Chapters 1, 2, 23, 37 from

almost everything you ever wanted to know about ASTRONOMY

Dr Copper. Are you watching the stars?

Sam. I wouldn’t notice if the stars dropped out of the sky. You’re an astronomer?

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Sam. Where?

Dr Copper. Anywhere. Everywhere.

MARTIN PROBERT

Chapters 1, 2, 23, 37
from the Paperback Version of

Almost Everything You Ever Wanted to Know About Astronomy

48 Lively Conversations About the Night Sky

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Almost Everything You Ever Wanted to Know About Astronomy

48 Lively Conversations About the Night Sky

Martin Probert

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Conversations 1-24

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1 The Celestial Sphere

DR COPPER. Are you watching the stars?

SAM. I wouldn’t notice if the stars dropped out of the sky. You’re an astronomer?

COP. I teach astronomy.

SAM. Where?

COP. Anywhere. Everywhere.

SAM. I scarcely know a thing about astronomy. The subject both fascinates and baffles me. Of course, I know the Earth’s not flat. And I’m dazzled by those amazing pictures of spiral galaxies in newspapers and magazines. I suppose I’d need a telescope to see such things myself?

COP. Even a telescope wouldn’t help you. Only the camera, by gathering the light over a period of time, can capture such stunning images. And yet the night sky, even seen by nothing more than the naked eye, has a story to tell.

SAM. Is the sky the same every night?

COP. The ancient astronomers—those who lived long before the invention of the telescope—believed that the Earth was surrounded by a ‘celestial sphere’, a star-spangled sphere that rotated about the Earth. We now know that no such sphere exists, but—look into the sky!—the same sphere that the ancients saw is still apparently rotating about us this very night. This is the same sky as was seen by Ptolemy and by Pythagoras and by all the ancient Greeks, and by the ancient Babylonians and by the ancient Egyptians too.

SAM. Your words remind me of something I once read:

> This sun, this moon, these stars, are the very same which your forefathers enjoyed, and which shall also entertain your posterity.
>
> —Montaigne, Essays (1580)

COP. You have a nice memory for a good line.

SAM. So, if I imagine that I'm looking up at the heavens through the eyes of an ancient astronomer, this vast black sky and the thousands of stars scattered over it is part of a great sphere that is rotating about us?

COP. You have entered quickly into the ancient world-view of the universe.

SAM. But, in reality, there is no such sphere surrounding the Earth?

COP. To our eyes, there is. We see it rotate around us every night of the year.

SAM. I'd never thought before of the night sky as a starry globe surrounding the Earth. The concept is beautiful.

COP. Luckily there are no clouds to spoil the beauty. And the view is always best from high up, out of the way of surrounding trees and buildings.

SAM. It's surprising, with so many references to the stars in literature, that I haven't looked up into the skies more often. A lot of the old novels, travel books and autobiographies mention the stars. Our ancestors were evidently better acquainted with the sky than we are today. And it's astonishing how many stars there are. We can't see this many back in town.

COP. The glow of street lights is absent out here in the country.

SAM. And you say this starry sphere rotates about us? There's a humorous seventeenth-century reference to the stars revolving around and around in the sky:

… the heavens, like a top,
Are kept by circulation up,
And were it not for their wheeling round,
They'd instantly fall to the ground …

—Samuel Butler, Hudibras (1663-78)

But to me the stars seem stationary. I can detect no movement.

COP. If you were to close your eyes now, and open them in an hour, you would detect a change.

SAM. That bright star there, if I were to close my eyes for an hour, where would it reappear?

COP. Nearer the horizon.

SAM. Your understanding of these things intrigues me. Did it take long to gain the knowledge?

COP. The understanding is not so very difficult. Would you like to learn?

SAM. Very much. I'd love to know what's going on up there in the sky.

COP. Perhaps I can help. There's plenty we might talk about: the Sun, Moon and planets, comets and asteroids, stars and galaxies, black holes, and space and time and relativity.

SAM. You make it sound fascinating. But do you have time to tell me about all these things?

COP. Certainly. That is, if you've no objection to spending your evenings beneath the stars.

SAM. None at all. I accept your offer.

COP. Excellent. Shall we begin at once?

SAM. By all means. And by the way, I'm Sam.

COP. My friends call me Cop. Short for 'Copperknickers the Astronomer'. It's a joke of theirs.

SAM. Copperknickers?

COP. After Copernicus, the famous sixteenth-century astronomer.

SAM. But tell me, that bright star, how do you know that in an hour's time it will be closer to the horizon? Can you see into the future? I'd like to acquire this skill.

COP. The skill to see into the astronomical future is one easily attained. We'll begin with something familiar …

2 The Pole Star and the Great Bear

COP. Look at that star in the northern sky, the one I'm pointing to.

SAM. Let me look along your arm. Yes, I see it.

COP. That's the Pole Star, or Northern Star. We'll always find the Pole Star in the north, in the same place in the sky. If we stand here and watch all night, the Pole Star will never move. Every other star in the night sky rotates about the Pole Star.

SAM. Ishmael, the narrator in Moby Dick and a sailor with a sailor's knowledge of the stars, was well acquainted with the Pole Star,

> the unsetting polar star, which through the … night sustains its piercing, steady, central gaze …
>
> —Herman Melville, Moby Dick (1851)

It's said that migrating birds too make use of the stars to find their way.

COP. So I've heard. There was an interesting experiment involving the Pole Star. Some migrating birds were released in a planetarium. As the constellations revolved about the Pole Star, the birds, identifying the one star that did not move, flew away from it, and thus headed south. But, when the constellations were made to rotate about another star, the birds changed direction and flew away from the star which was then stationary.

SAM. Which way do the stars rotate? Clockwise, like the hands of my watch? Or the other way?

COP. The other way. The stars rotate anticlockwise around the Pole Star. Those nearest to the Pole Star go round and round it without ever touching the horizon. Others, further away from the Pole Star, rise in the east, pass anticlockwise around the Pole Star, and set in the west.

SAM. How long do the stars take to rotate once about the Pole Star?

COP. A little less than a day.

SAM. So the stars will be in about the same position at the same time the next night?

COP. That’s right.

SAM. That explains the speech in Hamlet, where Bernardo indicates the time by the position of a star:

Last night of all,
When yon same star, that’s westward from the pole,
Had made his course to illume that part of heaven
Where now it burns …

—Shakespeare, Hamlet, 1. i

I also think I understand why that bright star is moving towards the horizon. The rotation of the celestial sphere about the Pole Star is carrying it downward?

COP. Yes. So, knowing where the Pole Star is, and knowing that the celestial sphere is rotating about the Pole Star in the opposite way to the hands of your watch, you can now tell where any star will be found later in the night.

SAM. This is a curious skill you've taught me, to foretell the future. But there's a problem.

COP. What's that?

SAM. If I look for the Pole Star from this hill, I know I'll find it above that tree down there. But stand me somewhere else, and I'd be at a loss to know where to find the star. I'd feel like the three travellers who, trying to find the direction by astronomy, had no idea where they were starting from:

> 'How do you mean, from here?' asked George.
> 'Why, from here, where we are,' returned Harris.
> 'But where are we?' said George.
>
> —Jerome K. Jerome, Three Men on the Bummel (1900)

COP. I'll teach you how to find the Pole Star from wherever you are. Do you know the group of seven bright stars known as the Big Dipper or the Plough?

> The Plough, or Charles' Wain, consists of seven bright stars arranged in a manner suggesting the handle and share of a plough, or else a wagon or a chariot with its horses, according to the pursuits or inclinations of the observer.
>
> —E. Walter Maunder, The Stars as Guides for Night Marching (1916)

SAM. That's one group of stars I can identify. Let's see if I can find it. Yes, that's it, isn't it?

COP. The Plough or Big Dipper is the brightest part of the constellation called the Great Bear. The name of Big Dipper comes from the resemblance to a 'dipper' or soup ladle. Four stars make up the bowl of the dipper, and three more the handle.

SAM. I see the bowl and handle clearly.

COP. Two stars of the bowl, those furthest from the handle, are known as the Pointers. One is at the base of the bowl, the other on the rim. Look! follow the direction of the Pointers, moving from the base of the bowl and out at the rim, and the first bright star you come to as you follow the Pointers is the Pole Star.

SAM. So, once I've found the Great Bear and have followed the Pointers to the Pole Star, and knowing that every star rotates about the Pole Star in the opposite way to the hands on my watch, I can predict where any star will be later in the night. This is magic indeed! But what if the Great Bear is not visible? If the Great Bear sinks below the horizon, how will I find the Pole Star?

COP. Well, for anyone north of the latitude of Athens or New York, the seven brightest stars of the Great Bear are circumpolar, which means they will always be above the horizon.

SAM. But further south they will disappear below the horizon?

COP. That's right. But the Pointers, which help identify the Pole Star, will still be visible throughout the year for anyone as far south as Memphis or the Straits of Gibraltar.

SAM. I recollect that Odysseus watched the Great Bear

> which turns round and round where it is, never dipping into the ocean …
>
> —Homer, The Odyssey

The circular motion of the Great Bear has also been compared to that of a bear tied to a stake:

… the Bear
That's fixed in northern hemisphere,
And round about the Pole does make
A circle, like a bear at stake,
That at the chain's end wheels about …

—Samuel Butler, Hudibras (1663-78)

But, if the Great Bear disappears below the horizon for anyone who lives too far south, what we see in the night sky appears to depend upon our latitude. How much does our latitude affect what we see?

COP. Imagine ourselves at the north pole of the Earth. The Pole or Northern Star would be directly overhead. If we now walk south, looking back over our shoulders at the Pole Star, the Pole Star will gradually sink lower and lower in the night sky. This fact was known to the ancient navigators. They could work out their latitude by measuring the height of the Pole Star using an astrolabe.

SAM. Don Quixote was acquainted with the use of the astrolabe:

'But doubtless,' said Don Quixote, 'we are there already, for we must have gone at least seven or eight hundred leagues. If I had an astrolabe, to take the elevation of the pole, I would tell the exact distance we have sailed.'

—Cervantes, Don Quixote (1605-15)

COP. Eventually, if we keep going south until we approach the equator, we'll find that the Pole Star will have fallen so low in the sky that it's on the horizon. And, if we go still further south, the Pole Star will disappear.

SAM. Is there a southern Pole Star?

COP. There’s a point in the southern sky about which the stars rotate—a south celestial pole—but there’s no bright star to mark it. On the equator we can see the stars circling both celestial poles. The stars rise in the east and set in the west, so looking north from the equator we’d see the stars rotate anticlockwise around the north celestial pole, while looking south we’d see the stars rotate clockwise around the south celestial pole.

SAM. And if we walk south from the equator?

COP. If we walk past the equator, into the southern hemisphere, the south celestial pole will rise higher and higher in the night sky.

SAM. Seafarers were evidently familiar with the changing view of the night sky as they sailed south across the equator:

> When we were [close to the equator] we lost the sight of the north pole … [Then, when we were] southward of the line, we had in sight the south pole.
>
> —Francis Fletcher, Sir Francis Drake’s 1577-1580 Voyage

COP. And the further south we go, the less of our northern constellations will be visible.

SAM. You mentioned that, from northern latitudes, the seven brightest stars of the Great Bear never disappear below the horizon. But the feet of the Great Bear must disappear, at least if I’m to believe some lines about the Bear dipping his feet into the sea and then whipping them out again:

> The Bear that in the Irish seas had dipped
> His grisly feet, with speed from thence he whipped.
>
> —Thomas Sackville, ‘The Induction’ (1563)

COP. Yes, you're right. For many of us in the northern hemisphere—everyone south of Alaska or Norway—the Bear's feet do indeed disappear below the horizon. The legs of the Bear are made up of several faint stars. Three of the paws are marked by three pairs of stars that lie on that side of the Plough or Big Dipper furthest from the Pole Star. The best time to look for the paws is when the Bear is high in the sky, such as during evenings in the first half of the year. As the Great Bear rotates about the Pole Star, the paws periodically dip below the horizon, and then rise up again, just as the poet says.

SAM. How many constellations are there?

COP. Since ancient times the word 'constellation' has referred to groups of stars that were seen as mythological characters. But different peoples have seen different numbers of these groups. Nowadays astronomers use the word 'constellation' to refer to one of eighty-eight regions into which the entire sky has been divided.

SAM. So every star in the sky belongs to one of these eighty-eight constellations?

COP. Yes. We can think of the celestial sphere as a gigantic eighty-eight piece jigsaw. Each piece of the jigsaw—each constellation in the sky—contains a vast number of stars. Astronomers now refer to the ancient familiar groups of bright stars—the mythological pictures seen by earlier civilisations—as 'asterisms'.

SAM. So the Big Dipper or Plough, being the familiar brightest part of the Great Bear, is an asterism?

COP. Exactly.

SAM. Are there other stars which, like those of the Plough or Big Dipper, never completely disappear below our horizon?

COP. Yes, and they’re easy to find. Let’s take a look at them …

Conversations 3-22 not included

Next

23 Mars: the Red Planet

23 Mars: the Red Planet

COP. Mars is in the sky. It’s so bright just now, there’s no mistaking it.

SAM. How do we work out when Mars is visible?

COP. There are many ways. We can look up the information in the monthly astronomical section of newspapers, or in astronomical magazines, or on the Internet, or in the Astronomical Almanac for the current year, or we could use an astronomical computer program.

SAM. So it’s too complicated to work it out oneself?

COP. Much too complicated. There are too many factors.

SAM. Such as?

COP. Well, Mars is further from the Sun than the Earth—any such planet is known as a ‘superior planet’—and, being further from the Sun, Mars can appear in the sky at midnight. That’s quite unlike the inferior planets, Mercury and Venus, which are only seen around sunrise and sunset. You remember, when we were talking about Mercury, we likened its movement in the sky to that of a moth circling a bright lamp, and said that just as the moth would always be seen close to the lamp, Mercury is always seen close to the Sun. Mars, however, has a movement more like that of a dog seen running around a street lamp in a wide circle, with us standing within the circle. The dog can appear against any part of the horizon, not just in the direction of the lamp, just as Mars won't always be in that part of the sky where the Sun happens to be.

SAM. So that's the first problem we have if we want to find Mars?

COP. Yes. But that's not the end of our problems. Every two and a bit years, after a period of invisibility when Mars was hidden more or less behind the Sun, Mars will become visible in the night sky. At first Mars will only be visible after midnight, but most of us will be in bed by then. Later in the cycle Mars becomes visible in the evening, but if it's summer, the evening sky may be too bright. Then, depending upon where Mars happens to be in the zodiac, Mars may be too close to the horizon to be seen easily.

SAM. But the published predictions will tell us when Mars is well placed for observation?

COP. Exactly. However, since the planets all rise in the east, pass through south, and set in the west, any particularly bright object along that path may well be a planet. Planets—for anyone in the northern hemisphere—will never appear in the northern sky. So, if we're looking for Mars, we only need to inspect the southern sky.

SAM. Mars, like Venus, has given its sign to the biologists and botanists, as explained in an old work on entomology:

> I may mention here that the little hieroglyphic marks attached to the figures [of drone and queen bee] denote the sex. They are, in fact, the old astronomical figures used to denote the planets by a sort of short-hand. The circle with the barbed point [♂] was used as the emblem of Mars, and is employed by naturalists to denote

the male sex. The circle with the crossed line below it [♀] was the emblem of Venus, and denotes the female sex …

—J. G. Wood, Insects at Home (1883)

The circle with the crossed line below, the symbol of Venus the goddess of love, is a depiction of a mirror and its handle. The circle with the barbed point, the symbol of Mars the god of war, is a depiction of a shield and spear.

COP. The most noticeable thing about the planet Mars—the 'Red Planet'—is its colour.

SAM. Yes, the reddish tinge is very obvious:

As red as Mars …

—Shakespeare, Troilus and Cressida, V. ii

What causes the redness?

COP. The redness is due to iron oxide. A rusty sand covers the plains of Mars. Periodically—especially every two years when Mars is closest to the Sun—this fine red sand is whipped up by strong winds. Then vast dust storms engulf the planet.

SAM. Is Mars always as bright as it is tonight?

COP. No. Mars can be a lot less bright. But about every two years it's as bright as this.

SAM. So there's something special going on just now?

COP. Mars is illuminated by the Sun. Just how bright Mars appears to us on Earth depends upon how close it is to us. Both the Earth and Mars orbit the Sun, with the Earth's orbit inside that of Mars, and with the Earth travelling faster. Every two years the Earth overtakes Mars. The event is known as an ‘opposition’ of Mars, since Mars is then on the opposite side of us from the Sun. Mars will also be at its closest to the Earth.

SAM. And so, as seen from the Earth, Mars will be at its brightest?

COP. That’s right. And if Mars also happens to be on the part of its oval-shaped orbit that’s closest to the Sun, then Mars will be particularly bright, brighter than the brightest star.

SAM. So just now we’re overtaking Mars, which is why Mars is so bright?

COP. Yes. And there’s something else going on that’s quite curious. But we’d need to watch Mars from night to night to observe what’s happening. Of course, the main picture we have each night is of Mars rising with the stars in the east, and setting with the stars in the west. But now let’s look at the smaller movement of Mars among the stars.

SAM. I remember—from when we were talking about the solar system—that all the planets move through the zodiac.

COP. That’s right. The Sun, the Moon and the planets all move through the twelve constellations of Pisces, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus and Aquarius. The Sun takes a year to complete the circuit. The Moon completes the circuit in about a month. Mars takes about two years to complete the circuit. But, whereas the Sun and the Moon keep moving forward all the time, Mars occasionally stops, reverses direction and moves backward for a while, stops a second time, reverses direction once more and continues moving forward along the zodiac. It's as if Mars changes its mind and starts to return the way it came, then changes its mind a second time and continues in the original direction.

SAM. Why does this happen?

COP. It's an optical illusion caused by the Earth overtaking Mars. The same thing occurs when two runners run round a circular track. Suppose that the inside runner manages to keep an eye on the outside runner without tripping over. If the inner runner is the faster, and watches the outer runner moving against the background scenery of distant trees or buildings, then most of the time the outer runner will be progressing forward but, at the moment that the inner runner passes on the inside, the outer runner will seem to move backward in relation to the scenery. So, whenever the Earth overtakes Mars, Mars will seem to travel backward through the zodiac for a couple of months before changing direction and proceeding forward once more.

SAM. Does this backward motion ever occur with any other planet?

COP. Yes, but the fairly rapid motion of Mars through the stars draws our attention to its movement. Our ancestors, who watched the sky far more than we do today, were well aware of these occasional backward motions. At such times a planet is said to be undergoing a 'retrograde motion' through the stars. This retrograde motion, which we can all observe with the naked eye, showed Copernicus that the Earth was not the centre of the universe, but the Earth and Mars both went round the Sun.

SAM. We can see the red sand covering Mars. What about craters? Does it have any?

COP. Mars, like many other bodies in the solar system, is pitted with craters. The craters were first seen on photographs taken by spacecraft in the 1960s.

SAM. Is there any water?

COP. Mars has ice caps at both poles, ice beneath some surface regions, and there’s a trace of water vapour in the Martian atmosphere. The ice caps can be seen through a small amateur telescope. But Mars is too cold, and the surface pressure is too low, for there to be any surface water.

SAM. So no sandy beaches!

COP. No. But if you feel like a holiday on Mars, you might find the moons entertaining.

SAM. How many moons are there?

COP. Two.

SAM. And why might we find them entertaining?

COP. Let’s imagine we’re on Mars. We can see the starry celestial sphere surrounding Mars. The celestial sphere is turning to the west. The two moons are on the celestial sphere, carried to the west by the turning of the sphere, but simultaneously moving east through the stars. Now, what happens?

SAM. It depends upon which motion is the faster, the westward turning of the celestial sphere, or the eastward motion through the stars.

COP. Well, it happens that, for one moon, its eastward motion is faster than the westward turning of the celestial sphere, while for the other moon the eastward motion is slower.

SAM. Does that mean that one moon will be seen travelling through the sky to the east, while the other travels to the west?

COP. Precisely.

SAM. It’s like Copperknickers’ Carousel once again, the merry-go-round you described when we were discussing the zodiac. We’re sitting in the central cabin watching the horses pass to the right. But this time there are two ticket collectors on the platform, both moving against the motion of the horses, one walking to the left quite slowly, the other dashing to the left faster than the horses are going to the right. The first ticket collector will be carried to the right, will disappear from sight for a while, and will reappear on the left, while the second collector will run off to the left, will disappear from sight, and will reappear on the right.

COP. And that’s just what we would see. If we were on Mars, we’d see one moon rise in the east, and the other in the west.

SAM. That would indeed be entertaining.

COP. Let’s try an experiment that just occurred to me. We’re going to look at the same situation from a slightly different point of view. We’re going to look at Mars turning on its axis, and at the two moons going around Mars. You’re Mars. Stand where you are, and turn slowly anticlockwise.

SAM. Like this?

COP. Yes. Now, I’m one of the moons, and I’m going to walk around you, also anticlockwise, but more slowly than you are turning. Tell me what you see.

SAM. Well, I’m turning round, and you’ve just appeared on my left. Now you’re passing in front of me. And now you’re disappearing on my right.

COP. Good. You saw me rise on your left, and set on your right. One of the moons of Mars is also like that. It’s also what we see when looking at the Moon from the Earth. Let’s try the experiment again.

SAM. Right, I’m turning anticlockwise.

COP. And I’m walking round you, still anticlockwise. But this time I’m going round faster than you are turning. Tell me what you see this time.

SAM. You’ve just appeared on my right. You’re passing in front of me. And now you’ve disappeared on my left.

COP. This time you saw me rise on your right and set on your left. That’s like the other moon of Mars. Every now and again, if you were standing on Mars, you’d see the two moons pass each other, travelling in opposite directions.

SAM. If there are any Martians on Mars, it’s a strange sky they’ve got.

Conversations 24-36 not included

Next
37 Double Stars

37 Double Stars

COP. Do you see the tail of the Great Bear?

SAM. Does the Great Bear have a tail? It's been argued that any reference to the tail of the Great Bear

> … must needs be false,
> Because your true bears have no tails.
>
> —Samuel Butler, Hudibras (1663-78)

However, in spite of that, bears do have tails. The tails are concealed beneath the fur. So, yes, I see the tail of the Great Bear. It's made up of three stars.

COP. Look closely at the middle star of the three.

SAM. I'm looking. Should something happen? Should the tail wag?

COP. Look closely and you'll see that there's not just one star where you're looking but two stars.

SAM. Why, so there is! I've often looked up at the Great Bear—at the seven bright stars making up the Plough or Big Dipper—but I'd never noticed before that there was a pair of stars in the tail.

COP. That pair of stars has been used as a test of good eyesight. If only one star is visible when we look straight at it, we can try finding the second star with averted vision. By looking to one side of the visible star we may find that the second star appears suddenly by its side. There are several other similar double stars in the sky, stars which seem single at first glance but—when we look carefully with the naked eye—turn out to be two stars close together. Such stars are known as ‘binary stars’.

SAM. Are the two stars related in some way?

COP. Some of the binary stars seen with the naked eye merely consist of two stars at very different distances from us. Other pairs of naked-eye stars may possibly be in orbit around one another, though if they are, the two stars are so far apart that they probably take half a million years or more to travel around each other.

SAM. Are there binary stars which orbit each other more rapidly?

COP. There are, but if they orbit each other more rapidly, they must also be closer together. So close together that we won’t be able to separate them with the naked eye. We’d need a telescope at the very least.

SAM. How quickly can such stars orbit each other?

COP. The binary stars seen through a telescope may take tens, or hundreds, or thousands of years to complete an orbit. By watching the two stars regularly it’s possible to make a drawing of their orbits.

SAM. What do the orbits look like?

COP. That’s what I wanted to show you tonight. I’ve got the answer to your question in this bag. Here’s the torch. Can you shine it on the bag while I rummage around inside.

SAM. How’s that?

COP. Fine. Here’s the first thing we need.

SAM. A couple of potatoes! Is this a picnic?

COP. They’re not just ordinary potatoes. I weighed them before I came out. One is almost exactly twice the weight of the other. And here’s the other thing we need. A knitting needle.

SAM. Uh huh.

COP. The needle’s got a point at each end. Now, if we fix a potato at each end, like this, we’ve got a model of a binary star.

SAM. And the big potato represents a more massive star?

COP. That’s right. Now, if I raise my left forefinger, I can just balance our binary star system on the tip of the finger.

SAM. The balance point is off centre. It’s nearer the heavier star.

COP. If I put my right forefinger on top of the balance point to steady the model, I can use my other right fingers to make the potatoes spin around the centre of mass—or ‘barycentre’—of the system.

SAM. And that’s what is happening with a binary star?

COP. More or less. You’ll notice that the more massive star has the smaller orbit. It’s going round quite close to the tip of my finger.

SAM. While the least massive star—the smaller potato—has the larger orbit.

COP. Any two-star system is also moving through space, just as our two-potato system will move through space if we take a short walk forward. Let’s do that.

The potatoes are orbiting nicely, and now we go forward. If we look at the movement of each potato against the ground, that's similar to what we see when we look at a binary star system moving through the sky against the background of more distant stars.

SAM. You weighed the two potatoes before starting out, and then constructed this model of yours in which the smaller potato has the larger orbit. Can we do that in reverse? Can we look at the orbits of a binary star system and work out the masses of the two stars?

COP. That's exactly what we can do. In fact, if we didn't have binary star systems to work with, we wouldn't be able to work out the masses of stars in the first place. We couldn't work out the masses if all stars were single stars. So binary star systems have been very important for astronomy. But, to work out the masses of the two stars in a binary system, we do need one additional bit of information. We need to know how far away the binary system is. If we know that, then we can calculate the mass of each star in the system.

SAM. I remember some ways to work out the distance to a star. We discussed them when we were talking about Proxima Centauri. Are there many binary star systems?

COP. There are vast numbers of them. Often the stars of a system are even closer together than those we've been talking about. So close together that the individual stars can't be separated in even the most powerful telescope.

SAM. If we can't separate them in a telescope, how can we tell that there's more than one star?

COP. By looking at the spectrum of the binary system. Stars which we know to be double by looking at their spectra are known as ‘spectroscopic binaries’.

SAM. If there are two stars, does that mean that there will be two sets of lines in the spectrum, one from each star?

COP. Yes. If we’re looking at the system face-on—like looking down at our two-potato system from above—that’s all we will see. But if we’re looking at the system from some other angle, then we’ll see one star moving towards us while the other is moving away. The spectral lines from the approaching star will shift towards the blue end of the spectrum, while the lines from the receding star will shift towards the red end.

SAM. And, because each star alternately approaches and recedes, each set of lines will oscillate back and forth, but in the opposite direction from the other set?

COP. That’s right. And the time taken for each set of lines to oscillate to the blue, then to the red, and then back to the beginning, will be the same as the time it takes for each star to complete its orbit.

SAM. So, by looking at the spectrum, we can work out the orbital period of the binary system?

COP. Exactly. But now, let’s take another look at our potato model of a binary star system. This time we’re going to take a look at it edge-on, from the side. What do we see?

SAM. We’re seeing one star eclipse the other. First the small potato gets in the way of the big potato, then the big potato gets in the way of the small potato.

COP. That’s known as an eclipsing binary. The two stars keep eclipsing each other. There are many eclipsing binaries in the sky, binary star systems that we see edge-on. Their brightness varies with time. Every now and then, as one star gets in the way of the other, the brightness drops. We can see the change in brightness from Earth. The most famous example of an eclipsing binary is the star Algol in the constellation Perseus.

SAM. Is that a naked-eye star?

COP. Yes. Algol appears as a second magnitude star for most of the time but the brightness drops to less than magnitude three whenever the hotter star is eclipsed by the cooler star. The orbital period is just under three days. Algol is visible during the autumn and winter months. Comparison of its brightness with that of nearby stars allows the change of magnitude to be detected with the naked eye. Astronomical societies have sections that specialise in monitoring the changing brightness of such variable stars.

SAM. What happens when Algol’s cooler star is eclipsed by the hotter star?

COP. The brightness will still drop, but by a smaller amount. In fact, by studying the change of brightness throughout the cycle, it’s possible to work out how much bigger one star is than the other. And if we examine the spectrum to work out how fast the stars are moving in their orbits, then we can also work out the mass of each star and the density of each star.

SAM. The sky, at least to the naked eye, seems to be full of single isolated points of light. It’s curious to think of many of them as double stars.

COP. Some are even multiple stars. There are many stars which seem to be one to the naked eye, are seen to be two in the telescope, and then, when the spectrum of each star is examined, each star of the pair is itself found to be a double star.

SAM. Which makes the original star a quadruple star?

COP. That’s right. The night sky is actually teeming with both double and multiple stars. The single stars are in a minority.

SAM. Our Sun is evidently a rather unusual object, being a star with no companion.

Conversations 38-48 not included

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About the Author

About the Author

The habit of discussing astronomy began in a society I founded many years ago while at school. The society, which attracted 55 members, was a fabulous success. We gave hour-long lectures to each other after school, and produced a magazine. Astronomer PATRICK MOORE described the magazine, on a postcard still in the author's possession, as 'the best school astronomical magazine I have ever seen'.

The third issue of the society magazine, which lies before me as I write, contained the following articles:

MARTIN PROBERT: '200 Years of Planetary Discoveries'
PATRICK MOORE: 'Is there life on Venus?'
BRIAN MAY: 'The Sun'

BRIAN MAY, a member of the society, went on to study astrophysics at university, and in 1970 co-founded rock band Queen.

The astronomer in the following pages is an amalgam of two fascinating personalities, J. HOME DICKSON and CECILIA PAYNE-GAPOSCHKIN. J. Home Dickson, the designer of the system of lenses by which forward-facing gunners in wartime aircraft could fire backwards at pursuing enemy craft, briefly joined the staff of the school while my society was running. With half-moon glasses and a white goatee beard, he was the schoolboy's picture of what an astronomer should look like. He invited me to his high London house where, after climbing many floors, we emerged into the loft to find telescopes poking skyward through holes in the roof. On retiring from teaching he presented me with a book by Cecilia Payne-Gaposchkin, a splendidly written account of astronomy by the outstanding twentieth century astronomer who had discovered, contrary to all contemporary thinking, that the most common element in the universe is hydrogen.

One day I was stopped in the street. ‘Hello, I have a photograph of you.’ It was a former pupil from one of my mathematics classes. The photo, it was explained, had been taken years before, and captured me out of doors with a screwed-up ball of paper in each hand demonstrating the motions of the Earth and Moon to a small crowd. Explaining astronomy to such an audience, an audience that could walk away at any moment and only stays to listen through a fascination with the subject, has always been a delight. The questions posed in such sessions have been an inspiration.

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“Suppose we imagine the Milky Way galaxy as a fried egg, and the Andromeda galaxy as another fried egg. We put each on a plate and hand the plates to someone with long arms. If the arms are held out sideways, then the sizes and positions of the fried eggs give us a good picture of the sizes and distance apart of these two galaxies.”

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