

Cambridge University Press  
978-0-521-18066-5 - A Question and Answer Guide to Astronomy  
Pierre-Yves Bely, Carol Christian and Jean-René Roy  
Frontmatter  
[More information](#)

---

## A Question and Answer Guide to Astronomy

Are we alone in the Universe?  
Was there anything before the Big Bang?  
Are there other universes?  
What are sunspots?  
What is a shooting star?  
Was there ever life on Mars?

This book answers all these questions and hundreds more, making it a practical reference for anyone who ever wondered what is out there, where does it all come from, and how does it all work?

Written in non-technical language, the book summarizes current astronomical knowledge, without overlooking the important underlying scientific principles. Richly illustrated in full color, it gives simple but rigorous explanations.

**Pierre-Yves Bely** is an engineer specializing in the design and construction of large optical telescopes. He was Chief Engineer for the Canada-France-Hawaii Telescope, has worked on the Hubble Space Telescope and the design of its successor.

**Carol Christian** is an astrophysicist and Deputy of the Community Missions Office at the Space Telescope Science Institute. In addition to technical and outreach support of NASA missions, she is a collaborator on the Google Sky and World Wide Telescope projects for exploration of the sky on the Internet.

**Jean-René Roy** is an astrophysicist specializing in the evolution of galaxies and the formation of massive stars. He is Senior Scientist at the Gemini Observatory, which hosts two of the largest telescopes in the world, one in Hawaii and the other in Chile.

Cambridge University Press  
978-0-521-18066-5 - A Question and Answer Guide to Astronomy  
Pierre-Yves Bely, Carol Christian and Jean-René Roy  
Frontmatter  
[More information](#)

---

Cambridge University Press  
978-0-521-18066-5 - A Question and Answer Guide to Astronomy  
Pierre-Yves Bely, Carol Christian and Jean-René Roy  
Frontmatter  
[More information](#)

---

# A Question and Answer Guide to Astronomy

Pierre-Yves Bely  
Carol Christian  
Jean-René Roy



Cambridge University Press  
978-0-521-18066-5 - A Question and Answer Guide to Astronomy  
Pierre-Yves Bely, Carol Christian and Jean-René Roy  
Frontmatter  
[More information](#)

---

CAMBRIDGE UNIVERSITY PRESS  
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore,  
São Paulo, Delhi, Dubai, Tokyo

Cambridge University Press  
The Edinburgh Building, Cambridge CB2 8RU, UK

Published in the United States of America by Cambridge University Press, New York

[www.cambridge.org](http://www.cambridge.org)  
Information on this title: [www.cambridge.org/9780521180665](http://www.cambridge.org/9780521180665)

© P.-Y. Bely, C. Christian, and J.-R. Roy 2010

This publication is in copyright. Subject to statutory exception  
and to the provisions of relevant collective licensing agreements,  
no reproduction of any part may take place without  
the written permission of Cambridge University Press.

First published 2008 as *250 réponses à vos questions sur l'astronomie* by La Compagnie des  
Éditions de la Lesse.

English translation published 2010

Printed in the United Kingdom at the University Press, Cambridge

*A catalog record for this publication is available from the British Library*

*Library of Congress Cataloging-in-Publication Data*

Bely, Pierre-Yves.

A question and answer guide to astronomy/Pierre-Yves Bely, Carol Christian, Jean-René Roy.  
p. cm.

ISBN 978-0-521-18066-5 (pbk.)

1. Astronomy--Miscellanea. I. Christian, Carol, 1950-- II. Roy, Jean-René. III. Title.  
QB52.B45 2010

520--dc22 2009046650

ISBN 978-0-521-18066-5 Paperback

Cambridge University Press has no responsibility for the persistence or  
accuracy of URLs for external or third-party internet websites referred to  
in this publication, and does not guarantee that any content on such  
websites is, or will remain, accurate or appropriate.

## Contents

Preface xiii

### Stars 1

- 1 Why do stars shine? 1
- 2 What are stars made of? 2
- 3 Why are stars round? 4
- 4 How many stars are there in the Galaxy? 4
- 5 How are the luminosities of stars measured? 6
- 6 How are the distances to stars measured? 7
- 7 Parsecs? Light-years? Why not miles or kilometers? 8
- 8 How are the masses of stars determined? 9
- 9 How big are the stars? 11
- 10 How big do stars get? 12
- 11 How old are the stars? 13
- 12 How old is the oldest star? 13
- 13 Do stars really come in different colors? 14
- 14 How many different kinds of star are there? 15
- 15 How do stars die? 17
- 16 What is a nova? A supernova? 19
- 17 What is a double star? 22
- 18 What are the Cepheids? 23
- 19 What is a pulsar? 24
- 20 Do stars ever collide? 24
- 21 Are we really made of stardust? 25
- 22 Do all civilizations recognize the same constellations? 26
- 23 How many constellations are there? 27
- 24 How are stars named? 29
- 25 Can we still discover and name stars? 30
- 26 Is there a southern polar star? 30
- 27 How many stars are visible to the naked eye? 31
- 28 Are the stars fixed or do they move? 32
- 29 Which star is closest to us? 32
- 30 Between stars that die and stars that are born, is the population of our galaxy growing or shrinking? 33
- 31 Are there any isolated stars, outside of the galaxies? 33
- 32 Could nuclear fusion solve our energy problems? 34

### The Solar System 36

- 33 How did the Solar System form? 36
- 34 Is any trace of our “ancestral” supernova still in existence? 39
- 35 How far out does our solar system extend? 39

vi Contents

- 36 How old is the Sun? 40
- 37 Has the Sun always been as bright as it is now? 40
- 38 What is our Sun's future? 41
- 39 What will happen to the Earth when the Sun dies? 41
- 40 How hot is the Sun? 42
- 41 What causes sunspots? 43
- 42 Do sunspots influence the weather on Earth? 45
- 43 How was the distance to the Sun measured? 45
- 44 Is the distance between Earth and the Sun changing? 46
- 45 How can we know the mass of the Sun? 47
- 46 What is solar radiation pressure? 47
- 47 What is the solar wind? 47
- 48 How long does light from the Sun take to reach us? 48
- 49 What is the difference between a star and a planet? 48
- 50 What is a brown dwarf? 49
- 51 Why are some planets rocky and others gaseous? 49
- 52 What are the interiors of planets and satellites like? 50
- 53 Where do the names of the planets come from? 51
- 54 What is Bode's law? 52
- 55 What is Planet X? 53
- 56 Why is Pluto no longer a planet? 53
- 57 Why do some planets have many satellites and others, none? 54
- 58 How can Mercury survive so close to the Sun? 55
- 59 Why does Venus have phases like the Moon? 55
- 60 What is the Great Red Spot on Jupiter? 56
- 61 What are Saturn's rings made of? 56
- 62 Do all the planets orbit in the same direction? 57
- 63 What are the Lagrangian points? 58
- 64 Why did the comet Shoemaker–Levy 9 break up as it approached Jupiter? 59
- 65 Can planetary alignments cause catastrophic events on Earth? 60
- 66 Did asteroids cause the mass extinctions on Earth? 61
- 67 Where did the asteroid implicated in the extinction of the dinosaurs fall? 63
- 68 What could be done if an asteroid threatened to collide with Earth? 64
- 69 What is the Kuiper Belt? 64
- 70 Where do comets come from? 65
- 71 How big are comets? 66
- 72 What is a comet's tail made of? 66
- 73 In the age of space probes, is it still useful to observe the planets with telescopes? 67
- 74 What do the Mars rovers do? 67
- 75 Why colonize Mars? 68
- 76 Which way to Mars? 69
- 77 What is solar sailing? 69
- 78 How could the Voyagers explore so many planets and satellites in one trip? 71

## The Earth 72

- 79 How was the size of the Earth measured? 72
- 80 How was the mass of the Earth measured? 73
- 81 How old is the Earth? 75
- 82 What is inside the Earth? 77
- 83 Where did the water on Earth come from? 79
- 84 Do any of the other planets have oceans? 80
- 85 Where does the oxygen of our atmosphere come from? 81
- 86 What causes the seasons? 82
- 87 What is the precession of equinoxes? 83
- 88 What caused the “ice ages” on Earth? 84
- 89 What causes the Earth’s magnetic field? 86
- 90 Does the Earth’s magnetism affect people? 87
- 91 Why is the magnetic north different from the geographic north? 87
- 92 What is the greenhouse effect? 88
- 93 Have days on Earth always been the same length? 90
- 94 What is sidereal time? 90
- 95 Why is the day divided into 24 hours? 91
- 96 How do sundials work? 92
- 97 How can the Sun be used to find directions? 93
- 98 How was the time zone system established? 93

## The Moon 95

- 99 How did the Moon form? 95
- 100 Why is the Moon covered with craters? 96
- 101 What are the large dark areas on the Moon? 97
- 102 What does the far side of the Moon look like? 97
- 103 Does the Moon have the same composition as the Earth? 98
- 104 Why does the Moon lack an atmosphere? 99
- 105 Why does the Moon always present the same face to Earth? 100
- 106 Why does the Moon, rather than the Sun, cause most of our tides? 101
- 107 If the tide is mainly caused by the attraction of the Moon 102
- 108 Is it just coincidence that the apparent diameters of the Moon and the Sun are the same? 103
- 109 How often do solar eclipses occur? 104
- 110 How can one tell if the Moon is waning or waxing? 105
- 111 What has been learned from our exploration of the Moon? 106
- 112 How useful would it be to return to the Moon? 107
- 113 What explains the dim light suffusing the dark portion of a crescent Moon? 109
- 114 Has the *Hubble Space Telescope* been used to observe the Moon? 109
- 115 “Moonstruck!” Does the Moon have an influence on human behavior? 110

## Celestial phenomena 111

- 116 What is a shooting star? 111
- 117 What causes meteor showers? 111
- 118 What causes the “northern lights?” 112
- 119 What is zodiacal light? 113
- 120 What causes the bright beams of light, like searchlights, that stream out from the setting Sun? 114
- 121 Why is the setting Sun red? 115
- 122 Why are sunsets usually more colorful than sunrises? 116
- 123 What is the green flash? 116
- 124 Why do we never tan in the late afternoon? 117
- 125 Why do stars twinkle? 118
- 126 Why does the Moon look so large at the horizon? 119

## The Universe 121

- 127 How old is the Universe? 121
- 128 How did the Universe begin? 122
- 129 How do we know that the Universe is expanding? 125
- 130 How fast is the Universe expanding? 126
- 131 Who invented the term “Big Bang?” 126
- 132 Does the Universe have a center? 127
- 133 What is the cosmic background radiation? 128
- 134 What is cosmic inflation? 130
- 135 When did the first stars form? 132
- 136 How did the first galaxies form? 133
- 137 Which came first, stars or galaxies? 134
- 138 What was there before the Big Bang? 135
- 139 What is string theory? 135
- 140 If the Universe is expanding, are we also expanding? 137
- 141 What explains the redshift of light? 137
- 142 How big is the Universe? 138
- 143 Does the Universe have boundaries? 140
- 144 What is the nature of gravity? 140
- 145 What is a black hole? 141
- 146 Can anything escape from a black hole? 143
- 147 What is dark energy? 144
- 148 If we cannot see dark matter, how do we know that it exists? 145
- 149 Were the laws of physics the same in the early Universe as they are now? 147
- 150 How much antimatter is there in the Universe? 148
- 151 How many galaxies are there in the Universe? 149
- 152 How many different types of galaxy are there? 150
- 153 What is the Milky Way? 151
- 154 What type of galaxy is the Milky Way? 152
- 155 What are the Magellanic Clouds? 154
- 156 How does the sky appear in different wavelengths? 156



- 157 What is a nebula? 157
- 158 How empty is space? 158
- 159 How did the theory of relativity affect astronomy? 160
- 160 What is meant by “four-dimensional space?” 161
- 161 Can anything go faster than the speed of light? 163
- 162 Why does everything in the Universe rotate? 164
- 163 Why is the night sky dark? 165
- 164 What is the anthropic principle? 166
- 165 What is the fate of the Universe? 168
- 166 What major questions remain to be answered in astronomy? 169
- 167 How can we hope to comprehend the *astronomical* numbers which astronomy confronts us with? 170
- 168 Is there a difference between the cosmos and the Universe? 171

### **Life in the Universe 173**

- 169 What is life? 173
- 170 How did life begin on Earth? 174
- 171 Does life violate the second law of thermodynamics? 176
- 172 Could intelligent life reverse the fate of the Universe? 177
- 173 Could life on Earth have originated in outer space? 177
- 174 Why is water so important for life? 178
- 175 Could life evolve based on a chemical element other than carbon? 179
- 176 What are extremophiles? 180
- 177 Given favorable conditions, will life inevitably appear? 181
- 178 Where in the Universe would life have the best chance of appearing? 181
- 179 Can planets exist around binary stars? 182
- 180 What are the odds that other intelligent life exists in our galaxy? 183
- 181 Where else in the Solar System could life exist? 184
- 182 How are exoplanets detected? 186
- 183 How could we detect the presence of life outside the Solar System? 188
- 184 Could the human race ever colonize exoplanets? 189
- 185 Could aliens have visited the Earth? 190
- 186 How could we communicate with other civilizations in the Galaxy? 191

### **History of astronomy 193**

- 187 Why did ancient astronomers study the sky so intently? 193
- 188 How did the cult of the Sun originate? 193
- 189 Why were the Greek and Roman gods associated with the different planets? 194
- 190 Can we learn anything from the astronomical phenomena reported in the Bible? 195
- 191 How could the ancient astronomers predict eclipses? 195
- 192 Who were the most important astronomers of antiquity? 196
- 193 What were the contributions of the Chinese, Indian, and Islamic civilizations to astronomy? 197

x Contents

- 194 Who was responsible for overturning the geocentric system? 199
- 195 Who was the first astronomer to use a telescope? 202
- 196 Where were the earliest observatories? 203
- 197 How did the modern observatory evolve? 204
- 198 What have the major milestones been in our quest to understand the Universe? 204
- 199 Have any astronomers won the Nobel Prize? 205
- 200 Astrology, astronomy, astrophysics ... what are the differences? 206
- 201 Is astronomy a “useful” science? 207

### Telescopes 209

- 202 How do refracting and reflecting telescopes differ? 209
- 203 What does a large modern telescope look like? 210
- 204 What are the most common optical configurations? 212
- 205 How is the performance of a telescope measured? 213
- 206 What is the shape of a telescope mirror? 214
- 207 How are telescope mirrors made? 215
- 208 What is a Schmidt telescope? 217
- 209 Why are telescopes housed in domes? 218
- 210 Reflection, refraction, diffusion, dispersion ... want a short refresher? 219
- 211 ... and diffraction? 219
- 212 How is the resolving power of a telescope defined? 221
- 213 Do celestial objects look bigger through a large telescope? 222
- 214 Who invented the telescope? 223
- 215 What major improvements have been made in telescopes since Galileo’s time? 224
- 216 Why do astronomers want ever-larger telescopes? 226
- 217 What are the largest optical telescopes today? 227
- 218 How does the atmosphere degrade telescope images? 229
- 219 What is adaptive optics? 230
- 220 Are there any alternatives to traditional mirrors? 231
- 221 Where are the best astronomical sites? 232
- 222 What are the advantages of observing from space? 234
- 223 What are the main space observatories? 234
- 224 Which orbits are used for space telescopes? 237
- 225 Would the Moon be a good site for an observatory? 238
- 226 How is a space telescope pointed? 239
- 227 What is an astronomical interferometer? 239
- 228 How does a radio telescope work? 241
- 229 What can we learn from observations at radio wavelengths? 243
- 230 What is a submillimeter telescope? 244
- 231 What does an x-ray telescope look like? 245
- 232 What can be learned by observing at x-ray wavelengths? 246
- 233 How does a gamma ray telescope work? 246
- 234 How are gravitational waves detected? 247
- 235 How are neutrinos detected? 248
- 236 How is observing time allocated in a modern observatory? 248

**Amateur astronomy 250**

- 237 Interested in amateur astronomy? What are the first steps? 250
  - 238 Which telescope should you choose? 251
  - 239 What can be seen with an amateur telescope? 253
  - 240 What is a Dobsonian telescope? 254
  - 241 What is a Schmidt–Cassegrain? 255
  - 242 What are the Messier objects? 256
  - 243 Where are skies the darkest? 257
  - 244 What important discoveries have amateurs made? 258
  - 245 How can planets be spotted in the night sky? 260
  - 246 Where and how can meteorites be found? 260
  - 247 Can amateur astronomers participate in serious research programs? 260
  - 248 You think you have made a discovery: what should you do? 261
  - 249 How does one become a professional astronomer? 261
  - 250 How can you find an amateur astronomy club? 262
- 
- Unit conversion and basic physical and astronomical measurements 264
  - References 265
  - Bibliography 267
  - Index 271

Cambridge University Press  
978-0-521-18066-5 - A Question and Answer Guide to Astronomy  
Pierre-Yves Bely, Carol Christian and Jean-René Roy  
Frontmatter  
[More information](#)

---

## Preface

Human beings are curious by nature and have marveled at the night sky ever since our *Homo sapiens* ancestors first gazed up into the heavens. What is “up there”? Why do stars shine? How did the Universe begin? Does life exist elsewhere? What is on the other side of the Moon?

Astronomy is one of the oldest sciences, but modern physics and technology, coupled with observations from space, have recently generated a stupendous wave of new knowledge. Most of our earliest questions about the nature of the Universe have now been answered, and many unexpected, intriguing new findings have been made, findings that invite us to be both humble and bold. And one needs not be a professional astronomer or physicist to understand them.

Our intent in writing this book has been to offer to the general reader a summary of current astronomical knowledge, generously illustrated and provided with rigorous but simple explanations, while avoiding mystifying professional jargon.

The 250 “windows” on astronomy in this book do not exhaust the topic, but we hope that they will pique the curiosity of our readers and stimulate them to explore further, by navigating on the World Wide Web or by consulting some of the many fine publications on astronomy, such as those suggested at the end of this book. Most important of all, we hope that they will find renewed wonder in the night sky!

April 2009

### Acknowledgments

We would like to thank Sally Bely for much assistance in the final editing and H el ene Allard for sharpening key concepts for the general reader. We are also grateful to Nathalie Bely and Robert Macpherson for several illustrations and their many useful comments.

We would like also to thank Vince Higgs and Jonathan Ratcliffe of Cambridge University Press for their support and editorial assistance.

### Units and numbers

We have used the metric system almost exclusively. Conversion factors for English equivalents can be found in the appendix.

In astronomy, distances, times, and temperatures are truly “astronomical numbers,” in which the long strings of zeros are awkward and cumbersome. We have therefore often used scientific notation, in which numbers are expressed in powers of 10. The exponent of 10 is the number of places the decimal point must be shifted in order to express the number in its full form (left for negative exponents, right for positive exponents). For example,  $2.5 \cdot 10^3$  is 2500,  $10^6$  is 1 followed by 6 zeros, or one million, and  $10^{-6}$  is 0.000 001.

### Notations

Numbers between square brackets (i.e. [3]) apply to the list of references at the end of the book.

References to related questions are noted by the letter Q followed by the number of the question. For example, (Q. 30) refers to question 30.

Cambridge University Press  
978-0-521-18066-5 - A Question and Answer Guide to Astronomy  
Pierre-Yves Bely, Carol Christian and Jean-René Roy  
Frontmatter  
[More information](#)



Young stars in the Small Magellanic Cloud. Credit: NASA/ESA.