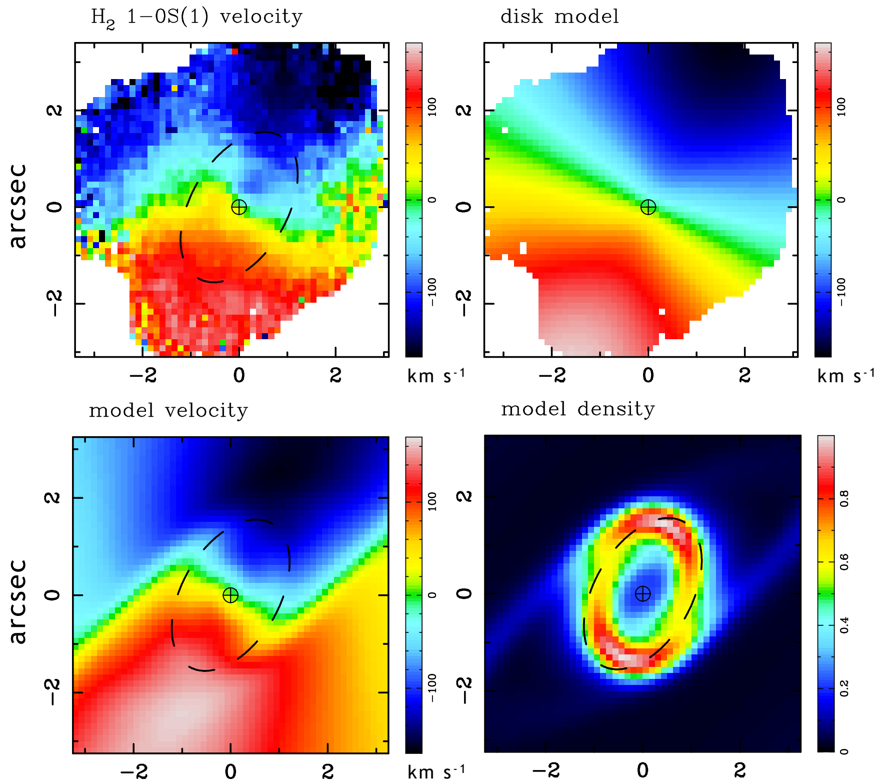
(3) more centrally concentrated H_2 surface brightness profiles

(4) elevated central H_2 1-0 S(1) luminosity ($r < 250$ pc)

- dynamically cold (in comparison to the bulge) component of gas and stars on scales of hundreds of parsecs *in Seyferts*
- significant gas reservoir and a relatively young stellar population
- nuclear stellar population requires a supply of gas from which to form
  → inflow required

Hicks et al. 2013

Kinematic Analysis: Inflows

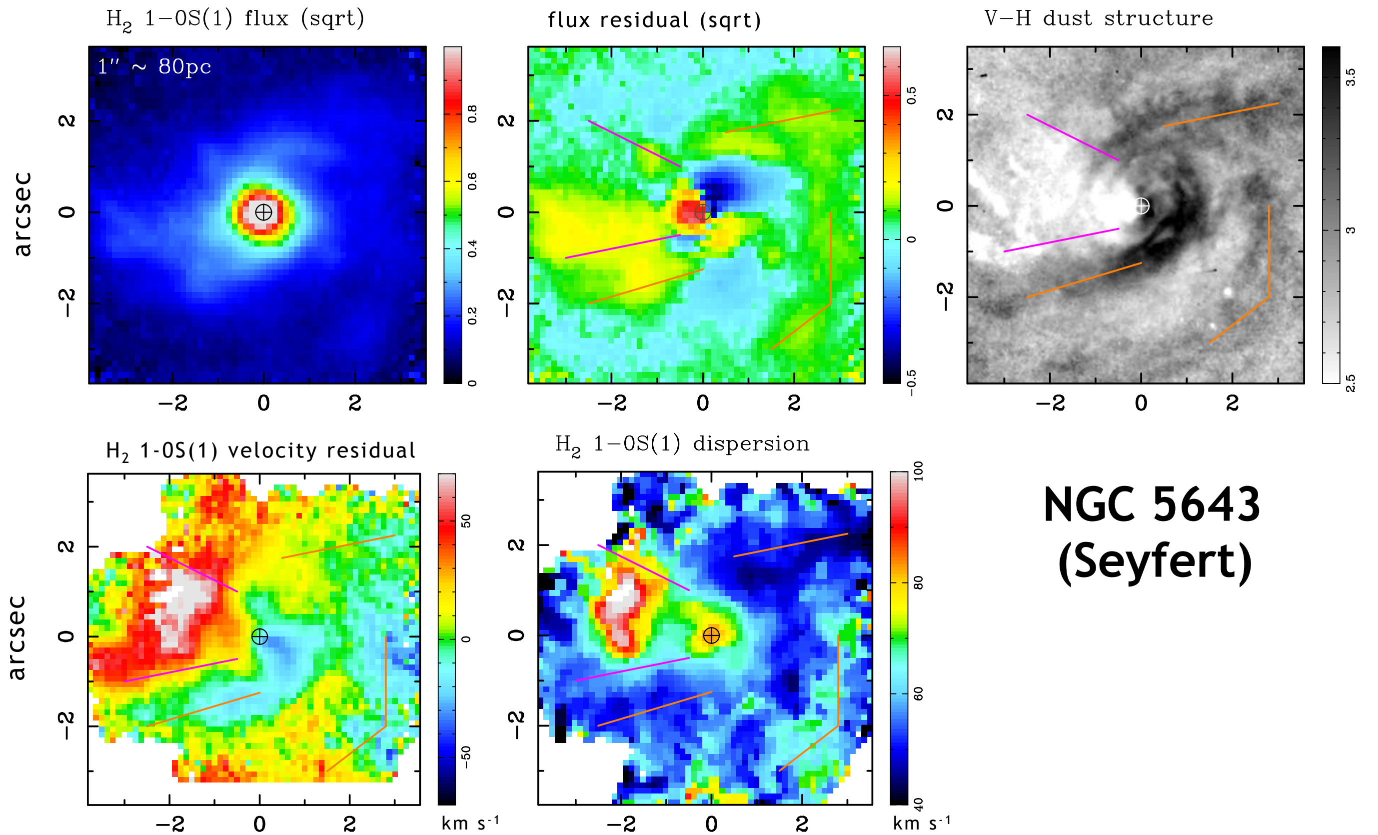


hydrodynamical models qualitatively verify that for **NGC 3227** there is **inflow in a bar** that settles in a nuclear ring

- H_2 detected in all 5 Seyferts and 2 inactive galaxies, all with rotating disk
- 3 Seyferts show signatures of inflow
- Inflow along large scale bars in 2 Seyferts

Kinematic Analysis: Outflows

- At least 3 Seyferts have spatially resolved molecular outflows (+1 with indirect evidence)



NGC 5643 (Seyfert)

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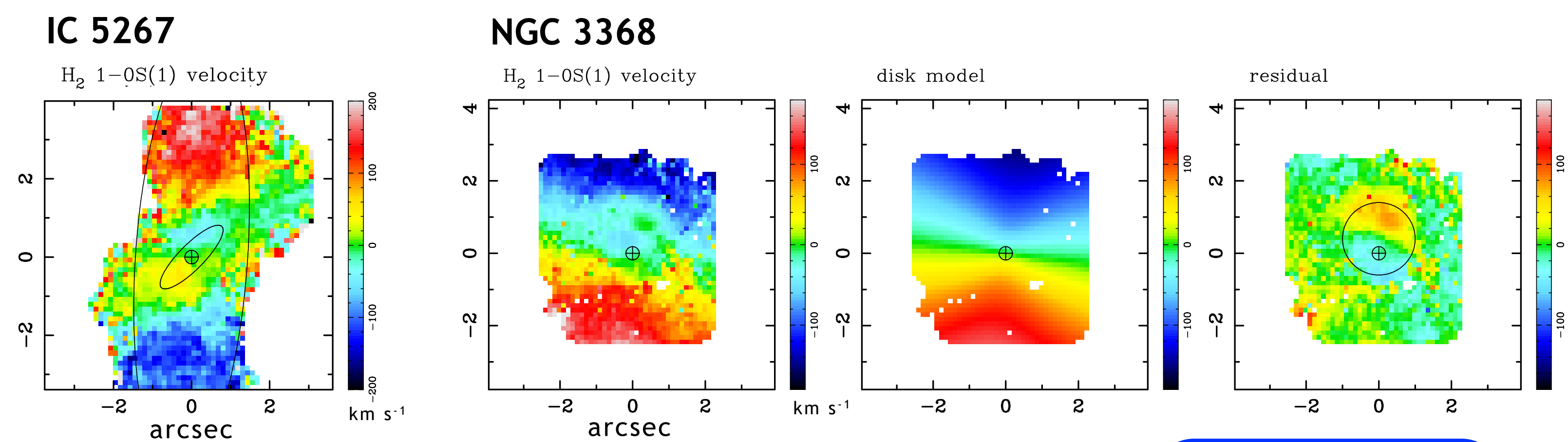
Inactive Galaxies: Counter Rotation

- Two inactive galaxies with H_2 detected have counter rotating molecular components



- Implies external accretion of molecular gas

- configurations are quasi-stable → a small perturbation would likely result in significant gas inflow

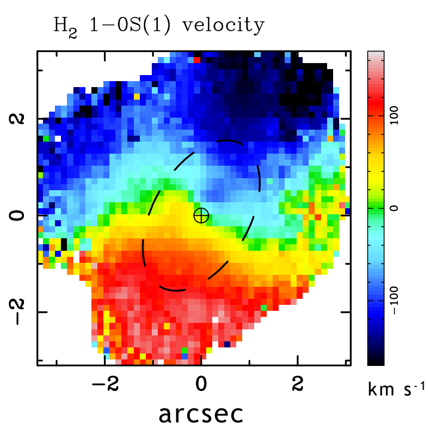
AGN in an off state?

Complex Molecular Gas Kinematics:
Inflows & Outflows Superimposed on Rotating Disks

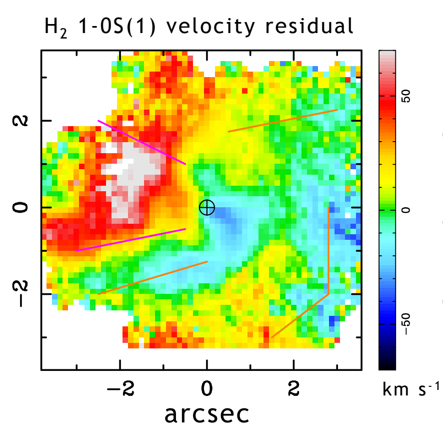
H_2 detections:	all 5 Seyferts, 2 inactive galaxies
rotating disks:	all with H_2 detection
inflow:	3 Seyferts
outflow:	3 (+1) Seyferts
perturbed:	2 inactive galaxies

All 10 galaxies have unperturbed stellar kinematics

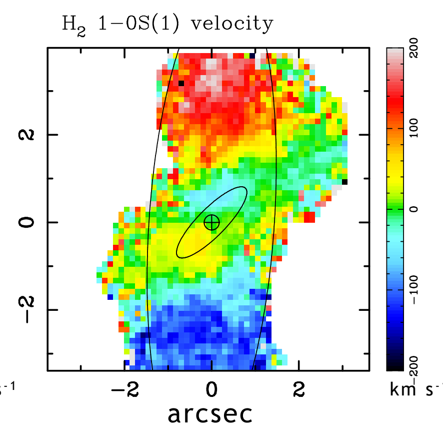
NGC 3227 (Seyfert)



NGC 5643 (Seyfert)



IC 5267 (inactive)



Testing the “External Accretion” Hypothesis for Early Type Galaxies

Predictions:

- lack of gas in inactive galaxies vs. presence of gas in active early type galaxies
- existence of counter-rotating gas in some early type galaxies vs. few in late type galaxies
- a sufficiently dense local intergalactic environment

Support found in:

- ✓ matched active/inactive galaxy samples: sample presented here, as well as Dumas et al. 2007 and Westoby et al. 2012
- ✓ by early type samples: Sarzi et al. 2006; Davis et al. 2011

Environmental Role in Fueling Seyfert AGN

There is a strong link between:

- local environment
- cirumnuclear dust structures (which may also be caused by dust superimposed along the line of sight)
- circumnuclear H_2 structures/kinematics

- Chaotic circumnuclear structures: associated with external accretion within moderately dense groups with 10–15 members (but not clusters).
- Circumnuclear ordered spiral structures: relatively isolated galaxies, indicate that the large scale disk is the source of gas.

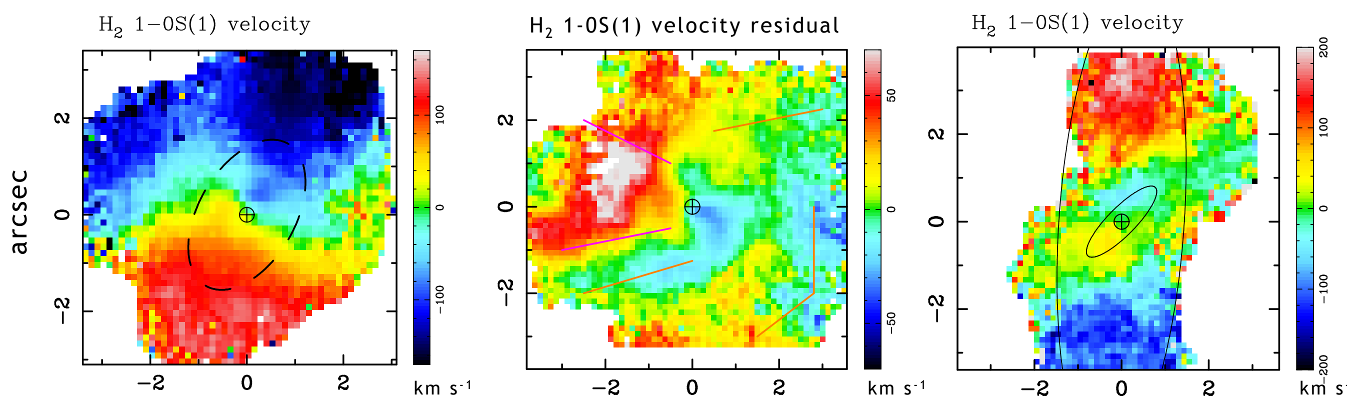
This difference is driven primarily by environment and the relation to galaxy type is secondary

Primary Fueling Mechanism of Seyfert AGN?

External accretion and environment may play a significant role in dictating fueling of nuclear activity.

Implications:

- Samples should take environment into account
- Relevant timescales must be considered when selecting inactive control sample



NGC 3227 (Seyfert) NGC 5643 (Seyfert) IC 5267 (inactive)