Molecular Absorption Lines as Traces in the Circumnuclear Region

S.Sawada-Satoh (Ibaraki Univ.), D.-G. Roh, S.-J. Oh, S.-S. Lee (KASI)

Molecular gas in AGN

- The activity of an AGN is driven by the accretion of gas onto a massive black hole.
- Molecular gas in AGN region provides important clues to the environment of AGN fueling.
- The actual structure and dynamics of the molecular gas in AGN show some constraints on the accretion process.

Molecular Absorption Line

- Absorption on compact radio sources in AGN
  - Small scale (parsec scale)
  - Broad velocity width (>100 km/s)
  - High column density (HI: $N_H \sim 10^{22\text{-}24}$ cm^{-2})
- Associated area
  - The near side gas of nuclear torus ?
  - Gas around NLR/BLR ?

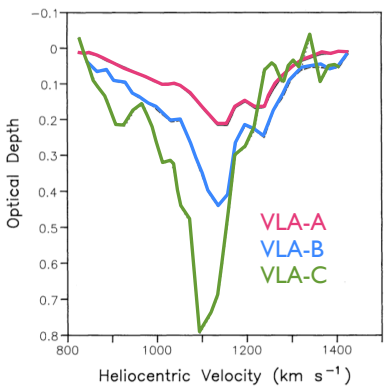
Observations

Target source	NGC 1052 (nearby Seyfert 2)
Target transition	HCO+ J=1-0
Array	Korean VLBI Network (KVN)
Bandwidth	128 MHz

Advantages of VLBI

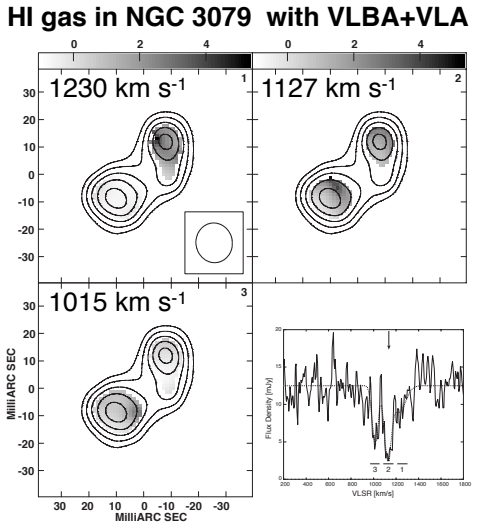
- High resolution images with the VLBI allows us to study the environment for AGN fueling in pc scale.
- Emissions of thermal molecular lines are not enough luminous to detect with the VLBI, but *absorptions* on synchrotron radiation are detectable.
- VLBI is sensitive to detect absorption lines in the AGN.
  - Absorbing gas in AGN is compact.
  - Beamsize smaller, filling factor larger.
- Many molecular transitions at mm bands, but few VLBI observations done yet.
- KVN has advantages for the study.
  - mm bands
  - Short baselines to detect background continuum emission significantly.
  - Wide band widths to detect broad absorption features.

HI gas in NGC 3079 with VLA



Irwin & Seaquist 1991

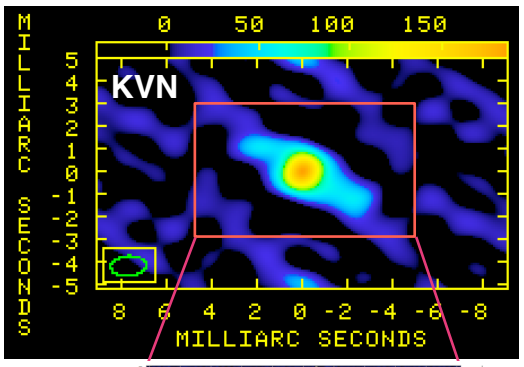
HI gas in NGC 3079 with VLBA+VLA



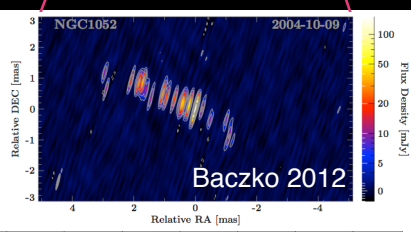
Sawada-Satoh+ 2000

Results

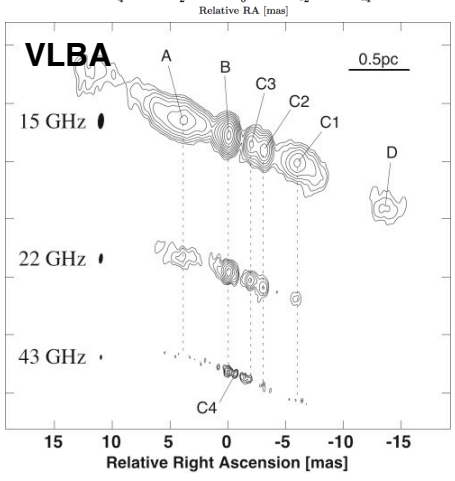
86-GHz radio continuum map



EVN



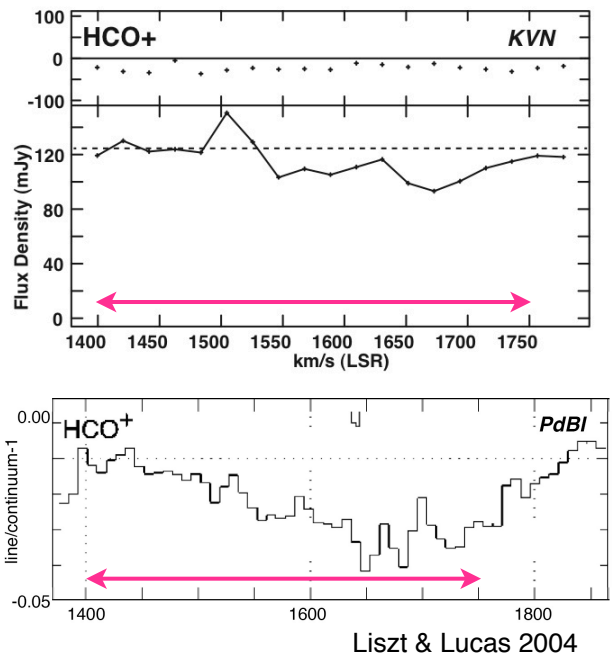
VLBA



Sawada-Satoh+ 2008

- Two-sided radio jet
  - Agrees well with the past VLBI observations at 15, 22, 43 & 86 GHz.
- Cross-power spectrum of HCO+ J=1-0 absorption
  - Possible first VLBI detection of HCO+ absorption in AGN.
  - Good tracer in the circumnuclear region to indicate the physical quantities of molecular gas associated with AGN in pc scale.

Spectral Profile



Liszt & Lucas 2004

Source	z	Transision
CenA	0	HCO+ 1–0, HCO+ 3–2, HCN 1–0,HNC 3–2, CO1–0, CN 1–0, CS 2–1, H2CO, C3H2
NGC3079	0	CO 1–0
NGC1052	0	HCN 1–0, HCO+ 1–0, CO 1–0
3C293	0	CO 1–0
4C31.04	0.1	HCO+ 1–0
1413+135	0.2	HCO+ 1–0, HCO+ 2–1, HCO+ 3–2, HCN 2–1, HCN 3–2, HNC 2–1, HNC 3–2, CO 1–0, CN 1–0, C3H2, CH3CN
1504+377	0.7	HCO+ 2–1, HCO+ 3–2, HCO+ 4–3, HCN 2–1, HNC 2–1, HNC 3–2, CO 1–0, 13CO 2–1, CO 3–2, CN 1–0, CS 2–1, H2CO, C3H2
0218+357	0.7	13CO 2–1, H2CO
1830–211	0.9	HCO+ 1–0, HCO+ 2–1, H13CO+ 1–0, H13CO+ 2–1, HCO+3–2, H13CO+ 3–2, HCN 1–0, HCN 2–1, HCN 3–2, H13CN 1–0, HNC 1–0, HNC 2–1, HNC 3–2, HN13C 1–0, CS 3–2, N2H+ 2–1, N2H+ 3–2, C3H2, CCH, HC3N, H2CO