Meteor Showers and Their Parent Comets

It is only in the past ten years that advanced computing techniques and painstaking observations have enabled the successful prediction and observation of meteor storms. Spectacular displays of "shooting stars" are created when the Earth crosses a meteoroid stream, causing the meteoroids to light up into meteors as they enter our atmosphere.

Meteor Showers and Their Parent Comets is a unique handbook for astronomers interested in observing meteor storms and outbursts. The author, a leading astronomer in the field and an active meteor storm chaser, explains how meteoroid streams originate from the decay of comets (and asteroids) and how they evolve into ever changing orbits by the gravitational pull of planets to cause meteor showers on Earth. He includes the findings of recent space missions that have visited comets and asteroids, the risk of meteoroid impacts on Earth, what showers to expect on other planets, and how meteor showers may have seeded the Earth with the ingredients that made life possible.

All known meteor showers are identified, accompanied by fascinating details on the most important showers and their parent comets. The book predicts when exceptional meteor showers will occur over the next 50 years, making it a valuable resource for both amateur and professional astronomers.

Astronomer PETER JENNISKENS completed his Ph.D. at Leiden University, the Netherlands, in 1992. He then worked as a National Research Council Associate at the Exobiology branch of the NASA Ames Research Center in Moffett Field, California, where he uncovered exotic properties of astrophysical ices, such as those in comets. Early in his studies, he became an amateur meteor astronomer with the Dutch Meteor Society. He has continued the study of meteor showers professionally at Ames and at the nearby SETI Institute, successfully predicting the α-Monocerotid meteor outburst in 1995. He went on to become the Principal Investigator of the NASA sponsored *Leonid Multi-Instrument Aircraft Campaign* that mobilized the scientific community to study 1998–2002 Leonid meteor storms. Amateurs continued to support his research. Dr Jenniskens is the chair of the Professional–Amateur Working Group of the IAU Commission 22 on meteoroids and interplanetary dust, and secretary of the IAU Commission 15 on the physical properties of minor bodies. In the course of writing this book, he identified the comet fragments remaining after the breakup that formed the meteoroid streams responsible for the Quadrantid and Phoenicid meteor showers, and in doing so he changed our ideas on how meteor showers predominantly originate.

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To my father,
Pierre Johan Jenniskens,

die altijd even bij me kwam staan
tijdens een waarneem aktie
totdat hij zelf ook een meteoor zag.

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Preface

It was a warm summer evening in June in the light polluted Dutch city of Leiden in 1981 when I first sat down and gazed at the sky, waiting. A meteor appeared and I made a wish: "One more, please!" After 90 min, I had plotted four arrows on a chart of stars. That record still exists and has played a small role in the ongoing exploration of meteor showers. A very modest beginning to what has become a lifelong adventure.

In those days, we were resigned to the believe that our two most intense showers had no parent body, that meteor showers were as irregular as the weather (and more difficult to predict), that meteor storms came unannounced, and that this would always be so.

Today, we have reached an impressive milestone: about half of all large (>1 km sized) minor bodies approaching Earth's orbit have been discovered, two of which are the extinct comet nuclei that once produced the Geminid shower in December and the Quadrantid shower in January. The identification of the Quadrantid parent and several others were made in the course of writing this book.

Computers have revolutionized our insight into meteoroid stream dynamics. Meteor storm forecasting is now a reality. Over the years, amateur astronomers were witness to outbursts quite coincidentally. Now, storm chasing has become a popular pastime. In this book you will find much practical information about when to see meteor outbursts in the next 50 years and how they might manifest. We can look further into the future, but by 2050 the raw computing muscle of top-of-the-line computers is expected to have increased a million fold, at which time better predictions will surely be available than can be made now.

While writing this book, I found that many of our main meteor showers are the product of comet fragmentation. That new paradigm revives old ideas that had gone into submission after Fred Whipple proposed water vapor drag as the spring of meteoroid streams. If you are a professional astronomer, you will find in this book an overview of your work and that of colleagues who have helped illuminate the evolution of meteoroid streams, the physical properties of their parent bodies, their influx on Earth's atmosphere, their danger to satellites in orbit, and their role in the origin of life.

Acknowledgements

I have been fortunate to find a path in life that brings so much excitement from anticipation and surprise. While at NASA Ames and the SETI Institute, I have had the fortune of meeting many able researchers and program managers at NASA and the US Air Force, with open minds, who appreciate that meteors are a unique window on the universe around us and a door to both our past and our future.

Early on, *Hans Betlem* and *Rudolf Veltman* introduced me to the field. While observing, my father would stand by my side, and bear the cold just long enough to see at least one meteor. I found friends among members of the Dutch Meteor Society who were my teachers and guides, and who continued to support my work after I completed my studies at Leiden University and moved to NASA Ames Research Center and the SETI Institute. In the USA, I thank *Mike Koop* and members of the California Meteor Society for their unwavering support, and my partner in life *Charlie Hasselbach*, who smiled down on me and won my heart with meringue meteors of the sublime sort.

This book was written only because of the help of *Esko Lyytinen* and *Jérémie Vaubaillon*, who performed many numerical simulations. Others made contributions as well. *Bill Bottke* identified what might be extinct comet nuclei, *Peter Gural* calculated the visibility figures for future Moon impacts, *Giovanni Valsecchi* studied the link between 2003 EH_1 and comet C/1491 Y_1, *Emmanuel Jehin* observed 2003 EH_1, *Marco Fulle* studied the possibility of outbursts by ejection at aphelion, *Teemu Mäkinen* studied the water production rate of comet Tempel–Tuttle, and *Apostolos Cristou* calculated showers on other planets. *Brian Marsden* and *Daniel W. Green* of the Minor Planet Center provided comet light curve data and investigated several links between minor planets and meteoroid streams. *Joshua Kitchener* and copy editor *Louise Staples* assisted with the proof reading. Earlier versions of chapters were reviewed by *Sang-Hyeon Ahn*, *Josep Trigo*, *Iwan Williams*, and *Apostolos Cristou*. *Vladimir Porubčan*, head of the IAU Meteor Data Center, helped review the list of annual meteor showers.

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