High Time Resolution Astrophysics IV - The Era of Extremely Large Telescopes

Book of Abstracts

May 5-7, 2010
Agios Nikolaos, Crete

Programme

Wednesday 7th May 2010: Day 1 - Current Status

Session 1: Object Reviews (I) - Isolated Neutron Stars and X-ray Binaries

09:00-09:30 **Isolated Neutron Stars (Invited Review)**
Joachim Trümper (Max Planck Institut für Extraterrestriche Physik)

We first critically discuss the classical method of determining dipolar magnetic field strengths and ages of neutron stars from the periods and period derivatives of pulsars. Recent observations of isolated neutron stars suggest that this method systematically underestimates the magnetic field strengths by a factor >2 and overestimates the age of middle age neutron stars by a large factor (>10). In the second part of the talk we will discuss the question of whether the AXPs and SGRs have magnetar type dipole fields or represent isolated neutron stars accreting matter from a fallback disk.

09:30-10:00 **Magnetars and their Extreme Variability (Invited Review)**
Luigi Stella (INAF, Osservatorio Astronomico di Roma)

Over the last decade considerable evidence has been found for the existence of magnetars, neutron stars whose electromagnetic emission is powered by the decay of their extremely high magnetic field. Two classes of high-energy sources have been identified with slowly spinning magnetars. Magnetars can emit subsecond duration bursts of gamma radiation during which they are more luminous than the entire Galaxy. The study of the exceptionally fast variability and enormous energy liberated in these events has opened new fields of research, which straddle fundamental physics. Especially promising are the prospectives for: (a) neutron star astroseismology and its potential as a diagnostic of ultradense matter and the structure of neutron stars; (b) extreme luminosity derivatives from non-expanding cosmic sources; (c) gravitational wave signals from newborn magnetars. In this talk I will also survey the prospects for multiwavelength observations of magnetars.

10:00-10:20 **High time resolution observations of millisecond pulsars with the Fermi Large Area Telescope**

Lucas Guillemot (Max-Planck-Institute)

A year and a half after Fermi was launched, the number of known gamma-ray pulsars has increased dramatically: pulsed gamma-ray emission has been detected from at least 56 pulsars by the Large Area Telescope (LAT), the main instrument aboard the Fermi satellite. Among these detections, a population of gamma-ray millisecond pulsars (MSPs) has been seen for the first time. The timing analysis of these rapidly-rotating (rotational period below 10 ms) and relatively faint (a few tens to hundreds of gamma-ray photons per year) objects illustrates the importance of highly-accurate photon time stamps, and the multi-wavelength monitoring of the pulsar rotational period as a function of time. These elements allow the LAT to observe variations in the light curve of MSPs at the 10 microsecond level, for photons accumulated over a year. I will review the observations of MSPs with the Fermi LAT. I will also discuss the recent discovery of numerous MSPs at the position of unassociated Fermi sources with high time resolution radio observations.

10:20-10:40 **Optical timing studies of neutron stars: Current Status**

Roberto Mignani (University College London - MSSL)

Being fast rotating objects, Isolated Neutron Stars (INSs) are natural targets of high-time resolution observations across the whole electromagnetic spectrum. With the number of objects detected at optical (plus ultraviolet and infrared) wavelengths now increased to 24, high-time resolution observations of INSs at these wavelengths are becoming more and more important. While rotation-powered radio pulsars, like the Crab and Vela pulsars, have been the first INSs studied at high-time resolution, observations performed in the last two decades have unveiled the existence of different types of INSs which are not rotation powered, although their periodic variability is still related to the neutron star rotation. In this talk I review the current status of high-time resolution observations of INSs in the optical domain for different classes objects: rotation-powered pulsars, magnetars, thermal emitting neutron stars, and rapid radio transients, I describe their timing properties, and I outline the scientific potentials of optical timing studies for different types of INSs.

10:40-11:10: Coffee Break and Poster Session

11:10-11:40 **Fast variability from X-ray binaries (Invited Review)**
Tomaso Belloni (INAF - Astronomical Observatory of Brera, Merate)

The X-ray emission from accreting black-holes and neutron stars features strong variability on sub-second time scales, with very complex and broad phenomenology. From high-frequency quasi-periodic oscillations to rapidly changing X-ray burst oscillations to millisecond pulsations, these are weak signals immersed in strong noise and their study is pushing instrument capabilities to their limit. The scientific significance of fast time variability studies are both astronomical (properties of accretion flows, nature and evolution of sources) and physical (effects of General Relativity, equation of state of degenerate matter). I will first review the main observational properties with an eye to multi-wavelength measurements, then discuss the future prospects and observational needs.

11:40-12:00 **Fast multiwavelength variability from jets in X-ray binaries**
Piergiorgio Casella (University of Southampton)

The frontiers of high time resolution Astrophysics are rapidly expanding, moving from the traditional X-ray Astronomy to more and more wavelengths. The study of X-ray variability in X-ray binaries has represented - and still is - one of the most powerful tools to study the accretion flow in the vicinity of compact objects. Recent optical variability suggests an important role played by the jet in these systems. However, in optical and ultraviolet light the emission from the outer accretion disk can strongly contaminate the jet signal, while at longer wavelengths, the variability will be smeared out in time due as it comes from far out in the jet. Infrared variability studies are thus ideal for looking at jet variability on the fastest possible timescales. Thanks to newly available detectors, fast infrared and mid-infrared photometry is now possible. This is opening a new exciting window to study the geometry and the Physics of relativistic jets and their connection with the accretion flow. I will present the first results from a large ongoing fast-timing multi-wavelength project, showing the first unambiguous evidence for sub-second jet variable emission. I will show how this type of data already allows us to put quantitative constraints to the jet speed, geometry and physics, and discuss the great potential of new observations in the near future.

12:00-12:20 **The Role of Jets in Black-hole X-ray Binaries**
Nick Kylafis (University of Crete, FORTH)

Jets have been observed from both neutron-star and black-hole X-ray binaries. Since the jets from neutron stars are much weaker than those from black holes, I will concentrate on the second ones. Contrary to common belief that jets are simply fireworks that emit radio waves, I will demonstrate that they play a central role in the observed phenomena. A simple jet model can explain not only the entire energy spectrum from radio to hard X-rays, but also the time lags between the hard and the soft X-rays and the characteristic frequency of variability in X-rays. In addition, the model explains in a natural way the stringent correlations seen in Cyg X-1 among the energy spectrum, the time lags, and the characteristic frequency of variability in X-rays. No other model has even attempted to explain these correlations.

12:20-12:40 **Mapping LMXBs with reprocessed X-ray bursts**
Teo Muñoz-Darias (INAF Osservatorio Astronomico di Brera)

Narrow, high-excitation, emission lines have been used during the last years to measure radial velocities in active low mass X-ray binaries. They are the result of X-ray reprocessing in the different sites of the binary, particularly, in the inner hemisphere of the companion star. By combining these radial velocities with complementary dynamical information it is possible to determine compact object masses for the first time in these systems. Here, we report on a novel technique that uses correlated type I X-ray outburst to constrain orbital inclinations in neutron star X-ray binaries. We present simultaneous, high-time resolution ($\sim$0.2s) RXTE and VLT+ULTRACAM / ESO-3.6m+ULTRASPEC observations of the systems 4U 1636-536 and EXO 0748-676 during burst events. For both cases, we measure phase dependent time-lags between X-ray and Bowen (optical) emission. This allows us to constrain the orbital inclination of these X-ray binaries and the masses of the neutron stars they harbor.

12:40-13:00 **Rapid variations of polarization in low-mass X-ray binaries**
David Russell (University of Amsterdam)

Time-resolved optical and infrared polarimetric observations of low-mass X-ray binaries are presented. Data were acquired with the VLT, UKIRT and HIPPO on the SAAO 1.9-m. We find that for some sources in outburst, a rapidly variable component of polarization is evident that is stronger in the redder wavebands. We attribute this to the polarimetric signature of synchrotron emission from jets in these systems, the emission of which is known to dominate these redder bands. Such synchrotron emission from jets launched close to black holes and neutron stars can be highly linearly polarized, depending on the configuration of the magnetic field. The variability of the polarization is suggestive of a tangled and turbulent magnetic field at the location of the compact jet. For some sources the position angle of polarization is consistent with a magnetic field that is parallel to the observed radio jet. These are some of the first observational constraints of the geometry and magnetic structure at the inner regions of the outflow. We also present the first ever test for a correlation between optical polarization and X-ray flux of an X-ray binary, using data taken simultaneously with RXTE and HIPPO with sub-second time resolution.

13:00-15:00: Lunch Break

Session 2: Object Reviews (II) - Compact Binaries and Transients

15:00-15:30 **White Dwarfs and Ultra Compact Binaries (Invited Review)**
Danny Steeghs (University of Warwick)

Galactic white dwarf binaries dominate the low frequency gravitational wave source populations, provide pathways to explosive events such as Type Ia supernovae and act as excellent benchmarks systems for testing and understanding binary evolution and accretion physics. With orbital periods as short as a few minutes, white dwarf spin and pulsation modes of order few hundred seconds and rapid accretion-driven variability, high-time resolution observations are clearly powerful probes of such objects. I review some recent efforts in HTRA observations of white dwarfs, with the availability of larger aperture telescopes and new detector technologies allowing a shift from fast photometry to fast spectroscopy in the near future.

15:30-15:50 **High speed spectroscopy of intermediate polars**
Steven Bloemen (Instituut voor Sterrenkunde, Katholieke Universiteit Leuven, Belgium)

Obtaining spin resolved spectroscopy of the intermediate polars with the fastest spinning white dwarfs is challenging. We present high speed spectroscopic observations of V455 And, which were obtained using the QUCAM2 electron-multiplier CCD (EMCCD) installed on the ISIS spectrograph at the William Herschel Telescope. This research demonstrates that EMCCDs make it possible to observe relatively faint targets at high cadence without burying the signal under the readout noise. Variations in the spectral lines on the white dwarf's spin period are detected and compared to a similar recent study on the prototype, and also fast-spinning, intermediate polar DQ Her.
(authors of this work: S. Bloemen, T. Marsh and D. Steeghs)

15:50-16:10 **Very fast photometric observations of the intermediate polar V2069 Cyg**
Ilham Nasiroglu (MPE, Garching)

We present fast timing photometric observations of the intermediate polar (IP) V2069 Cygni (RX J2123.7+4217) using the Optical Pulsar Timing Analyzer (OPTIMA) at the Skinakas Observatory 1.3 m telescope. OPTIMA is a single-photon counting aperture photo-polarimeter with a timing accuracy of about 4 microseconds and absolute (GPS) tagging of photon arrival-times. The optical light curve of V2069 Cygni was measured with sub second resolution during July 2009. We discovered a double-peaked pulsation with 743.385-s period, presumably the spin of the white dwarf, in the optical band (450-950 nm). Soft X-ray emissions (XMM-Newton and Swift observations) also shows a double-peak modulation at the white dwarf spin period. In a P_{orb} - P_{spin} diagram of all IPs V2069 Cyg is a rather undistinct member of this population. It has however a rather low spin to orbit ratio of $\sim$0.027.

I. Nasiroglu (1, 2), A. Slowikowska (3), G. Kanbach (2)
(1) Cukurova University, Adana, Turkey
(2) MPE, Garching, Germany
(3) Univ. of Zielona Góra, Zielona Góra, Poland

16:10-16:30 **Discovery of the Eclipsing Detached Double White Dwarf Binary**
David Kaplan (UC Santa Barbara)

We report the discovery of the first eclipsing detached double white dwarf binary. We identified 3-6% dips in the photometry lasting several hundred seconds. Subsequent radial velocity measurements of the primary confirmed that the dips are transits caused by an orbiting C/O WD orbiting with a low-mass He core white WD. We will describe our determination of the system parameters including constraints on the masses and radii of both objects and the eventual fate of the system, and conclude with what we may learn from future observations.

16:30-17:00: Coffee Break and Poster Session

17:00-17:30 **Extra-Galactic Transients (Invited Review)**
Nial Tanvir (Univeristy of Leicester)

Recent years have seen a rapid expansion in our knowledge of transient extragalactic sources, and in particular violent explosive events such as gamma-ray bursts and other exotic classes of supernovae. The opening of this time-domain has been made possible through the development of fast response multi-wavelength facilities, and this is likely to continue in the ELT era, with new non-photonic observatories providing complementary neutrino and gravity wave observations of transients. I will review some of these recent breakthroughs and consider their implications for ELT science drivers.

17:30-17:50 **Transient Radio Neutron Stars**
Evan Keane (University of Manchester)

I will review the current status of searches for Rotating Radio Transients (RRATs), a recently discovered class of transient radio neutron star. These stars appear to be as abundant as the well-known radio pulsars, something which may be difficult to reconcile with the Galactic supernova rate. To investigate where RRATs fit in a neutron star evolutionary sense, as well as to investigate their unusual intermittent emission it is important to identify many more sources. To this end I will discuss a recent re-analysis of the Parkes Multi-beam Pulsar Survey which has more than doubled the known sources in the survey. I will also discuss the unusual timing behaviour of RRAT J1819-1458 and present timing solutions for some of the newly discovered sources. These leads to an examination of where RRATs live in period-period derivative space and the spin-evolution of pulsars and magnetars.

17:50-18:10 **Probing magnetar physics through high time-resolved spectroscopy of X-ray flashes**
GianLuca Israel (INAF Osservatorio Astronomico di Roma)

In the latest years a number of important results have opened new horizons in the study and understanding of a small but important class of high energy emitting isolated neutron stars called magnetars. These are thought to shine in the X-rays due to the decay of the strongest magnetic fields present in the Universe (up to 10^{15} Gauss). In this talk the results obtained through the study of the transient phenomena displayed by some of them over more than 10 orders of magnitudes of time scale of variability (from fraction of milliseconds up to years) and of flux (from 10^{-9} up to 1 ergs/s/cm^2) will be shown and discussed. In particular we will focus on the first detailed time-resolved (down to 4ms) spectroscopic studies of intermediate flares from SGR1900+14, 1E1547.0-5408 and SGR0501+4516. Information related to the neutron star and magnetosphere structure, the emitting processes, and the confined fireball properties have been inferred for the first time and will be discussed on the light of the theoretical model(s).

18:10-18:30 **OPTIMA observations of the first optical magnetar SWIFT J1955+26: an update**

Gottfried Kanbach (MPE, Garching)

We describe the OPTIMA observations of very rapid optical flaring from the presumed galactic transient SWIFT J195509.6+261406. The source was initially triggered as GRB070610 by Swift and fast follow up monitoring by OPTIMA mounted on the Skinakas 1.3m telescope revealed flaring of a kind and amplitude that had never been previously reported for a 'GRB'. The optical light-curves are phenomenologically similar to the high energy light-curves of SGRs, which are thought to be neutron stars with extremely high magnetic fields (magnetars). This similarity suggests that the same emission processes may be at work, but in contrast to the other known SGRs the emission is principally in the optical band. We describe the complete set of detected flares and put the optical observations into context with other multi-wavelength detections.

19:00-20:00: Workshop Reception

Thursday 8th May 2010: Day 2 - Current Status and Future Goals

Session 3: Object Reviews (III) - Stars, Transits, Occultations

09:00-09:30 **Stellar Oscillations and Occultations (Invited Review)**
Andrea Richichi (European Southern Observatory)

High time resolution observations of phenomena such as occultations, transits and photometric lightcurves can provide direct and indirect information unaccessible to many other techniques. I will outline the scientific drivers for HTR in these areas, and highlight some representative results in areas of stellar and planetary physics. I will review the observational capabilities available at present, in particular at the European Southern Observatory, and those that could become available in the near future.

09:30-09:50 **Spectroscopic Confirmation of the 5.4min Orbital Period in HM Cnc**
Arne Rau (Max-Planck Institute for Extra-terrestrial Physics)

The Laser Interferometer Space Antenna (LISA) will measure gravitational waves at frequencies between 0.1m Hz and 1 Hz and will thus be sensitive to the orbital motions of ultra-compact binary stars, known to exist in the Galaxy. These will predominantly be detached double white dwarf binaries and their accreting counterparts, the AM CVn stars. One of the most extreme members of the class of Am CVn stars is HM Cancri, a candidate ultra-compact binary white dwarf system with a 5.4min periodicity, observed as X-ray and optical light-curve modulations. In my talk I will present the results of a Keck-I/LRIS time-resolved spectroscopy campaign of HM Cancri. The data confirm that the 5.4min represents the orbital period of an interacting binary white dwarf. This implies that HM Cancri is the shortest period binary star known, a unique test case for stellar evolution theory, and one of the strongest known sources of gravitational waves for LISA.

09:50-10:10 **Probing the nature of the shortest period binary HM Cnc through time-resolved multiwavelength studies**

Simone Dall'Osso (VESF & INAF - Osservatorio Astronomico di Roma)

We will present the latest results of a multiwavelength monitoring of RXJ0806.3+1527 (aka HM Cnc), the shortest period known binary (321.53s) we discovered in 1999, focussing mainly on timing and phase-resolved studies of its broad band spectral properties. The full potential of such studies in shedding new light on the nature of this extremely peculiar object is highlighted. The association of the 321.5s modulation from this source with the orbital period of an ultracompact binary was suspected/suggested soon after its discovery and has been recently proved with high reliability. However, the origin of its multiwavelength emission is still largely unclear, as new observations always reveal unexpected and/or unpredictable details.
Combining phase-resolved spectra and timing analysis with the evolution of the multiwavelength emission with orbital phase we are able to put strong constraints on the geometry and location of the different emission components. Based on our results, we discuss the merits and drawbacks of different scenarios proposed to explain the origin of the multiwavelength emission from this object. In particular, we show that important aspects of the observations cannot be reconciled with any of the standard paradigms assumed thus far. This eventually requires significant improvements/revisions of currently invoked models.

10:10-10:30 **Flare star observations with OPTIMA**

Jürgen Schmitt (Hamburger Sternwarte)

We have used the OPTIMA instrument mounted at the 1.3m telescope at the Skinakas Observatory, Crete, to study a small sample of flare stars at very high time resolution. The optical emission from stellar flares is usually interpreted as a proxy for a non-thermal particle population produced in the flare event. Therefore the typical timescales and amplitudes of variability are of central interest in a physical understanding of the flare energetics. We present OPTIMA observations of flares observed on UV Cet and EQ Peg, and derive their characteristic time scales, luminosities and fluences.

10:30-11:00: Coffee Break and Poster Session

11:00-11:30 **Fast and transient phenomena in stellar magnetospheres / flare stars (Invited Review)**

Jürgen Schmitt (Hamburger Sternwarte)

In the Sun transient phenomena in the form of flares and outbursts are observed over the whole range of the electromagnetic spectrum and provide evidence for non-thermal processes such as magnetic reconnection, particle acceleration and others. Flares and outbursts are also observed in a wide range of stars, preferentially at X-ray wavelengths, but also at radio and optical wavelengths. The released energies and radiated luminosities exceed those observed in solar flares by many orders of magnitude. I will give an overview of stellar flare observations addressing the following questions: Which stars are capable of producing flaring emission? What are the typical spectral properties of stellar flares? What physical processes are involved in the production of stellar flare emission?

11:30-11:50 **ULTRACAM observations of SDSS J0926+3624: The first known eclipsing AM CVn star**

Chris Copperwheat (University of Warwick)

The AM Canum Venaticorum (AM CVn) stars are ultracompact binaries with the lowest periods of any binary subclass, and consist of a white dwarf accreting material from a donor star that is itself fully or partially degenerate. These objects offer new insight into the formation and evolution of binary systems, and are predicted to be among the strongest gravitational wave sources in the sky. To date, the only known eclipsing source of this type is the 28 min binary SDSS 0926+3624. I will present multiband, high time resolution light curves of this system, collected with ULTRACAM in 2006 and 2009. These are supplemented by additional observations made with the Liverpool Telescope, XMM-Newton and the Catalina Real-Time Transient Survey. From light curve models we make the most precise parameter determinations for any AM CVn and determine the degree of degeneracy of the donor star; a key parameter in differentiating between the proposed formation paths for these objects. I will go on to discuss the additional phenomena apparent in the optical data, such as the superhump, quasi-periodic oscillations and the outbursting behaviour. I will discuss how, since any eclipsing AM CVns discovered in the future are likely to be significantly fainter than SDSS 0926, the next generation of telescopes will be key in exploring the nature of these systems.

11:50-12:10 **Detecting a small Kuiper Belt object using archival data of HST's Fine Guidance Sensor**

Shay Zucker (Tel Aviv University)

Detection of stellar occultaion events by Kuiper Belt Objects (KBOs), with a typical duration of 0.2 second, is a classic goal of high time-resolution astronomy. There are several on-going attempts to achieve this goal, with a rather poor success so far. We present a somewhat different approach. We use the archived data of the Fine Guidance Sensors on-board the HST, to search for the typical signature of occultations by KBOs. While we haven't scanned yet the complete database, we have already detected one bona-fide event (Schlichting et al., Nature, 462, 895). Depending on time constraints, I will present the instrument capabilities, the detection, and the astrophysical implications.

Session 4: Theory and Future Science Goals

12:10-12:40 **HTRA Discovery Potentials (Invited Review)**

Virginia Trimble (University of California, Irvine & LCOGT)

It is a truism of astronomy (indeed of science, though the cliché is ours) that when you open a new window, you see a new scene. So far, this has always been true for exploring new scales in the time regime, both longer and shorter than those available to Galileo. We will focus here on going to shorter time scales (both before and after photography nearly succeeded in making astronomy a leisurely pursuit. Classic cases include pulsars, gamma ray bursters, flashes on the moon, anything with a relativistic accretion disk, and a good many transients of uncertain nature. Optical observations are frequently supported by other wavelengths. I will try to identify some cases where there still seems to be a good deal of "discovery space" to be explored.

12:40-15:00: Lunch Break

15:00-15:20 **Optical timing studies of neutron stars: Future Goals**
Andy Shearer (National University of Ireland, Galway)

Neutron stars are not traditionally ‘optical’ objects. Although they are faint the optical radiation potentially contains a wealth of information about the local conditions within the pulsar magnetosphere - but this will require detectors and instruments with high time resolution, moderate photon energy resolution and which are sensitive to polarisation. This talk will review the possibilities of pulsar and neutron star astrophysics with E-ELTs with proposed and possible instrumentation.

15:20-15:40 **Partially Screened Gap - general approach and observational consequences**
Andrzej Szary (Institute of Astronomy, University of Zielona Góra)

Observations of the thermal X-ray emission from radio pulsars implicate that the hot spot size is is much smaller than the polar cap defined by the purely dipolar magnetic field. Most plausible explanation is that actual surface magnetic field is much stronger and curved then what follows standard model. We can determine magnetic field at the surface by the conservation of the magnetic flux along a bunch of open magnetic field lines. Then the value of the surface magnetic field is estimated as of the order of 10^{14} G. On the other hand observations show that the temperature of the hot spot is about few million Kelvins. Based on this observations the Partially Screened Gap (PSG) model was proposed which assumes that the temperature of the actual polar cap (hot spot) equals to the so called critical temperature which is defined by strength of the surface magnetic field. We present the observed values of black body temperature and corresponding area of X-ray emission for a number of pulsars. The results of our analysis show that the PSG model is suitable to explain both cases: when the hot spot is smaller or larger then conventional polar cap. For the second case both the structure and curvature of field lines are such that allows the pair creation in the closed field line region thus heating the surface outside actual polar cap.
Radio emission is a consequence of processes occurring in the polar region. We demonstrate that the strong non-dipolar magnetic field at the star surface causes generation of two main populations of particles: primary particles with Lorentz factors (limited by the Curvature Radiation) of the order of 5×10^5 and secondary particles with Lorentz factors (limited by the Inverse Compton Scattering) of the order of 100. Despite the fact that Lorentz factor of the secondary particles is several orders of magnitude smaller, our simulations show that the total energy of these particles is the same order as the total energy of primary particles.

15:40-16:00 **Searching Sub-Millisecond Pulsars in Accreting Neutron Stars**
Alessandro Patruno (University of Amsterdam)

Measuring the spin of Accreting Neutron Stars is important because it can provide constraints on the equation of state of ultra-dense matter. Particularly crucial to our physical understanding is a measurement of sub-millisecond pulsars, because this will immediately rule out many proposed models for the Ground State of the Strong Force. In the past, it has been impossible to accomplish this, because, for unknown reasons, only a small amount of Accreting Neutron Stars exhibit coherent pulsations. One of the most intriguing explanation for this is that only Neutron Stars accreting with a very low mass accretion rate can pulsate. We have now searched pulsations in two sources that have the lowest mass accretion rate among all known X-ray binaries and we do not find any evidence of pulsations. We conclude that our understanding of the physical processes underlying the formation of pulsations is not complete and we discuss which sources are optimal to continue the search of sub-ms pulsars.

16:00-16:30 **Fermi pulsar revolution (Invited Review)**
Patrizia Caraveo (IASF-INAF Milano, Italy)

2009 has been an extraordinary year for gamma-ray pulsar astronomy and 2010 promises to be even better. Not only have we registered an extraordinary increase in the number of pulsars detected in gamma rays, but we have also witnessed the birth of new sub-families: first of all, the radio-quiet gamma pulsars and later an ever growing number of millisecond pulsars, a real surprise.
We started with a sample of 6 gamma-ray emitting neutron stars (5 radio pulsars and Geminga) and now the Fermi-LAT harvest encompasses 24 "Geminga-like" new gamma-ray pulsars, a dozen millisecond pulsars and about thirty radio pulsars. Moreover, radio searches targeted to LAT unidentified sources yielded 18 new radio millisecond pulsars, several of which have been already detected also in gamma rays.
Thus, currently the family of gamma-ray emitting neutron stars seems to be evenly divided between classical radio pulsars, millisecond pulsars and radio quiet neutron stars.

16:30-17:00: Coffee Break and Poster Session

17:00-18:00: **The Future of HTRA (Round Table Discussion)**

Friday 9th May 2010: Day 3 - Instrumentation

Session 5: Optical HTRA with Current and Future Instruments

09:00-09:30 **HTRA with ULTRACAM and ULTRASPEC: past, present and future (Invited Review)**

Vik Dhillon (University of Sheffield)

Following a brief description of the ULTRACAM and ULTRASPEC instruments, I shall review the science that has been done in the 262 nights of telescope time awarded to these instruments on the VLT, NTT, ESO 3.6m and WHT since 2002. I shall then discuss the science we would like to do on the E-ELT and present some simulations of the results we would expect with different types of detector.

09:30-09:50 **Solid State Photon-Counters for High Time Resolution Astrophysics (HTRA)**

Giovanni Bonanno (INAF - O. A. Catania)

The needs to have detectors systems capable to push the time tagging capabilities of each incoming photon toward the 10 ps region, sustaining up to 1GHz count rates continuously for hours of uninterrupted acquisition has generated a new type of investigation on detectors and electronic front-end that can be able to satisfy these requirements.
For example, thanks to such extremely high time resolution and stability, and to the photon flux at the output of the future 40-m class telescopes as the European Extremely Large Telescope (E-ELT), these new instruments could study second order correlation functions in the photon stream from celestial sources in their different manifestations (statistical characteristics of the photon stream, photon correlation spectroscopy, Hanbury-Brown-Twiss intensity interferometry over two or more apertures). To investigate the real possibilities of such devices, we studied and characterized different detectors produced by various manufacturers.
Some results particularly focused on timing resolution and photo detection efficiency will be presented.

09:50-10:10 **Results of Iqueye at the NTT in 2009**
Cesare Barbieri (University of Padova, Dept. of Astronomy)

The very high time resolution photometer Iqueye has been operated at the ESO NTT in Jan and Dec 2009, observing optical pulsars and other peculiar objects. It has been used also on bright stars to acquire experience with Hanbury Brown Twiss Intensity Interferometry. The presentation will describe the main characteristics of the instrument and some of the obtained results.

10:10-10:30 **Spatial decomposition of polarization components of the Crab pulsar and its nebula**
Agnieszka Słowikowska (University of Zielona Góra)

We show results of archival polarization HST/ACS data of the Crab nebula and compare them to the polarization characteristics obtained with the very fast photo-polarimeter OPTIMA (Optical Pulsar Timing Analyzer). Our highly time resolved observations with OPTIMA allow us to decompose the polarized radiation into components from the pulsar, a localized DC source, and the surrounding nebula. By cross correlation with the spatial polarization map from HST we can investigate the origin of the DC emission.

A. Słowikowska (1), R. Mignani (2), G. Kanbach (3)
(1) University of Zielona Góra, Zielona Góra, Poland
(2) Mullard Space Science Laboratory, University College London, UK
(3) MPE, Garching, Germany

10:30-11:00: Coffee Break and Poster Session

11:00-11:30 **HTRA with the ELTs (Invited Review)**
Isobel Hook (University of Oxford)

I will present a summary of the science case for ELTs, which ranges from studies of exo-planets to the most distant galaxies and cosmology. Example science cases will be illustrated by recent results from simulations developed as part of the Design Reference Mission for the 42m European ELT project.

11:30-11:50 **The optical pulsar B0540-69**
Serena Gradari (University of Padova)

The high speed photometer Iqueye has been used at the NTT in January and December 2009, obtaining a series of data on the Crab, LMC and Vela pulsars.
Here I'll describe in particular the data obtained on B0540-69 (the second brightest optical pulsar) and the derived light curve. Conclusions will be drawn about the braking index and other characteristics.

11:50-12:10 **OCTOCAM: A multi-channel imager and spectrograph to explore the transient Universe**

Antonio de Ugarte Postigo (INAF - Astronomical Observatory of Brera, Merate)

OCTOCAM is a high time-resolution multi-channel instrument that is being proposed for the 10.4m GTC telescope. It will perform simultaneous observations in 8 bands, covering the complete spectrum from the ultraviolet (u-band) to the near infrared (K-band) in a single exposure. OCTOCAM will have an imaging mode with a field of view of $2'$ x $2'$ and a long slit spectroscopic mode with full wavelength coverage from 0.35 to 2.3 μm at a resolution of $\sim$ 1000 in a single exposure. It will be based on the use of electron multiplying CCD (EMCCD) detectors (with fast readout and negligible noise) in the optical, and new technology HAWAII-2RG detectors in the near-infrared (nIR) to achieve time resolutions of up to 10 milliseconds. In this way, OCTOCAM will be occupying a region of the time resolution - spectral resolution - spectral coverage diagram that is not covered by a single instrument in any other observatory, with an exceptional sensitivity.

12:10-12:30 **Fast photometry at the Paris observatory: portable cameras and multi-fibre instruments**

Françoise Roques (LESIA, Observatoire de Paris)

Occultations by distant objects of the Kuiper Belt can be done with two strategies
- To observe the occultations by known objects which path on Earth is computed by astrometry
- Search for serendipitous occultations by smaller objects. We develop dedicated instrumentation for each strategy :
- a set of performant portable cameras for campaigns of observation from several place of the predicted occultations.
- multi-fibre instrument associated with a rapid camera to perform fast accurate photometry on several targets in large fields. We have upgraded a 29-fibre spectrograph by replacing the spectrograph by a fast camera: Explorer is mounted it on the 1.93m telescope of the Observatoire de Haute Provence. The second step is to build UltraPhot, a very performant instrument for multi-object fast photometry on the VLT, with between 60 and 90 and a read-out frequency of 100 Hz in 3 colors.

Scientific subjects of EXPLORER and UltraPhot are numerous, serendipitous stellar occultations, young stellar objects, white dwarfs and exoplanet transits.

12:30-12:50: Poster Presentation Session

12:50-15:00: Lunch Break

Session 6: Multi-wavelength HTRA with Current and Future Instruments

15:00-15:30 **The HTRA potential of the SKA and its relation to observations with large optical telescopes (Invited Review)**

Michael Kramer (MPIfR / Jodrell Bank Centre for Astrophysics)

We are entering a new era in which the dynamic sky can be fully explored for the first time. Prime instruments will be telescopes which can monitor the full sky at once, such as the new generation of radio telescopes. Following the example of and lessons from LOFAR, the Square Kilometre Array (SKA) will be such a telescope that can sample the sky with unprecedented sensitivity and time resolution. It is expected that the SKA will uncover previously unknown sources, phenomena and processes. These efforts will not only be complemented by similar studies with large optical telescopes, but multi-wavelength studies and follow-up observations - in particular at optical frequencies - will be of utmost importance in the identification of newly discovered sources and source types. This talk will give an outline of the expected studies and results.

15:30-16:00 **The HTRA Potential of IXO (Invited Review)**

Werner Becker (Max Planck Institut für Extraterrestrische Physik)

X-ray astronomy has made great progress in the past several years thanks to telescopes with larger effective areas and greatly improved spatial, temporal and spectral resolutions. The next generation of observatories, like IXO and eROSITA, are supposed to bring again a major improvement in sensitivity. These new instruments will allow us to address many open questions related to the neutron star equation of state e.g. through photospheric atomic absorption line spectroscopy in phase-resolved spectral analysis during an X-ray burst of rapidly spinning neutron stars in LMXBs. Phase-resolved spectroscopy of rotation-powered pulsars will help to disentangle the various X-ray emission processes at work in these pulsars and to better explore the physical details of the pulsar emission mechanisms than currently possible. In my talk I will summarize the specification and status of the IXO and eROSITA missions and highlight their prospects for neutron star studies.

16:00-16:20 **The Chirpolator: A new method for detecting fast transients with radio interferometers**

Keith Bannister (University of Sydney)

The high time resolution radio universe is poorly explored over wide fields. Next generation wide-field interferometers such as ASKAP, the ATA and the SKA can offer a new window into the sensitivity vs field-of-view parameter space as long as the significant computational challenges can be overcome. 'The Chirpolator' is a new, antenna-coherent algorithm for detecting dispersed radio emission. It has a computational cost which is lower than other antenna-coherent methods, and which is achievable in the time-scale of these telescopes. I will describe its principle of operation, computational complexity, sensitivity properties, and performance with both simulated data, and data from the the Giant Metrewave Radio Telescope.

16:20-16:50: Coffee Break and Poster Session

16:50-17:20 **HTRA potential of future space-based X- and gamma-ray facilities (Invited Review)**

Ron Remillard (Massachusetts Institute of Technology)

The scientific productivity of X-ray timing analyses has been dramatically advanced with observations of the Rossi X-ray Timing Explorer (0.6 m^2) and other recent space missions. The era of quantitative applications for general relativity in astrophysics has arrived. Concept studies are underway to consider missions with effective areas of $4m^2$ or larger within NASA, ESA, Italy, and China. The leading science drivers are the neutron star equation of state, and the interpretation of high-frequency quasi-periodic oscillations in accreting black holes and neutron stars. Timing observation for Gamma-ray facilities are being redefined with results from Fermi. Pulsar astrophysics and jet processes are leading science themes, and prospects for advancement in future missions will be discussed. Multi-frequency coordination can provide important synergies for high-energy astrophysics, but we must solve logistical problems to achieve much higher levels of dedicated, coordinated source coverage.

17:20-17:50 **HTRA with Cerenkov Telescopes (Invited review)**
Felix Aharonian (DIAS/MPIK)

Because of the size restrictions of space-borne detectors, the study of VHE photons above 100 GeV can be most effectively performed with ground-based detectors. This concerns, first of all, the temporal studies of highly variable sources like gamma-ray loud binaries and AGN, as it has been demonstrated by the current generation of stereoscopc arrays of imaging atmospheric Cherenkov telescopes (IACTs) like HESS, MAGIC and VERITAS. The significant improvement of the detection performance in the "classical" 100 GeV - 10 TeV region, with angular resolution as good as 1-2 arcmin and minimum detectable flux below 1e-13 erg/cm2 s, by the next generation of IACT arrays, will provide comprehensive studies of gamma-ray properties of particle accelerators with unprecedented accuracy and quality which could lead to a dramatic, by an order of magnitude or more, increase of the number of VHE gamma-ray sources. Special efforts will be undertaken to reduce the energy threshold of Cherenkov telescopes down to 10 GeV in order to explore the highly variable gamma-ray sources in the energy interval between 10 GeV to 100 GeV. This can be best done by very large, 20m diameter telescope arrays, equipped with high quantum efficiency optical receivers, and located at very high altitudes.

17:50-18:10 **High resolution X-ray Timing from a LOFT**
Immacolata Donnarumma (INAF/IASF-Roma)

LOFT (Large area Observatory For x-ray Timing) is an innovative mission concept for the next generation of X-ray timing experiments. Recent developments in the field of Silicon detectors allowed to design a realistic observatory devoted to X-ray timing studies with an effective area above 15 m^2, in the energy range 2-30 keV. In this paper we will present the mission concept together with the key properties of the detectors, as demonstrated in our lab, including an energy resolution better than 500 eV at room temperature. The overall power and weight budgets fit to a standard mission design. Such an exceedingly large area (>30 times RXTE/PCA), with a time resolution better than 10-20 μs, will allow unprecedently fast and accurate time variability studies related to accreting collapsed objects (e.g. fast coherent pulsations and QPOs). We will describe the diagnostic potential of a timing observatory in the 10-meter class for open problems in fundamental physics, such as strong gravity effects, the measurement of the mass of black holes and neutron stars, the equation of state of ultradense matter. Finally, we will present the results of simulated LOFT observations.

18:10-18:40: Rapporteur

Poster Presentations

MIOSOTYS, a multi-object high-rate photometer designed for TNO serendipitous occultations
Yannick Bossel (Observatoire de Paris - LESIA)

MIOSOTYS, (Multi-object Instrument for Occultations in the SOlar system and TransitorY Systems), is a high speed photometry instrument designed for the observation of serendipitous stellar occultations by small (100m) trans-neptunian objects. The instrument can also be used for other high time resolution astrophysics, such as exoplanet transits, X ray binaries, young stellar objects... The instrument is an upgrade of the previously in-use MEFOS, a spectrograph on the 3.6m telescope at La Silla in the 90's. The new camera has been provided by the NTHU in Taïwan (National Tsing Hua University). The instrument is the result of a collaboration between Observatoire de Paris - LESIA and the NTHU.
MIOSOTYS is mounted at the Cassegrain focus on the 193cm telescope at OHP (Observatoire de Haute-Provence), France. 29 automate arms with two degrees of freedom, translation and rotation on a narrow angle, bring blends of optical fibres on selected stars in the field of view, which is about 25 arcmin in diameter. The 29 blends of fibres are then glued together and images are projected on a Princeton Instruments EM-CCD, at typically rate 20Hz (other rates can be achieved changing the settings of the CCD). The typical magnitude of observed stars are in a range 12 to 14 in V band.
The work presented here focus on the star selection method for serendipitous TNO occultations, and the expected results of observations performed by MIOSOTYS in this field.

Physical properties of IP Pegasi: an eclipsing dwarf nova with an unusually cool white dwarf
Chris Copperwheat (University of Warwick)

We present high speed photometric observations of the eclipsing dwarf nova IP Peg taken with the triple-beam camera ULTRACAM mounted on the William Herschel Telescope. We obtained eighteen observations of the eclipse in 2004/2005, simultaneous in the Sloan u', g' and r' bands. By phase-folding and averaging our data we make the first significant detection of the white dwarf ingress in this system and thus make the most secure photometric determinations of the binary parameters in this system to date, which are in agreement with the best spectroscopic determinations. The white dwarf temperature is more difficult to determine, since the white dwarf is seen to vary significantly in flux, even between consecutive eclipses. This is seen particularly in the u'-band, and is probably the result of absorption by disc material. Our best estimate of the temperature is 10,000 - 15,000 K, which is much lower than would be expected for a CV with this period, and implies a mean accretion rate that is more than 40 times lower than the expected rate. Unless the mass transfer in IP Peg has begun very recently, these findings imply either that CVs can sustain accretion rates well below the expected rate for very long periods of time, or that the classical picture whereby the long-term accretion rate scales with period is not correct.

X-ray thermal radiation from hot polar cap in pulsars

Janusz Gil (Kepler Institute of Astronomy, University of Zielona Góra, Poland)

We demonstrate that the features of the partially screened polar gap define properties of both X and radio emission of pulsars. The model implies that the temperature of the polar cap surface is almost equal to the so-called critical temperature which is defined by the strength of the magnetic field at the stellar surface. Parameters of observed thermal X-ray emission derived from the blackbody fit usually imply the surface of the hot spot to be much smaller than the conventional polar cap area, which can be naturally explained by assuming that the geometry and strength of the magnetic field at the stellar surface differ essentially from the pure star centered dipole field. The model assumes that the source of the pulsar activity is associated with the Partially Screened Gap (PSG) operating in the inner acceleration region above the polar cap where the electric field has a component along the magnetic field lines. Particles (electrons and positrons) are accelerated in both directions: outward and toward the stellar surface. Consequently, outstreaming particles generate the magnetospheric X-ray emission while the backstreaming particles heat the surface and provide necessary energy for the thermal emission. The model assumes that the potential drop near the stellar surface is partially screened by the positive ions. Therefore the accelerating potential drop depends on the temperature of the polar cap. If temperature increases the density of the charge also increases, which causes reduction of the potential drop and consequently reduction of heating rate. As a result the surface temperature should be stabilized near the critical value. The model described above predicts certain dependence between the hot spot area and temperature, derived from the black body fitting to the spectra of the neutron star thermal X-ray emission. The temperature should always equal to the critical temperature. On the other hand the critical temperature is defined by the strength of the magnetic field and the cohesive energy of the crust material. As a result the black body spectra fitting parameters (temperature and hot spot area) should not be treated as independent parameters.

The OPTIMA photo-polarimeter: updated configuration and calibration

Gottfried Kanbach (MPE, Garching)

OPTIMA, the Optical Timing Analyzer, is a small, high-speed photo-polarimeter designed to observe highly variable sources in the wavelength range 450-950 nm. The system presently contains 12 fiber fed APD single photon counters, a GPS timing receiver, an integrating CCD camera for target acquisition, guiding, and atmospheric monitoring, and a control and data acquisition PC. Seven directly illuminated pick-up fibers in the focal plane are bundled as a hexagonal, center filled array (target array for photometry). One fiber is located at some distance from the central array as a sky background monitor. A separate aperture in the focal plane selects light from a target for polarimetry. Behind this aperture a twin Wollaston prism splits the incoming light into 4 beams that are polarized at 45 degree intervals from 0 to 135 degrees position angle. Each polarized beam is again picked up by a fiber and the photons are individually counted. OPTIMA uses a GPS based absolute timing system to time stamp individual photons with an accuracy of better than 10 ns. We describe an updated version of OPTIMA and report recent calibration results from the polarimeter.

The orbital ephemeris and emission states of HU Aqr observed with OPTIMA
Gottfried Kanbach (MPE, Garching)

HU Aqr is an eclipsing cataclysmic variable binary system of the polar class. Its orbital ephemeris has been followed since the discovery of HU Aqr for more than 20 years. Since 1999 regular OPTIMA observation of eclipses of HU Aqr can be used to follow the secular changes of the binary orbit. We report a new description of the orbital ephemeris including recent 2008/2009 observations. We also describe the long term development of the emission states of HU Aqr.

Orbital Period Variations in Eclipsing Post Common Envelope Binaries
Steven Parsons (University of Warwick)

We present high speed ULTRACAM photometry of the eclipsing post common envelope binaries DE CVn, GK Vir, NN Ser, QS Vir, RR Cae, RX J2130.6+4710, SDSS 0110+1326 and SDSS 0303+0054 and use these data to measure precise mid-eclipse times in order to detect any period variations, in most cases our eclipse times are accurate to less than a second. The precise timing achieved by ULTRACAM reveals the possible existence of a third body in orbit around QS Vir and NN Ser, although magnetic braking could still cause the period change observed in NN Ser. The ULTRACAM times also display small quasi-sinusoidal variations which are most likely due to the activity cycle of the main-sequence companion. Models fit to the primary eclipses allow us to measure the scaled radius of the companion to an accuracy of $dR/R < 10^{-5}$, precise enough to detect variations in the shape of the star.

Timing X-ray Pulsars for Spacecraft Navigation

Tobias Prinz (Max-Planck-Institut für extraterrestrische Physik)

Today, spacecraft positions in space are determined by radar tracking. Although this is possible with an accuracy of the order of metres for near-earth orbiting spacecrafts, the uncertainty increases with distance from Earth, being of the order of 4 km/AU for interplanetary space missions. Alternatively, just as GPS-navigation, pulsar signals could be used similarly to the GPS-navigation for (1) Earth-distance independent spacecraft navigation and (2) for autonomous space flights. With this approach the position of a spacecraft is determined by measuring the time of arrival of an X-ray pulse and comparing this with the absolute pulse phase location. The pulse phase difference between the expected and measured pulse phase corresponds to a run-time difference along the line of sight towards the pulsar. The exact coordinates of a spacecraft are then determined by triangulation relative to the solar system barycenter. To make this approach workable, two important points need to be investigated: What pulsars are best suited and what accuracy can be achieved with this method? In answering these questions we re-analysed all available X-ray pulsar timing data from satellites like XMM-Newton, Chandra and the ROSSI X-ray Timing Explorer. The database holding these data currently contains the temporal emission characteristics of 53 X-ray pulsars, including their X-ray pulse profiles at various photon energies, pulse profile characteristics, pulsed fractions in various energy bands, harmonic content of their pulse profile and the approximation of their profiles by a sum of Gaussians or sinus functions. The latter is used to obtain pulse profile templates, allowing us to measure the pulse arrival time with relatively high accuracy even for sparse photon statistics. The typical error for measuring a pulse phase is of the order of 1/1000, corresponding to an error in the position of a spacecraft of about 300 m if the pulsar rotates at a period of milliseconds.

Tobias Prinz (1), Werner Becker (1), Mike Georg Bernhardt (1), Ulrich Walter (2)
(1) Max-Planck-Institut für extraterrestrische Physik
(2) Technische Universität München

OPTIMA-Burst photon-counting observations of GRB 090726

Alexander Stefanescu (HLL/MPE)

The high time resolution photometer OPTIMA-Burst observed GRB 090726 in photon-counting mode for a total of 7ks in two epochs, starting after the optical afterglow's plateau phase ended. The photon timetag data was binned using a time-binning scheme of exponentially increasing bin lengths to optimise the sampling and signal-to-noise ratio of a source following a power-law decay. The OPTIMA-Burst light-curve thus derived can be described by a fit of two simple power-law decays. These fits to the OPTIMA data connect well to all optical observations published in the literature for this burst, including a significant late-time datapoint. However, the pre-break decay index is significantly more shallow than values reported in the literature for this burst utilising less well sampled data, while the post-break power-law decay is significantly steeper. Neither of both decay indices on its own neither a combined fit is compatible with the simultaneous Swift X-ray power-law decay index, excluding an achromatic behaviour of the burst.

High Speed Detectors for Polarimetric Observations using GASP

Brendan Sheehan (Centre for Astronomy, NUI Galway)

We present an overview of the work currently ongoing into the detector system used on the Galway Astronomical Stokes Polarimeter (GASP). GASP is based upon a Division of Amplitude Polarimeter and has no moving parts or modulated components. The complete Stokes vector is measured from just one exposure. This means that the timing resolution depends only on the frame rate of the detector system. GASP has been used on the 2.2 m Telescope at Calar Altro (2009) and on 4.2 m WHT (2010). The system consists of the instrument box to which either an L3Camera system or an APD detector system is attached. A GPS Time & Frequency system controls all timing aspects for both detector systems. The choice of detector depends on the science target and objectives. For frame rates up to 500 Hz the L3Camera system can be used, but for faster varying targets, the system must be used with APD detectors. The latter can operate at resolutions of <1 μsec with a timing accuracy of 25 nsec. Data loads for the L3Camera system are typically 86 GB/Hr per camera (for full frame). The APD system only stores data if a photon is detected and each photon event is individually time tagged to a 40 MHz clock (25 nsec). For the APDs, 1TB of disc space would provide a minimum of $8\frac{1}{2}$ hours recording time.

Models of Gamma-ray Activity in Millisecond Pulsars in the Wake of Fermi LAT Results

Anna Zajczyk (Nicolaus Copernicus Astronomical Center)

Recent observations by the Fermi LAT have firmly established millisecond pulsars (MSPs) as a class of gamma-ray emitters. This long-awaited result is, however, accompanied by an astonishing finding: the radiation characteristics of all nine gamma-ray MSPs in terms of the phase-averaged spectra and the lightcurves are similar to the gamma-ray properties observed for classical pulsars. In particular, contrary to prior expectations the results suggest that particle accelerators in MSPs are spatially extended in a way predicted by outer-gap and/or two-pole-caustic (TPC) slot gap models. I will show how some particular versions of these models can be accommodated to MSPs despite their low values of magnetic field strength and spin-down power. The results of new 3D numerical simulations for MSPs will be presented and confronted with the Fermi LAT data.