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Contents

In 2012 the Institute produced a new strategic plan covering the period 2012-2016[1]. As part of the development of this overarching Institutional strategy each school also produced its own strategic programme of activities. In the case of the School of Cosmic Physics this identified four broad 'pillars' that together support the school. The first and most important of these is the School's reputation for pioneering and excellent research, the others being its contributions to the third-level educational system, its involvement in shared research infrastructure and general public service and finally its work in public outreach. This report aims as far as possible to follow this structure.

1 Research Work

1.1 Star Formation

1.1.1 Tentative Evidence for Relativistic Electrons Generated by the Jet of a Young Sun-like Star

R. E. Ainsworth, A. M. M. Scaife (Univ. of Southampton), T. P. Ray, A. M. Taylor, D. A. Green (Cavendish Laboratory, UK), and J. V. Buckle (Cavendish Laboratory and Kavli Institute for Cosmology, UK)

This group have presented data at 325 and 610 MHz taken with the Giant Metrewave Radio Telescope (GMRT) of the young, low-mass star DG Tau, an analog of the Sun soon after its birth. This is the first investigation of a low-mass young stellar object at such low frequencies. They detect emission with a synchrotron spectral index in the proximity of the DG Tau jet and interpret it to be associated with a prominent bow shock in the optical outflow. This result provides tentative evidence for the acceleration of particles to relativistic energies due to the shock impact of this otherwise very low-power jet against the ambient medium. They calculate the equipartition magnetic field strength $B_{min} \approx 0.11$ mG and particle energy $E_{min} \approx 4 \times 10^{40}$ erg, which are the minimum requirements to account for the synchrotron emission of the DG Tau bow shock. These results suggest the possibility of low energy cosmic rays being generated by young Sun-like stars [6].

[1] http://www.dias.ie/images/stories/admin/Strategystatements/diasstrategic%20plan2012-2016.pdf

1.1.2 Accretion in low-mass stars and substellar objects in Lupus

Alcalá, J. M., (INAF, Napoli), Natta, A. (INAF Arcetri and DIAS), Manara, C. F., (European Southern Observatory, Germany), Spezzi, L., (European Southern Observatory, Germany), Stelzer, B., INAF-Palmero), Frasca, A., (INAF-Catania), Biazzo, K., (INAF-Catania), Covino, E., (INAF-Napoli), Randich, S., (INAF-Arcetri), Rigliaco, E., (Univ. of Arizonia), Testi, L., (INAF-Arcetri, European Southern Observatory and Excellence Cluster Universe, Germany), Comerón, F., (European Southern Observatory, Germany), Cupani, G. (INAF-Roma) and D'Elia, V., (INAF-Roma and ASI-Science Data Centre, Rome)

This group have presented VLT/X-shooter observations of a sample of 36 accreting low-mass stellar and sub-stellar objects (YSOs) in the Lupus star-forming region, spanning a range in mass from ≈0.03 to $\approx 1.2 M_\odot$, but mostly with $0.1 M_\odot < M_* < 0.5 M_\odot$. The aim of this study was twofold: firstly, to analyse the relationship between excess-continuum and line emission accretion diagnostics, and, secondly, to investigate the accretion properties in terms of the physical properties of the central object. The accretion luminosity (L_{acc}), and in turn the accretion rate ($\dot{M}_{acc}$), was derived by modelling the excess emission from the UV to the near-infrared as the continuum emission of a slab of hydrogen. They computed the flux and luminosity (L_{line}) of many emission lines of H, He, and CaII, observed simultaneously in the range from ≈330 nm to 2500 nm. The luminosity of all the lines is well correlated with L_{acc}. They provided empirical relationships between L_{acc} and the luminosity of 39 emission lines, which have a lower dispersion than relationships previously reported in the literature. Their measurements extend the Paβ and Brγ relationships to L_{acc} values about two orders of magnitude lower than those reported in previous studies. They confirm that different methodologies of measuring L_{acc} and $\dot{M}_{acc}$ yield significantly different results: Hα line profile modelling may underestimate $\dot{M}_{acc}$ by 0.6 to 0.8 dex with respect to $\dot{M}_{acc}$ derived from continuum-excess measures. These differences may explain the probably spurious bi-modal relationships between $\dot{M}_{acc}$ and other YSOs properties reported in the literature. They derived $\dot{M}_{acc}$ in the range 2×10^{-12}-4×10^{-8} $M_{\odot}$ yr^{-1} and conclude that $\dot{M}_{acc} \propto M_{*}^{1.8(\pm0.2)}$, with a dispersion lower by a factor of about 2 than in previous studies. A number of properties indicate that the physical conditions of the accreting gas are similar over more than 5 orders of magnitude in $\dot{M}_{acc}$, confirming previous suggestions that the geometry of the accretion flow controls the rate at which the disc material accretes onto the central star [7].

1.1.3 Filamentary structure and Keplerian rotation in the high-mass star-forming region G35.03+0.35 imaged with ALMA

Beltrán, M. T., (INAF-Arcetri), Sánchez-Monge, Á., (INAF-Arcetri), Cesaroni, R., (INAF-Arcetri), Kumar, M. S. N, (Centro de Astrofísica da Universidade do Porto), Galli D., (INAF-Arcetri), Walmsley, C. M. (INAF-Arcetri and DIAS) and 10 Others

The submillimeter continuum emission of this high mass star forming region has revealed a filamentary structure fragmented into six cores, called A-F. The filament could be in quasi-equilibrium taking into account that the mass per unit length of the filament, 200-375 $M_{\odot}$/pc, is similar to the critical mass of a thermally and turbulently supported infinite cylinder, ˜335 $M_{\odot}$/pc. The cores, which are on average separated by ˜0.02 pc, have deconvolved sizes of 1300-3400 au, temperatures of 35-240 K, H_2 densities $>10^7 cm^{-3}$, and masses in the range 1-5 $M_{\odot}$, and they are sub-critical. Core A, which is associated with a hypercompact HII region and could be the driving source of the molecular outflow observed in the region, is the most chemically rich source in G35.03+0.35 with strong emission of typical hot core tracers such as CH_3CN. Tracers of high density and excitation show a clear velocity gradient along the major axis of the core, which is consistent with a disk rotating about the axis of the associated outflow. The PV plots along the SE-NW direction of the velocity gradient show clear signatures of Keplerian rotation, although infall could also be present, and they are consistent with the pattern of an edge-on Keplerian disk rotating about a star with a mass in the range 5-13 $M_{\odot}$. The high t_{ff}/t_{rot} ratio for core A suggests that the structure rotates quickly and that the accreting material has time to settle into a centrifugally supported disk. It would seem G35.03+0.35 is one of the most convincing examples of Keplerian disks rotating about high-mass (proto)stars. This supports theoretical scenarios according to which high-mass stars, at least B-type stars, would form through disk-mediated accretion [10].

1.1.4 Imaging the disk around IRAS 20126+4104 at sub-arcsecond resolution

Cesaroni, R., (INAF-Arcetri), Galli D., (INAF-Arcetri), Neri, R., (Institut de Radioastronomie Millimétrique, France) and Walmsley, C. M. (INAF-Arcetri and DIAS).

The existence of disks around high-mass stars has yet to be established on solid ground, as only a few reliable candidates are known to date. The disk rotating about the ˜10^4 $L_{\odot}$ protostar IRAS 20126+4104 is probably the most convincing of these. This group has performed observations at 1.4 mm with the IRAM Plateau de Bure interferometer attaining an angular resolution of ˜$0\farcs4$ (˜660 au). They imaged the methyl cyanide J = 12 →11 ground state and vibrationally excited transitions as well as the $CH_3{}^{13}CN$ isotopologue, which had proved to be disk tracers. Their findings confirm the existence of a disk rotating about a ˜7-10$M_{\odot}$ star in IRAS 20126+4104, with rotation velocity increasing at small radii. The dramatic improvement in sensitivity and spectral and angular resolution with respect to previous observations allowed them to establish that higher excitation transitions are emitted closer to the protostar than the ground state lines, which demonstrates that the gas temperature is increasing towards the centre. They have also found that the material is asymmetrically distributed in the disk and speculate on the possible origin of such a distribution. Finally, they demonstrate that the jet emitted along the disk axis is co-rotating with the disk. Iron-clad evidence has thus been produced of the existence of a disk undergoing rotation around a B-type protostar, with rotation velocity increasing towards the centre. They also demonstrate that the disk is not axially symmetric. These results prove that B-type stars may form through disk-mediated accretion as their low-mass siblings do, but also show that the disk structure may be significantly perturbed by tidal interactions with (unseen) companions, even in a relatively poor cluster such as that associated with IRAS 20126+4104 [11].

1.1.5 Temperaments of young stars: rapid mass accretion rate changes in T Tauri and Herbig Ae stars

Costigan, G., (Armagh Observatory and European Southern Observatory, Germany), Vink, J.S., (Armagh Observatory) Scholz, A., (Univ of St Andrews), Ray T. and L. Testi (European Southern Observatory, Germany; INAF-Arcetri, and Excellence Cluster Universe, Germany)

Variability in emission lines is a characteristic feature in young stars and can be used as a tool to study the physics of the accretion process. This group have presented a study of Hα variability in 15 T Tauri and Herbig Ae stars (K7 - B2) over a wide range of time windows, from minutes, to hours, to days, and years. They assess the variability using linewidth measurements and the time series of line profiles. All objects show gradual, slow profile changes on time-scales of days. In addition, in three cases there is evidence for rapid variations in Hα with typical time-scales of 10 minutes, which occurs in 10 per cent of the total covered observing time. The mean accretion rate changes, inferred from the line fluxes, are 0.01–0.07 dex for time-scales of < 1 hour, 0.04–0.4 dex for time-scales of days, and 0.13–0.52 dex for time-scales of years. In previous work they derived an upper limit finding that the intermediate (days) variability dominated over longer (years) variability. Their new results, based on much higher cadence observations, also provide a lower limit to accretion rate variability on similar time-scales (days), thereby constraining the accretion rate variability physics in a much more definitive way. A plausible explanation for the gradual variations over days is an asymmetric accretion flow resulting in a rotational modulation of the accretion-related emission, although other interpretations are possible as well. In conjunction with their previous work, they find that the time-scales and the extent of the variability is similar for objects ranging in mass from ≈0.1 to ≈5 solar masses. This confirms that a single mode of accretion is at work from T Tauri to Herbig Ae stars – across a wide range of stellar masses [13].

1.1.6 Near-infrared spectroscopy of young brown dwarfs in upper Scorpius

P. Dawson, A. Scholz, (Univ of St Andrews), T. P. Ray, D. E. Peterson, D., (Space Science Institute, Boulder), Rodgers-Lee, and V. Geers

Spectroscopic follow-up is a pre-requisite for studies of the formation and early evolution of brown dwarfs. This group present Infrared Telescope Facility/SpeX near-infrared spectroscopy of 30 candidate members of the young Upper Scorpius association, selected from their previous survey work. All 24 high-confidence members are confirmed as young very low mass objects with spectral types from M5 to L1, 15-20 of them are likely brown dwarfs. This high yield confirms that brown dwarfs in Upper Scorpius can be identified from photometry and proper motions alone, with negligible contamination from field objects (<4 per cent). Out of the six candidates with lower confidence, five might still be young very low mass members of Upper Scorpius, according to their spectroscopy. They demonstrate that some very low mass class II objects exhibit radically different near-infrared (0.6-2.5 μm) spectra from class III objects, with strong excess emission increasing towards longer wavelengths and partially filled in features at wavelengths shorter than 1.25 μm. These characteristics can obscure the contribution of the photosphere within such spectra. Therefore, they caution that near-infrared derived spectral types for objects with discs may be unreliable. Furthermore, they show that the same characteristics can be seen to some extent in all class II and even a significant fraction of class III objects (~ 40%), indicating that some of them are still surrounded by traces of dust and gas. Based on their spectra, they select a sample of objects with spectral types of M5-L1, whose near-infrared emission represents the photosphere only. They recommend the use of these objects as spectroscopic templates for young brown dwarfs in the future [14].

1.1.7 Jets and Outflows from Star to Cloud: Observations Confront Theory

A. Frank, (Univ of Rochester), T. P. Ray, S. Cabrit, (Observatoire de Paris), P. Hartigan (Rice Univ.), H. G. Arce (Yale Univ.), F. Bacciotti (INAF-Arcetri), J. Bally (Univ. of Colorado), M. Benisty, (Observatoire de Grenoble), J. Eislöffel (Thuringer Landessternwarte Tautenburg), M. Güdel (Univ. of Vienna), S. Lebedev (Imperial College London), B. Nisini (INAF-Roma), and A. Raga (Univ. Nac. Auto. de Mexico)

This major review for Protostars and Planets focuses on the role jets and outflows play in the star- and planet-formation process. The essential question can be posed as follows: Are jets/outflows merely an epiphenomenon associated with star formation, or do they play an important role in mediating the physics of assembling stars both individually and globally? This group address this question by reviewing the current state of observations and their key points of contact with theory. their review of jet/outflow phenomena is organized into three length-scale domains: (1) source and disk scales (0.1-10^2 au) where the connection with protostellar and disk evolution theories is paramount; (2) envelope scales (10^2-10^5 au) where the chemistry and propagation shed further light on the jet launching process, its variability and its impact on the infalling envelope; and (3) parent cloud scales (10^5-10^6 au) where global momentum injection into cluster/cloud environments become relevant. Issues of feedback are of particular importance on the smallest scales, where planet formation regions in a disk may be impacted by the presence of disk winds, irradiation by jet shocks, or shielding by the winds. Feedback on envelope scales may determine the final stellar mass (core-to-star efficiency) and envelope dissipation. Feedback also plays an important role on the larger scales with outflows contributing to turbulent support within clusters, including alteration of cluster star-formation efficiencies (SFEs) (feedback on larger scales currently appears unlikely). In describing these observations they also look to the future and consider the questions that new facilities such as the Atacama Large Millimeter/submillimeter Array (ALMA) and the Jansky Array can address. A particularly novel dimension is that they consider results on jet dynamics from the emerging field of high-energy-density laboratory astrophysics (HEDLA), which is now providing direct insights into the three-dimesional dynamics of fully magnetized, hypersonic, radiative outflows [16].

1.1.8 ATLASGAL-selected massive clumps in the inner Galaxy. I. CO depletion and isotopic ratios

A. Giannetti (INAF-Bologna), F. Wyrowski (Max-Planck-Institute for Radioastronomy, Bonn), J. Brand (INAF-Bologna), T. Csengeri (Max-Planck-Institute for Radioastronomy, Bonn), F. Fontani (INAF-Arcetri), C. M. Walmsley (INAF-Arcetri and DIAS), Q. Nguyen Luong (Univ. of Toronto), H. Beuther (Max Planck Institute for Astronomy, Heidelberg), F. Schuller (European Southern Observatory, Chile), R. Güsten (Max-Planck-Institute for Radioastronomy, Bonn) and K. M. Menten (Max-Planck-Institute for Radioastronomy, Bonn)

In the low-mass regime, molecular cores have spatially resolved temperature and density profiles allowing a detailed study of their chemical properties. It is found that the gas-phase abundances of C-bearing molecules in cold starless cores rapidly decrease with increasing density. Here the molecules tend to stick to the grains, forming ice mantles. This group have studied CO depletion in a large sample of massive clumps, and investigated its correlation with evolutionary stage and with the physical parameters of the sources. Moreover, they have also studied the gradients in $[^{12}C]/[^{13}C]$ and $[^{18}O]/[^{17}O]$ isotopic ratios across the inner Galaxy, and the virial stability of the clumps. From the ATLASGAL 870 μm survey they selected 102 clumps, which have masses in the range ˜ 10^2 - 3 × 10^4 M_{sun}, sampling different evolutionary stages. They use low J emission lines of CO isotopologues and the dust continuum emission to infer the depletion factor f_D. RATRAN one-dimensional models were also used to determine f_D and to investigate the presence of depletion above a density threshold. The isotopic ratios and optical depth were derived with a Bayesian approach. They find a significant number of clumps with a high degree of CO depletion, up to ˜ 20. Larger values are found for colder clumps, thus for earlier evolutionary phases. For massive clumps in the earliest stages of evolution they estimate the radius of the region where CO depletion is important to be a few tenths of a pc. The value of the $[^{12}C]/[^{13}C]$ ratio is found to increase with distance from the Galactic Centre, with a value of ˜ 66 ± 12 for the solar neighbourhood. The $[^{18}O]/[^{17}O]$ ratio is approximately constant (˜ 4) across the inner Galaxy between 2 kpc and 8 kpc, albeit with a large range (˜ 2 - 6). Clumps are found with total masses derived from dust continuum emission up to ˜ 20 times higher than M_{vir}, especially among the less evolved sources. These large values may in part be explained by the presence of depletion: if the CO emission comes mainly from the low-density outer layers, the molecules may be sub-thermally excited, leading to an overestimate of the dust masses. It is concluded that CO depletion in high-mass clumps seems to behave as in the low-mass regime, with less evolved clumps showing larger values for the depletion than their more evolved counterparts, and increasing for denser sources. The ratios $[^{12}C]/[^{13}C]$ and $[^{18}O]/[^{17}O]$ are consistent with previous determinations, and show a large intrinsic scatter [19].

1.1.9 Modelling the hidden magnetic field of low-mass stars

P. Lang (Univ. of St Andrews), M. Jardine (Univ. of St Andrews), J. Morin (Institute for Astrophysics, Gottingen), J.-F. Donati (Institute for Astrophysics, Gottingen), S. Jeffers (Univ of Utrecht), A. A. Vidotto (Univ. of St Andrews) and R. Fares (Univ. of St Andrews)

Zeeman-Doppler imaging is a spectropolarimetric technique that is used to map the large-scale surface magnetic fields of stars. These maps in turn are used to study the structure of the stars' coronae and winds. This method, however, misses any small-scale magnetic flux whose polarization signatures cancel out. Measurements of Zeeman broadening show that a large percentage of the surface magnetic flux may be neglected in this way. In this work the group assess the impact of this 'missing flux' on the predicted coronal structure and the possible rates of spin-down due to the stellar wind. To do this they create a model for the small-scale field and add this to the Zeeman-Doppler maps of the magnetic fields of a sample of 12 M dwarfs. They extrapolate this combined field and determine the structure of a hydrostatic, isothermal corona. The addition of small-scale surface field produces a carpet of low-lying magnetic loops that covers most of the surface, including the stellar equivalent of solar 'coronal holes' where the large-scale field is opened up by the stellar wind and hence would be X-ray dark. They show that the trend of the X-ray emission measure with rotation rate (the so-called 'activity-rotation relation') is unaffected by the addition of small-scale field, when scaled with respect to the large-scale field of each star. The addition of small-scale field increases the surface flux; however, the large-scale open flux that governs the loss of mass and angular momentum in the wind remains unaffected. They conclude that spin-down times and mass-loss rates calculated from surface magnetograms are unlikely to be significantly influenced by the neglect of the small-scale field [32].

1.1.10 Gas content of transitional disks: a VLT/X-Shooter study of accretion and winds

C. F. Manara (European Southern Observatory, Germany), L. Testi (European Southern Observatory, Germany; INAF - Arcetri and Excellence Cluster Universe, Germany), A. Natta (INAF-Arcetri and DIAS), G. Rosotti (Sternwarte University Munich, Max-Planck Institute for Extraterrestrial Physics, Munich), M. Benisty (Observatoire de Grenoble), B. Ercolano (Sternwarte University Munich and Excellence Cluster Universe, Munich), and L. Ricci (California Institute of Technology).

Transitional disks are thought to be a late evolutionary stage of protoplanetary disks whose inner regions have been depleted of dust. The mechanism responsible for this depletion is still under debate. To constrain the various models it is mandatory to have a good understanding of the properties of the gas content in the inner part of the disk. Using X-Shooter broad band - UV to near-infrared - medium-resolution spectroscopy, this group derive the stellar, accretion, and wind properties of a sample of 22 transitional disks. The analysis of these properties allows them to place strong constraints on the gas content in a region very close to the star (< 0.2 au) that is not accessible with any other observational technique. They fitted the spectra with a self-consistent procedure to simultaneously derive spectral type, extinction, and accretion properties of the targets. From the continuum excess at near-infrared wavelength they distinguished whether their targets have dust free inner holes. By analysing forbidden emission lines, they derived the wind properties of the targets. They then compared their findings with results for classical T Tauri stars. The accretion rates and wind properties of 80% of the transitional disks in their sample, which is strongly biased toward strongly accreting objects, are comparable to those of classical T Tauri stars. Thus, there are (at least) some transitional disks with accretion properties compatible with those of classical T Tauri stars, irrespective of the size of the dust inner hole. Only in two cases are the mass accretion rates much lower, while the wind properties remain similar. They detected no strong trend of the mass accretion rates with the size of the dust-depleted cavity or with the presence of a dusty optically thick disk very close to the star. These results suggest that, close to the central star, there is a gas-rich inner disk with a density similar to that of classical T Tauri star disks. In conclusion the sample analysed here suggests that, at least for some objects, the process responsible of the inner disk clearing allows for a transfer of gas from the outer disk to the inner region. This should proceed at a rate that does not depend on the physical mechanisms that produces the gap seen in the dust emission and results in a gas density in the inner disk similar to that of unperturbed disks around stars of similar mass [36].

1.1.11 An X-Shooter Analysis of Chromospheric Activity of Class III Low Mass Sources

C. F. Manara, (European Southern Observatory, Germany), L. Testi, (European Southern Observatory, Germany; INAF - Arcetri, and Excellence Cluster Universe, Germany), J. M. Alcalá; (INAF-Capodimonte), E. Covino, (INAF-Capodimonte), A. Natta, (INAF-Arcetri and DIAS), S. Randich, (INAF-Arcetri), E. Rigliaco, (Univ. of Arizonia) and B. Stelzer (INAF-Palmero)

The knowledge of the photospheric parameters and the level of chromospheric activity in young pre-main sequence stars is one of the main limitations when trying to measure mass accretion rates in Class II YSOs. A detailed characterization of photospheres and chromospheric activities in low-mass, young stars without disks (late K and M type Class III YSOs) is still missing. Using VLT/X-Shooter spectra this group have analysed a sample of Class III in the Spectral Type range between K5 and M9.5. They report on the characterization of the chromospheric emission in the stars in their sample and on the implications that their work has on accurate measurements of mass accretion rates in YSOs [35].

1.1.12 Physical properties of the jet from DG Tauri on sub-arcsecond scales with HST/STIS

L. Maurri (Univ. of Florence), F. Bacciotti (INAF-Arcetri), L. Podio (INAF-Arcetri), J. Eislöffel (Thuringer Landessternwarte Tautenburg), T. P. Ray, R. Mundt (Max-Planck-Institute for Astronomy, Heidelberg), U. Locatelli (Univ. of Rome), and D. Coffey (University College Dublin)

Stellar jets are believed to play a key role in star formation, but the question of how they originate is still being debated. This group derive the physical properties at the base of the jet from DG Tau both along and across the flow and as a function of velocity. They analysed seven optical spectra of the DG Tau jet, taken with the Hubble Space Telescope Imaging Spectrograph. The spectra were obtained by placing a long-slit parallel to the jet axis and stepping it across the jet width. The resulting position-velocity diagrams in optical forbidden emission lines allowed access to plasma conditions via calculation of emission line ratios. In this way, they produced a 3-D map (2-D in space and 1-D in velocity) of the jet's physical parameters i.e. electron density n_e, hydrogen ionisation fraction x_e, and total hydrogen density n_H. The method used is a new version of the so-called BE-technique. A fundamental improvement is that the new diagnostic method allows them to overcome the upper density limit of the standard [SII] diagnostics. As a result, they find at the base of the jet high electron density, $n_e \sim 10^5$, and very low ionisation, $x_e \sim$ 0.02-0.05, which combine to give a total density up to $n_H \sim 3 \times 10^6$. This analysis confirms previous reports of variations in plasma parameters along the jet, (i.e. decrease in density by several orders of magnitude, increase of x_e from 0.05 to a plateau at 0.7 downstream at 2" from the star). Furthermore, a spatial coincidence is revealed between sharp gradients in the total density and supersonic velocity jumps. This strongly suggests that the emission is caused by shock excitation. No evidence was found of variations in the parameters across the jet, within a given velocity interval. The position-velocity diagrams indicate the presence of both fast accelerating gas and slower, less collimated material. They derive the mass outflow rate, $\dot{M}_j$, in the blue-shifted lobe in different velocity channels, that contribute to a total of $\dot{M}_j \sim 8\pm4 \times 10^{-9}$ M_{sun} yr^{-1}. They estimate that a symmetric bipolar jet would transport at the low and intermediate velocities probed by rotation measurements, an angular momentum flux of $\dot{L}_j \sim 2.9 \pm 1.5 \times 10^{-6}$ M_{sun} yr^{-1} au km s^{-1}. It is concluded that the derived properties of the DG Tau jet are demonstrated to be consistent with magneto-centrifugal theory. However, non-stationary modelling is required in order to explain all of the features revealed at high resolution [37].

1.1.13 Grain growth in the envelopes and disks of Class I protostars

A. Miotello ((European Southern Observatory, Germany and Univ. of Milan), L. Testi (European Southern Observatory, Germany; INAF - Arcetri and Excellence Cluster Universe, Germany), G. Lodato (Univ. of Milan), L. Ricci (California Institute of Technology), G. Rosotti (Excellence Cluster Universe Germany and Max-Planck-Institute for Extraterrestrial Physics, Garching), K. Brooks (Australia Telescope National Facility), A. Maury (Harvard-Smithsonian Center for Astrophysics) and A. Natta (INAF-Arcetri and DIAS)

This group present new 3 mm ATCA data of two Class I young stellar objects (YSOs) in the Ophiucus star forming region: Elias29 and WL12. They compare them with archival 1.1 mm SMA data. In the (u,v) plane the two sources present a similar behaviour: a nearly constant non-zero emission at long baselines, which suggests the presence of an unresolved component and an increase of the fluxes at short baselines, related to the presence of an extended envelope. Their data analysis leads to unusually low values of the spectral index $\alpha_{1.1-3mm}$, which may indicate that mm-sized dust grains have already formed both in the envelopes and in the disk-like structures at such early stages. To explore the possible scenarios for the interpretation of the sources they perform a radiative transfer modelling using a Monte Carlo code, in order to take into account possible deviations from the Rayleigh-Jeans and optically thin regimes. Comparison between the model outputs and the observations indicates that dust grains may form aggregates up to millimetre size already in the inner regions of the envelopes of Class I YSOs. Moreover, they conclude that the embedded disk-like structures in their two Class I YSOs are probably very compact, in particular in the case of WL12, with outer radii down to tens of au [38].

1.1.14 Substellar Objects in Nearby Young Clusters (SONYC). VIII. Substellar Population in Lupus 3

K. Muzic (European Southern Observatory, Chile), A. Scholz (Univ. of St Andrews), V. C. Geers, R. Jayawardhana (Univ. of Toronto), and B. López Martí (Centre for Astrobiology (INTA-CSIC), Madrid and Saint Louis University-Madrid)

SONYC (Substellar Objects in Nearby Young Clusters) is a survey program to investigate the frequency and properties of sub-stellar objects in nearby star-forming regions. This group present a new imaging and spectroscopic survey conducted in the young (˜1 Myr), nearby (˜200 pc) star-forming region Lupus 3. Deep optical and near-infrared images were obtained with MOSAIC-II and NEWFIRM at the CTIO 4 m telescope, covering ˜1.4 deg^2 on the sky. The i-band completeness limit of 20.3 mag is equivalent to 0.009-0.02 M_{sun}, for A_V <= 5. Photometry and 11-12 yr baseline proper motions were used to select candidate low-mass members of Lupus 3. They performed a spectroscopic follow-up of 123 candidates, using VIMOS at the Very Large Telescope, and they identify 7 probable members, among which 4 have spectral type later than M6.0 and T_{eff} <= 3000 K, i.e., are probably sub-stellar in nature. Two of the new probable members of Lupus 3 appear under-luminous for their spectral class and exhibit an emission line spectrum with strong Hα or forbidden lines associated with active accretion. They derive a relation between the spectral type and effective temperature: $T_{eff} = (4120 \pm 175) - (172 \pm 26) \times SpT$, where SpT refers to the M spectral subtype between 1 and 9. Combining their results with the previous works on Lupus 3, they show that the spectral type distribution is consistent with that in other star-forming regions, as well as the derived star-to-brown dwarf ratio of 2.0-3.3. They compile a census of all spectroscopically confirmed low-mass members with spectral type M0 or later [39].

1.1.15 X-shooter spectroscopy of young stellar objects: Slow winds in T Tauri stars

A. Natta (INAF-Arcetri and DIAS), L. Testi (European Southern Observatory, Germany; INAF - Arcetri and Excellence Cluster Universe, Germany), J. M. Alcalá (INAF-Capodimonte), E. Rigliaco (Univ. of Arizonia), E. Covino (INAF-Capodimonte), B. Stelzer (INAF-Capodimonte), and V. D'Elia (ASI-Science Data Center, Rome)

Disks around T Tauri stars are known to lose mass, as best shown by the profiles of the forbidden emission lines of low-ionization species. At least two separate kinematic components have been identified, one characterized by velocity shifts of tens to hundreds of km s^{-1} (HVC) and one with a much lower velocity of a few km s^{-1} (LVC). The HVC are convincingly associated to the emission of jets, but the origin of the LVC is still unknown. This group analyse the forbidden line spectrum of a sample of 44 mostly low-mass young stars in Lupus and σ Ori observed with the X-shooter ESO spectrometer. They detect forbidden line emission of OI, O II, SII, NI, and NII, and characterize the line profiles as LVC, blue-shifted HVC, and red-shifted HVC. They focus their study on the LVC and show that there is a good correlation between line luminosity and both L_{star} and the accretion luminosity (or the mass accretion rate) over a large interval of values (L_{star}˜ 10^{-2}-1 L_{sun}; L_{acc}˜ 10^{-5}-10^{-1} L_{sun}; $\dot{M}_{acc}$˜ 10^{-11} - 10^{-7} M_{sun}/yr). The lines show the presence of a slow wind (V_{peak}< 20 km s^{-1}) that is dense (n_H> 10^8 cm^{-3}), warm (T ˜ 5000-10000 K), mostly neutral. They estimate the mass of the emitting gas and provide a value for the maximum volume it occupies. Both quantities increase steeply with the stellar mass, from ˜ 10^{-12} M_{sun} and ˜0.01 au^3 for

M_{star}˜ 0.1 M_{sun}, to ˜ 3 × 10^{-10} M_{sun} and ˜1 au^3 for M_{star}˜ 1 M_{sun}, respectively. These results provide quite stringent constraints to wind models in low-mass young stars, that need to be explored further [40].

1.1.16 Multifluid simulations of the magnetorotational instability in protostellar discs

W. O'Keeffe, and T. P. Downes

Turbulent motion driven by the magnetorotational instability (MRI) is believed to provide an anomalous viscosity strong enough to account for observed accretion rates in protostellar accretion discs. O'Keeffe and Downes have performed large-scale, three fluid simulations of a weakly ionized accretion disc and examine the linear and non-linear development of the MRI in the net-flux and zero net-flux cases. This numerical study is carried out using the multi-fluid magnetohydrodynamic code HYDRA. They examine the role of non-ideal effects, including ambipolar diffusion, the Hall effect and parallel resistivity, on the non-linear evolution of the MRI in weakly ionized protostellar discs in the region where the Hall effect is believed to dominate. They find that angular momentum transport, parametrized by the α-parameter, is enhanced by inclusion of non-ideal effects in the parameter space of the disc model. The case where Ω ṡ B is negative is explored and the Hall effect is shown to have a stabilizing influence on the disc in this case [41].

1.1.17 Millimetre spectral indices of transition disks and their relation to the cavity radius

P. Pinilla (Leiden Observatory and Univ. of Heidelberg), M. Benisty (Observatoire de Grenoble, France), T. Birnstiel (Harvard-Smithsonian Centre for Astrophysics), L. Ricci (California Institute of Technology), A. Isella (California Institute of Technology), A. Natta (INAF-Arcetri and DIAS), C. P. Dullemond (Univ. of Heidelberg), L. H. Quiroga-Nuñez (Leiden Observatory), T. Henning (Max Planck Institute for Astronomy, Heidelberg) and L. Testi (European Southern Observatory, Germany; INAF - Arcetri and Excellence Cluster Universe, Germany)

Transition disks are protoplanetary disks with inner depleted dust cavities that are excellent candidates for investigating the dust evolution when there is a pressure bump. A pressure bump at the outer edge of the cavity allows dust grains from the outer regions to stop their rapid inward migration towards the star and to efficiently grow to millimetre sizes. Dynamical interactions with planet(s) have been one of the most exciting theories to explain the clearing of the inner disk. This group have looked for evidence of millimetre dust particles in transition disks by measuring their spectral index α_{mm} with new and available photometric data. They investigate the influence of the size of the dust depleted cavity on the disk integrated millimetre spectral index. They present the 3-mm (100 GHz) photometric observations carried out with the Plateau de Bure Interferometer of four transition disks: LkHα 330, UX Tau A, LRLL 31, and LRLL 67. They used the available values of their fluxes at 345 GHz to calculate their spectral index, as well as the spectral index for a sample of twenty transition disks. They compared the observations with two kinds of models. In the first set of models, they considered coagulation and fragmentation of dust in a disk in which a cavity is formed by a massive planet located at different positions. The second set of models assumes disks with truncated inner parts at different radii and with power-law dust-size distributions, where the maximum size of grains is calculated considering turbulence as the source of destructive collisions. They show that the integrated spectral index is higher for transition disks (TD) than for regular protoplanetary disks (PD) with mean values of $\overline{\alpha_{mm}^{TD}} = 2.70 \pm 0.13$ and $\overline{\alpha_{mm}^{PD}} = 2.20 \pm 0.07$ respectively. For transition disks, the probability that the measured spectral index is positively correlated with the cavity radius is 95%. High angular resolution imaging of transition disks is needed to distinguish between the dust trapping scenario and the truncated disk case [42].

1.1.18 Brown Dwarf Disks with ALMA

L. Ricci (California Institute of Technology), L. Testi (European Southern Observatory, Germany; INAF - Arcetri and Excellence Cluster Universe, Germany), A. Natta (INAF-Arcetri and DIAS), A. Scholz, (Univ of St Andrews), I. de Gregorio-Monsalvo (European Southern Observatory, Germany and Joint ALMA Observatory (JAO)/ESO, Chile), and A. Isella (California Institute of Technology and Rice Univ.)

This group present Atacama Large Millimetre Array (ALMA) continuum and spectral line data at 0.89 mm and 3.2 mm for three disks surrounding young brown dwarfs and very low mass stars in the Taurus star forming region. Dust thermal emission is detected and spatially resolved for all the three disks, while CO(J = 3-2) emission is seen in two disks. They analyse the continuum visibilities and constrain the disks' physical structure in dust. The results of their analysis show that the disks are relatively large; the smallest one has an outer radius of about 70 au. The inferred disk radii, radial profiles of the dust surface density, and disk to central object mass ratios lie within the ranges found for disks around more massive young stars. They derive from their observations the wavelength dependence of the millimetre dust opacity. In all three disks, data are consistent with the presence of grains with at least millimetre sizes, as also found for disks around young stars, and confirm that the early stages of the solid growth toward planetesimals occur also around very low-mass objects. Their findings have implications for models of solids evolution in protoplanetary disks, the main mechanisms proposed for the formation of brown dwarfs and very low-mass stars, as well as the potential of finding rocky and giant planets around very low-mass objects [43].

1.1.19 The Herschel view of circumstellar discs: a multi-wavelength study of Chamaeleon-I

D. Rodgers-Lee, A. Scholz (Univ of St Andrews), A. Natta (INAF-Arcetri and DIAS), and T. Ray

This group present the results of a multi-wavelength study of circumstellar discs around 44 young stellar objects in the 3 million year old nearby Chamaeleon-I star-forming region. In particular, they explore the far-infrared/sub-mm regime using Herschel fluxes. It is shown that Herschel fluxes at 160-500 μm can be used to derive robust estimates of the disc mass. The median disc mass is 0.005 M_{sun} for a sample of 28 Class IIs and 0.006 M_{sun} for 6 transition discs (TDs). The fraction of objects in Chamaeleon-I with at least the 'minimum mass solar nebula is 2-7 per cent. This is consistent with previously published results for Taurus, IC348 and ρ Oph. Diagrams of spectral slopes show the effect of specific evolutionary processes in circumstellar discs. Class II objects show a wide scatter that can be explained by dust settling. They identify a continuous trend from Class II to TDs. Including Herschel fluxes in this type of analysis highlights the diversity of TDs. It is found that TDs are not significantly different from Class II discs in terms of far-infrared luminosity, disc mass or degree of dust settling. This suggests that inner dust clearing occurs independently from other evolutionary processes in the discs [44].

1.1.20 A necklace of dense cores in the high-mass star forming region G35.20-0.74 N: ALMA observations

Á. Sánchez-Monge (Univ of Cologne), M. T. Beltrán (INAF-Acetri), R. Cesaroni (INAF-Acetri), S. Etoka (Hamburger Sternwarte and Jodrell Bank Centre for Astrophysics), D. Galli (INAF-Acetri), M. S. N. Kumar (Centro de Astrofísica da Universidade do Porto), L. Moscadelli (INAF-Acetri), T. Stanke (European Southern Observatory, Germany), F. F. S. van der Tak (SRON Netherlands Institute for Space Research and Kapteyn Astronomical Institute, University of Groningen), S. Vig (Indian Institute of Space Science and Technology), C. M. Walmsley (INAF-Acetri and DIAS), K.-S. Wang (Leiden Observatory), H. Zinnecker (SOFIA Science Center, NASA), D. Elia (IAPS-INAF-Roma), S. Molinari(IAPS-INAF-Roma), and E. Schisano (Institute of Technology Pasadena)

The formation process of high-mass stars (with masses >8 M_{sun}) is still poorly understood, and represents a challenge from both the theoretical and observational points of view. The advent of the Atacama Large Millimetre Array (ALMA) is expected to provide observational evidence to better constrain the theoretical scenarios. The study carried out by this group aims at characterizing the high-mass star forming region G35.20-0.74 N, which is associated with at least one massive outflow and contains multiple dense cores, one of them recently found to contain a Keplerian rotating disk. They used the radio-interferometer ALMA to observe the G35.20-0.74 N region in the sub-millimetre continuum and line emission at 350 GHz. The observed frequency range covers tracers of dense gas (e.g., $H^{13}CO^{+}$, $C^{17}O$), molecular outflows (e.g., SiO), and hot cores (e.g., CH_3CN, CH_3OH). These observations were complemented with infrared and centimetre data. It was found that the ALMA 870 μm continuum emission map reveals an elongated dust structure (˜0.15 pc long and ˜0.013 pc wide; full width at half maximum) perpendicular to the large-scale molecular outflow detected in the region, and fragmented into a number of cores with masses ˜1-10 M_{sun} and sizes ˜1600 au (spatial resolution ˜960 au). The cores appear regularly spaced with a separation of ˜0.023 pc. The emission of dense gas tracers such as $H^{13}CO^{+}$ or $C^{17}O$ is extended and coincident with the dust elongated structure. The three strongest dust cores show emission of complex organic molecules characteristic of hot cores, with temperatures around 200 K, and relative abundances 0.2-2 × 10^{-8} for CH_3CN and 0.6-5 × 10^{-6} for CH_3OH. The two cores with highest mass (cores A and B) show coherent velocity fields, with gradients almost aligned with the dust elongated structure. Those velocity gradients are consistent with Keplerian disks rotating about central masses of 4-18 M_{sun}. Perpendicular to the velocity gradients they have identified a large-scale precessing jet/outflow associated with core B, and hints of an east-west jet/outflow associated with core A. It is concluded that the elongated dust structure in G35.20-0.74 N is fragmented into a number of dense cores that may form high-mass stars. Based on the velocity field of the dense gas, the orientation of the magnetic field, and the regularly spaced fragmentation, they interpret this elongated structure as the densest part of a 1-D filament fragmenting and forming high-mass stars [46].

1.1.21 Dust Evolution in Protoplanetary Disks

L. Testi (European Southern Observatory, Germany, INAF - Arcetri and Excellence Cluster Universe, Germany), T. Birnstiel (Harvard-Smithsonian Center for Astrophysics), L. Ricci (California Institute of Technology), S. Andrews (Harvard-Smithsonian Center for Astrophysics), J. Blum (Technische University Braunschweig), J. Carpenter (California Institute of Technology), C. Dominik (Univ of Amsterdam), A. Isella (California Institute of Technology), A. Natta (INAF-Acetri and DIAS), J. P. Williams (Univ of Hawaii), and D. J. Wilner (Harvard Smithsonian Center for Astrophysics)

In the core-accretion scenario for the formation of planetary rocky cores, the first step toward planet formation is the growth of dust grains into larger and larger aggregates and eventually planetesimals. Although dust grains are thought to grow up to micrometre-sized particles in the dense regions of molecular clouds, the growth to pebbles and kilometre-sized bodies must occur at the high densities within protoplanetary disks. This critical step is the last stage of solids evolution that can be observed directly in extrasolar systems before the appearance of large planetary-sized bodies. This group have reviewed the constraints on the physics of grain-grain collisions as they have emerged from laboratory experiments and numerical computations. They then review the current theoretical understanding of the global processes governing the evolution of solids in protoplanetary disks, including dust settling, growth, and radial transport. They have also examined the observational constraints on grain growth in disks from millimetre surveys, as well as the very recent evidence for radial variations of the dust properties in disks. In particular, they focus on the emerging evidence for a very efficient early growth of grains and the radial distribution of maximum grain sizes as the result of growth barriers. They also highlight the limits of the current models of dust evolution in disks, including the need to slow the radial drift of grains to overcome the migration/fragmentation barrier [50].

1.1.22 ATLASGAL - Complete compact source catalogue: 280° < l < 60°

J. S. Urquhart (Max Planck Institute for Radioastronomy, Bonn), T. Csengeri (Max Planck Institute for Radioastronomy, Bonn), F. Wyrowski (Max Planck Institute for Radioastronomy, Bonn), F. Schuller (Max Planck Institute for Radioastronomy, Bonn and European Southern Observatory, Chile), S. Bontemps (Laboratoire d'Astrophysique de Bordeaux), L. Bronfman (Univ of Chile), K. M. Menten (Max Planck Institute for Radioastronomy, Bonn), C. M. Walmsley (INAF-Acetri and DIAS), Y. Contreras (CSIRO Astronomy and Space Science, Australia), H. Beuther (Max Planck Institute for Astronomy, Heidelberg), M. Wienen (Max Planck Institute for Radioastronomy, Bonn) and H. Linz (Max Planck Institute for Astronomy, Heidelberg)

The APEX Telescope Large Area Survey of the Galaxy (ATLASGAL) is the largest and most sensitive systematic survey of the inner Galactic Plane in the sub-millimetre wavelength regime. The observations were carried out with the Large APEX Bolometer Camera (LABOCA), an array of 295 bolometers observing at 870 μm (345 GHz). This group have presented the compact source catalogue for the 280° < l < 330° and 21° < l < 60° regions of this survey. The construction of this catalogue was made with the source extraction routine SExtractor. The group have identified 3523 compact sources and present a catalogue of their properties. When combined with the regions already published, this provides a comprehensive and unbiased database of ˜10 163 massive, dense clumps located across the inner Galaxy [52].

1.1.23 High-resolution ammonia mapping of the very young protostellar core Chamaeleon-MMS1

M. S. Väisälä (Univ of Helsinki), J. Harju (FINCA, Univ of Turku), M. J. Mantere (Univ of Helsinki), O. Miettinen (Univ of Helsinki), R. S. Sault (Australia Telescope National Facility), C. M. Walmsley (INAF-Acetri and DIAS) and J. B. Whiteoak (Australia National Telescope Facility)

The aim of this study was to investigate the structure and kinematics of the nearby candidate first hydrostatic core Cha-MMS1. To do this Cha-MMS1 was mapped in the NH_3(1,1) line and the 1.2 cm continuum using the Australia Telescope Compact Array (ATCA). The angular resolution of the ATCA observations is 7′ (˜1000 au), and the velocity resolution is 50 m s^{-1}. The core was also mapped with the 64 m Parkes Telescope in the NH_3(1,1) and (2,2) lines. Observations from the Herschel Space Observatory and Spitzer Space Telescope were used to help interpretation. The ammonia spectra were analysed using Gaussian fits to the hyperfine structure. A two-layer model was applied in the central parts of the core where the ATCA spectra show signs of self-absorption. It was found by this group that a compact high column density core with a steep velocity gradient (˜20 km s^{-1} pc^{-1}) is detected in ammonia. They derive a high gas density (˜10^6 cm^{-3}) in this region, and a fractional ammonia abundance compatible with determinations towards other dense cores (˜10^{-8}). This suggests that the age of the high density core is comparable to the freeze-out time-scale of ammonia in these conditions, on the order of 10^4 years. The direction of the velocity gradient agrees with previous single-dish observations, and the overall velocity distribution can be interpreted as rotation. The rotation axis goes through the position of a compact far-infrared source detected by Spitzer and Herschel. The specific angular momentum of the core, ˜10^{-3}km s^{-1} pc, is typical for protostellar envelopes. A string of 1.2 cm continuum sources is tentatively detected near the rotation axis. The ammonia spectra suggest the presence of warm embedded gas in its vicinity. An hourglass-shaped structure is seen in ammonia at the cloud's average Local Standard of Rest (LSR) velocity, also aligned with the rotation axis. Although this structure resembles a pair of outflow lobes the ammonia spectra show no indications of shocked gas. It is concluded that the observed ammonia structure mainly delineates the inner envelope around the central source. The velocity gradient is likely to originate in the angular momentum of the contracting core, although influence of the outflow from the neighbouring young star IRS4 is possibly visible on one side of the core. The tentative continuum detection and the indications of a warm background component near the rotation axis suggest that the core contains a deeply embedded outflow which may have been missed in previous single-dish CO surveys owing to beam dilution [53].

1.1.24 Accretion-ejection connection in the young brown dwarf candidate ISO-ChaI 217

E. T. Whelan (Eberhard Karls Univ, Tubingen), J. M. Alcalä (INAF-Capodimonte), F. Bacciotti (INAF-Acetri), B. Nisini (INAF-Roma), R. Bonito (Univ of Palermo), S. Antoniucci (INAF-Roma), B. Stelzer (INAF-Palermo), K. Biazzo (INAF-Capodomone), V. D'Elia (ASI Science Center, Rome) and T. P. Ray

As the number of observed brown dwarf outflows is growing it is important to investigate how these outflows compare to the well-studied jets from young stellar objects. A key point of comparison is the relationship between outflow and accretion activity and in particular the ratio between the mass outflow and accretion rates ($\dot{M}_{out}/\dot{M}_{acc}$). The brown dwarf candidate ISO-ChaI 217 was discovered by this group, as part of a spectro-astrometric study of brown dwarfs, to be driving an asymmetric outflow with the blue-shifted lobe having a position angle of ˜20°. The aim here was to further investigate the properties of ISO-ChaI 217, the morphology and kinematics of its outflow, and to better constrain $\dot{M}_{out}/\dot{M}_{acc}$. The outflow is spatially resolved in the [SII] $\lambda\lambda$6716,6731 lines and is detected out to ˜1".6 in the blue-shifted lobe and 1" in the red-shifted lobe. The asymmetry between the two lobes is confirmed although the velocity asymmetry is less pronounced with respect to their previous study. Using thirteen different accretion tracers they measure log ($\dot{M}_{acc}$) [M_{sun}/yr] = -10.6 ± 0.4. As it was not possible to measure the effect of extinction on the ISO-ChaI 217 outflow, $\dot{M}_{out}$ was derived for a range of values of A_v, up to a value of A_v = 2.5 mag estimated for the source extinction. The logarithm of the mass outflow ($\dot{M}_{out}$) was estimated in the range -11.7 to -11.1 for both jets combined. Thus $\dot{M}_{out}/\dot{M}_{acc}$ [M_{sun}/yr] lies below the maximum value predicted by magneto-centrifugal jet launching models. Finally, both model fitting of the Balmer decrements and spectro-astrometric analysis of the Hα line show that the bulk of the HI emission comes from the accretion flow [56].

1.2 High-Energy Phenomena

1.2.1 Parametrisation of the γ-ray production cross-sections at hadronic interactions

Felix Aharonian and Andrew Taylor and E. Kafexhiu (MPIK/Heidelberg, Germany) and G. Vila (IAR-CONICET/Buenos Aires, Argentina)

The experimental data on the $pp \to \pi^0$ production cross-sections below 2 GeV and the results from publicly available Monte Carlo codes at higher energies were used to parametrise the γ-ray spectrum due to inelastic p–p collisions. The parametrisation provides an accuracy as better as ≤ 20 %, and spans from the p–p kinematic threshold to 1 PeV proton energy, and provides flexibility to switch between different high energy models. A procedure has been introduced to calculate the nuclear enhancement factor at high energies. This factor increases for $T_p < 2$ GeV/nucleon and eventually vanishes when approaching the p–p kinematic threshold at $T_p \sim 0.28$ GeV/nucleon. However, the nucleus–nucleus interaction continue to efficiently produce π^0 for $T_p < 0.28$ GeV/nucleon through the so-called sub-threshold production effect [28].

1.2.2 Hadronic gamma-rays from RX J1713.7-3946?

Felix Aharonian and S. Gabici (APC/Paris)

The young supernova remnant (SNR) RX J1713.7-3946, one of the brightest TeV gamma-ray sources on the sky, is a key object to check the SNR paradigm of the origin of Galactic cosmic rays. While the origin of its gamma-ray emission (hadronic versus leptonic) is still debated, the hard spectrum at GeV energies reported by the Fermi collaboration is generally interpreted as a strong argument in favour of a leptonic scenario. However, because of energy-dependent diffusion of relativistic particles, hadronic interactions can naturally explain the hard radiation spectrum if gamma-rays are produced in dense gas clumps inside the remnant shell. The absence of thermal X-rays from RX J1713.7-3946 fits well within this scenario [18].

1.2.3 Exploring the potential of ASTRO-H for study of nonthermal high energy phenomena

Felix Aharonian and M. Chernyakova together with Y. Uchiyama (Rikkyo University/Tokyo), D. Khangulyan and T. Fukuyama (ISAS/Tokyo), J. Hiraga (Tokyo University), and T. Tanaka (Kyoto University)

The potential of the future JAXA/NASA/ESA X-ray mission ASTRO-H for understanding of the physics of particle acceleration in different astrophysical environments has been studied. The selected topics include the acceleration and radiation processes in supernova remnants (SNRs) and clusters of galaxies, as well as in gamma-ray binaries. In the case of young SNRs, the observations with Soft X-ray Spectrometer (SXS) and Hard X-ray Imager (HXI) can provide unique information about parameters of shock acceleration. The detection of hard synchrotron X-ray emission of secondary electrons from the decay of charged π mesons produced at pp interactions would reveal the presence of PeV protons which already escaped the shell. In galaxy clusters, the accretion shocks can accelerate protons to ultra-high energies. But, because of interactions with the 2.7 K Cosmic Background Radiation, the energy spectrum of protons cannot extend beyond 10^{18}eV. The secondary electrons produced at the photomeson processes result in hard synchrotron X-ray emission which can be detected by HXI from nearby powerful rich galaxy clusters like Coma and Perseus. Finally, the X-ray observations of gamma-ray loud binary systems with XHI should reveal the nature of the mysterious extreme particles accelerators operating in these systems.

1.2.4 Detection of high energy gamma-rays from Sgr B2 complex

Felix Aharonian and Rui-zhi Yang (MPIK/Heidelberg) and D. Jones (Radboud University/Nijmegen

The publicly available Fermi LAT data towards the Galactic centre giant molecular cloud complex Sagittarius B have been analysed to test questions of how well-mixed the Galactic component of cosmic rays are, and to measure the level of the cosmic-ray sea in different parts of the Galaxy. The dust-opacity maps from the PLANCK satellite have been used to obtain independent methods for background subtraction, and an estimate for the mass of the region. The derived mass of the complex of $(1.5 \pm 0.2) \times 10^7 M_\odot$ using the PLANCK data agrees well with the estimated based on the molecular-line measurements. Then a high-quality spectrum of emission from 0.3 to 30 GeV has been obtained, and the spectrum of parent cosmic rays has been derived. The gamma-ray flux from this region is well-fit with a cosmic-ray spectrum the same as that observed locally, with evidence of a small over-density at intermediate (1–10 GeV) energies.

1.2.5 The Fermi bubbles revisited

Felix Aharonian and Rui-zhi Yang (MPIK/Heidelberg) and R. Crocker (Australian National University/Canberra)

60 months of all-sky data from the Fermi-LAT have been analysed. The Fermi bubble structures discovered previously are clearly revealed by in the new analysis. With more data, hence better statistics, both bubbles have been divided into constant longitude slices to investigate their gross gamma-ray spectral morphology. While the detailed spectral behaviour of each slice derived is somewhat dependent on the assumed background model, a relative deficit in the flux at low energies (i.e., hardening) toward the top of the south bubble has been robustly found. In neither bubble does the spectrum soften with longitude. The morphology of the Fermi bubbles is also revealed to be energy-dependent: at high energies they are more extended. One can conclude from the gamma-ray spectrum at high latitudes that a low energy break in the parent cosmic ray population is required in both leptonic and hadronic models. Possible leptonic and hadronic interpretations of this phenomenology have been discussed.

1.2.6 Plasma Diagnostic and Dynamics of the Galactic Center Region

Felix Aharonian and Maria Chernyakova, K. Koyama (Kyoto University) et al (ASTRO-H collaboration)

The most characteristic high-energy phenomena in the Galactic center (GC) region is the presence of strong K-shell emission lines from highly ionized Si, S, Ar, Ca, Fe and Ni, which form the Galactic Center X-ray Emission (GCXE). These multiple lines suggest that the GCXE is composed of at least two plasmas with temperatures of ~1 and ~7 keV. The GCXE also exhibits the K-shell lines from neutral Si, S, Ar, Ca, Fe and Ni atoms. A debatable issue is the origin of the GCXE plasma; whether it is a diffuse plasma or integrated emission of many unresolved point sources such as cataclysmic variables and active binaries. Detailed spectroscopy for these lines may provide a reliable picture of the GCXE plasma. The origin of the K-shell lines from neutral atoms is most likely the fluorescence by X-rays from a putative past flare of Sgr A*. Therefore ASTRO-H may provide unprecedented data for the past light curve of Sgr A*. All these lines may provide key information for the dynamics of the GCXE, using possible Doppler shift and/or line broadening. This paper overviews these line features and the previous interpretation of their origin. We propose extended or revised science with the ASTRO-H observations of some select objects in the GC region.

1.2.7 New gamma-ray features of the Binary Pulsar System PSR B1259-63/LS2883

Felix Aharonian and D. Khangulyan and S. Bogovalov (MEPHI/Moscow)

Observations of the binary pulsar PSR B1259-63/LS2883 in the high energy and very high energy domains have revealed a few quite unusual features. One of the most puzzling phenomena is the bright GeV flare detected with Fermi/LAT in 2011 January, approximately one month after periastron passage. Since the maximum luminosity in the high energy band during the flare nearly achieved the level of the pulsar spindown energy losses, it is likely that the particles, responsible for this emission component, had strongly anisotropic distribution resulting in an emission enhancement. One of the most prolific scenarios for such an emission enhancement is the Doppler boosting, which can be realized in sources with relativistic motions. Interestingly, a number of hydrodynamical simulations have predicted a formation of highly relativistic outflows in binary pulsar systems, therefore scenarios, involving relativistic boosting, are very natural for these systems. However a more detailed analysis of such a possibility, presented in this study, reveals certain limitations which put strict constraints on the maximum luminosity achievable in this scenario. These constraints render the "Doppler boosting" scenario to be less feasible, especially for the synchrotron models.

1.2.8 The "Jet" and "Arc" Molecular Clouds observations with NANTEN2 and Mopra Telescope toward Westerlund 2, RCW 49, and HESS J1023-575 12CO

Felix Aharonian, N. Furakawa (Nagoya University) et al (NANTEN2 collaboration

New CO observations of the so-called molecular clouds "jet" and "arc" have been performed toward the stellar cluster Westerlund 2 and the TeV gamma-ray source HESS J1023-575. The jet cloud shows a linear structure from the position of Westerlund 2 on the east. In addition, a new counter jet cloud on the west has been found. The arc cloud shows a crescent shape in the west of HESS J1023-575. A sign of star formation is found at the edge of the jet cloud and gives a constraint on the age of the jet cloud to be ~1 Myr. An analysis with the multi CO transitions gives temperature as high as 20 K in a few places of the jet cloud, suggesting that some additional heating may be operating locally. The new TeV gamma-ray images by H.E.S.S. correspond to the jet and arc clouds spatially better than the giant molecular clouds associated with Westerlund 2. It is suggested that the "jet" and "arc" clouds are not physically linked with Westerlund 2 but are located at a greater distance around 7.5 kpc. A microquasar with long-term activity may be able to offer a possible engine to form the jet and arc clouds and to produce the TeV gamma-rays, although none of the known microquasars have a Myr age or steady TeV gamma-rays. Alternatively, an anisotropic supernova explosion which occurred ~1 Myr ago may be able to form the "jet" and "arc" clouds, whereas the TeV gamma-ray emission requires a microquasar formed after the explosion.

1.2.9 Diffuse PeV neutrinos from EeV cosmic ray sources: Semirelativistic hypernova remnants in star-forming galaxies

Felix Aharonian and Ruo-yu Liu (MPIK/Heidelberg), Xiang-yu Wang (Nanjing University), S. Inoue (MPIK/Heidelberg, R. Crocker (Australian National University/Canberra)

It is argued that the excess of sub-PeV/PeV neutrinos recently reported by IceCube could plausibly originate through pion-production processes in the same sources responsible for cosmic rays (CRs) with energy above the second knee in the spectrum of CRs around 10^{18}eV. The pion-production efficiency for escaping CRs that produce PeV neutrinos is required to be ?0.1 in such sources. On the basis of current data, semirelativistic hypernova remnants can be identified as possible sources that satisfy these requirements. By virtue of their fast ejecta, such objects can accelerate protons to EeV energies, which, in turn, can interact with the dense surrounding medium during propagation in their host galaxies to produce sufficient high-energy neutrinos via proton-proton (pp) collisions. Their accompanying gamma-ray flux can remain below the diffuse isotropic gamma-ray background observed by the Fermi Large Area Telescope. In order to test this scenario and discriminate from alternatives, the density of target protons/nuclei and the residence time of CRs in the interacting region are crucial uncertainties that need to be clarified. As long as the neutrinos and EeV CRs originate from the same source class, detection of ≥ 10 PeV neutrinos may be expected within 5-10 years' operation of IceCube. Together with further observations in the PeV range, the neutrinos can help in revealing the currently unknown sources of EeV CRs.

1.2.10 Galactic Halo origin of the neutrinos detected by IceCube

Andrew Taylor and Felix Aharonian, and S. Gabici (APC/Paris)

Recent IceCube results suggest that the first detection of very high energy astrophysical neutrinos have been accomplished. It is proposed that the reported diffuse neutrino emission is galactic in origin, and it is produced from an outflow into the halo region. Emission scenarios from both the Fermi bubble and broader halo region are considered. This scenario requires cosmic ray transport within the outflow environment to be different to that inferred locally within the disk and that activity in the central part of the Galaxy accelerates cosmic rays to trans-"knee" energies before they escape into an outflow. The presence of a relatively large reservoir of gas in a very extended halo around the Galaxy, recently inferred from x-ray observations, implies that the relatively modest acceleration power of 10^{39} erg/s in PeV energy cosmic rays may be sufficient to explain the observed neutrino flux, provided that cosmic rays in the halo region propagate as slow as in the galactic disk. Such a luminosity is compatible with that required to explain the observed intensity of cosmic rays around the knee.

1.2.11 Giant Shocks in the Fermi Bubbles and the Origin of the Microwave Haze

Roland Crocker (Australian National University/Canberra), Geoff Bicknell (Australian National University/Canberra), Andrew Taylor, and Etore Carretti (Australian National University/Canberra)

Analysis of γ-ray data provided by the Fermi-LAT has revealed giant, hard-spectrum γ-ray lobes emanating from the Galactic nucleus (and extending to |b|~ 50 degrees). These 'Fermi Bubbles' have hard-spectrum, total-intensity microwave (~20-40 GHz) counterparts in their lower reaches (the microwave 'Haze' extending to |b|~ 35 degrees) and, on large scales, are subsumed by steep spectrum, polarised radio (2-20 GHz) structures (the 'S-PASS Lobes' extending to |b|~ 60 degrees). Here we show that all three of these disparate, non-thermal phenomena may be explained if the Bubbles contain giant, internal (reverse) shocks at heights of ~ kpc above the nucleus. At this height the ram pressure of the freely-expanding upstream flow from the nucleus equilibrates with the thermal pressure of the shocked plasma accumulated into the downstream bubbles. The shocks, for which we find signatures in both north and south bubbles, reheat and reaccelerate, respectively, the adiabatically cooling thermal plasma and cosmic ray content of the nuclear outflow.

1.2.12 Search for Extended γ-ray Emission around AGN with H.E.S.S. and Fermi-LAT

Kora Stycz (DESY- Zeuthen), Stefan Ohm (Leicester University), and Andrew Taylor, for the H.E.S.S. Collaboration

Context: Very-high-energy (VHE; E>100 GeV) γ-ray emission from blazars inevitably gives rise to electron-positron pair production through the interaction of these γ-rays with the Extragalactic Background Light (EBL). Depending on the magnetic fields in the proximity of the source, the cascade initiated from pair production can result in either an isotropic halo around an initially beamed source or a magnetically broadened cascade flux. Aims: Both extended pair halo (PH) and magnetically broadened cascade (MBC) emission from regions surrounding the blazars 1ES 1101-232, 1ES 0229+200 and PKS 2155-304 were searched for, using VHE γ-ray data taken with the High Energy Stereoscopic System (H.E.S.S.), and high energy (HE; 100 MeV<E<100 GeV) γ-ray data with the Fermi Large Area Telescope (LAT). Methods: By comparing the angular distributions of the reconstructed gamma-ray events to the angular profiles calculated from detailed theoretical models, the presence of PH and MBC was investigated. Results: Upper limits on the extended emission around 1ES 1101-232, 1ES 0229+200 and PKS 2155-304 are found to be at a level of few percent of the Crab nebula flux above 1 TeV, depending on the assumed photon index of the cascade emission. Assuming strong Extra-Galactic Magnetic Field (EGMF) values, $> 10--12\,$G, this limits the production of pair halos developing from electromagnetic cascades. For weaker magnetic fields, in which electromagnetic cascades would result in magnetically broadened cascades, EGMF strengths in the range $(0.3--3)\times 10^{-15}\,$G were excluded for PKS 2155-304 at the 99% confidence level, under the assumption of a 1 Mpc coherence length.

1.2.13 High energy emission from binary systems.

M. Chernyakova, Iu. Babyk, et al. In 2014 we have published [12] the results of our extensive multi-wavelength observations of the 2010-2011 periastron passage of the gamma-ray loud binary system PSR B1259-63. High resolution interferometric radio observations establish extended radio emission trailing the position of the pulsar. Observations with the Fermi Gamma-ray Space Telescope reveal GeV gamma-ray flaring activity of the system, reaching the spin-down luminosity of the pulsar, around 30 days after periastron. There are no clear signatures of variability at radio, X-ray and TeV energies at the time of the GeV flare. Variability around periastron in the H_α emission line, can be interpreted as the gravitational interaction between the pulsar and the circumstellar disk. The equivalent width of the H_α grows from a few days before periastron until a few days later, and decreases again between 18 and 46 days after periastron. In near infrared we observe the similar decrease of the equivalent width of Br_γ line between the 40th and 117th day after the periastron. For the idealized disk, the variability of the H_α line represents the variability of the mass and size of the disk. We discuss possible physical relations between the state of the disk and GeV emission under assumption that GeV flare is directly related to the decrease of the disk size.

2014 was also marked with a new periastron passage of the PSR B1259-63. New Fermi observations confirmed the repeatable nature of the GeV flare, and our optical observations indicates a rapid decrease of the H_α equivalent width, confirming our previous findings. X-ray observations demonstrates the spectral hardening corresponding to the rise of the GeV flux, which indicates the change of the cooling regime, which can also be related to the disk disruption. Paper about all our findings is currently under the preparation.

New missions, such as Astro-H and Loft would be able to shed a new light on the true nature of gamma-ray loud binaries. These ideas are summarized in the Astro-H and Loft white papers.

1.2.14 Galactic Center

M. Chernyakova et al.

The Galactic Centre is a bright γ source with the GeV-TeV band spectrum composed of two distinct components in the 1-10 GeV and 1-10 TeV energy ranges. The nature of the two components is not clearly understood. We report the analysis of the data of 74 months of observations of the Galactic Center by Fermi/LAT γ telescope with the goal to constrain the nature of the two components and the spatial morphology of the source. In our modelling we also use ~ 10 years of INTEGRAL/PICSIT data to constrain the low energy behaviour of the source. We find that spatially Galactic Center is consistent with a point source with a 3σ upper limit on it radius of $0.13°$. We show that the Galactic Centre source can be powered by high-energy electrons and find that a self-consistent interpretation of the full MeV – TeV spectrum of the source can be explained by a model in which the signal is produced via inverse Compton scattering of the ambient infrared radiation field. The GeV bump in the spectrum originates from an episode of injection of high-energy particles, which happened ~ 300 years ago. This injection episode coincides with the known activity episode of the Galactic Centre region, previously identified using X-ray observations. Consistently with the X-ray data, we find that the Galactic Centre source might have reached the luminosity $\sim 10^{39}$ erg/s in the γ band during this activity episode. We also discuss the modifications to the hadronic models needed to explain the observations. Paper about our findings is submitted to MNRAS.

1.3 General Theory

1.3.1 Cosmic Ray reacceleration power

Luke Drury and Andrew Thornbury (TCD)

Based on the final year project of Andrew Thornbury, an analytic expression was derived for the power required to drive the cosmic ray re-acceleration as used in many models of cosmic ray Galactic propagation including the *de facto* standard model GALPROP. It was shown that this could be a significant component of the total energy budget, but unfortunately the exact amount is sensitive to the poorly know low-energy part of the cosmic ray spectrum. The integral expression for the power can be used to show that second-order Fermi acceleration, at least as far as the energetics is concerned, is equivalent to a second-order energy gain per scattering and thereby validate Fermi's original heuristic discussion. A short note was published in MNRAS [51].

1.3.2 Magnetic field amplification

Luke Drury and Turlough Downes (DCU and DIAS)

More detailed numerical studies were carried out of magnetic field amplification through differential motions induced by a cosmic ray pressure gradient in a clumpy medium. These included the effects of gas cooling as well as different orientations of the initial bulk field relative to the flow. The results confirm that this is a viable mechanism for magnetic field amplification upstream of cosmic-ray accelerating shocks. The results were published in MNRAS [15] and presented at a number of workshops and conferences.

1.4 Invited talks and other conference activities

Felix Aharonian gave an invited talk on "Extreme Particle Accelerators" at the TEVPA-2014 workshop, Nor Amberd (Armenia), 22 to 26 September 2014, and an invited talk on "Cosmic Pevatrons" at the ICCUB 2014 meeting in Barcelona, 17 to 19 Dec 2014. He delivered two lecture courses on "High Energy Gamma Ray Astronomy" for PhD students of the Gran Sasso Science Institute (L'Aquila, March 2014) and on "Non-thermal X-ray Universe" for young researchers at the 5th ASTRO-H Summer School in APC (Paris, June 2014).

Luke Drury gave an invited talk on cosmic ray acceleration and the conference summary at the 10th Rencontres du Vietnam, "Very High Energy Phenomena in the Universe" held in the International Centre for Interdisciplinary Science Education, Quy Nhon, Vietnam from 3 to 9 August; he participated in the Gran Sasso Science Institute workshop on "Multiple Messengers and Challenges in Astroparticle Physics" in L'Aquila, Italy, from 6 to 17 October and gave a plenary talk on cosmic ray propagation; he gave an invited talk on "Cosmic Ray Acceleration and Magnetic Fields at strong Shock Waves" at the workshop on "Superbubbles, H I holes and Supershells" held in Freising, Germany from 10 to 12 November.

Tom Ray gave an invited talk on Radio Emission from Intermediate Mass Stars at the European Southern Observatory Workshop on Herbig Ae/Be Stars held in Santiago, Chile, from 7-11 April, an invited talk on "Outflows from Young Stars: A Rosetta Stone?", at the University of Tübingen, Germany, an invited talk at the General Assembly of the International Union of Radio Science on "Radio Emission from Young Stars", Beijing, China from 16-23 August, a seminar to the School of Physics, Trinity College Dublin on "The Einstein Lens and a Tale of Two Eclipses" on 28 November, an invited talk on "The James Webb Space Telescope" to the University of St Andrews, Scotland on 9 December.

Andrew Taylor gave an invited talk at DCU on "Galactic Cosmic Rays" in April; a talk on "Implications of Auger Composition Results" at the Dunsink workshop in July; an invited talk on "A Galactic Halo Origin for the Diffuse Neutrino Flux Detected by IceCube" at the 10th Rencontres du Vietnam, Quy Nhon, Vietnam, in August; an invited talk on "Multi-Messenger Aspects: Composition, Propagation & Acceleration" at

ISVHECRI, in Geneva, Switzerland, in August; a talk on “A Galactic Halo Origin for the Diffuse Neutrino Flux Detected by IceCube” at NOW 2014 in Otranto, Italy in September; and gave an invited talk on “TA vs Auger + the Physics of UHECR” at the GSSI Workshop in L’Aquila, Italy in October.

1.4.1 Conferences organised

Luke Drury together with Omar Tibola co-chaired the scientific organising committee for a conference on "Cosmic Ray Origin beyond the Standard Model" which was held in San Vito di Cadore, Italy, from 16 to 22 March.

Tom Ray was a member of the scientific organising committee for the High Energy Density Laboratory Astrophysics (HEDLA) Conference which was held in Bordeaux, France from 12 to 16 May.

Andrew Taylor, Luke Drury, and Felix Aharonian organised a workshop at the Dunsink Observatory on “the Origin of Ultra High Energy Cosmic Rays” from 14 to 16 July. This workshop was attended by an international group of scientists from Ireland, UK, France, and Germany. Over the three days of the workshop, formal talks on different aspects of the problem were followed by involved informal discussions. The third day of the conference included a “Hamilton Walk” excursion which retraced Hamilton’s famous steps when he discovered quaternions.

2 Contributions to Third-level Education

2.1 Lecture courses delivered

R. Azzollini Gave a set of 6 lectures on *An Introduction to Astronomy* to 1st year students at NUI, Maynooth. He also delivered a set of 15 lectures on galaxies as part of the course *Stellar and Galactic Structure* in Trinity College Dublin between October and December..

T. Ray Gave a course of 10 lectures on *Understanding Our Universe* to 1st year students in Trinity College Dublin between October and December.

2.2 PhD students

Rachael Ainsworth Registered in TCD and supervised by Tom Ray and Anna Scaife submitted her thesis on observations of young stellar objects.

Iurii Babik co-funded with DCU and supervised by Masha Chernyakova continued to work on gamma-ray observations of binary systems.

Paul Dawson Registered in TCD and supervised by Tom Ray and Aleks Scholz successfully defended his thesis on brown dwarf surveys.

Donna Rodgers-Lee Registered in TCD and supervised by Tom Ray, Antonella Natta and Turlough Downes worked on computational simulations of circumstellar discs.

Carlo Romoli registered in DCU and supervised by Felix Aharonian, Andrew Taylor and Masha Chernyakova continued his work on Fermi observations of transient sources.

2.3 Student final year projects

R. Azzollini Directed the final year research project of Adam Hagan (TCD) from

November 11st to January 121th (2015). Topic: "Dust Properties of Low Metallicity Dwarf Galaxies"

2.4 Secondment

Senior technical officer Mike Smyth was seconded to UCD to assist with the development of their taught MSc programme in space technology.

3 Contributions to research infrastructure and public service

3.1 HESS, Fermi, ASTRO-H, KM3NeT, CTA

The high-energy and astroparticle physics group in DIAS remains an active member of the HESS collaboration and participates in the production of high-impact papers of HESS. We also are involved in the data analysis, interpretation and publication of results based on the publicly available data banks of the the Fermi Large Array Telescope (LAT). We actively participate in the process of writing papers on the potential of the future gamma-ray (CTA) and neutrino (KM3NeT) telescopes. Finally, we play an important role in the preparation of scientific program of the future X-ray mission ASTRO-H.

3.2 MIRI, LOFAR, GRAVITY

3.2.1 MIRI

The Mid-Infrared Instrument (MIRI) on the James Webb Space Telescope underwent further cryo-testing at NASA Goddard. These tests were carried out after integration of the instrument with the others in the ISIM. DIAS staff participated in the testing which went very successfully.

The MIRI Test Team met in the University of Arizona including R. Azzollini and V. Geers. R. Azzollini reported on progress with the Medium Resolution Spectrometer (MRS) pipeline, development of an algorithm to do optimal (minimum variance) spectrum extraction, Low Resolution Spectrometer (LRS) pixel flat-fields, and on general software support to the various MIRI groups.

At the European Consortium Meeting held in Paris from 13th–15th May R. Azzollini presented a new version of the Relative Spectral Response Function, an innovative algorithm for doing cube building, and reported on investigations into the radiometric model of the MIRI-Telescope-Simulator (MTS), that was used in 2011 to test the

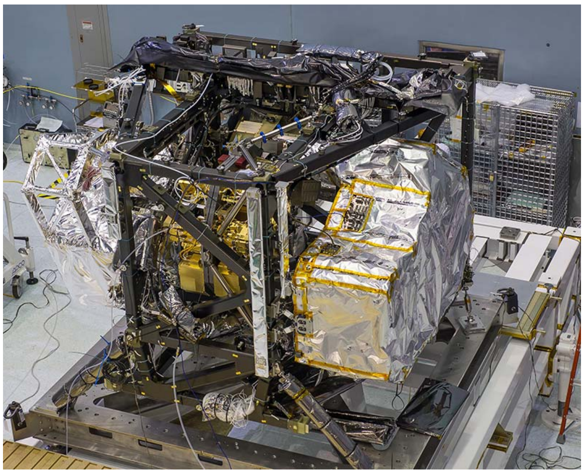


Figure 1: MIRI after installation in the Integrated Science Module (ISIM) at NASA Goddard.

instrument before delivery. In connection with the Calibrated Data Products (CDP) for MIRI, R. Azzollini delivered a new version of LRS pixel flat-fields in March.

R. Azzollini and V. Geers both participated in the second MIRI test campaign under cryogenic vacuum conditions (Cryo-Vac 2) at the Goddard Space Flight Center (Greenbelt) in the Summer of 2014.

R. Azzollini, as Chair of the MRS Pipeline Working Group, organized and edited the final MIRI commissioning review in connection with the MRS.

A series of papers concerning MIRI were prepared for publication in a special issue of *Publications of the Astronomical Society of the Pacific*. R. Azzollini, V. Geers, and T.P. Ray are co-authors.

V. Geers left DIAS in August to take up a post at the Astronomy Technology Centre (ATC) at the Royal Observatory Edinburgh. Following agreement with the European Space Agency on bridging funding for MIRI, his post has been advertised.

3.2.2 LOFAR

DIAS has joined the *Magnetism in the Universe* key Low Frequency Array (LOFAR) project and, in particular, will assist Tautenburg (one of the German LOFAR nodes) in developing interferometric imaging analysis software for the reduction of coherent and incoherent Stokes data. Such software is necessary to recover maximum sensitivity and maximum spatial resolution respectively when observations are obtained in so-called 'tied-array' mode. These modes are the ones that will be used to carry out the low frequency radio observations of outflows from young stars. Two research assistants supported by Science Foundation Ireland (C. Coughlan and R. Ainsworth) will work with Dr Jöchen Eislöffel and Dr Matthias Höft (Tautenburg) who are both key players in developing LOFAR. It is worth mentioning that lessons learnt in the development of this instrument will be of fundamental importance to the planned but even more challenging Square Kilometre Array (SKA) as the latter will require ExaFlop/s computing power and data rates of several hundred TB/s. Note also that DIAS has joined the consortium, led by Trinity College to build a LOFAR station in Birr, Co. Offaly.

3.3 GRAVITY

GRAVITY is a near-infrared interferometer being built for the European Southern Observatory (ESO)'s Very Large Telescope (VLT) in Chile. The VLT consists of 4 8-m class telescopes along with a number of outlier smaller Auxiliary Telescopes (ATs). GRAVITY combines the beams from up to four of these telescopes in the near-infrared to achieve an unprecedented resolution of 3 milli-arcseconds: the equivalent of viewing a cent coin in Rome from Dublin! While one of its primary science goals is to witness material spiralling around the event horizon of he Galactic Centre black hole and thus test General Relativity (hence its name), another is to understand how newborn stars generate jets that stretch for several light years, i.e. of central interest to the DIAS Star Formation Group..

GRAVITY as an instrument is obviously highly complex. Not only does it contain fast adaptive optics (AO) to correct for the vagaries of our atmosphere but also fringe tracking of sources to compensate for variations in baselines due to changing temperatures, flexure, etc. It also includes a laser metrology unit that will allow highly accurate measurements of how far stars are apart on the sky (to a precision of 10 micro-arcseconds, i.e. smaller than the lettering on that cent in Rome!). While the number of interferometer baselines is considerably less than LOFAR, the data handling rates are nevertheless still very challenging. The reason for this is high speeds at which the AO system must work (this is less of a problem with LOFAR as radio waves passing through the ionosphere are much more stable than optical/near-infrared waves).

Now the data acquisition software for GRAVITY is currently under construction: this will provide basic interferometry data, i.e. visibilities along different baselines and phase referencing information. It is however only through combining these data, using specially designed software, that an actual image can be reconstructed. With these ideas in mind, two research assistants (A. Caratti o Garatti and R. Garcia-Lopez) have been appointed to assist with the new data reduction algorithms/AO software in collaboration with the Max Planck Institute for Astronomy (MPIfA) in Heidelberg. Note that MPIfA are developing the AO system for GRAVITY. As a result of this collaboration, the DIAS SF Group will propose projects during the commissioning phase of the instrument (expected October 2015) and will also benefit from guaranteed time. The proposed work will also be done in collaboration with existing GRAVITY partners: these include the University of Grenoble (Dr Myriam Benisty), the University of Porto (Prof Paulo Garcia) as well as the Max Planck Institute for Astronomy (MPIfA) in Heidelberg.

3.4 Training week for National School Teachers

In association with the Department of Education and Skills a training week for National School science teachers was held in Dunsink.

3.5 Individual Contributions

Felix Aharonian continued as vice president of the division of the International Astronomical Union (IAU) 'High Energy Phenomena and Fundamental Physics'; as an ESA representative in the ASTRO-H project; served as an editor of the International Journal of Modern Physics; chaired the International Advisory Council of the Institute of Sciences of the Cosmos at the University of Barcelona; and was a Member of the Scientific Advisory Committee of Astroparticle Physics European Consortium (APPEC).

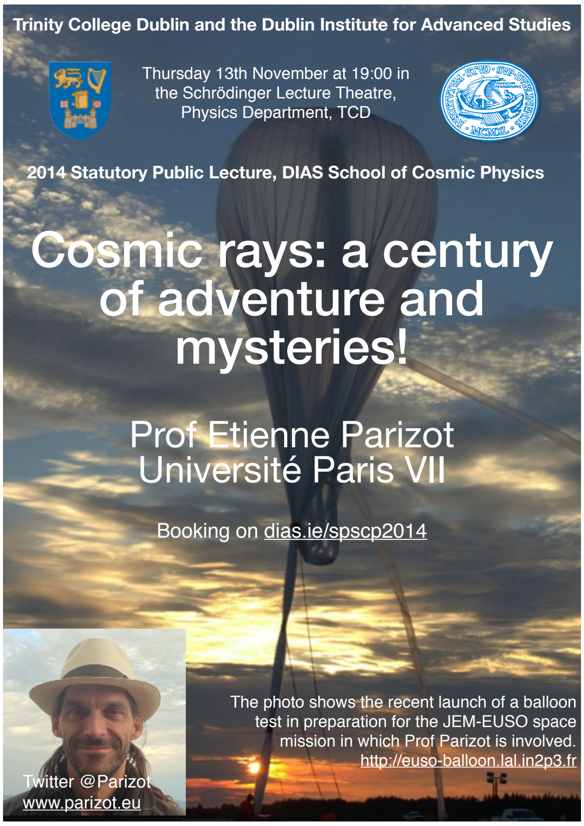
Luke Drury finished his term as President of the Royal Irish Academy at the March stated meeting; he took up office as Chair of the European Space Agency's Astronomy Working Group and *ex officio* member of the Space Science Advisory Committee with effect from 1 Jan; he was elected as a member of the Scientific Steering Committee of PRACE (the Partnership for Advanced Computing in Europe) with effect from July; he was nominated by the RIA as the Irish representative on the Euro-ICSU Management Group; he worked with the Irish node of CECAM in UCD to prepare an e-Infrastructure bid for H2020.

Tom Ray served on the Marie Curie Fellowship Physics Panel; on the Council of the Royal Irish Academy (RIA); as Chair of the Physical, Chemical and Mathematical Sciences Committee of the RIA, on the Science and Technology Facilities Council (STFC) e-MERLIN Steering Committee; on ESA's MIRI Steering Committee, on the Management Committee of the Armagh Observatory and Planetarium and on the Management Committee of ORIGINS (a European Commission COST project). He also served as an external PhD examiner for the University of Ohio and and as a committee chair and reviewer for the Belgian Science Policy Office (BELSPRO).

Malcolm Walmsley continued to serve as an editor of Astronomy and Astrophysics.

4 Public Outreach

4.1 Statutory Public Lecture



The statutory public lecture of the School for 2014, entitled "Cosmic Rays: a century of adventure and mysteries!" was given by Professor Etienne Parizot of the Université Paris VII, a former postdoctoral researcher in the School. Professor Parizot was introduced by the Provost of Trinity, Professor Patrick Pendergast and the lecture is available to view online at https://www.youtube.com/watch?v=wIG_P9RFQY4.

4.2 Dunsink

4.2.1 Open nights and other similar events

Hilary O'Donnell et al

Continuing a long tradition the observatory runs 'public open night' (PON) events, normally on the first and third Wednesday of each month, during the winter months. In addition a large number of special events were organised for interested parties, schools, graduate associations, scout groups etc. The typical programme involves a short presentation on the solar system while people assemble followed by a short introduction to the history of the observatory and a presentation by one of our researchers or associates before, weather permitting, people are allowed to look through the Grubb refractor. This programme is run in partnership with the Irish Astronomical Society whose assistance is gratefully acknowledged. During the year a total of 90 events were held, including 10 during science week.

DIAS staff and scholars who assisted in running and speaking at the events were Luke Drury, Tom Ray, Andrew Taylor, Vincent Geers, Ruyman Azzollini, Paul Dawson, Rachel Ainsworth, Carlo Romoli, Colm Coughlan, Donna Rodgers-Lee, Yuri Babyk, Anne Grace, Eileen Flood and former scholar Denis Malyshev; from the Irish third level sector Turlough Downes, Masha Chernyakova, Neill Smith, David Malone, Shaun Bloomfield, Sreejith Padinhetteri, Deirdre Coffey, Emmon Scullion, Pietro Zucca; from the irish Centre for High-End Computing Paul Nolan; from Dazult Ltd Paul Dempsey; and from the Irish Federation of Astronomical Societies John Flannery, John Dolan, Deirdre Kelleghen, Michael O'Connell, Terry Mosley. Kevin Smith. Brian Bersley and Dave Grennan.

Members of the Irish Astronomical Society who served as volunteers and stewards at the open nights were Val Dunne, Robin Moore, John Flannery, Patricia Carroll and Eamon Handley.

John Dolan (IAS) and Karl O'Brien (Space and Scope) assisted at the technical telescope evenings.

4.3 Other Outreach Contributions

4.3.1 Quaternion Quest

Dr Aisling O'Beirn collaborated with Luke Drury on a art project exploring through sculpture and video Hamilton's discovery of quaternions and the problems of representing rotations in higher dimensional spaces. The resulting exhibition, entitled "Quaternion Quest" was curated by Sheena Barett in Dublin City Council's LAB space and ran from 11 Sep to 15 Nov. Claire O'Connell reviewed the exhibition for Silicon Republic http://www.siliconrepublic.com/innovation/item/38375-wit2014.

A Mystic Dream of Four In conjunction with the "Quaternion Quest" exhibition poet Iggy McGovern and Luke Drury held a public conversation on 5 Nov including readings from Iggy's latest volume of poems based around the life of Hamilton. A recording of the evening is available on http://vimeo.com/111720266.

4.3.2 Transition Year Students

The following Transition Year Students were hosted:

Eoin Parsons O'Donnell - CBC Monkstown - January 13th – 17th

Eoin O'Donnell - Firhouse Community College - March 3rd – 7th

Abby Amodio - Firhouse Community College - April 7th – 11th

Ruben Beumer - Manix College, the Netherlands - April 7th – 16th

Mika McKeever - St Benildus College - December 1st – 5th

5 Detailed Bibliography of Publications

Note that where possible hyperlinks have been provided to the journal article and preprint version.

5.1 Peer-reviewed Publications in 2014

[1] A. Abramowski et al. "Diffuse Galactic gamma-ray emission with H.E.S.S." In: Phys. Rev. D 90.12, 122007 (Dec. 2014), p. 122007. DOI: 10.1103/PhysRevD.90.122007.

[2] A. Abramowski et al. "Discovery of the Hard Spectrum VHE γ-Ray Source HESS J1641-463". In: ApJ 794, L1 (Oct. 2014), p. L1. DOI: 10.1088/2041-8205/794/1/L1. arXiv: 1408.5280 [astro-ph.HE].

[3] A. Abramowski et al. "HESS J1640-465 - an exceptionally luminous TeV γ-ray supernova remnant". In: MNRAS 439 (Apr. 2014), pp. 2828–2836. DOI: 10.1093/mnras/stu139. arXiv: 1401.4388 [astro-ph.HE].

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[6] R. E. Ainsworth et al. "Tentative Evidence for Relativistic Electrons Generated by the Jet of the Young Sun-like Star DG Tau". In: ApJ 792, L18 (Sept. 2014), p. L18. DOI: 10.1088/2041-8205/792/1/L18. arXiv: 1408.1892 [astro-ph.SR] (cit. on p. 1).

[7] J. M. Alcalá et al. "X-shooter spectroscopy of young stellar objects. IV. Accretion in low-mass stars and substellar objects in Lupus". In: A&A 561, A2 (Jan. 2014), A2. DOI: 10.1051/0004-6361/201322254. arXiv: 1310.2069 [astro-ph.SR] (cit. on p. 2).

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[9] I. Babyk and A. Del Popolo. "Correlations in Relaxed Clusters of Galaxies". In: *Baltic Astronomy* 23 (2014), pp. 9–26.

[10] M. T. Beltrán et al. "Filamentary structure and Keplerian rotation in the high-mass star-forming region G35.03+0.35 imaged with ALMA". In: A&A 571, A52 (Nov. 2014), A52. DOI: 10.1051/0004-6361/201424031 (cit. on p. 2).

[11] R. Cesaroni et al. "Imaging the disk around IRAS 20126+4104 at subarcsecond resolution". In: A&A 566, A73 (June 2014), A73. DOI: 10.1051/0004-6361/201323065 (cit. on p. 3).

[12] M. Chernyakova et al. "Multiwavelength observations of the binary system PSR B1259-63/LS 2883 around the 2010-2011 periastron passage". In: MNRAS 439 (Mar. 2014), pp. 432–445. DOI: 10.1093/mnras/stu021. arXiv: 1401.1386 [astro-ph.HE] (cit. on p. 18).

[13] G. Costigan et al. "Temperaments of young stars: rapid mass accretion rate changes in T Tauri and Herbig Ae stars". In: MNRAS 440 (June 2014), pp. 3444–3461. DOI: 10.1093/mnras/stu529. arXiv: 1403.4088 [astro-ph.SR] (cit. on p. 3).

[14] P. Dawson et al. "Near-infrared spectroscopy of young brown dwarfs in upper Scorpius". In: MNRAS 442 (Aug. 2014), pp. 1586–1596. DOI: 10.1093/mnras/stu973. arXiv: 1405.3842 [astro-ph.SR] (cit. on p. 4).

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