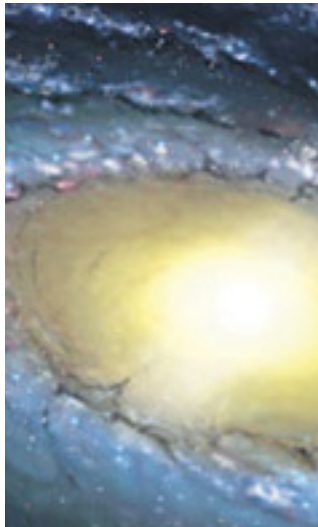


the age of the universe

WE'RE OBSESSED WITH measuring time. We celebrate new years, anniversaries and birthdays. We dedicate entire sports to seeing how long someone takes to get from one point to another. We take joy in counting the minutes before the end of a particularly boring English lesson (or before the beginning of a fantastically engrossing session of Physics). So it was only a matter of time before we made the ultimate measurement: how old is time itself? What is the age of the Universe?



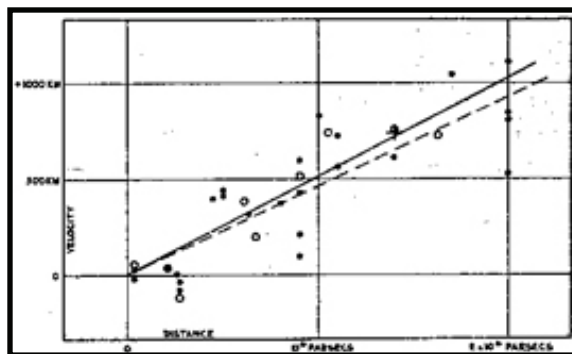
THE NIGHT SKY is dark. It might sound like an obvious statement, but someone had to point it out before we realised that it actually has quite profound implications. We used to think that the Universe was infinite – that is, it was always in existence, and went on, forever, in every direction. But in 1823, the German astronomer **Heinrich Wilhelm Olbers** realised that if this was true, then the night sky would be filled with an infinite number of stars and

appear brighter than daylight. Of course, we know this isn't true: if you take this sheet of paper to the middle of a field, in the middle of the night, and with no artificial light, you're not going to be able to read it. Which can only mean one thing: the Universe isn't infinite at all. It must have a **finite age**, and the light from the most distant stars **hasn't had the time to reach us**.

Heinrich Wilhelm Olbers



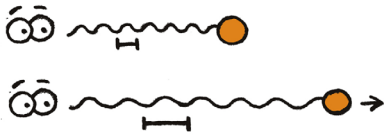
Right: the original velocity-distance graph plotted by Hubble (below left). Although he had the right idea, his actual results were quite inaccurate; we have since been able to produce more accurate results using the Hubble Space Telescope (below right).



NEARLY A HUNDRED years later, the American astronomer **Edwin Hubble** used a technique known as **redshift** (see "painting the sky red") to investigate the speed at which distant galaxies were moving away from us. He plotted a **velocity-distance** graph (left) and found that the distance of a galaxy was more or less **directly proportional** to its speed; that is, a galaxy twice as far away from us as another galaxy, was moving twice as fast. This was an astonishing discovery, and not what anyone expected. What's more, using some pretty basic physics and maths, it leads to quite a startling conclusion.



If an object emitting a wave is moving away from you, then the wave appears "stretched", and the wavelength appears longer.



painting the sky red: redshift

You know that a wave, such as the light emitted from a star, has a **wavelength** - the distance between two consecutive peaks or troughs. However, if the object is moving away from you, then the wave **seems stretched** and so the **wavelength appears longer**. In turn, this means that its frequency appears smaller.

The frequency of visible light determines what colour it is - red light has a

smaller frequency than blue light. So as the wavelength gets longer, and the frequency gets smaller, the light **appears redder** - which is why this phenomenon is known as **redshift**. If you measure the value by which the frequency decreases, you can then use a simple formula to calculate the **speed at which the object is moving away from you** - and this is what Hubble used to determine the speed of distant galaxies.

IMAGINE THAT YOU'RE standing on the side of a particularly long stretch of road, when, at exactly 12:00pm, two cars pass you at exactly the same time. One is travelling at **30mph**, and the other is travelling at **60mph**. At first you take no notice, but then at 1:00pm, exactly one hour later, you decide to look through your telescope to see where they are. As expected, **the first car is 30 miles away**, and **the second car is 60 miles away**. You notice, being the particularly bright person that

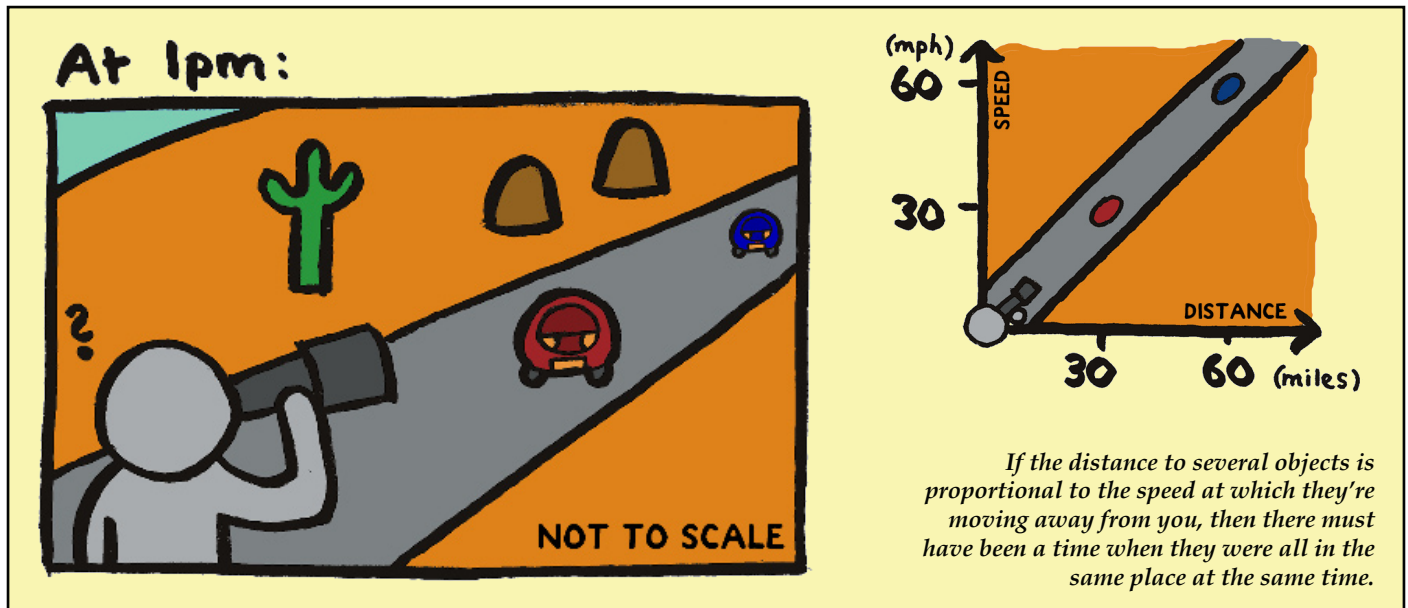
you are, that you're observing something similar to what Hubble saw in the stars: their speed away from you is proportional to their distance from you. But you have an extra piece of information: there was a time when **both cars where at the same place at the same time**. Applying the same logic to the stars, there must have been a time when everything in the Universe was also at the same place at the same time. We call it **The Big Bang**.

further reading!

If you want to find out more about the origin of our universe, and its potential fates, check out *A Brief History of Time* by Stephen Hawking, or *An Elegant Universe* by Brian Greene. Although be warned: the former isn't that brief, and the latter isn't always that elegant!

references

BW Carroll, DA Ostlie, *An Introduction to Modern Astrophysics*, 2nd Edition (2007, Addison Wesley, San Francisco).



$$v = H_0 r$$

$$H_0 = \frac{v}{r} \quad (1)$$

$$\frac{1}{H_0} = \frac{r}{v}$$

= time (2)

THE BIG BANG was when everything came into existence - so if we can calculate how long ago that was, then we'll know how old the Universe is. You know that quantities that are proportional to each other are related by a **proportionality constant**, and in this case, the speed, v , and the distance, r , are related by the **Hubble Constant**, H_0 . We can find it by **calculating the gradient** of the graph, which turns out to be quite a simple task, since it's a **straight line** - using data obtained from the Hubble Space Telescope, it is

believed to be about $2.33 \times 10^{-18} \text{ s}^{-1}$. This means we now have a relation between v and r , known as **Hubble's Law** - which states, quite simply, that $v = H_0 r$. If we rearrange the formula, we can see that the Hubble Constant is equal to speed over distance (1, left). Take the **reciprocal**, and we have something that is equal to distance over speed... or **time**(2). So if we take the reciprocal of the Hubble Constant, we've got what we're looking for. The age of the Universe. **14 billion years**.

Who wants to buy the candles? ■

LIST OF IMAGE SOURCES:

Portrait of Olbers:

http://upload.wikimedia.org/wikipedia/commons/a/a9/Heinrich_Wilhelm_Olbers_2.jpg

Portrait of Hubble:

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Portrait of Olbers: