



CAUGHT IN THE ACT BY HERSCHEL: GALACTIC STORMS SWEEP AWAY THE GAS

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Herschel press release 2011.05.09
Sturm, E., et al. 2011, ApJL, 733, L16
Massive molecular outflows and negative
feedback in ULIRGs observed by Herschel-PACS

NEWS

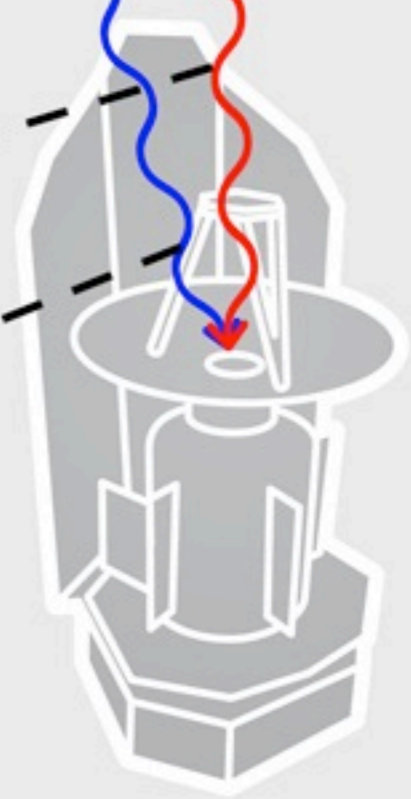
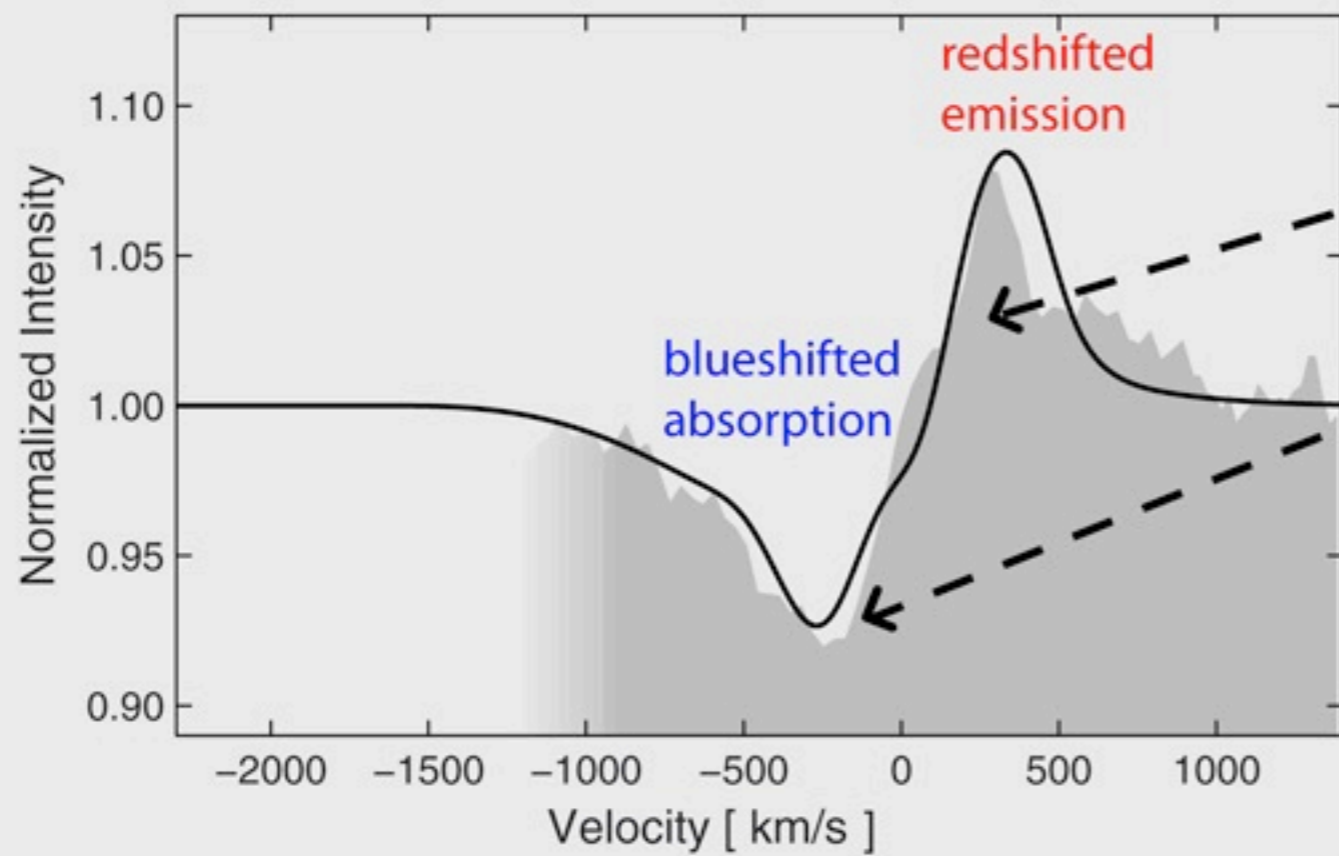
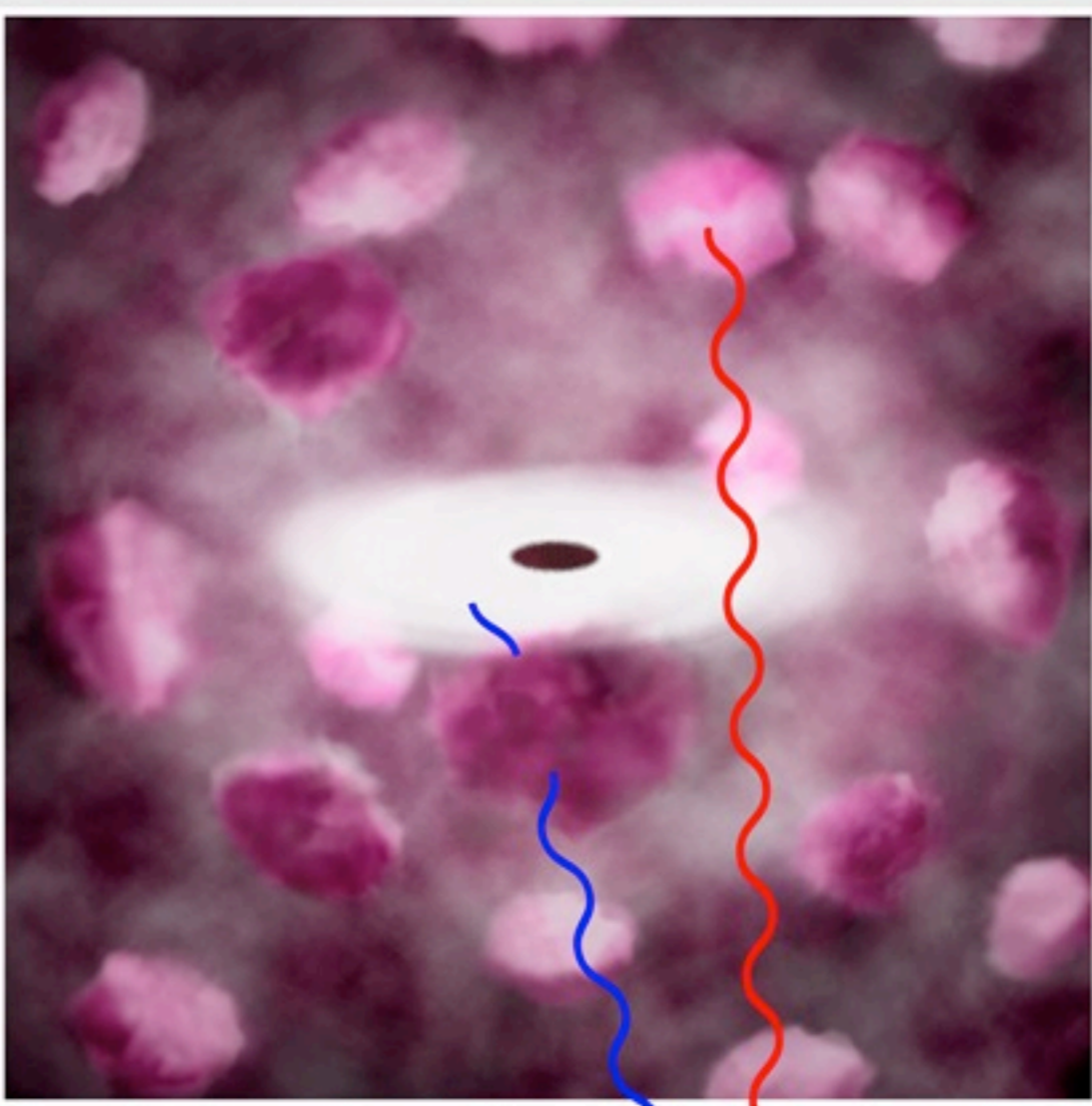
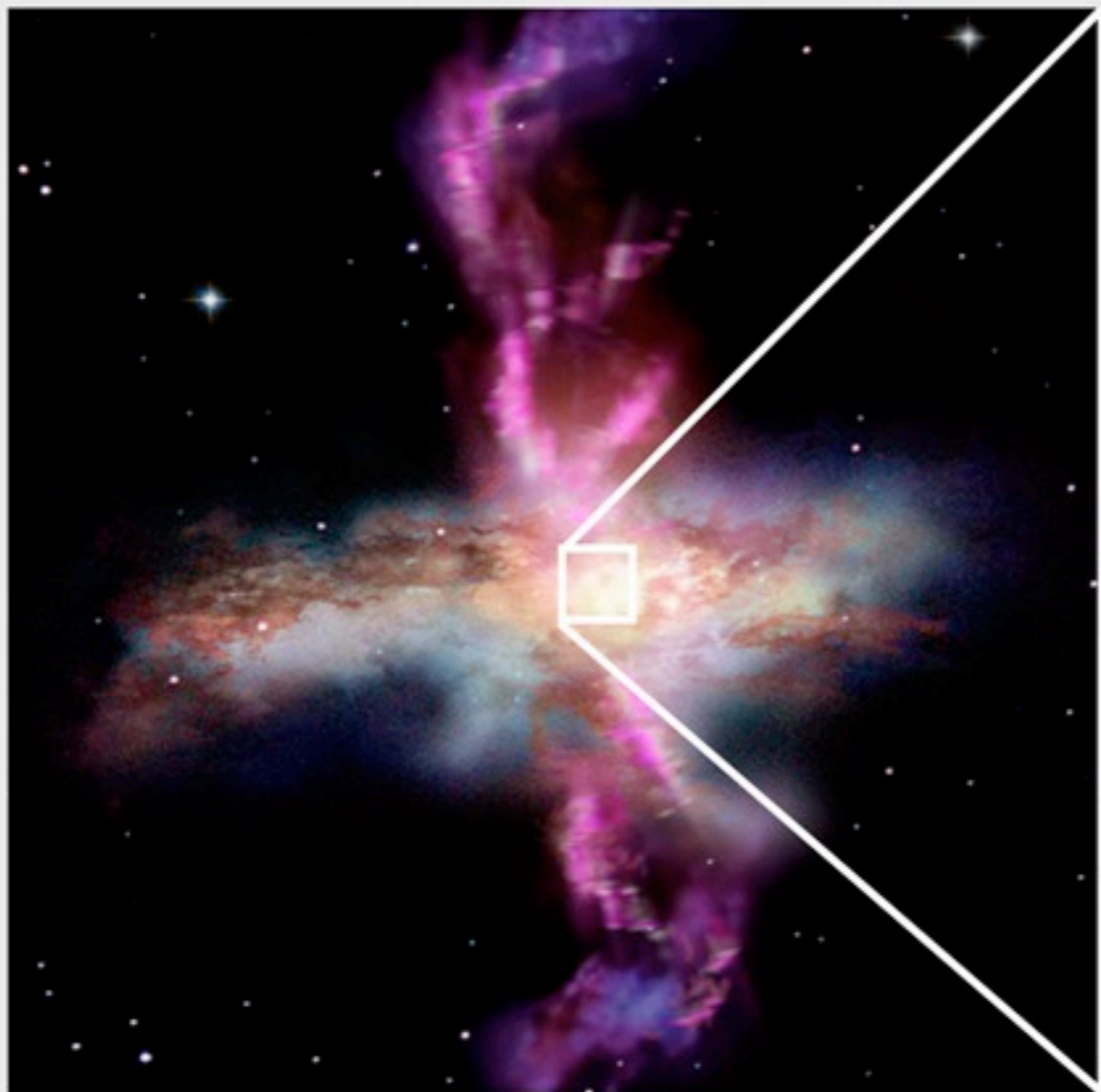
- Evidences showing that Ultra-Luminous InfraRed Galaxies (ULIRGs) exhibit massive outflows of molecular gas.
- In support of the **merger-driven scenario** for the formation of elliptical galaxies.

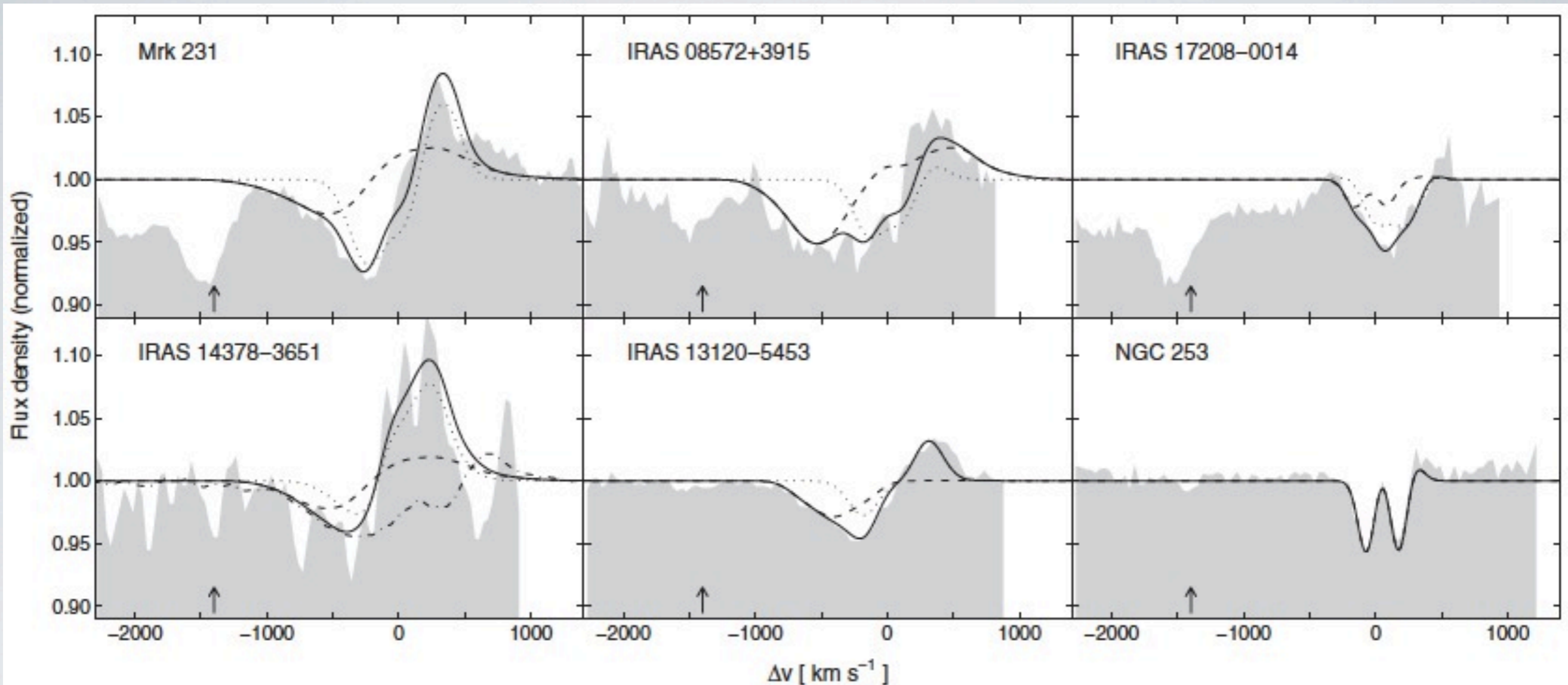
GALAXY EVOLUTION

- Gas-rich spiral galaxies with a central black hole merge → Ultra-Luminous InfraRed Galaxy (ULIRG) → AGN, gas-poor elliptical galaxies
- **Negative feedback process** suppresses the star formation and black hole mass growth/accretion.

HERSCHEL OBSERVATIONS

- **Cold molecular gas** component instead of atomic gas components; the molecular gas is responsible for the star formation materials.
- Herschel-PACS far infrared spectrometer observations of OH 79 μm lines with a resolution of $\sim 140 \text{ km s}^{-1}$.
- Targets: 6 samples.
 - a starburst template (NGC 253),
 - a cold, starburst-dominated ULIRG (IRAS 17208–0014),
 - warm ULIRGs ($S_{25}/S_{60} > 0.1$) and/or ULIRGs with strong AGN contributions (Mrk 231, IRAS 13120–5453, IRAS 14378–3651),
 - a heavily obscured ULIRG (IRAS 08572+3915), which hosts a powerful AGN.



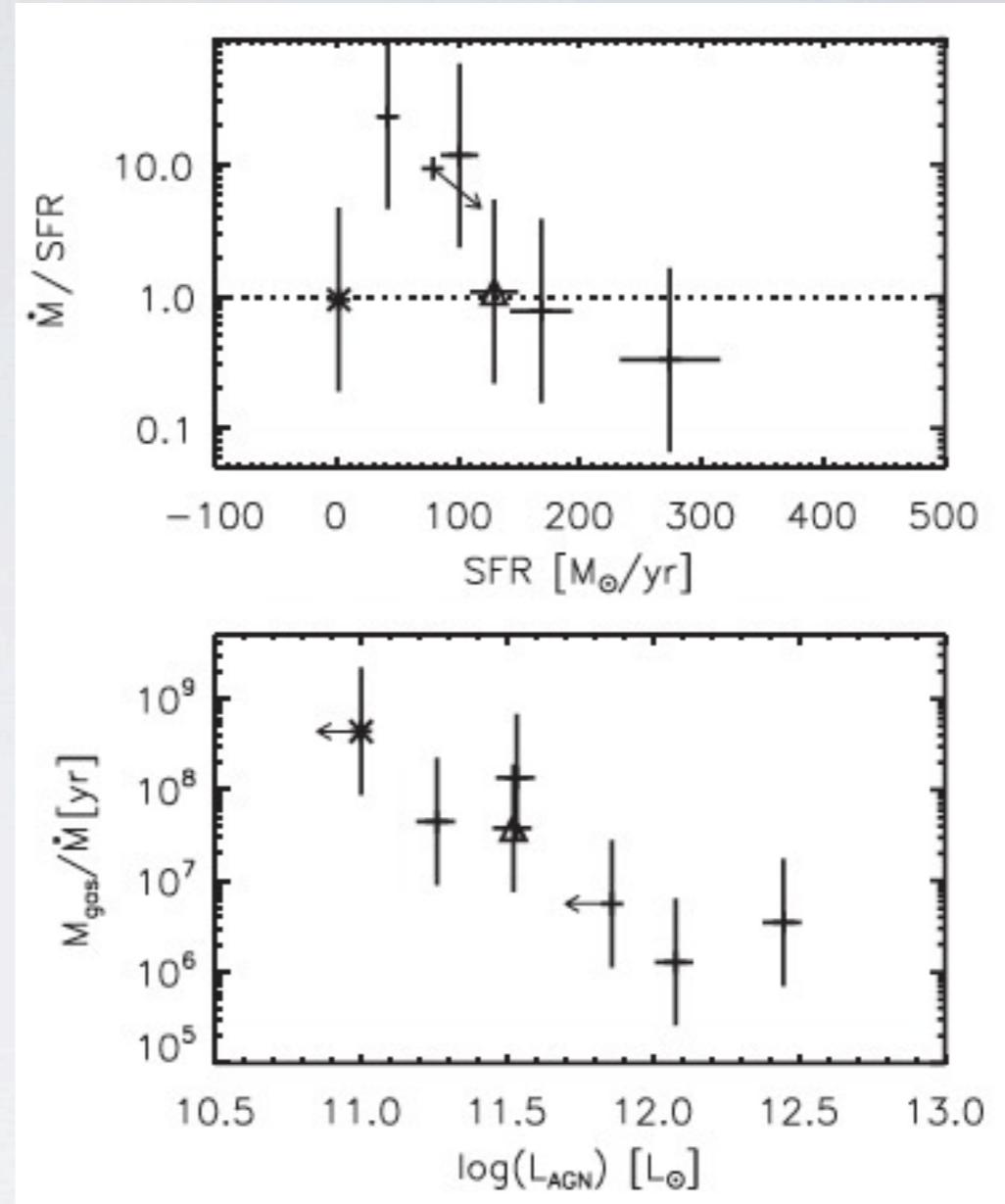
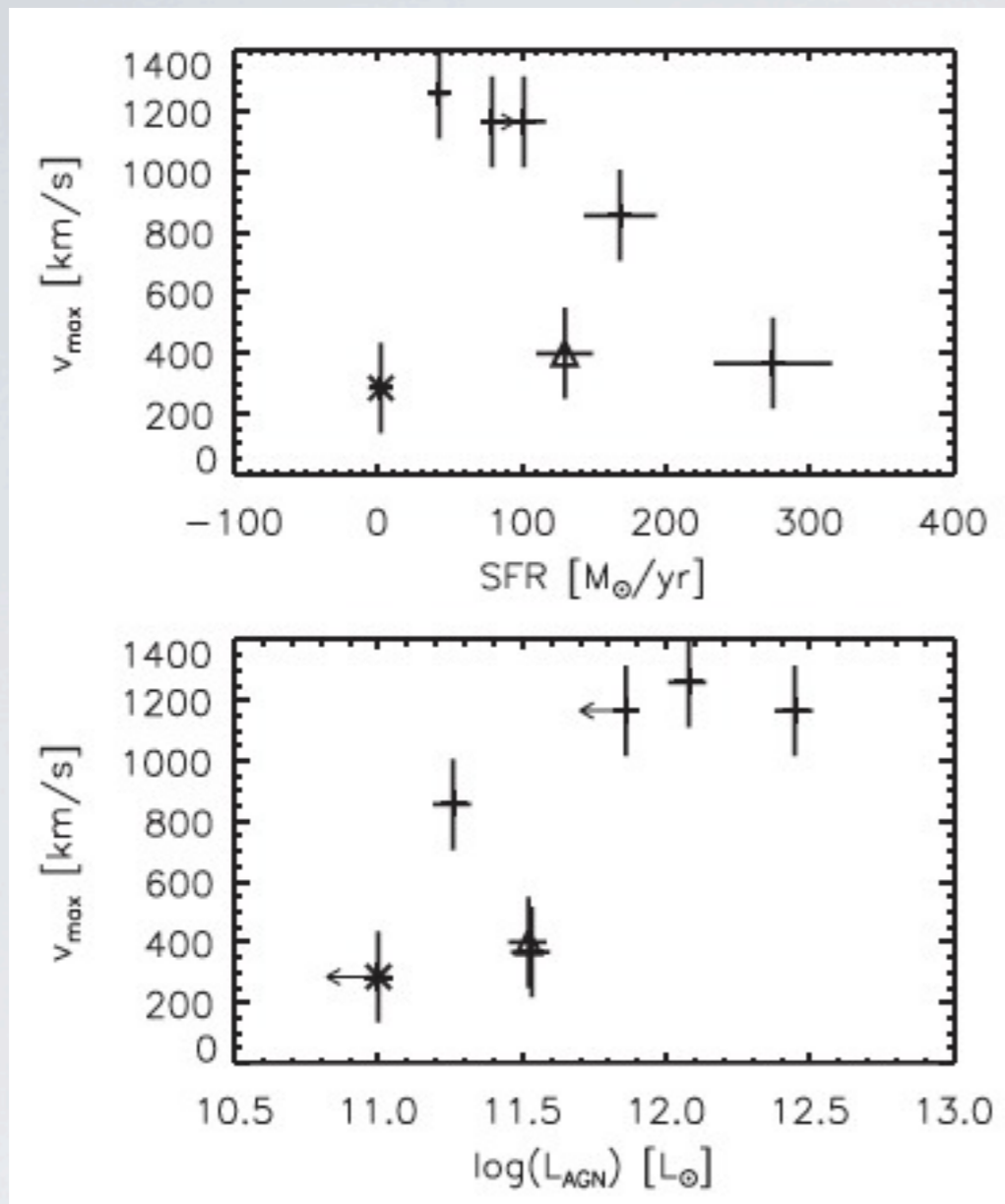


- Observed PACS spectra (continuum-normalized) of the OH transition at $79 \mu\text{m}$ (gray). Overplotted are the low-velocity (dotted) and high-velocity (dashed) fit components and the total fit (solid). The arrow indicates the rest position of $\text{H}_2\text{O } 4_{23}-3_{12}$. The dash-dotted line for IRAS 14378 shows the observed spectrum of the OH transition at $119 \mu\text{m}$ for this object.

Table 1
Target Properties, Outflow Rates, and Outflow Velocities (1σ Uncertainties in Parentheses)

| Source | SFR ($M_{\odot} \text{ yr}^{-1}$) | α^a (%) | L_{AGN} ($10^{11} L_{\odot}$) | M_{gas}^b ($10^9 M_{\odot}$) | \dot{M}^c ($M_{\odot} \text{ yr}^{-1}$) | v_{peak}^d (km s^{-1}) | $v_{85\%}^e$ (km s^{-1}) | v_{max}^f (km s^{-1}) |
|-----------------|--|-------------------|---|--|--|---|--|--|
| Mrk 231 | 101 (15) | 71 (11) | 28 (4) | 4.2 (1.3) | 1190^{+4700}_{-890} | -600 | -660 | -1170 |
| IRAS 08572+3915 | 42 (6) | 72 (11) | 12 (2) | 1.3 (0.4) | 970^{+2900}_{-730} | -700 | -740 | -1260 |
| IRAS 13120-5453 | 168 (25) | 9 (1.4) | 1.8 (0.3) | 5.8 (1.7) | 130^{+390}_{-95} | -520 | -600 | -860 |
| IRAS 14378-3651 | >79 | <45 | <7.2 | 4.2 (1.3) | 740^{+2200}_{-550} | -800 | -860 | -1170 |
| IRAS 17208-0014 | 274 (41) | 11 (1.7) | 3.4 (0.5) | 12.2 (3.7) | 90^{+270}_{-65} | -100 | -170 | -370 |
| NGC 253 | 1.7 (0.3) | 0 | 0 | 0.7 (0.2) | $1.6^{+4.8}_{-1.2}$ | -75 | -130 | -280 |

- Estimated uncertainty for all velocities: $\pm 150 \text{ km s}^{-1}$.
- a: Fraction of the AGN contribution to L_{bol} , where $L_{\text{bol}} = 1.15 \times L_{\text{IR}}$.
- b: Gas mass.
- c: Mass outflow rate.
- d: Peak velocity of the blueshifted high velocity component (relative to systemic velocities).
- e: Velocity for which 85% of the outflowing gas has lower (absolute) velocities.
- f: Terminal velocity.



- The strong outflows are driven by the AGN rather than by the star formation in these objects.
- The outflow carry sufficient molecular gas to remove the star formation fuel and actually quench the star formation.
- The asterisk denotes NGC 253 and the triangle denotes Arp 220.

THANK YOU!