Astronomy and Astrophysics Research Report 2007

Presented to the Governing Board
of the School of Cosmic Physics
on 19th March 2008

Contents

1 Highlights

In 2007 the combined Astronomy and Astrophysics Section has:

- published over 60 refereed publications including papers in Science and Nature;
- reported the detection of a second jet from a brown dwarf, this time of very low mass (24 Jupiter masses);
- published an estimate of the initial Lorentz factor of a GRB from observations of the starting time of the optical afterglow emission;
- seen evidence from X-ray observations of rapid acceleration in SNRs;
- hosted two major international meetings (JWST and HEPRO);
- secured 9.5MEuro under PRTLI cycle 4 for the e-INIS proposal;
- negotiated the purchase of the national capability computing service machine with the support of the HEA and HEAnet and in partnership with the universities, RCSI, DIT and the Tyndall Institute;
- taken on 3 new postdocs and 3 students;
- submitted two PhD theses;
- initiated enhanced outreach activities in Dunsink;
- published another book in the JETset lecture notes series;
- been included in the preparatory phase EU proposal for KM3NeT;
- moved into new offices in number 31 Fitzwilliam place with an internal 10GB fibre-optic data ring and modern fire-suppressed server room.

2 Staff

Senior Professors Luke Drury, Evert Meurs

Professors Felix Aharonian, Tom Ray

Emeritus Professors Denis O'Sullivan, Alex Thompson, Ian Elliott, Tao Kiang

Schroedinger Fellows Andy Lim, Carlos del Burgo, Masha Chernyakova (from 1 April)

EU Marie Curie Fellow Stefano Gabici (from 1 Oct)

IRCSET Fellow Paul Dempsey (from 1 Oct)

SFI-funded Researchers Rachel Curran, Linda Podio (from 17 Dec)

Visiting Scientists Peter Duffy (on sabbatical from UCD), Mark Dieckmann (Norköping University, Sweden)

Hamilton Scholars Sean Delaney (from 17 Sep), Jonathan Mackey, Denys Malyshev (from 15 Oct), Colin Melody (to 31 Oct), Elisa Nichelli (from 30 Apr), Susanna Vergani, Paul Ward (to 31 Oct)

Summer Student Interns Paul Dawson (11 Jun – 03 Aug), Sara-Jane Doogan (29 May – 13 Sep), Lynda Fennell (11 Jun – 31 Aug), Barry Whelan (5 – 29 Jun)

Experimental Officer (IT support unit) Stephane Dudzynski

Senior Technical Officer (Dunsink Observatory) Mike Smyth

Technical Officers Anne Grace, Hilary O'Donnell, Eileen Flood

Secretarial and Reception Carol Woods (to 27 Apr), Phyllis Daly, Iwona Pelcer (from 17 Oct), one vacancy

Groundsman (Dunsink Observatory) Thomás Mac Grioffa

CosmoGrid project positions Anna Avdeeva (student), Thibaut Lery (project scientist, to 22 Jan), Conor Masterson (project scientist, 22 Jan to 13 Jul), Anne Shaw (project administrator), Sebastian Leygnac (researcher, to 31 Oct), David Golden (IT system administrator, to 14 Apr), Phillipe Grange (IT system administrator, from 03 Sep), S Wang (researcher, seconded to Met Eireann), Tadashi Yamasaki (researcher, to 30 Jun)

JETSET project positions Emma Whelan (academic administrator), Jose Gracia (researcher), Fabio de Colle (researcher)

3 Research Reports

3.1 Interstellar Dust and Near-Infrared spectroscopy

3.1.1 Shells in elliptical galaxies

C. del Burgo, D. Carter, G. Peletier, M. Balcells and E. Valentijn

Two papers have been published on a sample of six shell galaxies based on Hubble Space Telescope observations (Sikkema, Carter, Peletier, Balcells, del Burgo & Valentijn 2007, A&A, 467, 1011) and Spitzer data of NGC 5982 (del Burgo, Carter & Sikkema 2008, A&A, 477, 105). A figure of the last paper was selected as cover of the journal. The distribution of dust traced by optical obscuration and infrared emission has been studied. HST data gauge small amounts of dust in the central regions of the sample, while the Spitzer data reveals the presence of a much bigger amount of cold dust forming a central disk in NGC 5982. In this galaxy shells are detected for the first time from mid-infrared emission and two new external shells are discovered (del Burgo et al. 2008). A prominent shell has been analysed revealing its blue V-I and [3.6]-[4.5] colours with respect to the underlying galaxy. Spitzer data of a few shell galaxies are also being studied.

3.1.2 Interstellar medium of the Milky Way

C. del Burgo with D. Froebrich (U Kent), G. Murphy (Grenoble), M. Smith (U Kent), J. Walsh (TCD)

A large-scale extinction map of the Galactic Anticentre from 2MASS has been published (Froebrich, Murphy, Smith, Walsh & del Burgo 2007, MNRAS, 378, 1447) based on the techniques developed in Froebrich & del Burgo (2006, MNRAS, 369, 1901). Next year CdB will work on the analysis of the near-infrared colours and far-infrared emission in the cloud complexes that are identified in the mentioned Galactic Anticentre map. In addition, he plans to analyse the anomalous emission detected in a few dust clouds with Prof. Rafael Rebolo and collaborators (IAC, Spain).

3.1.3 Integral Field Spectroscopy of Galaxies

C. del Burgo with Dr. Evencio Mediavilla (IAC, Spain) and Dr. Santiago Arribas (DAMIR, Spain)

A collaboration has been initiated to perform research on the circumnuclear regions of nearby normal and active galaxies from Integral Field Spectroscopy (IFS). IFS studies of shell galaxies have been continued in collaboration with Prof. Dave Carter (Liverpool, UK) and Dr. Marc Balcells (IAC).

3.2 High energy processes in Binary Systems

3.2.1 On the origin of TeV radiation in LS 5039

F. Aharonian, D. Khangulyan (MPIK, Heidelberg), V. Bosch-Ramon (MPIK, Heidelberg)

The recent detections of TeV gamma-rays from compact binary systems show that relativistic outflows (jets or winds) are sites of effective acceleration of particles up to multi-TeV energies. The aim of this study was to explore the conditions of acceleration and radiation of ultrarelativistic electrons in LS 5039, the gamma-ray emitting binary system for which the highest quality TeV data are available. Assuming that the gamma-ray emitter is a jet-like structure, detailed numerical calculations of the energy spectrum and light curves has been performed accounting for the acceleration efficiency, the location of the accelerator, the speed of the emitting flow, the inclination angle of the system, as well as specific features related to anisotropic inverse Compton (IC) scattering and pair production. The accelerator should not be deep inside the binary system unless one assume a very efficient acceleration rate. Within the IC scenario both the gamma-ray spectrum and flux are strongly orbital phase dependent, therefore the physical properties of the source can be constrained only by observations capable of providing detailed energy spectra for narrow orbital phase intervals ($\ll 0.1$).

3.2.2 Modeling the interaction of relativistic and nonrelativistic winds in the binary system PSR 1259-63/SS2883. I. Hydrodynamical limit

F. Aharonian, D. Khangulyan (MPIK, Heidelberg), S. Bogovalov (Moscow Engineering Physics Institute), D. Koldoba and G. Ustyugova (Keldysh Institute of Applied Mathematics, Moscow)

Detailed hydrodynamical studies have been conducted to study properties of the flow produced when a relativistic wind interacts with a nonrelativistic wind. In binary systems this scenario can be realized at collision of pulsar and stellar winds. The numerical calculations show that the wind collision could result in formation of an "unclosed" (at spatial scales comparable to the binary system size) pulsar wind termination shock even when the stellar wind ram pressure exceeds significantly the pulsar wind kinetic pressure. Moreover, the post-shock flow propagates in a rather narrow region, with very high bulk Lorentz factor ($\gamma \sim 100$). Interestingly, no magnetic field is required for formation of the ultrarelativistic bulk motion – the plasma acceleration is related to adiabatic losses, and thus has pure hydrodynamical origin. The obtained results offer a new interpretation for the orbital modulation of radio, X-ray and gamma-ray signals detected from binary pulsar PSR 1259-63/SS2883.

3.2.3 TeV light curve of PSR B1259-63/SS2883

F. Aharonian, D. Khangulyan (MPIK, Heidelberg), S. Hnatic (MPIK, Heidelberg), S. Bogovalov (Moscow Engineering Physics Institute)

The evolution of the energy spectra of relativistic electrons under different assumptions about the acceleration and energy-loss rates of electrons, and the impact of these processes on the

light curve of Inverse Compton gamma-rays have been studied. It is demonstrated that the observed by HESS TeV gamma-ray light-curve of the binary pulsar PSR B1259-63/SS2883 can be explained (i) by adiabatic losses which dominate over the entire trajectory of the pulsar with a significant increase towards the periastron or (ii) by the 'early' (sub-TeV) cut-offs in the energy spectra of electrons due to the enhanced rate of Compton losses close to the periastron. The calculated spectral and temporal characteristics of the TeV radiation provide conclusive tests to distinguish between these two working hypotheses. The Compton deceleration of the electron-positron pulsar wind contributes to the decrease of the non-thermal power released in the accelerated electrons after the wind termination, and thus to the reduction of the IC and synchrotron components of radiation close to the periastron. Although this effect alone cannot explain the observed TeV and X-ray light curves, the Comptonization of the cold ultrarelativistic wind leads to the formation of gamma-radiation with a specific line-type energy spectrum. While the HESS data already constrain the Lorentz factor of the wind, $\gamma \leq 10^6$, future observations of this object with GLAST should allow a deep probe of the wind Lorentz factor in the range between 10^4 and 10^6.

3.2.4 A Rotating Hollow Cone Anisotropy of TeV Emission from Binary Systems

M.Chernyakova & A. Neronov (ISDC)

Gamma-ray-loud binary systems are a newly identified class of sources in which either accretion onto the compact object or interaction of an outflow from the compact object with the wind and radiation from a massive companion star leads to the production of very high energy (VHE) γ-ray emission. The VHE γ-ray emission from the γ-ray-loud binaries is variable on the orbital period (or shorter) timescale. This implies that the emission region is located close to the binary system, in a highly inhomogeneous and anisotropic particle and photon background produced by massive companion star.

The γ-ray emission from such a region should have a characteristic rotating hollow cone anisotropy; i.e., most of the photons are emitted at a certain angle with respect to a symmetry axis directed radially away from the massive star. Orbital motion of the emission region around the massive star leads to the rotation of the emission cone and to the appearance of maxima in the orbit-folded light curve in the VHE band. The phases of the maxima and their width put constraints on the geometry of the system. For the case of LS 5039 we found that its TeV lightcurve can be interpreted in a straightforward way, in terms of this model, and that if the source of the electrons is located close to the compact object pulsar case), then the inclination of the orbit should be rather high, $i > 40^\circ$. Contrary, if the inclination of the binary orbit is small, the observed TeV γ-ray emission is produced far from the compact object (e.g. in jet).

3.2.5 Compactified pulsar wind nebula model of gamma-ray loud binary LSI +61 303

M.Chernyakova, A. Neronov (ISDC), A. Zdziarski (Copernicus, Poland)

LSI +61 303 is one of the three currently known γ-ray-loud X-ray binaries. The nature of the compact source is not known, but similarity of the spectral energy distribution of the source to the one of PSR B1259-63, powered by the rotational energy of the young pulsar makes its interesting to apply the "pulsar model" to the LSI +61 303 as well. If the activity of LSI +61 303 is powered by a young pulsar, the radio-to-γ-ray emission is generated in the course of collision of relativistic pulsar wind with the wind from companion star. Different physical processes determine cooling of high-energy particles at different distances from Be star. This leads to an onion-like structure in which the region of dominance of Coulomb losses is embedded into the region of dominance of inverse Compton (IC) losses which is, in turn, situated inside the region of dominant synchrotron loss. The density and inhomogeneity of the stellar wind determine the speed of escape of the high-energy particles injected in the region of pulsar/stellar wind interaction. Anisotropy of the stellar wind leads to the dependence of the escape speed on the orbital phase and, as a consequence, to the variations of the relative importance of Coulomb, IC, and synchrotron losses along the orbit. Such model explains the puzzling behaviour of radio, X-ray and γ-ray lightcurves of the system (shifts of the maxima from the periastron, shifts between the maxima of X-ray and radio lightcurves, shifts of the maxima from orbit to orbit).

3.2.6 Unusual bright state of the X-ray pulsar 4U0352+309/X Persei Be/X-ray binary

M.Chernyakova, A.Lutovinov (IKI), S. Tzygankov (IKI)

4U0352+309/X Persei is a Be/X-ray binary, consisting of a X-ray pulsar 4U0352+309 and a Be star companion optically identified with the star X-Persei. Contrary to other Be/X-ray binaries there is no clear correlation between the X-ray and optical flares from the system, though this can be related to the fact that X-ray data were much more sparse than optical ones until the launch of the RXTE observatory. In order to understand the physical properties governing the system we study the 1996-2007 ASM/RXTE lightcurve along with the available PCA/RXTE, INTEGRAL and optical data from this period.

3.3 Synchrotron radiation of young SNRs

3.3.1 Extremely fast acceleration of cosmic rays in a supernova remnant

F. Aharonian, Y. Uchiyama, T. Tanaka, T. Takahashi and Y. Maeda (ISAS, Tokyo)

Galactic cosmic rays (CRs) are widely believed to be accelerated by shock waves associated with the expansion of supernova ejecta into the interstellar medium. A key issue in this long-standing conjecture is a theoretical prediction that the interstellar magnetic field can be substantially amplified at the shock of a young supernova remnant (SNR) through magnetohydrodynamic waves generated by cosmic rays. Based on the Chandra observations of RXJ1713.7-3946, we revealed remarkable brightening and decay of X-ray hot spots in the shell of this young SNR on a one-year timescale. This rapid variability shows that the X-rays are produced by ultrarelativistic electrons through a synchrotron process and that electron acceler-

ation does indeed take place in a strongly magnetized environment, indicating amplification of the magnetic field by a factor of more than 100. The X-ray variability also implies that we have witnessed the ongoing shock-acceleration of electrons in real time. Independently, broadband X-ray spectrometric measurements of RXJ1713.7-3946 indicate that electron acceleration proceeds in the most effective ('Bohm-diffusion') regime. Taken together, these two results provide a strong argument for acceleration of protons and nuclei to energies of 1PeV ($10^{15}\,\mathrm{eV}$) and beyond in young supernova remnants.

3.3.2 Analytical solutions for energy spectra of electrons accelerated by nonrelativistic shock-waves in shell type supernova remnants

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

Recent observations of hard X-rays and very high energy gamma-rays from a number of young shell type supernova remnants indicate the importance of detailed quantitative studies of energy spectra of relativistic electrons formed via diffusive shock acceleration accompanied by intense nonthermal emission through synchrotron radiation and inverse Compton scattering. The aim of this work was derivation of exact asymptotic solutions of the kinetic equation which describes the energy distribution of shock-accelerated electrons for an arbitrary energy-dependence of the diffusion coefficient. Methods: The asymptotic solutions at low and very high energy domains coupled with numerical calculations in the intermediate energy range allow analytical presentations of energy spectra of electrons for the entire energy region. Results: Under the assumption that the energy losses of electrons are dominated by synchrotron cooling, the exact asymptotic spectra of electrons without any restriction on the diffusion coefficient have been derived. We also obtained simple analytical approximations which describe, with accuracy better than ten percent, the energy spectra of nonthermal emission of shock-accelerated electrons due to the synchrotron radiation and inverse Compton scattering. The results can be applied for interpretation of X-ray and gamma-ray observations of shell type supernova remnants, as well as other nonthermal high energy source populations like microquasars and large scale synchrotron jets of active galactic nuclei.

3.4 Particle acceleration and gamma-ray production in the vicinity of black holes

3.4.1 Production of TeV Gamma Radiation in the Vicinity of the Supermassive Black Hole in the Giant Radio Galaxy M87

F. Aharonian, A. Neronov (INTEGRAL Science Data Centre, Versoix)

Although the giant radio galaxy M87 harbors many distinct regions of broadband nonthermal emission, the recently reported fast variability of TeV gamma-rays from M87, on a timescale of days, strongly constrains the range of speculations concerning the possible sites and scenarios of particle acceleration responsible for the observed TeV emission. A natural production site of this radiation is the immediate vicinity of the central supermassive black hole (BH). Because of its low bolometric luminosity, the nucleus of M87 can be effectively transparent for

gamma-rays up to an energy of 10 TeV, which makes this source an ideal laboratory for the study of particle acceleration processes close to the BH event horizon. We critically analyze different possible radiation mechanisms in this region and argue that the observed very high energy gamma-ray emission can be explained as the inverse Compton emission of ultrarelativistic electron-positron pairs produced through the development of an electromagnetic cascade in the BH magnetosphere. Through detailed numerical calculations of acceleration and radiation of electrons in the magnetospheric vacuum gap it is demonstrated that the "pulsar magnetosphere-like" scenario can satisfactorily explain the main properties of the TeV gamma-ray emission from M87.

3.4.2 Variable VHE gamma-ray emission from non-blazar AGNs

F. Aharonian, F. Rieger (MPIK, Heidelberg)

The observation of rapidly variable very high energy (VHE) gamma-rays from non-aligned active galactic nuclei (AGNs), as reported from M87, proves challenging for conventional theoretical acceleration and emission models. We re-examine the centrifugal acceleration of particles by rotating jet magnetospheres in the vicinity of accreting supermassive black hole systems and analyze the energy constraints imposed for highly underluminous systems. Applications are presented for conditions expected to be present in the radio galaxy M87, assuming accretion onto the central black hole to occur in an advection-dominated (ADAF) mode. We show that for a highly underluminous source like M87, centrifugally accelerated electrons may reach Lorentz factors up to $\gamma \sim (10^7 - 10^8)$, allowing inverse Compton (Thomson) upscattering of sub-mm disk photons to the TeV regime. Upscattering of Comptonized disk photons results in a flat TeV spectrum $L_\nu \propto \nu^{-\alpha_c}$ with spectral index $\alpha_c \simeq 1.2$. The characteristic variability time scale is of the order $r_{\rm L}/c$, which in the case of M87 corresponds to $\simeq 1.7$ d for a typical light cylinder radius of $r_{\rm L} \simeq 5r_{\rm s}$. Centrifugal acceleration could thus provide a natural explanation for the challenging VHE emission features in M87. Our results suggest that some advection-dominated accreting (non-blazar) AGNs could well be observable VHE emitting sources.

3.5 Relativistic jets in AGN

3.5.1 Off-Axis Emission from Relativistic Plasma Flows

F. Aharonian, E. Derishev and Vl.V. Kocharovsky (Institute of Applied Physics, Nizhny Novgorod)

There is no universal law describing how the spectra and luminosity of synchrotron and inverse Compton radiation from relativistic jets change with increasing observation angle. Instead, the physics of particle acceleration leaves pronounced imprints in the observed spectra and allows for a freedom in numerous modifications of them. The impact of these effects is the strongest for high-energy radiation and depends on the details of the particle acceleration mechanism(s). Thus, the observed impact is sensitive to the models' details, and one can use that sensitivity to discriminate between various (but maybe rather similar) models. Generally, the beam patterns

of relativistic jets in the GeV-TeV spectral domain are much wider than the inverse Lorentz factor. The off-axis emission in this energy range appears to be brighter and has a much harder spectrum and a much higher cutoff frequency compared to the values derived from Doppler-boosting considerations alone. The implications include the possibility of explaining high-latitude unidentified EGRET sources as off-axis but otherwise typical relativistic jet sources, such as blazars, and the prediction of GeV-TeV afterglow from transient jet sources, such as gamma-ray bursts. The phenomenon of beam pattern broadening may have a strong impact on the high energy neutrino emission.

3.5.2 Formation of hard VHE gamma-ray spectra of blazars due to internal photon-photon absorption

F. Aharonian, D. Khangulyan (MPIK, Heidelberg), L. Costamante (Stanford University)

The energy spectra of TeV gamma-rays from blazars, after being corrected for intergalatic absorption in the Extragalactic Background Light (EBL), appear unusually hard, a fact that poses challenges to the conventional models of particle acceleration in TeV blazars and/or to the EBL models. A natural solution of this problem could be internal absorption of gamma-rays caused by interactions with dense narrow-band radiation fields in the vicinity of compact gamma-ray production regions. This process can lead to the formation of gamma-ray spectra of an almost arbitrary hardness. If so, this would allow significant relaxation of the current tight constraints on particle acceleration and radiation models, although at the expense of enhanced requirements to the available nonthermal energy budget. The latter, however, is not a critical issue, as long as it can be largely compensated by the Doppler boosting, assuming very large (≥ 30) Doppler factors of the relativistically moving gamma-ray production regions. The suggested scenario of formation of hard gamma-ray spectra predicts detectable synchrotron radiation of secondary electron-positron pairs which might require a revision of the current "standard paradigm" of spectral energy distributions of gamma-ray blazars. If the primary gamma-rays are of hadronic origin related to pp or $p\gamma$ interactions, the "internal gamma-ray absorption" model predicts neutrino fluxes close to the detection threshold of the next generation high energy neutrino detectors.

3.6 Multiwavelength studies of TeV gamma-ray sources

3.6.1 TeV Gamma-Ray Emission of a PWN in the Galactic Center?

F. Aharonian, J. Hinton (University of Leeds)

The intense Compton cooling of ultrarelativistic electrons in the Klein-Nishina regime in radiation-dominated environments, such as that found in the Galactic center, may result in radically different electron spectra than those produced by synchrotron cooling. We explore these effects and their impact on the X-ray and γ-ray spectra produced in electron accelerators in this region in comparison to elsewhere in our Galaxy. We calculated the broadband emission expected from the newly discovered pulsar wind nebula G359.95-0.04 and the possible relationship of this X-ray source to the central TeV gamma-ray source HESS J1745-290.

3.6.2 XMM-Newton Observations Reveal the X-Ray Counterpart of the Very High Energy Gamma-Ray Source HESS J1640-465

F. Aharonian, S. Funk and O. Reimer (University of Stanford), J. Hinton (University of Leeds), W. Hofmann (MPIK, Heidelberg), G. Pühlhofer and S. Wagner (LSW, Heidelberg)

X-ray observations of the as of yet unidentified very high energy gamma-ray source HESS J1640-465 have been proposed with the aim of establishing a counterpart of this source in the keV energy range, and identifying the mechanism responsible for the VHE emission. The 21.8 ks XMM-Newton observation of HESS J1640-465 in 2005 September represents a significant improvement in sensitivity and angular resolution over previous ASCA studies in this region. These new data show a hard-spectrum X-ray-emitting object at the centroid of the H.E.S.S. source, within the shell of the radio supernova remnant (SNR) G338.3-0.0. This object is consistent with the position and flux previously measured by both ASCA and Swift XRT, but is now shown to be significantly extended. We argue that this object is very likely the counterpart to HESS J1640-465, and that both objects may represent the pulsar wind nebula of an as of yet undiscovered pulsar associated with G338.3-0.0.

3.6.3 XMM-Newton observations of HESS J1813-178 reveal a composite Supernova remnant

F. Aharonian, S. Funk and O. Reimer (University of Stanford), J. Hinton (University of Leeds), Y. Moriguchi and Y. Fukui (Nagoya University), W. Hofmann (MPIK, Heidelberg), G. Pühlhofer and S. Wagner (LSW, Heidelberg)

X-ray and 12CO(J=1-0) observations of the TeV gamma-ray source HESS J1813-178 have been analyzed with the aim of understanding the origin of the gamma-ray emission. High-angular resolution X-ray studies of the VHE gamma-ray emission region are performed using 18.6 ks of XMM-Newton data, taken on HESS J1813-178 in October 2005. NANTEN 12CO(J=1-0) data are used to search for correlations of the gamma-ray emission with molecular clouds which could act as target material for gamma-ray production in a hadronic scenario. The NANTEN 12CO observations show a giant molecular cloud of 2.5×10^5 solar masses in the vicinity of HESS J1813-178. The X-ray data show a highly absorbed ($nH = 10^{23}$ cm^{-2}) non-thermal X-ray emitting object exhibiting a compact core and an extended tail towards the north-east, located in the centre of the radio shell-type SNR G12.82-0.02. The central object shows morphological and spectral resemblance to a Pulsar Wind Nebula and therefore it is likely that this object is a composite SNR. In order to connect the core X-ray emission to the VHE gamma-ray emission electrons have to be accelerated to energies of at least 1 PeV. This supports the plerionic origin of highest energy electrons.

3.6.4 Potential neutrino signals from Galactic gamma-ray sources

F. Aharonian, S. Kelner (MPIK, Heidelberg), A. Kappes and C. Stegmann (University of Erlangen-Nuremberg), J. Hinton (University of Leeds)

A certain fraction of TeV gamma-ray sources discovered by HESS in the galactic disk are believed to be of hadronic origin, and hence they are potential sources of high energy neutrinos. The neutrino flux of these sources can be estimated with good accuracy. Using the energy spectra and source morphologies measured by H.E.S.S., together with recent parameterisations of pion production and decay in pp interactions, the signal and background rates expected from these sources have been calculated for the proposed 1km3 scale neutrino detector in the Mediterranean Sea (KM3NeT). It appears that at energies above 1 TeV the brightest gamma-ray sources can initiate in KM3NeT neutrino events with rates comparable to the background rate from atmospheric neutrinos (a few events per year). Thus these sources can be marginally detected by KM3NeT, after several years of continuous operation, provided that the contributions of gamma-rays of leptonic (inverse Compton) origin to the gamma-ray fluxes detected by HESS are negligible.

3.7 Star Formation

3.7.1 Automatic Pipeline from Jet Simulations to Synthetic Observations

J. Gracia, JETSET Collaboration

Numerical simulations and observations cannot be compared directly. While the former describes the plasma in terms of physical quantities such as density, pressure, magnetic field and velocity, the latter observes only photon flux as a function of frequency. Translating numerical simulations into synthetic observations is a highly non-trivial task. In principle, the JETSET collaboration possess all the necessary skills to bridge this gap, however it is scattered over a number of nodes. The goal of this project is to produce a set of tools for processing model simulations, leading to synthetic spectra which can be directly compared with observations. This requires assembling various inputs and know-how from individual members of the collaboration, defining interfaces between the different tools and rewriting them in a consistent manner within a single code. A prototype implementation of the pipeline was completed.

3.7.2 Extending radially self-similar MHD models by introducing an outer disk radius

J. Gracia and M. Stute (University of Athens)

One geometrical limitation of self-similar MHD models for jets is the non-existence of an intrinsic scale. The jets formally extend to radial infinity. The aim of this project is to investigate numerically, how imposing an outer radius of the jet, i.e. cutting off the analytical solution at arbitrary radii, affects the topology and structure, the stability and ability to explain observations of a radial self-similar analytical solution.

3.7.3 Resistive MHD Jet Launching Models

J. Gracia and M. Cemeljic (University of Athens)

It is generally accepted, that MHD processes play an important role in the initial formation, acceleration and collimation of jets from accretion disks. While ideal MHD is in principle sufficient to describe these processes in the actual jet, non-ideal MHD cannot be neglected in the accretion disk. Global models of accretion and jet launching must therefore necessarily include magnetic resistivity. Building on previous analytical and numerical studies, this project aims to understand the influence of non-ideal MHD on jet launching emphasizing the effect of resistive heating. Preliminary results seem to indicate, that at low values of resistivity the numerical results coincide very well with the ideal models. Only, an additional (resistive) heating is observed along the flowlines. However, above a critical resistivity value, the flow completely changes character and becomes intrinsically time-dependent, i.e. no steady-state solutions were found. We are currently investigating if this is a numerical artifact, and, if real, what is the relationship of the time-scale for variability to the flow parameters.

3.7.4 On the Origin of Knots in YSO Jets

F. De Colle, J. Gracia, G. Murphy (LAOG Grenoble)

Jets from young stars normally consist of chains of knots, Herbig-Haro (HH) objects, with some periodicity in their spatial distribution, corresponding to changes in ejection from the protostar/disk system on timescales around 10 yrs. We have studied different possibilities for the origin of the HH objects and, using simple analytical arguments, we have shown that a periodic or quasi-periodic variation in the stellar magnetic field produces a variation in the ejection velocity of the outflow from the star-disk system, large enough to generate the observed knots.

3.7.5 Diagnostics of inhomogeneous stellar jets

F. De Colle, C. Del Burgo, A. Raga (UNAM, Mexico)

We have studied the effects of projection and beam convolution on the determination of the physical parameters (electron density and temperature, and hydrogen ionization fraction) of stellar jets. Additionally, we applied standard tomographic techniques to reconstruct the values of the parameters across the HH30 jet, obtaining in this way a three dimensional picture of the observed jet. The jet presents larger gradients in density in comparison to those determined from previous studies, and a reasonable decrease in temperature along the axes of propagation.

3.7.6 Development of a photoionization/MHD code

F. De Colle, W. Henney (UNAM, Mexico), J. Arthur (UNAM, Mexico), G. Mellema (Stockholm University)

We have developed a photoionization code as a hybrid of the Mezcal code (developed by F. De Colle) with the C2Ray code (by G. Mellema). The code is currently being used to run three dimensional radiation MHD simulations of photoionized globules and the formation and

expansion of HII regions in turbulent magnetized molecular clouds. Additionally, the AMR version of the MHD code was parallelised during a six weeks visit to CINECA (Bologna, Italy), including a simple strategy to handle load balancing.

3.7.7 Outflow activity in brown dwarfs

E. Whelan and T.P. Ray

Early in 2007 we reported, using the technique of spectro-astrometry, the discovery of the second brown dwarf (BD) with an outflow. The BD in question, 2MASS1207-3932, is a $24\,\mathrm{M_{JUP}}$ object hence it is now *the lowest mass galactic object* with a known outflow. ESO also released a press release describing this result (See Figures 1 and 2). A further 30 hours of ESO VLT observing time was granted to continue this work: 25 hours to obatin more spectra and 5 hours for imaging. Analysis is currently underway. A 3rd outflow from the BD ISO Cha 217 has already been identified. Using FORS 1 on the VLT we will attempt to directly image a number of these outflows for the first time.

3.7.8 Spectro-astrometry as a probe of the inner regions of young stellar objects

E. Whelan, L. Podio and T.P. Ray

We are using the specialised technique of spectro-astrometry to search for outflow components in emission lines from young stars. This method can also be used to identify dust holes in their surrounding disks on a couple of AU scales. To continue this work MIKE spectra (from the Magellan 8m telescope) is being analysed of the classical T Tauri star RU Lupi. The idea here is to see how the size of dust hole changes in different permitted emission lines (Hα, Hβ, Hγ). In addition, observing time was granted in December to study a sample of T Tauri and Herbig Ae/Be stars using UIST on the United Kingdom Infrared Telescope (UKIRT). Due to bad weather only 30$\%$ of the project was completed during the run, however, the observations still remain in the que and will be completed. Linda Podio, a new IRCSET Fellow, joined the group in December and is a collaborator for this project. In addition 11 hours of ESO time has been granted to observe near-infrared permitted lines with ISAAC on the VLT.

3.7.9 Large-scale outflows from classical T Tauri stars

T.P. Ray, F. McGroarty (Maynooth) and D. Froebrich (University of Kent)

We have examined the environment of a number of evolved low-mass young stars, i.e. classical T Tauri stars, to see if they are capable of driving parsec-scale outflows. These stars - CW Tau, DG Tau, DO Tau, HV Tau C and RW Aur were previously known to drive only small-scale outflows of a few hundreths of a parsec. We discovered that they drive outflows of 0.5 pc-1 pc, based on the morphology and alignment of newly discovered and previously known HH objects with these sources and their jets. A cross-correlation method was used to determine the proper motions of the HH objects in these five outflows (HH 220, HH 229, HH 702, HH 705 and HH 826 - HH 835) which in turn allows us to confirm their driving sources. Tangential

Figure 1: Artist's impression of the DIAS discovery of a bipolar outflow from the brown dwarf 2MASS1207-3932, published by ESO as a press release. This is the lowest mass galactic object with a jet.

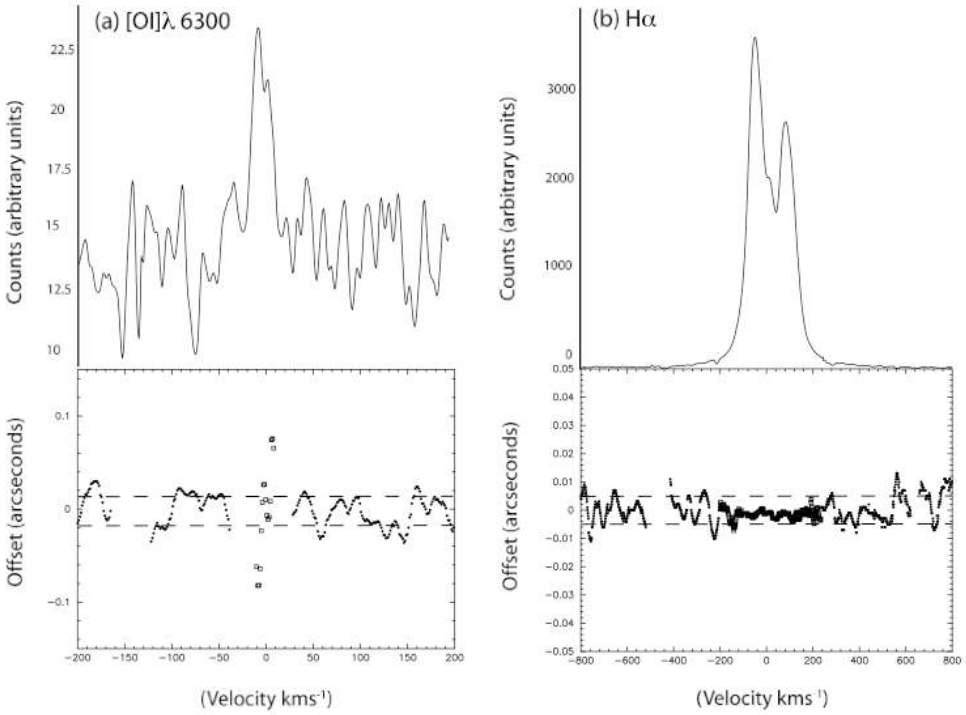

Figure 2: Offset velocity diagrams in the vicinity of the [OI]λ6300 and Hα lines of the brown dwarf 2MASS1207-3932. Data have been averaged by 3 pixel rows in the spatial direction centred on the continuum. Note the continuum has not been subtracted. The green dashed lines delineate the $\pm$ 1 σ error envelope for the centroid position of the continuum. No offsets are measured in the Hα line as expected, ruling out the possibility of spectro-astrometric artifacts. The large offsets, in the vicinity of the forbidden [OI] line and on either side of the continuum, are due to the bipolar outflow. The Hα emission is largely dominated by accretion and thus coincides with the source.

velocities of HH objects at large distances from their origin are currently poorly known so these proper motions will allow us to determine how outflow velocities change with distance from their source. We found tangential velocities of typically 200 km s^{-1} for the more distant objects in these outflows. Surprisingly, similar tangential velocities were found for the jets. This leads us to suggest that either the outflow velocity was much higher 10^3 years ago when the more distant objects were ejected and that these objects have decelerated to their current velocity or that the outflow velocity at the source has remained approximately constant and the more distant objects have not undergone significant deceleration due to interactions with the ambient medium. Numerical simulations are needed to help decide between these scenarios.

3.7.10 Investigating the transport of angular momentum from embedded young stellar objects

T.P. Ray, A. Chrysostomou (University of Hertfordshire), C.J. Davis (Joint Astronomy Center, Hawaii), F. Bacciotti (Arcetri), B. Nisni (Rome Observatory), J. Eislöffel (Tautenburg Observatory) and H. Takami (Subaru)

In this pilot study, we have examined molecular jets from the embedded Class I sources, HH 26 and HH 72, to search, for the first time, for kinematic signatures of jet rotation from young embedded sources. High resolution long-slit spectroscopy of the H2 1-0 S(1) transition was obtained using VLT/ISAAC, position-velocity (PV) diagrams constructed and intensity-weighted radial velocities transverse to the jet flow measured. Asymmetric PV diagrams were seen for both objects which a simple empirical model of a cylindrical jet section shows could in principle be reproduced by jet rotation alone. Assuming magneto-centrifugal launching, the observed HH 26 flow may originate at a disk radius of 2-4 AU from the star with the toroidal component of the magnetic field dominant at the observed location, in agreement with magnetic collimation models. We have estimated the angular momentum transported by the HH 26 jet and shown that it already amounts to 70% of the angular momentum that has to be extracted from the disk for accretion to proceed at the observed rate. The results of this pilot study suggest that jet rotation may also be present at early evolutionary phases and supports the hypothesis that they carry away excess angular momentum, thus allowing the central protostar to increase its mass.

3.7.11 Searching for Jet Rotation with the Hubble Space Telescope

T.P. Ray, D. Coffey and F. Bacciotti (Arcetri), and J. Eislöffel and J. Woitas (Tautenburg Observatory)

We have continued our study using the Hubble Space Telescope Imaging Spectrograph (STIS) at optical and near-ultraviolet (NUV) wavelengths to investigate rotation in young stellar object jets. Results were presented for the approaching jet from DG Tau, CW Tau, HH 30, and the bipolar jet from TH 28. Systematic asymmetries in Doppler shift were detected across the jet, within 100 AU from the star. At optical wavelengths, radial velocity differences were typically (10-25)+/-5 kms^{-1}, while differences in the NUV range were consistently lower, at typically 10+/-5 kms^{-1}. Results were interpreted as possible rotation signatures. Importantly,

there is agreement between the optical and NUV results for DG Tau. Under the assumption of steady magnetocentrifugal acceleration, the survey results lead to estimates for the distance of the jet footpoint from the star, and give values consistent with earlier studies. Therefore, if indeed the detected Doppler gradients trace rotation within the jet, then under the assumption of steady MHD ejection, the derived footpoint radii support the existence of magnetized disk winds. However, since we do not resolve the innermost layers of the flow, we cannot exclude the possibility that there also exists an X-wind or stellar wind component.

3.7.12 Magnetic Fields in Molecular Outflows

A. Lim, R.L. Curran and T.P. Ray

MHD models (axi-symmetric and full-3D) of molecular outflows are being developed for the purpose of producing simulated polarised emission from the dust and CO in molecular outflows. These will be compared with existing polarimetric observations of star-forming regions and also used as a basis for application for observing time on the SMA in the upcoming semester (and in the future, ALMA). Alignment of the dipole moments of dust and molecules with an ambient magnetic field results in partial polarisation of the emission from these components of the ISM. From this emission it will be possible to determine the magnetic field in stellar jets/molecular outflows. Only within the last year has it become possible to observe the polarised emission at the resolution required. However, these observations only yield the plane-of-the-sky component, summed along the line-of-sight, hence a number of field morphologies may be consistent with any given observed polarisation pattern. Without detailed modelling, it is not clear what these field morphologies are. A modified version of the Reefa adaptive-mesh MHD code will be used to conduct a series of simulations of the propagation of a stellar jet into magnetised media in which the field strength varies both quantitatively and morphologically. From each of these simulations the polarised emission maps will be calculated, these can then be used to constrain the field morphologies which are inferred from observations.

3.7.13 Magnetic Fields in High-Mass Star-Forming Regions

R.L. Curran and A. Chrysostomou (University of Hertfordshire)

The process of high-mass star formation is not nearly as well understood as that of low-mass stars. Recently, the favoured method of high-mass star formation has been a scaled-up version of the low-mass process (rather than the coalescence of low-mass stars). The magnetic field plays an important role in this process, providing (it is thought) support to the cloud initially, then, once the support begins to fail, allowing collapse. The magnetic field is also responsible for driving and collimating jets and outflows, thus removing the excess angular momentum. This is currently the largest sample of high-mass star-forming regions observed using submillimetre imaging polarimetry. This method traces the plane-of-the-sky magnetic field morphology throughout these regions. Analysis of this sample reveals that there is no single magnetic field morphology responsible during the star-forming process. A decrease in polarisation percentage with increasing total intensity is observed in all but the youngest objects, suggesting that these younger objects are either less centrally condensed, or have less tangling of the magnetic field at the centre of the cores.

3.7.14 Magnetic Fields in Low-Mass Star-Forming Regions

R.L. Curran and A. Chrysostomou (University of Hertfordshire)

Submillimetre imaging polarimetry is being used to analyse the plane-of-the-sky magnetic field in low-mass star forming regions, with an aim of understanding the role played by the field in this process. The majority of low-mass stars either form as singles or binary systems (as opposed to high-mass star formation, which generally takes place in clusters). This should lead to less complex magnetic field morphologies in these low-mass cores, making interpretation of the observed polarimetry patterns less difficult. However, low-mass star-forming regions are much fainter in the submillimetre than their high-mass counter-parts, and so many more observations are required to build enough signal-to-noise.

3.7.15 Establishing the Direction of Rotation in Circumstellar Discs

R.L. Curran, E.T. Whelan, T.P. Ray, D. Coffey (Arcetri), F. Bacciotti (Arcetri), and P. Garcia (University of Porto)

Circumstellar discs play a fundamental role in star and planet formation. The central protostar gains a significant fraction of its mass by accretion through the disc. Also in many generally accepted models it is the disc, threaded by open magnetic field lines that launch the observed jets and outflows centrifugally, thus removing the excess angular momentum and preventing the protostar from reaching break-up velocity. It is, however, only just becoming possible to test these theories observationally. By observing the CO v = 2 - 0 bandhead, a known tracer of these discs, for a sample of T-Tauri stars, it should be possible to establish the sense of rotation of the discs. Furthermore, comparison of the measured displacements with the locations predicted will test current circumstellar disc theory.

3.7.16 Homogeneous Reduced Polarimetry Data from the JCMT

R.L. Curran and B. Matthews (Herzberg Centre for Astrophysics, Canada)

In the past, it has been found that polarimetry data is especially susceptible to data reduction methods. Rachel Curran has previously analysed various data reduction techniques for SCUBA polarimetry taken with the JCMT. Using the data reduction of Curran & Chrysostomou 2007, all polarimetry map data in the JCMT archive have been downloaded, and reduced. This reduced data has since been re-entered into the archive, allowing for the first time a fully reduced, homogeneous data set available to the public from the JCMT. Such a data set allows for direct comparisons to be made between data of different objects, taken at different times, for different projects.

3.8 Extragalactic Jets

3.8.1 MHD models and synthetic synchrotron emission maps for the M87 jet

J. Gracia, S. Bogovalov (State University of Moscow), K. Tsinganos (University of Athens)

We have calculated self-consistent MHD models for the jet of M87. The model consists of two distinct zones: an inner relativistic outflow, which we identify with the observed jet, and an outer cold disk-wind. While the former does not self-collimate efficiently due to its high effective inertia, the latter fulfills all the conditions for efficient collimation by the magneto-centrifugal mechanism. Given the right balance between the effective inertia of the inner flow and the collimation efficiency of the outer disk wind, the relativistic flow is magnetically confined into a well collimated beam for a wide range of parameters and matches the measurements of the opening angle of M87 over several orders of magnitude in spatial extent.

In the second part of this work, we present synthetic synchrotron emission maps for our MHD models. In principle the two-zone model can reproduce the morphological structure seen in radio observations, as central-peaked profiles across the jet close the the source, limb-brightening further down the jet, and a bright knot close to the position of HST-1. However it is difficult to reconcile all features into a single set of parameters.

3.9 Gamma Ray Burst studies

3.9.1 REM Telescope observations

S. Vergani, P. Ward, E.J.A. Meurs, L. Norci (DCU), E. Molinari, S. Covino, et al. (Brera Observatory)

The arrangement by which groups participating in the REM Telescope project participated as Duty Scientists for several week-long periods ceased to be in force in 2007. Now with a centralized management of the REM observations, again a number of Gamma Ray Burst (GRB) afterglows was detected throughout the year.

The publication of the initial fireball Lorentz factor determination, which could be derived from the early afterglow onset detection for the two bursts GRB060418 and GRB060607A, led to Press Releases by the European Southern Observatory and by Dublin City University.

The lightcurves of the two short bursts GRB050724 and GRB070707 (see Fig. 3) were studied, along with their host galaxy properties. Though short, both these bursts feature lightcurves that have been well monitored.

3.9.2 Modelling of supernova contributions to GRB afterglow lightcurves

P. Ward, E.J.A. Meurs, C. Rebelo (Porto)

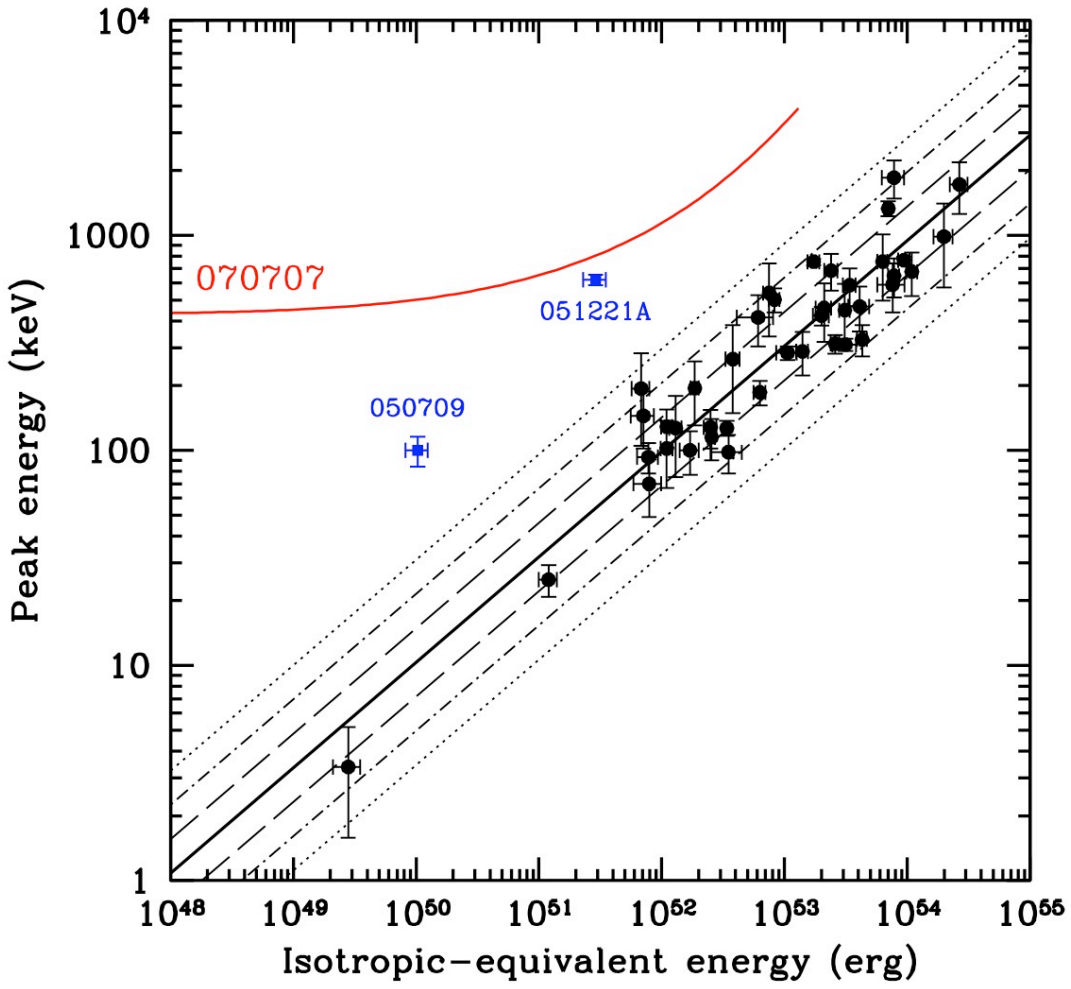

Figure 3: The red curved line represents the position of the short burst GRB070707 as a function of the (unknown) redshift, in a plot showing the 'Amati' relationship between isotropic and peak energies.

In order to model supernova contributions to the lightcurves of Gamma Ray Burst (GRB) afterglows, we have extended our determination of so-called K-corrections. The K-correction accounts for the effects of cosmological expansion on the emission properties of astronomical objects. This is important for GRBs as they are often found at cosmological redshifts (i.e., distances). The K-corrections were derived previously for type Ia supernovae, now they have been expanded to cover all known supernova types (see Fig. 4).

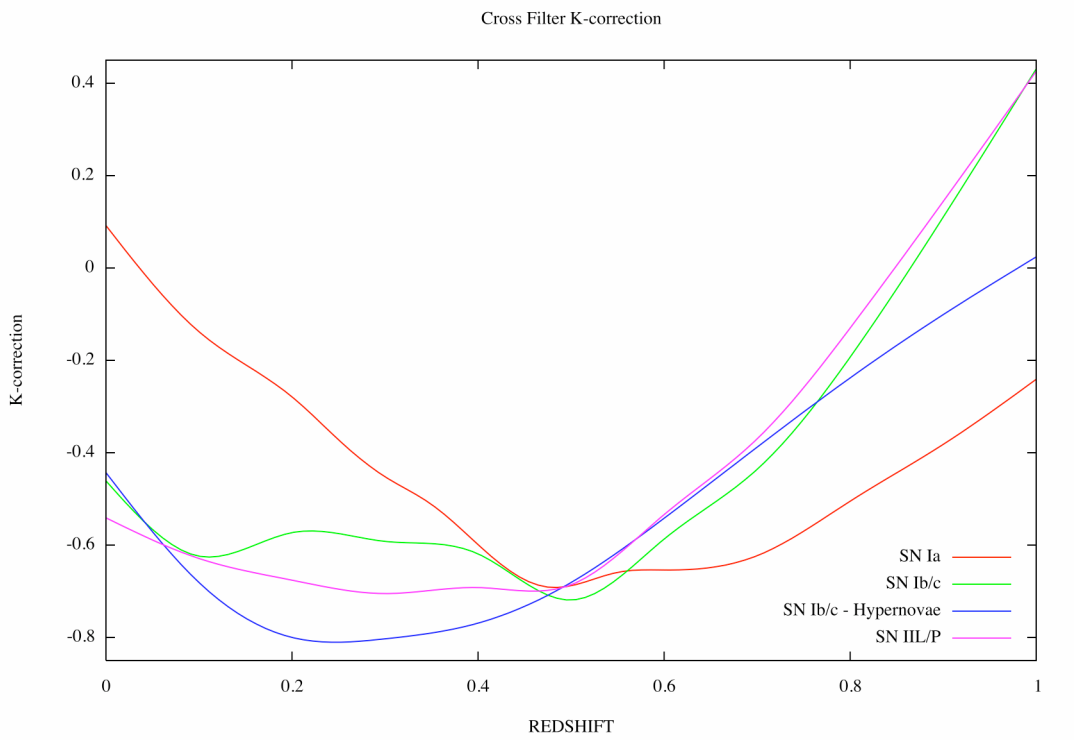

Figure 4: Cross-filter K corrections (in magnitudes) for different supernova types, over the redshift interval $0 < z < 1$

The set of K-corrections thus obtained was then applied to model the possible contributions by different supernova types to a number of GRB afterglow lightcurves that have exhibited late-time re-brightenings. In this way we can assess which supernova types may explain the observed afterglow lightcurve bumps and which ones cannot do this.

Overall, the supernova type Ic (which is often taken as a default choice) comes mostly out on top. But some other types can on the other hand not always be ruled out, in particular types Ia. This is interesting, as the peak emission of types Ia is dominated by Nickel production, which is thought to be also produced in type Ic supernovae associated with GRBs.

3.9.3 Swift satellite observations of GRBs

S. Vergani, E.J.A. Meurs, the Brera Observatory Swift team

The Swift satellite kept detecting Gamma Ray Bursts (GRBs) regularly. Contributions to the operation of the satellite, by way of Burst Advocate were made by S. Vergani.

Multiwavelength studies were carried out for two bursts, GRB060418 and GRB070311. GRB060418 exhibits a huge early time X-ray flare, which phenomenologically shows similarities to the prompt γ-ray emission. For GRB070311, the prompt emission, early afterglow and late re-brightening may all be ascribed to externally shocked material.

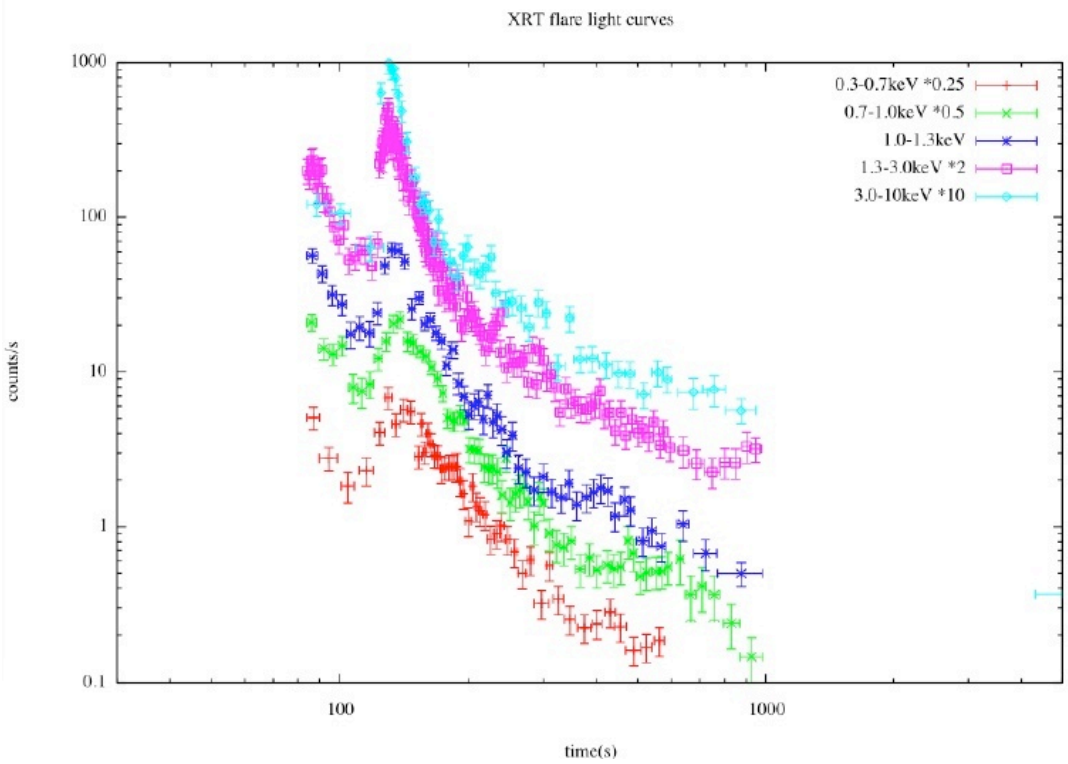

Figure 5: X-ray lightcurves of GRB060418 in different energy bands, as reported in the legend (with an added factor giving a vertical displacement with respect to the 1.0-1.3 keV data, for clarity). The plot shows a pulse that is narrower in the high-energy (hard) bands and with a peak time that occurs later in the soft bands. This is reminiscent of what is observed for the prompt emission γ-ray pulses.

3.9.4 High resolution echelle spectroscopy of GRB afterglows

P. Ward, S. Vergani, E.J.A. Meurs, L. Norci (DCU), F. Fiore, V. DElia, S. Piranomonte (Rome Observatory)

High-resolution echelle spectroscopy is a relatively new and exciting tool for GRB astronomy. Sometimes data are obtained only minutes after a burst has occurred, which is important because of the transient nature and decreasing brightness of the afterglows. The echelle spectroscopy highlights the presence of intervening material along the line of sight, in the immediate surroundings of a burst as well as in separate intervening systems.

Echelle spectra for GRB050922C display a complex absorption system at the redshift of the host galaxy, with 7 components. The identification of multiple fine structure transitions allows for a constraint on the ionisation mechanisms involved. Also, for the first time we could identify which components are associated with the medium surrounding the burst and which are

associated with the host galaxy. In addition, through the detection of MgI we can determine which components are closest to the GRB site.

The redshift system of the host galaxy of GRB060607A, at a redshift of 3.074, shows little complexity; just CIV and SiIV are detected (apart from Ly_{α}, see Fig. 6). By far the most complex system is one of the intervening systems, at z=2.933, which shows a great number of absorption features. It is possible that the burst occurred at the edge of a galaxy and as a result there was not as much galactic material in the line of sight. Another possible reason for the uncomplicated nature of the absorption system of the host is the ejection of the progenitor from the rich starforming region in which it was born.

3.10 Runaway star studies

3.10.1 Production mechanisms

C. O'Maoileidigh, E.J.A. Meurs, L. Norci (DCU), M. Wilkinson (Leicester)

OB runaway stars are massive, early-type, high-velocity stars which have been ejected from their parent birthplaces. Two mechanisms offer plausible explanations for these objects. A supernova occurring in a binary system can often result in the system becoming unbound and the companion star being released from the system with a velocity comparable to its orbital velocity. On the other hand, close gravitational interactions between two or more stars can result in dynamical ejection of one or more of the stars as they are being flung from the system with a high velocity. Both of these mechanisms have been shown to exist in nature; however, which mechanism dominates the production of OB runaways is still unknown.

An extensive set of Nbody simulations was completed in order to explore the parameter space relevant to the production of runaway stars, such as initial cluster density, binary fraction, binary binding energy, etc. The dynamical ejection mechanism was investigated using a sophisticated Nbody code, Aarseth's Nbody6 programme, which simulates gravitational encounters between stars in a realistic cluster environment, including many other cluster properties and details relating to stellar evolution. The initial conditions of star clusters in general are unknown, but also there exists a wide variety of clusters with different properties, such as mass, size, density, etc. Thus, a range of cluster conditions was studied in order to determine how the rate of ejection of massive stars is altered within these varying environments. Several effects were considered: low, intermediate and high stellar densities; initial binary populations; initial binary binding energies; primordial mass segregation; gas expulsion; population size; and stellar mass distributions.

Subsequently, a set of population synthesis routines was employed in order to study the supernova in a binary ejection mechanism in detail. The implications of the natal kick velocity, given to the neutron star at explosion, on our runaway population were considered. The number of ejections changes as a result of different initial binary separation ranges. From the velocity dispersion of binaries ejected via this supernova in a binary mechanism we give evidence that the applied natal kick velocity distribution is bimodal, with lower kicks being applied to binaries which subsequently become Be/X-ray binaries and higher kicks to binaries which become OB supergiant X-ray binaries. From a consideration of mass transfer from the primary star

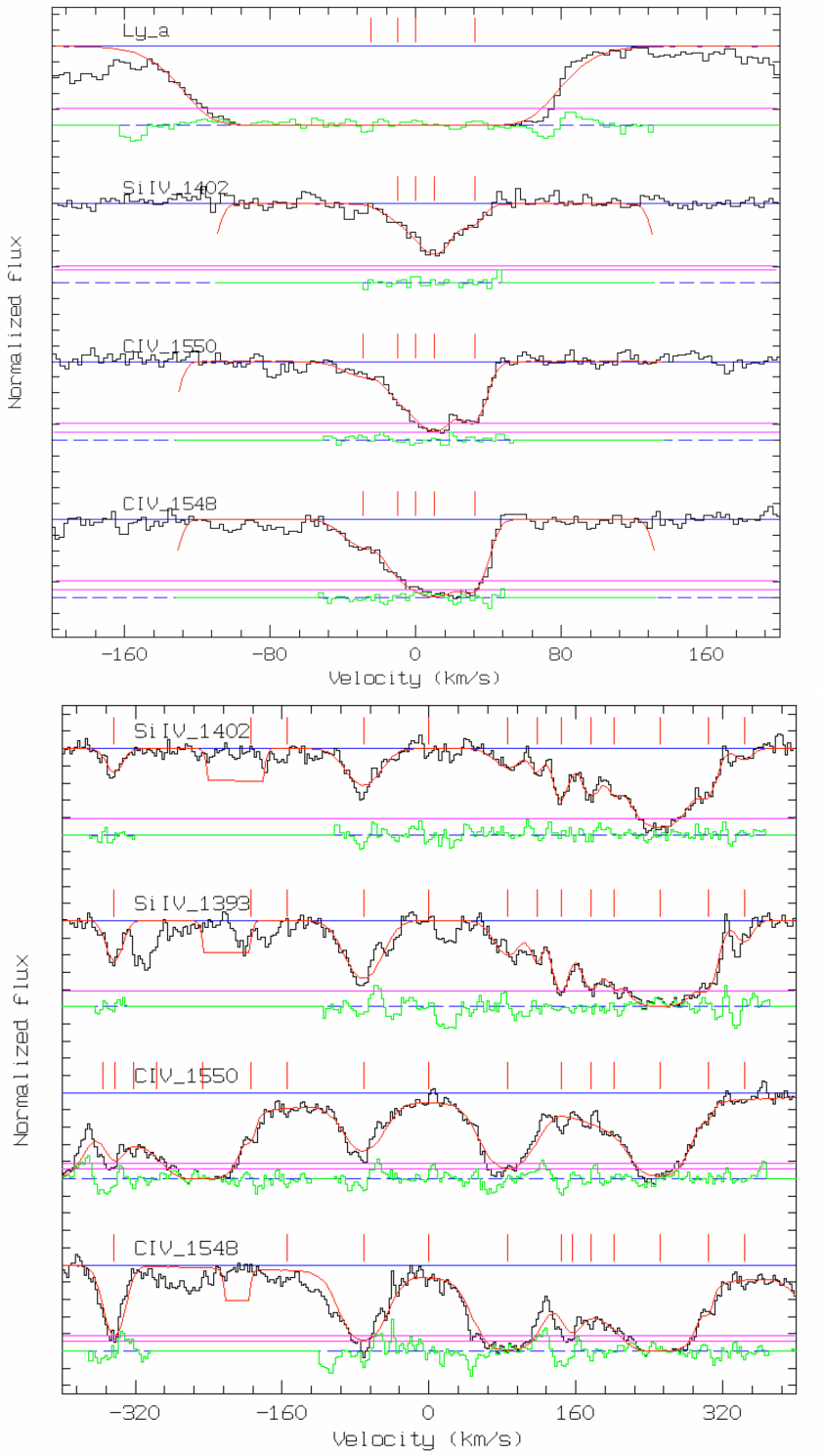

Figure 6: Top: Absorption features found in GRB060607 at z=3.074. Bottom: The intervening absorber at z=2.933 with more complex absorption features.

to the companion prior to the supernova explosion we find that nearly all O and only 30% of B star runaways are likely to be observed as Blue Stragglers with respect to their parent clusters. It is also suggested that 15% of runaways ejected via this mechanism may be so-called Thorne-Zytkow objects (stars where a companion neutron star has spiralled in and occupies their centres). The statistics of binary runaways created via either mechanism allow to consider the observational implications of these results.

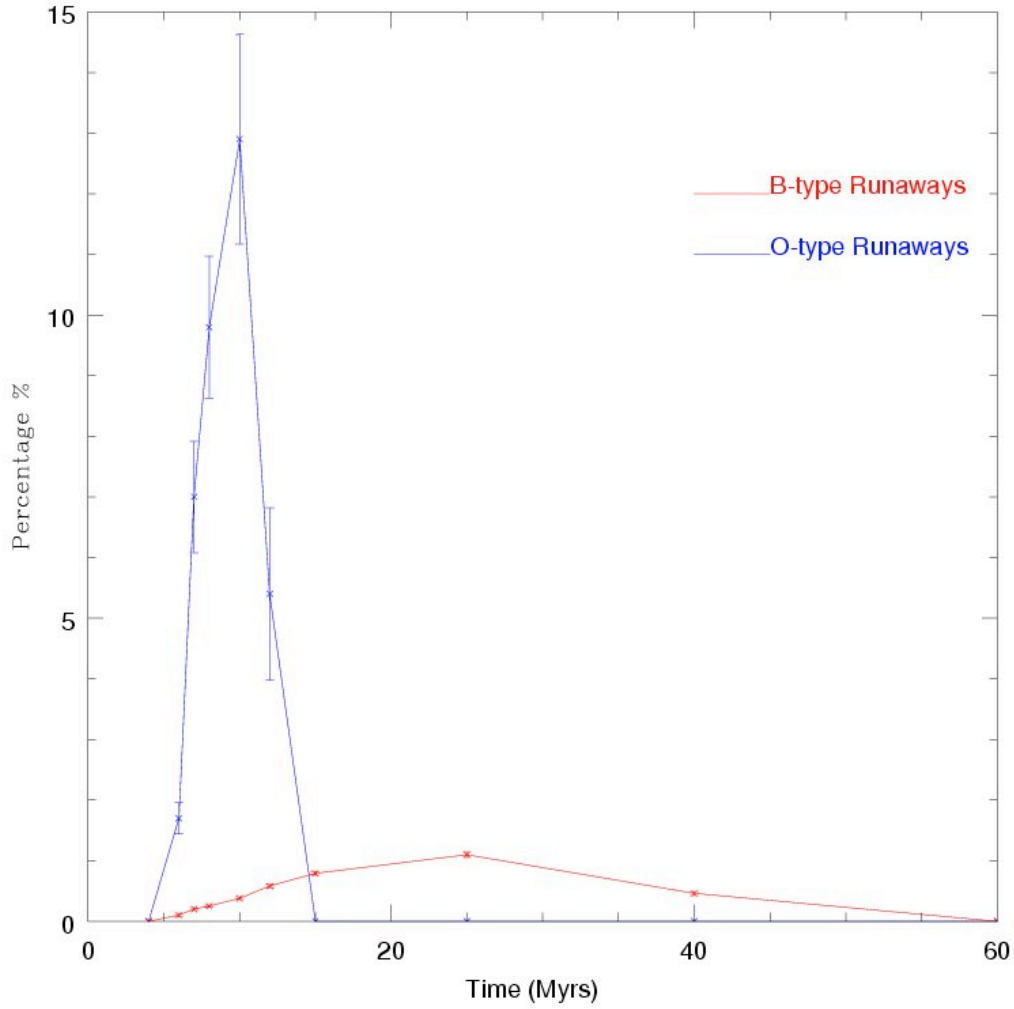

Figure 7: The percentage of runaway stars ejected via the supernova in a binary scenario, with respect to time.

3.10.2 Echelle spectroscopy of runaway stars

C. O'Maoileidigh, E.J.A. Meurs, L. Norci (DCU), C. Rossi and V.F. Polcaro (Rome)

Blaauw suggested in 1993 that excess rotation in runaway stars may be an indicator of close binary evolution as increased rotational velocity is a natural consequence of mass transfer to the companion star prior to the supernova explosion of the primary star. The implication is that the

runaways were ejected via the supernova in a binary scenario. Following this, we determined rotation rates for 38 OB runaways and added these values to the database of runaways with known rotation velocities, thus extending the body of such data by 20%. The results confirm Blaauws conclusion that O-type runaways show excess rotation rates suggesting that the majority of O-type runaways is ejected via the supernova in a binary scenario. The B-type runaways show no excess rotation with respect to the rotation velocity of typical B stars, therefore the majority of B-type runaways is likely to have been dynamically ejected.

3.11 X-ray astronomy

3.11.1 Stellar hardness ratios

E.J.A. Meurs, L. Norci (DCU), P. Kavanagh (DCU), P. Casey (NUIM)

Following our earlier, statistical result that the X-ray hardness ratios of stars (which provide a measure for the spectral characteristics of X-ray sources) vary chiefly as a result of interstellar absorption, we have embarked on a star-by-star evaluation of X-ray versus optical data. This is to demonstrate the inferred effect of line-of-sight absorption in much greater detail. To support the interpretation of the observational data, we have extended earlier work on the dependence of the X-ray hardness ratios on emission and absorption processes, featuring greater parameter ranges than investigated previously. A web-based tool that will allow to determine emission and absorption characteristics for X-ray sources from their hardness ratios is in preparation.

3.11.2 Young stellar clusters

E.J.A. Meurs, P. Kavanagh (DCU), L. Norci (DCU)

The high-energy emission from very young stellar clusters may be modelled without encountering difficulties due to the intricacies introduced by close-binary evolution. We have started a project to analyse X-ray data for several very young stellar clusters and to compare the results with model calculations for these clusters. For a start, we are analysing two such clusters, NGC346 in the Small Magellanic Cloud and the Galactic Super Star Cluster Westerlund 1. To support these investigations, we are preparing a master list of Super Star Clusters that will be made available on the World Wide Web.

3.12 General Theory

3.12.1 Particle Acceleration by Multiple Parallel Shocks

P. Dempsey, J. Tammi (UCD) and P. Duffy (UCD)

Using both numerical and semi-analytical techniques we are examining particle acceleration in multiple parallel relativistic shocks. The non-relativistic results have been known for some time and by extending these results to the relativistic limit we hope to apply them to the internal shock models of gamma-ray bursts.

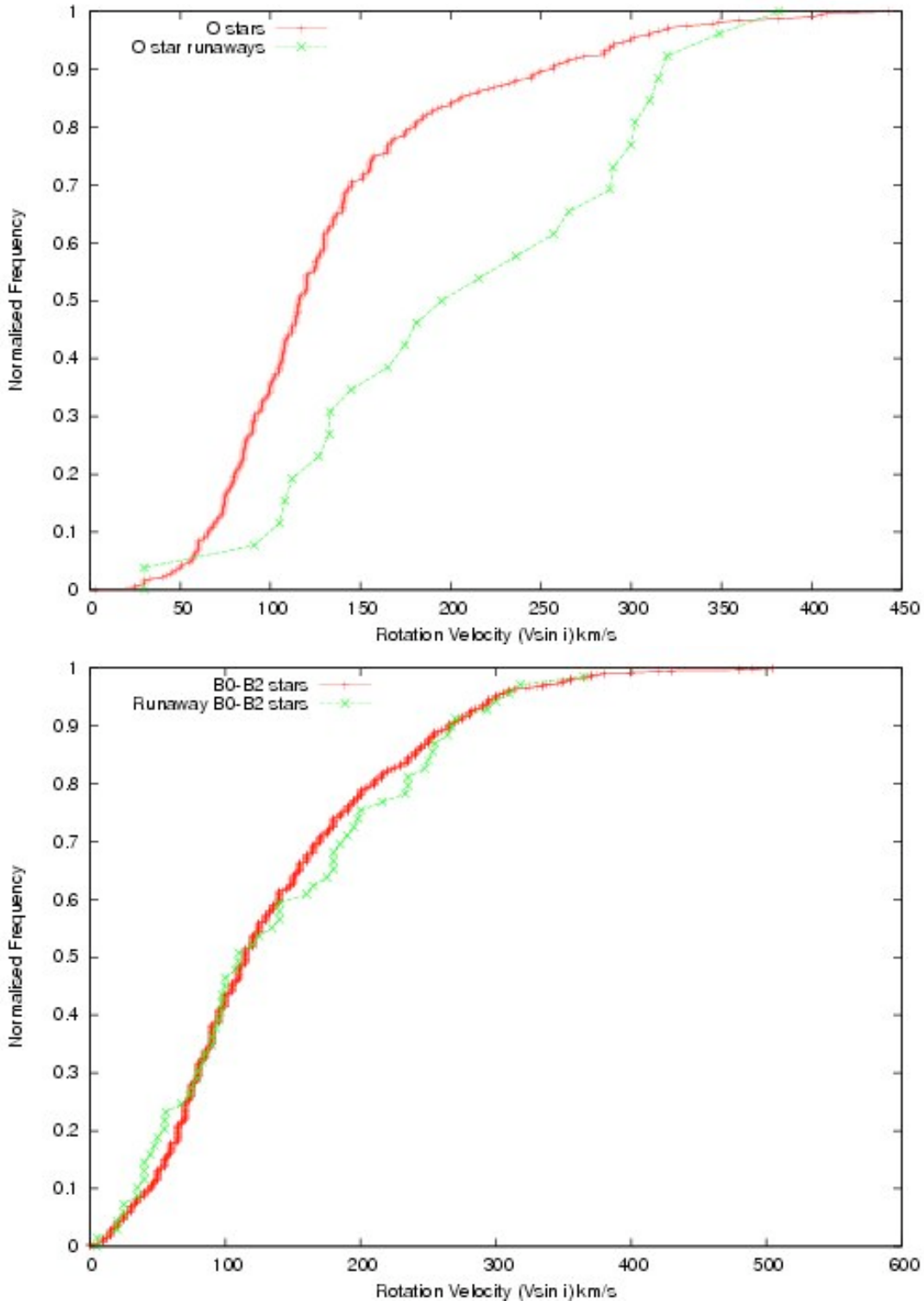

Figure 8: Cumulative distribution functions of rotation velocity, for normal (red) and runaway (green) O stars (top) and B0-B2 stars (bottom).

3.12.2 Approximate Analytic Solutions to Relativistic Shock Acceleration

P. Dempsey, J. Kirk (MPIK Heidelberg)

Keshet & Waxman (2005) produced a simple formula for the power law index of particles accelerated at shocks of arbitrary velocity. While their formula fits previous values very well, their derivation contains several errors and their method fails to produce a pitch angle distribution that is consistent with previous numerical and semi-analytical work. By making certain analytical approximations we have produced power law indices that are close to those previously calculated, while simultaneously obtaining pitch angle distribution which agree with those found in early semi-analytic work.

3.12.3 PIC simulations of relativistic shock formation

M. Dieckmann and L. Drury

The plasma processes responsible for shock formation in the case of relativistic flow speeds are complex and can only really be studied using particle in cell simulations. Studies to date have mainly used a reflection geometry in which an incoming plasma flow is "reflected" off a solid wall at one end of the simulation box. While this is a very convenient way to set up a shock simulation it is equivalent to the collision of two plasma streams of equal density. The physically more relevant case of unequal densities has been little studied. Previous work has also focussed mainly on the case of weak initial magnetic fields. In this work we consider shocks forming from the interaction of magnetised clouds of unequal density. The magnetic field is shown to strongly suppress the filamentation instabilities seen in the weak-field case and allows the use of 1-D simulations to complement and study in more detail aspects of the 2-D simulations. Strong electromagnetic structures are seen, involving both electric and magnetic fields, and are associated with fast electron energisation.

3.12.4 Radiative Processes in the Interstellar Medium

J.Mackey, and A.Lim

As part of J. Mackey's Ph.D. programme we have been developing a modular Magneto-Hydrodynamics (MHD) code with optional radiative transfer, with a view to studying various radiative effects in the interstellar medium. The JETSET School on "Numerical MHD and Instabilities" in January 2007 was a very useful introduction to the methods we have used. A parallel MHD code on a uniform grid has been developed and tested on the ICHEC computing cluster 'Walton.' The radiative transfer module is currently in development/testing, and we anticipate using our code during 2008 to study a number of astrophysical situations, including photo-evaporation of gas clouds in planetary nebulae, radiation from young stars, and radiative precursors of jets.

3.13 Space Dosimetry

D O'Sullivan with Johnson Space Center, Houston

The first phase of the Matroshka-1 project was completed during the year and results were prepared for submission to Nature. The Matroshka experiment measured for the first time the doses experienced by astronauts from the various components of ionising radiation in space on the surface and internal organs of a human like phantom located outside the International Space Station. This allowed the simulation of extra vehicular activity by an astronaut. The results show a steep gradient from the uppermost layer of the skin to the deep organs with a ratio of about 20 to 1.The skin dose at about 1mGy/d is the greatest followed by the dose rate at the eye. With the exception of the breast and salivary glands, the dose rates for other organs such as the kidneys, pancreas, esophagus, lungs, brain, heart etc, are in the range from 0.2 to 0.3 mGy/d. In total, values were determined for 24 organs. Although several international track detector groups participated in the project, only the DIAS/JSC data has been selected for the first major publication due to difficulties with the interpretation of all other track results.

The DOBIES experiment continued during 2007 and analysis of the detectors flown on the Soyuz Mission 13S in Sept 2006 was completed. The objective of the experiment was to investigate how bacteria cope with space flight conditions such as reduced gravity, space radiation and other environmental extremes. The detectors were located in the Zvezda service module in association with several bacterial cultures. The preliminary results which were reported at an international meeting in Delft in July, showed how reference dose values can be provided for comparing biological samples located at different positions on the ISS or flown on different missions. The values of dose equivalent measured were about 580 micro Sievert per day, some 40% higher than that obtained on a previous flight. The increase is consistent with the solar cycle variation. Further work awaits the launch of the European Columbus Laboratory. A launch due to take place in December was postponed and is now scheduled for February 2008.This mission will also carry an further extension of the Matroshka work.

4 International Collaborations

4.1 HESS, HESS-II and CTA

The HESS (High Energy Stereo System) collaboration of which DIAS is a member continued to produce a stream of new discoveries and has established ground-based TeV astronomy as a genuine new astronomical window allowing us for the first time to see the extreme non-thermal universe. This success was recognised by the award of the Descartes prize for European Collaborative research to the collaboration at a ceremony in Brussels on March 7th (see Fig. 9)

The HESS-II project aims to extend the HESS system with an additional large telescope located at the centre of the existing four telescope system. Preliminary engineering work was completed during the year.

A joint initiative by the HESS and MAGIC collaborations, as well as other interested individuals and institutes, was launched in 2006 to plan for a large Cherenkov Telescope Array

Figure 9: The Award Certificate for the Descartes Prize 2006 announced on 7 March 2007 in Brussels

(CTA) project which would be the natural successor to the HESS, MAGIC and VERITAS collaborations. Unlike the existing projects this would be run as a public observatory and not an experimental collaboration. Luke Drury, in collaboration with Alessandro de Angelis, was convener of the "Physics Working Group for CTA" until March 2007 and coordinated the first draft of the "physics case for CTA" document. An application, coordinated by Heidelberg and with DIAS as a partner, was submitted to the EU for an FP7 design study in May.

4.2 JETSET

T.P. Ray, JETSET Network Coordinator

In 2007 the Jet Simulations, Experiment and Theory (JETSET) network had two schools and associated science meetings:

1. *Numerical MHD and Instabilities*, including a special session dedicated to visualization techniques and virtual reality in Sauze D.Oulx near Turin in January
2. *From Models to Observations and Experiments* in Ponta Delgada, San Miguel Island, in the Azores in June

In both cases approximately 60-80 people attended

During 2007, the JETSET network had its mid-term review in the Azores coinciding with the fifth school. The review, by the European Commission, was conducted over one day. It in-

Figure 10: The JETSET School in Sauze d'Oulx near Turin in January 2007

volved presentations by the network scientists, early stage researchers (ESRs) and experienced researchers (ERs) directly employed under the contract. The Commission representative also held private sessions with the ERs and ESRs so they could express their views confidentially on the network. In July the Commission reported that "the network is working in an excellent manner and provides a stimulating environment for young researchers in a challenging and topical area of astronomy (as was clear from the lively discussions).". The network thus passed its mid-term review with flying colours.

Judging by the extensive mid-term report (submitted in April to the EC), the network has produced a very large number of joint publications and observing campaigns using facilities such as the ESO's VLT, Magellan, IRAM, the Plateau de Bure Interferometer, etc. In addition applications have also been submitted to utilise current or future space missions including Spitzer and Herschel (due for launch in 2008).

The next school (the sixth) and JETSET science meeting will be on *High Performance Computing in Astrophysics* in NUI, Galway. It is jointly being organised by DIAS and NUI Galway's Department of Physics.

All ESR and ER positions are currently filled and it should be noted that there was only one change in personnel (at the University of Athens node) since the inception of the network. The latter vacancy was quickly filled. Finally it is also worth noting that all ESRs are currently on course to complete their PhDs within the lifetime of the network (scheduled to finish in January 2009).

4.3 KM3NeT

F. Aharonian and L. Drury

DIAS, mainly in the person of Professor Felix Aharonian, was invited to participate in the FP6 design study for a deep underwater neutrino telescope to be located in the Mediterranean sea, KM3NeT, coordinated by Professor Uli Katz of the University of Erlangen. The accession of DIAS to the collaboration was formally announced at the general assembly of the KM3NeT consortium held in the Nestor Institute, Pylos, Greece, from 16th to 18th April.

4.4 MIRI

T. Ray

The Mid-Infrared Instrument (MIRI) on board the james Webb Space Telescope (JWST) consists of an imager (including a four-quadrant coronagraph phase mask), a low-resolution spectrometer (with $R \approx 100$ for wavelengths $5\,\mu\mathrm{m} \leq \lambda \leq 10\,\mu\mathrm{m}$) and an intermediate resolution integral field spectrograph ($R \approx 3000$ for $5\,\mu\mathrm{m} \leq \lambda \leq 28\,\mu\mathrm{m}$) cryogenically cooled to 7K using a NASA supplied cooling system. The European Consortium is supplying the MIRI optics while the focal plane detectors are the responsibility of the US (primarily the Jet Propulsion Laboratory in Pasadena).

The Dublin Institute for Advanced Studies (DIAS) is part of the MIRI European Consortium. DIAS, as its contribution to the hardware, supplied the long wavelength filters for the imager and beam-splitters for the intermediate resolution spectrograph. As the filters and beam-splitters were manufactured in batch mode, DIAS has effectively delivered not only the hardware required for the demonstration and verification models (DM and VM respectively) but also the flight model (FM). Delivery Review Boards (DRBs) are currently in progress for these items and final sign off is expected in January 2008.

Transmission of these multi-layer filters (see Fig. 11) has proven to be excellent (typically 60-80%) and in most cases10% better than spec. Obviously this will significantly reduce exposure times for a given signal to noise and save expensive telescope resources.

MIRI is a complex instrument as it utilises not only imaging modes but also integral field unit spectroscopy. While the overall plan for data processing is now more or less clear, the process whereby the necessary software is developed is only now being put in place. In any event, the MIRI Consortium has taken the decision that this will be done by a distributed team of software engineers. Obviously this will require a clear and organised structure to ensure success.

In particular it is envisaged that:

- A common development plan is agreed upon and maintained
- Issues that impact on other sub-teams are directly communicated to the whole team
- A basic common development environment will be in place for flight model (FM) testing similar to the mission environment
- There will be open access to software resources for all parties involved

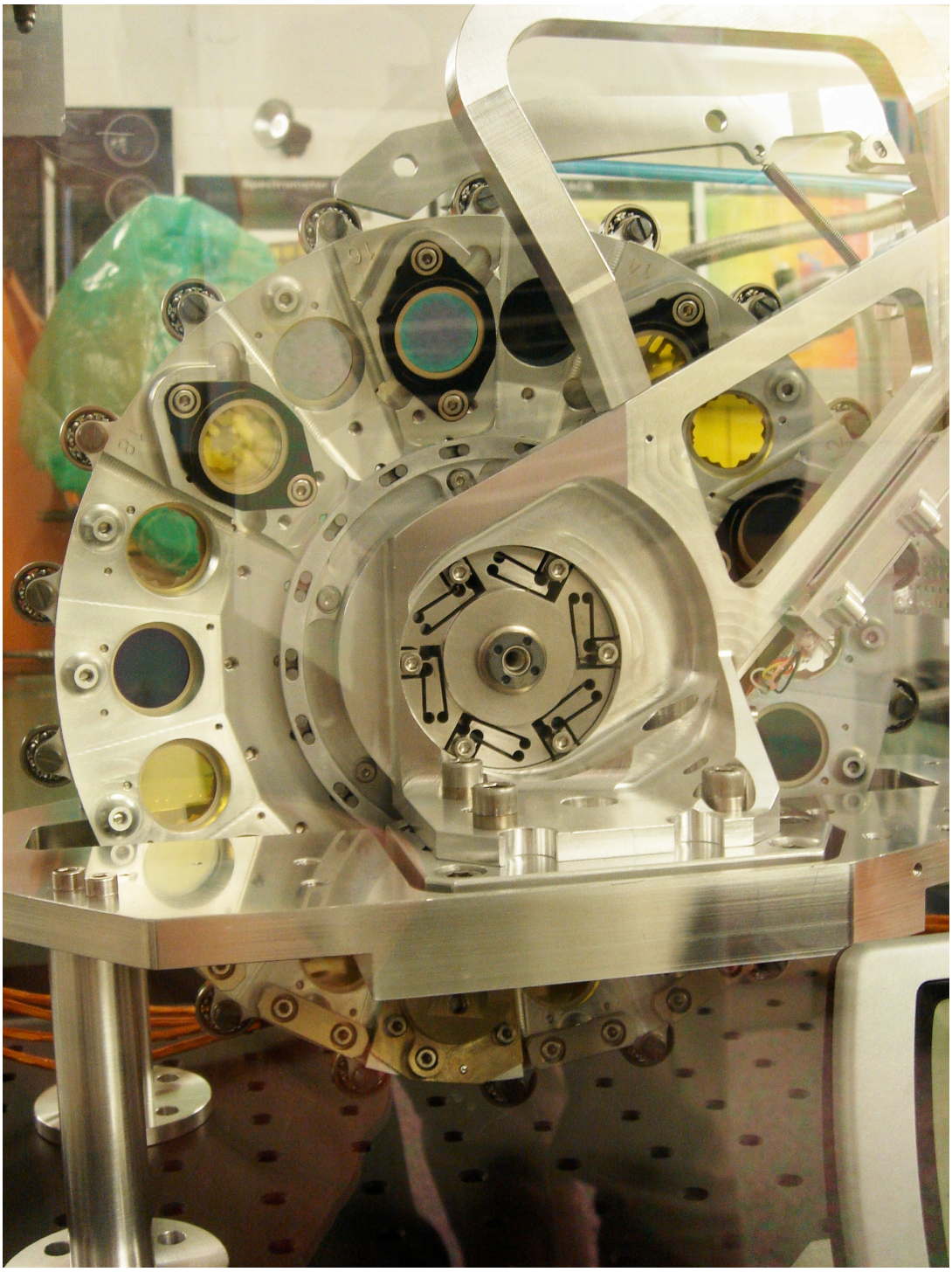

Figure 11: Mid-infrared filters, supplied by the Dublin Institute for Advanced Studies, that were used to populate the MIRI verification model (VM) filter wheel in the CEA, Saclay

- A Configuration Control system is in place for all phases of development

At this stage, the Consortium intend to agree on a common development environment, with the Space Telescope Science Institute (STScI), at the first MIRI Software Summit which is scheduled for early next year.

The MIRI Software Team will be located (alphabetically) in the University of Arizona, Commissariat l'nergie Atomique (CEA), DIAS, ATC (Edinburgh), University of Leiden, University of Leuven, Max Planck Institute for Astronomy in Heidelberg (MPIA), Rutherford Appleton Laboratory, Stichting Astronomisch Onderzoek Nederland (SRON) and STScI (Baltimore).

Negotiations are ongoing with Enterprise Ireland for an extension of our PRODEX funding to cover the period 2008-2013 and, in particular, to fund two software engineers based at DIAS who will play a fundamental role in developing MIRI software, in particular to support its spectroscopy modes.

4.5 NAHUAL

C. del Burgo

CdB is a co-PI of NAHUAL, a near-infrared ($0.9 - 2.5\,\mu\mathrm{m}$) high-resolution spectrograph (R=65000) for the $10.4\,\mathrm{m}$ GRANTECAN telescope on the Observatorio Roque de Los Muchachos (La Palma, Spain). NAHUAL is developed in the framework of an international collaboration led by the Instituto de Astrofsica de Canarias (IAC, Spain) with the participation of research centres in Germany, Italy, Portugal and Ireland. CdB leads the Irish team, which is working on the general optics and the grating mechanism, the acquisition camera and the polarimetric mode. NAHUAL will be mainly aimed at searching for extrasolar planets of a few times the Earth mass. I am currently working on the comparison of models with high-resolution spectroscopy of brown dwarfs obtained with NIRSPEC (Hawaii, USA). We have obtained a grant for personal and performance expenses for the development of NAHUAL. Also we have recently got a grant for the project RoPACS. The main goal of RoPACS is the study of extra-solar planets around cool stars.

4.6 REM

E. Meurs

The Rapid Eye Mount (REM) Telescope is a robotic telescope with the principal aim to provide quick follow-up observations of Gamma Ray Bursts detected by satellite γ-ray observatories. The telescope has a 60 cm diameter mirror, is located at La Silla (Chile), and carries Near-InfraRed as well as optical cameras. The REM project is led by Brera Observatory in Milan-Merate (Italy), with Irish participation by DIAS and UCD.

When not just observing Gamma Ray Bursts, the REM Telescope carries out a variety of monitoring observations. In this way, several blazers are being followed in time (blazers are a class

of highly variable, luminous active nuclei of galaxies). The blazers studied here are notorious for being also known high-energy emitters. Results were obtained notably for blazers that exhibited high amplitude maxima or flares during our observations (see Fig. 12)

Other types of object that we have been monitoring with the REM Telescope include Luminous Blue Variables in the Magellanic Clouds and a special sub-class of Be stars that is characterized by warm dust.

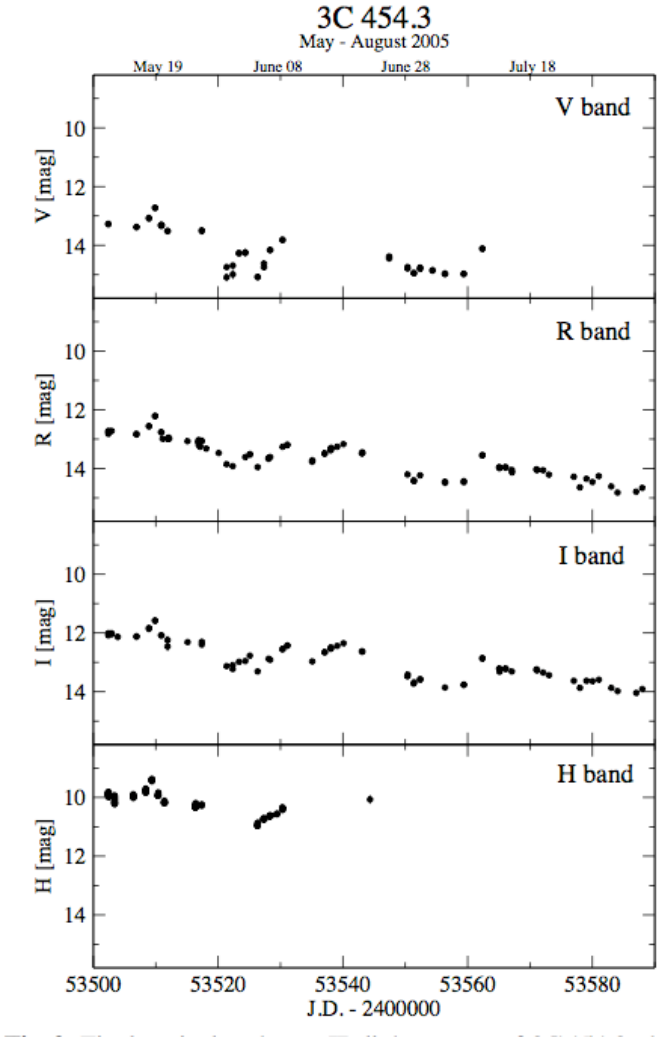

Figure 12: The brightness variation of the blazar 3C454.3 in 2005. On 19 May 2005 this object reached a historical maximum, more than a magnitude brighter than had been observed previously. The brightness subsequently decayed the next couple of months.

4.7 ROTSE

F. Aharonian

The Robotic Optical Transient Search Experiment (ROTSE) is dedicated to observation and detection of optical transients with an emphasis on prompt afterglows of gamma-ray bursts

(GRBs). The ROTSE-III program involves establishing fully automated, robotic telescopes in sites around the world to facilitate uniform, rapid follow-up of celestial transient events. The wide field of view and the fast response of the HESS telescopes provides measurements which cannot be performed by conventional telescopes. The ROTSE telescopes are installed at four locations including the site close to Mt. Gamsberg, Namibia, and in collaboration with the HESS project.

4.8 Echelle spectroscopy of bright GRBs

E. Meurs

In a collaboration led by Rome Observatory (Italy), high-resolution echelle spectroscopy is obtained as a means to study the immediate surroundings of Gamma Ray Bursts.

5 Contributions to the national e-Infrastructure

5.1 e-INIS

Building on the success of the Programme for Research in Third Level Institutions (PRTLI) cycle 3 project CosmoGrid (which played a major role in establishing the Irish Centre for High-End Computing, ICHEC) the school through the Institute submitted a two-component proposal to the Higher Education Authority under PRTLI-4. The first part, e-INIS, was a collaborative programme to develop an integrated national e-Infrastructure and the second, e-PSI, was an institutionally-led e-science programme building on the infrastructure. Unfortunately, while e-INIS was highly praised by the reviewers and funded, the e-PSI programme was regarded as less coherent and failed to get funding.

5.2 Blue Gene

For a number of years there has been an intensive debate about the need for Ireland to make a strategic investment in enabling true capability (as distinct from capacity) computing. In this context, and in discussions with the Higher Education Authority and other interested parties, the Institute offered to make resources from the CosmoGrid project available for this purpose. The seven universities and other major research institutions all strongly supported this and an understanding was reached that if we acquired a high-performance system to be run as a national service, they would subscribe to this at a level which would cover the recurrent running costs, estimated at 57K per institution per year. The HEA agreed to the reallocation of funding on condition that the system would be hosted in the HEAnet national hosting centre and operated by the Irish Centre for High-End Computing (ICHEC). On this basis an EU public procurement exercise was carried out by HEAnet on behalf of DIAS, ICHEC and the academic community for “Purchase of a Supercomputer”. This process ultimately resulted in the selection of IBM and its BlueGene architecture as the recommended vendor and a Blue Gene system consisting of one rack of L and one rack of P was ordered and installed by the end of the year.

As part of the deal IBM will also provide 4 person-years of scientific support to Irish research groups and guaranteed access to the large deep-computing facilities of IBM.

The original objective was to make a strategic investment opening up the possibility of true high-capability computing to Irish researchers. This has been achieved. Groups can experiment and test codes on the L, do production runs on the P, and then if necessary obtain access to some of the most powerful machines on the planet. Looking to the future the Blue Gene acquisition gives us a number of very valuable things:

- it demonstrates in a very concrete way that the academic sector can come together under the leadership of the Institute and contribute to the implementation of national strategic objectives;
- it gives the Institute a strong link to a major industrial partner in IBM;
- most importantly, it enables us to push the boundaries of computational science as applied to Cosmic Physics.

Figure 13: The IBM Blue Gene/P in the National Hosting Centre

6 Publications

6.1 Refereed publications

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2. Dieckmann, M. E., Lerche, I., Shukla, P. K., & Drury, L. O. C.: Aspects of self-similar current distributions resulting from the plasma filamentation instability *New Journal of Physics* (2007) **9** 10

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5. Kappes, Alexander, Hinton, Jim, Stegmann, Christian, & Aharonian, Felix A.: Potential Neutrino Signals from Galactic γ-Ray Sources *Astrophysical Journal* (2007) **656** 870-878.

6. The HESS collaboration: First ground-based measurement of atmospheric Cherenkov light from cosmic rays *Physical Review D* (2007) **75** 042004

7. The HESS collaboration: Primary particle acceleration above 100 TeV in the shell-type supernova remnant RX J1713.7-3946 with deep HESS observations *Astronomy and Astrophysics* (2007) **464** 235-243.

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6.3 Preprints

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2. Blasi, Pasquale, Gabici, Stefano, & Brunetti, Gianfranco: Gamma rays from clusters of galaxies *arXiv:astro-ph/0701545*
3. Piranomonte, S., D'Elia, V., Ward, P., Fiore, F., & Meurs, E. J. A.: UVES/VLT High Resolution Spectroscopy of Gamma Ray Burst Afterglows *arXiv:astro-ph/0701563*
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7. Aharonian, Felix: Galactic Sources of High Energy Neutrinos *arXiv:astro-ph/0702680*
8. Amato, Elena, Blasi, Pasquale, & Gabici, Stefano: Kinetic approaches to particle acceleration at cosmic ray modified shocks *arXiv:0705.3723*
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10. Malesani, Daniele, Molinari, Emilio, Vergani, Susanna, Covino, Stefano, & for the REM team: The GRB afterglow onset observed by REM: fireball Lorentz factor and afterglow fluence *arXiv:0706.1772*
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25. Neronov, A. & Aharonian, Felix A.: Production of TeV Gamma Radiation in the Vicinity of the Supermassive Black Hole in the Giant Radio Galaxy M87 *arXiv:0704.3282*
26. Tammi, Joni & Dempsey, Paul: Particle acceleration by multiple parallel shocks *arXiv:0712.1749*
27. Gracia, J., Bogovalov, S., & Tsinganos, K.: MHD models and synthetic synchrotron maps for the jet of M87 *arXiv:0712.2734*
28. Rieger, F. M. & Aharonian, F. A.: Variable VHE gamma-ray emission from non-blazar AGNs *arXiv:0712.2902*
29. Neronov, A. & Chernyakova, M.: A Rotating Hollow Cone Anisotropy of TeV Emission from Binary Systems *arXiv:0711.3085*

7 Invited talks

- Luke Drury
    1. First International GLAST symposium, Stanford USA, 5–8 Feb, "TeV gamma-ray sources and GLAST"
    2. 3rd Belief Brainstorming Workshop, Dublin, 17–18 May, "The e-INIS vision"
    3. TeVPA'07, Venice, Italy, 27–31 Aug, "The Next Generation of ground-based gamma-ray telescopes"
    4. HEAnet annual conference, Kilkenny, 15–16 Nov, "e-INIS building the Irish National e-Infrastructure"
- Evert Meurs
- Felix Aharonian
    1. Astrophysical Implications of Very High Energy Gamma-Ray Observations with HESS, Max-Planck Institut fuer Radioastronomy, Bonn, Germany, January 26, 2007 (Astronomy Colloquium)

2. Very high energy gamma ray sources, University of Leiden, Leiden, Holland, February 15, 2007 (Astronomy Colloquium)
3. Recent results from HESS, MIT, Cambridge, USA, March 13, 2007 (Astrophysics Colloquium)
4. Supernova Remnants and Pulsar Driven Nebulae, Harvard University, Cambridge, USA, March 15, 2007 (Harvard-Smithsonian Astrophysics Center Colloquium)
5. Ground Based Gamma Ray Astronomy: Status and Perspectives, CALTECH, Pasadena, March 21, 2007 (Astronomy Colloquium).
6. Next generation ground-based gamma-ray detectors: scientific motivations, potential and perspectives, Stanford University, USA, May 10, 2007 (ACKS Seminar)
7. Exploring the TeV sky with HESS, Roma Astronomical Observatory, National Institute for Astrophysics, Italy, June 19, 2007
8. Origin of cosmic rays, invited (plenary) talk at the Conference on "Ultra-high energy cosmic rays, neutrinos and photons", Pennsylvania State University, May 2007
9. On the potential and objectives of ground based gamma-ray astronomy, invited talk, at the Workshop on "The light of the dark: solving the mysteries of the Universe" Villa Mondragone, Frascati, June 2007
10. The Very High Energy Gamma Ray Sky, invited (plenary) talk at the "JENAM07" (Joint European and National Astronomy Meeting), Yerevan, Aug 2007
11. Future of High Energy Gamma ray Astronomy, invited (plenary) talk at the "10th ICATPP Conference on Astroparticle, Particle, Space Physics, Detectors", Como, October 2007
12. The TeV Universe, invited talk at the Symposium on "High Energy in Space", Palermo, October 2007

- Tom Ray
  1. JETSET School and Workshop: Numerical MHD and Instabilities Visualization Techniques and Virtual Reality, Sauze d'Oulx, Turin, Italy, January 8-13, 2007
  2. Lindsay Symposium, Armagh Observatory, January 26
  3. University of Wales, Cardiff, March 21
  4. IAU Symposium 243: Star-Disk Interaction in Young Stars, Grenoble, 21-25 May
  5. Hellenic Astronomical Conference, Thassos, Greece, 13-15 September
- Carlos del Burgo
  1. The infrared signature of dust in the interstellar medium of galaxies, Departamento de Astrofsica Molecular e Infrarroja (DAMIR), Instituto de Estructura de la Materia (CSIC), Madrid, Spain, December

8 External Funding

- Luke Drury
  1. PRTLI-3 CosmoGrid, until end of year
  2. PRTLI-4 e-INIS, from September
  3. IRCSET, one postdoc
- Felix Aharonian
  1. EU FP6 Design Study KM3NeT
  2. SFI RFP, two postgrads
  3. EU Marie Curie fellowship
- Tom Ray
  1. EU Research Training Network JETSET
  2. PRODEX MIRI
  3. SFI RFP, one postdoc and one postgrad
  4. IRCSET, one postdoc
- Carlos del Burgo
  1. co-I on proposal of PI Eduardo Martin, project: AYA2007-67458, "Detection of exoplanets using high spectral resolution spectrographs in big telescopes" funded with 0.5MEuro over three years.

9 Community Service

- Luke Drury:
  1. invited by NUI,G to be a member of the ICHEC oversight board;
  2. invited to serve as chairman of the interview panel for the NUI travelling studentships;
  3. member of the H.E.S.S. Collaboration Board;
  4. member of the KM3NeT consortium.
- Felix Aharonian
  1. Co-PI of the ROTSE project;
  2. Member of the H.E.S.S. Collaboration Board
  3. Member of the Consortium of the KM3NeT

4. Member of ARGOS X - a member of the proposal team “Argos-X: A Panoptic X-ray Observatory (a project submitted to NASA)
5. Member of the working group “Science with NeXT” (Japanese next generation X-ray mission)
6. chair of the PhD theses defense Committee on Astrophysics (University of Barcelona)
7. member of the PhD theses defense Committee on Physics (Oxford University)
8. Lectures in University College Dublin “Introduction to High Energy Gamma Ray Astrophysics” (a course of 6 lectures for final-year students)
9. Member (”Principal Scientist/Professor”) of the Heidelberg Graduate School of Fundamental Physics at the University of Heidelberg
10. External scientific member of the MPIK in the High Energy Astrophysics Group
11. Co-director of LEA - European Associated Laboratory on High Energy Astrophysics (jointly supported by CNRS and MPG)
12. member of the European Astronet Infrastructure Roadmap Panel A: “High energy, astro-particle astrophysics and gravitational waves”
13. member of the group of referees for the ESA’s Cosmic Vision 2015-2025 proposals
14. peer reviewer of proposals within the frameworks of the ESF (European Science Foundation, NWO (the Dutch research council), DPG (Deutsche Physikalische Gesellschaft), ANR (Agence Nationale de la Recherche), ICREA (Catalan Foundation for Research and Innovation), Swiss National Science Foundation (”Mathematics, Natural and Engineering Sciences), NSERC (Natural Sciences and Engineering Research Council of Canada).
15. an Editor of the International Journal of Modern Physics D

- Evert Meurs:
  1. member of the RIA Astronomy and Space Science Committee;
  2. member of the Joint Management Committee, Armagh Observatory and Planetarium.
  3. edited a National Plan for Astronomy in Ireland to support the case for membership of the European Southern Observatory
- Tom Ray
  1. Co-PI of the MIRI project;
  2. Chairman of the e-MERLIN Steering Committee (Steering committee for national radio astronomy facilities in the UK);
  3. External Expert EU Framework 7 Programme;
  4. Member of the Herschel Observatory Time Allocation Committee;

5. PhD Thesis Defense Committee, University of Hertfordshire;

6. Member of the Physical and Chemical Sciences Committee, Royal Irish Academy

10 Public Outreach

The normal programme of Open Nights recommenced in October and was supplemented by a number of special events. In addition the Irish Astronomical Society were faciilitated by being allowed use Dunsink for their meetings while their normal meetings rooms were being refurbished. Tom Ray took over (on a temporary six-month) basis as Public Outreach Coordinator for the School.

Date	Event	Time	Principal Speaker
17 Sep	IAS Group Meeting	19:00	Terry Moseley
3 Oct	Open Night	20:00	Deirdre Kelleghan
15 Oct	IAS Group Meeting	19:00	Michael O'Connell
16 Oct	Hamilton Walk	13:00	NUIM
17 Oct	Open Night	20:00	Dr Mohsen Shadmehri (DCU)
23 Oct	CBS Swords	19:00	Astronomy in Schools
7 Nov	International Ladies Association	19:30	Prof Tom Ray
Science week 2007			
12 Nov	Bray schools and teachers	19:00	Dr Carlos del Burgo
13 Nov	West Dublin schools	19:00	Dr Peter Duffy
14 Nov	South Dublin schools	19:00	Dr Rachel Curran
15 Nov	St Ciaran's Kells	10:00	Dr Mohsen Shadmehri
	Our Lady's Templeogue	19:00	Dr Emma Whelan
19 Nov	IAS Group meeting	19:00	Deirdre Kelleghan
21 Nov	Open Night	20:00	Dr David Malone
28 Nov	TCD Physics Society	19:00	Dr Rachel Curran
3 Dec	IAS Group meeting	19:00	Derek Heatly
4 Dec	ISTA Branch meeting	19:00	Multiple speakers
5 Dec	Open night	20:00	Dr Brian Espey
19 Dec	Open night	20:00	Dr Dirk Froebrich

The following assisted regularly in running the above events: Clare Raftery, Nicola Meenan, Orna Nicholl (TCD students); Tomas Griffin, Denys Malishev, Paul Dawson, Luke Drury, Ann Grace, Eileen Flood, Hilary O'Donnell, Mike Smyth (DIAS); Deirdre Kelleghan, Robin Moore, Val Dunne (IAS).

Architecture students from UCD (Mark Costello) and DIT Bolton street (Bronagu Page,Brendan FitzPatrick, Flow O Droma, Dan Shanahan) visited Dunsink as part of student projects in conservation studies.

Three talks on astronomy for CETNS primary school (Castleknock Educate Together National School), for fourth, fifth and sixth classes were given by Prof E. Meurs.

10.1 Statutory Public Lecture

The JWST project scientist, Professor John Mather, Nobel Physics Laureate of 2006, gave the School's Statutory Public Lecture, on 14th June in the Clinton auditorium, UCD, to a full house. There was a lively discussion with the public after the talk.

11 Conferences Organised

11.1 High Energy Phenomena in Relativistic Outflows

Figure 14: Participants of the HEPRO workshop before the conference dinner in the TCD dining hall

This workshop, which ran for the week from Monday 24 to Friday 28 September 2007, was devoted to the comprehensive discussion of recent theoretical and phenomenological developments concerning the interpretation of high energy phenomena related, in one way or another, to objects containing relativistic winds and jets. The meeting attracted an excellent list of speakers and participants including such world-class scientists as Peter Meszaros, Andy Fabian, Jonathan Arons and Ari Koenigl. In total 116 participants registered for the five day event (see Fig. 14). Originally it had been intended to hold the meeting in Burlington Road, but due to pressure of numbers it was moved to the Joly lecture theatre in TCD which proved an excellent venue. Local logistics, including a trip on the Wednesday afternoon to the Boyne valley, were handled in house and the conference ran within budget. The Proceedings will be published in a special issue of the International Journal of Modern Physics D.

Local organising committee: Felix Aharonian, Luke Drury, Tom Ray, Peter Duffy, Hilary O'Donnell. Scientific Organising Committee:Felix Aharonian, Katherine Blundell, Paolo

Coppi, Luke Drury, Peter Duffy, Peter Meszaros, Josep M. Paredes, Tom Ray, Gustavo E. Romero, Guy Pelletier, Marek Sikora, Marco Tavani. The presentations are available online at:

`http://www.dias.ie/~pdempsey/HEPROpdfs/index.html`.

11.2 JWST meeting

From June 11th to the 13th some 300 NASA, ESA and Canadian Space Agency (CSA) personnel, along with prime contractors, and instrument scientists, met in the Royal Hospital Kilmainham to review progress with the James Webb Space Telescope (JWST) scheduled for launch in 2013. The meeting was held at the invitation of the Dublin Institute for Advanced Studies who are involved in building the Mid-Infrared Instrument (MIRI), one of the four main instruments on board JWST .

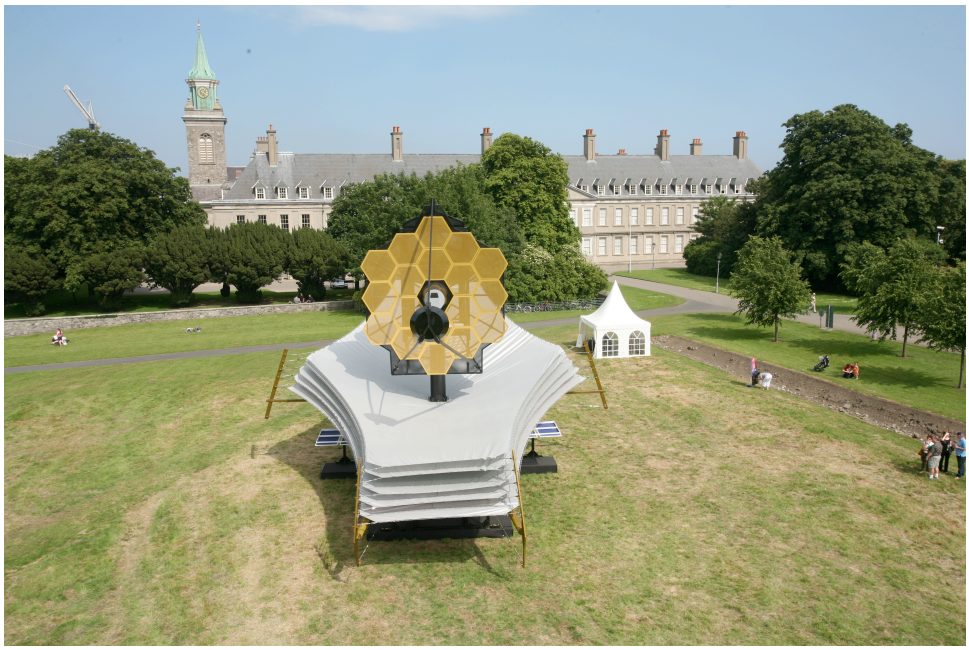

Figure 15: Full-scale model of the James Webb Space Telescope at the Royal Hospital Kilmainham where NASA, ESA and the CSA reviewed the project.

The project is progressing well and is currently not only on schedule but within budget. JWST when launched will replace the very successful Hubble Space Telescope but unlike Hubble it will be placed beyond the Moon (at the second Lagrange point) to keep its instruments passively cooled to 47K. MIRI itself, because of its operating wavelengths, will be cryogenically cooled to 7K using liquid helium.

To launch the meeting, and to attract public interest, a full-scale model of the JWST was brought to Dublin (see Fig. 15) for six weeks. The model was built by Northrop Grumman (the projects main contractors) but it was erected and disassembled by a team of FÁS trainees under supervision. The model attracted a lot of interest from the public not only after featuring on the front

page of the Irish Times but also in TV and radio programmes such as the RTE News, Pat Kenny and Drive Time.

The JWST project scientist, John Mather, Nobel Physics Laureate of 2006, gave a joint Royal Irish Academy/DIAS public lecture on 12th June in the Edmund Burke Theatre (TCD) and the School's Statutory Public Lecture on 14th June in UCD. On both occasions, John lectured to full houses.

Sponsorship (approximately 100K Euro) was very kindly provided for the event from a number of bodies including Enterprise Ireland, FÁS, Omega Air, An Post and Discover Science and Engineering. FÁS also provided manpower, as previously mentioned, to erect and disassemble the model. Finally ESA sent a 10:1 scale model of the launch vehicle (the Ariane V rocket), which was placed in the Baroque Chapel of the Royal Hospital Kilmainham (see Fig. 16).

Figure 16: Children enjoying a day out in the RHK at the Ariane V Rocket Model in the Baroque Chapel