On doing cosmology with a large optical telescope

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Abstract

This paper highlights the interesting problems in cosmology that require observational inputs normally available from optical telescopes in the 4-6 m class. The case is made that a large optical telescope built for and in India in the next few years can generate sufficient astronomy of world class to justify its cost.

Introduction

In supermarkets eggs are sold in three categories: medium, large and extra large. (Marketing wisdom decrees that nobody would buy eggs that are labelled 'small'). Likewise astronomers of the professional variety choose to call their telescopes medium, large or giant-sized. In my talk I will assume a medium optical telescope to be of 2 m size, a large one of 4-6 m size and a giant one of 8 m. My purpose is to highlight the usefulness of a large optical telescope in solving problems of cosmology.

At the outset I wish to make a practical point. A giant optical telescope necessarily requires new technology (e.g. multiple mirror, segmented mirror etc.) which takes a long time to perfect and whose costs are prohibitive. In case a decision is to be made to build a new technology giant telescope, we, in India should not attempt it alone. It makes more sense to seek collaboration, both financial and technical with some advanced country by offering an attractive site on the Indian soil. Many of the world's big telescopes are now-a-days operated by two or more countries together (e.g. the Anglo-Australian Telescopes, Canada-France Telescope, ESO etc.).

There have been researches in the last two decades, however, which seek to modify the conventional telescope designs to make the dishes lighter, more maneouvrable and the domes smaller. Such proven techniques should certainly be adopted in building a Large Optical Telescope (LOT). An example is the Mersenne-Schmidt model discussed by Willstrop1.

A question often asked is the following. There are a lot of LOTS (- no pun intended!) in the world today. So is it any more relevant to build another LOT today? Can a LOT do 'frontier' class observations anymore? The answer is 'yes'. There are still many different

areas in extragalactic astronomy wherein astronomers can use a LOT. I propose to describe some in this talk. It is necessary, however, to equip the LOT with high grade back up instrumentation like CCD cameras, automatic plate measuring machine, low and intermediate spectrographs, and an efficient software for image processing etc.

Cosmology, old and new

When I was a research student in the early 1960s, cosmology was still regarded somewhat aloof from the rest of astronomy and astrophysics. Its basic theory came from general relativity which was somewhat away from the mainstream of theoretical physics. The observational problems in cosmology were still revolving round the tests of rival models. These tests consisted of

(1) The m-z relation to determine H_0 and q_0,
(2) The θ-z relation to determine q_0 from the predicted minimum value of the angular size θ
(3) The number counts of galaxies and radio sources
(4) The determination of the mean density parameter S_2

While interest in these tests continue[2], cosmology has come much closer to physics and astronomy today largely because of the following circumstances:

1. The successful application of theory of nuclear fusion to explain primordial abundances of light nuclei[2],
2. The apparent confirmation of the 'early hot universe' scenario by the discovery of cosmic microwave background[2],
3. The input of the latest speculations from particle physics into the problem of galaxy formation,
4. The improved understanding, both observational and theoretical, of discrete extragalactic energetic sources.

It is against this new background that we should look at cosmological problems today and ask what observational data could help towards their solution.

Briefly the future observational studies would be classified under three categories:

(i) The study of populations of discrete sources to find evolutionary evidence or lack of it,
(ii) The study of specific individual sources,
(iii) The study of radiation backgrounds at different wavelengths.

Of these, the last one may not be quite relevant to the LOT since the optical sky background does not seem to play much role in cosmological issues. I will discuss briefly the observations that fall under the first two categories.

Some interesting and worthwhile programmes for the LOT

Given a LOT today, what 'new' can it discover? Here are some problems or programmes that merit serious consideration.

1. ***Cluster evolution:*** How do clusters of galaxies at earlier epochs compare with those now? Measurements of various properties in clusters of high redshifts ($z \geq 1$) can help answer this question and tell us whether the universe as a whole is evolving. These measurements include luminosity functions, velocity dispersion, galaxy types, spectral features etc.

2. ***Deep redshift surveys:*** As in the classic tests of cosmological models, it should be possible to carry out deep redshift surveys of galaxies to understand the large scale structure of the universe (e.g. superclustering, voids, stringy structure etc.).

3. ***QSO environments:*** Do QSOs have host galaxies? Measurements of spectra of the fuzz around some QSOs could answer this question. Other features of QSO environments are clustering, extended emission lines, absorption line systems etc.

4. ***Active galactic nuclei:*** As stepping stones to QSOs, the AGN's are very important objects to study. Their spectra and variability, the anisotropy of their radiation, provide checks on theoretical models.

5. ***Deep CCD imaging of galaxies:*** This can help understand the structure and morphology of galaxies, the nature of interaction between neighbouring galaxies etc. In addition a LOT can be used for intermediate dispersion spectral synthesis of galaxy spectra.

6. ***Follow up on observations at different wavelengths:*** The study of 3C and 4C radio sources by optical telescopes has been proving extremely instructive. There will be other sources from different telescopes/missions like the HST, ROSAT, IRAS, ISO etc. ROSAT alone is expected to provide $\sim 10^5$ sources for further study. In India we need LOT to do further work on sources found by GMRT.

7. ***Study of peculiar systems:*** Peculiar systems like irregular galaxies, systems with anomalous redshifts[3], galaxy nuclei showing signs of explosion need to be studied in detail to understand why they are peculiar.

8. ***Unexpected phenomena:*** A good LOT can be an asset for studies of phenomena that crop up unexpected. The Supernova 1987A, SS433, The Crab Pulsar, the Twin Quasar are examples which are serendipitous but extremely interesting and challenging to the theoreticians.

Concluding remarks

"What do you expect to find with this proposed new telescope?" Hubble and Eddington were asked at a press conference when the 200-inch (Hale) Telescope was under construction. The reply was "If we knew the answer there is no point in building the instruments".

No telescope has ever made an important discovery for which it was designed and built. In spite of the prevalent feeling that by and large we understand the universe, I am confident that new astronomical discoveries of great importance are waiting to be made. Although we may justify a LOT for any of the first seven reasons given in §3, the most exciting prospect lies in the last possibility.

References

1. Willstrop, R.V., Proceedings of the IAU Colloquium No. 79 on "Very Large Telescopes,their Instrumentation and Programmes", Garching 1984, p.395
2. Narlikar, J.V., "Introduction to cosmology", 1983 (Jones & Bartlett): for details of the tests.
3. Arp, HC., "Quasars, Redshifts and Controversies". 1987 (Interstellar Media, Berkeley): for anomalous systems.

Discussion

J.C. Bhattacharyya : Will there be many advantages in our experiments in observational cosmology if large telescopes are operated in the infra-red?

J.V. Narlikar : I believe so. At high redshifts we expect to observe lines in the infrared. Also, some radio sources that are too faint to be visible may be observable in the infrared.

Gopalkrishna : For the purpose of cosmology when we wish to compare the optical shapes of nearby galaxies with the shapes of high redshift galaxies, it is essential but the latter be imaged in the near-infrared.

N. Kameswara Rao : A big telescope is primarily a zenith instrument where you get optimum seeing which is essential criterion for a telescope. As such there is lot of scope for several big telescopes at different longitudes.

P.C. Agarwal : (1) I want a little clarification on the quasar event survey which you mentioned as an area of research for LOT. Quasar surveys up to 22 mag have been done by Green et al. and others. Are you suggesting extension of these surveys to still fainter quasars or suggesting extensions of these surveys over larger areas?

: (2) You mentioned detection and studies of host galaxies of quasars. I will like to point out that faint fuzz has been detected around several quasars but due to its extremely low surface brightness the spectroscopic studies of these fuzzy features seem very difficult even with large telescopes.

J.V. Narlikar : 1. Green & Schmidt number counts were for brighter quasars. There have been counts by others down to fainter magnitudes. However, as you go to faint samples, the number per sq. deg increases and it is not possible for a single survey to cover the whole sky. Thus it is necessary to do the quasar counts to fainter magnitudes (say down to 22^m) because of their possible cosmological significance. So far, there is lot of scope for this work.

2. There have been claims in the literature that the redshift of the

fuzz has been measured and that it agrees with the redshift of the quasar. However, I agree that it is a difficult observation. A LOT should be able to conduct it with high grade instrumentations.

U.C. Joshi : Imaging is limited by sky brightness, Surveying sky with a schmidt telescope using photographic method gives information upto about 22 mag. Going fainter even with a large ground based Schmidt telescope is rather difficult. Would you comment or elaborate your statement on detecting faint quasars? HST is expected to give us data upto 26 mag.

J.V. Narlikar : I have dealt this point in my reply to Prof Agarwal's first question. Naturally LOT cannot compete with HST in limits of faintness but it can do a follow up on several of the observations of HST.