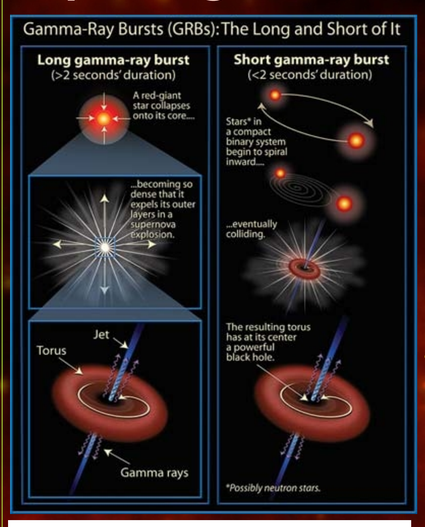
# STARS

# WORK DONE @ IUCAA

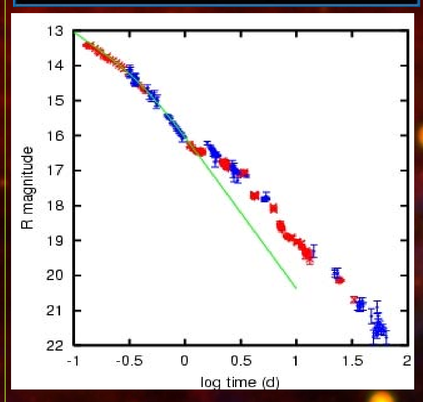
## Exploding Stars: Supernovae and Gamma Ray Bursts



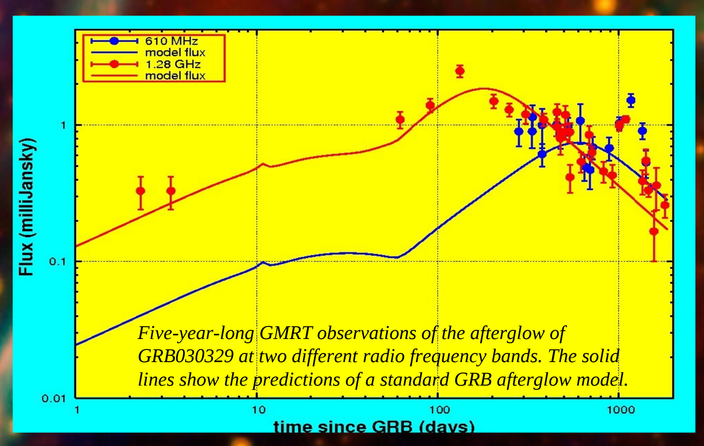

In the end phase of a massive star an enormous amount of gravitational binding energy, ~$10^{53}$ erg, is suddenly released due to collapse of the core, an event called Supernova Explosion. A supernovae explosion may end up forming a neutron star or a black hole at its centre.

In cases, when the object produced at the centre is a rapidly spinning black hole, two powerful jets of material stream out producing a bright flash of gamma rays lasting a few seconds. These are called Gamma Ray Bursts (GRB), one of the brightest gamma ray sources in the universe. These bright flashes can be seen from the most distant of galaxies making the GRBs an ideal tool to study evolution of our universe.

Scientists at IUCAA are studying emission from GRBs at optical and radio wavelengths to determine the energy content of the outbursts and the density of surrounding matter. These can help determine what type of stars produce the GRB events and also tell us about the properties of the galaxies where the GRB has occurred.



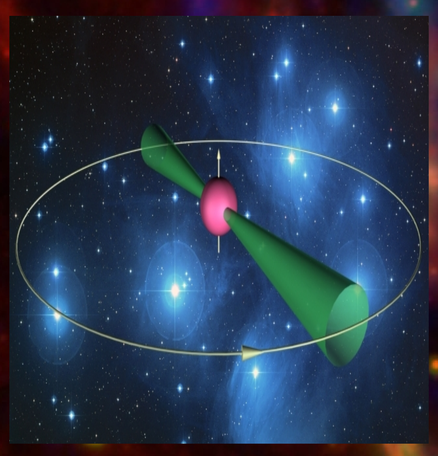

The optical light curve of GRB030329. The red points are observations done in India and blue points are from the rest of the world. The green line shows a standard GRB model. Excess emission due to associated supernova is seen at late times




*Five-year-long GMRT observations of the afterglow of GRB030329 at two different radio frequency bands. The solid lines show the predictions of a standard GRB afterglow model.*

## Pulsars

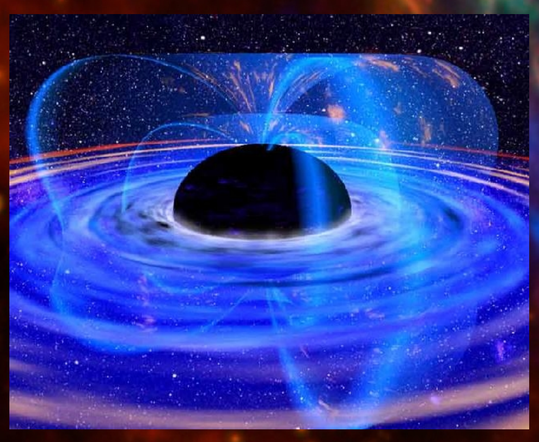
A typical Neutron Star produced in a stellar collapse would possess a strong (Teragauss) magnetic field and very rapid spin (period ranging from milliseconds to seconds). They produce strong, beamed radio emission from their magnetic polar regions.



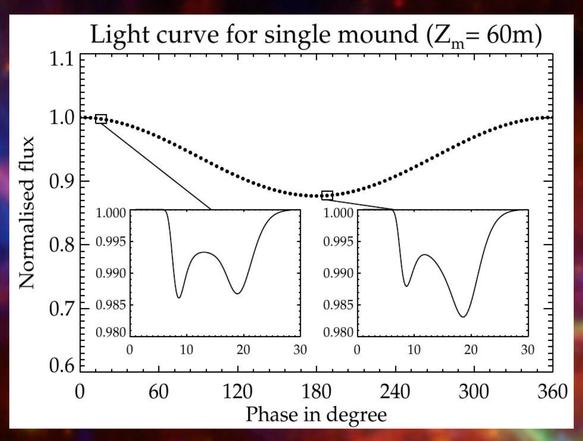
As the beam sweeps past us, we see a pulse of the radio emission - such objects are called Pulsars. These are among the most accurate known clocks. It is estimated that our galaxy contains about 100,000 active pulsars, only about 2000 of which have been detected by us so far.

A recent development in this field involves discovery of low magnetic field pulsars which also emit Gamma rays. Scientists at IUCAA and NCRA, in collaboration with FERMI consortium, are jointly conducting a deep survey with the GMRT to find more such pulsars. Currently 6 new such pulsars have been discovered from the ongoing survey. Study of such objects will help us in understanding the various complex physical processes going on in the vicinity of such objects.

## Black Holes and X-Ray binaries



A cartoon of accretion disc around a neutron star with matter also flowing to the poles along magnetic field lines.




Simulated cyclotron spectra from an accretion mound on the poles of a neutron star. The complex shapes arise due to local variation of magnetic field due to accretion.

Matter from a regular star, may be stripped off and captured by a nearby neutron star or black hole. This matter does not fall directly to the neutron star or black hole, but instead spiral down, forming a disk, called an accretion disk (see Figure above).

The inner region of an accretion disk produces a large amount of X-rays and Gamma-Rays. Since X-rays are absorbed by the earth's atmosphere, these systems can only be observed by using detectors on board on satellites (See Figure on the top right). At IUCAA, theoretical models of accretion disks are developed and the expected spectra and variability are then compared with the observations.

**Some of the recent highlights of our studies have been:**

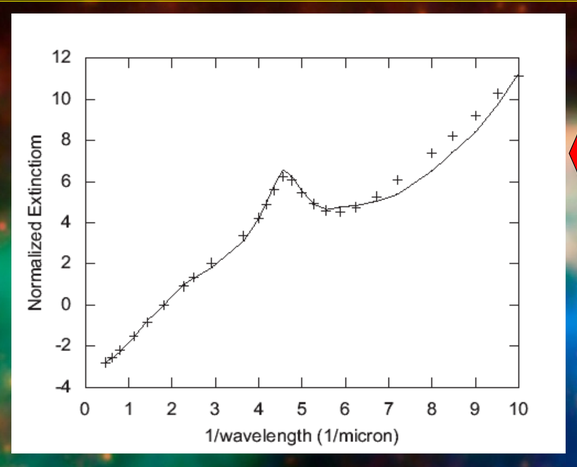
i) X-ray spectra of High mass neutron star binaries show absorption like features due to cyclotron resonance scattering. Such features help us in understanding the local environment of such accreting objects. Scientists at IUCAA are involved in modelling such spectra through theoretical simulation.

ii) The X-ray spectra of black hole systems may have some contribution from the interaction of energetic protons. Such studies may eventually allow us to test the laws of physics

( like Einstein's General Theory of Relativity).

## Interstellar Dust and Extinction

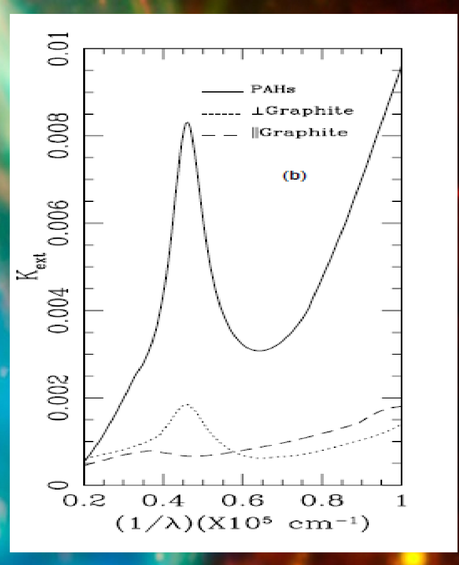
Dust constitutes 1% of the mass of ISM (Inter-Stellar Medium). It plays the most important role in which the light seen form stars suffers extinction (absorption as well as scattering). Recent space probes have confirmed that the dust grains are highly porous and fluffy (i.e. aggregates or clusters) rather than having regular shapes (spherical, cylindrical or spheroidal), homogeneous in composition and structure. Composite fluffy dust grains have been used to explain the observed interstellar extinction curve.

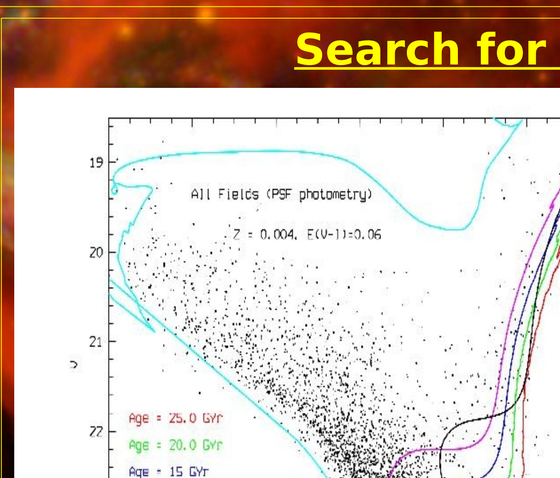



A comparison of the observed average interstellar extinction data (solid line) and the one obtained using an analytical formulas (points). Wavelength range covers visible and infrared regions.
Ref: Roy et. al. JQSRT 111 (2010) 795

### Polycyclic Aromatic Hydrocarbons (PAH):

It was first proposed in 1956 that very small grains of about 10Å size to be present in Inter-Stellar Dust (ISD). These were later found to be polycyclic aromatic hydrocarbons or PAH's, which are molecules containing aromatic rings with varying ring numbers. Studies over the past few decades have shown the ubiquity and importance of PAH's as a constituent of ISD.
The adjacent figure shows the extinction (Kext) due to equal volumes of Graphite and PAH's in a particular size range (5-50Å). The importance of PAH's is very evident from the figure. PAH's are now considered to be one of the major components of the model which previously contained only graphite and silicates first proposed by B. Draine & A. Li.

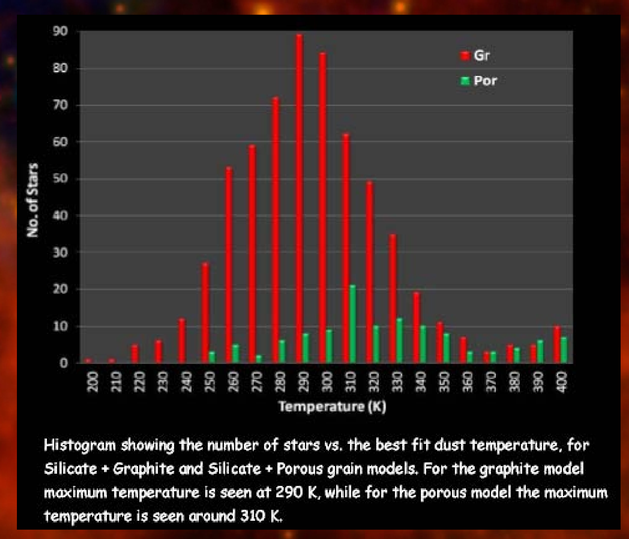



Normalized infrared flux vs. wavelength, with dots representing actual data, smooth curve representing the best fit model.

Circum-stellar dust shells are usually found around young evolving stars and completely evolved stars. Dust shells present around evolved stars are significant sources of new grain material.
The Infrared Astronomical Satellite (IRAS), during its survey of the sky, observed many such stars with dust shells around them. In a study done to model the dust grains that make up such shells, infrared flux from dust shells around 732 stars from the IRAS database were used. The observed flux was compared with the flux obtained using various grain models.

Oblate spheroid dust grain composed mainly of silicates with some porosity or containing varying quantities of graphite, with different dimensions, were used to find the best fit model. The grain models composed of silicates and graphite were found to provide the best fit for majority (615 of 732) of these stars, while the rest 117 stars gave better fit with silicates and porous models.
The temperature of the dust grain models was found to lie between 200 K and 400 K.




Histogram showing the number of stars vs. the best fit dust temperature, for Silicate + Graphite and Silicate + Porous grain models. For the graphite model maximum temperature is seen at 290 K, while for the porous model the maximum temperature is seen around 310 K.

## Search for Very Old Stars!




These very old stars can be:
a) Stars of higher metallicity
b) Pre-main sequence stars i.e. stars being formed.
c) Distant stars in the LMC halo.
d) Stars undergone excess redenning due to local LMC dust. OR
e) **Stars older than our universe!**

A color magnitude diagram alongside is a very powerful tool that allows us to know about star's life, age, composition and future.
On such a diagram, one can plot lines called "isochrones". Stars lying on these lines have the same age.
About 42 objects have been identified from the LMC (Large Magellanic Cloud) HST data which cannot be explained as lying on ischrones corresponding to the accepted age of the universe (13.7 G Yr).

Future observations are required for confirming one of the above scenarios. If it is found that these stars cannot be fitted by the alternate explanations, these stars become older than the accepted age of the universe.