Neutron Stars at the Crossroads

All of the talks are in Hennings 201. The posters are in Hennings 302 and 304.

1 Wednesday 10 August 2005

8:50am - 9am : Opening Remarks

1.1 9am - 10am : Progenitors

- Supernova Simulations and Neutron Star Formation (40 minutes)

  Hans-Thomas Janka – Max Planck Institute for Astrophysics

  The current status of supernova modeling will be reviewed. Improvements in the treatment of neutrino transport and neutrino-matter interactions have advanced the models to a new level of sophistication. Successful and robust explosions by the neutrino-heating mechanism can be reported for progenitors with 8-10 solar masses, and explosions supported by hydrodynamic instabilities seem in reach for stars with masses between 10 and 12 solar masses. State of the art simulations for more massive progenitors are not yet finally conclusive, but offer new and interesting insights into the role of convection, hydrodynamic instabilities, and rotation in supernovae and during neutron star birth.

- Implications of the birth period - magnetic field relationship in the for the origin of magnetic fields in pulsars. (20 minutes)

  Lilia Ferrario – Australian National University

  We model the recent results from the 1374 MHZ Parkes Multibeam Survey to investigate the magnetic field distribution and the birth period distribution of pulsars as a function of magnetic field. Using population synthesis calculations we relate these to the magnetic properties of their progenitor stars on the main sequence exploring the hypothesis that the fields in neutron stars are of fossil origin.

  We show that the observations of radio pulsars can be explained by the fossil hypothesis if the mean field of their progenitors is of about 15 Gauss.The required distribution implies that the vast majority of main sequence stars will have fields well below the current detectability limit, while the implied high field extrapolation of the distribution naturally explains the magnetars.

  We also show that as with the magnetic white dwarfs, there is evidence from the radio pulsars that there is a tendency for the stronger field pulsars to be born as slower rotators, and argue that this may be a characteristic that can be used to distinguish between the fossil and dynamo models for the origin of fields in compact stars.

10am - 10:30am : Morning Break

1.2 10:30am - 11:40am : Strange Stars

- Strange Stars: where are they? (30 minutes)

  Dany Page – Instituto de Astronomia, UNAM

  Strange Stars, i.e., compact stars made of self-bound quark matter, are an intriguing alternative to "neutron" stars. To date there is not yet any convincing evidence either in favor or against their existence. I'll argue that if Strange Stars exist then the most massive compact stars in LMXB should be strange stars, and vice-versa, if these are not Strange Stars then Strange Stars do not exist. Models of thermal evolution of massive Strange Stars in LMXBs, in particular superbursting sources and SXRTs, could give an answer to this question.

- Thermal emission from hot bare strange stars and their observational appearance (20 minutes)

  Vladimir Usov – Weizmann Institute

Strange stars made almost entirely of deconfined quarks have long been proposed as a possible alternative to neutron stars. Strange quark matter with the density of $\sim 5x10^{14}$ g cm^{-3} might exist up to the surface of strange stars. Such bare strange stars (BSSs) differ qualitatively from neutron stars which have the density at the surface (more exactly at the photosphere) of about 0.1-1 g cm^{-3}. This opens observational possibilities to distinguish BSSs from neutrons stars, if indeed the formers exist. We present the results of calculations of the thermal emission of photons and electron-positron pairs from the surface of a hot BSS. Since strange quark matter at the surface of a BSS is bound via strong interaction rather than gravity, such a star is not subject to the Eddington limit in contrast to a neutron star, and its thermal luminosity in photons and pairs may be up to $\sim 10^{52}$ ergs/s or even more. Using the thermal emission from the surface of a BSS as a boundary condition, we consider numerically the structure of pair winds and the emerging emission from BBSs for total luminosities of L = $10^{34} - 10^{42}$ ergs/s. We find that for $L > 2x10^{35}$ ergs/s, photons dominate the emerging emission. As L increases from $\sim 10^{34}$ to 10^{42} ergs/s, the mean energy of emergent photons decreases from $\sim$ 400 keV to $\sim$ 40 keV, as the spectrum changes in shape from that of a wide annihilation line to nearly a blackbody spectrum with a high energy ($>$ 100 keV) tail. These results are pertinent to the deduction of the outside appearance of hot BSSs, which might help discern them from neutron stars. Some criteria are suggested for a compact object to be considered as a BSS candidate. Soft gamma-ray repeaters are among such candidates. The bursting activity of a soft gamma-ray repeater may be explained by fast heating of the surface of a BSS up to the temperature of $\sim (1-3) \times 10^9$ K and its subsequent thermal emission.

- Probing quark matter in compact stars with cosmic rays (20 minutes)

  Jes Madsen – University of Aarhus

  I will review the properties of small lumps of quark matter ("strangelets") and the possibility of detecting them in cosmic rays as a result of binary compact star collisions. An ongoing search in lunar soil as well as a coming search from the International Space Station will be described.

11:40am - 12:10pm : Open Discussion

12:10pm - 1:40pm : Lunch Break

1.3 1:40pm - 3:10pm : Nuclear EOS

- Neutron Rich Matter at Subnuclear Densities in Neutron Stars and Supernovae (30 minutes)

  Charles J Horowitz – Indiana University

  The virial expansion is used to make model independent determinations of the composition, equation of state, and neutrino response of nuclear matter at densities near 10^{11} to 10^{13} g cm^{-3}. Experimental nucleon-nucleon, alpha-nucleon, and alpha-alpha scattering phase shifts are used as input. We compare to existing model dependent equations of state such as Lattimer-Swesty and Shen. Our virial expansion corrects nuclear statistical equilibrium (NSE) models for the strong interactions between nuclei and or nucleons. Next, properties of the complex nuclear pasta phases in the inner crust of neutron stars are determined with large scale molecular dynamics simulations. Finally, we present an update of the Parity Radius Experiment (PREX) to measure the neutron skin in ^{208}Pb. This has many implications for neutron stars.

- Neutron-rich nuclei in Heaven and Earth (20 minutes)

  Jorge Piekarewicz – Florida State University

  An accurately calibrated relativistic parametrization is introduced to compute the ground state properties of finite nuclei, their linear response, and the structure of neutron stars. Among the predictions of this model are a symmetric nuclear-matter incompressibility of K=230 MeV and a neutron skin thickness in ^{208}Pb of Rn-Rp=0.21 fm. Further, the impact of such a softening on the properties of neutron stars is as follows: the model predicts a limiting neutron star mass of Mmax=1.72 Msun, a radius of R=12.66 km for a "canonical" M=1.4 Msun neutron star, and no (nucleon) direct Urca cooling in neutrons stars with masses below M=1.3 Msun.

- The cooling of quasi-persistent neutron star transients (20 minutes)

  Edward Brown – Michigan State University

  Neutron star transients with outburst durations of several years allow observations to constrain the cooling rate of the heated neutron star crust. Pycnonuclear reactions in the crust heat the neutron star interior and can elevate the crust temperature considerably with respect to that of the core if the thermal conductivity is sufficiently low. For various scenarios of the physics of the crust and core, we have computed families of quiescent lightcurves for different outburst durations, accretion rates, and quiescent intervals. I will compare these lightcurves with observations, and highlight recent efforts to compute the nuclear reaction chains in the crust for a realistic distribution of rp-process ashes. The unstable ignition of carbon, which powers superbursts, is strongly dependent on the temperature in the neutron star crust and is thus also sensitive to the physics of the crust and core. Interestingly, KS1731-260 had at least one superburst during its protracted accr! etion outburst but also had a rapidly declining quiescent luminosity. I will compare the superburst ignition conditions from our time-dependent calculations with observations.

- Neutron Star Structure and Neutron-Rich Matter (20 minutes)

  James M. Lattimer – Stony Brook University

  The liquid-droplet equations of state of LPRL (Lattimer, Pethick, Ravenhall Lamb) and LS (Lattimer Swesty) are extended to incorporate better descriptions of the nuclear surface, the neutron skin of nuclei, and density-dependent effective nucleon masses, and are generalized to include both non-relativistic potential and relativistic field-theoretical nucleon-nucleon interactions. Laboratory measurements of nuclear masses, giant resonances, and neutron skin thicknesses provide some constraints to the models. Nevertheless, some basic parameters of the nucleon-nucleon interactions, conveniently expressed as the nuclear incompressibility, the nuclear symmetry energy (and its density dependence), and the specific heats of both bulk nuclear matter and the nuclear surface, are not yet adequately determined. Implications of uncertainties in these parameters for the structure of the crusts of neutron stars, including possible pasta phases, are discussed. Astronomical constraints from observations of neutron star thermal emissions and the timing of radio pulsars (i.e., mass, glitch, and moment of inertia measurements) are explored.

3:10pm - 3:40pm : Afternoon Break

1.4 3:40pm - 5pm : Type-I X-ray Bursts

- Burst Oscillations and Non-Radial Oscillations of Neutron Stars (20 minutes)

  Anthony L Piro – UC Santa Barbara

  Accreting neutron stars often show coherent modulations during type I X-ray bursts, called burst oscillations. Recently there has been much theoretical work suggesting that a nonradial mode can serve as an explanation. After reviewing the phenomenology of burst oscillations, I will discuss the basics of shallow ocean waves in the context of neutron stars, including the interesting complications brought about by rotation. We find that a surface wave in the shallow burning layer evolves into a crustal interface wave as the envelope cools, a new and previously uninvestigated phenomenon. This provides frequencies and drifts that match those observed, and furthermore, the drifts can be used as a probe of the neutron star crust. By modeling the pulsed emission we can begin the exciting process of using burst oscillations to learn about the properties of these accreting neutron stars.

- Constraining Neutron Star Masses and Radii Using High Resolution Spectra (20 minutes)

  Feryal Ozel – University of Arizona

  While recent X-ray missions provide us with high resolution spectra of thermally emitting neutron stars, the largest uncertainties in determining neutron star masses and radii from from these spectra are still theoretical. In order to obtain accurate constraints, (i) the surface layers of neutron stars need to be modeled in detail, (ii) the effects of strong gravity and rotation on surface emission need to be taken into account, and (iii) possible temperature non-uniformity and unknown emission geometry need to be addresses. In this talk, I will discuss recent models of neutron star surface layers and the general relativistic effects on the surface, pointing out the uncertainties in mass-radius determination arising from each. I will then show how combining timing information of neutron stars with their spectra reduces greatly the uncertainties arising from general relativistic and geometrical effects. Finally, I will discuss how combining several different spectral and timing measurements of X-ray sources provides us with complementary and the most promising method for accurate determination of neutron star masses and radii, as well as minimizes observational uncertainties such as source distances.

- Constraints on Neutron Star Interior Physics from Long Type I X-ray Bursts (20 minutes)

  Andrew Cumming – McGill University

  Long term monitoring of accreting neutron stars has revealed a new sample of long duration X-ray bursts. They are thought to occur when a thick layer of fuel undergoes a thermonuclear runaway, either carbon in the case of "superbursts", or helium for other "intermediate duration" bursts. I will present a new comparison of theory and observations of long X-ray bursts, including models of both lightcurves and ignition conditions. The observed properties of helium and carbon bursts are reproduced only if the neutrino emission from the core and crust of the star is inefficient. The ignition conditions for these thick layers are extremely sensitive to the thermal profile of the neutron star interior, and provide a new way to probe neutron star cooling, complementary to observations of isolated neutron stars and accreting neutron stars in quiescence.

- Mass, radius, surface gravity and gravitational redshift determination for the neutron star in the X-ray burst source MXB 1728-34 (20 minutes)

  Agnieszka Majczyna – Warsaw University Observatory (Warsaw, Poland)

  We analyse archival X-ray spectra of MXB 1728-34 obtained in 1996-99 by the instrument PCA on board of the RXTE satellite. X-ray spectra were fitted to our extensive grids of model atmosphere spectra to determine the effective temperature T_{eff} on the neutron star surface, logarithm of surface gravity log(g), and the gravitational redshift z simultaneously. We have chosen fitting by numerical model spectra plus broad gaussian line, modified by interstellar absorption and the absorption on dust. We arbitrarily assume either hydrogen-helium chemical composition of a model atmosphere, or H-He-Fe mixture in solar proportion. The best values of log(g), and z were subsequently used to determine mass and radius of the neutron star. We obtained the best values of the parameters for the neutron star in X-ray burst source MXB 1728-34: mass either M=0.52 or 0.64 M_{sol} (for H-He or H-He-Fe models, respectively), radius and R=5.7 or 5.8 km, log(g)=14.4 or 14.5 and the gravitational redshift z=0.17 or 0.22. Confidence limits are rather large, however, they strongly support the equation of state for strange matter.

5pm - 5:30pm : Open Discussion

2 Thursday 11 August 2005

2.1 9am - 10:30am : Colour Superconducivity I

- A Hot Water Bottle for Aging Neutron Stars? (40 minutes)

  Krishna Rajagopal – MIT

  We understand many of the properties of the densest phase of quark matter rigorously from first principles QCD. However, the nature of the second-most-dense phase of quark matter remains unclear. A recently proposed candidate for this phase features both neutrino emissivity and specific heat that are parametrically enhanced relative to those of all other proposed phases of dense matter – quark or nuclear. If present within a layer of a neutron star, it would control the cooling of the star. The neutrino-dominated cooling would look like standard Direct-URCA as the two enhancements cancel, but old stars, say tens of millions of years and older, would stay orders of magnitude warmer than in any other scenario. Most of my talk will consist of explaining this abstract. At the end, I will explain why it currently remains unclear whether this hot water bottle phase really is the second-densest form of quark matter, and will discuss an alternative possibility.

- Fermion Superfluidity in Compact Stars (30 minutes)

  Sanjay K Reddy – Los Alamos National Laboratory

  Recent theoretical developments in dense matter and neutron star evolution has led to renewed interest in Fermion superfluidity - especially in the strong coupling regime. In this talk I will explore the role Fermion pairing in dense matter inside compact stars and on the phase structure of dense QCD. I will highlight recent work on pairing in asymmetric Fermi systems and on the response of superfluids to external perturbations. I will discuss these result in context of observable aspects compact star structure and evolution.

- Pulsar kicks via spin-1 color superconductivity (20 minutes)

  Andreas Schmitt – MIT

  We propose a new neutrino propulsion mechanism for neutron stars which can lead to strong velocity kicks, needed to explain the observed bimodal velocity distribution of pulsars. The spatial asymmetry in the neutrino emission is naturally provided by a stellar core containing spin-1 color-superconducting quark matter in the A phase. The neutrino propulsion mechanism switches on when the stellar core temperature drops below the transition temperature of this phase.

10:30am - 11am : Morning Break

2.2 11am - 12 noon : Colour Superconducivity II

- Color-spin locking phase in two-flavor quark matter for compact star phenomenology (20 minutes)

  Deborah N. Aguilera – University of Rostock

  We study a spin-1 single flavor color superconducting phase which results from a color-spin locking (CSL) interaction in two-flavor quark matter. This phase is particularly interesting for compact star cooling applications since the CSL phase may survive under charge neutrality constraints implying a mismatch between up- and down-quark chemical potentials which can destroy the scalar diquark condensate. CSL gaps are evaluated within an NJL model and they are found to be consistent with cooling phenomenology if a density dependent coupling constant is used.

- Phase diagram of dense QCD with and without neutrino trapping (20 minutes)

  Igor A Shovkovy – Frankfurt Institute for Advanced Studies

  We study the phase diagram of dense, locally neutral three-flavor quark matter within the framework of the Nambu–Jona-Lasinio model. In the analysis, dynamically generated quark masses are taken into account self-consistently. The phase diagrams in the plane of temperature and quark chemical potential, as well as in the plane of temperature and neutrino chemical potential are presented. We show that neutrino trapping favors two-flavor color superconductivity and disfavors color-flavor-locked phase at imtermediate densities of matter. The implications of these results for the evolution of protoneutron stars are briefly discussed.

- Quantum Anomalies and Topological Currents in Dense Matter (20 minutes)

  Ariel Zhitnitsky – UBC

  We derive an anomalous effective Lagrangian describing the interactions of light particles such as axions, photons and superfluid phonons in the dense matter background. This effective Lagrangian, among other things, imlies that some nontrivial persistent non dissipating currents and charge densities may be formed in the dense matter. We speculate that these effects may influence such phenomena as neutron star kicks, glitches, cooling rate...

12 noon - 12:30pm : Open Discussion

12:30pm - 2pm : Lunch Break

2.3 2pm - 3:30pm : Magnetars I

- Observational Properties of Magnetars (40 minutes)

  Vicky Kaspi – McGill University

  I will review recent observational results concerning magnetars.

- Hard X-ray Characteristics of Anomalous X-ray Pulsars: Results from RXTE and INTEGRAL (20 minutes)

  Peter R. den Hartog – SRON - Netherlands Institute for Space Research

  Until recently anomalous X-ray pulsars (AXPs) were known as soft X-ray emitters. This has changed drastically since the discovery of hard X-ray emission (¿10 keV) from several AXPs by INTEGRAL (Molkov et al. 2004, Revnivtsev et al. 2004 and den Hartog et al. 2004). Kuiper et al. (2004) discovered pulsed emission in the same energy range using RXTE (PCA and HEXTE) data. Currently four AXPs (1RXS J170849.0-400910, 1E 1841-045, 4U 0142+614 and 1E 2259+586) have been detected, some of them showing emission up to 200 keV. The spectra exhibit extremely hard power laws with photon indices < 1.0 and with apparent luminosities 2-3 orders of magnitude above the rotational energy loss. The origin of this behaviour is not yet understood.

  An overview containing the current observational status in the temporal and the spectral domains as well as future prospects of AXPs at high energies is presented.

- XMM-Newton observations of the two Anomalous X-ray pulsars 1E 1048.1-5937 and 1RXS J170849.0-400910 (20 minutes)

  Silvia Zane – Mullard Space Science Laboratory, University College of London

  We report the results of XMM-Newton observations of two Anomalous X-ray pulsars: 1E 1048.1-5937 and 1RXS J170849.0-400910. 1E 1048.1-5937 was observed in 2000, 2003, and 2004. The comparison of the three data sets shows an anti-correlation between flux and pulsed fraction, implying that previous estimates of the source energetics based on the assumption of a large and constant pulsed fraction might be significantly underestimated. The source spectrum is well described by a power law plus blackbody model ($kT \sim 0.63keV$, photon index $\Gamma \sim 2.7 - 3.5$) or, alternatively, by the sum of two blackbodies of which the hotter is Comptonized by relativistic electrons. The long term luminosity variation of a factor > 2 is accompanied by relatively small variations in the spectral shape. Phase resolved spectroscopy indicates a harder spectrum in correspondence of the pulse maximum.

  1RXS J170849.0-400910 was observed in 2003 August and was found at a flux level a factor of about two lower than previous observations.A significant spectral evolution appears to be present, the source exhibiting a much softer spectrum than in the past. Comparison of the present properties with those from archival data shows a clear correlation between the X-ray flux and the spectral hardness. We discuss a possible explanation for the glitches and for the softening of the source emission which followed the flux decrease, in the framework of the magnetar model.

- On the Parallax of Geminga (10 minutes)

  Frederick M Walter – Stony Brook University

  Geminga is one of the seminal sources for high energy astrophysics. It is a radio-quiet X-ray and gamma-ray pulsar, and one of the strongest sources of pulsed gamma ray emission in the sky. Its spectrum features a soft thermal component and a hard tail. Its characteristic age is 340,000 years, and it may have been born in the Orion OB1 association. Carraveo et al (1996) claimed a distance of 157 (+59, -34) pc using a parallax determination based on 3 HST WFPC2 images.

  Given the importance of this object for understanding the high energy radiation processes in magnetized neutron stars, we decided to confirm the parallax using an optimized set of HST/ACS images. We obtained deep V-band images in September 2003, March and September 2004, and March 2005, at the extrema of the parallactic shift of Geminga. As of this writing, we are analyzing the images and coming to terms with the instrumental anomalies of the ACS. We expect to report a preliminary parallax of Geminga.

Collaborators on this work include Jacqueline Faherty, James Lattimer, and George Pavlov. This work is supported by a grant from the Space Telescope Science Institute.

3:30pm - 4pm : Afternoon Break

2.4 4pm - 5:10pm : Magnetars II

- Detection of a Debris Disk around an AXP with Spitzer (20 minutes)

  Zhongxiang Wang – MIT

  We have detected of a debris disk around a young isolated neutron star (specifically, an AXP) using Spitzer data. There is a clear signature of thermal emission from a disk in the mid-IR (it is a completely distinct spectral component from the optical emission), and it is well-fit by an X-ray heated disk model (a passive, irradiated debris disk, not an accretion disk). This may well be the first detection of a supernova fallback disk.

- Understanding Magnetars with Conservative Physics (20 minutes)

  David Eichler – Ben-Gurion University of the Negev

  I review recent progress in understanding observations of SGRs and AXPs under the assumptions that they have normal (non-strange) crusts and superfluid cores. Several qualitative manifestations of ultrastrong fields have probably been observed, including the recent 27 December 2004 event, and others remain theoretical possibilities.

- Magnetospheres of Magnetars (30 minutes)

  Andrei M Beloborodov – Columbia University

  Properties of magnetar magnetospheres will be reviewed. Then a model of their persistent nonthermal emission will be presented, which relates emission to the electric circuit in a twisted magnetosphere. A self-consistent model of plasma dynamics in the circuit allows one to answer basic questions: What are the magnetospheric particles? What are their temperature and density? What is the dissipation rate in the magnetosphere? How and where is the observed nonthermal emission produced?

5:10pm - 6:40pm : Poster Session in Hennings 302 and 304

7pm : Banquet

3 Friday 12 August 2005

3.1 9am - 10:30am : Young Neutron Stars I

- Absorption lines in the spectra of nearby neutron stars (30 minutes)

  Marten H van Kerkwijk – Univ. of Toronto

  Over the last year, photospheric absorption features - likely due to hydrogen in strongly magnetized atmospheres - have been found in X-ray spectra taken with XMM and Chandra for three nearby neutron stars. I will discuss what we have learned from those observations and describe the new puzzles they have posed. I will also present initial results from our large, 300 ks Chandra programme on one of the brightest sources.

- Optical Properties and origin of Radio-Quiet X-ray Dim Isolated Neutron Stars (20 minutes)

  Christian Motch – Observatoire de Strasbourg

  ROSAT has discovered a small group of X-ray emitting isolated neutron stars (INS) characterised by a lack of radio emission and a soft thermal-like X-ray spectrum. Weak interstellar absorption indicates relatively small distances of a few hundred parsecs and the absence of nearby SNR suggests middle-age objects or old neutron stars re-heated by accretion from the interstellar medium. Their proximity and the absence of strong non-thermal activity make them unique laboratories for testing radiative properties of neutron star surfaces, high gravity and high magnetic field physics. Most of these INS have optical counterparts from which contraints on the surface emitting properties can be derived. Optical imaging also allows sensitive searches for proper motion which can provide information on space velocity and birth place. I will report on the current problems faced by the modelling of the optical to X-ray energy distributions and will discuss the evolutionary status, age and origin of this particular population.

- Constraints on the formation of magnetars from associated supernova remnants (20 minutes)

  Jacco Vink – SRON Netherlands Institute for Space Research

  It is now generally accepted that Anomalous X-ray Pulsars (AXPs) and Soft Gamma-ray Repeaters (SGRs) are magnetars, i.e. neutron stars with surface magnetic fields of $10^{14} - 10^{15}$ G. The origin of this magnetic field is uncertain, but one of the hypotheses is that magnetars are born with an initial spin period close to the break-up limit (< 1 ms), which results in a powerful dynamo action, greatly amplifying the seed magnetic field. A neutron star spinning at such a rate has a rotational energy in excess of 10^{52} erg, and part of that energy will power the supernova through rapid magnetic breaking. In other words it is expected that if magnetars are born with periods of ~ 1 ms their supernova remnants should be very energetic. However, we have investigated two supernova remnants which contain magnetars, Kes 73 (1E 1841-045) and N49 (SGR 0526-66), and they appear to be the results of explosions with the canonical supernova explosion energy of 10^{51} erg. Converting this to an initial rotation period suggests that the initial period was longer than ~ 6 ms. This poses problems for the theory. However, there is the possibility that the conversion of rotational energy to magnetic field energy is so efficient that $\sim 90\%$ of the rotational energy is used to generate an interior magnetic field of $\sim 10^{17}$ G, far in excess of the surface magnetic field estimated from the spin-down rate.

- Nearby radio-quiet isolated neutron stars with strong magnetic fields (20 minutes)

  Frank Haberl – MPE Garching

  Presently seven radio-quiet isolated neutron stars with thermal X-ray emission are known. Their X-ray spectra are characterized by soft blackbody-like emission (kT $\sim$ 45-120 eV) without indication for harder, non-thermal components. These stars apparently show no radio emission and no association with supernova remnants. Five of them exhibit pulsations in their X-ray flux with periods in the range of 3.45 s to 11.37 s. XMM-Newton observations revealed broad absorption lines in the X-ray spectra which may be caused by cyclotron resonance absorption of protons or heavy ions. I'll review our present knowledge about this group of isolated neutron stars with particular emphasis on their X-ray properties.

10:30am - 11am : Morning Break

3.2 11am - 12:20pm : Neutron-Star Atmospheres

- Constraining the Properties of Isolated Neutron Stars Through Astrometry and (20 minutes)

  David L Kaplan – MIT

  We will discuss the results of dedicated programs that use high-precision optical astrometry and phase-coherent X-ray timing to measure the distances, proper motions, ages, and magnetic field strengths of nearby, isolated neutron stars.

- Searches for Absorption Lines in Neutron Star Atmospheres (20 minutes)

  Herman L Marshall – MIT Kavli Institute

  There have been many observations of neutron stars with high resolution X-ray spectrometers where the primary goal was to observe narrow absorption features that could then be used to determine the surface redshift. To date, there is still only one reported detection. I will summarize results from many of the observations using the Chandra grating spectrometers, including X-ray bursters, magnetars, and weakly magnetized isolated neutron stars. I will describe some of the difficulties involved and what efforts may be required.

- A Unique Neutron Star: Detailed Spectral and Theoretical Analysis of 1E1207.4-5209 (20 minutes)

  Kaya Mori – Canadian Institute for Theoretical Astrophysics

  1E1207.4-5209 is unique because it is the only isolated neutron star with multiple spectral features. We present our detailed analysis of the 260 ksec XMM-Newton data focusing on the putative absorption features at 2.1 and 2.8 keV reported by Bignami et al. 2003. Our statistical tests show the 3rd and 4th feature are insignificant, and only the two broad absorption features previously reported are significant. We have also confirmed that the residuals are consistent in strength and position with the instrument Au-M residuals observed in 3C273. We also present the results from our recent phase-resolved spectral analysis of 1E1207. At the end, we discuss our model for the two absorption features in terms of atomic transition lines from highly-ionized Oxygen or Neon and compare that picture with other competing models. Future high resolution spectroscopy is essential to elucidate the surface composition of 1E1207 and to understand why 1E1207 is unique compared to other isolated neutron stars.

- Resonant Cyclotron Scattering and Comptonization in Neutron Star Magnetospheres (20 minutes)

  Maxim Lyutikov – UBC

  Resonant cyclotron scattering of the surface radiation in magnetospheres of neutron stars may considerably modify emergent spectra. Resonant tranfer has a number of unusual characteristics: (i) in the limit of high resonant optical depth, cyclotron resonant layer is half opaque, in a sharp contrast to the case of non-resonant scattering; (ii) transmitted flux is on average Compton up-scattered by 1+ 2 betaT, where betaT is a typical thermal velocity in units of the velocity of light; reflected flux has on average the initial frequency. (iii) for both transmitted and reflected fluxes the dispersion of intensity decreases with increasing optical depth; (iv) emerging spectrum is appreciably non-Plankian while narrow spectral features produced at the surface are erased; (v) optical optical photons are less affected by resonant Comptonization than X-rays due to different polarization of normal modes in resonances. We discuss applications to Anomaous X-ray Pulsars and thermally emitting Isolated Neutron Stars

12:20pm - 12:50pm : Open Discussion

12:50pm - 1:50pm : Lunch Break

3.3 1:50pm - 3:10pm : SGR 1806-20

- XMM-Newton Observations of SGR 1806-20 in the Pre-Giant Flare Epoch (20 minutes)

  Roberto Turolla – Dept. of Physics, University of Padova, Italy

  I present results from XMM-Newton observations of the Soft Gamma-ray Repeater SGR 1806-20. Four pointings were carried out in 2003-2004 and catched the source in different states of activity. During these two years the 2-10 keV flux doubled with respect to the historical level observed previously. The long term raise in luminosity was accompanied by a gradual hardening of the spectrum, with the power-law photon index decreasing from 2.2 to 1.5, and by a growth of the bursting activity. The pulse period measurements obtained in the four observations show a steady increase and are consistent with a high spin-down rate at an average value of 5.5e-10 s/s. The long term behavior of SGR 1806-20 follows the correlation between spectral hardness and spin-down rate previously observed only by comparing different SGRs and AXPs. The relevance of these results for the magnetar scenario, and for the twisted magnetosphere model in particular, are discussed also in the light of post-flare Chandra and XMM observations.

- Burst Observations from the Two Neighboring Magnetars SGR 1806-20 and XTE J1810-197 (20 minutes)

  Alaa I. Ibrahim – GWU

XTE J1810-197 is a newly discovered magnetar with a new flavor of being transient (Ibrahim et al. 2004). Monitoring observations revealed that the source emitted a few X-ray bursts that appear to show different properties than most SGR bursts (Woods et al. 2005). We confront these bursts with those from SGR sources, especially SGR 1806-20, and discuss the implications of the results to a number of open questions on magnetars including whether SGR and AXP bursts are intrinsically different and the presence of spectral line feature in some magnetar bursts.

Ibrahim, A. et al. 2004, ApJ, 609, L21 Woods, P. et al. 2005, ApJ, in press

- Evidence for a magnetospheric untwisting in the post-Giant Flare X-ray emission of SGR 1806-20 (20 minutes)

  Nanda Rea – SRON - National Institute for Space Research

  The Chandra satellite observed the magnetar candidate SGR 1806-20 almost one month after its Giant Flare in December 2004. This was the first X-ray observation after the flare with a high spectral resolution instrument. The X-ray emission of the source strongly suggest that a magnetospheric untwisting took (or is still taking) place, soon after the twist which could have triggered the Giant Flare.

- Rapid X-ray oscillations in magnetar giant flares (20 minutes)

  Anna L Watts – NASA Goddard Space Flight Center

  Israel and co-authors recently reported the detection of high frequency QPOs in the December 2004 giant flare from the magnetar SGR 1806-20. They suggested that the QPOs may have their origin in torsional vibrations of the neutron star crust. In this talk we report the discovery of similar high frequency oscillations in the August 1998 giant flare of SGR 1900+14. We discuss our findings in the light of the torsional mode model and show that if the stars have similar masses then the magnetic field of SGR 1806-20 must be about twice as large as that of SGR 1900+14, which is broadly consistent with magnetic field estimates from pulse timing. We also show how detailed mode identifications could lead to constraints on the nuclear equation of state.

3:10pm - : Free Afternoon

4 Saturday 13 August 2005

4.1 9am - 10:20am : Young Neutron Stars II

- Central Compact Objects in Supernova Remnants (30 minutes)

  George Pavlov – Pennsylvania State University

  X-ray observations show puzzling compact objects near centers of some SNRs. Having X-ray luminosities in a range of $10^{32} - 10^{34}$ erg/s, they have not been seen in radio, optical, and gamma-ray bands, and they do not show pulsar wind nebulae expected for active radio and/or gamma-ray pulsars. Their X-ray spectra are predominantly thermal, with temperatures of a few million kelvins and emitting areas much smaller than the surface area of a neutron star. About eight such sources are currently known, and it is not clear whether they constitute a uniform class or it is a collection of physically different objects. It seems plausible that at least some of these sources are related to magnetars, but no firm confirmation of this hypothesis has been obtained. I will give an overview of the available observations of the whole class and discuss possible interpretations of their properties. I will also present our recent deep X-ray and optical observations of two best-studied (and most puzzling) CCOs, with most distinct properties: the central source of the Cas A SNR and the famous 1E 1207-5209 in the SNR G296.5+10.0. The Cas A CCO is the youngest member of this class, and its properties most strongly resemble those of magnetars, although its period has not been detected yet. In contrast, 1E 1207-5209 shows pulsation with a period of about 424 ms, which varies with time nonmonotonically, possibly because it is in a wide binary system with a low-mass companion. This is the only CCO from which spectral lines have been detected, which provides an opportunity to measure the gravitational redshift at the neutron star surface. I will discuss the properties and possible interpretations of these puzzling lines.

- Cooling Limits from the Youngest Neutron Stars (20 minutes)

  Patrick Slane – Harvard-Smithsonian Center for Astrophysics

  One of the primary means of constraining the cooling properties of neutron stars, and thus the structure and composition of their deep interiors, is through measurements of their X-ray properties. The youngest neutron stars provided some of the strongest constraints, particularly in cases where the total luminosity is low. However, the X-ray emission from young neutron stars is often dominated by nonthermal emission. Thus, high-sensitivity observations and subsequent spectral modeling are necessary to confidently identify the emission, or limits to the emission, directly from the stellar surface. Here I summarize recent work on establishing the temperature properties of the youngest neutron stars.

- Neutrino Pulsars (30 minutes)

  Bennett Link – Montana State University

  Neutron stars are efficient accelerators for bringing charges up to relativistic energies. I show that if positive ions are accelerated to ~ 1 PeV near the surface of a young neutron star, protons interacting with the star's radiation field will produce beamed μ neutrinos with energies of ~ 50 TeV resulting in certain neutron stars being the brightest neutrino sources at these energies yet proposed. The neutrinos would be roughly coincident with the radio beam, so that if the star is detected as a radio pulsar, the neutrino beam will sweep the Earth; the star would be a "neutrino pulsar". Looking for ν_μ emission from young neutron stars will provide a valuable probe of the energetics of the neutron star magnetosphere.

10:20am - 10:50am : Morning Break

4.2 10:50am - 12:20pm : Spin and Binaries

- Internal dissipation through beta processes and thermal emission from old neutron stars "rotochemical heating" constraints on a time-variation of Newton's "constant" of gravity (30 minutes)

  Andreas Reisenegger – Pontificia Universidad Catolica de Chile (PUC)

  The equilibrium composition of neutron star matter is achieved through weak interactions, which proceed on relatively long time scales. If the density of a matter element is perturbed, it will relax to the new chemical equilibrium through non-equilibrium reactions, which produce entropy that is partly released through neutrino emission, while a similar fraction heats the matter and is eventually radiated as thermal photons. We examined two possible causes of such density perturbations: 1)the reduction in centrifugal force caused by spin-down (particularly in millisecond pulsars), leading to "rotochemical heating" (astro-ph/0502116), and 2)a hypothetical time-variation of the gravitational "constant", as predicted by some theories of gravity and current cosmological models ("gravitochemical heating"). If only slow weak interactions are allowed in the neutron star (modified Urca reactions, with or without Cooper pairing), "rotochemical heating" can roughly account for the observed ultraviolet emission from the closest millisecond pulsar, PSR J0437-4715, which also provides a constraint on —dG/dt— of the same order as the best available in the literature.

- Global, time-dependent flow of a neutron star superfluid (20 minutes)

  Andrew Melatos – University of Melbourne

  The global time-dependent flow of superfluid inside a neutron star has received little theoretical attention in the past, partly thanks to numerical challenges (including visualization), and partly because local processes (e.g. vortex pinning), which set the boundary conditions for the global flow, have taken precedence. In this talk, we describe several new phenomena that emerge when the global problem is considered, driven by differential rotation in the star. (i) A Kelvin-Helmholtz instability occurs at the boundary between the (anisotropic) 3P2 core superfluid and the (isotropic) 1S0 crust superfluid, suddenly transferring circulation (carried by clusters of vortices) to the crust in amounts comparable to those observed during glitches (and in accord with high-resolution laboratory experiments). (ii) Quasiperiodic torque noise ("oscillations") occurs as a natural consequence of the frictionally coupled

(Hall-Vinen-Bekharevich-Khalatnikov) flow of normal fluid and superfl! uid inside a sheared spherical shell, as in the stellar inner crust. We present the results of high-resolution, 3-dim hydrodynamic simulations of this flow, which displays a rich structure of Taylor-like vortices, Ekman layers, and meridional currents. (iii) The rectilinear vortex array in the core quickly breaks up into a reconnecting vortex tangle when the meridional flow exceeds a threshold. We present the results of line vortex simulations which show that the mutual friction and tension forces in the HVBK theory decrease suddenly when this happens, exciting jumps and damped oscillations in the torque. These phenomena are related to radio observations of timing irregularities in rotation-powered pulsars.

- Highlights of Recent Binary Pulsar Observations at Arecibo (30 minutes)

  David Nice – Princeton

  I will describe some recent results of binary and millisecond pulsar observations with the Arecibo radio telescope. Topics to be described include (1) the surprisingly high mass (2.1+-0.2 solar masses) of PSR J0751+1807 and a possible inverse correlation between pulsar mass and orbital period, (2) the surprisingly low proper motion of the Hulse-Taylor binary PSR B1913+16, and (3) first results from the PALFA survey, a deep pulsar search along the Galactic plane.

- Timing the Double-pulsar System (10 minutes)

  Ingrid Stairs – UBC

  I will present the current status of the timing solution for the double pulsar J0737-3039, and will discuss future observables, including the prospect of measuring a neutron-star moment of inertia through the spin-orbit contribution the advance of periastron.

12:20pm - 12:50pm : Open Discussion

12:50pm - 2:20pm : Lunch Break

4.3 2:20pm - 3:50pm : Masses and Radii

- Neutron Star Radii: At the Crossroads (30 minutes)

  Robert E Rutledge – McGill

  Transient Low Mass X-ray Binaries in quiesence have offered a primary means to measure neutron star radii. In this talk, I will review the theory which motivated the investigation of these sources for neutron star radius measurements, the observational status of this direction, what we have learned so far in the era of high throughput X-ray spectroscopy, and where we can expect these observations to take us.

- The extremely faint quiescent NS SXT 1H 1905+00: constrainst on the NS EoS (20 minutes)

  Peter G Jonker – SRON Utrecht / CfA Cambridge

  Observations of black hole and neutron star Soft X-ray Transients (SXTs) with Chandra and XMM-Newton turned out to have a profound impact on two important areas of high energy astrophysics. First of all, comparing the quiescent luminosity of neutron star SXTs with that of black hole SXTs it was found that black hole (BH) SXTs are systematically fainter in quiescence than neutron stars (e.g. Narayan, Garcia, McClintock 1997, Garcia et al. 2001). This has been interpreted as evidence for advection of energy across a BH event horizon. Despite many objections to this interpretation, alternative explanations for the difference in quiescent luminosity, and neutron stars which turned out to be fainter than initially found to be rule, none of the neutron star SXTs is as faint as the BH SXT A 0620-00 in quiescence. Secondly, in observations of neutron star SXTs in quiescence which allow for a spectral study, the spectrum was found to be well-fit by a neutron star atmosphere model (NSA) sometimes supplemented with a power-law component. Well established theories about the time averaged mass accretion rates in neutron star SXTs, the pycnonuclear reactions taking place in the neutron star crust combined with neutron star cooling theory predictions, yield a neutron star core temperature. This hot neutron star core, moderated by the neutron star atmosphere, is thought to be observed during the quiescent phase of neutron star SXTs. In theory, a NSA-fit provides means to measure the mass and radius of the neutron star and hence constrain the equation of state (EoS) of matter at supranuclear densities. The description of the relations between pressure and density of matter (the EoS) under the extreme conditions encountered in neutron stars is one of the ultimate goals of the study of neutron stars. We recently observed the neutron star SXT 1H1905+000 in quiescence with ACIS-S. However, the source was not detected even though the distance and interstellar extinction are well known. This means that the source (thermal) luminosity in the 0.5-10 keV band is lower than 10^{31} erg $s^{-}1$. From this and from the fact that it is known from binary evolution theory that the time averaged mass accretion rate cannot be much less than 10^{-12} Msun per year, we conclude that the neutron star must be so massive that only EoSs with a nucleonic core can exist.

- Atomic Transition Lines During Type I X-Ray Bursts (20 minutes)

  Philip Chang – University of California Santa Barbara

  The discovery of the first atomic transition lines from a bursting neutron star (NS) by Cottam, Paerels and Mendez is the solid measurement of gravitational redshift from a NS surface. I will review the observation and discuss the basic physics of the neutron star atmosphere and line formation in this context. I will highlight the important effects of Stark broadening, resonant scattering and NLTE effects (level population) on the formation of the Fe Hα and Lyα lines. With the inclusion of these effects, I reproduce the appropriate equivalent width of the observed line with Fe columns that are consistent with solar metallicity accretion. I also compare the fully relativisitic rotationally broadened line profile to the data and find that the NS spin is $\nu_{\rm s} \sin i (R/10\,{\rm km}) = 32^{+52}_{-28}\,{\rm Hz}$ with 95% confidence, in agreement with the 44.7 Hz spin detected by Villarreal and Strohmayer. However, fine structure splitting of the line precludes a meaningful constraint on the radius of this NS. Finally I highlight future prospects for detecting other features on more rapidly rotationing NSs and their application in determining both the redshift and radius to contraint the nuclear equation of state.

- Neutron Stars at X-ray Wavelengths: NASA's Constellation-X Mission (20 minutes)

  Divas Sanwal – JHU/GSFC

  Among the most important topics in Neutron Star (NS) astrophysics is the equation of state of the matter in their interiors. Observations in X-rays wavelengths with the improved sensitivity and spectral resolution provided by Chandra and XMM-Newton have greatly enhanced our understanding of NSs. We have discovered long sought spectral lines from NSs, increased the number of NSs detected in X-rays and started to perform phase-resolved spectroscopy of NS to map the surface and differentiate among the different emission components.

  The Constellation-X observatory is being developed to perform spatially resolved high-resolution X-ray spectroscopy. This talk focuses on the driving science behind this mission, which is one of two flagship missions in NASA's Beyond Einstein program. A general overview of the observatory's capabilities and basic technology will also be given. Constellation-X would provide an opportunity to study Neutron Star with high sensitivity and spectral resolution. I will also present the projections into the impact on Neutron Star astrophysics with the Constellation-X observatory.

3:50pm - 4:20pm : Afternoon Break

4.4 4:20pm - 5:10pm : Magnetospheres

- Signatures of neutron star oscillations in post-glitch emission of radiopulsars (20 minutes)

  Andrey Timokhin – Sternberg Astronomical Institute

  Experimental determination of neutron stars eigenmodes parameters would provide important information about internal structure of the neutron stars. Isolated NSs should be more suitable for such studies, because their power spectra are not contaminated by numerous instabilities in accreted material. The vast majority of known isolated NSs are radiopulsars, in ~ 50 of them glitches are observed. Glitches can excite neutron star oscillations, because they are connected with transfer of rotation energy from one stellar component (core) to another (crust). The main attention in this work is drawn to distortion of pulsar magnetosphere by neutron star oscillations. Pulsar "standard model" of rotating magnetized conducting sphere surrounded by plasma is generalized in its essential parts for the case of oscillating star. Goldreich-Julian charge density, electromagnetic energy losses, as well as polar cap scenario of particle accelerations, are considered. The changes in the Goldreich-Julian charge density due to star pulsations for oscillation modes with high harmonic numbers (l,m) are essential, and will lead to substantially distortion of accelerating electric field in pulsar polar cap. This can result in remarkable changes of individual pulse profiles of radiopulsars. It is shown, that for moderately optimistic scenario of NS's oscillations excitation by the glitch, such changes in pulsar radiation could be detected by contemporary radiotelescopes.

- Magnetospheres of neutron stars (30 minutes)

  Anatoly Spitkovsky – KIPAC, Stanford University

  Rotating magnetized neutron stars generate enormous electric fields near the surface and populate their magnetospheres with relativistic plasma. The detailed structure of pulsar and magnetar magnetospheres has remained an unsolved problem for a long time. Understanding the magnetospheric structure is crucial for determining the neutron star energy loss rate and its radiative properties. In this talk I present the time-dependent numerical solution of pulsar magnetospheric structure in the limit of force-free relativistic MHD. Both aligned and oblique dipole case are addressed, paying particular attention to the spontaneous formation of current sheets in the magnetosphere. The numerical method is applicable to generic differentially rotating magnetized configurations and is further used to study magnetospheres of magnetars, both in the quescent state, and during rapid field reconfiguration in flares.

5:10pm - 5:40pm : Open Discussion and Closing Remarks