Molecular gas kinematics in early-type galaxies.

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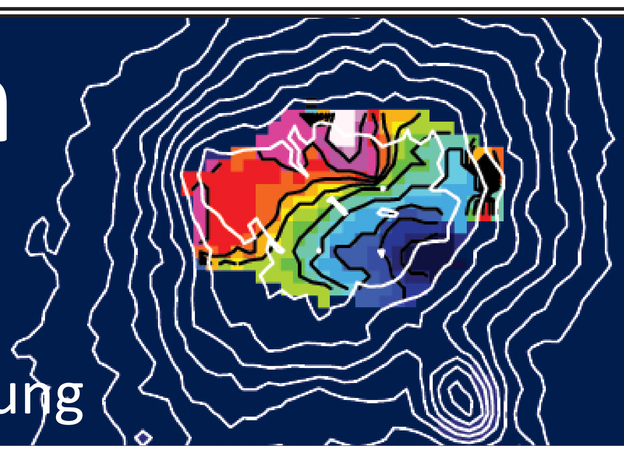


Abstract:

As part of the ATLAS^{3D} project, we have conducted the first complete, volume limited survey of the molecular gas content in over 250 nearby early-type galaxies using the IRAM-30m telescope. We report a detection rate of ~23%, independent of environment, and molecular gas masses in the range 10^7-10^9 solar masses. We are now in the process of mapping the molecular gas with the CARMA interferometer. This allows us to study the molecular gas distribution, kinematics and, by combining with the available IFU data, the recent star formation history in a statistically significant sample of early-types. From measurement of molecular gas kinematic misalignments we present preliminary results suggesting that ~50% of the molecular gas in early-types has an external origin, and that the ionized and molecular gas seem to share a common origin. Environment appears to be important, all the detected cluster galaxies have molecular gas disks aligned with the rotation of their stars, while galaxies in the field show a wide range of misalignments.

ATLAS^{3D}:

The ATLAS^{3D} project is a complete, volume limited survey of all northern early-type galaxies within 40Mpc. It is a direct follow-on to the SAURON project (Bacon et al., 2001). The aim is to determine how star formation and feedback affect the transformation of galaxies, on a large, statistically significant sample at z=0.

For all 263 galaxies we have obtained:

- IFU data (from the SAURON integral field spectrograph)
- Photometry (from SDSS or WFC)
- CO(1-0) and CO(2-1) spectra (from the IRAM-30m telescope)

We have HI data (from WSRT) for many of the galaxies, and are now following-up the molecular gas detections with the CARMA and IRAM interferometers. An example is shown below:

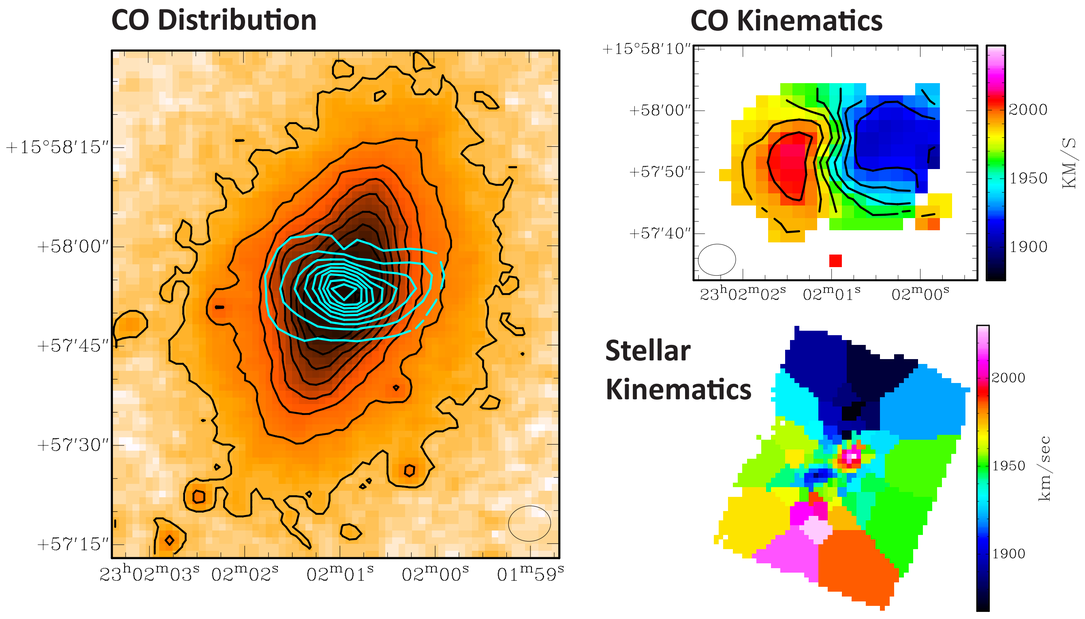


Figure 1: ^{12}CO(1-0) distribution from CARMA observations overlaid on a DSS image of NGC7465 (left). The CO kinematics are displayed at the top right, and may be compared with the stellar kinematics from SAURON, bottom left (same scale). Note the kiloparsec-scale KDC in the stellar kinematics, and the counter-rotation of the molecular gas.

Kinematic Misalignments:

By combining interferometric molecular gas observations with IFU stellar and ionised gas kinematics it is possible to calculate the kinematic misalignment of the molecular gas to the other galactic components.

Preliminary results suggest ionised and molecular gas in early-type galaxies seem to share a common origin, while approximately 50% of galaxies have misalignments between the stellar kinematics and the molecular gas kinematics (in agreement with the results of Sarzi et al., 2006) The gas in these galaxies is likely to have an external origin.

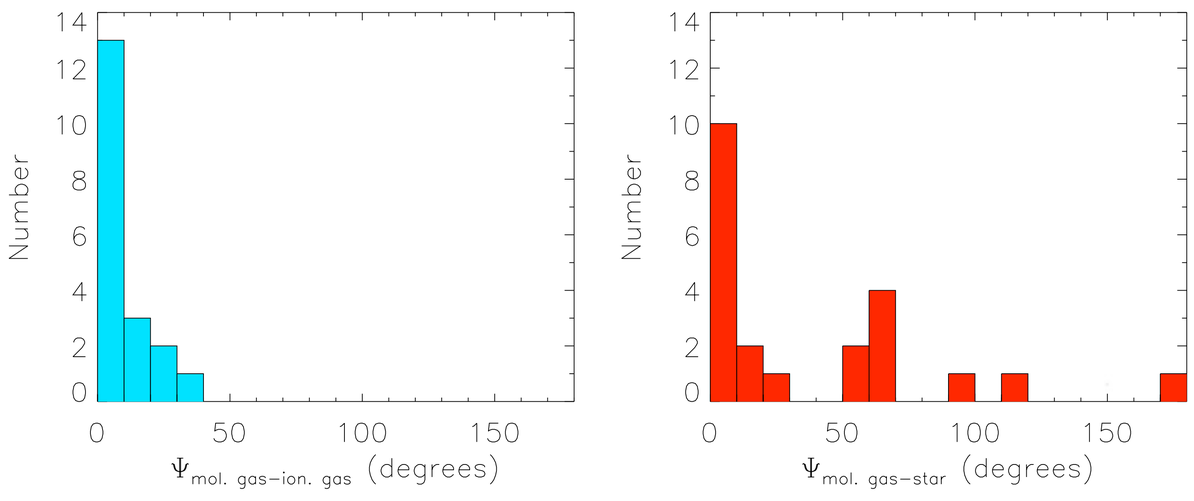


Figure 2: Kinematic misalignment of the molecular gas to the ionised gas (left) and to the stars (right). Kinematic misalignments were calculated using the find_kinematic_pa routines, as detailed in appendix c of Krajnovic et al. (2006)

Environmental Dependance:

The ATLAS^{3D} sample contains both field early-type galaxies and those in the Virgo Cluster. Hence we are able to examine the effect of environment on the molecular gas.

The single-dish survey reported no change in the detection rate inside Virgo, and that the molecular-gas fractions found inside Virgo were consistent with those found in the field. The interferometric follow-up however has shown that galaxies in Virgo always have their molecular gas kinematic axis aligned with the stellar kinematic axis, whereas in the field a wide rage of misalignments are seen.

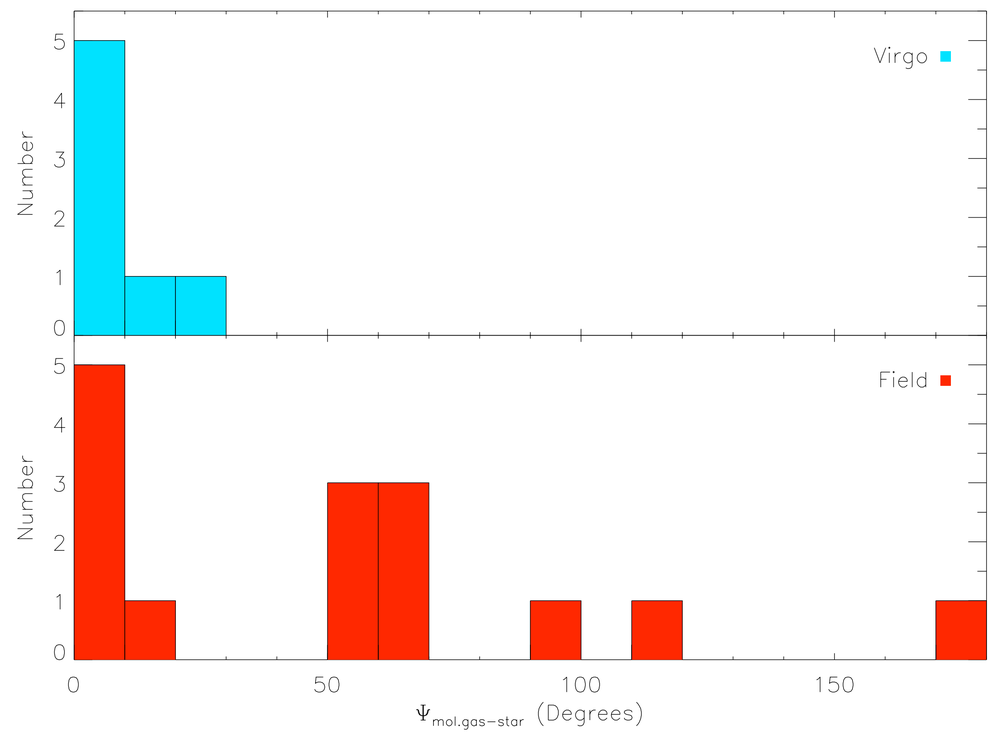


Figure 3: Kinematic misalignment of the molecular gas to the stars in the Virgo Cluster (top), and in the field (bottom).

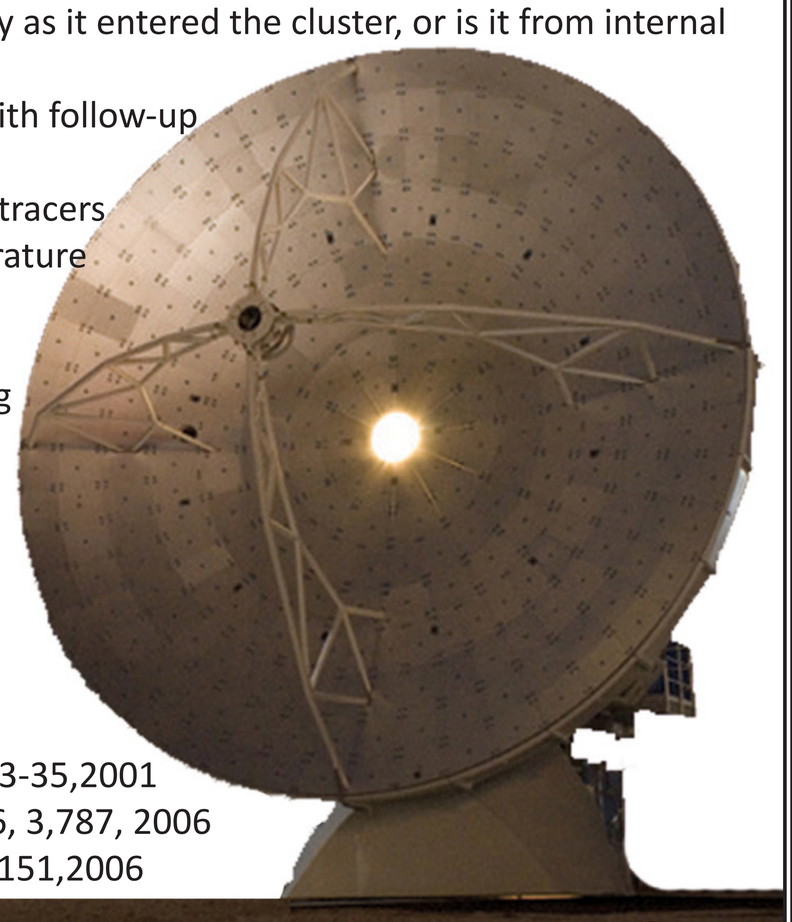
Future Plans:

Now:

- Complete sample - currently have ~50% of the galaxies in hand or due to be observed.
- Investigate the environmental dependance. Is this old gas that was not stripped from the galaxy as it entered the cluster, or is it from internal stellar mass loss.
- Confirm these results with follow-up of other clusters.
- Observe higher density tracers to constrain the temperature and density of the gas.

With ALMA:

- High resolution mapping
- Investigate CO dimmest galaxies.
- Observe high redshift galaxies to trace the evolution of H_2 over cosmic time.



References:

Bacon et al., MNRAS, 326,23-35,2001

Krajnovic et al., MNRAS,336, 3,787, 2006

Sarzi et al., MNRAS,366,4,1151,2006

ALMA antenna photograph courtesy of NRAO/AUI: www.almaobservatory.org

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