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Contents

1 Research Reports

1.1 High-Energy Astrophysics

1.1.1 Final results from the Ultra-Heavy Cosmic Ray Experiment on the Long Duration Exposure Facility

J. Donnelly (DIT), A. Thompson, D. O'Sullivan, J. Daly, L. Drury, V. Domingo (U. Valencia) and K.-P. Wenzel (ESTEC)

The LDEF Ultra-Heavy Cosmic-Ray Experiment (UHCRE) detected Galactic cosmic rays (GCRs) of charge $Z \geq 70$ in Earth orbit with an exposure factor of $170\,\mathrm{m^2\,sr\,yr}$, much larger than any other experiment. A careful re-analysis was made of the final data from the experiment using modern techniques of Monte-Carlo likelihood estimation. The major results include the first statistically significant uniform sample of GCR actinides with 35 events passing quality cuts, evidence for the existence of transuranic nuclei in the GCR with one $_{96}$Cm candidate event, and a low $_{82}$Pb/$_{78}$Pt ratio consistent with other experiments. The probability of the existence of a transuranic component is estimated as 96%, while the most likely $_{92}$U/$_{90}$Th ratio is found to be 0.4 within a wide 70% confidence interval ranging from 0 to 0.96 (see Figure 1). Overall, the results are consistent with a volatility-based acceleration bias and source material which is mainly ordinary interstellar medium material with some recent contamination by freshly synthesised material. Uncertainty in the key $_{92}$U/$_{90}$Th ratio is dominated by statistical errors resulting from the small sample size and any improved determination will thus require an experiment with a substantially larger exposure factor than the UHCRE.

The paper was accepted for publication in the ApJ in early 2012.

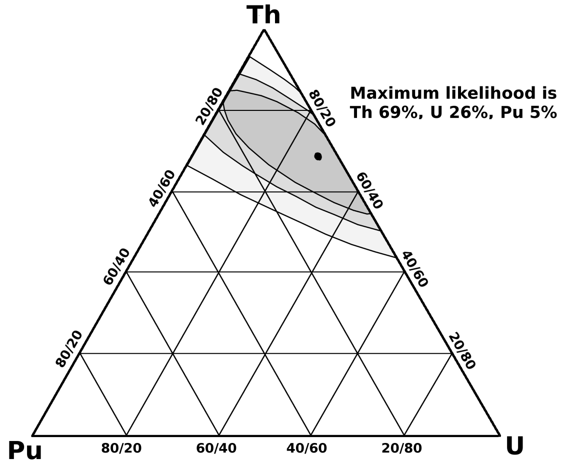

Figure 1: Likelihood contours (at the 90%, 70% and 50% levels) for a ternary U/Th/Pu composition of the actinides in the GCR as derived from the UHCRE data.

1.1.2 Nuclear reactions in hot astrophysical plasmas

F. Aharonian, and E. Kafexhiu (MPIK, Heidelberg, Germani), G. Vila (IAR, Buenos-Aires, Argentina)

Low-density optically thin two-temperature ($T_\mathrm{i} \gg T_\mathrm{e}$) plasmas with ion temperature T_i exceeding 10^{10}K, can form near compact relativistic objects, such as accretion flows close to black holes and strong shock waves related, for example, to supernova explosions. The importance of nuclear reactions in such plasmas, including the excitation and spallation of nuclei, production of neutrons and their capture by protons, proton-neutron bremsstrahlung, etc., has been recognized in the early 1980s. However, the lack of comprehensive data banks of relevant nuclear reactions and the limited computational power did not allow detailed theoretical studies. Recent developments in these areas make it timely to conduct comprehensive studies which are of great interest, in particular in the context of scientific programs of future low-energy cosmic γ-ray spectrometry. Recently, the publicly available code TALYS, we have built a large nuclear network relevant for temperatures exceeding 10^{10} K. We have studied the evolution of the chemical composition and accompanying prompt gamma-ray emission of such high temperature plasmas. In particular, the abundances of light elements D, T, ^{3}He, ^{4}He, ^{6}Li, ^{7}Li ^{9}Be, ^{10}B, ^{11}B have been calculated, and the implications on these results have been discussed.

1.1.3 Origin of the extremely hard VHE gamma-ray spectra of blazers

F. Aharonian, E. Lefa, F. Rieger and O. Zacharopoulou (MPIK, Heidelberg, Germany), D. Khangulyan (ISAS/JAXA, Tokyo, Japan), L. Costamante (Stanford University, USA)

The very high energy (VHE) gamma-ray spectra of some TeV blazars, after being corrected for absorption due to interactions with the extragalactic background light (EBL), appear unusually hard. This poses challenges to conventional acceleration and emission models. We have proposed and developed two different scenarios of formation of hard spectra of blazers. The first one is based on the assumption of internal time-dependent absorption of gamma-rays inside the source. In particular, we have studied this possibility for gamma-rays produced through synchrotron radiation of ultrarelativistic protons in highly magnetized blobs to two blazers - 1ES 0229+200 and 3C 66A, and have shown that for certain combinations of reasonable model parameters, even with quite modest energy requirements, the scenario allows a self-consistent explanation of the non-thermal emission of these objects in the keV, GeV, and TeV energy bands. The second model is based on the assumption of production of gamma-rays by electrons with very hard acceleration spectrum. We have investigated the parameter space that allows the production of hard TeV gamma-ray spectra within time-dependent leptonic models, both for synchrotron self-Compton and external Compton scenarios. In the context of the interpretation of very hard gamma-ray spectra, time-dependent considerations become crucial because even extremely hard, initial electron distributions can be significantly deformed due to radiative energy losses. We show that very steep VHE spectra can be avoided if adiabatic losses are taken into account. Another way to keep extremely hard electron distributions in the presence of radiative losses is to assume stochastic acceleration models that naturally lead to steady-state, relativistic, Maxwellian-type particle distributions. We demonstrated that in either case leptonic models can reproduce TeV spectra as hard as $dN/dE \propto E^{-1}$. In the case of very hard spectra of the blazer Mkn 501 reported by the *Fermi* collaboration during the high state of the source in 2009, we have introduce a "leading blob" scenario, applicable to active flaring episodes, when one (or a few) of these components become distinct over the "background" emission, producing hard spectral features.

1.1.4 Fermi Bubbles: Giant, Multibillion-Year-Old Reservoirs of Galactic Center Cosmic Rays

F. Aharonian and R. Crocker (MPIK, Heidelberg, Germany)

Recently evidence has emerged for enormous features in the gamma-ray sky reported by the *Fermi* collaboration: bilateral ‘bubbles’ of emission centered on the core of the Galaxy and extending to around ± 10 kpc from the Galactic plane. These structures are coincident with a nonthermal microwave ‘haze’ and an extended region of X-ray emission. The bubbles’ gamma-ray emission is characterized by a hard and relatively uniform spectrum and uniform surface intensity, and an overall luminosity 4×10^{37} erg/s, around 1 order of magnitude larger than their microwave luminosity while more than order of magnitude less than their X-ray luminosity. Here we show that the bubbles are naturally explained as due to a population of relic cosmic-ray protons and heavier ions injected by processes associated with extremely long time scale (≥ 8 Gyr) and high star formation rate in the Galactic center. If the model is correct, the planned KM3NeT high energy neutrino detector should be able to detect neutrino signal from Fermi Bubbles.

1.1.5 Radioactivity and electron acceleration in supernova remnants

F. Aharonian and V. Zirakashvili (IZMIRAN, Troitsk, Russia)

We argue that the decays of radioactive nuclei related to Ti^{44} and Ni^{56} ejected during supernova explosions can provide a vast pool of mildly relativistic positrons and electrons which are further accelerated to ultrarelativistic energies by reverse and forward shocks. This interesting link between two independent processesâ the radioactivity and the particle accelerationâ can be a clue for solution of the well known theoretical problem of electron injection in supernova remnants. In the case of the brightest radio source Cas A, we demonstrate that the radioactivity can supply adequate number of energetic electrons and positrons for interpretation of observational data, provided a modest pre-acceleration (presumably of stochastic origin) to energies $E_{\rm inj} \sim 0.1$ GeV takes place in the upstream regions of the forward and reverse shocks. The proposed scenario can explain not only the overall flux of galactic CR electrons by SNRs, but also the recently reported tendency of gradual increase of the positron-to-electron ratio with energy.

1.1.6 X-Ray diagnostics of giant molecular clouds in the Galactic Center region and past activity of Sgr A*

F. Aharonian, and H. Odaka, S. Watanabe, Y. Tanaka, D. Khangulyan, T. Takahashi (ISAS/JAXA, Tokyo, Japan)

Strong iron fluorescence at 6.4 keV and hard-X-ray emissions from giant molecular clouds in the Galactic Center region have been interpreted as reflections of a past outburst of the Sgr A* supermassive black hole. Careful treatment of multiple interactions of photons in a complex geometry is essential for modeling of the reprocessed emissions from the dense clouds. We have developed a new numerical model for calculations of the process of X-ray reflection from molecular clouds based on Monte Carlo simulations, and present the first calculations of morphological and spectral properties of the reflected X-ray emission for different configurations of Sgr B2, the most massive molecular cloud in our Galaxy. The morphology of scattered hard X-rays above 20 keV is significantly different from that of iron fluorescence due to their large penetrating power into dense regions of the cloud, probing the structure of the cloud. High-resolution spectra provide quantitative evaluation of the iron line and its Compton shoulder to constrain the mass and the chemical composition of the cloud. These predictions can be checked in the near future with future X-ray missions such as NuStar (hard X-rays) and ASTRO-H (both iron lines and hard X-rays).

1.1.7 Non-variable cosmologically distant gamma-ray emitters as a propagation imprint of ultra-high-energy protons

F. Aharonian, and A. Prosekin, S. Kelner (MPIK, Heidelberg, Germany)

The acceleration sites of ultra-high-energy (UHE) protons can be traced by the footprint left by these particles when they propagate through cosmic microwave background radiation (CMBR). Secondary electrons produced in the extended region of several tens of Mpc are cooled via synchrotron radiation predominantly in the initial direction of the parent protons. This forms a non-variable and compact (almost point-like) source of high-energy gamma rays. The importance of this effect is increased for cosmologically distant objects. Because of severe energy losses, UHE protons cannot reach us even in the case of extremely weak intergalactic magnetic fields. Moreover, at high redshifts the energy conversion from protons to secondary particles becomes significantly more effective because of the denser and more energetic CMB in the past. This increases the chances of UHE cosmic rays to be traced by the secondary synchrotron gamma radiation. We discuss the energy budget and the redshift dependence of the energy transfer efficiency from UHE protons to synchrotron radiation. The angular and spectral distributions of radiation in the gamma- and X-ray energy bands are calculated and discussed in the context of their detectability by the *Fermi* gamma-ray and *Chandra* X-ray observatories.

1.1.8 A local source of ultrahigh-energy cosmic-ray nuclei?

F. Aharonian, and A. Taylor (ISDC, Versoix, Switzerland), M. Ahlers (Stony Brook, New York)

Recent results of the Pierre Auger Cosmic Ray Observatory fluorescence detectors indicate an increasingly heavy composition of ultra-high energy (UHE) cosmic rays. Assuming that this trend continues up to the highest energies observed by the Auger surface detectors, we obtained robust constraints on the local source distribution of UHE cosmic ray nuclei. Utilizing an analytic description of UHE CR propagation, we derived the expected spectra and composition for a wide range of source emission spectra. We found that sources of intermediate-to-heavy nuclei are consistent with the observed spectra and composition data above the ankle. This consistency requires the presence of nearby sources within 60 Mpc and 80 Mpc for silicon and iron-only sources, respectively. The necessity of these local sources becomes even more compelling in the presence of nano-Gauss local extragalactic magnetic fields.

1.1.9 Constraining the emissivity of ultrahigh energy cosmic rays in the distant universe with the diffuse gamma-ray emission

F. Aharonian, Xiang-Yu Wang; Ruo-Yu Liu (Nanjing University, China)

Ultrahigh cosmic rays (UHECRs) with energies exceeding 10^{19}eV emitted at cosmological distances are attenuated by cosmic microwave radiation (CMBR) through photomeson processes. Lower energy extragalactic cosmic rays can only travel a linear distance smaller than 1 Gpc in the Hubble time due to the diffusion if the extragalactic magnetic fields are as strong as nano-Gauss. These prevent us from directly observing most of the UHECRs in the universe, and thus the observed UHECR intensity reflects only the emissivity in the nearby universe within hundreds of Mpc. However, UHECRs in the distant universe, through interactions with CMBR, produce electrons and gamma rays that in turn initiate electromagnetic cascades. The secondary cascade radiation forms part of the extragalactic diffuse GeV-TeV gamma-ray radiation and, unlike the original UHECRs, is observable. Motivated by new measurements of extragalactic diffuse gamma-ray background radiation by Fermi/Large Area Telescope, we obtained upper limit placed on the UHECR emissivity in the distant universe by requiring that the cascade radiation they produce not exceed the observed levels. By comparison with the gamma-ray emissivity of candidate UHECR sources, e.g. gamma-ray bursts (GRBs) and active galactic nuclei (AGN) at high redshifts, we find that the obtained upper limit for a flat proton spectrum is 30 times larger than the gamma-ray emissivity in GRBs and approximately 10 times smaller than the gamma-ray emissivity in BL Lac objects. In the case of iron nuclei composition, the derived upper limit of UHECR emissivity is a factor of 3-5 times higher. Robust upper limit on the cosmogenic neutrino flux is also obtained, which is marginally reachable by the IceCube detector and the next-generation detector UHECR detector JEM-EUSO.

1.1.10 Non-thermal processes in relativistic outflows

V. Bosch-Ramon, F. A. Aharonian

Astrophysical sources with relativistic outflows are powerful non-thermal emitters from radio to gamma rays. These relativistic outflows interact with their environment in galactic and extragalactic objects, leading to complex magnetohydrodynamical processes, particle acceleration and non-thermal emission. Usually, leptonic mechanisms are good candidates for the non-thermal emission of these sources, with synchrotron radiation dominating from radio to X-rays, and inverse Compton in gamma rays (e.g. [86, 58, 27, 24]). The properties of the non-thermal emission are strongly linked to dynamical processes of the involved flows (e.g. [23, 25]), and thus non-radiative losses are to be considered together with radiative ones (e.g. [86]). Although less common, thermal radiation can be also expected in these sources (e.g. binary systems with strong stellar winds, or in large-scale interactions with the external material), its study being also a source of physical information [85, 24]. Radiation reprocessing in some cases (e.g. compact binary systems, base of jets) is to be accounted for, and gamma-ray absorption and creation of pairs, with their subsequent emission, can be of primary importance [26, 87].

1.1.11 Multiwavelength emission from the gamma-ray loud binary systems.

M. Chernyakova, A. Neronov (ISDC, Geneva)

Gamma-ray-loud binary systems (GRLB) are a newly identified class of X-ray binaries in which either accretion onto the compact object (a neutron star, or a black hole), or interaction of an outflow from the compact object with the wind and radiation emitted by the massive companion star leads to the production of very-high energy (VHE) gamma-ray emission. Four such systems PSR B1259-63, LS 5039, LSI +61Âś 303 and HESS J0632+057, have been firmly detected as persistent or regularly variable TeV gamma-ray emitters.

PSR B1259-63 is the only GRLB where we know the nature of the compact object - in this system 47.76 ms radio pulsar is orbiting a massive star (LS 2883) in a highly elliptical (e 0.87) orbit with a period of about 3.4 years. Shock interaction between the relativistic pulsar wind and the wind and photon field of the Be star is believed to give rise to the variable unpulsed X-ray emission observed throughout the orbit and the unpulsed radio and TeV γ-rays observed within a few months of periastron. The energy of the relativistic particles of the pulsar wind is still not known for sure and there was a hope that Fermi observations of the system will finally help to resolve this issue. In order to prepare for the December 2010 periastron passage we have organized along with Fermi team a multiwavelength (from radio up to VHE) campaign [1]. While the periastron passage itself doesn't bring too big surprises, the huge post-periastron flare observed only at GeV energy was absolutely unexpected. An interesting theoretical explanation of the phenomena was proposed in [23, 58], but the work on better understanding of the physical processes taking place in the system is still ongoing.

LSI +61 303 is another high-mass X-ray binary which emits high-energy (GeV-TeV) gamma-rays. It is known to be variable on different timescales. The orbital period is 26.5 days (Gregory 2002), the superorbital period is about 1667 days. In LSI +61 303, the high-energy particle outflow is directly observed in the radio band, where angular resolution is sufficient to resolve the source and detect variations of its morphology on the orbital period timescale. The observed morphological changes indicate that the outflow is, most probably, not a jet with a well-defined position angle on the sky, but is rather a variable morphology outflow filling a region the size 100 - 1000 times larger than the binary separation distance. The radio signal could not be used to trace the outflow down to the production site inside the binary orbit because of the free-free absorption in the dense stellar wind environment. To understand the nature of the high energy particle carrying outflow one has to use complementary high-energy data in X-ray and/or gamma-ray bands. In the X-ray band the source is known to exhibit one flare per orbit, on average preceding the radio one. The GeV band light curve during the first year of LAT observations also exhibited a one-flare pattern. Both X-ray and GeV band light curves exhibit large orbit-to-orbit variations so that the systematic periodic variability is often washed out by an erratic behavior of the source. The origin of the X-ray and radio flares as well as the relation between the flaring activity of the source in different energy bands is not well understood. The orbital phase of the periodic flares drifts on a superorbital timescale by half-an-orbit. Such a drift is difficult to explain in scenarios based on various types of precession, where one expects a drift by a full orbit. An alternative possibility for the explanation of the 4.5 yr timescale is the buildup and decay of the equatorial disk around the massive Be star in the system. A new insight into the nature of the 4.5 yr periodicity/variability might be given by the study of the changes in the behavior of the X-ray and gamma-ray emission on this timescale. We performed such a study based on the analysis of the monitoring of the source with RXTE, INTEGRAL, and Fermi. The X-ray/gamma-ray data were complemented by the contemporaneous radio monitoring data. In our work we discover a systematic constant time lag between the X-ray and radio flares, persistent over a long, multi-year, timescale (see Fig. 2). We propose that the constant phase lag corresponds to the time of flight of the high-energy particle-filled plasma blobs from inside the binary to the radio emission region at the distance 10 times the binary separation distance. We put forward a hypothesis that the X-ray bursts correspond to the moments of formation of plasma blobs inside the binary system. Paper on this study was accepted to ApJL in early 2012.

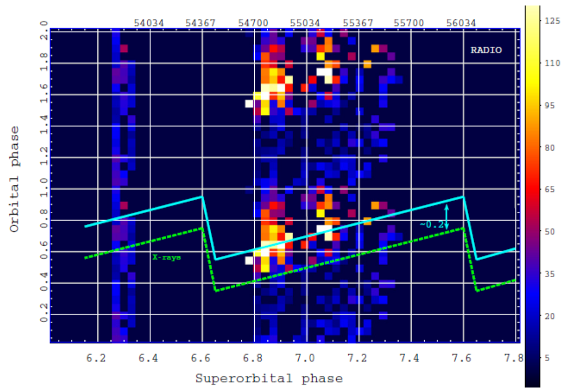

Figure 2: Radio flux from LSI +61 303 as a function of the orbital and superorbital phases. Green and cyan lines allow comparison of X-ray and radio superorbital variability patterns.

1.1.12 Systematic study of the variable GeV sky.

M.Chernyakova, D.Malyshev(BITP, Kiev)

The study of the sky using the most energetic photons Ãś gamma-ray astronomy - plays a crucial role in detecting and exploring high-energy phenomena in the universe. The observation of the sky with the recently launched FERMI mission opened a completely new window in gamma-ray astronomy and reveals more than 1500 point-like gamma-ray sources candidates. Some of these sources demonstrate surprisingly high efficiency of particle acceleration, close to theoretical limits. The studying of the gamma-ray properties (spectral and timing characteristics) of extreme accelerators is required for the testing theoretical models of particle acceleration and understanding the nature of the source. However, the detection of gamma-ray sources, especially at low Galactic latitudes (where the sources most probably have galactic origin that is an interesting sub-class of extreme accelerators) is a complicate task. Strong diffuse emission from the Galaxy prevents reliable identification of isolated point sources. Indeed, typical angular scale of spatial variations of diffuse gamma-ray emission is comparable or smaller than the point spread function of FERMI/LAT, especially at the low energy (100MeV) end of the LAT energy range. This means that spatial variations of intensity of diffuse gamma-ray emission could be easily miss-interpreted as possible new unidentified point sources. To distinguish the diffuse emission excesses from real sources, one should manage to use certain properties of real sources (e.g. pulsars, supernova remnants or binary systems) which could not be found in the excesses of diffuse emission. The most straightforward distinguishing property of real gamma-ray sources is variability. Diffuse gamma-ray emission, both Galactic and Extragalactic is not expected to be variable on week / month / year time scales. To the contrary, compact gamma-ray sources, such as gamma-ray loud binaries, are generically expected to be variable on the orbital time scale. Neutron star and stellar mass black hole powered sources could be variable on the time scale as short at the light crossing time of the compact object, which is in the millisecond range. A simple way to verify if gamma-ray emission from a given direction on the sky is variable or constant is to analyze the light curve and check if it is consistent with a constant flux. In order to check this idea we built a set of variability maps at different energies and on different timescales (see e.g. Fig.3) have been built using all available for the moment Fermi data (3years). These maps reveal a number of variable sources, some of which are unidentified sources from the second FERMI catalog and some of them are not presented in 2 year catalog. Now we are looking in more details into each particular case. The work is ongoing.

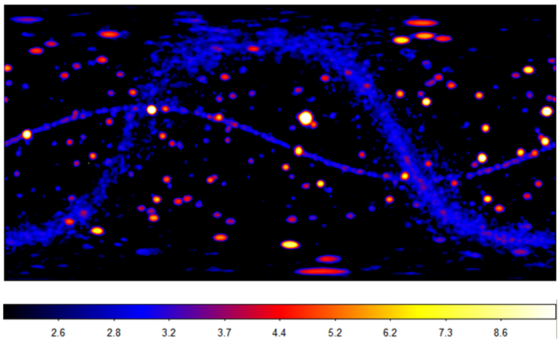

Figure 3: Variability map of the sky at energies 300MeVÃş300GeV on 6 hours timescale

1.1.13 Strong outbursts activity of the X-ray pulsar X Persei in 2001-2011

M.Chernyakova, A. Lutovinov, S. Tsygankov (IKI, Moscow)

We present a comprehensive analysis of the X-ray pulsar X Persei over the period 1996 to 2011, encompassing the quite low state and subsequent strong outbursts activity. Using data from the *RXTE* and *Swift* observatories we detected several consecutive outbursts, in which the source luminosity was increased by factor of ~ 5 up to $L_X \simeq 1.2 \times 10^{35}$ ergs. This is only the second episode from the X Persei discovery, when the source is observed in a high state. The source spectrum in a standard energy band ($4-25$ keV) is remained a relatively stable with flux changes and can be well described by two models, including both thermal and non-thermal components. Data of the *INTEGRAL* observatory allowed us to register at the high significance level the cyclotron absorption line in the source spectrum and, for the first time, to significantly detect a hard X-ray emission from the pulsar up to ~ 160 keV. We report also drastic changes of the pulsar pulse period during the period of the outbursts activity: a long period of the spin-down was changed by the spin-up with the rate of $\dot{P}/P \simeq -(3-5)\times 10^{-3}$ yr^{-1}, that by several times higher than previous rates of spin-up and spin-down. No significant correlation between optical and X-ray fluxes at any time lag from dozens of days to years was found. Paper on this study is submitted to MNRAS.

1.1.14 Study of extragalactic soft X-ray transients in M31

N. Nooraee, P. Callanan (UCC)

During numerous X-ray observations of M31 over the last decade, more than 50 soft X-ray transients have been detected. Galactic soft X-ray transients, a subgroup of low mass X-ray binaries, show evidence for being powered by accreting stellar mass black holes. To confirm the presence of black holes in soft X-ray transients, high resolution optical observations are needed which the Hubble Space Telescope is able to provide. In this study several new transients were detected and investigated with follow up optical observations. The study of the light curves of bright soft X-ray transients, from outburst down to quiescence, may help to understand the physical mechanisms responsible for the outburst, in particular whether disk irradiation can explain the longer outbursts as compared to dwarf novae.

1.2 Star Formation

1.2.1 POISSOIN Project: YSO optical NIR spectral survey star forming regions

A. Caratti o Garatti, R. Garcia Lopez, T. Ray (DIAS), S. Antoniucci (INAF-OAR), T. Giannini (INAF-OAR), J. Eislöffel (TLS), B. Nisini (INAF-OAR), D. Lorenzetti (INAF-OAR), S. Cabrit (Lerma-Paris)

Characterising stellar and circumstellar properties of embedded young stellar objects (YSOs) is mandatory for understanding the early stages of the stellar evolution. This task requires the combination of both spectroscopy and photometry, covering the widest possible wavelength range, to disentangle the various protostellar components and activities. At this aim we started the POISSON project (Protostellar Optical-Infrared Spectral Survey On NTT), a low-resolution optical-near IR spectroscopic survey (0.6âĂŽÃĎÃň2.4 μm) of a sample of Class I and Class II young stellar objects in six different star forming regions (Chamaeleon I and II, L 1641, Lupus, Vela, and Serpens). The main results of the first two published papers, on Chamaeleon I and II, L 1641 regions, are the following. Low mass YSO empirical classification relies on the shape of the Spectral Energy Distribution (SED) alone. On the basis of the derived stellar properties of our targtes, we show that geometrical effects can significantly modify the SED shapes, and sometimes the classical YSO classification does not match with the real age of the objects. The youngest YSOs have the highest $\dot{M}_{acc}$, whereas the oldest YSOs do not show any detectable jet activity in either images and spectra. We also observe a clear correlation among the YSO $\dot{M}_{acc}$, M_*, and age. For YSOs with $t > 10^5$ yr and $0.4\,M_\odot \leq M_* \leq 1.2\,M_\odot$, a relationship between $\dot{M}_{acc}$ and t ($\dot{M}_{acc} \propto t^{-1.2}$) has been inferred, consistent with mass accretion evolution in viscous disc models and indicating that the mass accretion decay is slower than previously assumed. Finally, our results suggest that episodic outbursts are required for Class I YSOs to reach typical classical T Tauri stars stellar masses.

1.2.2 The nature of the embedded intermediate-mass T Tauri star DK Cha

R. Garcia Lopez, A. Caratti o Garatti, T.P. Ray (DIAS), B. Nisini (INAF-OAR), S. Antoniucci (INAF-OAR), T. Giannini (INAF-OAR), J. Eislöffel (TLS), D. Lorenzetti (INAF-OAR)

Most of our knowledge about star formation is based on studies of low-mass stars, whereas very little is known about the properties of the circumstellar material around young and embedded intermediate-mass T Tauri stars (IMTTSs) mostly because they are rare, typically more distant than their lower mass counterparts, and their nearby circumstellar surroundings are usually hidden from us. We present an analysis of the excitation and accretion properties of the young IMTTS DK Cha. The nearly face-on configuration of this source allows us to have direct access to the star-disk system through the excavated envelope and outflow cavity. Based on low-resolution optical and infrared spectroscopy obtained with SofI and EFOSC2 on the NTT we derive the spectrum of DK Cha from ~0.6 μm to ~2.5 μm. From the detected lines we probe the conditions of the gas that emits the H I IR emission lines and obtain insights into the origin of the other permitted emission lines. In addition, we derive the mass accretion rate ($\dot{M}_{acc}$) from the relationships that connect the luminosity of the Brγ and Paβ lines with the accretion luminosity (L_{acc}). The observed optical/IR spectrum is extremely rich in forbidden and permitted atomic and molecular emission lines, which makes this source similar to very active low-mass T Tauri stars. Some of the permitted emission lines are identified as being excited by fluorescence. We derive Brackett decrements and compare them with different excitation mechanisms. The Paβ/Brγ ratio is consistent with optically thick emission in LTE at a temperature of ~3500 K, originated from a compact region of ~5 $R_\odot$ in size: but the line opacity decreases in the Br lines for high quantum numbers nup. A good fit to the data is obtained assuming an expanding gas in LTE, with an electron density at the wind base of ~10^{13} cm^{-3}. In addition, we find that the observed Brackett ratios are very similar to those reported in previous studies of low-mass CTTSs and Class I sources, indicating that these ratios are not dependent on masses and ages. Finally, L_{acc} ~9 $L_\odot$ and $\dot{M}_{acc}$ ~$10^{-7}\,M_\odot\,yr^{-1}$ values were found. When comparing the derived ÂůĬĂÃĎacc value with that found in Class I and IMTTSs of roughly the same mass, we found that ÂůĬĂÃĎacc in DK Cha is lower than that found in Class I sources but higher than that found in IMTTSs. This agrees with DK Cha being in an evolutionary transition phase between a Class I and II source.

1.2.3 The outburst of an embedded low-mass YSO in L1641

A. Caratti o Garatti, R. Garcia Lopez, A. Scholz

(DIAS), T. Giannini (INAF-OAR), J. Eislöffel (TLS), B. Nisini (INAF-OAR), F. Massi (INAF-OAA), S. Antoniucci (INAF-OAR)

Strong outbursts in very young and embedded protostars are rare and not yet fully understood. They are believed to originate from an increase in the mass accretion rate ($\dot{M}_{acc}$) onto the source. We report the discovery of a strong outburst in a low-mass embedded young stellar object (YSO), namely $2MASS-J05424848-0816347$ or $[CTF93]216-2$, as well as its photometric and spectroscopic follow-up. Using near- to mid-IR photometry and NIR low-resolution spectroscopy, we monitor the outburst, deriving its magnitude, duration, as well as the enhanced accretion luminosity and mass accretion rate. $[CTF93]216-2$ increased in brightness by ~4.6, 4.0, 3.8, and 1.9 mag in the J, H, K_s bands and at 24 μm, respectively, corresponding to an L_{bol} increase of ~20 $L_\odot$. Its early spectrum, probably taken soon after the outburst, displays a steep almost featureless continuum, with strong CO band heads and H_2O broad-band absorption features, and Brγ line in emission. A later spectrum reveals more absorption features, allowing us to estimate $T_{\rm eff}$~3200 K, M_*~0.25 $M_\odot$, and $\dot{M}_{acc}$~1.2×10^{-6} $M_\odot$ yr^{-1}. This makes it one of the lowest mass YSOs with a strong outburst so far discovered. We are carrying on new observations at ESO/VLT to study this rare phenomenon.

1.2.4 NIR spectroscopic survey of jets from massive YSOs

A. Caratti o Garatti, B. Stecklum (Tautenburg), C. Davis (JAC), H. Linz (MPIA), T. Stanke (ESO), and H. Zinnecker (AIP).

The detection and study of jets and outflows from high-mass young stellar objects (HMYSOs) is of primary importance to understand the mechanism which produces massive strars. We undertook an unbiased spectroscopic follow-up of the H_2 emissions detected during our previous imaging runs (ESO-NTT/SofI, TNG/NICS), to clarify the nature and the origin of such emissions (shock vs fluorescence; jet vs photo-dissociation region), derive their excitation conditions (T, A_V), and the flow properties (mass, mass ejection rate, H_2 luminosity), correlating them with the evolutionary stage of the driving YSO.

1.2.5 Observing Outflows close to the Ejection Engine

D. Coffey, T. Ray (DIAS), Elisabetta Rigliaco, Francesca Bacciotti (Arcetri), Jochen Eislöffel (Tautenburg)

We have progressed our study of whether we can observe a rotation signature in jets from young stars. We published the results of long awaited observations from the Hubble Space Telescope Imaging Spectrograph (HST/STIS), which had been delayed due to instrument failure and postponement of Servicing Mission 4. These observations are extremely challenging and push the limits of current instrumentation, but have the potential to provide long-awaited observational support for the magneto-centrifugal mechanism of jet launching in which jets remove angular momentum from protostellar systems. The results were of particular interest since they address the previous controversy surrounding T Tauri system RW Aur, which present a paradox of apparently counter-rotating jet and disk. This paradox cast a shadow over the rotation interpretation of differences in Doppler shift between the two sides of the jet as it propagates. These new data reveal that the slope of the Doppler profile transverse to the jet axis is not in the same direction in the approaching jet lobe as has been measured in the receding jet lobe 8 years earlier. Furthermore, the slope disappears six months later. Overall, in the case of RW Aur, measurements are not consistent with a simple jet rotation interpretation. Indeed, given the renowned complexity and variability of this system, it now seems likely that any rotation signature is confused by other influences, with the inevitable conclusion that RW Aur is not suited to a jet rotation study. We continue our jet rotation study of other jet-disk systems, via GEMINI/NIFS data obtained in the infrared of two T Tauri jets for which we already know the sense of disk rotation.

1.2.6 Computational studies of ISM turbulence

T. Downes (DIAS/DCU), S.O'Sullivan (DIT)

Observations of molecular clouds indicate that they are turbulent. This turbulence is dynamically significant and may well affect both the overall evolution of molecular clouds as well as the progress of star formation within these clouds. However, the properties of turbulence in such clouds is not well understood. Although much work has been done on studying turbulence in these clouds under the assumption of ideal magnetohydrodynamics we know that multifluid effects are important on scales of less than a parsec or so.

The second phase of a comprehensive study of the decay of multifluid MHD turbulence in molecular clouds using HDYRA was submitted to ApJ in late 2010. It showed that, as expected from previous work, multifluid effects enhance the rate of decay of turbulence and decreases the amount of structure present in the mass distribution on small scales. Interestingly, it would appear that the gross features of multifluid turbulence can be modeled rather well by approximating the influence of the multifluid effects by spatially and temporally constant resistivities.

The third phase of this study, involving high resolution simulations of driven turbulence, was completed during 2011 using resources from the final DEISA DECI call. Unexpectedly high computational demands for these simulations meant that reliable results for power spectra were difficult to obtain. However, it is clear that the influence of the multifluid effects on power spectra seen in the decay of turbulence is the same, at least qualitatively, as that seen in driven turbulence.

1.2.7 The multifluid magnetorotational instability

T. Downes (DIAS/DCU), W. O'Keeffe (DCU)

It is known that the magnetorotational instability (MRI) may be an important factor in determining the rate of accretion of material from an accretion disk onto the central object. Accretion disks around young stellar objects are known to have regions of very low ionisation, and hence it is expected that multifluid effects will be important. Using resources awarded by PRACE we have performed the first fully multifluid simulations of accretion disks around young stellar objects. Analysis and interpretation of the results is ongoing and it is already clear that multifluid effects have a very significant impact on the predicted accretion rates.

1.3 Software Development for the Mid-Infrared Instrument (MIRI)

T. Ray, A. Scaife, J. Morin

MIRI software development environment The development framework for MIRI-EC software developers (engineered by JM in 2010) has been maintained and upgraded to provide enhanced functionalities. This environment includes the code repository architecture, documentation and testing framework, reference code examples as well as the software installation procedures for all the supported platforms. It ensures that the requirements in terms of code documentation, quality and availability can be fulfilled. The corresponding technical documentation is available online for MIRI-EC and STScI developers and has been regularly updated. JM has presented the MIRI development environment in a poster at the conference Euroscipy 2011 (Paris, France, 25–28 Aug). A technological review of the libraries and software design methods presented at this conference has been by presented by JM to the rest of the MIRI-EC software group (Leiden, Netherlands, 5 Sep).

Support for simulators and analysis software JM has continued supporting the development of SCASim, which has fully taken advantage of the new development environment. The performed tasks include software design, python coding, and support for usage of the environment. SCASim simulates the response of the

MIRI Sensor Chip Array to a given illumination map. It has been adapted from a previous implementation included in SpecSim (the Medium Resolution Spectrometer Simulator), with the aim to provide a unique tool for the simulators developed for the various instrument modes. SCASim has been used during the flight model performance test campaign that occurred in Spring and Summer 2011.

Common tools and data products definition
The various MIRI software components need a number of common tools including various levels of data products (corresponding e.g. to science data for different instrument modes, at different processing levels). The work initiated in 2010 has been pursued with further integration of the first functional modules in the aforementioned SCA simulator. Development of the next modules has gone through the following steps: from the requirements drawn in 2010, JM has presented several solutions for the MIRI data products that have been discussed with the rest of the software team. Design choices have been made, they are summarized and justified on the MIRI wiki pages.

1.3.1 Global simulations of fully convective stars

J. Morin, B. Dintrans (Toulouse)
3D direct numerical simulations of fully-convective stars have been performed using the PENCIL CODE. Their two main aims are (i) to study the effect of the global rotation rate of the star on the amplitude and profile of the internal differential rotation in purely hydrodynamic simulations; and (ii) to study dynamo action in MHD simulations, in order to determine how the properties of the field depend on rotation and (ii) the effect of the generated magnetic field on convection and differential rotation.

1.3.2 Weak and strong field dynamos from the Earth to the Stars

J. Morin, E. Dormy (ENS Paris), M. Schrinner (ENS Paris), J.-F. Donati (Toulouse)
Observations of magnetism in very low mass stars recently made important progress, revealing characteristics that are now to be understood in the framework of dynamo theory. In parallel, there is growing evidence that dynamo processes in these stars share many similarities with planetary dynamos. We investigate the extent to which the weak-field versus strong-field bistability predicted for the geodynamo can apply to recent observations of two groups of very low mass fully-convective stars sharing similar stellar parameters but generating radically different types of magnetic fields (strong dipolar field *vs* weak multipolar). We show in particular that (i) the amplitude of the observed large-scale magnetic field in the dipolar regime is compatible (in order of magnitude) with theoretical expectations for a strong-field dynamo branch. (ii) The observed gap between the typical field strengths in the dipolar and multipolar regime is consistent with theoretical expectations based on two different force balances in the two regimes [64].

1.3.3 Modelling coronal emission from spectropolarimetric observations

J. Morin, G. Hallinan (Berkeley), M. Jardine (St Andrews),P. Lang (St Andrews), A. Vidotto, J.-F. Donati (Toulouse)
The recently discovered radio pulses on ultracool dwarfs have been attributed to electron cyclotron maser instability (ECMI) associated with the presence of strong large-scale magnetic fields. Similar pulses have been observed on a fully convective M4 dwarf and are compatible with the large-scale topology extrapolated from Zeeman-Doppler Imaging. This preliminary work is being pursued, contemporaneous radio and spectropolarimetric observations allow us to model more accurately the ECMI emission and disentangle pulses from flares. We also investigate the evolution of the pulses properties in order to assess the potential radio observations of ECMI

emission to study stars out of reach of spectropolarimetry. In parallel, models of stellar coronae are developed from surface magnetograms obtained with ZDI (Zeeman-Doppler Imaging). They allow us to investigate how the change in magnetic topologies that is observed close to the fully convective transition impacts the coronal emissions observed at X-ray and radio wavelengths [Lang et al., submitted].

1.3.4 Can we predict the global magnetic topology of a PMS star from its position in the Hertzsprung-Russell Diagram?

S. Gregory (Caltech), J.-F. Donati (Toulouse), J. Morin, G. Hussain (ESO), N. Mayne (Exeter), L. A. Hillenbrand (Caltech), M. Jardine (St Andrews)

Zeeman-Doppler imaging studies have shown that the magnetic fields of T Tauri stars can be significantly more complex than a simple dipole and can vary significantly between sources. Using the observational data as a basis, we argue that the general characteristics of the global magnetic field of a pre-main sequence star can be determined from its position in the Hertzsprung-Russell diagram, across which there are four distinct magnetic topology regimes. This idea is supported by observations of main sequence M dwarfs which exhibit similar relations between the topology of their surface magnetic field and their internal structure. If the magnetic topology trends across the Hertzsprung-Russell diagram are confirmed they may provide a new method of constraining pre-main sequence stellar evolution models, while also allowing the selection of interesting targets in order to optimize future spectropolarimetric observing campaigns [Gregory et al., submitted].

1.3.5 Magnetic monitoring of Sun-like stars

A. Morgenthaler (Toulouse), P. Petit (Toulouse), J. Morin, M. Auriere (Toulouse), B. Dintrans (Toulouse)

A sample of 19 solar-type stars, probing masses between 0.6 and 1.4 solar masses and rotation periods between 3.4 and 43 days, was regularly observed using the NARVAL spectropolarimeter between 2007 and 2011. The Zeeman-Doppler Imaging technique is employed to reconstruct the large-scale photospheric magnetic field structure of the targets and investigate its long-term temporal evolution. The first results of this project reveal short magnetic cycles in several stars, showing up a succession of polarity reversals over the timespan of our monitoring. Preliminary trends suggest that short cycles are more frequent for stellar periods below a dozen days and for stellar masses above about one solar mass. The cycles lengths unveiled by the direct tracking of polarity switches are significantly shorter than those derived from previous studies based on chromospheric activity monitoring, suggesting the coexistence of several magnetic timescales in a same star [63].

1.3.6 The (Reverse) Luminosity Problem

A. Scaife, R. Ainsworth, T. Ray (DIAS) & the AMI Consortium

The evolutionary stages of low-mass star formation are reasonably well defined, although a number of open questions still remain. One important uncertainty is the behaviour of the luminosity distribution at low and very low luminosities. The classic 'luminosity problem' has been known for some time (Kenyon et al. 1990), where the minimum accretion luminosities produced by the standard spherical collapse model (Shu 1977) are up to several orders of magnitude larger than those observed for embedded protostars. This problem has been emphasised by recent star formation surveys, notably that of the *Spitzer Space Telescope* (Evans et al. 2003), and non-steady accretion, starting in the earliest protostellar stages, is currently the best solution to this discrepancy (Kenyon & Hartmann 1995; Young & Evans 2005; Enoch et al. 2007). The luminosity problem is most difficult to rectify in very low luminosity objects (VeLLOs; Young et al. 2004; Dunham et al. 2008) with extreme luminosities $L_{\rm int} \leq 0.1\,L_{\odot}$. The nature of these objects is unclear, whether they are young Class 0 protostars which are just powering up, or are more evolved but in a low accretion state (Dunham et al. 2008; Evans et al. 2009). The existing sample of VeLLO sources, although expanded by *Spitzer* (Dunham et al. 2008), is in no way complete. VeLLOs are difficult to confirm as protostars in the infrared due to their low luminosity and embedded nature, and measuring their molecular outflows can be problematic as exemplified by the case of L1014 (Bourke et al. 2005; Crapsi et al. 2005). It is also the case that VeLLOs are often found in cores which are not only assumed to be starless, but which were also not believed to be approaching collapse (Bourke et al. 2006). Nevertheless, identifying a complete sample of these low luminosty embedded protostars is vital for understanding low mass star formation.

A solution to the luminosity problem has been proposed as a non-steady or episodic mass accretion rate onto such objects (e.g. Kenyon et al. 1990; Dunham et al. 2008), and more recently it has been shown using radiative transfer models including both time dependent accretion rates and episodic accretion bursts that the observed distribution of protostars at low luminosities can in fact be reconciled with predictions (Dunham & Vorobyov 2011). This work showed that in order to match the observational data both non-steady accretion components were necessary, notably that neglecting bursts of episodic accretion reduced the agreement between the model and the data. A further interesting result of this work was the prediction of a 'reverse luminosity problem'. This discrepancy exhibits as a theoretically predicted *overabundance* of objects with $L_{\rm int} \leq 0.1\,{\rm L}_{\odot}$ relative to the observed numbers. Currently this difference is ascribed to observational completeness issues at low-luminosities, however, further accurate comparison to models below $0.1\,{\rm L}_{\odot}$ will not be possible without further observational data specifically targeted at identifying and characterizing the very low luminosity population of embedded protostars.

Radio emission from ionized gas in the vicinity of these young objects is a good method for detecting (very-) low luminosity objects (LLOs), as their surrounding dust cores are optically thin to longer wavelength radio emission, and radio surveys (e.g. Scaife et al. 2011a; b; c) have shown that objects with luminosities below the limit for spherical accretion are consistently detected at the 80 per cent level. These detections are important not only for identifying LLOs, but also for understanding the energetics of their evolution. Radio luminosity of YSOs has been shown to correlate well with a number of characteristics derived from other parts of the electromagnetic spectrum - including physical quantities such as internal luminosity, which are only otherwise obtainable following complex modeling. At present the underlying reasons for a number of these correlations are not well understood and further investigations, in addition to improved datasets, are necessary to increase our understanding of the complex processes leading to these relationships.

In general, the variability of centimeter continuum sources (most probably due to episodic accretion bursts) has not been properly addressed, since observations of sources are limited to a few epochs. There has not been a systematic monitoring campaign of deeply embedded sources to characterize their centimeter variability. In spite of this, there is observational evidence for variability among deeply embedded protostellar sources (Avila et al. 2001; Reipurth et al. 2002), which contributes scatter to the luminosity correlations. In additional to the known variable thermal sources, several nonthermal protostellar sources are known to be highly variable (e.g., T Tauri; Scaife 2011); but, most of those objects are more evolved than deeply embedded protostars.

The timescale over which radio flares toward low-mass stars are observed tends to be minutes to hours. This is very different from the variability observed toward embedded sources where no evidence for short-term variability has been detected. Such sources (e.g. L1014; Shirley et al. 2007) appear to have a nearly constant "flare" flux for at least an 8 hr period. One possibility to explain this discrepancy is that the elevated emission is not due to a flare, but due to rotational modulation of a nonthermal component associated with the magnetic connection between disk and accretion onto the star (i.e. Bieging & Cohen 1989). Although negative spectral indices are expected for nonthermal emission mechanisms, it has been shown that (partially-)unresolved gyrosynchrotron emission from opposite poles of a protostellar magnetosphere will in fact possess a flat, or even positive, spectral index (Kuznetsov et al. 2011). Systematic monitoring campaigns are required to investigate these questions further

We have been undertaking a cm-wave radio follow-up program to the *Spitzer* cores to disks program specifically targeting (Ve)LLO sources (Scaife et al. 2011a; b; c). This extensive program has almost doubled the amount of archival data on the radio emission from low-mass protostellar objects, and these data are made publicly available throughout the Vizier catalogue tool. A number of significant conclusions can already be drawn from these data. As well as confirming that the radio-bolometric luminosity correlation known from higher luminosity objects extends to very low luminosities, a number of completely new correlations have also emerged: (1) *that the radio luminosity is correlated with the internal luminosity of embedded protostellar objects*; (2) *that the radio emission from an increasing number of low luminosity objects cannot be explained by the shock ionization model of Curiel et al. (1989) when drawing correlations with outflow momentum*; (3) *that the radio luminosity is correlated with the envelope mass of embedded objects and that this quantity provides a better tracer than bolometric luminosity*. The most important conclusion from these three points is that the dominant source of radio luminosity for embedded objects is not a consequence of shock ionization in their molecular outflows as previously thought, but is a more global function of **accretion**, which is related to both the internal luminosity and the envelope mass for Class 0 objects.

Further to this, our results have also revealed that there is a significant discrepancy in the detection rates at cm-wavelengths for Class 0 and Class I objects, indicating that the radio emission mechanism in protostellar objects is a function of their evolutionary state. Since accretion in protostellar objects is expected to decrease with age, this conclusion is tied to that drawn independently from the correlation information: radio emission from protostellar objects is a function of accretion.

As part of her PhD thesis, R. Ainsworth has been examining the cm-wave emission from a sample of low-mass YSOs which form part of the eMERLIN legacy project on protostellar jets. She has completed this work (paper submitted) revealing that the sample selected are biased towards high radio luminosities, but otherwise agree well with larger surveys. In addition she has isolated the dominant sources of error in the estimation of radio luminosity and examined how these will affect statistical results from more extended samples.

1.3.7 Circumstellar Disks and Planet Formation

A. Scaife, R. Ainsworth, T. Ray (DIAS) & the AMI Consortium

Sub-mm measurements towards circumstellar disks are often used to determine their potential for planet formation, as longer wavelength information provides a unique perspective on the cooler dust in the outer part of the disk. It is this region where protoplanets are expected to form. Alternative methods of disk mass estimation, such as spectral line measurements of molecular gas, are complicated by opacity effects (e.g. Beckwith & Sargent 1993) and require complex models to account for these effects as well as those of depletion (Dutrey 2003; Kamp & Dullemond 2004). Sub-mm and radio measurements are useful not only as a probe of the disk mass itself, but with multi-wavelength data available, they can also be used to determine the evolution of the opacity index as a function of frequency (Shirley et al. 2011a;b) and place constraints on the growth of dust grains in such disks. This can be used to determine whether the timescales assumed in current models of planet formation (e.g. Boss 1998) are consistent with observational data. However, to date the disk masses determined from sub-mm data appear to be too low to agree with theoretical models of planet formation (see e.g. Andrews & Williams 2005), although there are a number of observational caveats associated with these data.

Our observational work has established that for Class I objects the emission at cm-wavelengths is still dominated by the tail of the dust greybody spectrum, rather than alternative radio emission mechanisms, with 70-100 per cent of the cm-wave emission being attributable to thermal dust emission, compared with 20 per cent in Class 0 objects (Scaife et al. 2011d). This supported our earlier results that suggested the radio emission mechanism in protostellar objects is a function of their evolutionary state.

Using a combination of radio and sub-mm data, our work has demonstrated a flattening of the opacity index towards longer (cm-)wavelengths, consistent with a significant population of large dust grains, and in accordance with theoretical models for the collisional growth of grains within circumstellar disks. Deriving disk masses directly from the thermal dust contribution to the cm-wave flux densities under assumptions consistent with the literature we found that *cm-wave disk mass estimates are systematically higher than those determined from sub-mm data* and attributed this difference in disk masses to an increased emission contribution from larger dust grains within the disk at centimetre wavelengths, which is precluded at sub-mm frequencies by opacity effects. Under these assumptions we discovered that disk masses in excess of the lower limit required for giant planet formation (Boss 1998) are recovered in almost 50 per cent of cases when using cm-wave tracers, where none are sufficiently massive from sub-mm data for the same sample.

1.3.8 Brown dwarfs and their properties

A. Scholz, P. Dawson, T. Ray (DIAS), R. Jayawardhana, K. Muzic (Toronto), V. Geers (Zurich), M. Tamura (Tokyo)

Brown dwarfs are substellar objects intermediate in mass between stars and planets, and crucial for our understanding of star and planet formation. The aim of our SONYC program (short for Substellar Objects in Nearby Young Clusters) is to find and characterise all brown dwarfs in nearby star forming regions. In 2011 we have completed our survey work in ρ-Ophiuchus and Chamaeleon-I, presented a new census in NGC1333, and continued to work on the census in Lupus-3. In total, this survey has now discovered ~ 30 previously unknown young brown dwarfs, using data from 8-m class telescopes (Subaru, ESO/VLT). Among them are a handful of objects with estimated masses below 20 Jupiter masses, one of them at around 6 Mjup – one of the lowest mass free-floating objects identified thus far.

As the first part of his Ph.D. thesis, P. Dawson has carried out a brown dwarf survey in the Upper Scorpius star forming region and identified about two dozen candidates based on photometry and proper motions from the UKIDSS project. Combining the census data for all regions, we find that the number ratio between stars and brown dwarfs is not constant in all regions, possibly related to environmental differences in the formation of brown dwarfs.

In addition, we have started projects to exploit the newly released data from the WISE satellite to determine the lifetimes and properties of disks around brown dwarfs.

1.3.9 Variability of young stellar objects

A. Scholz, G. Costigan, T. Ray, A. Natta (DIAS), J. Vink (Armagh), B. Stelzer (Palermo), S. Mohanty (London), L. Testi (ESO Garching)

Variability is a key property of young stars in their first few Myr after formation, and can be used as a diagnostic of accretion, disk evolution, and magnetic activity. For her Ph.D. thesis, Grainne Costigan investigates the long-term accretion variability of a sample of YSOs in the Chamaeleon-I star forming region based on spectroscopic time series from ESO/VLT. This project was completed in 2011. We found that accretion-related variability occurs on timescales of one week or shorter (or longer than 2 years). The total variations in the mass accretion rate are at most half an order of magnitude over time windows up to 2 years.

Using a photometric and spectroscopic time series obtained at the Calar Alto observatory in 2010, we analysed the curious behaviour of FU Tau A, a very low mass benchmark object in the Taurus star forming region which appears anomalously bright compared with similar-type objects. We found evidence for cool spots corotating with the source, most likely caused by magnetic activity. Furthermore, the objects shows indications for long-term variability due to accretion-related hot spots. These findings bolster the hypothesis that the anomalous brightness can be explained by a combination of magnetically suppressed convection and accretion.

A archive study using data from 2MASS, DENIS, and UKIDSS was carried out to search for long-term variability in a large sample of ~ 600 YSOs. No evidence for accretion outbursts were found, which puts a lower limit of ~ 2000 – 2500 years on the duty cycle of accretion bursts. In general, strongly variable objects with $\Delta K > 0.5$ mag are rare (2-3%). These findings allow us to put strong limits on the contribution of variability to the ubiquitously observed scatter in HR diagrams and to the errors in luminosity estimates.

1.3.10 Outflow Activity in the Brown Dwarf Mass Regime

E. Whelan, T. Ray (DIAS), F. Bacciotti (Arcetri), C. Dougados (Grenoble), J-L. Monin (Grenoble), S. Maddison (Swinburne), A. Natta (DIAS/Arcetri)

The formation mechanism of brown dwarfs (BD) is currently an open question in the field of star formation. As BDs occupy the gap between solar mass stars and planets this question has garnered much attention in recent years. The most logical approach is to observe key processes involved in the formation of solar mass stars i.e. accretion, outflow activity and variability, at BD masses. In particular, we have been leading a study of BD outflow activity. This began with the first confirmed detection of a BD outflow made by us in 2005 (Whelan et al. 2005). These initial observations were done at optical wavelengths and targeted forbidden emission lines like [O I]λ6300. Over the last number of years we have been developing this work by increasing the known sample of BD outflows and through expansion into other wavelength regimes e.g. near infrared (NIR) and sub-millimeter (sub-mm). As outflows act as an indirect probe of the central engine observations of outflow activity can provide details important for understanding BD formation. For example our observations to date suggest that the mass outflow to accretion rate in BDs is significantly higher than in solar mass stars. In solar mass young stars $\dot{M}_{acc}/\dot{M}_{out}$ is typically ~ 10% however in BDs the rates were found to be comparable (Whelan et al. 2009) or in a subsequent study ~ 50% (Bacciotti et al. 2011). Work aimed at constraining $\dot{M}_{acc}/\dot{M}_{out}$ in young BDs is ongoing.

In 2011 we grew our research into BD outflows, firstly through the use of X-Shooter, the new instrument on the ESO VLT. X-Shooter provides simultaneous NIR, optical and UV spectra and hence is an important tool for the study of jets and outflows. Specifically X-Shooter observations allow us to make more accurate estimates of $\dot{M}_{acc}/\dot{M}_{out}$ in a sample of BDs. One paper was published in 2011 (Bacciotti et al 2011) and work is continuing. In addition, in 2011 we began a project to investigate BD molecular outflows. As a first step we did a survey of the ^{12}CO(2-1) emission in a sample of 16 BDs with the aim of searching for extended molecular emission. All the BDs previously associated with [O I]λ6300 emission showed evidence of the presence of a molecular outflow. Observations were carried out with the IRAM 30 m telescope in July 2011. A paper is currently in preparation and follow-up observations with the Plateau de Bure interferometer and the SMA are underway / planned. In addition, further time on the 30 m has been granted to observe a second large sample of BDs. Finally in 2011 observing time was granted on the Keck telescope to search for evidence of outflow activity in a sample of Taurus BDs. However observations were unsuccessful due to poor weather and will likely be re-scheduled in 2012.

1.3.11 Using AO-assisted Integral Field Observations and Spectro-astrometry to Investigate the Launching of Jets from Young Stars

E. Whelan, T. Ray (DIAS), C. Dougados (Grenoble), S. Cabrit (Observatoire de Paris), M. Benisty (Grenoble), L. Podio (Grenoble), F. Bacciotti (Arcetri), C. Davis (Joint Astronomy Center, University of Hawaii)

While great strides have been made in our understanding of how jets from young stars are launched, collimated and interact with the ambient medium of the driving source, open questions remain and high angular resolution observations on the scale of the central engine are needed. We have been using the techniques of AO-assisted integral field spectroscopy (AO-IFS) and spectro-astrometry (SA) to study the jet launch regions of a sample of young stars including classical T Tauri stars (CTTSs), Herbig Ae/Be stars and FU Orionis stars (FUOR). Jets from CTTSs have been much studied as the optically visible nature of these low mass protostars makes their central engines particularly accessible to observations. In addition, they are numerous in near-by star forming regions. Herbig Ae/Be stars in contrast are less understood and outflows from FUOR have only recently been investigated (Whelan et al. 2010). In order to get an accurate picture of star formation, activity must be investigated across a range of masses and mass accretion rates from BDs to the Herbig Ae/Be stars. AO-IFS is an extremely useful technique as it provides spectro-images (images over a very narrow wavelength range) at high angular resolution. SA offers spatial information on milli-arcsecond scales and when combined with AO-IFS scales reached are a fraction of a milli-arcsecond. We are particularly interested in the origin of permitted emission lines such as Hα or Brγ.

Several important projects were started in 2011. For example a multi-faceted study of the RW Aur protostellar system was begun. RW Aur was one of the first CTTSs to be observed and studied. It has many interesting properties including a strong mass accretion rate, highly variable permitted emission and an asymmetric jet. AO-IFS observations produced stunning near-infrared spectro-images of the RW Aur jet at $\approx 0\farcs1$ angular resolution. Interestingly the jet shows evidence of wiggling which points to a close companion to RW Aur. The presence of a companion has already been invoked to explain the variability of RW Aur. In addition, SA is also being used to probe the origin of key permitted lines e.g Hα emitted by RW Aur. The main result of this study is that the bulk of the Hα emission is tracing a wide-disk wind which we trace to within 5 mas or $\approx$1AU of the star. Two papers are currently in preparation (Whelan et al. 2012a,b). We are also studying the Herbig Ae/Be stars HD163296 using SA and interferometry (Benisty et al. 2012). The aim of this work is to understand the origin of the Brγ line and to compare with Hα. Finally in 2011 time on Gemini/ NIFS was granted to do NIR AO-IFS and 2D SA of a large sample of protostars including CTTS, Herbig Ae/Be stars and FUOR.

1.4 General Theory

1.4.1 Magnetic field amplification by cosmic ray pressure instabilities

L. Drury and T. P. Downes

Magnetic field amplification in the shock precursors created by strong particle acceleration is now thought to be an essential aspect of cosmic ray production in supernova remnants and may well also be essential for the production of the ultra-high energy cosmic rays in extra-galactic sources. Attention to date has mainly focussed on the current-driven plasma instability identified by Bell, but this suffers from the problem of amplifying the field on scales small compared to the gyro-radius of the driving particles. As pointed out by Malkov there are alternatives, and in particular the acoustic instability identified by Drury and Falle is a promising candidate. A simple toy model was identified to study the impact of this process on magnetic field amplification and preliminary three dimensional computer simulations performed. These results were presented at the International Cosmic Ray Conference in Beijing.

1.4.2 Mechanics and kinetics in the Friedmann-Lemaitre-Robertson-Walker space-times

F. Aharonian, and S. Kelner, A. Prosekin (MPIK, Heidelberg, Germany)

Using the standard canonical formalism, the equations of mechanics and kinetics in the Friedmann-Lemaitre-Robertson-Walker (FLRW) space-times in Cartesian coordinates have been obtained. The transformation law of the generalized momentum under the shift of the origin of the coordinate system has been found, and the form invariance of the Hamiltonian function relative to the shift transformation has been proved. The derived equations allow one to shift the origin of the coordinate system to the point of location of the observer. The space in the vicinity of this point can be considered as a Euclidean one which makes straightforward the interpretation of calculations. For the distribution function in the phase space, the general solution of the collisionless Boltzmann equation has been found. The results of this work can be used for treatment of evolution of the distribution function of particles arriving from the cosmologically distant objects. We discuss, in particular, two important cases of astrophysical interest: (i) the homogenous distribution particles taking into account energy losses, and (ii) the spherically symmetric case with arbitrary angular distribution. While the first problem is linked to the diffuse distributions of particles produced at cosmological epochs, the second one is relevant to the discrete astrophysical objects.

1.4.3 Electron acceleration by plasma shocks

G. C. Murphy, L. O'C. Drury, M. Dieckmann (U. Linkoping)

Gamma ray bursts (GRBs) are thought to originate from highly relativistic jets. The fireball model predicts internal shocks in the jets, causing magnetic field to be amplified & particles to be accelerated. We model the effects of an asymmetric density configuration for an internal plasma collision in a quasi-parallel magnetic field. We measured electron acceleration & found that a tenuous population of electrons is accelerated to Lorentz factors of ~ 300 - close to energy equipartition with ions. We found that the filaments did not remain static, but were deflected by the Lorentz force & rolled up into small vortices, which themselves merge to form a larger current vortex. By increasing the runtime of simulations, we derived electron distributions which were injected into one-zone models to predict synthetic observations.

1.4.4 Filament formation in counterstreaming plasma

G. C. Murphy, L. O'C. Drury, M. Dieckmann (U Linkoping), G. Sarri, K. Quinn, M. Borghesi (QUB)

The magnetic fields which are inferred in observations of gamma ray bursts and supernova remnants can originate from plasma effects. 2D particle simulations model the filamentation instability. Our results show that exponential growth is followed by saturation of the magnetic field. The composition of the beams affects the growth of the electrostatic field and the in-plane current coherency and correlation scale. The growth rate is close to the analytical value of $\beta\sqrt{2/\Gamma_b}$.

1.4.5 PRACE particle-in-cell scalability testing

Gareth C. Murphy, M. Browne, G. Civario (ICHEC)

0.5 million core hours were awarded to investigate the performance of the PIC plasma simulation code (PSC) on two Tier-0 architectures. PSC was shown to scale well on JUGENE (Julich) and CURIE (France). We found that the proportionally more time was spent in global MPI communication during timing routines in the code. These could be reduced in frequency causing a speedup of 14.9%. We found proof of code scaling to 32,000 cores on Jugene. We gained experience on scaling testing and identifying bottlenecks in the parallel algorithms. The speedup of 14.9% was maintained on higher numbers of cores, resulting in near-linear strong scaling.

2 Invited talks

- F. Aharonian
  - Exploring the Very High Energy Sky with H.E.S.S, Rossi Prize talk at the American Astronomical Society meeting, Jan 12, Seattle, USA
  - Predicting Galactic Neutrino Fluxes from Gamma Ray Data, XIV International Workshop on Neutrino Telescopes, March 15-18, Venice, Italy
  - High Energy Gamma Ray Astronomy, 3rd Roma International Conference on Astroparticle Physics, May 25-27, Rome, Italy
  - Probing Cosmic Ray Accelerators With Gamma Rays and Neutrinos, 32nd International Cosmic Ray Conference, August 11-18, Beijing, China
  - Gamma Rays: Physics Interpretation, 12th International Conference on Topics in Astroparticle and Underground Physics (TAUB 2011), September 5-9, Munich, Germany
- V. Bosch-Ramon
  - Multifrequency Behavior of Microquasars in the GeV-TeV era: A review, Frascati Workshop 2011, Vulcano, Italy, May.
  - Non-Thermal Emission from Galactic Jets, High-energy phenomena in relativistic outflows III, Barcelona, Spain, June.
  - Particle acceleration in microquasars and binary systems, 13th ICATPP Conference, Como, Italy, October.
  - Multi-GeV astrophysics in gamma-ray binaries, Multi-GeV astrophysics with ground-based detectors, Dublin, Ireland, December.
- A. Caratti o Garatti
  - 16/02/2011 -Talk "Investigating Class I/II YSOs in L1641 through combined optical/IR spectroscopy" at the Thüringer Landessternwarte Tautenburg, Tautenburg, Germany
  - 24/02/2011 -Talk "Investigating Class I/II YSOs in L1641 through combined optical/IR spectroscopy" at the Max Planck Institut für Radioastronomie, Bonn, Germany
  - 2/03/2011 -Talk "Investigating Class I/II YSOs in L1641 through combined optical/IR spectroscopy" at the Department of Physics, Universität zu Köln, Germany
  - 18/05/2011 -Talk on "Massive jets from massive YSOs" at the Department of Physics and Astronomy of the University of Leeds, United Kingdom
  - 01/06/2011 -Talk on "Massive jets from massive YSOs" at the Max Planck Institut für Radioastronomie, Bonn, Germany
  - 17/11/2011 -Talk on "Massive jets from massive YSOs" at the Thüringer Landessternwarte, Tautenburg, Germany
- D. Coffey
  - Invited conference talk, 'The Enigma of Jets and Outflows from Young Stars', The Indian Institute for Astrophysics, Bangalore, June.
- T. Downes

- Invited seminar, “Multifluid MHD in weakly ionised plasmas”, Princeton University, 22 April.

- L. Drury
  - Cosmic Rays, Gamma Rays and Galactic Neutrino Astronomy, VLVnT11, Erlangen, Germany, 13 October.
- G.C. Murphy
  - Magnetic field amplification and electron acceleration in mildly relativistic protoshocks , Niels Bohr Institute, Denmark, 16 November
- T. Ray
  - The Grubbs of Dublin and the Great Vienna Refractor, Vienna Observatory, 13 April
  - Outflows from Young Stars: The Rosetta Stone of Astrophysical Jets? European Conference on Laboratory Astrophysics, Paris, 28 September
  - The First 3 Million Years, Bolton Lecture to Schools, University of Leeds, 18 October
- A. Scaife
  - The LOFAR Magnetism Key Science Project, seminar, University of Manchester, UK, 2 January.
  - The LOFAR Magnetism Key Science Project, seminar, University of Hertfordshire, UK, 8 February.
  - The Application of Bayesian Methods in Radio Astronomy, seminar, University of Newcastle, UK, 1 April.
  - Compressed Sensing for Rotation Measure Synthesis, CALIM 2011, Manchester, UK, 26 July.
  - Next Generation Polarization Science (review), International Union of Radio Science General Assembly, Istanbul, Turkey, 15 August.
  - The Application of Compressed Sensing Techniques in Radio Astronomy (review), International Union of Radio Science General Assembly, Istanbul, Turkey, 17 August.
  - Prospects for Compressed Sensing Reconstruction in Rotation Measure Synthesis, BASP, Villars, Switzerland, 8 September.
  - Using Radio Emission from Low-Mass Protostars to Tackle the Luminosity Problem, seminar, Royal Observatory, Edinburgh, UK, 30 November.
- A. Scholz
  - Brown dwarfs vs. stars, G2000 seminar, University of Toronto, Canada, November.
  - Young brown dwarfs: testing star and planet formation, RG seminar, CfA/Harvard, Boston, USA, December.
- E.T. Whelan
  - Disks, Accretion and Outflows in Brown Dwarfs.

– Astronomische Gesellschaft 2011, âĂIJFormation, atmospheres and evolution of brown dwarfs’, September 2011

3 Externally funded projects and grants of resources

3.1 Observing Runs: Completed or Awarded in 2011

- A. Caratti o Garatti
  - **An REM/TNG study of IR variability in embedded Young Stellar Objects** *Aug 2010 - Jan 2011* - 4 hrs + 96 hrs at TNG/REM, service. PI/CoI: **Caratti o Garatti A.**, Massi F., Garcia Lopez R., Nisini B., Scholz A., Antoniucci S., Giannini T., Coffey D., Ray T.
  - **An REM/Spitzer survey of the optical/IR variability of Young Stellar Objects in Serpens** *Apr 2011 - May 2011* -30 hrs at REM, service. PI/CoI: **Caratti o Garatti A.**, Covey K., Garcia Lopez R., Scholz A., Stauffer J., Morales-Calderon M., Rebull L., Gutermuth R.
  - **Revealing the nature of the outbursting Class I protostar [CTF93]216-2 and its environment** *Oct. 2011 - Mar. 2012* - 8 hrs at VLT (SINFONI + ISAAC) service. PI/CoI: **Caratti o Garatti A.**, Garcia Lopez R., Stecklum B., Scholz A., Nisini B., Eislöffel J., Antoniucci S., Giannini T., Ray T.
  - **Origin of the Brγ emission in Young Stars: AMBER MR-K observations of three Herbig AeBe stars** *Febrauary 2011* - 2.5 hrs at VLTI (AMBER). PI/CoI: Dougados C., Bacciotti F., Benisty M., Podio L., Whelan E., Antoniucci S., Alecian E., **Caratti o Garatti A.**, Garcia P., Nisini B., Malbet F.
  - **Jet launch and properties of the most luminous H_2 YSO outflow** *April 2011* - 4 hrs at VLT (SINFONI + ISAAC). PI/CoI: Stecklum B., **Caratti o Garatti A.**, Linz H.
- D. Coffey
  - ESO VLTI / AMBER: 1 night completed in 01 Apr 2011 (GTO 087.C-0604(A)
  - ESO VLTI / AMBER: 1 night completed in 03 Apr 2011 (GTO 087.C-0598(A)
- J. Morin
  - **Improving detection limits of planets orbiting moderately active M dwarfs with polarimetric monitoring**
    May–Aug 2011, ESO/HARPS, 4.5 nights, visitor (087.C-0412). PI/CoI: J. Morin, J.-F. Donati (Toulouse), X. Delfosse (Grenoble), T. Forveille (Grenoble)
  - **Understanding the M dwarf Radius Discrepancy at the Fundamental Level: Magnetic Field Mapping of Two M dwarf Eclipsing Binaries**
    Jan 2012, CFHT/ESPaDOnS, 40 hr, service (11BF14, 11BF97). PI/CoI: J. Morin, L. Hebb (Vanderbilt Univ.), G. Hussain (ESO), K. Stassun (Vanderbilt Univ.), J.-F. Donati (Toulouse)
- A. Scaife
  - Effelsberg telescope: 40 hours completed (87-10)
  - Green Bank telescope: 105 hours awarded, 39 hours completed (GBT11B-068)
  - ATCA telescope: 14 hours awarded, 14 hours completed (C2468)

- eMERLIN telescope: 862 hours awarded (eMERLIN legacy Super-CLASS project)
  - LOFAR telescope: 12 hours completed (LEA192)
  - AMI telescope: 500+ hours awarded and completed (various)
- A. Scholz
  - Subaru telescope: 1 night completed (S11B-053)
  - ESO/VLT: 8.5h awarded for 2012 (089.C-0432), 9.3h awarded for 2012 (089.C-0311), 9.1h awarded for 2012 089.C-0652, 8h completed (088.C-0413), 10.2h completed (087.C-0386)
  - ESO/VISTA: 100h completed (087.D-0829)
  - ESO/2.2m: 40h granted from MPI for 2012
  - IRTF: 3 nights granted (2012A005)
  - SMARTS consortium: 4 nights observing time granted for 2012
- E.T Whelan
  - IRAM 30 m: 1 night completed July 2011, 1 night awarded 2012 (04-11-Monin)
  - Plateau de Bure: 3.0h awarded for 2012 (V070-Whelan)
  - ESO/VLT: awarded for 2011/2012, 3.5 hrs (288.C-5013(A)), 0.5 hrs (086.C-0080(B)), 9.3 hrs (089.C-0311(A))
  - Keck/HIRES: 1 night completed in 2011
  - Gemini/NIFS: 10.5 hrs granted (GN-2012A-Q-116)

3.2 Supercomputer Access in 2011

- T. Downes
  - "Accretion disk dynamics: the multifluid regime", 14 million core hours on JUGENE awarded by PRACE, May 2011 – April 2012.
- G.C. Murphy
  - Shocks: Understanding Relativistic Plasmas Acceleration Systems, PRACE (Jugene and Curie), 500,000 hours Feb-Aug 2011

3.3 Current Research Project Grants

- A. Caratti o Garatti
  - **Marie Curie European Reintegration Grant**, FP7-PEOPLE-2009-RG, Proposal N 249157, title: 'A photometric and spectral survey of young stars in nearby star-forming regions: towards a revised evolutionary sequence based on quantitative accretion/ejection diagnostics'
- D. Coffey
  - Italian Space Agency grant (6 month postdoc, E. Rigliaco)

- T. Ray
  - Science Foundation Ireland, RFP grant 10/RFP/AST2780 (1 postgraduate student)
- A. Scholz
  - Science Foundation Ireland, RFP grant 11/RFP/AST3331 (1 postgraduate student)

3.4 Proposals submitted

- Bosch-Ramon, V.
  - European Research Council, Starting Grant (pending)
- Scaife, A.
  - European Research Council, Starting Grant (pending)
- Scholz, A.
  - European Research Council, Starting Grant (pending)

4 Contributions to Teaching

- J. Morin
  - Evry Schatzman 2011 School, "Low-mass stars and the transition stars/brown dwarfs" (2 lectures), Roscoff, France, 11–16 Sep.
- G. C. Murphy
  - "Introduction to Numerical Methods" (24 lectures), UCD School of Mathematical Sciences, Dublin
  - "Introduction to Astrophysics" (18 lectures) , Loughborough University, UK
- T. Ray
  - "Astronomy and Astrophysics" (9 lectures), Trinity College Dublin
  - "Galactic Structure" (15 lectures), Trinity College Dublin
- E.T Whelan
  - NUI Maynooth, 6 lectures, "Hot Topics in Astrophysics"

5 Community Service, Awards and Distinction

- Bosch-Ramon, V.
  - Associated member of the MPIK high-energy astrophysics theory group (Heidelberg, Germany)
  - Associated member of the group of relativistic astrophysics and radioastronomy (La Plata, Argentina)

  - Associated member of the group of high-energy galactic sources (Barcelona, Spain)

- T. Downes
  - Chair of PRACE User Forum
  - Director of the SCI-SYM computational science research centre
- L. Drury
  - Election as President of the Royal Irish Academy, 16 March.
- T. Ray
  - Election as a Member of Council, Royal Irish Academy, 16 March
  - Chair Herschel Time Allocation Committee (Interstellar Medium, Star Formation and Solar System)
  - Royal Irish Academy Committee for Astronomy and Space Science
  - Irish Research Council for Science, Engineering and Technology, Ulysees Panel
  - e-MERLIN Steering Committee
  - NASA/ESA Mid-Infrared Instrument Science Committee
  - Marie Curie Fellowship Panel
  - PhD Thesis Panel, School of Archaeology, UCD
  - High Energy Density Laboratory Astrophysics, Scientific Organising Committee
  - Armagh Observatory and Planetarium Management Committee
  - School of Cosmic Physics, Postgraduate Student Advisor
- A. Scaife
  - Young Scientist Award from the International Union of Radio Sciences (URSI).
- D. O'Sullivan
  - continued as a member of the panel of experts chosen to advise the Government Chief Scientific Adviser.
  - continued role on the ESA Theseus team which is drawing up a strategy for future human space travel
- A. Scholz
  - press release for the SONYC project, issued by the Subaru telescope: ' "Failed Stars" Galore with One Youngster Only Six Times Heftier than Jupiter', October 2011 (this release was covered by numerous international press outlets, including MSNBC, space.com, wired.com.

6 Contributions to research infrastructures

6.1 National Capability Computing Initiative

The agreed three year period for operation of the two Blue Gene systems came to an end at the end of 2010 and both systems were powered down in early January 2011. An expression of interest in taking over the P-system was received from IBM and TCD and following extended discussions with the funding agencies it was eventually agreed to transfer ownership of the P-system to TCD for a nominal sum of €1. The transfer took place in August 2011. A review of the impact of the initiative concluded that it had met, and in many areas exceeded, the *ex ante* expectations for the project.

6.1.1 e-INIS

During 2011 the e-INIS project continued to progress well and has now been very successful in improving the quality and quantity of shared ICT research infrastructure available in Ireland.

High Performance Computing (HPC) The provision of service (compute, data management and visualization) for users in Ireland and their international collaborators continues with a large number of publications enabled by resources managed by TCHPC and ICHEC in this period. Stokes, Stoney, Kelvin and the BlueGene/P resource are facilitating enhanced research output.

The National Compute Service operated by ICHEC, on infrastructure majority or wholly funded under e-INIS (Stokes and Stoney), continued to see widespread use from across the sector. The TCHPC capability-lite infrastructure (Kelvin) became operational and is being used by researchers from several third level institutions including TCD, NUIM, UCD and UCC/Tyndall.

The Grid-Ireland Operations Centre has installed a 20TF GPU-based capacity computing enhancement at their Grid site in TCD. The 32-GPU/64-core cluster came online in Jun-2011.

Networking The e-INIS optical network now has connections from DIAS, NUIG, UCC and UCD. The 10Gbit/s network, operated by HEAnet, has a separate routed connection to the rest of HEAnet and onward via GEANT which enables the increased throughput particularly important to data-intensive research.

Data Management The area of Research Data Management has become a hotbed of activity and the pilot e-INIS data store has played a considerable role in supporting the sharing and re-use of data among high profile national and international collaborations. During 2011 the available storage volume grew to exceed one Petabyte (1 million gigabytes) adding significant research capacity to the Irish community.

Due to continued demand from the user community, further expansion of the data management service will be required over the remainder of the project and we expect to compile a number high profile use cases and associated publicity material. Access and Service Support The e-INIS Federated Access service was formally launched as Edugate in November 2010. At the end of September 2011, it had 31 services and 25 identity providers, representing 90% of staff and students in publicly-funded higher education institutions. As per our stated objective in the first year of production, we have successfully attracted some of the world's leading publisher and electronic journals as service providers.

The identity providers include 6 of 7 universities, and 14 of 15 Institutes of Technology. 100% membership of the HEI sector is expected by October 2011. See http://www.edugate.ie/content/edugate-federation-members for details of services and members.

Outlook The reduction in funded staff numbers (due to the exhaustion of project budgets along with the departure of highly skilled personnel to the private sector) will no doubt present additional challenges over the remainder of the project but it has been encouraging to see increased levels of collaboration among partners in an attempt to make up for some of these shortages.

The anticipated restructuring of the national HPC services is expected to bring exciting new opportunities for the long-term sustainable provision of e-Infrastructure in Ireland. During 2012, the e-INIS partners will invest significant effort in developing governance and sustainability plans to ensure that pilot services such as the e-INIS Data Store can be migrated to a long-term production basis within appropriate organisations.

6.2 The Mid-Infra-Red Instrument (MIRI) for the James Webb Space Telescope (JWST)

6.2.1 JWST

All JWST mirrors have now been polished, gold coated and re-assembled into flight configuration. Vibration tests had been carried out on the flight primary mirror segments and 2 sets of 6 have completed final cryo-verification, with the remaining 6 due to done during January 2012. The Fine Steering Mirror (FSM), secondary and tertiary mirrors are complete and have been individually tested. The telescope assembly ground support equipment (GSE) is now ready for shipment to the Goddard Space Flight Center (GSFC) and the Integrated Science Instrument Module (ISIM) structure is finished and prepared for cryo-testing and vibration using dummy instruments as proof loads. The first template sun-shield membrane had been completed and mounted in the test stand for shape measurements.

During the year there were concerns over the NASA budget, the schedule stretch, thermal margin issues and near-infrared (NIR) degradation of instruments (this does not affect MIRI) and instrument schedules (again excluding MIRI). The JWST budget has now been restored, with a revised launch date of 2018 allowing 13 months contingency to the schedule. The NIR detector degradation issues are being resolved as the contractors had identified a fix to make the coating on the back of the substrate thicker and more even, to improve insulation, and a dedicated team have been working on this.

In the interim, the MIRI Flight Model (FM) will be be stored at the Rutherford Appleton Laboratory (RAL) and then shipped to NASA when required. A fit check is needed and ideally NASA will agree to do this with the MIRI cooler integrated. Once MIRI is shipped to NASA (late in 2012), there will be a requirement for an ESA representative and a system engineer to be in attendance permanently.

6.2.2 MIRI

MIRI DIAS Personnel Anna Scaife (AS) and Julian Morin (JM) came to the end of their contracts in 2011 and left to take up a permanent lectureship in Southampton and an Alexander von Humboldt fellowship in Germany respectively. Following informal agreement from Enterprise Ireland

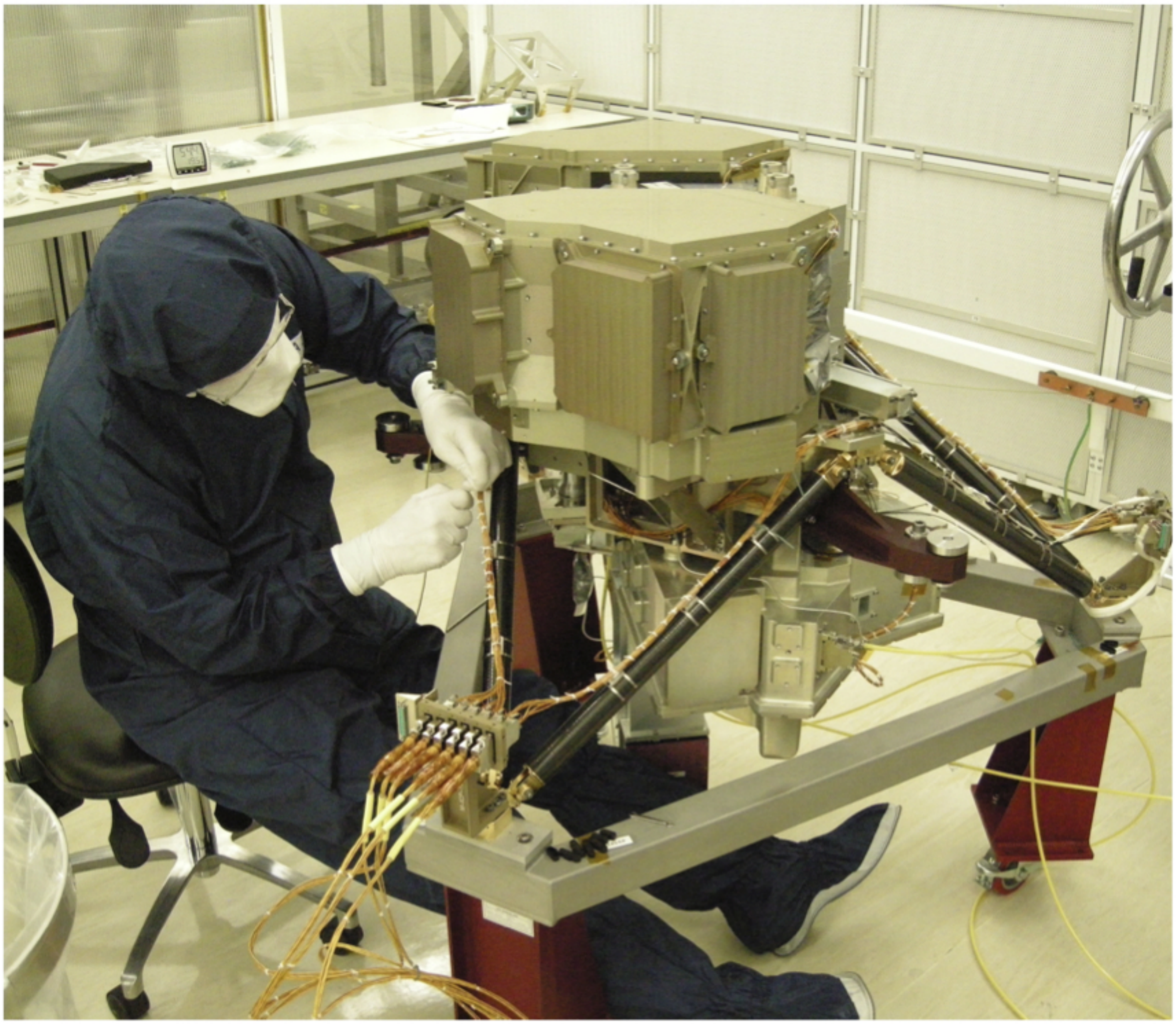

Figure 4: Integration of the flight harness onto MIRI at Rutherford Appleton Laboratory prior to testing in the cryo-chamber during Summer 2011.

that PRODEX funding should be available for another 3 years (from mid-2012 until mid 2015), it was decided to postpone advertising the 2 vacant posts created by their departure until the new year and clarification of the JWST budget status.

MIRI Flight Model (FM) Testing The filter wheel mechanism (carrying the DIAS supplied filters) was the subject of a qualification review which was closed out in February. The FM was assembled, standard thermal/vibration tests were performed and this was followed by 86 days of cryo-testing at RAL (at approximately 7 K) to test the instrumentâĂŹs optical performance. The two DIAS MIRI personnel participated in the testing which resulted in 6.5Tb of data. Analysis of this data is now underway across the consortium. MIRI, the test chamber and the GSE all performed very well. The instrument was well aligned and sensitive, and there was no need to modify any hardware.

As a result of the testing, two issues were noted: the sensitivity of the Focal Plane System is somewhat lower than expected (this is not a European Consortium issue but instead has to be resolved by JPL) and the Channel 4 (18.6-28.3 microns) Integral Field Unit (IFU) response is some 1.7 below requirement. With assistance from ESA, it was determined that the cause is the groove profile in the Channel 4 gratings (they are not precisely saw-tooth in shape). Nevertheless no JWST Level 1 science requirements are impacted and NASA/ESA have fully endorsed a âĂIJuse as-is' solution.

MIRI Acceptance Much of the work towards the end of 2011 was carried out with two milestones (scheduled for early 2012) in mind: the acceptance review (from our consortium to ESA) and the pre-shipment review (from ESA to NASA) The reviews of the Optical System (from the European consortium) and the Cooler system (JPL) shared common objectives and had similar datapacks, so they will be combined into a single Acceptance/Pre-shipment Review co-chaired by ESA and NASA. The data-pack was finalised and delivered just before the end of the year. As the consortium will effectively be âĂIJhanding over' the MIRI flight model (FM) in early 2012, it is intended to have a special public relationships day (Irish newspapers will be informed).

MIRI Contingency Fund A contract has been signed between ESA and the Science Technology Facilities Council (STFC) for use of the MIRI Contingency Fund (in the case of DIAS this will result in monies *in addition* to those from PRODEX funding). The list of claims will be maintained by ESA. The first change proposal, for the cryo-cooler, had been finalised and agreed, and the process is now established.

7 Institutional Partnerships

Signed framework agreements on cooperation are now in place with all three local universities (TCD, UCD and DCU) and regular meetings to coordinate cooperation in research, teaching and outreach activities have been initiated.

8 Public Outreach

- Bosch-Ramon, V.
  - Powerful outflows in the Universe, Dunsink Observatory, Dublin, January 2011

  - Black holes: lighthouses of the Universe, Dunsink Observatory, Dublin, November 2011

- Caratti o Garatti, A.
  - 19th of January 2011, Dunsik Observatory, Dublin. Public lecture on ‘Stellar evolution’.
- Coffey, D.
  - Evening lecture, ’Disks and jets: observations and unsolved problems’, The Indian Institute for Astrophysics, Bangalore, June 2012.
- Coffey, D.
  - Evening lecture, ’Disks and jets: observations and unsolved problems’, The Indian Institute for Astrophysics, Bangalore, June 2012.
- T. Downes
  - Master of ceremonies for two lectures by Cosmonaut Mikhail Kornienko delivered on 14 April and attended by a total of 2,500 people.
- L. Drury
  - The 2011 McCrea lecture: “The hundred year mystery of cosmic rays”, given on 9 Dec in TCD.
- J. Morin
  - Dunsink Observatory Open Nights, 25 Jan and 15 Mar.
- G.C. Murphy
  - Astronomy Ireland Science Week Lecture, Trinity College Dublin, 11 Nov
- T.P. Ray
  - “Seeking Clearer Skies: From the Bog of Allen to the Atacama Desert", Irish Meteorological Society, 20 October
  - “TCD Student Night”, Dunsink Observatory, 7 December
  - RTE Nationwide Program, 12 December
  - Winter Solstice at Newgrange, 21 December
- Scholz, A.
  - talk ’Brown Dwarfs’, Dunsink Observatory, Dublin, December 2011
  - popular science book ’Das neue Lexikon des Unwissens’ (in German) published, September 2011
- F. Aharonian
  - "The Extreme Universe", invited lecture at the Inauguration of the Center for Astroparticle Physics ‘CAP Geneve, March 9, 2011, Versoix, Switzerland
- E.T. Whelan
  - talk ’Star and Planet Formation’, Dunsink Observatory, Dublin, November 2011
  - Interview, Siliconrepublic.com, Science Week 2011

8.1 Statutory Public Lecture

The School's statutory public lecture was delivered by Prof Malcolm Longair as a public event associated with the Summer School on High-Energy Astrophysics. The title was "The dark side of the Universe" and it was delivered in Room B004, University College Dublin, on Tuesday July 4th at 6:30pm (see Fig. 5).

Figure 5: Malcolm Longair delivering the statutory public lecture.

9 Conferences, Workshops and Summer Schools Organised

9.1 Summer School on High Energy Astrophysics

Felix Aharonian (DIAS) and Lorraine Hanlon (UCD)

Local Organising Committee: F. Aharonian, L. Hanlon, V. Bosch-Ramon, R. Byrne, M. Chernyakova, L. Drury, L. Fallon, E.Flood, B. Fox, A. Grace, Jamie Keating, A. Martin-Carrillo, G. Murphy, H. O'Donnell and M. Topinka.

Scientific Advisory Committee: J. Arons, L. Bergstrom, C. Cesarsky, A. Loeb, M. Longair, J. Silk and R. Sunyaev.

Dates: 4th - 15th July 2011

Astroparticle Physics is a new field of research emerging at the intersection of particle physics, astronomy, and cosmology. It aims to answer fundamental questions related to the story of the Universe such as: What is the Universe made of? What is the origin of cosmic rays? What is the nature of gravity? The rapid and exciting progress in this emerging interdisciplinary field is attracting ever growing numbers of students and young researchers. However, currently very few Universities or Research Centers are able to provide systematic courses on different aspects of this rapidly developing field for young researchers entering it. This two-week, 36-lecture course filled this gap by providing a coherent series of advanced lectures on Observational and Theoretical Cosmology, High Energy Non-thermal Galactic and Extragalactic Source Populations, Origin of Cosmic Rays, Particle Acceleration and Radiation Processes. The lectures were given by active researchers who covered the latest developments in their respective areas, while at the same time introducing the basics of the field thereby giving their lectures a pedagogical character. Full details of the programme, including the lectures, can be found at:

http://homepages.dias.ie/~cappa/

The school attracted some 70 students of whom the majority were from outside Ireland.

Figure 6: A group photograph of some of the summer school attendees with the two school directors, Felix Aharonian and Lorraine Hanlon, in the front row.

9.2 Multi-GeV Astrophysics with Ground-Based Detectors

F. Aharonian, L. Bergstrom (OKC), V. Bosch-Ramon, J. Conrad (OKC), L. Drury and F. Ryde (OKC)

Figure 7: Animated discussion at the summer school!

This workshop was held in Dublin from 12 to 14 December and was the first of a series of small to mid-size scientific meetings dedicated to specific topics of High Energy Astrophysics and Cosmology as a joint initiative of the the Dublin Institute for Advanced Studies and the Oskar Klein Centre for Cosmoparticle Physics, University Stockholm.

The aim of the workshop was a comprehensive discussion of the scientific topics and formulation of main objectives and motivations of study of the sky in the rather narrow, but astrophysically extremely important, energy interval between 10 to 100 GeV, being presently a quite poorly explored energy band of the cosmic electromagnetic spectrum. While the small detection area of the Fermi LAT does not allow adequate photon statistics, the current Cherenkov telescope arrays operate effectively in the energy range above 100 GeV. However, the principal possibility of extension of the Imaging Atmospheric Cherenkov Telescope (IACT) technique towards 10 GeV promises a new breakthrough in gamma-ray astronomy. The relatively large gamma-ray fluxes in this energy interval, together with the huge detection areas offered by the IACT technique, can provide the highest gamma-ray photon statistics compared to any other energy band of cosmic gamma-radiation. This should allow detailed spectroscopic and temporal studies of a broad variety of astrophysical phenomena related to pulsars, compact binary systems, gamma-ray bursts, active galactic nuclei, as well as cosmological issues related to the indirect search for Dark Matter, Diffuse Extragalactic UV Background, and Intergalactic Magnetic fields.

The workshop was attended by 41 participants and used the newly refurbished facilities in Dunsink Observatory as well as the Institute's lecture theatre in Burlington Road.

9.3 SKA CALIM 2011, July 25-29, Manchester, UK

The CALIM meeting focuses on progress in algorithms, software and computing aimed at addressing the challenges of calibration and imaging for the Square Kilometre Array (SKA), its pathfinders and other major new radio telescopes such as EVLA, ALMA, LOFAR, ASKAP, MeerKAT, ATA, FAST, MWA, LWA, PAPER/HERA, eMERLIN, GMRT, WSRT/APERTIF etc.

The 2011 meeting was the 6th in a series, following the successful previous meetings held in Dwingeloo (2005), Cape Town (2006), Perth (2008), Socorro (2009) and Dwingeloo (2010). The aim of CALIM is to bring together specialists in the field in order to maintain a coherent strategy for SKA development, consequently it is a highly focused meeting with no general topics addressed. Participation was limited to 50 attendees (excluding local observers) and all major next-generation telescopes were represented by participants from multiple continents.

See http://www2.skatelescope.org/indico/conferenceDisplay.py?confId=171

A. Scaife (DIAS) was one of the nine chairs of the meeting.

10 Detailed Bibliography of Publications

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

10.1 Peer-reviewed Publications in 2011

[1] A. A. Abdo et al. "Discovery of High-energy Gamma-ray Emission from the Binary System PSR B1259-63/LS 2883 around Periastron with Fermi". In: ApJ 736, L11 (July 2011), p. L11. DOI: 10.1088/2041-8205/736/1/L11. arXiv:1103.4108 [astro-ph.HE] (cit. on p. 8).

[2] A. A. Abdo et al. "Fermi Large Area Telescope Observations of Markarian 421: The Missing Piece of its Spectral Energy Distribution". In: ApJ 736, 131 (Aug. 2011), p. 131. DOI: 10.1088/0004-637X/736/2/131. arXiv:1106.1348 [astro-ph.HE].

[3] A. A. Abdo et al. "Insights into the High-energy γ-ray Emission of Markarian 501 from Extensive Multifrequency Observations in the Fermi Era". In: ApJ 727, 129 (Feb. 2011), p. 129. DOI: 10.1088/0004-637X/727/2/129. arXiv:1011.5260 [astro-ph.HE].

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