ALMA Observations of a Candidate Molecular Outflow in an Obscured Quasar SDSS J1356+1026

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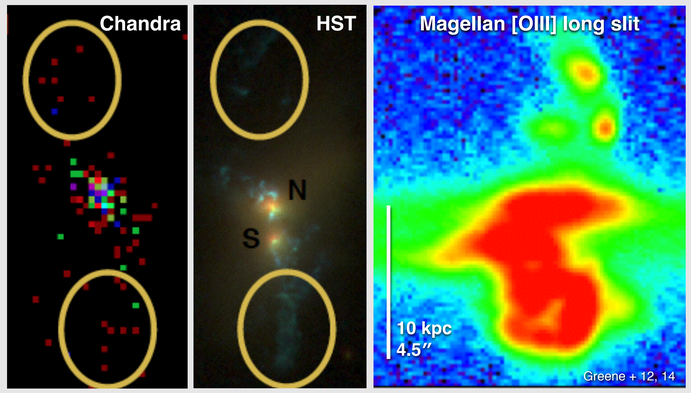
Abstract

We present **ALMA CO (1-0)** and **CO (3-2)** observations of SDSS J135646.10+102609.0, an **obscured quasar and ULIRG with two merging nuclei and a known 20-kpc-scale** ionized outflow. In the spatially resolved CO (3-2) data, we find a compact ($r \approx 0.3$ kpc) high velocity ($v \approx 500$ km/s) red-shifted feature in addition to the rotation at the N nucleus. We propose that molecular outflow as the most likely explanation for the high velocity gas. **The outflowing mass of $M \approx 7 \times 10^7$ $M_\odot$ and the short dynamical time of $t_{dyn} \approx 0.6$ Myr yield a high outflow rate of $\dot{M} \approx 350$ $M_\odot$/yr and can deplete the gas in 1 Myr.** We find a low star formation rate (< 21 $M_\odot$/yr from the far-infrared SED decomposition) that is inadequate to supply the kinetic luminosity of the outflow. **Therefore, the active galactic nucleus, likely powers the outflow.** Its momentum boost rate $\dot{p}/L_{bol} \approx 3$ is lower than typical molecular outflows associated with AGN, which may be related to its compactness. The molecular and ionized outflows are likely two distinct bursts induced by episodic AGN activity that varies on a time scale of 10^7 yr.

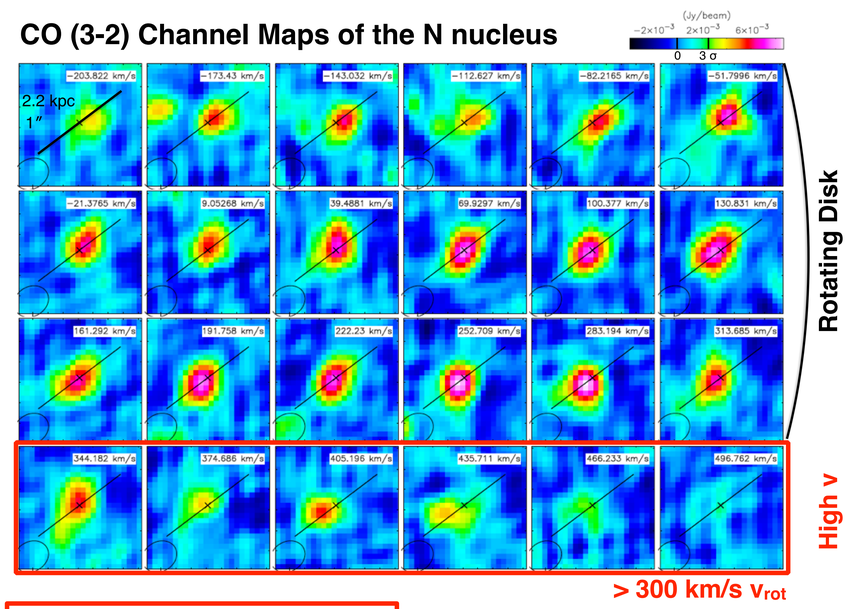
SDSS J1356+1026



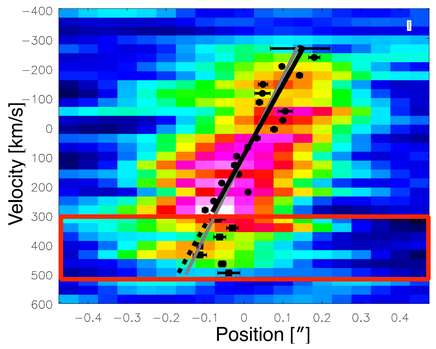
- **Luminous obscured quasar; $L_{bol} \approx 10^{46}$ ergs s^{-1}**
- **Two merging nuclei (N:S = 4:1) 2.5 kpc apart**
- **Extended ionized outflow; r ≈ 10 kpc, v ≈ 1000 km/s**
- ULIRG (AGN heated); $L_{FIR} = 2.7 \times 10^{45}$ ergs s^{-1}
- Unresolved in radio; $FWHM_{1.4\ GHz} < 5''$
- Primary an elliptical; $M_* \approx 10^{11}$ $M_\odot$, $\sigma \approx 210$ km/s
- z=0.1 (1″ = 2.2 kpc)

Results

Signs of Molecular Outflow



The high velocity component has velocity too high to be rotation and is misaligned with the nuclear disk.
→ **Outflow?**



r ≈ 300 pc, v ≈ 500 km/s

Outflow Properties

$M \approx 7 \times 10^7$ $M_\odot$, $\dot{M} \approx 350$ $M_\odot$/yr

$t_{dyn} \approx 0.6$ Myr, $t_{dep} \approx 1$ Myr

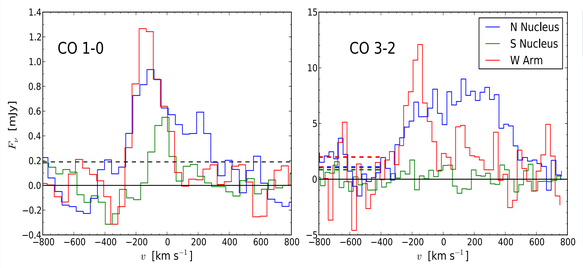
$\dot{E} \approx 0.3\%\ L_{bol}$

3×10^{43} ergs/s, too high to be SF driven

$\dot{P} \approx 3\ L_{bol}/c$

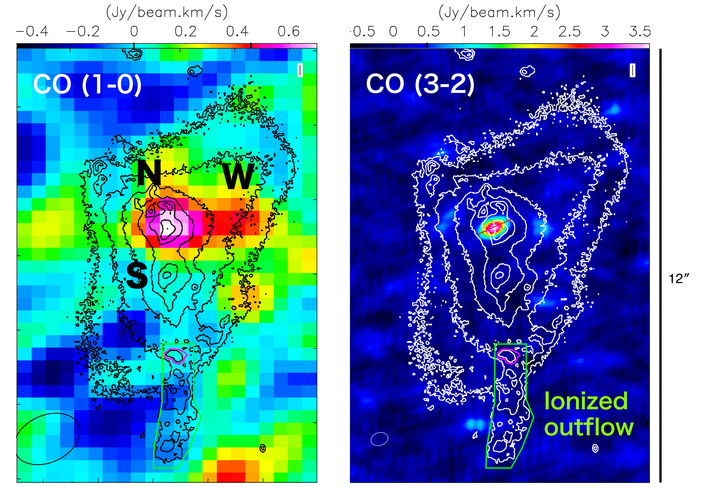
close to be AGN wind momentum-driven

Molecular Components



	M_{mol} [$M_\odot$]
N Nucleus	3×10^8
W Tidal Arm	5×10^8
S Nucleus	8×10^7
Total	9×10^8

ALMA Observations



	CO (1-0)	CO (3-2)
Band	Cycle-0, Band-3	Cycle-1, Band-7
# of Antennae	16, 23	27
On-Source	27, 24 minutes	19 minutes
Resolution	1.9″ × 1.3″	0.35″ × 0.29″
M.R.S.	29″	10″

Conclusions

- SDSS J1356+1016 is likely a primary elliptical/secondary disk merger. The molecular gas from the secondary (S) falls into the nucleus of the primary (N) to form a compact disk and possibly trigger the nuclear activities.
- High velocity component deviating from rotation is found at the N nucleus, as a sign of a compact molecular outflow. As the star formation is not energetic enough, AGN is the most likely driving mechanism. This outflow could deplete the nucleus in ≈ 1 Myr.
- This compact molecular outflow and the extended ionized outflow are likely driven by two separate bursts of AGN activity, varying on a time scale of 10 Myr.