6th Netherlands ALMA Science Day

Contributed Talk Abstracts

Joshua Butterworth: "Understanding if molecular ratios can be used as diagnostics of AGN and starburst activity: The case of NGC 1068"

The Interstellar Medium (ISM) of gas and dust present with galaxies is not consistent on universal scale. As a result of the extreme activities of particular regions such as Active Galactic Nuclei (AGN) and Starburst (SB) regions the ISM may be greatly disrupted and altered (Bayet et al. (2009), Watanabe et al. (2014)). These regions and their effects on the ISM have been observed at a galactic scale (~kiloparsecs), but also with the availability of interferometric instruments, such as ALMA, observations of these variances in the ISM at a scale of dozens of parsecs within external galaxies have been observed across many molecular species and transitions (Scourfield et al. (2020)).
Molecular line ratio diagnostics are often used to investigate the physics and chemistry of the ISM. For example, as the gas chemistry located in the central/nuclear regions of galaxies is believed to be dominated by X-rays emitted from the AGN, this greatly affects the conditions of the ISM in the surrounding regions, especially compared to regions located in starbursts (Usero et al. (2004), Garcia-Burillo et al. (2010)). Hence, line ratios of specific molecules have been proposed as indicators of certain energetic or physical processes e.g. HCN/HCO+ as a tracer of AGNs; HCN/HNC as a 'thermometer', HCN/CO as a density tracer (Loenen et al (2007), Leroy et al. (2017), Hacar et al. (2020)). In order to investigate these diagnostics we have performed a global investigation into the use of molecular line ratios as tracers particularly of AGN versus SB activity, making great use of the high resolution observations available through ALMA. As a Seyfert 2 barred spiral galaxy that contains a prominent SB ring, NGC 1068 is the perfect source to be used a 'laboratory' for a study of this kind. Making use of radiative transfer modelling we are able to both delve into the respective properties of these regions as well as testing the reliability of the ratios themselves.

Ko-Yun (Monica) Huang: "Reconstruct shock history in NGC 253 with ALCHEMI"

Multi-line multi-species molecular observations are an ideal tool for a systematic study of the physico-chemical processes in the ISM, given the wide range of critical densities associated with different molecules and its transitions, and the dependencies of chemical reactions on the energy budget of the system. In our recent work (Huang et al. in prep.) we were able to characterize the gas properties (such as kinetic temperature, gas density) probed by the shock tracers, SiO and HNCO, in the nearby starburst galaxy NGC253 by ALMA multi-line imaging at GMC-scale (~30pc) with ALCHEMI large program. From our modeling analyses, which includes radiative transfer as well as chemical modeling, we found that the gas components traced by these two species are indeed subjected to shocks with different shock strengths, and possibly with a variety of shock history.

Mathilde Bouvier: "Sulphur-bearing species in NGC 253: what do they trace?"

Sulphur-bearing species are known to be highly reactive in the gas phase of the interstellar medium. Their abundance depends greatly on the thermal and kinetic properties of the gas (Viti et al. 2004), which makes sulphur-bearing species extremely useful in the reconstruction of both the chemical history and dynamics of the studied objects. Various processes can participate to increase the abundance of sulphur-bearing species in the gas phase, such as (i) thermal evaporation and (ii) sputtering and/or shattering of dust grains in shocked regions. Therefore, in our Galaxy, sulphured species are ubiquitous and present in various environments, from diffuse clouds to star-forming regions.

What do sulphur-bearing species trace in nearby external galaxies? What is their sulphur budget? Is it similar to our home Galaxy? Thanks to the advent of powerful interferometers such as ALMA, it has now become possible to perform molecular line surveys of nearby galaxies with a resolution down to scales of Giant Molecular Clouds (GMCs; i.e. tens of pc). In particular, the ALMA Comprehensive High-resolution Extragalactic Molecular Inventory (ALCHEMI) is the first ALMA large programme which provides a most complete unbiased molecular survey towards the nuclear region of the starburst galaxy NGC 253, at an unprecedented angular resolution of 1.6" (~27pc) (Martin et al. 2021). In this context, several S-bearing species, as well as several *transitions of the same species were detected, which is mandatory to constrain accurately the region of emission of a species. I will present preliminary results about sulphured species in NGC 253, in the frame of the ALCHEMI Large programme.*

Ian Roberts: "Gas Compression from Ram Pressure in Nearby Cluster Galaxies"

As cluster galaxies orbit through the intracluster medium, they experience a ram pressure that can remove ("strip") gas off of their disks, eventually removing the fuel for future star formation. It is predicted that this ram pressure should also compress gas on the leading side of these galaxies, potentially catalyzing a burst of star formation. I will present resolved maps of molecular gas (CO) for galaxies within the Virgo and Coma clusters, including dense molecular gas (HCN, HCO+) measurements for one galaxy, IC3949. We find evidence for enhanced molecular gas emission on the leading sides of these cluster galaxies as well as enhanced star formation, consistent with theoretical predictions. Thus while ram pressure stripping is a viable mechanism to shut off star formation in cluster galaxies, it is not a "one way street" and may involve a temporary, localized enhancement of star formation activity.

Raffaella Morganti: "On-going feeding of the radio galaxy 3C84"

The radio galaxy 3C84 is located in the centre of the iconic gas-rich, cool-core Perseus cluster and is one of the most famous radio galaxies known to have a fast duty cycle. Large amounts of molecular gas are present in this cluster, mostly distributed in filaments, resulting from the radio lobes expanding in the cluster medium. In addition, recent high resolution ALMA observations have also revealed the presence of a small (~100 pc full size) circum-nuclear disc, a structure only seldom seen in cluster galaxies. Thanks to an improved calibration of ALMA archival data (to overcome the effects of the strong continuum source on the bandpass) we were able to drastically improve the quality of the final image/cube and trace (with a spatial resolution of about 20 pc) the molecular gas in both the circum-nuclear disc and in the filaments. Most importantly, we could trace the kinematical connection between the two structures. This shows how the disc is forming and how the continuous fuelling of the central SMBH is happening. We *discuss this in the context of the feeding and feedback cycle of radio sources expanding in a gas-rich medium.*

Ivana van Leeuwen: "Dust-obscured star formation at z ~ 6 from [CII] selected companion galaxies"

One of the most exciting frontiers in extragalactic astronomy is understanding how rapidly galaxies formed stars in the Early Universe. This involves us constraining the Star Formation Rate Density (SFRD) at z >~ 6. Estimating the Star Formation Rate Density (SFRD) at z > 4 is more difficult given the much greater ease in surveying the z > 4 universe in the rest-UV. This biases our view of the SFRD to focus on the unobscured sources. Recent work shows that the dust-obscured sources could contribute quite meaningfully to the z > 6 SFRD. Here we present a new method for deriving a measure of the SFRD at z ~ 6 correcting for dust-obscured galaxies missed by rest-UV surveys. This method uses serendipitous sources that are found through [CII] (157 um) emission which is equally sensitive to both dust-obscured and unobscured star formation. Using a sample of these sources detected by ALMA, we characterize the obscuration in galaxies as function of their total star formation rate and derive a corrected UV luminosity function and SFRD at z ~ 6.

Violeta Gamez Rosas: "Kinematics of the molecular torus in NGC 1068"

NGC 1068 is one of the most studied AGN all across the electromagnetic spectrum. It is a nearby barred galaxy (d=14.4 Mpc) considered to be the prototypical Seyfert 2. Analyses of molecular lines in the millimeter and submillimeter wavelength range have given insight on the complicated kinematics of the gas at parsec scales from the black hole in the "molecular torus". Some of the conclusions include descriptions like "enhanced turbulence", "non-circular motions", "high-velocity outflows", and, most puzzling of all, "misaligned counter-rotating disks". Other works have explained the latter as only an apparent counter-rotation that results from instabilities in the torus. In this talk I will present our interpretation of new ALMA Band 7 observations with the highest spatial resolution achieved so far that aim to shed light on this disagreement.

Di Wen: “Testing Primordial Black Hole Dark Matter with ALMA Observations of Strong Gravitational Lensing”

I examine the flux density ratio anomaly in the quadruply-imaged strong gravitational lens, B1422+231, and consider the contribution of 10-1000 solar mass primordial black holes (PBH) as a potential dark matter constituent. I describe the first flux density ratio measurement of B1422+231 in the millimeter-wave band using the Atacama Large Millimeter Array. The observed flux density ratios at 233 GHz are similar to those measured in radio, mid-infrared and optical bands, which cannot be explained by a simple smooth mass model of the lens galaxy. I examine the probability of the flux density ratio anomaly arising from PBH microlensing using ray tracing simulations. The simulations consider the cases where 10% and 50% of dark matter are 10-1000 solar mass PBHs with a power law mass function. I show that the anomalous flux density ratio for B1422+231 can be explained by a lens model with a significant fraction of dark matter being PBHs. This study demonstrates the potential for new constraints on PBH dark matter using ALMA observations of multiply imaged strong gravitational lenses.

Hector Olivares: “Black hole physics and the Event Horizon Telescope”

The ALMA observatory plays a crucial role within the Event Horizon Telescope (EHT), an Earth-size very long baseline interferometric (VLBI) array. The EHT has observed two of the nearest supermassive black hole (SMBH) candidates at a resolution comparable to the size of their event horizon. In this talk, we will summarize some of the insights on gravitational and accretion physics gained from these observations. We will also glimpse at future directions in simulation-based modeling of accretion onto SMBHs and at some of the planned enhancements of the EHT array.

Margot Leemker: “Hot or cold: finding the temperatures in transition disks using ALMA”

Most disks observed at high angular resolution show signs of substructures like rings, gaps, arcs, and cavities. So far, most attention has focused on the dust, whereas little is still known about the gas at ~10 au resolution. Gas substructures can be caused by *planets but also other mechanisms such as internal photoevaporation, disk winds or chemical effects. We have very high resolution ALMA observations of two transition disks to determine the nature of their large central cavities. We compare the rarely observed 13CO J=6-5 transition in ALMA Band 9 to archival 13CO J=2-1 data to infer the temperature across the cavities of these disks. This is crucial to find the column density drop in the cavities, which helps to identify the nature of these cavities. We find that the cavities of both disks still contain gas which is warmer than that in their outer disks. In this talk we will discuss the astrophysical implications of this for the nature of the cavity: is it caused by planets or not?*

Logan Francis: "Accretion Burst Echoes as Probes of Protostellar Environments and Episodic Mass Assembly"

Protostars likely accrete material at a highly time-variable rate, but measurements of accretion variability from the youngest protostars are rare, as they are still deeply embedded within their envelopes. Sub-mm/mm observations can trace the thermal response of dust in the envelope to accretion luminosity changes, allowing variations in the accretion rate to be quantified, however, relative flux calibration strageties are key to providing accurate flux measurements and constructing useful light curves. In this talk, I will present recent observations of of variable protostars in Serpens Main, as observed by the ALMA Atacama Compact Array (ACA), the Submillimeter Array (SMA), and the James Clerk Maxwell Telescope (JCMT). The most recent outburst of EC 53 (V371 Ser), an ~18 month periodic variable, is well sampled in the SMA and JCMT observations. The SMA light curve of EC 53 is observed to peak weeks earlier and exhibit a stronger amplitude than at the JCMT. Stochastic variations in the ACA observations are detected for SMM 10 IR, with an amplitude a factor of ~2 greater than that seen by the JCMT. I will discuss a toy model developed to analyze the envelope response to accretion outbursts, and show that EC 53's light curves are plausibly explained by the delay associated with the light travel time across the envelope and the additional dilution of the JCMT response, due to the incorporation of cold envelope material in the beam. The larger JCMT beam can also wash out the response to rapid variations, which may be occurring for SMM 10 IR.

Milou Temmink: "Investigating the Cold Chemistry in the Asymmetric Disk of HD 142527"

Planets form in the disks around newly formed stars and their atmospheric composition is set by the ongoing chemistry in the disk. Studying the gas phase molecular composition of planet-forming disks thus allows us to infer what the atmospheric compositions of possible exoplanets forming in these disks might be. Recent studies of the nearby IRS 48 disk have shown an interesting scenario where, for the first time, the observed chemistry could directly be related to the (asymmetric) distribution of large grains in the disk. The leading hypothesis is that the dust trap is also an ice trap. Through radial and vertical transport of the dust grains and sublimation of the icy mantles, oxygen-rich molecules are released into the gas-phase, making them observable with ALMA. To infer whether this scenario holds for other (asymmetric) disks we used ALMA archival data the study the HD 142527 disk. Through observations of CO, CS, HCN, HCO+ and H2CO and their isotopologues we were able to probe elemental abundances, infer the gas temperature and gas mass. In this talk I will present the results, make comparisons between IRS 48 and HD 142527 and discuss what these results imply for possible planet(s) forming in the HD 142527 disk.

Lucas Stapper: "Herbig disks: flat vs flared, really?"

Herbig disks are divided into group I and group II disks. This separation may be evolutionary and related to the vertical structure of these disks. With ALMA, we now have the possibility to test this 20 year-old hypothesis directly by measuring the height of the 12CO emitting layer for a small sample of Herbigs of both groups. We find that all group I disks are vertically extended with a height to radius ratio of at least 0.25, and for three of the disks the gas emission profile can be traced out to 200-500 au. The group II disks on the other hand are divided between disks with similar emission height profiles as the group I disks and disks which are very flat (not exceeding a height of 10 au over the full extent traced) and more compact (<200 au in size). These findings hint at a dichotomy present in group II Herbig disks: vertically extended disks which we see now before a cavity has formed that would allow irradiation of the outer parts of the disk changing it into a group I disk, and flat disks due to an advanced age. These large differences in vertical structures are not reflected in the spectral energy distributions of these disks, showing that spatially and spectrally resolved observations are necessary to further characterize the Herbig sub-groups.