Compact Objects

Work done @ IUCAA

In astronomy, the term compact object (sometimes compact stars) is used to refer collectively to white dwarfs, neutron stars, other exotic dense stars, and black holes (see poster on Types of stars for definitions of these).These objects are all small for their mass. For example a neutron star has 5 lakh Earth masses squeezed into a 10 km radius.

Birth of Compact stars after death of normal stars

When a star has exhausted all its fuel, the gas pressure of the hot interior can no longer support the weight of the star and the star dies by collapsing to a denser state : a compact star is born. Most compact objects are end points of stellar evolution and thus called stellar remnants; the form of the remnant depends primarily on the mass of the star from which it is formed.

Why do we study compact objects

Being the remnant of a massive star, a compact object itself is a fossil record of past star formation, particularly for low−mass X−ray binaries (LMXRBs, XRBs where the donor star has a low mass). And the young, massive donor stars in high−mass X−ray binaries make them proxies for ongoing star formation. Studies of white dwarfs, neutron stars, and black holes
(compact objects) can reveal a wide range of important astrophysical phenomena, such as their relationship with the formation of stars and galaxies, the universal processes of accretion and jet formation, and fundamental gravitational physics.

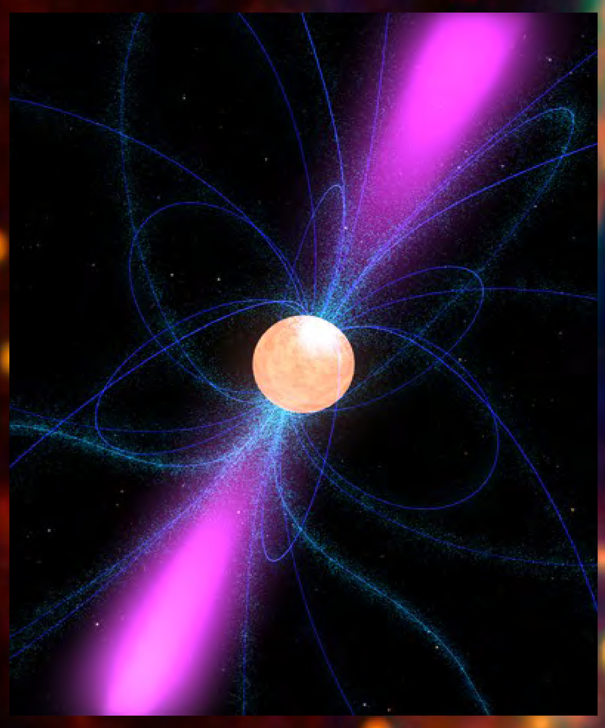
Research at IUCAA

Because of the rich reservoir of open scientific questions that can be probed with compact objects, our research at IUCAA focuses on theoretical as well as multi−wavelength observational studies of compact objects, ranging from Galactic sources as close as a few hundred parsecs away to accreting compact objects (X−ray binaries; XRBs) in nearby galaxies, and active galactic nuclei (AGNs) billions of light years away. With observations spanning across the electromagnetic spectrum (using interferometric radio arrays, ground−based optical and infrared telescopes, and optical and X−ray satellites), statistics, and astronomical data−mining, we are able to study a wide range of properties of compact objects.

Pulsars

A typical Neutron Star produced in a stellar collapse would possess a strong (Teragauss) magnetic field and very rapid spin (period ranging from milliseconds to seconds).

They produce strong, beamed radio emission from their magnetic polar regions.



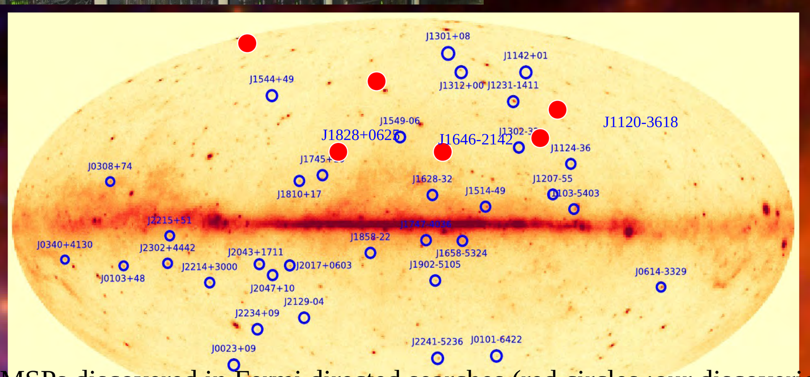
As the beam sweeps past us, we see a pulse of the radio emission - such objects are called Pulsars. These are among the most accurate known clocks.

Millisecond pulsars (pulsars with millisecond periodicity) are Superb Tools for studying many aspects of Fundamental Physics, for example:

- Equation of state at nuclear densities
- Relativistic dynamics in binary systems
- Gravitational wave detection
- Interstellar medium
- Binary evolution (80% of MSPs are in binary)
- Atomic physics (atmospheres)
- Solid state physics (crusts)
- Plasma physics (eclipses, magnetospheres)

Fermi directed millisecond pulsar(MSP) search

Estimates for the Galactic population of MSPs is more than 40000, only about 200 of which have been detected so far. MSP discovery demands very sensitive observing facility, and intensive computing.



MSPs discovered in Fermi directed searches (red circles :our discoveries)

In the past four years the population of Galactic disk MSPs has increased by 58%. 42% of these discoveries are from Fermi directed searches at radio frequencies.

Scientists of IUCAA and NCRA in collaboration with FERMI pulsar search consortium are conducting a deep survey with the GMRT for millisecond pulsations.

The compute intensive search analysis is performed at the IUCAA super computing clusters.

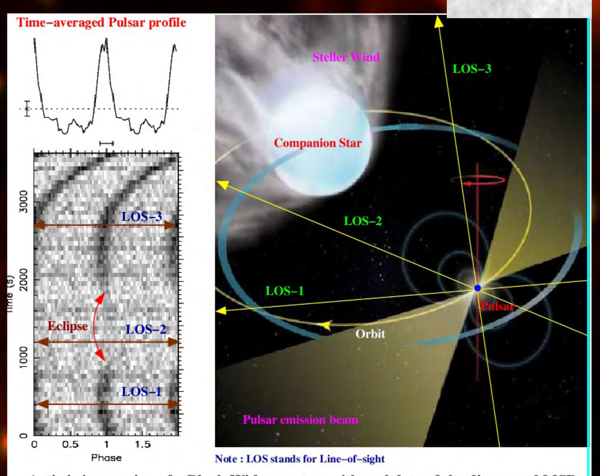
Discovery of 6 interesting MSPs from the ongoing survey

: Our discoveries are already pushing the parameter space of known MSPs

: These are the first Galactic disk MSPs discovered with the GMRT

Majority of MSPs are naturally expected to be in binaries
(i.e. orbiting around another star)

Isolated MSPs are thought to be formed in binary systems where pulsar radiation can vaporize away the companion !
: Such systems are called **Black Widow** systems
(in analogy with certain kind of Spiders found in United States, which eat up their companions)



Note : LOS stands for Line-of-sight
Artistic impression of a Black Widow system with real data of the discovered MSP

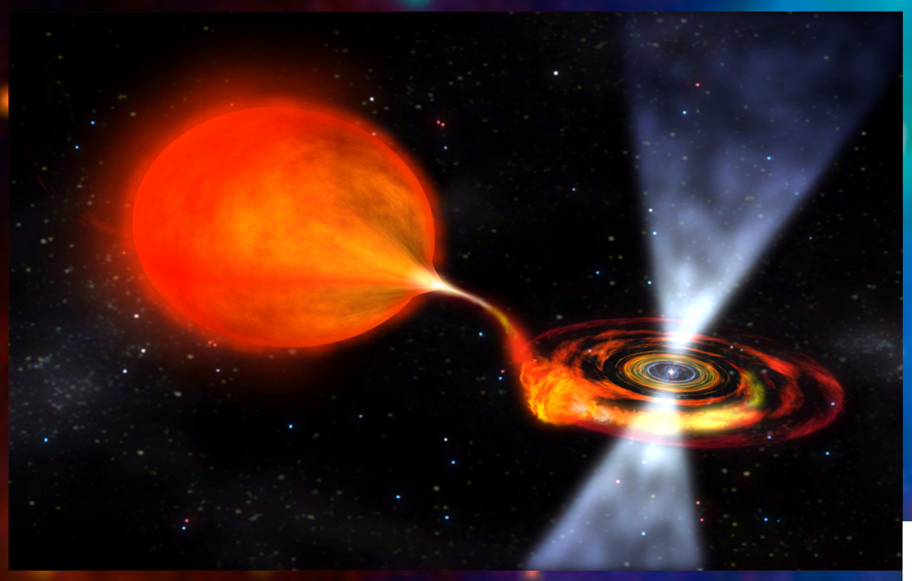
One of our newly discovered MSP is a Black Widow system

The pulsar is destroying its own companion
Eclipses seen for very large duration
Very low mass companion ~ 20 Jupiter mass

Eclipsing material too distended to be gravitationally bound.
Pulsar is ablating its companion and creating significant amount of intra binary matter to block pulsar emission.

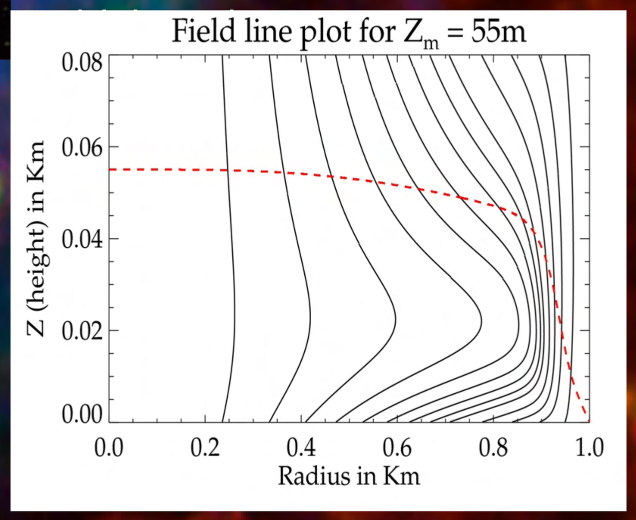
Eclipsing BLACK WIDOW pulsars help
-- Provide better understanding of evolutionary history of isolated MSPs
-- The study of eclipse mechanism
-- The study of relativistic pulsar winds
-- Probe the pulsar magnetosphere

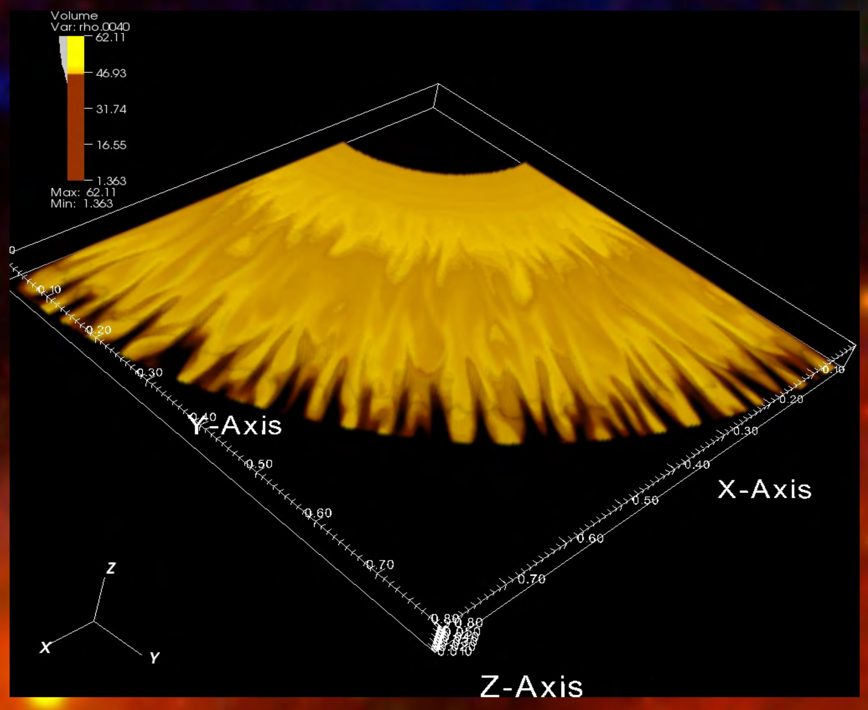
Accreting neutron stars



Often neutron stars have a companion star in a binary system.
Matter from the companion is attracted towards the neutron star and forms an accretion disc.
The strong magnetic field of the neutron star guides the infalling matter on to the poles

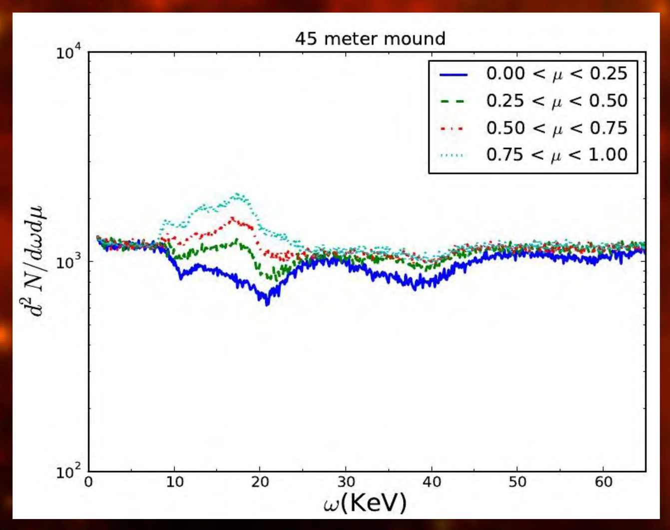
Scientists in IUCAA have been trying to understand the acrretion process on such objects. The accreted matter accumulates on the poles to form mounds confined by the magnetic fields. Such accretion mounds significantly distort the local magnetic field.



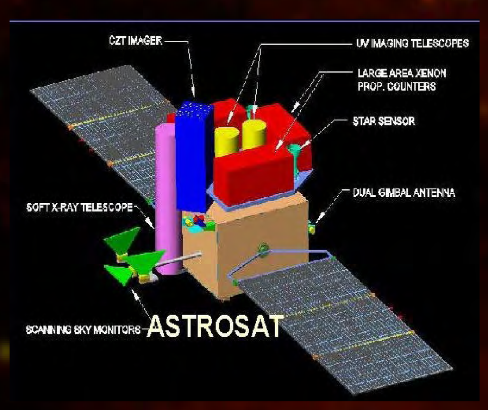


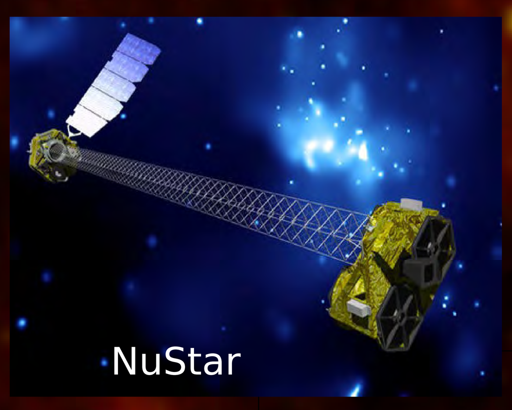
Magneto-hydrodynamic simulations performed in IUCAA show that accretion mounds will be severly affected by fluid instabilities, forming finger-like channels in the radial direction and causing
outflow of matter

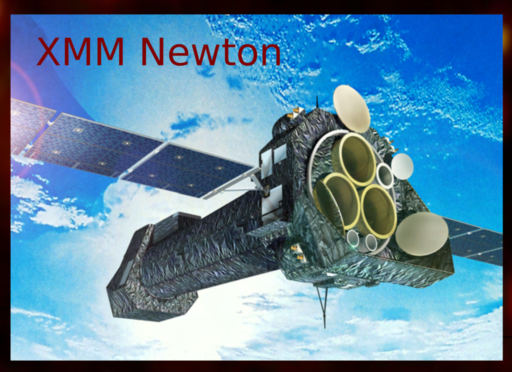
Scientists in IUCAA have also been simulating cyclotron spectra expected from such mounds using Monte-Carlo treatment of photon propagation. The simulated spectra show complex features due to the variation of local magnetic field. Observing such exotic objects in X-rays will help us understand the various underlying physical processes.



Scientists at IUCAA are observing such objects through many X-ray telescopes in space, and are actively planning to utilize future such missions.







Amongst them, ASTROSAT is an indigenously built X-ray telescope with multiple detectors and instruments. It is India's first major space telescope and will be launched soon!