ma temperature of 40,000 K was computed. These lines are very narrow and their velocities are near 285 km/sec, indicating that they may originate in a circumstellar shell (ejected from the progenitor during an earlier mass-loss phase?)

A long-term programme is under way with the Bochum telescope on La Silla; see the article by Hanuschik et al., in this *Messenger* issue. In the far-infrared spectral region, several flights with the Kuiper Airborne Observatory (KAO) have showed emission lines from iron-group elements, synthesized during the supernova explosion. SN 1987A continues to be radio-quiet and the longest wavelength at which it has recently been detected is 95 μm.

Speckle interferometric observations with the 4-m telescope at the Cerro Tololo Inter-American Observatory in November have resolved the supernova shell at about 0.02 arcseconds, corresponding to a mean velocity of about 4,000 km/sec since the explosion. Similar observations with the 4-m Anglo-Australian Telescope, also in November, show that if there is a secondary object within about 0.8 arcsec of SN 1987 A, then it must be at least 4 magnitudes fainter.

The supernova faded to magnitude 6.4 in mid-January and to about 6.8 in mid-February. After a period of linear decline on the magnitude scale, corresponding to the radioactive decay rate of Cobalt-56, the decline became more rapid. Towards the end of January, observers at the South African Astronomical Observatory found that the bolometric (total) luminosity was 7% below a straight extrapolation from the linear decline between July and October 1987. The light in the U-band which had been constant over a long period, again started to fade in late December 1987.

The Editor (February 23, 1987)

Some Prospects of Galactic and Extragalactic Studies*

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The main purpose of the astronomical work is to obtain information about all kinds of bodies and systems existing in the Universe, about their past and future, and regularities of processes going on in them. Studies and the observational work with this purpose are developing in three main directions: the study of the Solar system and of its members (planets, comets, meteorites), the galactic research which studies our stellar system and its members (stars, nebulae, clusters of stars), and the extragalactic research.

Since the discoveries of Galileo, astronomers have applied and continue to apply optical telescopes in all three directions mentioned above. However, during this century new methods have been invented. It is sufficient to mention here the ground based radio telescopes, the X-ray receivers and telescopes, γ-ray receivers which are observing from the space around the Earth. But, of course, the recent technical progress has affected in the strongest degree the planetary astronomy. Some of the space vehicles give us the possibility to observe the planets, comets, satellites from the immediate vicinity. There is no doubt that the role of investigations with space vehicles in planetary studies will enormously increase in future and this means that the role of ground based telescopic observations in this field will diminish.

Of course, in the fields of galactic and extragalactic research the modern methods (radio astronomy, X-ray astronomy, far infrared, space missions and particularly space interferometry in different wavelengths) will play an increasing role, but they cannot replace, at least during the next several decades and probably during the next century the work of optical telescopes.

Therefore, let us concentrate our attention on galactic and extragalactic research, though we must not forget that the solar-system studies can have a great indirect influence on the studies of phenomena on the stellar and galactic scale.

What is the main purpose of astronomical research in the galactic and extragalactic fields?

I think it is (1) to understand the constitution of stars and nebulae as well as of systems, including the increasing volume of the Metagalaxy and (2) to study the origin, life, evolution and the future destiny of these bodies and systems.

This is the general formulation of goals of these fields of science. However, in the practice of scientific work these general goals dissolve into countless subjects, problems, questions and topics, each of which can prove its importance and can require a special programme of studies.

And you know well that very often the solution of each problem raises a large number of new problems, which in the past were under the scientific horizon.

The difficulty of formulating the multitude of special problems, of programming the ways of their solution is complicated by the fact that they very often intersect and penetrate each other.

Let us take one example. Everybody understands that we have two important and seemingly independent problems of stellar astronomy: the distribution of the stars in the Galaxy and the origin of stars. By studying the distribution of early-type stars in the Galaxy we arrived at the concept of OB associations, and the nearer study of OB associations has brought us nearer to the solution of the origin of early-type stars. In the same way the study of the distribution of dwarf variables of T Tauri and RW Aurigae stars has immediately demonstrated us the existence of T associations. From this the concept of the origin of stars in groups has followed.

Inversely, the understanding of the fact of desintegration of stellar associations has opened many questions on the kinematics of open clusters and individual stars which are the *remnants* of stellar associations.

Thus there are two problems: the origin of stars and their distribution in the Galaxy, and they are closely connected.

On the other side, the observations show that the formation of stars in the association is taking place in smaller subgroups in the, so to say, *recent star formation regions* which have linear sizes smaller than one parsec and comprise only a very small part of the volume of the associations.

The study of such regions where the complicated phenomena of the ejection of gaseous matter, of H_2O and other masers, as well as the formation and ejection of Herbig-Haro objects are characteristic is to be carried out with many different techniques, among which optical and infrared telescopes are playing an important part.

Last Wednesday Dr. Moorwood showed us some infrared pictures of such a region in Orion where the Becklin-Neugebauer object and other infrared sources are situated.

We are sure that the study of these phenomena will bring us much nearer to

* Talk given at First School for Young Astronomers Organized by ESO and the Astronomical Council of the U.S.S.R. Academy of Sciences (see the *Messenger* **50**, p. 43–44).

the understanding of the origin of stars of the disk population.

I am convinced that the study of such regions of "recent star formation" by direct, spectroscopic, infrared, radio methods promises to become one of the most rewarding fields of observations.

But if we know the direction in which we can strongly hope to find the solution of the problems of the origin of stars of Population I and of galactic nebulae, the situation in regard to Population II stars is not so hopeful.

Anybody who has some experience in the treatment of the problems of stellar origin will agree that the problem of the origin of Population II stars must be closely connected with the problem of the origin of globular clusters.

But apparently our Galaxy at its recent phase of evolution is deprived of the young Population II objects, at least we don't see them in our neighbourhood. It seems therefore that the progress towards the solution of this problem will be accelerated by combining the information obtained from observations of galactic and extragalactic objects.

Let me bring here two more problems which require the combination of galactic and extragalactic data.

We observe in our Galaxy a limited number of Wolf-Rayet stars. They are young objects. We observe them as a rule in OB associations. But there are many OB associations which don't contain any WR stars. The best example is the Orion association. It contains no WR star in spite of the fact that different parts of this association are apparently at different stages of evolution. Therefore, the evolutionary status of WR stars is not quite clear, but of course we are sure that they are comparatively young objects.

But the remarkable fact is that in 30 Doradus, which is a superassociation (or giant H II region), in its central part we observe at once a whole group of WR stars which form together with a number of O stars a compact nucleus of the superassociation. With great probability we can suppose that many superassociations in other galaxies also contain WR stars. We know also, that some Markarian galaxies contain not one, but several superassociations.

The future large telescopes will allow us to establish the abundance of WR stars in them.

The last problem which requires both the galactic and extragalactic information is connected with the giant molecular clouds. As is known, the considerable percentage of giant molecular clouds contains stellar associations. However, the emergence of the OB association in a molecular cloud must lead to its destruction and dissipation. We do not know the exact percentage of GMC which contain OB stars. Apparently, 30% or 50% is a good estimate of the order of the magnitude. But this will mean that the life-time of a GMC cannot be longer than the life-time of an OB association by more than *one order* of magnitude. On the other hand, the life-time of OB associations was estimated (until now) as 10^7 years. This means that the life-time of GMC must not be longer than 10^8 years. The urgent problem arises on the origin of molecular clouds. Of course, this is also a problem for theoreticians. However, it seems to me that the solution can be found on the basis of detailed observational studies of the whole problem of connection between the molecular clouds and young stars.

As I have insisted in some of my papers, the problem of the origin of nebulae and particularly of molecular clouds is now not less actual than that of the origin of stars.

Of course, there are countless problems which are to be solved in the frame of pure galactic observations.

As an example, we can consider the nature and cause of changes in T Tauri stars. A special problem is the variability of very faint red dwarfs (of visual absolute magnitude of about +17 or +18). We know that we can find the flare stars among very faint dwarfs. But are there also T Tauri variables among them? This requires the observation of very faint stars (of apparent magnitude of 21 or 23) both in open clusters and the general field.

In this connection I would like to remind you that by building larger telescopes we acquire the ability to study more distant objects as well as to observe intrinsically fainter objects. Comparing in this respect the requirements of galactic research we notice that for extragalactic research both abilities are equally important. However, in the galactic research the second is relatively more important. This is why I emphasize here specially the problems connected with extremely faint red dwarfs. But of course the study of white dwarfs is of no less importance.

Passing to extragalactic problems and taking into account our last remark we begin of course with the most distant objects – the quasars of very high redshifts. It is quite natural that astronomers are awaiting with deep emotions the discovery of new record redshifts. But it is necessary to tell that we need also the systematic study (both statistical and physical) of the whole range of quasars beginning with $z = 0.2$ to $z = 4.5$ and larger if they are there.

At the same time it is very important to consider deeper the connections between the world of Seyfert galaxies and quasars. For this the detailed study of the nearest quasars is important.

For us, theoreticians, quasars are galaxies which have a very bright nucleus. The stellar surroundings of them are sometimes of the scale of usual giant galaxies. But apparently there are cases where these surroundings are relatively faint. To understand the regularities of relationship between nuclei of galaxies and of stellar population around them is one of the major problems of extragalactic astronomy and in this respect the study of the nearest quasars must be of the greatest value.

On the opposite flank of extragalactic research is the study of dwarf galaxies. The most important regularity here is their irregular structure. Another property which apparently is connected with the question on their evolution is the relatively high mass of the neutral atomic hydrogen in them. It is a great priviledge for us and specially for ESO that our Galaxy has two of them so near. But to recognize the regularities within the irregularities apparently will require the study of a larger number of objects and therefore the detailed study of a number of objects on intermediate distances of the order of several millions of parsec is necessary. But there the stronger ties with radio astronomy, especially with 21-cm astronomy, are necessary. May I remind you that during the last years objects have been discovered which are giant H I clouds of galactic dimensions and at the same time have no discernible stellar population. It is of interest to find intermediate objects where gas and stars have masses of equal orders.

Between these two fields (very faint dwarfs and quasars) we see the vast field of investigations of normal galaxies and processes in them, the work on more detailed and apparently multidimensional classification of normal galaxies.

Of special importance are studies of active galaxies and specially of their nuclear regions, of wonderful changes of brightness and spectral properties of the nuclei of active galaxies and quasars.

The problem of large-scale distribution of galaxies and their clusters is a bridge between extragalactic astronomy and cosmology. And I am sure that the large telescopes of the near future will open fascinating prospects also here.

One of the important subjects of investigation remains the physical nature of interstellar matter. Now we are sure that the bulk of interstellar matter consists mainly of *molecular clouds*. The so-called Great Molecular Clouds (GMC) are individual objects of great interest and the problems of their origin are not less intriguing than those of stellar clusters. But at the moment our knowledge of them is very superficial. Great efforts are necessary.

But GMC clouds form only one of the components of interstellar matter.

The other components are connected with the general structure of the Galaxy as a whole as well as with external influences on the Galaxy. We are only beginning to understand their role in the Galaxy.

My talk, as I mentioned, reviewed only some aspects of the problems of galactic and intergalactic research and reflects mostly my personal views and interests, the interest of a theoretician. May I repeat here what I have said in my welcome to this school:

The real essence of our knowledge of the Universe is contained in the observational data. The role of the theory is to systematize the data and to connect them logically between themselves and with the data from other sciences.

Galactic Chronometry with the Coudé Echelle Scanner

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Introduction

I have recently proposed that observations of the radioactive nucleus 232 Th in stars may be used to derive a new kind of galactic chronometer (*Nature*, vol. 328, pp. 127–131, 1987). The extraordinary performance of the Coudé Echelle Spectrometer on La Silla has played a central role in making possible the difficult observations required. I congratulate the ESO staff on producing such an outstanding instrument.

The idea is simple – if G-dwarf stars sample a well-mixed interstellar medium in the Galaxy at the time of their birth, and if the compositions of their atmospheres have not changed since birth except for radioactive decay, then the abundances of radioactive species in these stars will represent an integration of element production and destruction (via radioactive decay, astration and possibly dilution) in the Galaxy, up to the moment of stellar birth, followed by free decay still observed today. If one can develop a sample of stars with accurately known ages, then one has a record of the history of nucleosynthesis, at least for thorium and the r-process elements, which may help resolve the model dependencies inherent in using solar system data alone. That is, solar system material provides an integration of element production and destruction activity up to 4,6 Gyr ago; observations of radioactive species in the oldest stars known will yield an integration over only a short period at the beginning of the Galaxy; and data on the youngest stars give an integration over the whole galactic history.

Thorium has several faint absorption lines in the solar spectrum, and the strongest of these, at 4019.129 Å, even has an accurately measured transition probability (Andersen and Petkov, *Astron. Astroph.* **45**, 237–238, 1975).

When combined with the measured line strength, this probability yields the same abundance for thorium as found in meteorites. The line, therefore, appears to be largely unblended and a good candidate for use in setting up a chronometer based on thorium. It should also be remarked that the element thorium has only one long-lived isotope, 232 Th, so that measurement of the elemental abundance is expected also to give the isotopic abundance of interest.

The Chronometer

Figure 1 shows the region around Th II 4019.129 Å in alpha Cen B, one of the stars in my final sample. The thorium line is seen to appear in the wing of a stronger line, which turns out to be a blend of a Fe I and a Ni I line. Also indicated is a nearby absorption line of neodymium, Nd II 4018.823 Å. This line has a lower level excitation only 0.05 eV above that of Th II 4019.129, and neodymium has a first ionization potential close to that of thorium. Both lines are, therefore, from the dominant ion throughout late-type stellar atmospheres, and will behave with temperature and pressure essentially identically. Furthermore, both lines are unsaturated in G-dwarf spectra, so that their strength ratio is proportional to the abundance ratio of these two elements, and is largely unaffected by unknown or poorly estimated stellar atmospheric properties. And finally, it is important that there exist two rather good continuum points, at 4018.66 and 4019.67 Å, in the near vicinity (see for example the high resolution but compacted plots of the solar spectrum displayed in Figure 5 of Rutten and van der Zalm, *Astron. Astrophys. Suppl. Ser.* **55,** 143–161, 1984). Because the lines are so close together in wavelength and are bracketed by good continuum points, the ratio of their strengths may be determined with considerable reliability.

The proposed chronometer is the ratio of the strengths of these two lines. This ratio has the property that it can be measured to high accuracy. Whether it will in the end provide a useful and reliable chronometer depends on the details of the measurement errors and on the reality of a crucial assumption.

A Crucial Assumption

To have a useful chronometer, it is necessary to be able to compare the abundance of the radioactive species at synthesis, which is normally a quantity predicted theoretically, with the observed abundance. For the U-Th data in meteorites, for example, one can estimate the relative production ratios of 232 Th, 235 U, and 238 U, rather accurately, because they are very close to each other in atomic mass and in a mass range expected to exhibit a relatively smooth variation of abundance with mass in the r-process. Nevertheless, a major source of uncertainty in applying U-Th data in the solar system for chronometry are the uncertainties in the production ratios.

The situation in the stellar case is, in principle, much, much worse. Thorium

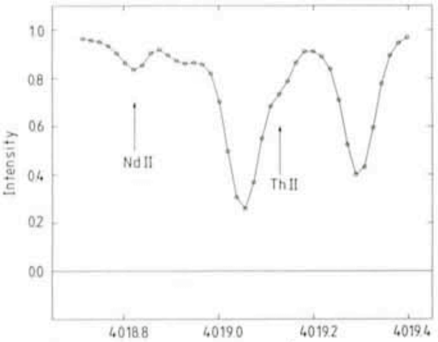

Figure 1: *CES spectrum of α Cen B in the region of Th II 4019.129 Å. The thorium and neodymium lines used to form the chronometric quantity Th/Nd are indicated.*