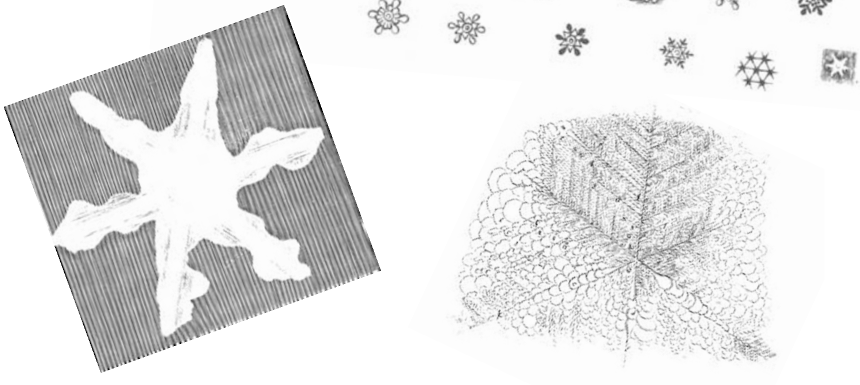
Science in culture

Kepler's seasonal gift

What lies behind the hexagonal shape of the snowflake?

Martin Kemp



In 1611 Johannes Kepler, the German cosmologist with a passion for geometry, offered his patron, John Matthew Wacker, a highly seasonal "New Year's gift". Unlike most such gifts, it not only outlasted the festive season but also acquired enduring renown. Kepler's present was his small book, *On the Six-Cornered Snowflake*. It was a sprightly and speculative expression of delight and perplexity in the face of the marvellous regularity of snow crystals.

Kepler provided no illustration, as his patron well knew what a hexagon looked like. But Kepler was unaware of the astonishing variety within the crystalline structures, which was to be revealed by the microscope and illustrated in Robert Hooke's *Micrographia* in 1665, as shown here.

The account by Kepler of what triggered his thoughts on the snowflake gives a nice idea of his book's tone: "Specks of snow fell here and there on my coat, all with six corners and feathered radii. 'Pon my word, here was something smaller than any drop, yet with a pattern; here was the ideal New Year's gift for the devotee of Nothing'." The jest that his patron was a "devotee of Nothing" may be a philosophical play on the fact that the fundamental unit of pure geometry, the point, is 'nothing', as it has no physical dimension.

Kepler tries to identify the cause of the snowflake's six-cornered configuration. But before doing so, he notes the ubiquity of polygonal and polyhedral constructions in nature, from the cosmos to the world in miniature. He is delighted to observe how the polyhedral architecture of the snowflake has analogies across all scales of natural design. He had himself argued that the geometry of the five 'platonic solids', or regular polyhedra, provided a kind of invisible armature for the orbits of the planets (see *Nature* **393,** 123; 1998). On a smaller scale, the rule of geometry is manifest in the world of plants, Kepler points out: "in a flower the authentic flag of this faculty is flown, the pentagon". The classic case is the bee's honeycomb: "The architecture is such that any cell shares not only six walls with the six cells in the same row, but also three plane surfaces on the base with three other cells from the contrary row."

Such geometrical packing, which Kepler compares to the seeds in a pomegranate, is attributed to a physical process similar to that observed when pellets are systematically compressed in a round vessel. But the regularity of the physical actions must themselves be caused by something, and Kepler concludes that God prescribed to the bee "these canons of its architecture" that resulted in the geometrical constructions.

But what lies behind the form of the snowflake, when no animate architect is involved? Observation and delight are one thing; explanation, beyond the adducing of divine agency, is very much another. Kepler's review of a range of physical explanations for the forms of the snowflake proves frustratingly inconclusive. He is convinced that "the cause of the six-sided shape of a snowflake is none other than that of the ordered shapes of plants and numerical constants". In the absence of any obvious agent, he adduces the presence of a "formative faculty" — the *facultas formatrix* — which God has insinuated into matter in terms of "world-building figures". But, in the final analysis, Kepler senses that something is missing in his explanation, and he concludes by announcing that he has "knocked at the door of chemistry".

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Beginning again

Big Bang: The Most Important Scientific Discovery of All Time and Why You Need to Know About It
by Simon Singh
Fourth Estate: 2004. 544 pp. £20, $27.95

Peter Coles

When the British astrophysicist Fred Hoyle coined the phrase 'Big Bang' to describe the rival to his beloved 'steady state' theory of the Universe, he meant it to be disparaging. It was bad enough for Hoyle that his pet theory turned out to disagree with astronomical observations, but it must have been especially galling that his cosmological adversaries embraced his derisive name. The tag has since spread into the wider cultural domain — nowadays even politicians have heard of the Big Bang.

But what is the Big Bang? In a nutshell, it is the idea that our Universe — space, time and all its matter content — was born in a primordial fireball, from which the whole caboodle has been expanding and cooling ever since. Pioneering theorists such as Aleksander Friedmann and Georges Lemaître derived mathematical solutions of Einstein's field equations that could be used to describe the evolution of a Big Bang Universe. These models involve a creation event, in which space-time and matter-energy sprang into existence to form our Universe. We are still in the dark about how this happened, but we think it took place about 14 billion years ago.

Edwin Hubble's discovery of the recession of distant galaxies gave support to the idea that the Universe was expanding, but the notion that it might be evolving from a hot beginning was rejected by many theorists, including Hoyle. He favoured a model in which the origin of matter was not a single event but a continuous process in which atoms were created to fill in the gaps created by cosmic expansion. The battle between these competing views of creation raged until the accidental discovery in 1965 of the cosmic microwave background radiation, which marked the beginning of the end for the steady-state theory.

This conflict between the two theories plays a central role in Simon Singh's book *Big Bang*. His previous books, *Fermat's Last Theorem* and *The Code Book*, succeeded admirably in bringing difficult mathematical subjects to a popular readership, using a combination of accessible prose, a liberal sprinkling of jokes and a strong flavouring of biographical anecdotes. The recipe for his new book is similar.

In *Big Bang*, Singh uses the historical development of modern cosmological theory as a case study for how scientific theories

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are conceived, and how they win or lose acceptance. He rightly points out that science rarely proceeds in an objective, linear fashion. Correct theories are often favoured for the wrong reasons; observations and experiments are frequently misinterpreted; and sometimes force of personality holds sway over analytic reason. Because cosmology has such ambitious goals — to find a coherent explanation for the entire system of things and how it has evolved — these peculiarities are often exaggerated. In particular, cosmology has more than its fair share of eccentric characters, providing ample illustration of the role of personal creativity in scientific progress.

This very well written book conveys the ideas underpinning cosmological theory with great clarity. Taking nothing for granted of his readership, Singh delves into the background of every key scientific idea he discusses. This involves going into the history of astronomical observation, as well as explaining in non-technical language the principles of basic nuclear physics and relativity. The numerous snippets of biographical information are illuminating as well as amusing, and the narrative is driven along by the author's own engaging personality.

As a fan of Singh's previous books, I have to admit that, although this one has many strengths, I found it very disappointing. For one thing, there isn't anything in this book that could be described as new. The book follows a roughly historical thread from pre-classical mythology to the middle of the twentieth century. This is a well-worn path for popular cosmology, and the whole thing is rather formulaic. Each chapter I read gave me the impression that I had read most of it somewhere before. It certainly lacks the ground-breaking character of *Fermat's Last Theorem*.

The past ten years in cosmology have witnessed a revolution in observation that has, among many other things, convinced us of the existence of dark energy in the Universe. Theory has also changed radically over this period, largely through the introduction of ideas from high-energy physics, such as superstring theory. Indeed, some contemporary Big Bang models bear a remarkable resemblance to the steady-state universe, involving the continuous creation not of mere atoms, but of entire universes.

Frustratingly, virtually all the exciting recent developments are missing from this book, which leaves off just when things started to get interesting, with the COBE satellite in 1992. Readers who want to know what is going on now in this field should definitely look elsewhere. The processes of cosmic discovery and controversy are ongoing, not just relics of the past. ■

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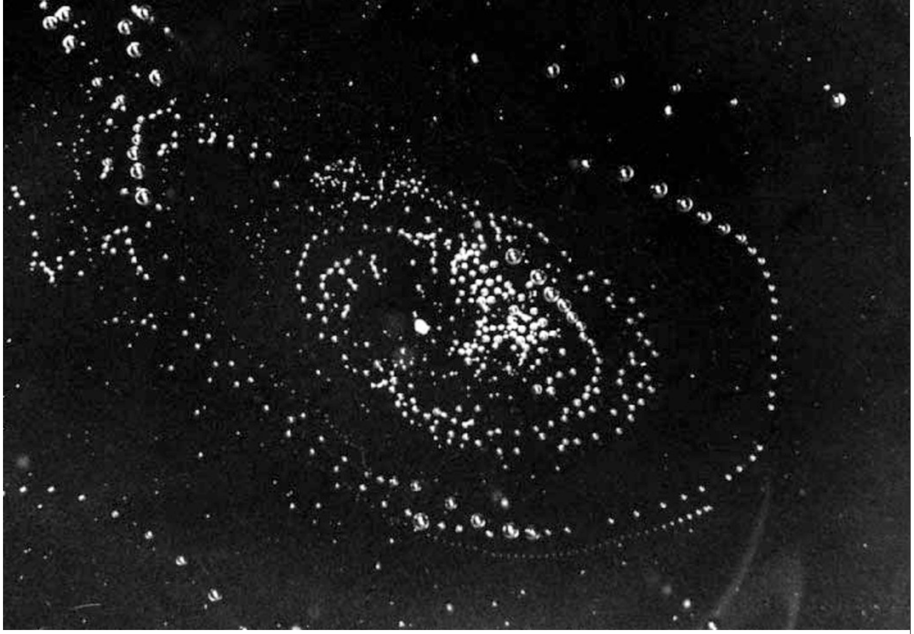

G. LIGER-BELAIR

Star quality: bubbles at the surface of champagne arrange into vortices that look like galaxies.

Fizzical attraction

Uncorked: The Science of Champagne
by Gérard Liger-Belair
Princeton University Press: 2004. 152 pp. $19.95, £12.95

Richard N. Zare

This book presents the birth, life and death of a champagne bubble with such gusto, good humour and clarity that you will devour its delicious contents in one gulp. Whereas good champagne is to be sipped, this book is not. You will never experience the sensual elegance of champagne in quite the same way again once you have read this entertaining account of its history and 'fizzics'.

The author is associate professor of physical sciences at the University of Rheims Champagne-Ardenne and consultant for the research department of champagne house Moët & Chandon. He brings to this topic not only great expertise, but also a fine sense of aesthetics, as he shares his striking photographs of how a bubble forms, rises and bursts. These phenomena are often much more complex than we imagine, but Liger-Belair explains bubble science without resorting to a single equation. He succeeds in clarifying for the non-expert such abstruse topics as fluid dynamics, nucleation phenomena, fermentation and the competition between buoyancy and drag. *Uncorked* provides just enough science to be authoritative and instructive, and carries the reader enthralled from one chapter to another, like a good detective story.

Liger-Belair has made several important original contributions to the science of champagne. For example, he offers photographic proof that bubbles form more on impurities — often fibres that adhere to the walls of the champagne container (a fluted glass, say) — than on microscratches and irregularities in the container walls. These hollow fibres, which act as tiny bubble guns, are deposited on the walls when the champagne flute is dried with a paper towel or cloth. Indeed, without these defects, champagne would not fizz at all. But bursting bubbles are not the only way champagne loses its sparkle. The dissolved carbon dioxide escapes primarily from the liquid surface of the champagne, rather than from the popping of its many tiny bubbles.

Many mysteries are revealed. Why do bubbles rise more rapidly in soda water than in champagne, and more rapidly in champagne than in beer? All three liquids are mostly water and have approximately the same viscosity. For a solution to this riddle, read *Uncorked*.

For my own taste, I would have preferred the discussion to have stuck to champagne. Instead, the author ends with an afterword on the future of champagne wines, emphasizing the connection of the human production of carbon dioxide to global warming. He concludes with some speculation: It is "not completely unrealistic to think that we eventually may witness the emergence of fine sparkling wines in Great Britain". Climate change deserves its own book, a much larger one of a more serious nature; the emphasis on it seems out of place in this vignette, although Liger-Belair's concern about our effect on the environment is shared by almost all scientists.

Many scientists feel that physical principles are part of our daily lives, not just something to be studied in the laboratory. This book reinforces that belief. It would make an excellent Christmas gift to anyone who wants to learn how a scientist views the world — or to anyone who has ever wondered about the mysterious fluid that has launched so many ships and toasted so many celebrations. ■

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