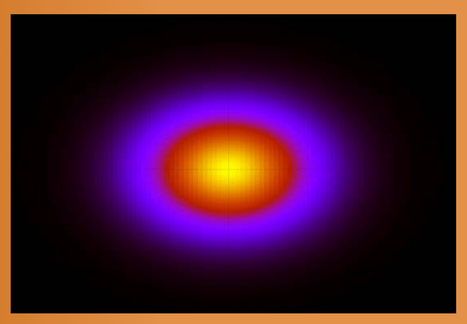
Cosmology Research@IUCAA-1

Observational issues in CMBR

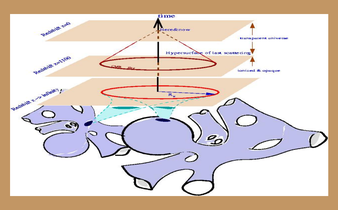


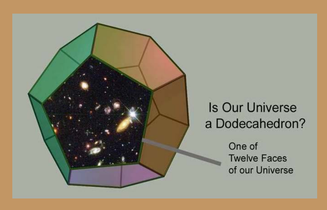
All experiments have beam response functions that are not circularly symmetric. Researchers in IUCAA have developed a method to account for the effects of non-circularity of the beam in current and future CMBR experiments.

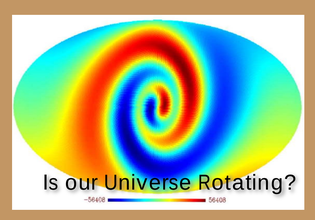
Bipolar spectrum of CMBR (BiPS)

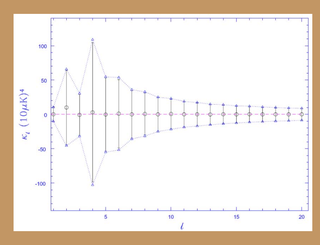
Inflationary expansion has blown a small patch of the early universe to cosmic scales. Hence it is possible that the universe is very complex beyond the cosmic horizon.CMB anisotropy probes the cosmos on the largest scales comparable to, and beyond the horizon.

Researchers at IUCAA have placed strong constraints by developing and using a novel, sensitive measure of correlation patterns in the CMB anisotropy – Bipolar spectrum of CMBR.









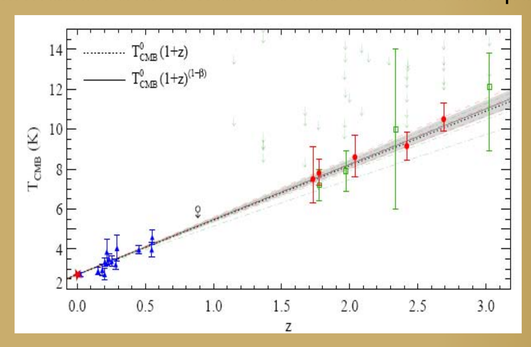
Researcher of IUCAA uses BiPS of CMBR to constrain the rotating Universe models like Bianchi model

Primordial power spectrum from Early Universe:

The measured spectrum of CMB anisotropy can be used to directly estimate the spectrum of primordial seed fluctuations. Therefore CMB anisotropy is an excellent probe of conditions in the early universe. Research in IUCAA explores this important and exciting link.

Did the Universe start in hot Big Bang?

New measurements of the temperature of the Universe when it was young provide exciting confirmation that it was indeed hotter in the past.



Measurements of CMBR at various redshifts. Our measurement is the vertical red bar. The lower limit to the temperature means that CMB temperature is not caonsant at high redshift.

The Puzzle of Dark Energy

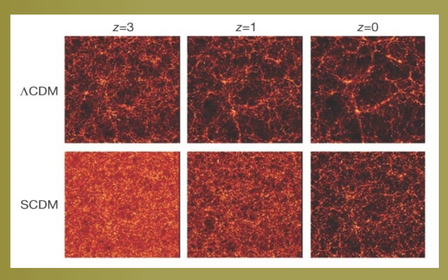
Observational evidence shows that expansion of the universe that is currently accelerating. there appear to be two distinct ways in which the universe can be made to accelerate:

(i) Dark energy. Physical DE models possess large negative pressure and lead to the violation of the strong energy condition, $\rho + 3P \geq 0$, which forms a necessary condition for achieving cosmic acceleration.

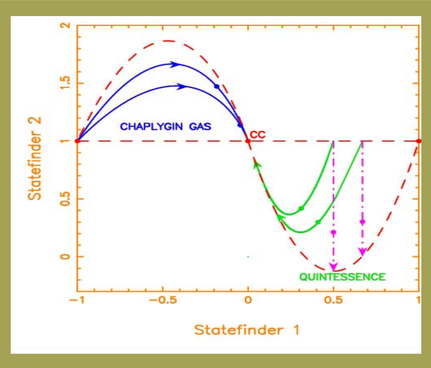
(ii) The universe can also accelerate because of changes in the gravitational sector of the theory. These models (sometimes referred to as geometrical DE or modified gravity) include f(R) theories, extra-dimensional Braneworld models, etc.

If we consider DE to be a perfect fluid then we use its equation of state (ratio of its pressure to density). People at IUCAA have also proposed a parameter pair - Statefinders - to measure how fast Universe accelerates. Recently, a new diagnostic of Dark Energy (called Om diagnostic) was proposed by IUCAA scientists to tell whether the Dark energy is cosmological constant or not.

a. The simplest model of DE is the cosmological constant (CC), where dark energy density is constant over time.
b. Some believe that DE arises out of scalar fields - Quintessence.
c. There are the unified models of dark energy and dark matter - Tachyon field and Chaplygin Gas.

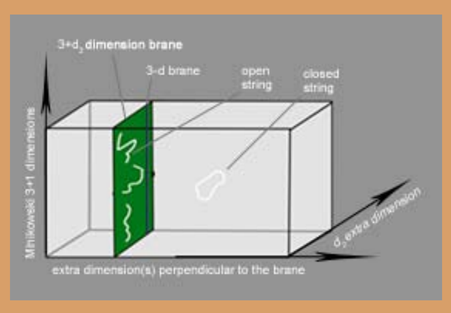


The presence of Dark energy affects the structure formation in the universe. Structure formation is much faster in a universe dominated by matter, available data favors models based on Dark Energy domination.



The evolution of the Stetefinder pair for different DE models. Circles represent their present value

Higher Dimensional Universe



String theory and its extension M-theory suggest that we may be living in a universe which has more than four space-time dimensions.

According to this scenario our observed universe is hypersurface called a *brane* embedded in a higher-dimensional space called the *bulk* and have lead to variety of braneworld cosmological models.

The braneworld cosmologies can display quite distinctive behavior, which departs from that in general relativity either during early or late times.

The particular braneworld model of interest is the induced gravity model, which can explain the observed late time acceleration of the universe.

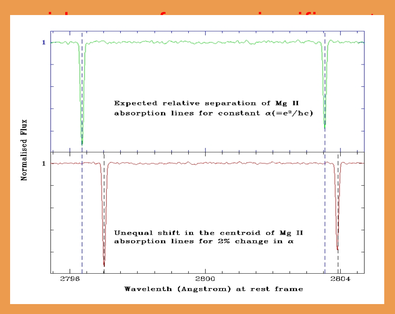
Along this setting the researchers at IUCAA have developed a new induced gravity braneworld model.

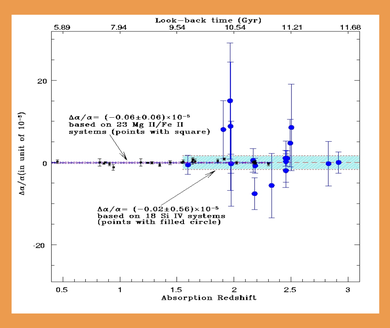
They investigate the cosmological properties of an 'induced gravity' brane scenario, in the absence of mirror symmetry with respect to the brane.

This model provides an interesting way of inducing a sufficiently small cosmological constant on the brane, due to a small asymmetry in the values of bulk fundamental constants on the two sides of the brane.

Variation of Fundamental Constants

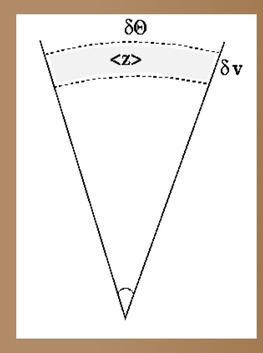
- In physics the Fundamental Constants of nature, such as Newton's gravitational constant G, the charge of an electron e, the Planck's constant *h* and the speed of light *c* are not predicted theoretically but measured experimentally.
- Some modern theories trying to unify all the forces of nature predict that the Fundamental Constants should vary on a cosmic time-scale.
- There have been claims of detecting the variation of a well known dimensionless constant; the fine structure constant which appears in the electromagnetic theory.
- Members of IUCAA have used a refined methodology to test the hypothesis of varying α by using high quality data of quasar spectra.
- The absorption due to the atom or the ion occurs at characteristic energies, which result in doublets of absorption lines. These lines shift by unequal amounts if it varies.
- This physical effect was used in analyzing high quality quasar spectra taken from 8.2 meter Very Large Telescope at Chile.
- Unlike other groups, scientists at IUCAA find no



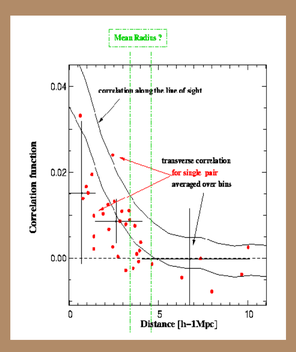


Cosmology with Lyman-α Clouds

For a spherical object, its measured radial and transverse diameters are equal. The diameters can be observed, and their ratio then used to constrain cosmological parameters - Alcock-Paczynski Test.

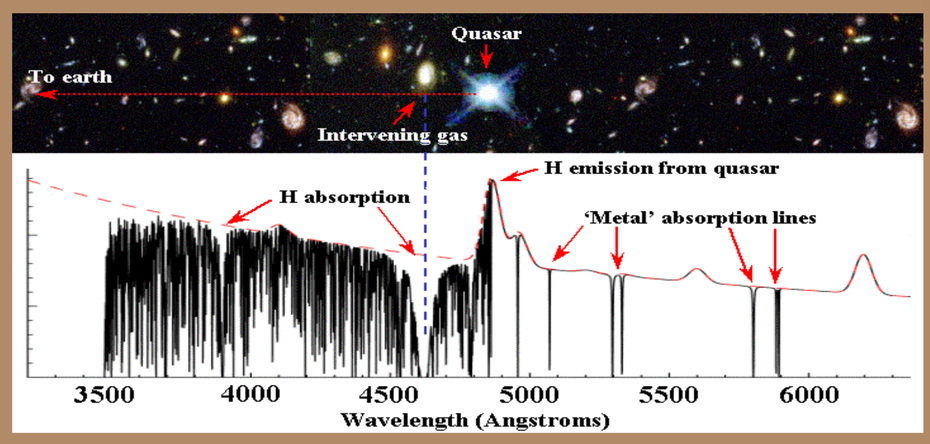


The neutral hydrogen (HI) located on the way of light from quasars absorbs a fraction of the ultraviolet photons with a large cross section. The quasar-light gets redshifted while travelling across the expanding universe. Hence, the further an HI cloud is from the quasar, the smaller the wavelength at which it absorbs the ultraviolet photons.



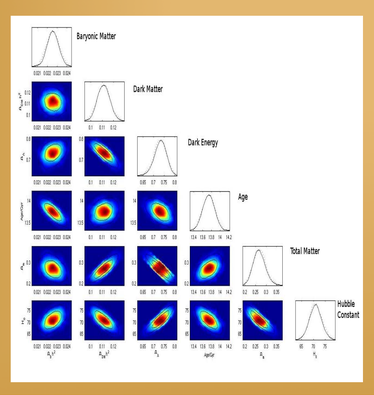
In reality, the HI clouds at high redshift are not perfectly spherical.
The absorption lines of two near by quasars with their light piercing through the same HI cloud show similar patterns - correlation of absorption lines.
This effect can be used to measure the mean radius of the clouds of hydrogen.

The correlations in the figure are computed from the largest sample of pairs of quasars currently available, observed with the Very Large Telescope of European Southern Observatory.



The quaser-spectrum observed on earth reveals a series of H1 absorption lines (the Lyman-α forest). The position and amplitude of these lines tell us how dense h1 clouds are. This allows us to estimate the structure of the universe,

Cosmological Parameters estimation



Cosmological parameter estimation i.e. measuring the values of amount of Dark matter, dark energy, Hubbles constant etc. from the CMBR data and fixing the likelihood of these measurements is one of the most important research in this field. Researchers at IUCAA estimate cosmological parameters upto an higher degree of accuracy.