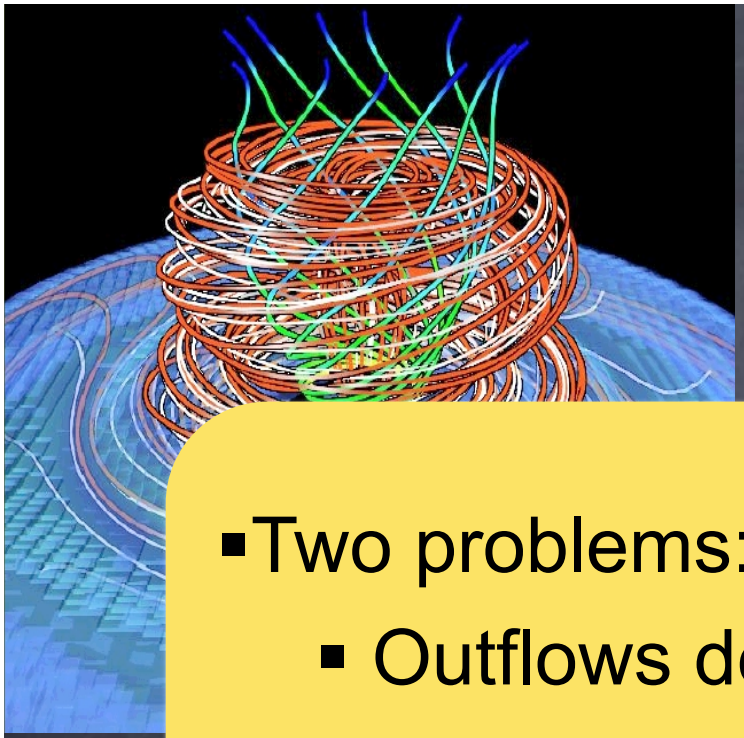
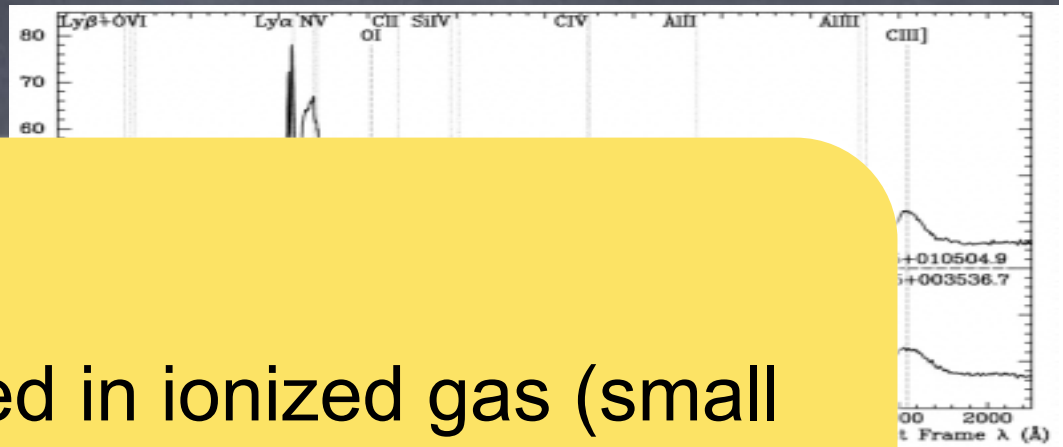
AGN winds and outflows



BAL QSOs (10-40% of all QSOs)

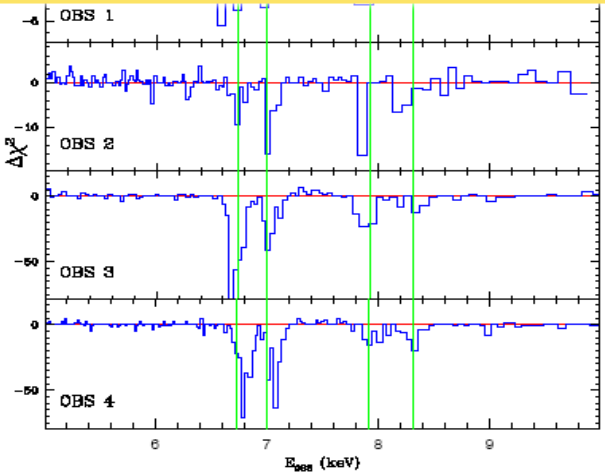


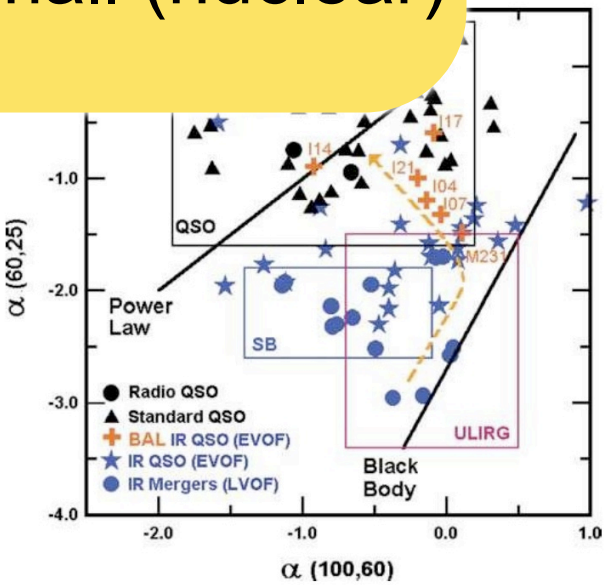
- Two problems:
  - Outflows detected in ionized gas (small fraction of all galaxy gas)
  - Physical scale unknown or small (nuclear)

Fast w
to a fr
observ
regions of AGNs; they likely originate from the acceleration of disk outflows by the AGN radiation field.

Crenshaw+03, Pounds+03, Reeves+09, Moe+09

+ 2006





Galaxy scale ionized outflows

- IFU observations of [OIII] emission of radio galaxies, up to z=2.5 (Nesvabda+ 2006, Swinbank+ 2005,2006)
  - Extent of broad [OIII] similar to radio emission
  - Ekin~1-40% Ejet
- SMMJ1237, a QSO in a z~2 ULIRG (Alexander+ 2010)
  - Extent of broad [OIII] ~4-8kpc
  - E_{kin}~10^{59} ergs over 30Myr ~ binding energy of galaxy spheroid
- Giant SF clumps at z~2 (Genzel +2011)
  - Broad Hα wings, mass outflow rate > SFR

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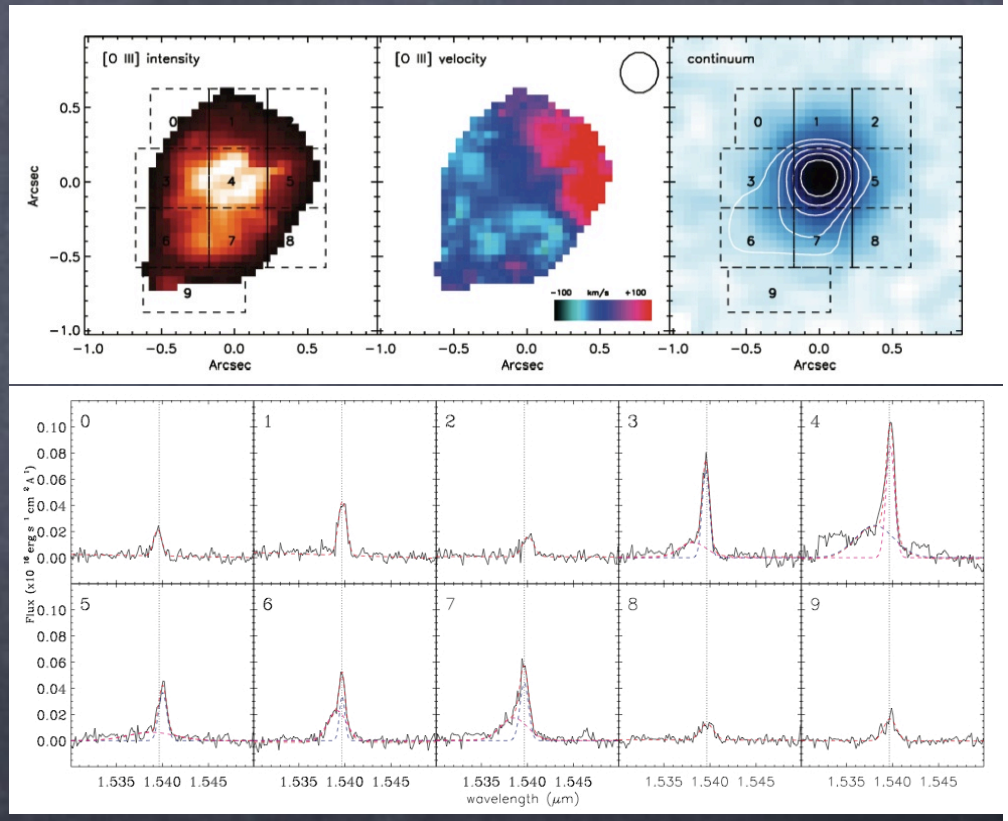

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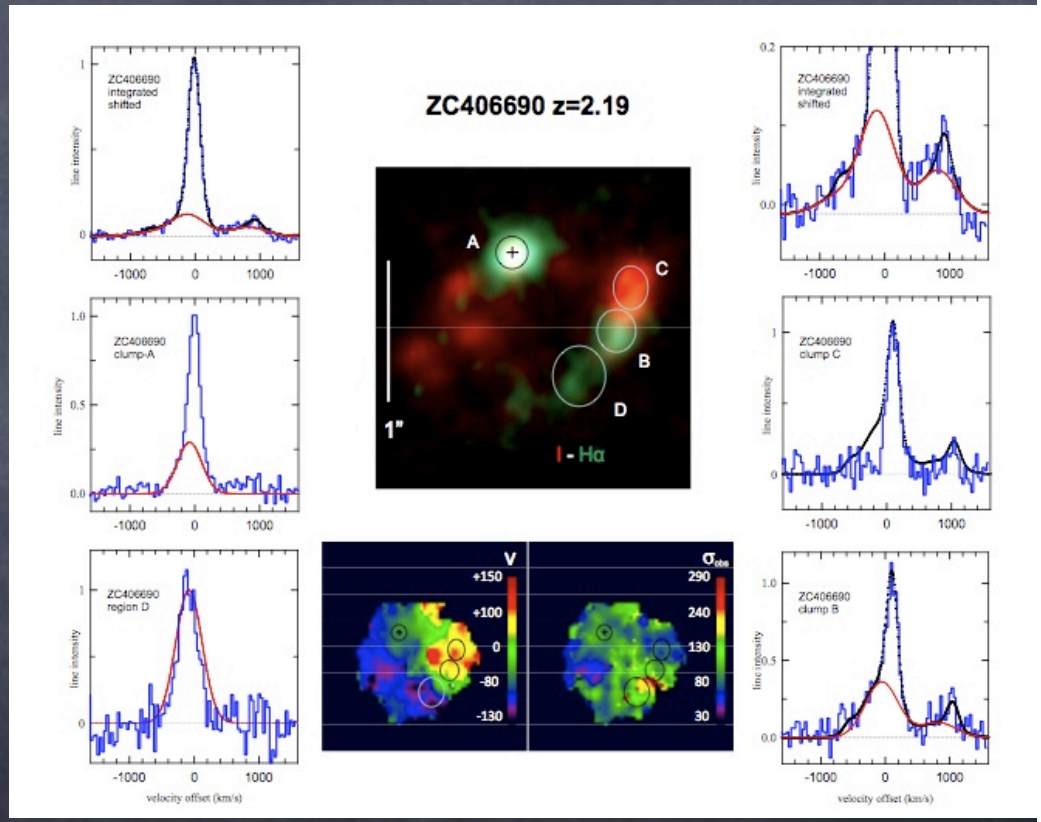

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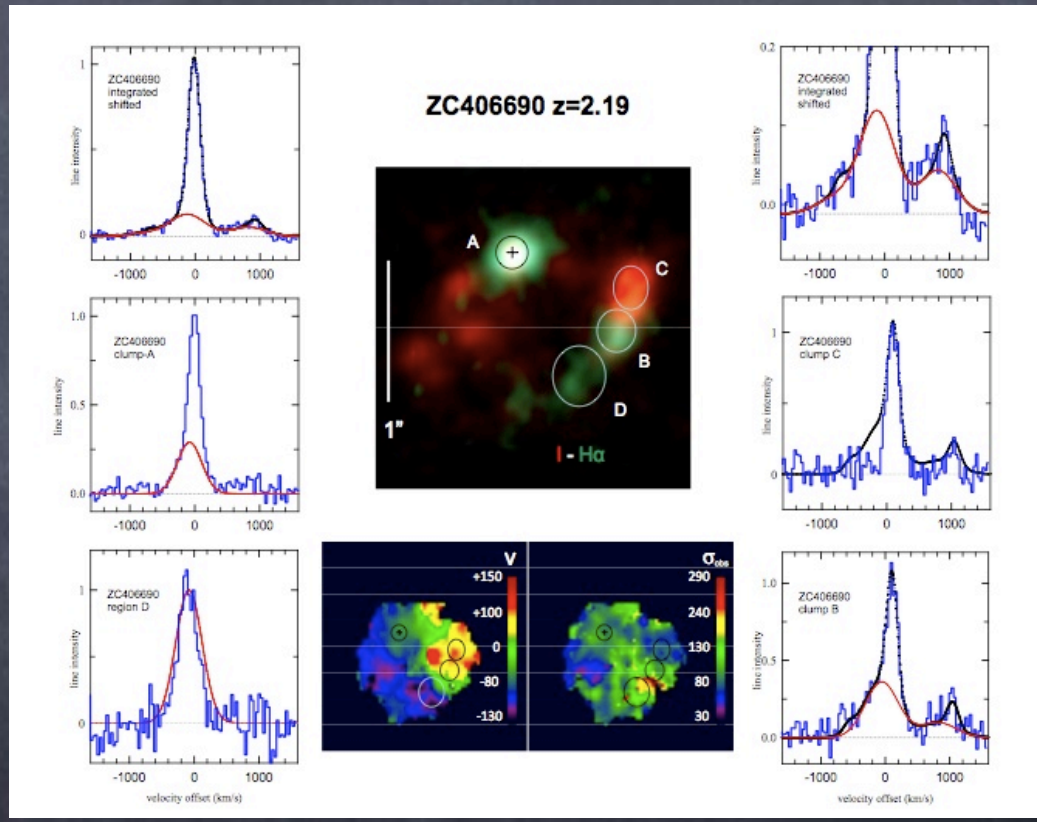


Mid-IR & Far-IR lines revealing AGN-driven outflows:

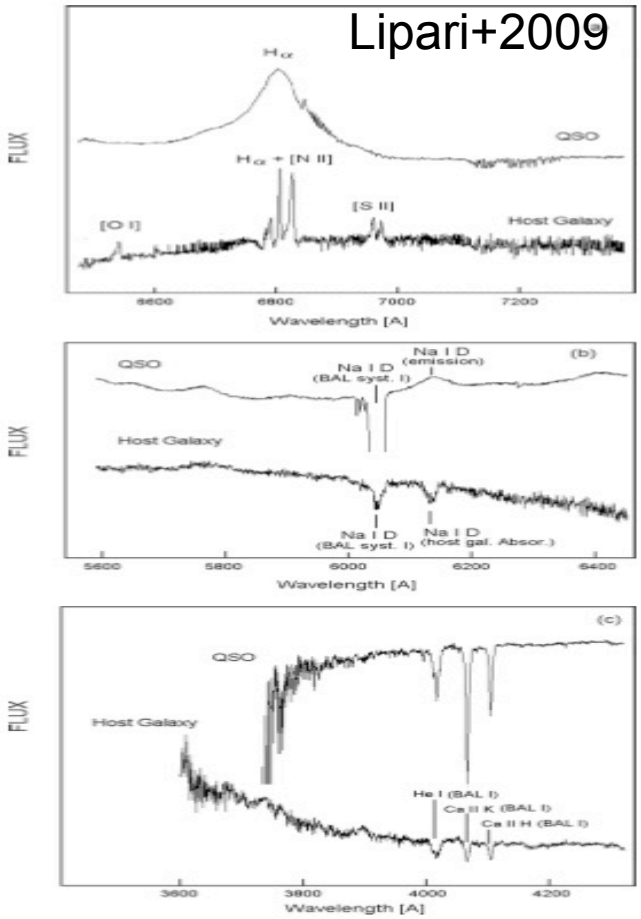
(I) Molecular gas
(II) Ionized gas

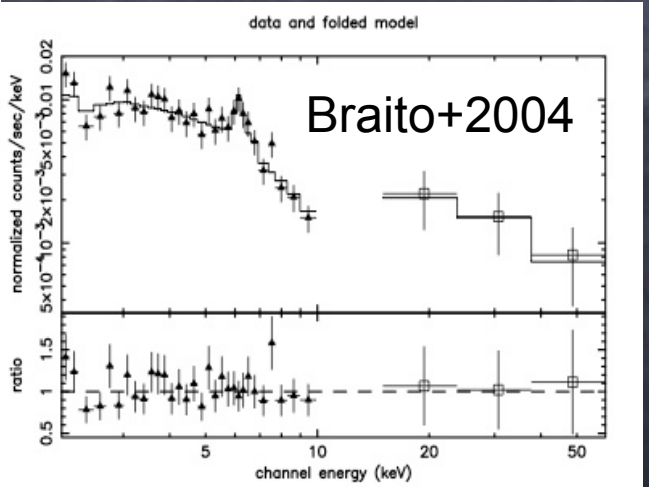
▪Three science cases for testing the role of AGN feedback by a detailed kinematic study of the outflowing gas

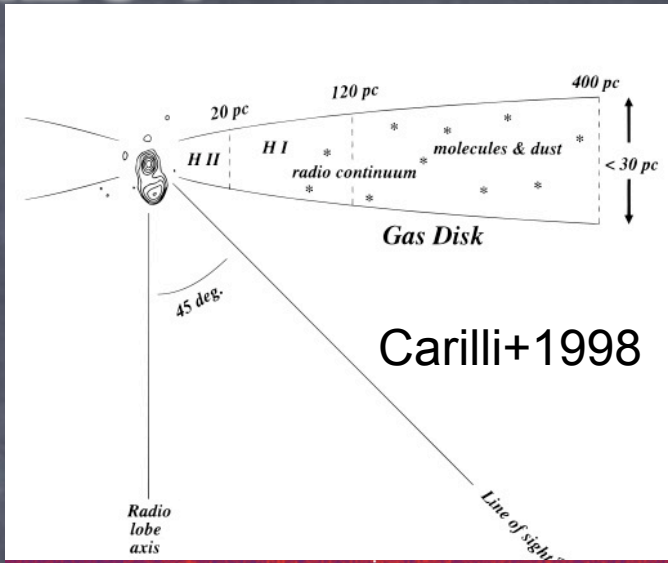
- Massive CO, OH outflows (Feruglio+2010, Sturm+ 2011)
- Warm H2 gas (Dasyra & Combes 2011)
- Blueshifted [Ne III] + [Ne V] lines (Spoon & Holt 2009)

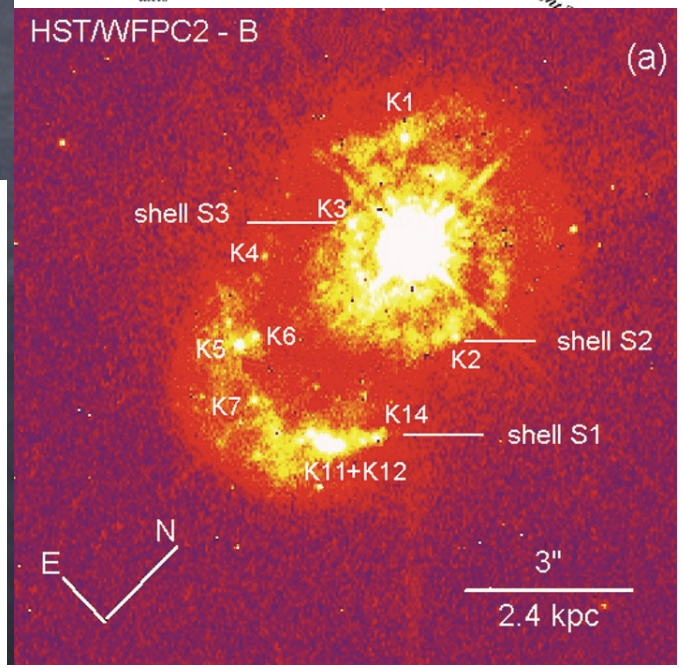
Galaxy scale molecular outflows: the case of Mrk231

- The nearest (z=0.042, 187Mpc), high luminosity (L_{bol}~10^{46} erg/s), highly obscured (N_H~10^{24} cm^{-2}) (BAL)QSO.



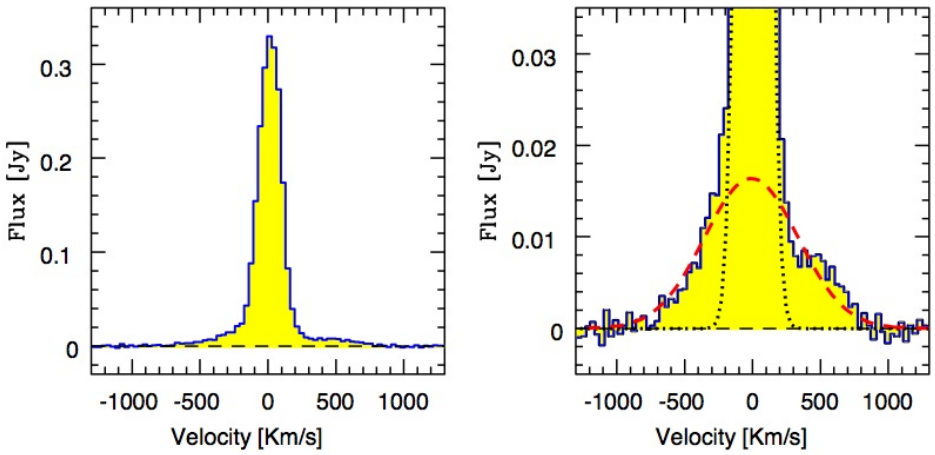






AGN outflows vs star formation

Mark231 broad CO line wings Feruglio+2010



L_{bol}~5×10^{45} ergs/s

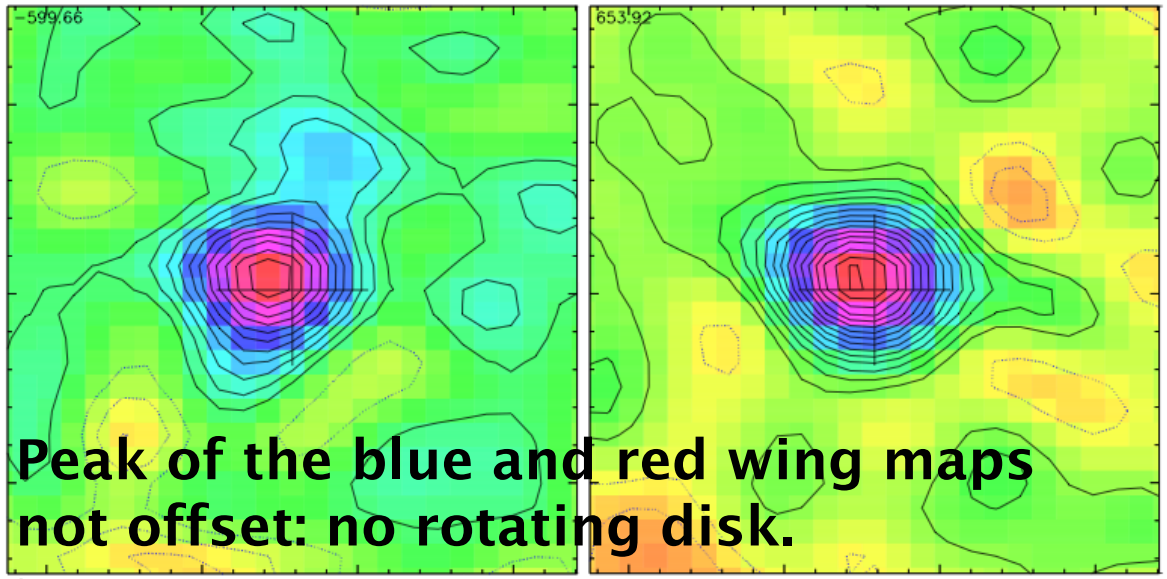
M_{H2}~7×10^{7} M_{sun}

(uncertain conversion L'CO to M_{H2})

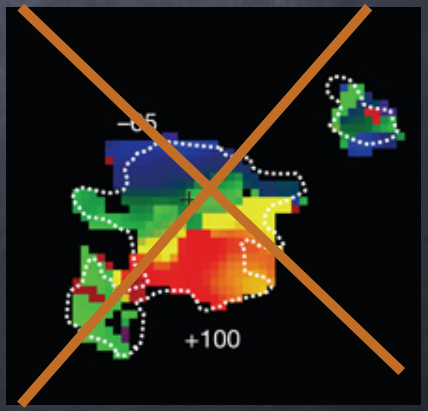
M_{out}~700 M_{Sun}/yr, SFR~200M_{sun}/yr:

L_{bol}/M_{out}~7×10^{42} erg/s / M_{Sun}/yr

Wings are spatially resolved and extended on 1.2 kpc scales.



Peak of the blue and red wing maps not offset: no rotating disk.

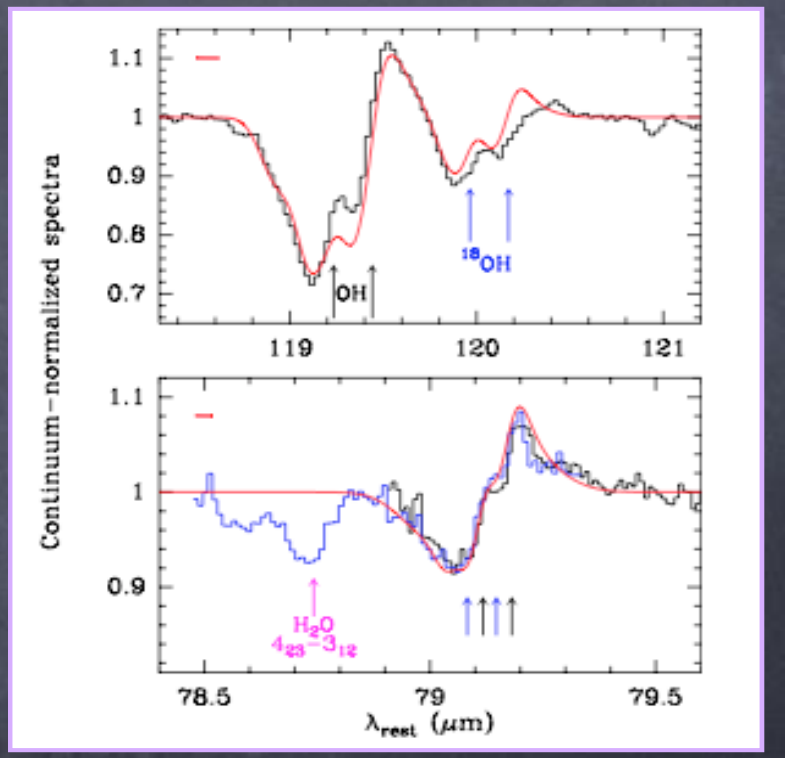


OUTFLOW!!!

AGN outflows: Herschel spectroscopy

P-cygni profile in OH, Herschel PACS spectra

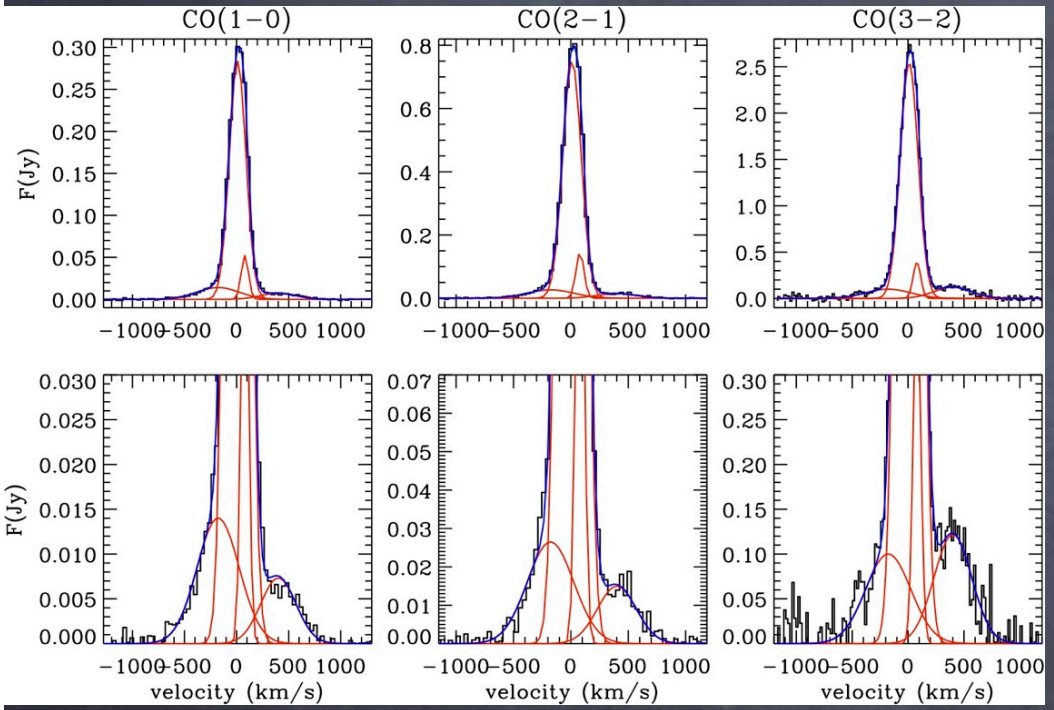
Fisher+2012



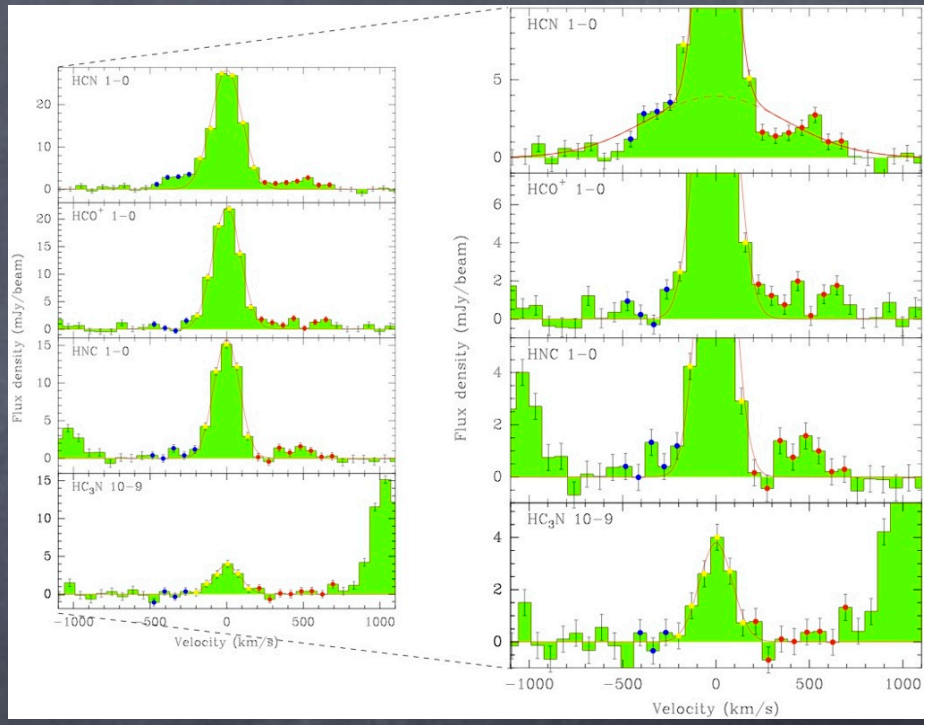
- Mass loss rate larger than the SFR: gas depletion time of the order 10^7-10^8 yr
- No stellar populations younger than 10^6 years in the central kpc (Lipari+2009)

The prototype Massive Outflow: Mrk 231

Broad wings detected in several other molecular transitions (Aalto+ 2012, Cicone+ 2012)



CO transitions

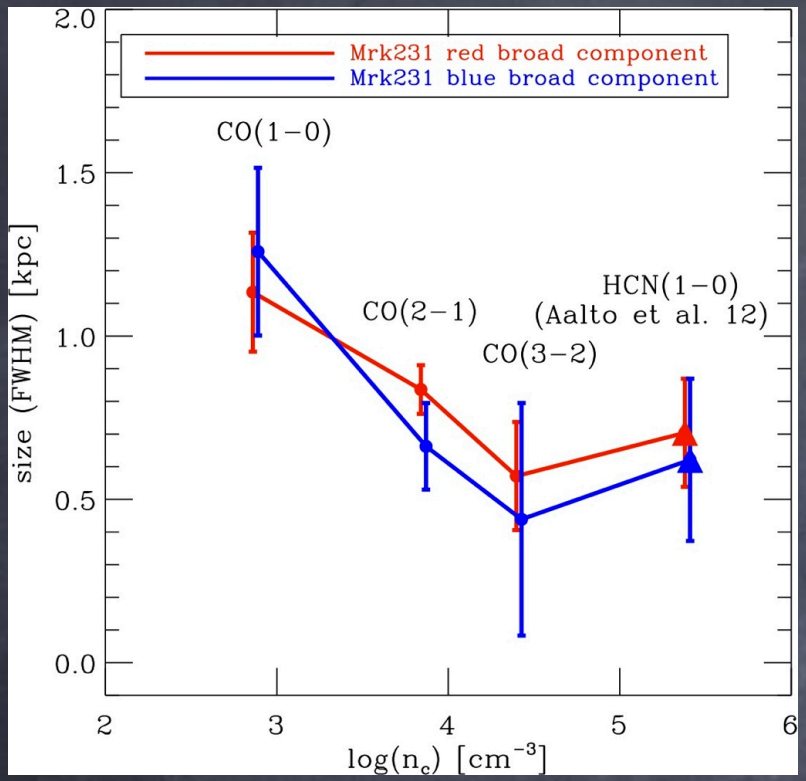


HCN HCO+ tracing dense clumps

Kinetic energy of outflowing gas: $E = 1.2\times10^{44}$ erg/s = a few % L_{Bol} (5×10^{45} erg/s) of the AGN

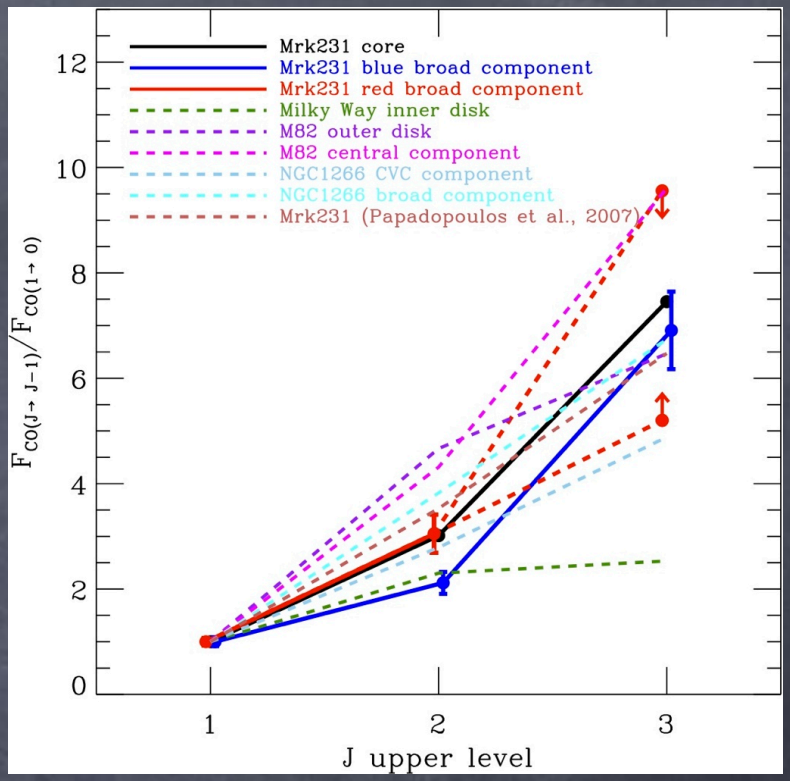
compatible with models of AGN-driven outflow through a shock wave.

The prototype Massive Outflow: Mrk 231



Size is anti-correlated with the critical density: denser outflowing gas has more compact morphology

Cicone+ 2012



No difference in excitation of CO transitions in the high-v vs low-v gas.

Large uncertainties, CO(4-3) red wing may be blended with H13CN(4-3)

Agrees with King & Zubovas 2012: dense outflowing clouds embedded in a atomic outflow are not excited by shocks.

The prototype Massive Outflow: Mrk 231

Rupke+ 2011

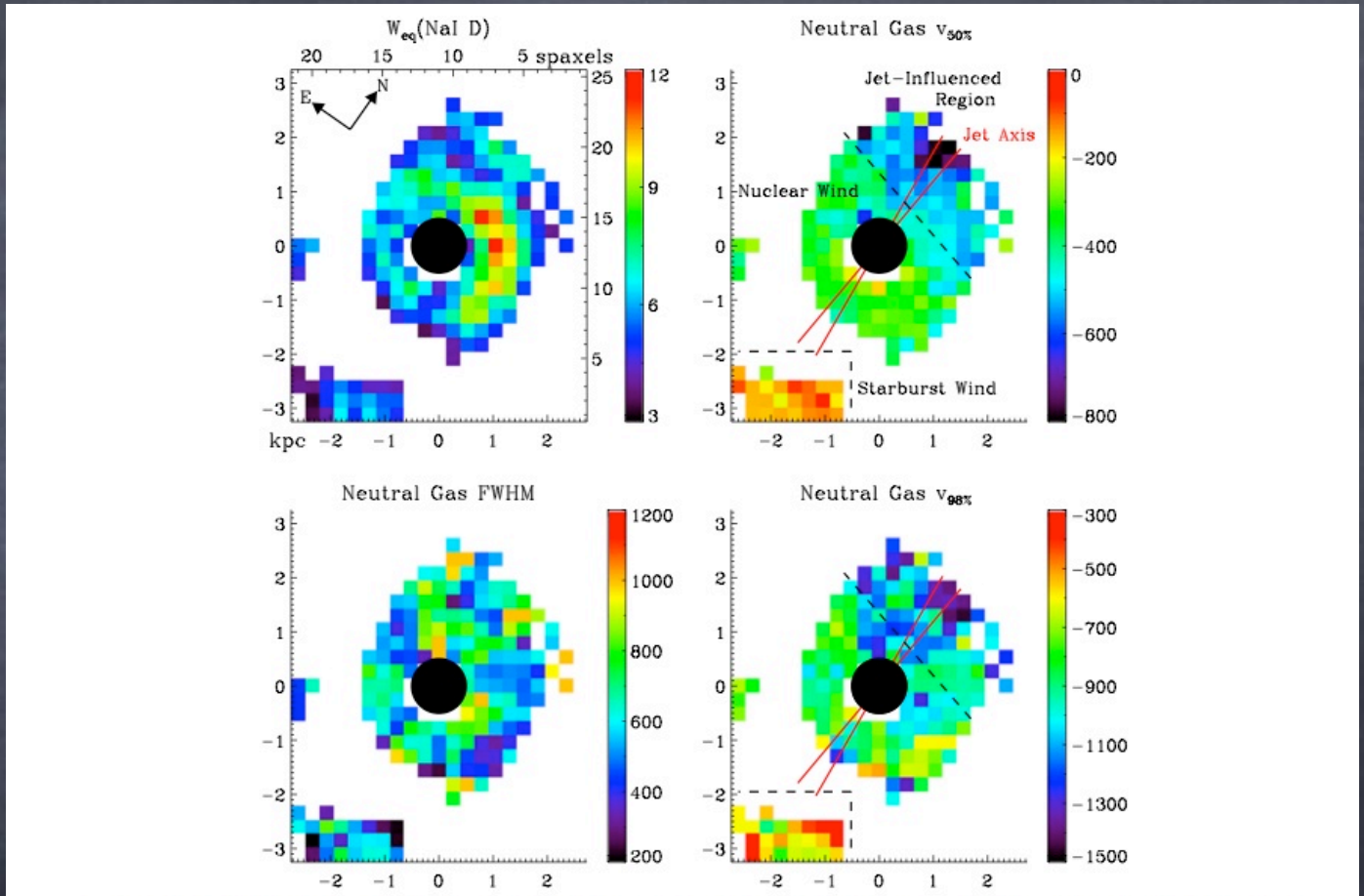


Figure 4. Equivalent width, central velocity, FWHM, and $v_{98\%}$ maps of N I D. A nuclear outflow extends from the nucleus up to 2–3 kpc in all directions (as projected in the plane of the sky). The high velocities suggest that the AGN powers the nuclear wind. The northern quadrant of the nuclear wind is further accelerated by the radio jet. A lower-velocity starburst-driven outflow is present in the south.

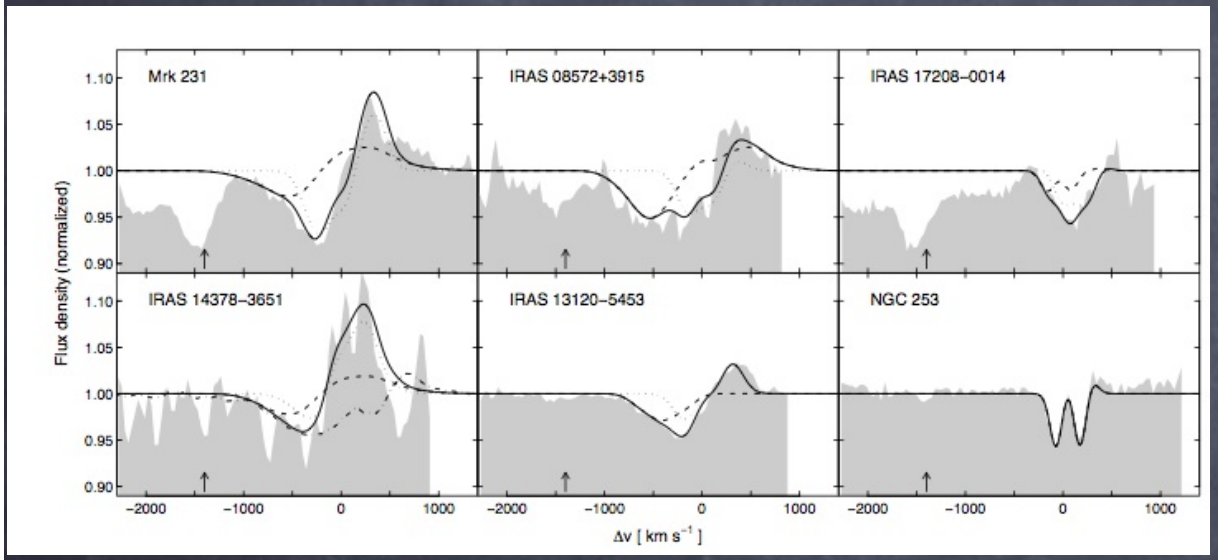
Extended outflow detected in IFU IR observations of neutral gas as well

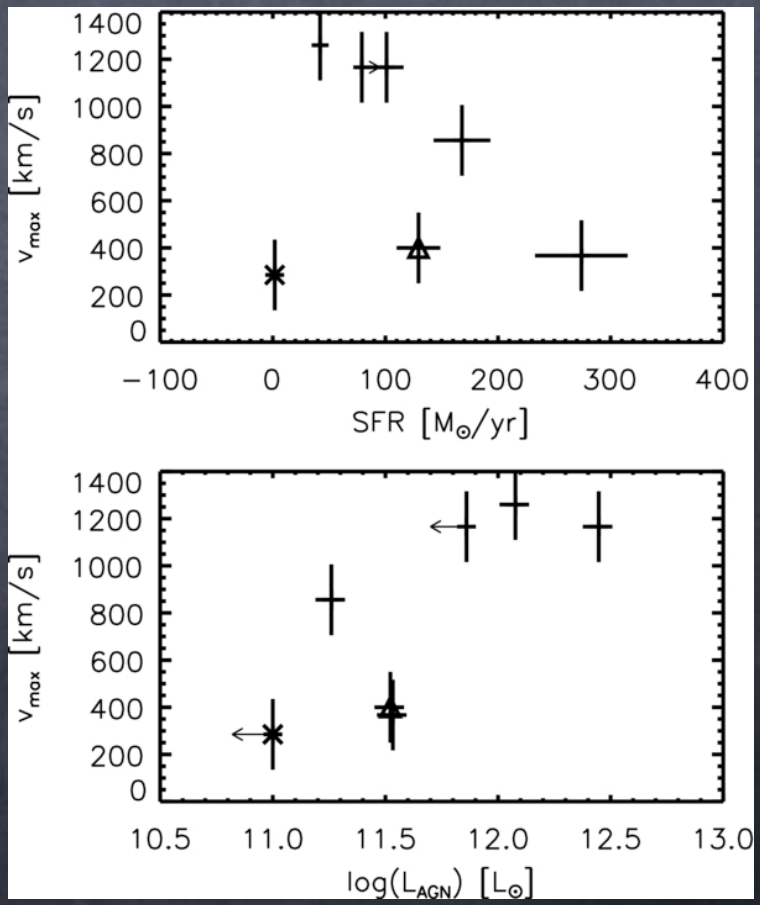
Also a blu-shifted HII region, probably outflow powered by star-formation.

Showing the complex nature of Mrk 231 :OUTFLOWS from AGN and SF acting at the same time

AGN outflows vs star formation

Sturm+2011 Herschel PACS BAL spectra composite sample of both AGN and SF-dominated ULIRGS. Outflows detected through P-cygni profiles of OH. Mass loss rate depends on the OH abundance but > several hundreds M_{Sun}/yr





What is powering the outflows?

Terminal velocity vmax correlated with LAGN --> powered mainly by the AGN

Terminal velocities > 1000 km/s in AGN-dominated objects