Feeding and feedback in nearby AGN with ALMA

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Eating VLBI - East Asia to Italy: Nearly Global
AGN fueling

- Super Massive Black Holes (SMBHs) reside in the nuclei of all galaxies with massive spheroids, both in the Local Universe and at high z.

- Nearby Seyfert nuclei and quasars are fueled by accretion of material onto the SMBH.

- Relation of BH growth with galaxy formation and galaxy evolution is not completely understood.
AGN fueling: Open Problem

Removal of the angular momentum from the disk gas and driving infall down to scales of tens of pc

- Cosmological simulations rely on merger-driven gas inflow driven by bar instabilities (e.g., Hopkins et al. 2006, di Matteo et al. 2008).

- Nevertheless, in the Local Universe, there has been no clear correlation between AGN either companions or the presence of bars (e.g., Combes 03, Jogee 06).

- It is possible that locally the relation between these large-scale phenomena and duty cycle of nuclear activity is masked by different timescales (Hunt & Malkan 99).
AGN fueling: how do we study it?

We must examine the nuclear kinematics around local AGN:

MOLECULAR TRACERS
AGN fueling: how do we study it?

NUGA: NUclei of GALaxies
A high-resolution CO IRAM PdBI+30m survey of 12 nearby Seyfert or Liner galaxies. @ CO(2-1): spatial resolution of \( \sim 100 \) pc.

PIs

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Morphologies found in NUGA

17 papers: Boone et al. 07; Casasola et al. 08, 10, 11; Combes et al. 04, 09; García-Burillo et al. 03, 05, 09; Hunt et al. 08; Krips et al. 05, 07; Lindt-Krieg et al. 08; ..... 

On-going fueling at 0.1-1 kpc scales for only 5/12 cases.

The most common feeding mechanism: kinematically decoupled embedded bars.

IRAM observations have insufficient resolution to probe the gas within 100 pc of the AGN.
AGN fueling with ALMA

We MUST IMPROVE spatial resolution to resolve the inner gas distribution: ALMA (∼30-950 GHz) Early Science Cycle 0 and Cycle 1 have offered this opportunity.
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**ALMA-ES Cycle 0**
- Deadline: July 2011
- Sixteen 12-m antennas
- Max baselines: 125 m - 400 m
- Receiver Bands 3, 6, 7 & 9 (3, 1.3, 0.8 & 0.45 mm)
- Angular resolution: up to ~0.2"
- Single field imaging and mosaics up to 50 pointings
- Continuum and spectral line observations
- Highest Priority Projects: Observed and Delivered (partly or completely), ~50%

**ALMA-ES Cycle 1**
- Deadline: July 2012
- Thirty-two 12-m antennas
- Max baselines: 160 m - 1 km
- Receiver Bands 3, 6, 7 & 9, as for Cycle 0
- Angular resolution: up to ~0.08"
- Single field imaging and mosaics up to 150 pointings
- Continuum and spectral line observations
- Nine 7-m + two 12-m antennas for total power obs: Atacama Compact Array in combination with 12m array for imaging of extended structures
AGN fueling with ALMA

ALMA-ES Cycle 0/Cycle 1 Proposals

1. Feeding and feedback in nearby Seyfert Galaxies
   PI: F. Combes

2. The footprints of SF and AGN activity in NGC 1068: a case study for ALMA
   PI: S. García-Burillo

NUGA SOUTH

Smoking gun evidence of feeding
AGN fueling with ALMA

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**Cycle 0:** Both proposals rated as **Highest Priority** and have been **observed**

**Cycle 1:** November 2012, Announcement of the outcome of Proposal Review
Two Targets selected among barred spiral nearby southern AGN with existing wealth of data and CO detection:

NGC 1433 (Seyfert 2) and NGC 1566 (Seyfert 1)

Both at D ~ 10 Mpc with embedded bars
NGC 1433 (Seyfert 2) -- “Lord of rings”:
nuclear, inner, and outer rings (Buta & Combes 96)

Optical image, FOV=18"

NIR image, FOV=18"

Nuclear bar inside the nuclear ring (r = 200 pc, Jungwiert et al. 97).

Atomic gas (HI-21cm map) concentrated in the inner and outer rings, with depletion in the nuclear ring and bar (Ryder et al. 96).
NGC 1433 (Seyfert 2) -- "Lord of rings": nuclear, inner, and outer rings (Buta & Combes 96)

Contrary to HI-21cm the central region is filled with molecular gas (Bajaja et al. 95).

Optical image, FOV=18"

SEST
NGC 1566 (Seyfert 1):

It has intermediate bar (SAB) and two strongly contrasted spiral arms, emanating from the bar, and winding up in an outer pseudo ring.
NUGA SOUTH

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It has intermediate bar (SAB) and two strongly contrasted spiral arms, emanating from the bar, and winding up in an outer pseudo ring

2MASS: nuclear bar (r=35")

SEST
(Bajaja et al. 95)
We proposed to map the morphology and kinematics of the cold dense gas in two Seyfert nuclei, known to have embedded bars, at the unprecedented spatial resolution.

- To map the CO(3-2) (high density gas, $10^4$-$10^5$ cm$^{-3}$) line in both galaxies, simultaneously with HCN(4-3) and HCO$^+$ (4-3) (densest clumps, excitation and chemistry)

- Extended Configuration, Band 7, spatial resolution = 0.45" (20 pc)

- 2 hrs of integration time for each galaxy, S/N=25 for CO(3-2) and S/N=4-6 for HCN(4-3) and HCO$^+$ (4-3)

- To map continuum emission of the dust: @0.85 mm we expect S/N > 100
NUGA SOUTH: Expected Results (1)

In 5 hrs (including calibrations) we expect to obtain results able to shed light on the way SMBH are fueled in each spiral galaxy, like our own.

The high S/N images obtained and kinematics will make the link the bar-spiral dynamics at large scales and the accretion onto the monster.
This clear progress is also an essential step to prepare even higher resolution observations, to tackle the molecular torus below 10 pc in the future.

Illustration Credit: V. Beckmann (NASA’s GSFC) et al., ESA
NGC 1433: ALMA Cycle 0 data

CO(3-2) + continuum: Asymmetric nuclear spiral/pseudo-ring in rotation

The gas seems to fuel in ...

Work in progress!

PI: F. Combes
The Italian ALMA REGIONAL CENTRE (ARC)

http://www.alma.inaf.it/

- INAF-IRA hosts the Italian ARC (one of the European ARC nodes)
- Build a community (e.g., tutorials, seminars, schools, workshops, ...)
- Provide face-to-face user support (pre- and post-observations)
- Offer help in specific areas of expertise
- Be involved with ALMA software development & testing, manuals, cookbooks, ...
- Be involved in ALMA Science Verification phase
The Italian ALMA REGIONAL CENTRE (ARC)

SCIENCE: From Solar System to Cosmology

- Physics and chemistry of cometary atmospheres and nuclei
- Circumstellar disks and envelopes
- Physics and chemistry of the galactic ISM
- Galactic star formation, masers, galactic gradients
- Molecular gas and star formation in nearby galaxies, AGN fueling
- Extra-galactic radio sources; polarimetry
- Physics and evolution of compact steep-spectrum radio sources
- High-z galaxies, Galaxy clusters, SZ-effect
- Variation of physical constants
- .....
The Italian ALMA REGIONAL CENTRE (ARC)

Support + Scientific Staff

- 1 coordinator (J. Brand), 1 ARC-staff (M. Massardi)
- 4 post-docs (J. Boissier, V. Casasola, A. Mignano, R. Paladino)
- 1 ARC system manager (F. Bedosti)
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Possible Synergy:
VLBI (Italy, Japan, Korea) + ALMA (Italian ARC)
mm-VLBI (see Sohn’s Talk)

martedì 16 ottobre 2012
Thanks