5th Netherlands ALMA Science Day
Contributed Talk Abstracts

Alice S. Booth: “Molecules with ALMA at Planet-forming Scales - an ALMA large program to understand the chemistry of planet formation”

Planets form in the disks of gas and dust around young stars and we can now readily observe these disks at high angular resolution with ALMA. Since the first long-baseline observations of HL Tau we have seen that the dust in disks is highly structured showing most often concentric ring and gap features. These structures could be due to dynamic interactions between the disk and planets forming within it. In order to learn more about the planet formation process, we require corresponding high angular resolution observations of molecular lines. In this talk, I will present an overview of the ALMA Large Program 'Molecules with ALMA at Planet-forming Scales' (MAPS) which was designed to expand our understanding of planet formation and in particular the chemistry. We explore the chemical structures in 5 planet-forming disks down to 10 au scales. Together these observations provide constraints on a range of disk properties related to planet formation. In particular, MAPS was designed to answer the following key questions: how are dust and chemical substructures linked; what are the main organic reservoirs, C/N/O/S, and D/H ratios in the planet-forming disk regions; and how can we probe ionization and dynamic disk processes?

Alex Hygate: “Discovery of a massive, highly star-forming, morphologically complex ULIRG at z = 7.31”

A key frontier of astrophysics is understanding the emergence of the first galaxies: the transition from the Cosmic “Dark Ages”, through the Epoch of Reionisation at 6 < z < 11. Analysis of the history of the infrared luminosity function suggests that obscured star formation is dominated by so-called ultra-luminous infrared galaxies (ULIRGs) at high redshift. Such sources have, however, proven difficult to find at the highest redshifts. I will present a massive, highly star-forming, morphologically complex ULIRG discovered at z=7.31 as a part of the Reionisation Era Bright Emission Line Survey (REBELS). REBELS is an ALMA Large Programme (PI: Rychard Bouwens) intended to identify and study massive galaxies with substantial ISM reservoirs in the Epoch of Re-ionisation. I will show the results of the characterisation of the galaxy’s ISM and SFR properties using the REBELS ALMA observations in conjunction with archival data and explore the possible future evolution of the galaxy.

Ko-Yun (Monica) Huang: "The chemical footprint of AGN feedback in the outflowing circumnuclear disk of NGC1068"

In the nearby (D=14 Mpc) AGN-starburst composite galaxy NGC 1068, it has been found that the molecular gas in the CND is outflowing, which is a manifestation of ongoing AGN feedback (García-Burillo et al. 2014).
The induced interaction between the AGN ionized wind & jet with the molecular gas on the CND has produced large-scale molecular shocks on spatial scales of up to r=400pc from the AGN.
The outflowing gas has a large spread of velocities, which likely drive different shock chemistry signatures at different locations in the CND.
In this talk we are presenting our recent ALMA multi-line molecular study using SiO, HNCO and methanol as tracers of chemical differentiation across the CND.
With a radiative transfer analysis coupled with Bayesian inference processes, we are able to determine the gas properties of potentially shocked gas in the CND.

Lucas Stapper: "The mass and size of Herbig disks as seen by ALMA"

In the past decade many population studies have been performed with the Atacama Large Millimeter/submillimeter Array (ALMA) to understand the bulk properties of protoplanetary disks around young stars. These population studies mostly consisted of late spectral type (i.e. G, K & M) stars, with relatively few of the more massive Herbig stars (spectral types B, A, F). With GAIA updated distances, now is a good time to use ALMA archival data to do a Herbig disk population study, an important step towards our understanding of planet formation. Using ALMA Band 6 and Band 7 archival the dust masses and sizes of the 36 Herbig disks are determined. We find that in general, the mass and size of Herbig disks are skewed towards higher dust masses and larger radial extents compared to the disk populations of Lupus and Upper Sco, although it extends over similar ranges. Group I objects are found to be both more massive and larger than group II objects, although only a few of the group II objects have been observed with angular resolutions similar to the group I objects. Based on these results we speculate that these find their origin in an initial disk mass that increases with the stellar mass, and that subsequent disk evolution enlarges the differences, especially if (sub)mm continuum optical depth plays a role. Moreover, this could be linked to the increase in prevalence of giant exoplanets with host star mass.

Eva Schinnerer: "Resolved molecular gas properties of nearby massive star-forming galaxies"

Molecular gas is the reservoir out of which stars form in galaxies across cosmic time. Using ALMA, it is now possible to resolve the molecular gas properties in nearby galaxies on the star-forming main sequence at scales of molecular clouds (~150pc) and study how they vary between and within galactic disks. The ALMA large project

PHANGS (Physics at High Angular resolution in Nearby GalaxieS) has now fully covered an impressive set of 90 nearby main sequence galaxies, imaged their molecular gas via the 12CO(2-1) line at ~1" resolution (corresponding to 150pc or better) across the star-forming disks, and represents the most complete census of resolved molecular cloud conditions in these systems.
I will present an overview of the PHANGS-ALMA survey, the content of the first public data release, and first results which unambiguously demonstrate the variation of molecular gas properties from centres, to disk outskirts, from spirals arm to inter-arm or bar regions. These data provide a robust evidence of the diversity of regimes driven by, e.g., dynamics and feedback and the ability of the host galaxies to regulate the collapse of cold gas and subsequent star formation.

Michael Janssen: "The latest results from the Event Horizon Telescope: Zooming into the heart of Centaurus A"

Centaurus A is the closest radio galaxy to Earth and has been studied extensively as a laboratory for AGN feedback and potential UHECR source after its discovery as one of the first extragalactic radio sources in 1949.
I will present the results from our ALMA+EHT observations of this southern source. Compared to previous VLBI studies, we have imaged the AGN jet of Cen A at a 16x sharper resolution and 10x higher observing frequency. The addition of phased ALMA to the EHT array gives us the sensitivity and resolution to probe the launching region of an extragalactic radio jet on sub-lightday scales.
We show that our observations provide further support for the fundamental plane of black hole activity in an intermediate mass regime. From the location of the resolved radio core in Cen A, we predict the source's black hole shadow to be visible at THz frequencies, which marks Cen A for future high-frequency space VLBI missions.

Lisa Wölfer: "Spiral structures in the gas disc of CQ Tau"

In the past years, high angular resolution observations have revealed that circumstellar discs appear in a variety of shapes with diverse substructures being ubiquitous. This has given rise to the question of whether these substructures are triggered by planet-disc interactions. Besides direct imaging, one of the most promising methods to distinguish between different disc shaping mechanisms is to study the kinematics of the gas disc. In particular, the deviations of the rotation profile from Keplerian velocity can be used to probe perturbations in the gas pressure profile that may be caused by embedded planets. In this work we analyze the gas brightness temperature and kinematics of the transitional disc around CQ Tau in order to resolve and characterize substructure in the gas, caused by possible perturbers. For our analysis we use spatially resolved ALMA observations of 12CO, 13CO and C18O (J=2-1). We further extract robust line centroids for each channel map and fit a number of Keplerian disc models to the velocity field. The gas kinematics of the CQ Tau disc present non-Keplerian features, showing bent and

twisted iso-velocity curves in 12CO and 13CO. Significant spiral structures are detected between 10-180 au in both the brightness temperature and the rotation velocity of 12CO after subtraction of an azimuthally symmetric model, which may be tracing planet-disc interactions with an embedded planet or low-mass companion. We identify three spirals, two in the brightness temperature and one in the velocity residuals, spanning a large azimuth and radial extent. The brightness temperature spirals are morphologically connected to spirals observed in NIR scattered light in the same disc, indicating a common origin. Together with the observed large dust and gas cavity, the spirals support the hypothesis of a massive embedded companion in the CQ Tau disc.

Filippo Fraternali: "Fast rotating and not-so-turbulent discs in z~4 galaxies"

After decades of being mostly confined to the local Universe, the study of gas dynamics in galaxies, via a variety of emission-line gas tracers, has now become a key tool of investigation across cosmic time. In this talk I will present results on rotation curves and velocity dispersions obtained through 3D reconstruction techniques of [CII] emission-line datacubes. These are ALMA observations of lensed and non-lensed starburst galaxies at z~4. They reveal fast rotations and surprisingly low velocity dispersions leading to typical V/sigma values of order 10. These results pose new challenges to our understanding of galaxy formation at early times.

Nikki Zabel: "The Virgo environment traced in CO: how do HI-identified environmental mechanisms affect the molecular gas in cluster galaxies?"

Understanding galaxy formation and evolution is one of the key goals of astronomical research. With roughly half of the galaxies in the local Universe residing in dense environments, it is therefore important to study the effects of environment on galaxy evolution. It has been known for several decades that galaxy clusters harbour a relatively large fraction of early-type galaxies. This suggests that dense environments can cause the premature quenching of star formation. Several environmental processes have been suggested to contribute to this, such as ram pressure stripping, starvation, violent fly-bys, and tidal interactions. However, the relative importance of these mechanisms, and how exactly they lead to the quenching of star formation, is still poorly understood. Typically distributed in an extended disc, atomic gas has long served as an excellent tracer for environmental mechanisms. However, it is the molecular gas that is the direct fuel for star formation. Therefore, any direct effects of the cluster environment on the more tightly bound and centrally located molecular gas would have strong implications for galaxy evolution in dense environments.
VERTICO: "the Virgo environment traced in CO", is an ALMA large programme that was designed to systematically study the physical mechanisms that drive galaxy evolution in dense environments, using ACA observations of CO(2-1) in a sample of 51 spiral galaxies in the Virgo cluster. In this talk I will present the results from one of its early science projects, in which I study how environmental processes, identified

through resolved HI observations from the VLA Imaging of Virgo (VIVA) survey, affect its molecular gas. To this end, I compare their global masses and deficiencies, as well as resolved properties, such as radial profiles, radii, and surface densities.

Christian Ginski: "From microns to mm - multi wavelength studies of circumstellar disks"

In the past several years ALMA mm observations, as well as near-infrared scattered light observations, have opened a new window into the spatially resolved study of young, planet forming disks. Both techniques are highly complementary, tracing different constituents of the circumstellar environment. In my talk I will present results from the DESTINYS scattered light survey of nearby young stars, carried out with the extreme adaptive optics instrument SPHERE at the ESO-VLT. I will show how near infrared and mm data can be combined to understand the complex structures that we are observing.

Raffaella Morganti: "ALMA view of the molecular gas in radio galaxies"

I will present preliminary results from an on-going study (using ALMA) of the molecular gas in a sample of radio galaxies, the 2Jy sample. The overall goal is to investigate how occurrence, distribution and kinematics of the molecular gas are related to properties of the radio AGN and to the host galaxy. In about 25% of the targets we detect CO(1-0) distributed in a variety of structures. While a few of the sources show large molecular gas masses, consistent with ULIRG-like major gas-rich mergers, most have much lower molecular masses, consistent with more minor or less gas-rich mergers (and also consistent with the dust mass results).
Because of the detailed multi-wavelength characterisation of the objects in the sample, a comparison between molecular gas masses, stellar and dust masses and SFR can be done in a similar way as for samples available in literature, at low and high redshifts.

Part of the presentation will be dedicated on a recently published, detailed study of one of the targets, illustrating the complex interplay between radio emission and the surrounding molecular gas. The ALMA observations suggest that the mode of coupling between radio jets and the ISM changes from an outflowing phase limited to the sub-kiloparsec region to a maintenance phase, excavating cavities devoid of dense gas, at larger radii. This provides information on how radio AGN can impact on galactic scales.

Violeta Gamez: "NGC 1068 MATISSE imaging and thermal map of the dust close to the AGN"

In the unification theory of AGNs the concept of "the torus" plays a crucial role to discern between Type-1 and Type-2 AGNs. Despite multiple observations indicating its existence, its true nature remains a mystery. MATISSE, the second generation mid-infrared spectro-interferometer at the VLTI, incorporates high spatial resolution and high sensitivity with a wide spectral range in the MIR and the availability of closure phases. This makes possible a more complete analysis of the warm and hot dust in astronomical sources. I will present the first image reconstructions of the most central dusty structures of NGC 1068, across the L, M and N bands, and the thermal map derived through Gaussian modelling. Combining these images with ALMA and VLBA observations we are able to locate the position of the SMBH. We find a peculiar similarity between the dusty structures and the free-free emission and that the dust must be composed by Mg rich olivines with iron, possibly including some carbon grains. We also find evidence of a geometrically and optically thick structure obscuring the AGN. However, its peculiar morphology and its high degree of asymmetry points to a very complex system that challenges our current understanding of "the torus".