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Brainstorming Session on Liquid Mirror Telescopes: An Indian Perspective

Participants of the Brainstorming session on Liquid Mirror Telescope

A brainstorming session on Liquid Mirror Telescopes (LMT) was held at IUCAA during August 27-28, 2001. The main resource persons for this session were Paul Hickson and Ermanno Borra from Canada, who were the pioneers of this type of telescopes. They covered all aspects of such telescopes in about 10 lectures, which were very informative for the Indian participants. A total of about 25 participants attended this session. They were from the University Sector (Allahabad University, Delhi University and Bhavnagar University) and several astronomy and upper-atmosphere research institutions (like NPL, USO, UPSO, IIA, NCRA, IUCAA and ISRO). Many of the participants made presentations on how an Indian LMT can be used fruitfully. Towards the end of the session a working group was formed, which will make a proposal to different funding agencies (including ISRO) for fabricating an Indian LMT.

This activity was initiated by A. K. Gupta from Allahabad University and sponsored by ISRO. A.N. Ramaprakash and Ranjan Gupta from IUCAA were the coordinators of this session.

Contents...

IUCAA Reference Centres (IRC)

As a step in its objective of reaching out to universities for promotion of astronomy and astrophysics, IUCAA has set up four Reference Centres in different parts of the country. These have been provided with books, internet connection and electronic subscriptions to some important journals. IUCAA also provides travel support to university and college teachers and students interested in astronomy, astrophysics and related areas, who live in the region around the Centre, to visit the Centre from time to time. The host institution, where the Centre is located, provides office space, computer facilities and accommodation to visitors. Each Centre has a coordinator from the host institution, who provides academic leadership as well as manages the IRC.

IUCAA is now considering the setting up of a few more IRCs to further expand its activities. The Centres will be set up in university departments, which already have significant interest in subject areas of interest to IUCAA, and are willing to take up the responsibility of vigorously pursuing the functions of an IRC. Those interested in setting up an IRC should write to the Dean, Visitor Academic Programmes, (e-mail : akk@iucaa.ernet.in) IUCAA by December 1, 2001 for further information, including mode of application.

Inter-University Centre for Astronomy and Astrophysics and Astronomical Society of India

The 21st Meeting of the Astronomical Society of India, February 5 - 8, 2002, IUCAA, Pune.

The 21st Meeting of the Astronomical Society of India will be hosted by the Inter-University Centre for Astronomy and Astrophysics, Pune, during February 5 - 8, 2002. Details regarding this meeting as well as online registration form is available at :

http://www.iucaa.ernet.in/~asi2002.

Please visit this site for further details. In case you face any difficulty in accessing this site or navigating through it's links, please send an email to asi2002@iucaa.ernet.in. Alternatively, you could also contact: LOC-ASI 2002, IUCAA, Post Bag 4, Ganeshkhind, Pune 411 007, India.

T. Padmanabhan
Chairman, LOC.

Proposals for holding Workshops/Schools Outside IUCAA

Proposals to conduct workshops/schools in Astronomy and Astrophysics or related areas are invited from university departments/affiliated colleges and the same may be sent to the Chairman, Scientific Meetings Committee, IUCAA by March 1, 2002 (for events to be conducted during August 2002 - July 2003), so as to be included in the academic calendar for the next academic year.

The following details should be given while sending the proposals: (i) the title (topic), (ii) duration of the workshop/school, (iii) topics to be covered and number of lectures in each topic, (iv) the level of audience and their number, (v) the number of resource persons available locally and the number of resource persons expected from IUCAA and (vi) a description of the facilities available and the budget estimates (clearly stating the support offered by the host university/ institute).

It is generally expected that infrastructural facilities and accommodation to the participants as well as the resource persons will be provided by the host institution. Other expenses will be borne by IUCAA. The proposers are encouraged to consult IUCAA faculty while framing the proposal.

Once the workshop/school is approved, IUCAA will nominate a coordinator from its faculty, who will interact with the organiser in relation to academic programme, budget, and identifying and approaching the resource persons.

The Passing of an Iconoclast

Professor Sir Fred Hoyle, who was an honorary fellow of IUCAA right from its inception, passed away on August 20, 2001.

Educated in Cambridge\ with a prestigious award and a College Fellowship, worked on radars during the second world war, elected to Professorship at Cambridge, founded a world-renowned institution, successfully launched a major observatory, Fellow of the Royal Society and several other academies, knighted. received honorary doctorates, national and international awards. The roll of achievement might suggest a man who made it good in the Establishment. Quite the contray! Fred Hoyle who passed away on August 20 this year, had the reputation of being a rebel, an iconoclast who questioned many of the accepted beliefs and practices.

Born in Bingley in Yorkshire, the above trait was displayed by young Fred in the primary school. His class teacher asked the kids to go and collect a certain type of flower which, she claimed had five petals. Children in the class brought several to show that she was right. Fred produced one of the same variety that had six petals. So, he asked the teacher, whether the rule of five petals was not sacrosanct after all. The teacher did not like being contradicted and hit the boy on the left ear. Whereupon, he left the class in protest and came home announcing that he was not returning to the school unless and until the teacher properly answered the question. Fred Hoyle's autobiography describes how the situation was handled by his mother, who fully supported his stand and the school authorities.

Some five decades later, history was to repeat itself, when Fred Hoyle, then Plumian Professor of Astronomy and Experimental Philosophy resigned from the chair on an issue of principle and opted for the life of an academic recluse. A lover of hiking in the mountains, he bought a house in a less frequented part of the Lake District in Northwestern England and spent the next fifteen years there. But this did neither stop his creativity, nor did it prevent his influence being felt on whatever subject he chose to work on.

The clue to Fred's creativity may be found in his originality. His argument was that the beaten track did not interest him; for, with so many clever brains working along it if anything really new were to be found, it would have been found by now. So he preferred to explore off the beaten track, where his remarkable intuition and reasoning uninhibited by conventional lines of reasoning would help him unearth gems. Let us look at one.

In the mid-1950s, astrophysicists knew that a star like the Sun is shining on the strength of the energy its core produces by nuclear fusion of hydrogen to helium, the same reaction that sets off the hydrogen bomb. But they were bogged down at the next step: what happens to the star after it has exhausted all its hydrogen fuel? Does the star get 'extinguished' or does it find a new source of energy? Proceeding further along the nuclear fusion ladder suggested that some of the helium produced by the star could be used as a fuel to make bigger nuclei. But how? Conventional thinking using the then available knowledge of nuclear physics led to the result that ahead lay a series of unstable nuclei which could not sustain the fusion process.

If you are climbing a ladder and the next rung you wish to stand on is known to be weak, what would you do? Look for a higher rung which is strong and try to bypass the weak one. Hoyle calculated that to proceed further there had to be an excited state (of higher energy) of the familiar nucleus of carbon. Moreover, to attain this excited state of carbon, Hoyle used the idea of a resonant reaction well known to nuclear pysicists. Just as a sitar player adjusts the tension of the sitar wires so that they resonate and augment the tone produced by the instrument, Hoyle argued that resonance helped nuclear reactions to proceed faster and thereby produce enough carbon from helium. Without resonance, very little carbon would be produced.

Apart from this reasoning, Hoyle was convinced that the chemical elements like carbon, oxygen, neon, silicon and metals like iron, cobalt and nicket, etc. are all produced inside stars through reactions like this. But, if the helium to carbon reaction were not possible, then there would neither be any carbon in the universe, nor any of the elements we see around us. What is more, we humans or indeed life as we know it here on the Earth should not be existing. So the bottom line of this argument was: we exist, ergo, so must the excited state of carbon!

For testing this hypothesis, Hoyle asked the nuclear physicists at Caltech to look for such an excited state of carbon. Willy Fowler at Caltech who was awarded a Nobel Prize for his work in nuclear astrophysics, recalled how their first reaction was to dismiss this claim, because of its unconventional reasoning. However, Hoyle persuaded Fowler and his colleagues to perform the necessary experiment and lo and behold, they did find the predicted state. That proved to be a turning point in Fowler's career and he began a long-time collaboration with Fred Hoyle. Indeed in 1957, Hoyle, Fowler, and husband-wife team of renowned astrophysicists Geoffrey and Margaret Burbidge published a mammoth paper detailing how most of the familiar chemical elements are produced inside stars and ejected in stellar explosions. Most astronomers today express surprise that Hoyle was not awarded the Nobel Prize for his work on stellar nucleosynthesis.

In the age of super-specialization today, it is impossible to find an astronomer like Hoyle, whose work influenced a wide sweep of fields ranging from the solar system, through stars and galaxies, all the way to cosmology. He was for ever opposed to the widely accepted view that the universe exploded into existence some ten to fifteen billion years ago. There was a brief period during 1965-66, when the microwave background was discovered, when he wavered in his opposition to this theory. However, when he saw it become increasingly speculative with no direct proof, he reverted to his skepticism. His last major work published last year, together with Geoffrey Burbidge and myself was to present a case opposing this paradigm and to suggest an alternative. This book, called *A Different Approach to Cosmology* reflects Hoyle's iconoclastic view on cosmology.

It is ironic that it was he who, in a derisory fashion, coined the phrase 'Big Bang' to describe this exploding model, in his famous lectures on the BBC radio, delivered half a century ago. The lectures were immensely popular and the name stuck and is proudly used by the big bang supporters. An astronomy magazine polled its readers a few years ago to suggest any alternative name for the model; but the 'big bang' came out way ahead of the rest.

The BBC lectures launched Hoyle as a successful science populariser, and his public outreach was immense. His science fiction play for school children called *Rockets in Ursa Major* played to packed houses in Bernard Miles' Mermaid Theatre in London in 1964. His sci-fi novel, *The Black Cloud* turned out to be a precursor to the discovery of giant molecualr clouds in the Galaxy. Hoyle once mentioned that because astronomers would not accept the idea of huge interstellar clouds containing chemical molecules, he described the idea through the novel! In many respects he was ahead of his times. Such visionaries have to face considerable hostility in their lifetime. And when they are proved right, it is often too late.

- J.V. Narlikar

Vacation Students' Programme

Participants of the Vacation Students' Programme

The Eleventh Vacation Students' Programme (VSP) was held in IUCAA during May 21-July 6, 2001. Ten students in the penultimate year of their M.Sc. (Physics) and Engineering degree course were selected from over 75 applicants from various Indian universities, IITs and engineering institutes. A number of IUCAA's visiting associates made special efforts to encourage their students to apply and helped the selection procedure by thoughtfully written recommendation letters. Depending on their aptitude and interest, each student chose the research project to work during the programme from a selection offered by the IUCAA faculty members and postdoctoral fellows. The students displayed a lot of enthusiasm and made good use of the IUCAA facilities and resources. They interacted freely with the IUCAA graduate students, postdocs, visitors and faculty members during their stay. The average quality of project work and its presentation was quite good. The students also attended over 40 expository lectures given by members of NCRA, IUCAA (including visiting associates of IUCAA) on a broad range of topics in Astronomy and Astrophysics. The lectures included six special evening seminars. The lectures were jointly organised with the Vacation Students' Research Programme (VSRP) of NCRA. During their stay, day trips were also organised to see the IUCAA's 2-meter telescope site and the Giant Meterwave Radio Telescope (GMRT) near Pune. Tarun Souradeep was the faculty coordinator for this programme.

First Workshop on the Interface of Gravitational and Quantum Realms

The first Workshop on the Interface of Gravitational and Quantum Realms will be organised during December 17 - 21, 2001 at IUCAA. It is intended to be an advanced level meeting of active workers to discuss the current problems in this emerging area of research. To facilitate intense and focused discussions, number of participants will be limited to about 30.

Participation would be by invitation. There would be some room for graduate students and post-docs, who could write to Naresh Dadhich, IUCAA (e-mail: nkd@iucaa.ernet.in) with a recommendation of their supervisor.

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Cosmological N-Body Simulations

Cosmological N-Body simulation is a useful tool for studying gravitational instability in an expanding background, formation of large scale structure, and formation and evolution of galaxies. This subject is vast and we will restrict our attention in most part to simulations that ignore non-gravitational effects. For a discussion of general details and a longer list of references, we refer you to a recent review[1]. Detailed discussion of Cosmology can be found in text books[2, 3, 4].

Cosmological simulations differ from typical N-Body simulations in one very important way: the Universe is very large, if not infinite. Thus, we can either simulate a spherical chunk of the Universe that is large enough, or we have to use periodic boundary conditions.

1 Dark Matter Simulations

Nearly all Cosmological models have a collisionless dark matter component that dominates over the baryonic component in terms of energy density. Fluctuations at small scales in the dark matter component, unlike fluctuations in baryonic component, grow in the interval between the beginning of the matter dominated era and the decoupling of radiation and matter[2, 3, 4]. Thus fluctuations in the dark matter component will govern the evolution of fluctuations in the baryonic component after the epoch of decoupling. This dominance persists in most models to later times due to the larger energy density of the dark matter component. Due to these reasons, Cosmological N-Body simulations must be able to handle fluctuations in dark matter.

Dark matter is generally assumed to be collisionless, the only interaction of interest in most cases is gravitational as the dark matter particles interact very weakly, if at all. This may not be true in regions with very high density such as cores of galaxies and clusters of galaxies. Studies of interacting dark matter suggest that such interaction must be negligible even in high density regions or it would produce an observable effect[5, 6].

The collisionless dark matter may be relativistic, or non-relativistic. In the former case, it will have a significant pressure/velocity dispersion and one cannot take the fluid limit. In such a case one needs to solve the Boltzmann equation in order to correctly model effects of free streaming[7]. However, observations suggest that the Universe is not dominated by relativistic matter. This allows us to take the fluid limit and describe the motion of dark matter particles using simple Newtonian equations.

Simulations of dark matter represent density distribution using particles. This can be achieved either by assigning mass in proportion to the local value of density, or by distributing particles with the same mass such that the number density of these particles is proportional to the density of dark matter. For Cosmological simulations, each N-Body particle will represent a very large number of dark matter particles as we would like to simulate evolution of structures at scales which are of interest in Cosmology. Thus, our ability to probe small scales will be limited by the mass of typical N-Body particles. Details of methods used to set up initial conditions can be found in many papers[8, 9].

The equations that govern the evolution of this set of particles are given below. These equations are valid for non-relativistic matter ($v \ll c$, $\varphi \ll c^2$) at scales that are much smaller than the Hubble radius[2].

$$\ddot{\mathbf{x}} + 2\frac{\dot{a}}{a}\dot{\mathbf{x}} = -\frac{1}{a^2}\nabla\varphi \tag{1}$$

$$\nabla^2\varphi = 4\pi G\bar{\varrho}(t)a^2\delta = \frac{3}{2}H_0^2\Omega_0\frac{\delta}{a} \tag{2}$$

$$\delta = \frac{\varrho(\mathbf{x},t)}{\bar{\varrho}(t)} - 1. \tag{3}$$

Here $\mathbf{x}$ is the co-moving position of a particle, $a(t)$ is the scale factor, φ is the perturbed component of the gravitational potential, H_0 is the Hubble's constant and Ω_0 is the energy density in matter at the present epoch in units of the critical density and δ is the density contrast, $\bar{\varrho}(t)$ is the average density of matter in the Universe at time t and $\varrho(\mathbf{x},t)$ is the density at $\mathbf{x}$ at time t. Density as a function of position is recovered from the distribution of particles at any given instant using some convenient interpolation scheme or by using a smoothing function.

We ensure collisionless evolution by requiring that two body collisions do not play a significant role in the evolution of the system of particles. This is done by softening the force at small scales. An alternative approach is to assign a finite size to particles. The net result is that particles can pass through each other and the force between two particles does not diverge as the distance between them goes to zero, i.e., force between these goes to zero with distance.

1.1 Direct Summation Method

The direct summation method, also known as the particle-particle (PP) method is the most obvious way of calculating force, i.e., by directly summing the force on each particle due to all other particles. This method works well for a small number of particles, but it is difficult to simulate a system with a large number of particles on conventional computers. Typically, simulations using this method are limited to 10^4 particles on present day computers, as the number of operations required grows as N^2, where N is the number of particles[10]. The attractive feature of this method is the simplicity of algorithm and the absence of approximations made in other methods. There has been some resurgence in the use of this method after the advent of the GRAPE chip[11, 12]. This chip is essentially a hard wired computer that calculates inverse square force between every pair of particles, though the newer versions have many other useful features that are commonly needed for N-Body simulations. With the modern versions of this chip, one can easily simulate systems with millions of particles.

Direct summation method has not been used in very many Cosmological simulations, even though the earliest Cosmological N-body simulations used this method.

1.2 Particle-Mesh Method

Particle-Mesh (PM) method has the distinction of being the first method to produce representative simulations of Cosmological models. At the heart of this method lies the realisation that Poisson's equation (eqn.2) is a simple algebraic equation in Fourier space. Thus solving the Poisson's equation is trivial, if we have a fast method of computing Fourier transforms. Fast Fourier Transform (FFT) is just such a method as in this method, the number of operations required for computing the Fourier transform scales as $N \log N$, instead of N^2 for a function defined on N regularly spaced points in configuration space. The requirement of uniformly spaced points forces us to use a regular mesh, usually a cubic box with equal number of mesh points along each axis. Quantities δ and φ are defined and computed at these mesh points. We still use particles to represent the density field and we compute density at mesh points by using weight functions. This method derives its name from concurrent use of a mesh and particles. For details of this method, we refer you to some of many papers on PM methods[13, 8, 9]. A useful spin off of using Fourier methods is that we get periodic boundary conditions for free.

PM method is a very fast way of doing Cosmological N-Body simulations and many useful results have been derived using such simulations. However, use of a mesh and the requirement that the simulation box contain a representative chunk of the Universe reduce the effective dynamic range of such simulations. Use of weight functions imposes a stringent lower limit to resolution at the scale corresponding to the support of this function or the distance between neighbouring mesh points, whichever is larger [14, 15].

1.3 P^{3}M Method

The success of the PM method and its obvious limitations prompted researchers to devise schemes for enhancing resolution of this method while retaining useful features. FFT gives the long range force for a very small computational cost, along with periodic boundary conditions. The limitation of the PM method at short distances, where the force is softened at the mesh scale, has been the focus of efforts by many researchers and the P^{3}M method was the first in a long line of attempts to overcome this limitation. The basic idea is to add a "correction" to the long range force computed using the PM method. This correction is computed by summing the contribution of close neighbours using the direct summation, or the particle-particle method (hence the name PP+PM = P^{3}M). It is assumed that the correction depends only on the distance and is generally added out to a distance of about 1.5 times the distance between neighbouring mesh points[8]. P^{3}M was the first method to produce high resolution N-Body simulations. Many detailed studies of gravitational clustering were carried out using this method.

There are three problems with the P^{3}M method. First relates to the fact that the correction force is assumed to be isotropic, whereas it is not. Thus, the resulting force must be very anisotropic at the mesh scale. Second, the correction is added only up to a relatively short distance, whereas the PM method underestimates the force out to a much larger distance[15]. Lastly, P^{3}M simulations slow down at late times when the distribution of particles becomes highly clustered and computation of the correction term dominates the number of operations required.

A modified implementation of the P^{3}M method uses refined mesh in regions of high density to reduce the time taken in direct summation for calculating the short range correction[16]. This takes care of the third problem mentioned above.

1.4 Tree Method

The tree method of doing simulations uses an approximation for calculating the force that reduces the number of operations required so that these scale as $N \log N$, where N is the number of particles. This is done by arranging all the particles in a tree structure and treating sufficiently distant groups of particles as a single unit for the purpose of calculating force[17]. The quantification of "sufficiently distant groups" has to be done carefully. Early papers suggested simple criteria that can give large errors in some situations[18].

This method is very effective for simulations of isolated objects, such as clusters of galaxies[19]. It is an extremely general method for N-Body simulations, useful in a whole range of situations. Periodic boundary conditions can be included[20], but this tends to slow the code down by a significant amount. In the Cosmological context, this method is useful for simulating highly non-linear clustering as the number of operations is less sensitive to the degree of clustering, as compared to the P^{3}M method.

The errors in force can be large for a uniform distribution, such as the initial conditions for Cosmological simulations. This can be avoided by employing a more stringent criterion for using distant groups as single entities in force calculation at early times, or by using alternative criteria[19].

This method is relatively slow compared to other methods. Many tricks have been suggested to speed up the tree code, chief amongst these is vectorisation of tree traversals while computing the force[21, 22, 23]. Use of these method can result in a speed up by upto a factor of four.

1.5 TPM Method

The TPM method[24, 25] is similar to the P^{3}M method, except that the tree method is used for computing the short range correction in force, instead of direct summation. N-Body particles are divided into two groups, those in low density regions are called PM particles and short range correction is not computed for these. Particles in high density regions are called tree particles and a tree code is used to compute the short range correction in force for these particles. Unlike P^3, TPM method avoids slow down for highly clustered distributions of particles but other problems remain. However, all other problems remain and some more are introduced by splitting of particles in two groups as this leads to nonuniform resolution across the box.

1.6 TreePM Method

The TreePM method too is similar in spirit to the P^3M method. The gravitational force is partitioned into short range and long range components[26] that add up to give the required force at all scales, both the components are isotropic by construction. The long range force is computed in the Fourier space. The short range force is calculated in real space using the tree method. The short range force between two particles is added out to a distance where it falls below 1% of the total force. It combines good features of the tree and the PM method and avoids pitfalls of both these methods. Unlike the TPM method, resolution is the same for all particles. There is one key difference between the TreePM and other types of codes that use a short range correction to enhance the force resolution at small scales, i.e., methods such as the P^3M and TPM. The long range force is different from the force computed in the PM method, large wave modes are suppressed to ensure isotropy at all scales where the long range force is significant. It is this that allows us to reduce the error budget in TreePM codes as compared to the TPM and P^3M methods.

1.7 Adaptive Mesh Refinement Methods

These methods also seek to overcome the limited resolution of PM codes. The trick used here is to refine mesh in regions of interest, either around one structure or in regions of high density — this is done by introducing a new mesh, that has smaller spacing between neighbouring points. One then solves for the potential in the region of the refined mesh using the long range potential on the edges as the boundary condition. It is possible to carry out successive refinements and obtain good resolution[27, 28, 29]. However, one must be careful about the effect on motion of particles close to the interface of meshes of different levels. There is also the problem of non-uniform resolution.

1.8 Other Methods

There are several other, less popular methods of doing N-Body simulations in the Cosmological context. These include the moving mesh method [30], fast multi-pole method[31], etc. This last method is particularly interesting as the number of operations required scales as the number of particles.

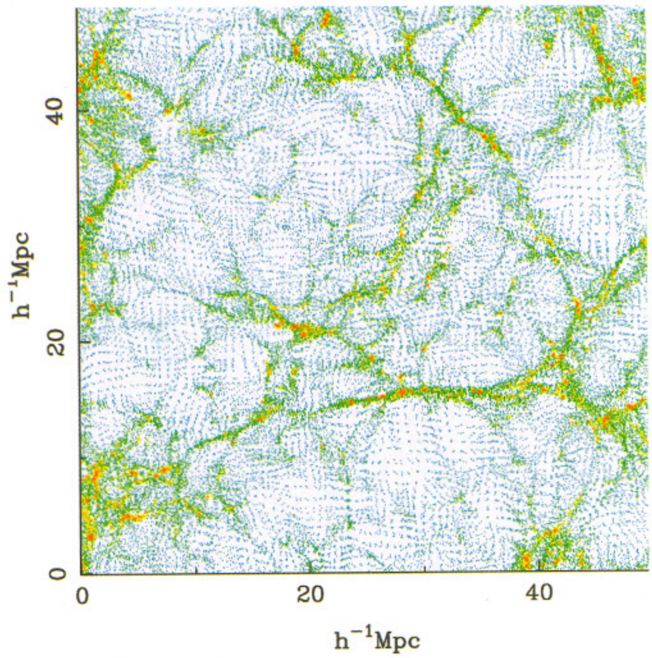

Figure 1: A slice from a TreePM simulation. This figure shows a $2h^{-1}$Mpc thick slice at $z = 3$ from a simulation of the ΛCDM model. Particles have been colour coded by the local value of density, red/yellow corresponds to high densities and blue corresponds to low densities.

Present development of N-Body simulation methods is guided by the emergence of distributed parallel computing as a platform of choice for high performance computing. Parallel versions of many of the popular methods have been implemented, or are being implemented[19, 32, 33, 24, 34].

2 Adding Baryons

As long as we are concerned with collisionless dark matter, the physics involved is relatively simple as we only have to worry about the gravitational force. This simplicity is lost once we try to include baryons into the picture as we have to include effects of pressure, temperature, heating, cooling, shocks, chemical reactions, radiation transport, interaction of matter with radiation, etc. Clearly, our understanding of many of these effects is far from complete when studied in isolation. However, the situation is not hopeless. We can study special cases, where a number of these effects do not play a significant role and we can use these cases to further our understanding of these effects. Basic understanding of these effects can be developed using symmetrical systems that allow us to probe some special cases in great detail. Examples of these are the studies of spherically symmetric systems[35].

There are two basic methods of doing hydrodynamic simulations, these are either mesh based methods, where the equations of fluid mechanics and thermodynamics are solved on a grid of fixed points. The other method assigns fluid properties to "particles" and one finds the values of these quantities at any point using weight functions: these are the smoothed particle hydrodynamics (SPH) codes[36, 37]. SPH method is easier to implement, but mesh based methods are generally more robust. Mesh based methods have poor resolution in high density regions, where there may be many dark matter particles in each mesh cell, but this can be corrected using adaptive mesh techniques.

There have been some attempts to add chemical reactions, particularly for the study of formation of first stars[38]. Similarly, there have been many attempts to incorporate radiation transfer in Cosmological simulations. Most attempts so far have required considerable simplification of the full problem but interesting results have already been derived from such simulations[39, 40].

3 Summary

The above discussion has summarised, very briefly, the methods used for Cosmological N-Body simulations. We have tended to focus on simulations of dark matter, primarily because the techniques there are better developed and understood. Hydrodynamic simulations, particularly simulations that try to incorporate effects like chemical reactions and radiation transfer are relatively new and much work needs to be done before all the subtleties are understood. On the positive side, much work needs to be done to understand gastrophysical effects and we will need much more than greater computational power to do it.

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IUCAA-NCRA GRADUATE SCHOOL COURSES

The IUCAA-NCRA Graduate School (conducted jointly with the National Centre for Radio Astrophysics (NCRA), Pune) is divided into two semesters (four terms) spread over one year. Each term is of roughly eight weeks duration. During the Graduate School, the Ph.D. students (Research Scholars) are taught relevant advanced courses in Physics and are also introduced to courses in Astronomy and Astrophysics. The Graduate School structure is given below. The number of teaching hours is shown in brackets after each course.

Semester I, Term I, From August second week to October first week.

01. Methods of Mathematical Physics I (21)
02. Introduction to Astronomy and Astrophysics I (14)
03. Electrodynamics and Radiative Processes I (14)
04. Quantum and Statistical Mechanics I (14)

Semester I, Term II, From October third week to December second week.

05. Methods of Mathematical Physics II (14)
06. Introduction to Astronomy and Astrophysics II (14)
07. Electrodynamics and Radiative Processes II (14)
08. Quantum and Statistical Mechanics II (14)

Semester II, Term I, From January first week to February fourth week.

09. Astronomical Techniques I (14)
10. Galaxies : Structure, Dynamics and Evolution (21)
11. Extragalactic Astronomy I (21)

Semester II, Term II, From March second week to May second week.

12. Astronomical Techniques II (14)
13. Interstellar Medium (14)
14. Extragalactic Astronomy II (14)
15. Topical Course (for earlier batch of students) (< 21)
16. Project Work (During May - June - July).

Syllabus for the Graduate School Courses

1. The courses are designed, emphasizing the aspects which are directly relevant to Astronomy and Astrophysics. It is assumed that unnecessary repetition of material which is already taught at M.Sc. is avoided. While selecting students for IUCAA/NCRA, we usually ensure that the student is familiar with physics at the level of M.Sc. and there is no need for routine material to be repeated in the graduate course.

2. The syllabus provide enough avenues for topics which are of "local interest" to be included in the graduate school. This is necessary so that graduate students coming out of IUCAA/NCRA, not only have a comprehensive grasp of the A & A but are also aware of the key research areas in which these two institutions are concentrating at present.

If any of the Research Scholars from Indian universities/colleges are interested to attend any of these courses, they may contact : The Coordinator, Core Programmes, (e-mail : vch@iucaa.ernet.in) IUCAA.

Seminars

12.7.2001 Ujjaini Alam on *A study of the magnetic field in the cometary globule S. 131-37;* 26.7.2001 Amrit Lal Ahuja on *Processing of dual frequency pulsar data from GMRT to obtain accurate dispersion measure*; 27.7.2001 Atul Deep on *Correlations in CMB anisotropy*; 21.8.2001 Ashok Ambastha on *Total solar eclipse 2001 from Lusaka, Zambia: USO experiments and preliminary results* and 23.8.2001 Ajit Kembhavi on *First light in the universe.*

Colloquia

20.7.2001 Bharat Ratra on *Is the univese flat or open*?; 2.8.2001 Vijay Pandharipande on *Theory of neutron stars*; 20.8.2001 Spenta R. Wadia on *String theory and the information puzzle of black hole physics.*

IUCAA Preprints

Listed below are the IUCAA preprints released during July - September 2001. These can be obtained from the Librarian, IUCAA (library@iucaa.ernet.in).

B.F. Roukema, et al., *Star formation losses due to tidal debris in `hierarchical' galaxy formation*, IUCAA-31/2001; B.F. Roukema, G.A. Mamon and S. Bajtlik, *The cosmological constant and quintessence from a correlation function comoving fine feature in the 2dF quasar redshift survey*; IUCAA-32/2001, T. Morel, et al., *The European large area ISO survey VI-Discovery of a new hyperluminous infrared galaxy*, IUCAA-33/2001; Margarita Safonova, Diego F. Torres and Gustavo E. Romero, *Microlensing by natural wormholes: theory and simulations*, IUCAA-34/2001; Kaushik Bhattacharya, Avijit K. Ganguly and Sushan Konar, *Effective neutrino photon interaction in a magnetized medium*, IUCAA-35/2001; T. Morel, R. Doyon and N. St-Louis, *Near-infrared [Fe II] emission from supernova remnants and the supernova rate of starburst galaxies*, IUCAA-36/2001; Mira Dey, Monika Sinha, Subharthi Ray and Jishnu Dey, *Astrophysical consequences of diquark formation on the surface of strange star*, IUCAA-37/2001; R. G. Vishwakarma, *Consequences on some dark energy-candidates from SN 1997ff*, IUCAA-38/2001; Arnab Rai Choudhury and Sushan Konar, *Diamagnetic screening of the magnetic field in accreting neutron stars*, IUCAA-39/2001; Bikash Chandra Paul, *On the mass of a uniform density star in higher dimensions*, IUCAA-40/2001 and Tapas K. Das, *Psudo-Schwarzschild description of accretion-powered spherical outflow.*

Welcome to...

Rajesh Nayak, who has joined as a Post-doctoral Fellow. His research interests are Gravitational Radiation Data Analysis, Classical General Relativity and Cosmology.

Hum Chand and **Sanjit Mitra**, who have joined as Research Scholars.

... Farewell to

Yogesh Wadadekar, who has joined the IAP, Paris, France.

Arun Thampan, who has joined SISSA, Trieste, Italy.

Visitors during July - September

Kanti Jotania, S. Sen, Murali Krishna, S. Dave, K.D. Purohit, N. Banerjee, B.B. Walwadkar, S. Ramakrishnan, G.C. Anupama, B. Ratra, R.P. Bambah, L. Chaturvedi, O.P. Nigam, K. Siddappa, S. Chakrabarty, A. Bhatnagar, S. Gopal, V.N.R. Pillai, Sipra Guha-Mukherjee, M. Bhattacharyya, S.K. Pandey, S.M. Chitre, C.L. Khetrapal, S.S. Katiyar, A.S. Reddy, V.C. Kuriakose, Hari Gautam, R.Ramakrishna Reddy, A.A. Ubachukwu, S. Ray, M. Sinha, J. Dey, P. Baki, A. Nigavekar, K.G. Chhaya, T. Rama Raju, Spenta Wadia, A.Ambastha, C.S. Mali, M.K. Das, L.M. Saha, Z. Turakulov and A. Sen.

Apart from the above list, there were about 30 visitors who attended the Brainstorming Session on Liquid Mirror Telescopes.

Workshop on Photometric Data Reduction and Analysis

The workshop will be conducted at the Physics Department of J.E.S. College, Jalna (Maharashtra) during January 14-18, 2002. A 12" Meade L X 200 telescope is being installed at J.E.S. College with SSP-3A automated photometer as a back-end instrument. This facility will be mainly used for study of variable stars.

The purpose of the workshop is to highlight the use of small telescopes mainly for photometric observations, data reduction and analysis. Observing programmes of academic interest will be discussed.

The candidates who are having or likely to have access to small telescope will be given preference. Interested candidates should mention about their interest and relevance and send their applications to M. L. Kurtadikar, Department of Physics, J.E.S. College, Jalna 431 203, Maharashtra, latest by November 10, 2001.

IUCAA Postdoctoral Positions

Applications are invited for post-doctoral fellowships at IUCAA. The duration of the fellowship is flexible within a range of one to five years. Post-doctoral fellows with excellent performance can be considered for a tenured position. The fellowship includes a remuneration, contingency grant, accommodation on the campus and medical benefits. Facilities required for research are provided through the general IUCAA budget.

Applications and enquiries should be sent by post or e-mail to:

The Coordinator, Core Programmes
IUCAA, Post Bag 4, Ganeshkhind
Pune 411 007, India.
e-mail : vch@iucaa.ernet.in

The Inter-University Centre for Astronomy and Astrophysics (IUCAA) is an autonomous institution under the University Grants Commission. It was set up in December 1988 amidst the picturesque surroundings of the University of Pune. IUCAA has an integrated campus which includes the academic facilities as well as residential and recreational areas. IUCAA aims at being a centre of excellence within the university sector for teaching, research and development in astronomy and astrophysics. The centre at present consists of about 30 academic members, including core faculty, post-doctoral fellows and graduate students, with potential for growth in the numbers. IUCAA has a vigorous visitor programme, involving short and long term visits of scientists from India and abroad. The centre has about 80 visiting associates from universities and colleges, who visit periodically and participate in all its activities. Further information can be obtained from the IUCAA website at http://www.iucaa.ernet.in/

Applicants should send a curriculum vitae and list of publications, and arrange for three confidential references to be sent independently. All the relevant material should reach IUCAA by November 25, 2001. Candidates will be informed of the result by January 15, 2002. Successful candidates are normally expected to commence their fellowship during 2002.

Facilities at IUCAA include a network of state-of-the-art computers, high speed internet connections, mirror sites of important databases like ADS and VIZIER, a very well equipped instrumentation laboratory and a library with exhaustive collections of books and periodicals. A 2m optical telescope is being set up by IUCAA at a site which is about 100 kms from the IUCAA campus. The telescope will be operational in 2002.

Research Areas covered by faculty members at IUCAA include:

- Classical and quantum gravity
- Cosmology and large scale structure
- Gravitational wave detection
- Galactic and extragalactic astronomy
- High energy astrophysics
- Galaxy dynamics
- Interstellar medium
- Astronomical instrumentation

IUCAA has a vigorous observational programme in several areas. Support is available for guest observing from international facilities.

Other academic activities include a graduate school for Ph.D. students, teaching at the Master's level for students from University of Pune and other universities, schools and workshops, refresher courses for university and college teachers and a vigorous public outreach programme.

How Well Do you Know Your Big Bang?

In these days when cosmologists are giving press conferences, telling people how the universe began, it is worth recalling what Abbe' Lemaitre, a catholic priest and cosmologist thought about it all. Today, Lemaitre's ideas on a universe starting with a primeval state and being driven by a cosmological constant are again finding favour amongst the cognoscenti. Bernard Lovell, the creator of the Jodrell Bank Radio Telescope, recalls in a book review his encounter with Lemaitre at the 1958 Solvay Conference in Brussels.``..One evening I walked from the meeting into a crowded Brussels street with Georges Lemaitre. He had worked with Eddington, and they had developed the cosmological theory of the evolving universe from a primeval condensation to which Lemaitre referred as the primeval atom. As we dodged the passers-by, I said, 'But Lemaitre, you are a Jesuit priest and you are the author of this theory of the universe from primeval atom - how was the primeval atom formed and how did the universe really begin?' He stopped in this crowded street, threw his arms asunder and responded: 'If you ask me as a scientist, the answer is I do not know, but as a priest I can tell you.'"

[*source: Times Literary Supplement, July 13, 2001, p.4*]

Visitors Expected

October 2001: Susmita Chakraborty, Calcutta Univ.; K.S.V.S. Narasimhan, Chennai; R.S. Kaushal, Univ. of Delhi; Yuri Shatanov, KIEV, Ukrain; Susmita Singh, J.D. Women's College, Patna; J. Bagla, HRI, Allahabad; Jihad Tauma, Center for Advanced Mathematical Sciences, American Univ., Beirut, Lebanon; Usha Malik, Univ. of Delhi; S. Banerjee, Calcutta; A Banerjee, Jadavpur Univ.; Sarbeshwar Chaudhuri, Burdwan; B.C. Paul, NorthBengal Univ.; S. Mukherjee, North Bengal Univ. and P.P. Hallan, Zakir Husain College, Delhi.

November 2001: Monika Sinha, Calcutta; Sushant Ghosh, Science College, Nagpur; R. Tikekar, Sardar Patel Univ.; D.B. Vaidya, Gujarat College; A.K. Sen, Assam Univ.; Kavan Ratantunga, Carnegie Mellon Univ.; Jishnu Dey, Maulana Azad College and Mira Dey, Presidency College.

December 2001: Yannick Mellier, Institut d'Astrophysique de Paris; Thomas Erben, Paris; Subir Sarkar, Oxford Univ. and Stanley Wolpert, Univ. of California.

Please note the change in Telephone and Fax Numbers !!!

Khagol **(the Celestial Sphere) is the quarterly bulletin of IUCAA. We welcome your responses at the following address:**

IUCAA, Post Bag 4, Ganeshkhind,
Pune 411 007, India.

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