COMPOSITION AND ORIGIN OF COMETARY MATERIALS

Cover illustration: Picture of Come Hale-Bopp taken on March 21, 1997 with the Schmidt 92/67 telescope by Giovanni Costa, Sergio Dalle Ave and Claudio Lissandrini, Osservatorio Astronomico di Padova, Sede di Asiago.

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COMPOSITION AND ORIGIN OF COMETARY MATERIALS

*Proceedings of an ISSI Workshop,
14–18 September 1998, Bern, Switzerland*

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ISSI Workshop, September 14 - 18, 1998, Bern, Switzerland

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FOREWORD

The current volume, the eighth in the "Space Sciences Series of ISSI" (International Space Science Institute) presents the proceedings of the workshop on "Composition and Origin of Cometary Materials", which was held at ISSI in Bern on September 14-18, 1998.

Following the advice of three ISSI Working Groups that had studied several aspects of comet research, ISSI appointed four convenors, Kathrin Altwegg (University of Bern), Pascale Ehrenfreund (University of Leiden), Johannes Geiss (ISSI), and Hans Rickman (Astronomical Observatory Uppsala), to set up the programme and to nominate participants.

The topic of this workshop is highly interdisciplinary in nature, and consequently scientists from different fields, including optical and radio astronomers, chemists, experimental physicists, as well as theorists and modellers of cometary and interstellar processes, participated.

The data discussed at the workshop were mainly those obtained in 1986 of the coma of Comet Halley by the Giotto spacecraft of ESA and the Vega spacecraft of the Soviet Union and those more recently obtained by remote sensing of the comae of the bright Comets Hyakutake (C/1996 B2) and Hale-Bopp (C/1995 O1). In addition, new laboratory data and model results were presented and discussed.

Comparison of data on interstellar and cometary grains confirmed earlier ideas on their origin and evolution: Tiny refractory grains are produced in stellar envelopes and explosions and transported into the interstellar medium. When a dense Interstellar Molecular Cloud (IMC) forms, these grains serve as nuclei for the condensation of gas-phase molecules and radicals. During recycling of such cloud materials through the diffuse interstellar medium, the mantles of the grains are processed by UV and cosmic radiation. It is thought that the organic material (also called CHON) found in the coma of Halley's Comet is the result of such processing. Cycling between IMCs and the diffuse interstellar medium may have occurred several times until 4.6×10^9 years ago. At that time a molecular cloud collapsed to form protostellar discs — among them the solar nebula. During the collapse phase and in the solar nebula some evaporation, molecular alteration, and recondensation occurred, but it appears that the CHON material found in comets has preserved most of its interstellar identity.

New results presented at the workshop confirmed that at least some constituents of comet ices are also of interstellar origin: Two types of species are considered as specific indicators for IMC chemistry: deuterated molecules and certain radicals. In IMCs, deuterium is highly enriched in condensable molecules. Similarly, D is enriched (above the proto-solar abundance) by an order of magnitude in cometary

water and by two orders of magnitude in the hydrogen-cyanide of Comet Hale-Bopp. Such strong enrichments result from ion-molecule reactions at very low temperatures. The D/H ratios measured in cometary water and cometary hydrogen are similar to values found in the hot cores of IMCs. This suggests that significant fractions of H₂O and HCN molecules of Comets Halley and Hale-Bopp were synthesised in the ancient IMC from which the solar system formed 4.6×10^9 years ago. Some CH₂ and C₄H, which were detected in the inner coma of Comet Halley, appear to be primary species that have been vaporised from the ice of the nucleus. If so, these radicals are likely to be of IMC origin, and their survival places important constraints on the thermal history of comet ices.

This volume is a collection of the papers resulting from the invited and contributed presentations, each of which was reviewed by an independent referee. Furthermore, it contains an article by the four editors and Ann-Chantal Levasseur-Regourd that summarises and integrates the various views presented at the workshop. The article concludes with a list of recommendations. At the end, the reader will find a list of abbreviations as well as a subject index and an index of comets. Furthermore, we have included an index of molecules, put together by Stephan Graf and Ursula Pfander, which should be useful for the reader. Comet missions mentioned in this volume are those that had been approved at the time of the workshop. This list may change even before this volume is published.

We wish to express our sincere thanks to all those who have made this volume possible. First of all, we should like to thank the authors for their contributions and the reviewers for their critical and timely reports, which have significantly contributed to the quality of this volume. It is a pleasure to thank the directorate and the staff of ISSI for their support in organising this workshop, in particular D. Taylor, X. Schneider, G. Nusser Jiang, U. Pfander, and S. Wenger. We thank Stephan Graf for designing the chemical index and his help with the manuscript, Paul Wild for his advice concerning the Comet Index, and Diane Taylor for correcting the English in some of the papers. The editors could not have published this volume at the foreseen date without the support of the editorial assistant Ursula Pfander. Her help to authors and editors in producing camera-ready texts, tables, and figures, and her preparing the camera-ready version of the volume including the indexes is very much appreciated.

September 1999

K. Altwegg, P. Ehrenfreund, J. Geiss, W. F. Huebner