

# Comets in the Post-Halley Era

Volume 1

R. L. Newburn, Jr.  
M. Neugebauer  
J. Rahe  
(editors)



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# COMETS IN THE POST-HALLEY ERA

VOLUME 1

IN PART BASED ON REVIEWS PRESENTED AT THE  
121ST COLLOQUIUM OF THE  
INTERNATIONAL ASTRONOMICAL UNION,  
HELD IN BAMBERG, GERMANY, APRIL 24-28, 1989

Edited by

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# COMETS IN THE POST-HALLEY ERA

VOLUME 2

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FIRST COLLOQUIUM OF THE  
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## COMETS IN THE POST-HALLEY ERA

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VOLUME 167

We dedicate these volumes to Fred L. Whipple  
("Fred" to everyone in the field),  
Grand Young Man of cometary science,  
who led us all to the right path

The Editors

## PREFACE

In the early 1980s, it became clear that the 1986 apparition of P/Halley would likely result in a considerable advance in our knowledge of comets, especially if some of the spacecraft being planned were successful. It also became clear that, after a reasonable period, during which the new observations could be analyzed and mentally digested, a conference and a book should review the new discoveries.

Following up on that idea, two of the undersigned began planning just such a conference. The conference was held in Bamberg, Federal Republic of Germany, on April 24–28, 1989—more than three years after Halley perihelion and the mission encounters, giving the investigators time to reduce and analyze their data. The reviews presented at that conference became the basis of this book.

Rather to everyone's amazement, all of the cometary spacecraft—ESA's Giotto, NASA's ICE, IKI's VEGA-1 and VEGA-2, and ISAS' Sakigake and Suisei—were successful. So, too, was the IHW, which coordinated much of the ground-based observing of the comet. In excess of 20 gigabytes of ground-based Halley data and much of the spacecraft data will appear later this year in *The Comet Halley Archive*. P/Halley itself apparently has retained some residual activity at heliocentric distances beyond that of Saturn! As a result, although the 1986 apparition is nearly over, the data still are being reduced and ideas still are developing rapidly. This healthy continuing development in our field made it important to the editors to produce this book as rapidly as was consistent with thorough reviews and editing. It appears that about 21 months will have been the interval required.

We originally intended that every paper would be reviewed by two external reviewers, as well as by at least one of the technical editors and by the production editor. In this, we were largely successful, and we wish to extend our sincere and heartfelt thanks to all of those who helped with the critical reviewing work. Their names are listed in the acknowledgments.

This book has been produced from camera-ready manuscripts. As a result, it contains some inevitable nonuniformities that could have been avoided only by completely retyping it entirely at one location. That probably would have resulted in new errors in the manuscripts, as well as requiring both additional time and additional resources. We chose not to retype it.

There has been perhaps a tendency in some places to think of Halley as a sort of divide, providing many answers and marking a peak in research activity on comets. However, as is usual in research, Halley provided more questions than answers. Just since the Bamberg conference, three moderately bright and exciting comets—P/Brorsen-Metcalf, Austin, and Levy—have received considerable ground-based study. Further, most experiments on the Giotto spacecraft survived their 70-km/s flyby 600 km from the nucleus of Halley in sufficiently good health to justify at least consideration of an encounter with P/Grigg-Skjellerup in 1992. Also, the U.S. Congress has approved funding for the Comet Rendezvous Asteroid Flyby (CRAF) mission. Therefore, this book provides one more interim report on our attempts to understand the nature, origin, and evolution of those enigmatic solar system members called comets.

Ray L. Newburn, Jr.  
Marcia Neugebauer  
Jürgen Rahe

August 1990



## ACKNOWLEDGMENTS

We particularly wish to acknowledge the help of our many reviewers, who are listed below. Most reviewed two papers, and a few even read three. Without these reviewers' help in this thankless task, the book would not have achieved the level of technical quality that it now has.

Ray L. Newburn, Jr.  
Marcia Neugebauer  
Jürgen Rahe

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# CONTENTS

## Volume 1

### SECTION I: OBSERVING TECHNIQUES AND INTERPRETATION

Cometary Orbital Dynamics and Astrometry.....	3
<i>D.K. Yeomans</i>	
Cometary Photometry .....	19
<i>D. Jewitt</i>	
Infrared Techniques for Comet Observations .....	67
<i>Martha S. Hanner and Alan T. Tokunaga</i>	
Infrared Spectroscopy of Cometary Parent Molecules .....	93
<i>H.A. Weaver, M.J. Mumma, and H.P. Larson</i>	
Carbonaceous Compounds in Comets: Infrared Observations .....	107
<i>T. Encrenaz and R. Knacke</i>	
Ultraviolet Spectroscopy of Cometary Comae.....	139
<i>Paul D. Feldman</i>	
The Study of Comets at Radio Wavelengths .....	149
<i>J. Crovisier and F.P. Schloerb</i>	
A Review of Radio Interferometric Imaging of Comets.....	175
<i>Imke de Pater, Patrick Palmer, and Lewis E. Snyder</i>	
The Modern Role of Visual Observations of Comets .....	209
<i>S.M. Larson, S.J. Edberg, and D.H. Levy</i>	

### SECTION II: LABORATORY STUDIES AND SIMULATIONS

Physical Properties of Frozen Volatiles—Their Relevance to the Study of Comet Nuclei .....	227
<i>J. Klinger</i>	
Irradiation Effects on Comets and Cometary Debris .....	243
<i>G. Strazzulla and R.E. Johnson</i>	

Laboratory Simulation of Cometary Processes:  
Results From First KOSI Experiments..... 277  
*E. Grün, A. Bar-Nun, J. Benkhoff, A. Bischoff, H. Düren, H. Hellmann,  
P. Hesselbarth, P. Hsiung, H.U. Keller, J. Klinger, J. Knölker,  
H. Kochan, H. Kohl, G. Kölzer, D. Krankowsky, P. Lämmerzahl,  
K. Mauersberger, G. Neukum, A. Oehler, L. Ratke, K. Roessler,  
G. Schwehm, T. Spohn, D. Stöffler, and K. Thiel*

Laboratory Simulation of Cometary Structures ..... 299  
*Kh.I. Ibadinov, A.A. Rahmonov, and A.Sh. Bjasso*

Recent Laboratory Photochemical Studies and Their Relationship  
to the Photochemical Formation of Cometary Radicals..... 313  
*William M. Jackson*

**SECTION III: COMETS, ORIGINS, AND EVOLUTION**

The Accumulation and Structure of Comets ..... 335  
*Bertram Donn*

Chemical Theories on the Origin of Comets..... 361  
*Tetsuo Yamamoto*

Nature and History of the Organic Compounds in Comets:  
An Astrophysical View ..... 377  
*A.H. Delsemme*

Noble Gases in Terrestrial Planets: Evidence for Cometary Impacts? ..... 429  
*Tobias Owen, Akiva Bar-Nun, and Idit Kleinfeld*

Biological Implications of Organic Compounds in Comets ..... 439  
*Joseph N. Marcus and Margaret A. Olsen*

Dynamical History of the Oort Cloud..... 463  
*Paul R. Weissman*

Statistical and Evolutionary Aspects of Cometary Orbits..... 487  
*J.A. Fernández and W.-H. Ip*

End Products of Cometary Evolution: Cometary Origin of  
Earth-Crossing Bodies of Asteroidal Appearance ..... 537  
*G.W. Wetherill*

Debris From Comets: The Evolution of Meteor Streams ..... 557  
*Bruce A. McIntosh*

Evolution of Cometary Debris: Physical Aspects ..... 593  
*Anton Hajduk*

Evidence for Physical Aging of Periodic Comets..... 607  
*Ľ. Kresák*

Physical Aging in Comets ..... 629  
*Karen J. Meech*

CONTRIBUTING AUTHORS..... 671

INDEX ..... 673

Volume 2

SECTION IV: THE COMETARY NUCLEUS

Characterization of the Rotation of Cometary Nuclei..... 691  
*Michael J.S. Belton*

P/Halley, the Model Comet, in View of the Imaging Experiment  
Aboard the VEGA Spacecraft ..... 713  
*K. Szegő*

The Thermal History and Structure of Cometary Nuclei..... 733  
*Hans Rickman*

Surface Morphology of Cometary Nuclei..... 761  
*D. Möhlmann and E. Kührt*

Cometary Activity, Discrete Outgassing Areas, and  
Dust-Jet Formation ..... 769  
*Z. Sekanina*

Possible Mechanisms for Cometary Outbursts ..... 825  
*David W. Hughes*

SECTION V: THE COMETARY COMA

The Composition of Comets ..... 855  
*Dieter Krankowsky*

Isotopic Ratios in Comets ..... 879  
*V. Vanysek*

The Hydrogen Clouds of Comets.....	897
<i>Mikio Shimizu</i>	
Structure of the Coma: Chemistry and Solar Wind Interaction .....	907
<i>W.F. Huebner, D.C. Boice, H.U. Schmidt, and R. Wegmann</i>	
Hydrodynamic Models of the Collisional Coma.....	937
<i>J.F. Crifo</i>	
Multidimensional Dusty Gasdynamical Models of Inner Cometary Atmospheres .....	991
<i>Tamas I. Gombosi</i>	

## SECTION VI: COMETARY DUST

Optical Properties of Cometary Dust .....	1005
<i>David J. Lien</i>	
Physical Properties of Cometary Dust .....	1043
<i>J.A.M. McDonnell, P.L. Lamy, and G.S. Pankiewicz</i>	
Chemical Properties of Cometary Dust and a Note on Carbon Isotopes .....	1075
<i>Elmar K. Jessberger and Jochen Kissel</i>	
The Electrodynamics of Charged Dust in the Cometary Environment.....	1093
<i>M. Horanyi and D.A. Mendis</i>	

## SECTION VII: PLASMAS AND FIELDS

The Magnetic Field Structure of the Cometary Plasma Environment .....	1107
<i>F.M. Neubauer</i>	
The Global Interaction of Comets With the Solar Wind.....	1125
<i>K.R. Flammer</i>	
Plasma Processes in the Outer Coma .....	1145
<i>A.A. Galeev</i>	
Cometary Plasma Waves and Instabilities .....	1171
<i>Bruce T. Tsurutani</i>	
Plasma Processes in the Inner Coma.....	1211
<i>T.E. Cravens</i>	

## SECTION VIII: FRED WHIPPLE REFLECTS

The Forest and the Trees .....	1259
<i>Fred L. Whipple</i>	

APPENDICES

A. Cometary Apparitions: 1990–2010 ..... 1281  
*Donald K. Yeomans and Ravenel N. Wimberly*

B. Historical Comets Over Bavaria: The *Nuremberg Chronicle*  
and Broad­sides ..... 1309  
*R.J.M. Olson and J.M. Pasachoff*

CONTRIBUTING AUTHORS ..... 1343

INDEX ..... 1345

# Section I

## Observing Techniques and Interpretation





## COMETARY ORBITAL DYNAMICS AND ASTROMETRY

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**ABSTRACT.** Comets are the only large solar system bodies where nongravitational forces directly affect their dynamic motions. Their approach to within a few AU of the Sun initiates the vaporization of nucleus ices, and the resulting rocket-like effects either add to or subtract from the comet's orbital energy; the sign of the energy change depends upon the comet's rotation direction and its spin pole orientation. The cometary outgassing phenomena have generally been modeled by assuming a rapidly rotating nucleus of water ice that outgasses symmetrically with respect to perihelion. Although this nongravitational acceleration model has been quite successful in providing accurate orbits and ephemerides, several comets exhibit water production rates and visual light curves that are noticeably asymmetric with respect to perihelion. New asymmetric models are being developed that attempt to represent more closely the cometary outgassing phenomena. For the same comet, derived nongravitational parameters can differ widely, depending upon which model is used to fit the astrometric data. The uncertainties in the data and in the nongravitational acceleration model prevent realistic extrapolations of these objects' motion beyond a few hundred years, particularly if close planetary encounters are involved. Accurate orbits, ephemerides and efforts to model the nongravitational effects ultimately depend upon the quality of the astrometric data. Using a combination of long-focus telescopes, charge coupled device (CCD) detectors, microdensitometer reductions and modern star catalogs, cometary astrometric data can be generated that are accurate to the sub arcsecond level. While occultation, spacecraft, and radar observations can provide powerful astrometric data when available, it is still the ground-based optical observations that must provide the vast majority of data for cometary astrometry in the foreseeable future.