Address to the Plenary Session and to the Study Week on the Subject ‘The Problem of Stellar Populations’

The Supreme Pontiff surveys the state of scientific research into the ‘starry firmament’, whose immensity and order speaks to humanity of the ‘power and wisdom of its Author’. He stresses that such inquiry implies a search for higher truths and observes that advance in this area, as in others, must be linked to higher aspirations: ‘since the moral universe transcends the physical world, every gain made by science is on a plane lower than that of man’s personal destiny’. The scientist, therefore, must also turn to the ‘acquisition of spiritual values, of justice and of charity’.

Like the other physical sciences, whose prodigious development we of the present day contemplate with admiration, astronomy is now passing through a period of extremely fruitful researches and discoveries. Thus we are particularly glad to welcome today, with the elect group of astronomers taking part in the conference convened at the Vatican Observatory, also the members of our Pontifical Academy of Sciences. In the midst of this assembly of distinguished scientists and tireless investigators of the wonders of creation, we feel an ardent desire to repeat the hymn that the Creator puts on the lips of all those who receive gratefully from Him the gift of life, of intelligence and of love: *Caeli enarrant gloriam Dei et opus manuum eius annuntiat firmamentum.*1

In order to know better this starry firmament which speaks to you, by its immensity and its order, of the power and the wisdom of its Author, the conference convened under our auspices proposes to debate in free and friendly discussion questions of great interest, which are absorbing the attention of specialists, and also of all those who are interested in one way or another in our knowledge of the physical universe. When the Congress of the International Astronomical Union was held in Rome in 1952, we took the opportunity of congratulating its members on the marvellous conquests

that their science had accomplished during recent years. We then retraced the salient steps which enabled astronomers to form a more precise idea of the galactic system and of the position that the Sun occupies within it; and then to determine the real nature of spiral nebulae, recognising in them other galaxies analogous to ours and containing thousands of millions of stars. Beyond the worlds already known, one could suspect the existence of others, which would soon reveal themselves with the aid of giant telescopes. At this very time, moreover, there was published Baade's discovery that the hitherto accepted scale of the universe had to be multiplied by a factor of two or even more.

To the same astronomer we owe the first mention of the central theme of your present discussions, the existence of two types of stellar populations. Baade's paper, published in 1944, starts with the statement that recent photographs on red-sensitive plates, taken with the 100-inch telescope at Mount Wilson, for the first time resolved into stars the two companions of the Andromeda nebula and the central region of the Andromeda nebula itself. This was no chance discovery, it was the fruit of long and painstaking research. With giant modern telescopes it was possible to resolve the outer parts of the nebula and to photograph individual stars, but the central nucleus remained completely amorphous, even photographed with the most powerful instruments. Finally, skill and patience overcame the difficulty. On various grounds it seemed reasonable to suppose that the nucleus really contained individual stars, but that these stars were too faint to appear as such on the plates. It also seemed likely that the brightest stars in the nucleus would be red giant stars. Baade thought that it should be possible, by using red-sensitive plates, to pick up at least these red giants. By taking every precaution and using very long exposures (of up to nine hours) Baade reached the very limit of what was possible with the means then available and succeeded in photographing great numbers of stars in the nucleus of the Andromeda nebula and in its two companions.

Baade then showed that these newly discovered stars are cooler and less luminous than the blue giants in the spiral arms of the nebula and came to the conclusion that the stellar populations of the galaxies can be divided into two groups, one represented by the blue giants and the stars in galactic clusters (Type I), the other by the stars in the nucleus, those in globular clusters and short period Cepheid variables (Type II). The two types of stars differ not only in brightness and colour, but in age, location, chemical composition, and in the mode and rate of energy production.

In the same paper Baade points out that, as early as 1926, Oort had distinguished in our Galaxy two groups of stars, a group of stars moving with high velocity relative to the Sun, as contrasted with the stars moving more slowly. These two classes, which differ also in frequency of their spectral types and in galactic concentration, correspond to Baade's type II and type I respectively. Thus these discoveries of Baade and Oort supplement each other. They opened the way to a flood of theories and researches, with which you will deal in this conference.

A glance at the programme that you have prepared shows, even to one who is not a specialist in these matters, the complexity of the topics that bear on your problem and the many different lines of approach that are needed for a thorough examination of the subject. You commence with a study of external galaxies and proceed later to a detailed discussion of our own Milky Way system. This is indeed the logical approach to a study of the question of stellar populations, and the line

which advance in knowledge has in fact taken, for it has been extremely difficult to chart the details of our own Galaxy, owing to the fact that our own solar system is embedded in it. The first indications of your problem were found in external galaxies, although in the meantime a great deal has been learnt about our own Galaxy. The Dutch astronomers, for instance, have succeeded in tracing the spiral arms of the Galaxy by means of their observations of radio waves emitted by the hydrogen in the arms. Since the stars of our system are much less distant than those in external galaxies, the astronomer can learn a great deal more about them, by studying their brightness, their spectra, their motions and distribution in space.

Much of this knowledge could be acquired only with the aid of the most powerful means available. Thus the study of globular clusters, which has proved so fruitful in providing information about stars of population II, has been carried out with the 200-inch telescope at Mount Palomar. Nevertheless, much excellent work can be done with more modest instruments, notably in the study of variable stars, to which, we are happy to note, the Vatican Observatory is making a useful contribution. For the Cepheid variables, which constitute a precious source of information for the problem of stellar populations, one needs a more precise estimate of their distribution in the Galaxy, as well as more information about their spectra and their motions and about the mechanism which is responsible for their variability. As for the flare stars, those remarkable objects that flare up suddenly, remaining bright for a short time and then fading more slowly to their original brightness, no doubt new ones will be discovered and more will be learned about their behaviour and their distribution.

You will give much attention to problems connected with the evolution of the stars, the production of energy in their interior, the formation of atoms and the transmutations which they undergo. Here you need the aid of nuclear physicists and of experts in statistics, in order learn more about the nuclear changes in the intensely hot interior of a star, the different cycles that may succeed one another in the development of an individual star and the differences in this respect between the various types of stars. You will try to determine how the chemical composition affects the development of the different types and what changes it then undergoes, as well as what effects the interstellar medium, dust or gas, has on the stars which pass through it, what exchange of matter there is between medium and star, and what effect these processes have on both.

Of very great interest is the enormous difference in the ages that you now assign to various types of stars. Whereas you believe that stars of population II are about 5,000 million years old, about as old as the universe itself, the age of population I stars seems to be at most some tens of millions of years. It is understandable that the blue supergiants, which emit continously such a vast quantity of energy in the form of heat and light, are so spendthrift of their store that they must burn themselves out comparatively quickly, whereas such ancient stars as our Sun husband their resources better, though even the Sun pours out what seems to us enormous quantities of energy. You may succeed in discovering stars more youthful still, or even perhaps in observing the very birth of a star.

The formation and evolution of the older stars of population II will also demand much of your attention, in spite of the interest naturally evoked by the spectacular transformations of their younger companions. Our Sun, in particular, cannot be neglected, for, apart from the direct

influence it has on the earth and its inhabitants, it is so much nearer to us than any other star that we can learn far more about its secrets, and its study must ever remain an essential department of astronomy.

No one would think, on that account, of neglecting the external galaxies, the importance of which for astronomical research we have already emphasised. The Magellanic Clouds, in particular, have the advantage of being the two stellar systems nearest of all to our Galaxy, and information can be obtained from them that cannot be obtained from more distant systems. You have therefore invited to your conference the representative of a great observatory in the Southern hemisphere, who has devoted much of his labours to these systems.

The elliptical galaxies, which contain mainly stars of population II, bear some resemblance to globular clusters, but differ from them certainly in size and origin. The globular clusters themselves, when subjected to precise examination, show certain differences from one to another. Thus the Hertzsprung-Russell diagram in one cluster does not correspond precisely to that in another. It is even possible that the types of stellar population are not limited to two. It is now your task to debate among yourselves and to communicate on this point, as on the other topics which we have mentioned, the facts that you have gathered and the conclusions to which you have been led.

The tireless search for precise facts, the development of theories to explain the facts, the verification of theory by new observations, the modification of a theory when necessary, its replacement by another more perfect theory which fits better the data acquired, such is the incessant labour of the astronomer, a labour which appears titanic even to the uninitiated. Whatever stage the astronomer has reached by his researches, he cannot dispense with a general picture of that universe, whose minutest details he is scrutinising. Even if awkward gaps in his knowledge cause some of his constructions to break down, he cannot lose the exciting conviction that by thought he is greater than the cosmos, and will sooner or later tear from it new secrets.

But even when he holds in his hands the keys which will open to him doors as yet closed, his task will still be far from finished; not only because the evolution of stellar worlds constantly renews the object of his interest, but also because the truth which will satisfy his urge is in reality on a higher plane than that of scientific research. The knowledge of the physical universe, from the infinitely small to the infinitely great, intoxicates the mind of man, by its tantalising, but alluring riddles; yet it does not free him from his unease. Like all other scientists, like the engineer at grips with modern applications of electronics or of nuclear energy, but also like the humblest of intellectual or manual workers, the astronomer seeks a truth which far surpasses that of mathematics, or of general laws of physics, or of material objects which he can measure, move, or control. What would the immensity of the cosmos, its splendour, its organisation be, without the intelligence which discovers itself in contemplating the cosmos and which sees in it as it were its own image? Is not what man reads in the stars a symbol of his own greatness, a symbol which invites him to mount higher, to seek elsewhere the meaning of his existence? Contemporary scientific thought is accustomed not to retreat before any problem, and that is legitimate so long as it remains within its own domain. But, since the moral universe transcends the physical world, every gain made by

science is on a lower plane than that of man's personal destiny – the ultimate aim and purpose of his existence – and of the relations which unite him to God. Scientific truth becomes a decoy from the moment when it is considered adequate to explain everything, without being linked up with other truths and above all with subsistent truth, which is a living and freely creative Being. The labour of the scientist, however disinterested and courageous, loses its ultimate motive if he refuses to see, beyond purely intellectual ends, those proposed to him by conscience, the decisive choice between good and evil, the profound orientation of his life towards the acquisition of spiritual values, of justice and of charity; above all of that charity which is not merely philanthropy or a feeling of human solidarity, but which proceeds from a divine source, from the revelation of Jesus Christ.

Happy is he who can read in the stars the message which they contain, a message worthy of its author, and capable of rewarding the seeker for his tenacity and his ability, but inviting him also to recognise Him who gives truth and life and who establishes His dwelling in the heart of those who adore and love Him. While expressing the sincere wish that your discussions will come up to your expectations and will bring you the lively satisfaction of having accomplished a most fruitful task, we beg the Author of all good to grant you His aid and protection, in pledge of which we give you with all our heart our Apostolic Blessing.

1 *Ps* 18:2.