LOOKING FORWARD, LOOKING BACK

We were off to start at the end of her life and work back.

John D. MacDonald (1969)

Our ignorance of microscopic physics stands as a veil, obscuring our view of the very beginning.

Steven Weinberg (1977)

It ... now takes enormous machines and a great deal of money to perform an experiment whose results we cannot predict.

Stephen Hawking (1980)

It is quite astonishing how old ideas keep turning up in new guises as we probe back to the moment of creation.

John Gribbin (1986)

Modern physics has made amazing strides towards explaining the universe, heroically driving our ignorance back into the first fraction of a second after the Big Bang.

Richard Dawkins (2008)

When he arrives this morning I kick off by showing him a Hawking quote. He reads it three times through. Maybe it makes him think. To make sure, I tell him that it takes no machine and not a penny to perform an experiment whose result we cannot understand, and simply wave my hand. Something less egocentric, any move of anything, would serve me just as well. To really grasp what's going on, I say, we need to know exactly how it all began. Maybe it isn't his intention but Hawking gives the reason why more of the same will not produce the answer.

The time is right to motivate him with a pep talk—how he has a big advantage, looking in the right direction, not inching back with ponderous machines that never get to the initial end, but rather taking a Big Leap to the Beginning and then moving *forward* into time. He knows too little to know how enormous this advantage is. He doesn't know, since I don't say it, that Poe advocated just this kind of leap. I don't say it as he's not a fan of Poe.

Of course this leaves the modest task of finding the Beginning. Impossible, no doubt. But he and I are funded to pretend it can be done. And in truth we look much better than the expert gang. As Wilson says, each of them works his or her ‘own’ piece of the problem. And they’ve all got it all ass-backward: They’re inching down the highway in the wrong lane in reverse; they’re driving straight into the sun. Though this lays it on a little thick he seems to get the drift.

Their mistake is easy made. Given that we’re here-and-now it makes sense to think back in hope of finding where and when it all began. It makes sense but it doesn’t work. It works fine for the last 13,750,000,000 years of the universe’s 13,750,000,000-year lifetime. That is, it works after the universe was just one minute old. Then there are speculations back to fractions of a micro-pico-yoctosecond. Close to the beginning there is *only* speculation. The theory says it was so hot it is impossible to check what actually happened. Experiments that reach a little further back become far hotter, and much bigger and far more expensive. Already they are too expensive for a single country to afford. They may tell us more about the early universe; but they will not get back to when and how it all began.

It’s like setting a record. Many thought no one could run a sub-four-minute mile. Until Bannister did it. Since then his record has been broken many times. No doubt it will keep on being broken. In 1999 El Guerrouj got it down to 3:43.13. But no one thinks that it will ever get to zero.

Then there is the great pretender. Not Buck Ram’s, it’s James Trefil: He writes a book he calls *The Moment of Creation*. In it there’s a chapter also called The Moment of Creation. At its end the eager reader comes upon the Moment in a final figure; but the Moment is just cartoon dragons. ‘Here Be Dragons’ says the label. What a drag. Lemaître is the only one to take a run at zero.

Frank drops in to pick up his installment. He scowls at the dragons. To my surprise he gets it. He says this is a no-brainer. If with big machines and lots of speculation physics is still stuck short a micro-pico-yoctosecond, one may as well leap straight to zero. The question—now he says, as if he’s never heard it—is: How? That’s for him to figure out but I don’t rub it in. I’m not used to hearing him make so much sense.

Another thing he seems to get is redshifts. Possibly because it deals with facts. Light from distant objects carries information. Its colors, split up by a prism, tell what elements emitted it. Missing colors tell what elements it finds along its way. The color signatures of elements are clear. So light from distant objects tells how fast they’re moving relative to Earth. How? Well, that’s redshifts. They start with Einstein’s constant speed of light. If its source is moving its frequency shifts like a siren sounding on a passing car. The shift in pitch reveals the difference between the source’s speed and ours: higher if they move together, lower if they move apart. This is the *Doppler effect*. With light, for shift in pitch we see its color change. Bluer if source and detector move together; redder if they move apart. When a source—a galaxy, let's say—and a detector—a telescope and camera—move apart in space, the color of the light shifts to the red. The shift is checked against the color pattern from the element on Earth. A red-shifted galaxy is leaving us. A redder one is leaving faster.

So an astrophysicist who stares at stars knows what they're made of and how fast they move—toward us or away. Because light takes time to travel, it's a message from the past. So when Hubble starts deciphering these messages in 1929, he begins a big change in our understanding of the universe. It isn't just a new view of the size of space and of our place within it. The big change is a way to look far back in time as well as far away in space.

Frank is squirming in his seat; I tell him he should take a break. I guess he wants to skip the theory and get to facts. If that is what he wants he should be gazing at the stars himself. Instead he looks to me to find the facts. But I don't stargaze; I just read. The things I read—his so-called facts—are all expressed in terms of theories; there's no way to escape them.

If he were to stargaze, what would he be gazing at? Looking at the sky with naked eye some clear and moonless night out in the desert, he might think that he can see a lot of stars. Actually, five bright lights are planets. Almost all the rest are stars. Each of them is in our galaxy. He could see several thousand and wouldn't know the hazy glow is some 400 billion more. The light he sees set out some time ago; decades for a few close stars, millennia for more.

Using a telescope he could see more. Some dim dots are galaxies. There are billions of them. They are far farther than the stars. Each holds billions of suns like our own. Their light left them long ago. Millions of years for the nearby ones; billions of years for the farthest that astronomers can see. Looking at the sky is looking back in time. These facts are based on theory. The facts have been there longer than the Earth has been here. But they have been known for fewer than a hundred years.

In 964 CE a Persian, Abd al-Rahman al-Sufi, observes two distant galaxies. He is about a thousand years before his time. In the 1900s a consensus will emerge that there *are* more galaxies, each like our own. The cosmos is far larger than our galaxy. Moffat says, 'Not only was the Earth not the center of the universe, but the galaxy it was located in was merely one of millions in a universe more enormous than anyone had imagined before.'

In 1908 Henrietta Leavitt invents the key to all these observations. It's called a standard candle. Her invention is astronomy's best tool. Doppler's color tells astronomers how fast; Leavitt's standard candle tells how vast.

I ask him to imagine a night scene with points of light. Some bright, some dim. How can he tell if bright means bright or close? And dim means vice versa?

Well, what if someone tells him they are standard light bulbs? With this he could figure distance to each one. What Leavitt does is figure out the brightness of a kind of pulsing star. All she needs to do is see how fast it pulses. For astronomers it's a Rosetta stone. It sets them to exploring the vast reaches of the universe. Leavitt shows them how to measure it.

He's at his desk and digging with his own computer. Hallelujah! Of course he's not checking physics. He is looking at what people did. Oddball behavior, he has told me more than once, in his experience can be a clue. Minutes later he parades a prize. In 1932 Sir Arthur Eddington, professor of astronomy at Cambridge University, president of the International Astronomical Union, spoke on standard candles at Cambridge, Mass. He wrote a book about it eight years after that. He sang the praises of Leavitt's discovery. Both without a single mention of her name! I agree that it's a gross injustice, thinking: Frank as feminist? Perhaps for him it is the moment that *Ms. Magazine* calls: Click! But I have to tell him it's no clue. Not even a small storm in the old academic teacup. In her day and his it is the temper of the times.

Light from distant sources can be very faint. But good equipment—like the Hubble, for example—can photograph a galaxy whose light took flight 12 billion years ago. NASA has such pictures on its website. Some show Andromeda, our next-door neighbor. They show the way it was three million years ago. Others show light that set out before the Earth existed. He sits, spellbound by the picture of the day, which shows him hundreds of vast galaxies in some small corner of the cosmos. Plain facts at last, so I imagine he imagines.

Hubble finds that light from distant galaxies is shifted to the red. They are all moving away. He finds the further Leavitt's method says they are from us, the faster they are leaving. Today, telescopes see further than did Hubble's. Everywhere they look the galaxies are fleeing with a speed that is a constant—Hubble's constant—times how far they are away. Most physicists see this as showing that space is itself expanding. It has been expanding as far back in time as they can see.

This is the movie that cosmologists run in reverse back to the Big Bang. Looking back in time reverses the expansion; space seems to shrink. Look back far enough and it shrinks to a single point.

In 1931 Lemaître drafts this movie script. He uses GR. He doesn't call it the Big Bang but lays the basis for Fred Hoyle to call it that. Lemaître calls it 'the hypothesis of the primeval atom'. Even Frank can guess which label sticks. Lemaître doesn't care; he has two problems: He's working with a theory that doesn't solve his problem; and he is a priest. What happens? Well, the Big Bang lives on minus its beginning. And the point at the beginning of the movie vanishes behind the scarlet and the black of the Monsignor's cassock. The hypothesis of the primeval atom is accepted—but the atom is excepted.

Two generations later, evidence arrives. It is the most amazing scientific revelation of all time. Yet even now it is not widely known. In 1949 Alpher and Herman say the Big Bang must have left a radiation echo that by now must be extremely cold. In 1965 Penzias and Wilson find it. Now known as the cosmic microwave background, or *CMB*, it is a blast of energy from every corner of the universe. As predicted it is cold, close to absolute zero—minus 455 degrees Fahrenheit, just 2.4 degrees Kelvin. It bears the spectral signature of a black body. Why would something so cold give off so much heat? The short answer is: It wouldn't. This is the residue of the Big Bang. Here's how it happens: For a quarter million years the infant cosmos is a sea of hot charged particles. It conducts electricity like copper. So like copper it's opaque to light and heat. It is expanding so, like a refrigerant, it's cooling. At 3,000 degrees Kelvin (5,400 degrees Fahrenheit) the charged particles form neutral atoms. The universe is now transparent. Its energy is free to fly around. Today this energy's still flying at the speed of light although it is much cooler. It looks the same all over; well, almost but not *quite* the same.

After its discovery this ancient energy is mapped in all directions. The map, like an old photo, shows the universe soon after it was born. It is 13,750,000,000 years old. This makes it three times older than the oldest rocks on Earth. Some call it the Big Flash. An asbestos-clad observer at that time would see it as white-hot like a light bulb. It dims slowly. In a million years the light is out. All is dark. It stays dark for a hundred million years. It takes that long for gravity to suck the matter into some vast parts of space at the expense of others. Some spots get very dense. The first stars ignite their thermonuclear reactions. The long haul on the path to people is now underway.

I have him google cmb+picture so he sees the Big Flash on his screen. This, I say, is not a clue. It's evidence! In this case evidence is friend and foe. We need all the evidence that we can get but he is looking the wrong way. He's looking back!

There's a reason why the Big Flash is a picture. A photo uses photons from the atoms of the subject. They must go straight to the camera. If many were reflected or absorbed and re-emitted, then the image would be fuzzy as if in a fog. The Big Flash is a picture because space is almost empty. Nearly all the Big Flash photons fly from ancient atoms to the camera direct.

But there is more to their story. Something happens to them on the way. Space stretches by a factor of about a thousand while they travel. The photons get stretched with it. This shifts their color. Their hot white color becomes red. Then infra-red. Now short-wave radio, so Frank can't see them, just as he can't see the microwaves reheat his coffee. But like night-vision goggles see a lamp long after it's turned off, a microwave-tuned camera can catch low-level Big Flash heat.

Better cameras get sharper pictures. It's like the difference between a 1960s TV set and HDTV. Over time the CMB is imaged more than once. It's like pictures from a baby's birth day in a photo album. Some may have finer grain or better focus. All show the same baby. Each captures that same moment in the baby's life. None show and none will ever show the birth. Each shows the universe—what we can see of it—at age 370,000 years. On the scale of human lifespan it is maybe four hours old. The picture shows a sphere—the entire sky in all directions. It wraps round from far left to far right like a flat map of the Earth but it looks up, not down. It looks through the stars and other bodies and ignores them. Instead of elevations, its colors code for temperatures the day the cosmos turned transparent. The code is simple:

Blue is hot

Green's warm

Yellow is cool

Red is cold

How hot is hot? How cold is cold? He hasn't asked so it can wait. His eyes are on the screen. Perhaps the picture tells him he is seeking something real. Could it be the search is on? He pulls his gaze away. His eyes say no more looking back. Finity begins with the Beginning.

Tomorrow he can wrestle with another fact that he can see, thanks to theory. The universe *is* expanding. It is a billion-fold bigger than the universe the Big Flash shows. The physicists should have a handle on what's going on.

They don't.