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SUPERNOVAE AND SUPERNOVA REMNANTS

Edited by Cristiano Batalli Cosmovici

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SUPERNOVAE AND SUPERNOVA REMNANTS

PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON SUPERNOVAE HELD IN LECCE, ITALY, MAY 7–11, 1973

Edited by

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PREFACE

> This conference is a tribute to those astronomers who pioneered the investigation of this subject such a short time ago and who carried it through to its present state.
>
> (H. Arp, *Concluding Remarks of the Conference*)

A previous conference, covering mainly the observational aspects of Supernovae, was held at the Haute Provence Observatory in September 1963.

In the following ten years this field of research has considerably increased; it seemed, therefore, the right time to organize an international conference on Supernovae taking into account that in the meantime important discoveries, such as the Pulsars, had been made, and new techniques of observation were available. This book contains the proceedings of this conference held at Porto Cesareo (Lecce), Italy, during the period May 7 through 11, 1973. About one hundred participants from eighteen countries attended the conference.

It was also the first attempt to hold an international conference in the Salento, the southernmost region of Apulia, in whose capital, Lecce, the newly founded Faculty of Sciences of the University of Lecce is located.

The program of the conference included the results and techniques of Supernova surveys, photometric and spectral studies, statistics of Supernovae, Supernova Remnants, and finally, theories on Supernovae and Supernova Remnants.

The review and contributed papers were of an excellent scientific standard, thus assuring the complete success of the conference. Among the people who contributed to the organizational success I would like first to thank Prof. Francesco Bertola for suggesting this conference and for continuous help in preparing it, and all the other members of the Scientific Committee for their valuable suggestions and advice.

The Director of the Institute of Physics, Prof. Saverio Mongelli was most helpful in providing financial support and all necessities for the conference.

Dr Emilia D'Anna, general secretary of the conference, was an excellent and untiring collaborator in its organization, and in the preparation of the proceedings.

Dr Alfredo Borghesi and Dr Livio Ruggiero were especially cooperative in providing excellent residential and conference facilities.

My special thanks are also due to Prof. Guido Pizzella, to the Rector of the University of Lecce, Prof. Giuseppe Codacci-Pisanelli, to the President of the Faculty of Sciences, Prof. Ida Gasparini-Cattaneo, and to my wife, Beatrice, for their moral support.

The conference would not have been possible without the financial support of the following institutions:

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Lecce, September 1973 CRISTIANO BATALLI COSMOVICI

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REVIEW OF THE RESEARCH ON SUPERNOVAE

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1. The Original Scenario

In the 1928 April issue of Harper's Magazine there appeared an article by George Ellery Hale, then Director of the Mount Wilson Observatory, which was entitled 'The Possibilities of Large Telescopes'. The article starts out with the following sentence,

> "Like buried treasures, the outposts of the universe have beckoned to the adventurous since immemorial times."

It has been related that Mr Rockefeller read only this first sentence of the article and immediately called up Hale, offering to support any of his big plans financially. A few months later the International Education Board of the Rockefeller Foundation awarded the California Institute of Technology in Pasadena six million dollars for the construction of a new Astrophysical Observatory and Laboratory, to be conducted in close cooperation with the Mount Wilson Observatory of the Carnegie Institution of Washington. Hale's plans for the new observatory envisaged the building of a 200-in. reflecting telescope and all necessary auxiliary apparatus and devices.

At the California Institute of Technology, there were at that time five of us who had previously dabbled with various problems of theoretical, observational and instrumental astronomy, namely R. C. Tolman, Professor of Physical Chemistry, Dr J. J. Johnson, who had been on many solar eclipse expeditions, Dr John Strong, working on various phases of applied astronomy and on infrared radiation, Dr Sinclair Smith, who had helped perfecting many instruments at the Mount Wilson Observatory and who had considerable experience as an observer, and especially in the evaluation of the performance characteristics of various telescopes and the effects upon them of atmospheric seeing, and finally myself. As developments went, the five of us subsequently worked together most efficiently for many years on a great variety of problems. Three of the men having passed away, there remain only Professor John Strong and myself cooperating more intensively than ever on problems in astronomy, as well as in morphological research, he and I acting respectively as the Vice President and the President of the International Society for Morphological Research.

The temptation, in 1928, for the five of us above mentioned faculty members at CIT to switch our allegiance from physics to astrophysics and astronomy was of course very great, and we were soon engaged working on various aspects of the new observatory, as well as making plans for future observational projects. We were accompanied on our way by Hale's advice,

> "Do not make any mean plans."

C. B. Cosmovici (ed.), Supernovae and Supernova, Remnants, 1–16.

With this license, and Hale's confidence in us, we started on projects which fairly stunned the Babylonians among the staid astronomical fraternity, but which, to our own amazement turned out to be successful beyond all expectation.

Personally I felt that, although Hale had established astrophysics as a new discipline, astronomers in general simply did not know enough physics to apply its fundamental principles to their science and that they did not at all realize that beyond measuring positions, motions, apparent luminosities and spectra of conspicuous stars and galaxies with admirable precision, there awaited us an unknown buried multitude of hidden treasures, that is, new cosmic bodies and phenomena which could only be divined through systematically directed intuition and subsequent tenacious search with proper instruments. Actually to this very day the morphological method of directed intuition has been studied and applied by only a very few. This is not the place to systematically explain this method. To those who eventually intend to make use of the morphological approach, however, it may be of interest if we sketch briefly how, with the method of directed intuition, specifically the field of supernovae was opened up and how the search for and the research on cosmic implosions and explosions was planned and conducted during the past four decades.

Morphological thought attempts to visualize all possible solutions of any given problem and all possible explanations for any set of facts which are not immediately and uniquely interpretable. To explore and to evaluate all aspects of a given situation, however, is only possible in limited cases in which all of the items involved, as well as the interactions between them, are clearly known. In practical cases we must limit ourselves to what Professor John Strong has proposed to call MODEST MORPHOLOGY.

Thus, when I started occupying myself with problems in astronomy I was not satisfied, for instance, with accepting the theory of the expansion of the universe as the only possible explanation of the large redshifts in the spectra of distant galaxies and, in several papers (*Proc. Nat. Acad. Sci* **15** (1929) 773–779 and *Phys. Rev.* **34** (1929) 1623–1624) I studied other alternatives. Among these the possibility, nay even the certainty of the existence of a gravitational drag on light, which lowers the frequency of quanta while they travel through intergalactic space has remained foremost in my mind.

My principal interest, however, was directed toward predicting the existence of new cosmic bodies and phenomena and then use optimally suited instruments and procedure for their discovery. After tenaciously implementing this approach for the past forty years I feel satisfied that it has proved most fruitful and that it has been successfully tested in a sufficient number of cases to merit incorporation in the curriculae of instruction of all institutions of learning. Among the scientists, who came to the same conclusion, Dr P. Chamaraux of Paris Observatory in Meudon, in a letter of 1972 to me states this conclusion most succintly by writing about the discovery of compact galaxies, "Je trouve en effet très remarquable que vous ayez prévu l'existence de ces objects avant de les *découvrir*, puis de les *étudier*. Cela me fait beaucoup penser à la découverte de Neptune par Le Verrier, excepté que Le Verrier n'a pas lui-même identifié la planète."

Concerning the prediction of the existence of new cosmic bodies and phenomena, I

started in 1928 (*Proc. Nat. Acad.* **14** (1928) 592–597) from a few elementary principles or socalled pegs of knowledge that promised to direct the intuition into the proper channels.

(a) Obviously, because of atractive forces acting between the elementary particles and bodies of microscopic and cosmic sizes, matter in general has a tendency to agglomerate and to compact.

(b) The tendency toward compaction is counteracted by preexisting kinetic energy possessed in different degree by the various bodies in the universe.

(c) Furthermore, compaction cannot proceed unilaterally since, in the process, energy will be released which automatically will result in some of the matter involved being ejected with high speeds of escape. Thus, at the same time that compact bodies are formed, matter is also being dispersed into space, interplanetary, interstellar or intergalactic.

(d) The process of compaction of matter can take place in many ways, slowly, by accretion for instance, or by fast implosion. This point is exceedingly important, since some of the most serious mistakes have been made by prejudices of various investigators concerning the kinetics of the compacting processes. One of these 'Denkfehler' was largely responsible for the face that my original theory of the existence of neutron stars and their role as the compact remnants of some supernovae was not accepted for more than three decades.

Contemplating the above stated aspects of possible avenues to discoveries to be made at our new observatory on Palomar Mountain, it struck me in particular that the study of cosmic implosions and explosions and their inevitable results of compaction and of dispersion of matter had not been given enough attention in the past. In fact, Henry Norris Russell, who spent some time every year at the Mount Wilson Observatory as an Associate of the Carnegie institution tried to impress on me time and again that implosive processes were freaks and played no role whatever in the evolution of matter in the universe. Eddington in 1930, when I lectured in Cambridge, England on cooperative phenomena and the physics of crystals told me the same thing.

Disregarding these wise councils, Dr Walter Baade and I focussed our attention on one of the best known phenomena in the realm of fast cosmic reactions and engaged in a study of novae, that is of stellar implosions and explosions which within a few hours or days result in outbursts that increase the luminosity of the stars involved by factors up to the order of one million. A careful perusal of the literature, however, revealed that, in addition to what we later on proposed to call common novae, such as the well known Nova Persei of 1901, Nova Aquilae of 1918 and others, some outbursts had been observed and reported on in the past which indicated the occurrence of a much brighter class of novae. These, in 1933, Baade and I proposed to call supernovae.

There were in particular two types of observations pointing to the existence of supernovae, thousands of times as bright as common novae, or billions of times as bright as the Sun, at maximum luminosity.

In the first place, since the discovery in 1885 of a temporary star near the nucleus of