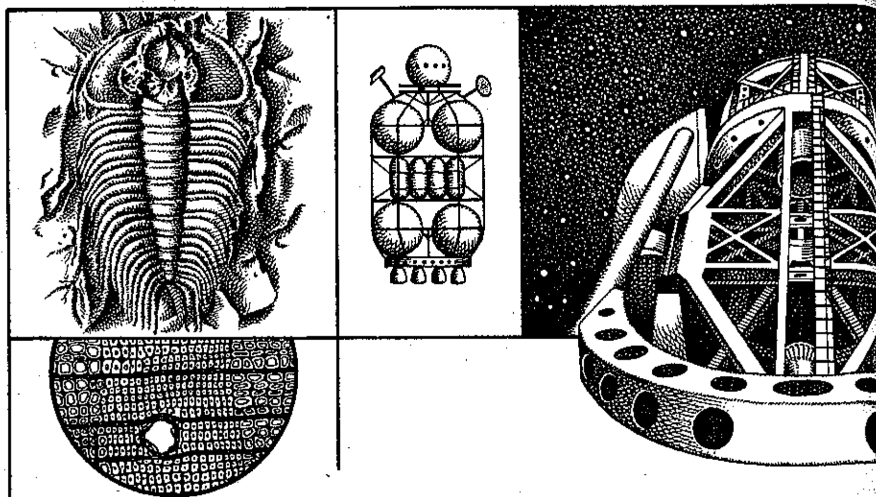

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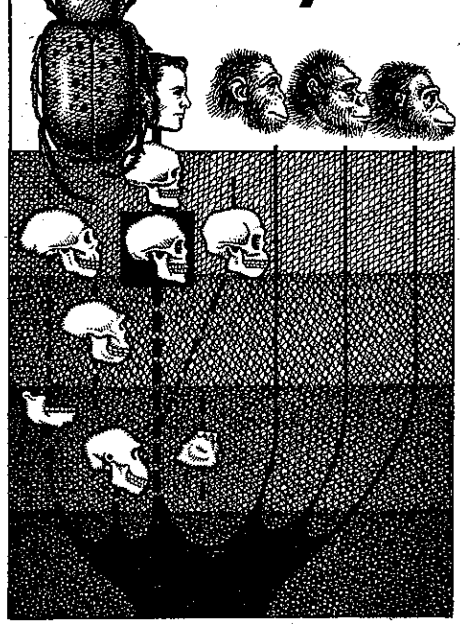

By WILLY LEY

## DEATH OF THE SUN

ONE of the first books I ever bought—a mixture of curiosity and nostalgia caused me to buy another copy some ten years ago, my first having been lost—was a small volume by the German astronomer, M. Wilhelm Meyer, called *World's End*. It was paperbound, with a melancholy cover painting which carried out the theme. There a small group of emaciated humans huddled in the snow near a dead tree, and low in the sky was an enormous deep-red sun.



It was the same basic idea which had been painted with words by H. G. Wells in his *Time Machine*. You probably remember the story: After having seen and experienced the end of the human race on a trip into the future, the Time Traveler lets his machine race far, far ahead. At first, there is the "blinking succession of day and night" to which he has grown accustomed during earlier time trips, but as the machine continues into the future, things slowly change:

"The band of light that had indicated the sun had long since disappeared; for the sun had ceased to set—it simply rose and fell in the west, and grew ever broader and more red. All trace of the moon had vanished. The circling of the stars, growing slower and slower, had given place to creeping points of light. At last, some time before I stopped, the sun, red and very large, halted motionless upon the horizon, a vast dome glowing with a dull heat, and now and then suffering a momentary extinction. At one time it had for a little while glowed more brilliantly again, but it speedily reverted to its sullen red heat. I perceived by this slowing down of its rising and setting that the work of the tidal drag was done. The earth had come to rest with one face to the sun . . ."

IF I saw this old German painting or read the *Time Machine* for the first time now, I could date both painting and story from this one fact. Both would have to fall into the period from roughly 1880 to 1900, because of this dying red sun which looks so much larger because the Earth has moved closer to it along the tight spiral of a steadily shrinking orbit. Actually, the story was written in 1895 and the picture was painted in 1903—only ten years later, the writer would have been doubtful and the painter would have picked something else from the book.

The very question of whether the Sun might one day die was still relatively new when Wells actually wrote, strange as that may seem to us. It had been the subject of doubtful speculation and worried calculations for only a few decades. In earlier days, that question simply did not exist and we don't even have to go back to the time of Homer when the Sun was the chariot of the sun-god to find it lacking. While people had thought about the end of the "world" on and off in olden days, the possible end of the Sun had never been considered.

None of the Greek philosophers concerned themselves with this problem. The Roman writers had far more mundane things to consider. The Bible even stated, by implication, the opposite: "while the earth remaineth . . . summer and winter, and day and night shall not cease."

Nor did the astronomical revolution started by Nicholas Copernicus change the picture. What *did* begin to change the attitude was not philosophical ideas, but facts which were uncovered because of the spare-time activities of one Jan Lippershey in the Netherlands, which resulted in the invention of the telescope. In December, 1610, it was found for the first time that the Sun was literally not spotless.

The man who usually is credited with the discovery of the Sun spots is the pastor David Fabricius, but part of the credit should go to his son Johannes, for father and son worked together in observing the skies with their recently acquired "optick tube." Johannes, in fact, saw it first.

The Sun, he wrote later, did not look as clear and smooth as he had expected. "It seemed to have various kinds of roughnesses and unevennesses, even at the rim. As I watched carefully, an unexpected darkish spot showed itself, not at all small as compared to the size of the Sun. I thought that drifting clouds caused the spot."

Even after reassuring himself "about ten times" that the spot could not be a cloud, "I did not trust myself completely and called my father . . ." The father-and-son team not only discovered the Sun spots, but, by observing them, the rotation of the Sun.

BEFORE David Fabricius had published the findings, a Jesuit priest, Father Christoph Scheiner, in Ingolstadt, saw several Sun spots. As required by his order, Scheiner reported his find to his superior Buseaeus, who listened carefully, thought for a while and said: "My son, I have read all the writings of Aristotle several times from beginning to end and can assure you that I found nothing in them which says what you tell. Go and calm yourself; be assured that what you believe to be spots in the Sun are flaws of your glasses or your eyes." *

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* This is not quite as bad as what was done some 45 years later. Christian Huyghens in the Netherlands had invented a new method for grinding and polishing lens. He built himself a telescope and promptly discovered Titan, Saturn's largest moon. He just as promptly discontinued his observations, reasoning that there were six planets (Mercury, Venus, Earth, Mars, Jupiter and Saturn) and now also six moons, that of Earth, the four of Jupiter discovered by Galilei and the one of Saturn he had discovered. Since the number of moons could not be larger than the number of planets, they obviously had all been found!



The Sun's corona was discovered, too, as soon as a suitable eclipse occurred. It was, of course, elementary knowledge even then that an eclipse was the result of the Moon moving across the line of sight from the Earth to the Sun. The question was which of the two was the possessor of the corona.

Around the year 1700, Giacomo Filippo Maraldi, a nephew of the great Jean Dominique Cassini, and famous as an astronomer in his own right, stated as his opinion that the corona was the atmosphere of the Sun which suddenly became visible during a total eclipse. But the majority of his colleagues considered it much more probable and "reasonable" that the corona was the atmosphere of the Moon, which was illuminated for good visibility only if the Sun stood directly behind it.

The question was solved by elimination: The more the Moon was observed, the clearer it became that the Moon did not have an atmosphere worth that name. Hence the corona had to belong to the Sun.

Yes, but what were the Sun spots?

Galileo Galilei believed they were black—or at least dark—clouds that were high above the luminous surface of the Sun. Others did not contradict this view, but were more specific—these were the dark clouds that formed above gigantic volcanoes in eruption.

A few decades later, about 1670, it was Cassini who turned the idea around. The Sun spots were not dark clouds of one kind or another, but just the opposite: When a storm tore a hole in the luminous cloud layers of the Sun, it might grow tenuous enough to be pierced by a vast black mountain peak on the Sun's surface.

THAT it might be the Sun's atmosphere which was luminous while the surface was dark was not Cassini's original idea. It had been uttered somewhat timidly at an earlier date by pointing out the highly luminous clouds we now call sunset cumulus and which are so much brighter than the ground. Cassini's authority merely reinforced this older idea.

A century later—things did not move as fast then as they do now—Cassini's special contribution to this theory was removed, but the theory itself seemed strengthened some more.

In November 1769, the Sun sported an especially large spot and Alexander Wilson in Glasgow, who observed it with meticulous care, realized for the first time what virtually everybody knows now from photographs.

Such a Sun spot was not just a dark blot; it showed some differentiation in itself. The center was really dark, but between this dark spot and the surrounding bright surface of the Sun was a medium-dark area. When such a spot had wandered all the way to the rim, one could see that perspective made the relative positions of the dark center spot and the not-so-dark surrounding area shift.

In short, one could see that the semi-dark area was lower than the surrounding luminous area, while the dark center area was still lower.

Obviously, then, there were several layers in the Sun's atmosphere, one highly luminous top layer (but still below that ghostly corona one could not normally see) and a less luminous lower layer. Each layer developed holes on occasion and if the holes in both layers happened to match, we could see the dark "real surface" of the Sun.

Although Sir William Herschel held to the maxim that "it is sometimes of great use in natural philosophy to doubt of things which are commonly taken for granted," he wholeheartedly accepted Wilson's reasoning. He only made a minor correction: Wilson had spoken of the "lower layer" as less luminous, whereas Sir William considered it to be dark. We could see it at all only because of the fact that it reflected the light of the higher luminous layer.

In the elder Herschel's opinion, the surface of the Sun was *protected* against the heat and glare of the top layer by this reflecting and absorbing lower layer. To bolster the idea that all the luminousness might originate only from the Sun's upper atmosphere, Sir William pointed out that all heavenly bodies, "we have pretty good reason to believe, emit light in some degree." The dark side of the Moon did so on occasion—actually reflected Earthlight which is reflected sunlight in the first place—the night side of Venus often glowed (probably aurora) and, in the polar night of the Earth there was the glowing *aurora borealis* in the north and the equally bright *aurora australis* in the south.

IT was a difference in degree rather than a fundamental difference. "The sun's similarity," Sir William wrote in 1794, "to the other globes of the solar system with regard to its solidity, its atmosphere and its diversified surface; the rotation upon its axis, and the fall of heavy bodies, lead us on to suppose that it is also most probably inhabited, like the rest of the planets, by beings whose organs are adapted



to the peculiar circumstances of that vast globe."

We would be hard put nowadays to invent anything wilder than this concept, but it covered all the then available information. As long as not even the nature of chemical combustion was properly understood, it made sense.

To us, it seems like an especially striking contrast that Herschel, with such a concept in mind, also tried to establish whether the Sun spots influenced the weather on Earth. Having neither astronomical nor meteorological statistics available, he picked the only one there was—the recorded wholesale prices of grain. Even so, he might—with luck—have discovered the Sun-spot cycle, but the tool was too inadequate.

The actual discovery of the Sun-spot cycle by Heinrich Samuel Schwabe did not take place until 1843, but around 1770, a Danish astronomer had resolutely entered a remark in his daily diary to the effect that "in time, a periodicity of the Sun-spot phenomenon will be found, since every other astronomical phenomenon shows periodicity."

Herschel's concept of the Sun was not disproved by one man and one discovery at a specific date. It seems to have died very gradually, its last remnants being swept away by the discovery of spectrum analysis in 1859.

In the meantime, a large number of other discoveries had been made and some known phenomena had been thought about. By 1840, no astronomer doubted any more that all the so-called fixed stars were suns, too—as had been guessed by an Arab eight centuries earlier—and the phenomenon of the Milky Way had been explained, by Herschel as a result of observation, and by Immanuel Kant independently by careful reasoning. One of the discoveries that became importaant was that some stars showed definite colors. That some were red was obvious, but there also were blue ones.

So stars could have different colors—at that time, it was just an item of information to be filed away.

THEN there were the recurrent "new stars." Pliny the Elder reported that Hipparchos had started his famous star catalogue because of such a new star. You could not tell whether a star was "new" if you did not have a list of the "old" ones.

Two or three other new stars had been reported from Roman times. Then there had been one during the ninth century when Arab astronomy was at its peak under Caliph al-Mamun. In 1012, Hepidanus, a monk of St. Gallen in Switzerland, listed another "new star" in his *Chronicle of Miracles*. One especially famous super-nova, to use the modern term, occurred in the time of Tycho Brahe (1572). Another one soon after, in 1604, has often been called Kepler's new star. Jean Dominique Cassini got "his" in 1670; then there was a pause until 1848.

Of course, there have been quite a number since, but the ones that influenced thinking in 1840 were those associated with the names of Tycho, Kepler and Cassini.

If stars could have different colors, would it be possible that there were *dark* stars? When Alexander von Humboldt wrote jokingly in a letter about such dark celestial ghosts, the then famous astronomer Friedrich Wilhelm Bessel (the first to measure the distance to a star, 61 Cygni) replied simply: "that innumerable stars are visible obviously does not disprove the existence of an equal number of invisible stars." So if there were dark stars and also "new" stars, wasn't the simplest explanation of the "new" stars that two dark stars had collided? Thus the novas seemed to furnish a roundabout proof for the existence of dark stars.

Such an event was both end and beginning, but the idea of "the end" had entered astronomical thinking, so to speak, by the back door. For what were the dark stars?

In 1814, Joseph Fraunhofer, discoverer of the lines named after him and *almost*-discoverer of spectrum analysis, had compared the lines of various stars. He had found that his lines were in places where the Sun did not show lines and had concluded that there probably were different kinds of stars.

Fraunhofer's discovery had come clearly too early to be fully understood. It took until 1860, when Giovanni Batista Donati came across Fraunhofer's statement in an old volume of the proceedings of the Munich Academy of Sciences. Donati himself went to work on the problem, but most of the work was done by Father Angelo Secchi, the Papal Astronomer.

ANGELO Secchi sorted all the stars he investigated into four classes. Class I were the "blue stars" of which Sirius and Vega are examples. Class II were the "yellow stars" with our own sun as the prime example. Class III were the "red and orange stars," such as Betelgeuse and alpha in Hercules. Class IV, finally, was a type of which very few and very small stars were then known. They were dark red and their spectrum was strange.



Such stars, Father Secchi wrote, "which show such zones in their spectra must have a lower temperature than those which show only the fine lines (of Fraunhofer)." In fact, the explanation seemed to be that the stars of Class I and Class II were far too hot to permit the existence of chemical compounds, while the stars of Class III and especially of Class IV were not hot enough to prevent their existence.

We now know that this is wrong, but the consequences of this careful pioneer work were very obvious: Secchi's four classes were clearly four successive stages of a star. Or a sun. At first, it began hot, blue-white. In the course of time, it cooled to yellow. Then to orange. Then to red. In the end, it was too cool to be visible at all—Bessel's dark stars.

So far, everything looked logical and fine. The stumbling block appeared with the logical enquiry of how long this development would take. It was the same question as "what keeps the Sun going?" There were estimates of how much heat the Sun produced. We know that these estimates were too small, but they appeared enormous.

John Tyndall (a physicist, not an astronomer) said in despair, "the facts are so extraordinary that the soberest hypothesis must appear wild." The Sun kept everything going on Earth, as had been well realized by then, but the Earth intercepted only a tiny fraction of the Sun's production of heat and light. Any reasonably bright high-school boy, knowing the diameters of the Sun and the Earth and the distance between them, could calculate just how much radiation the Earth intercepted. The figure is on the order of 1/2,200,000,000.

A few scientists (but not physicists), both astonished and somewhat frightened by such figures, tried to think a way out. Maybe the Sun did *not* radiate into space in all directions. Maybe radiation between the Sun and the planets was a proposition resembling static electricity—it went only in the direction in which it was received.

This was a somehow valiant guess, utterly wrong, of course, and promptly disbelieved by every expert, even before James Clerk Maxwell's *Treatise on Electricity and Magnetism* in 1873 furnished the final demolishing weapon.

The fact remained that the Sun threw enormous amounts of energy into space. Where did it come from?

SIR William Thomson, the later Lord Kelvin, made a quick side calculation. Even if the Sun consisted of the best grade of anthracite and were furnished with the necessary oxygen, it would not last more than 5000 years, so it could not possibly be chemical energy. In the first place, it obviously wasn't. In the second place, geologists had already shown that the Earth was far older than 5000 years and that, moreover, there had been life on Earth for a very much longer period.

But what other energy than chemical energy was there? Here Hermann von Helmholtz had given an answer. The Sun must have had a beginning and the only possibility one could think of was that it had condensed out of cosmic dust. It must have been large and loose in the past, but the mutual gravitational attraction of the particles caused this body to condense into what we now call the Sun. Such contraction generates heat. Helmholtz advanced the theory, for the first time, in 1853, that the Sun kept going by continued contraction.

Calculation showed that a contraction of about 300 feet per year should account for the observed release of energy. And since, with contraction, its surface is diminished, it should actually grow hotter. Because the contraction would amount to one mile every 17 years and the diameter was 864,000 miles, however, the shrinkage would be too small to detect easily. It certainly could not be detected by comparing older records with modern (1860) observations.

Extrapolating backward from this idea, it turned out that the Sun could not be older—as a shining star—than 18 million years at the most. Simon Newcomb, extrapolating forward at a later date, calculated that after five million years, the Sun would have shrunk to half of its present diameter and be eight times as dense. After that, the ability to contract any more would be drastically reduced and the temperature would have to fall off sharply.

The overall conclusion was that the Sun would last another eight million years or so.

The maximum figure of 18 million years for the past was greeted with pleasure at first by the geologists, who found in their own researches that every new discovery they made needed more elapsed time. But the geologists kept on making discoveries and the figure of 18 million years soon grew tight for them.

Well, astronomers and physicists interested in astronomical matters were willing to oblige with an alternate idea. Lord Kelvin, who himself estimated the age of the Earth as about 100 million years, was in favor of the meteoritic theory, which claimed that the Sun maintained its heat by the impact heat of the steady rain of meteorites that must fall into it.



TO get a grip on the problem, Lord Kelvin calculated how the solar furnace would be stoked by the impact of the planets it now has. If Mercury fell into the Sun, it would make up for the energy release of about 6½ years and Venus would account for nearly 84 years of energy release. The table looked as follows:

| | | |
|---|---|---|
| **Mercury** | **6.6** | **years** |
| **Venus** | **83.8** | " |
| **Earth** | **95.0** | " |
| **Mars** | **12.6** | " |
| **Jupiter** | **32,254.0** | " |
| **Saturn** | **9,652.0** | " |
| **Uranus** | **1,610.0** | " |
| **Neptune** | **1,890.0** | " |
| **Total:** | **45,604.0** | **years** |

From this table, one could calculate back how much matter would have to fall into the Sun daily to keep the process continuous. The result happened to produce a nice even figure: If a mass equal to 1/365th of one per cent of the mass of the Earth fell into the Sun daily, it would account for the energy release. Rounded off: one Earth-mass per century. This would not show up as an increase of the diameter of the Sun for a long, long time.

If the geologists had balked at the contraction hypothesis because it did not allow them enough time in the past, the astronomers balked against the meteoritic hypothesis because it would put too much matter into space.

If the equivalent of one Earth-mass fell into the Sun every century, the equivalent of several Earth-masses—no, of scores of Earth-masses—must be in space reasonably near the Sun.

But the astronomers would see them. The Earth itself, for one thing, would find a heavy meteoritic bombardment going on all the time. The orbits of the inner planets would be influenced. It might work theoretically, but it did not agree with observed facts. It was like saying that the observed level of street noise at a busy intersection could be accounted for by pistols being fired at the rate of four rounds per second. The noise might be the same, but the bullets would cause other effects which, however, did not show up.

The majority of astronomers thought along a different path. The observed energy release of the Sun—facts first!—could be accounted for by either of these two theories. But either should have effects which disagreed with observation. Therefore, both probably worked together.

A steady hail of meteorites stoked the solar furnace, but there was not enough to replace all the lost heat. The difference was made up by contraction which, under these circumstances, could be much slower. Hence the geologists got more time in the past because of lesser contraction, while the observing astronomers were still not asked to accept larger amounts of cosmic matter than they would willingly do.

ALL this could be made to account for continued sunshine. But most likely there were elaborations. One could see the red suns in space. They had obviously run out of meteoric material and then contracted as far as possible, after which they only lost heat, with no chance of replenishing the supply, until their temperature had dropped to the point where chemical compounds became possible. Soon they would be completely dark.

But if they had planets, there would be respites, just as suggested by Lord Kelvin's calculations. The planets, moving around their suns, must find some slight resistance—infinitesimal, to be sure, but resistance nevertheless. Slowly, their orbits would shrink and finally one would crash. The sun would be rekindled — remember Wells: "had for a little time glowed more brilliantly again" — and then slowly disappear again in reddish blackness until the next planet crashed. Seen from a long distance, this would be one of the "new" stars.

This concept also explained the observed fact that these new stars did not last long. They suddenly flamed into enormous brilliance from "nothing," outshone everything else for months, but then became faint and could not be found any more after a few years. If they had been collisions between two dark stars, they should be permanent as far as short-lived humans were concerned. But a crash of a small planet seemed to fit the facts.

Extending speculation a bit, there were two schools of thought. Both agreed on the general scheme for quite a long way. A star formed somehow and, with the aid of meteoric material and contraction, it kept shining for a long time, until the meteoric material was used up and contraction, as higher densities were reached, became more difficult. Near the very end came the borrowed time of the planet crashes.

The question was—and here the two schools of thought differed from each other—what was likely to happen if you did not look at one sun, but at all of them together—at the Galaxy, as it were?

One party maintained that the



average number of luminous stars would remain substantially the same because of collisions of dark stars and the "original formation" of new ones. The other group maintained that the number of luminous stars must decrease steadily, for there was no "original material" left to form new stars and every pair of dark stars that met would make just one new, though larger, luminous star.

Therefore, after eons and eons of time, all the matter would be concentrated into just two supergigantic stars. Alone in space, they would, of course, attract each other and these two would suffer a head-on collision of enormous masses striking at fantastic speed.

This unimaginable collision could not produce a single star. It would disperse the matter of both!

But the end of one cycle would be the beginning of the next, for then there would be again matter in space, to condense and form completely new stars and planets and moons!

THE picture was complete around 1890.

In 1896, the professor of the *Ecole Polytechnique,* Antoine Henri Becquerel, put uranium ores into the same desk drawer in which he kept unexposed photographic plates, wrapped in black paper. Two years later, Pierre and Marie Curie isolated something they called polonium.

And in 1910, Dr. Ralph Allen Sampson, the Astronomer Royal for Scotland, when asked to write the article "The Sun" for the forthcoming new edition of the *Encyclopaedia Britannica,* only expressed the general feeling when, after reciting the older ideas, he wrote: "a source which seems plausible, perhaps only because it is less easy to test, is rearrangement of the structure of the elements' atoms. An atom is no longer figured as indivisible . . ."

The no longer indivisible atom was to turn most of the older ideas upside down once more, as we'll see in next month's conclusion of this discussion.

—WILLY LEY