

1
00:00:01,829 --> 00:00:05,580
Humanity has always been drawn to the night sky.

2
00:00:05,580 --> 00:00:12,929
We draw pictures in the stars, track the planets, see signs and portents in celestial objects.

3
00:00:12,929 --> 00:00:16,839
But so much of the universe is beyond our reach.

4
00:00:16,839 --> 00:00:22,350
Vast distances separate us from the sights that might answer some of our biggest questions.

5
00:00:22,350 --> 00:00:24,920
How do galaxies form?

6
00:00:24,920 --> 00:00:28,410
How do stars and planets come to be?

7
00:00:28,410 --> 00:00:32,780
Do distant planets have the conditions necessary for life?

8
00:00:32,780 --> 00:00:36,908
To construct and test our theories, we need to see what's happening.

9
00:00:36,908 --> 00:00:39,369
So we build tools to extend our vision.

10
00:00:39,369 --> 00:00:41,500
They get bigger.

11
00:00:41,500 --> 00:00:43,229
More powerful.

12
00:00:43,229 --> 00:00:44,889
More advanced.

13
00:00:44,890 --> 00:00:51,850

As time goes on, astronomy stops relying on the light we can see only with our eyes.

14
00:00:51,850 --> 00:00:53,660
[music]

15
00:00:53,659 --> 00:01:01,859
When you look at the world, you're seeing something we call "visible light."

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00:01:01,859 --> 00:01:05,829
But visible light is really only a certain form of radiation.

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00:01:05,829 --> 00:01:09,670
Our universe is full of many different types of radiation.

18
00:01:09,670 --> 00:01:12,170
It surrounds us.

19
00:01:12,170 --> 00:01:16,189
Our bodies evolved to detect visible light with our eyes.

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00:01:16,189 --> 00:01:21,189
But they also evolved to detect another kind of radiation, called infrared light.

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00:01:21,189 --> 00:01:24,840
Our bodies feel infrared light as heat.

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00:01:24,840 --> 00:01:30,939
This "infrared radiation" was discovered by the astronomer Frederick William Herschel.

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00:01:30,939 --> 00:01:35,769
Herschel knew that a prism could be used to break white light into colors.

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00:01:35,769 --> 00:01:40,090
He wanted to know whether the colors had different temperatures.

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00:01:40,090 --> 00:01:41,390

They did.

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00:01:41,390 --> 00:01:45,450

But then Herschel measured the empty space just beyond the red light.

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00:01:45,450 --> 00:01:48,810

Though no sunlight was visible, it was hot.

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00:01:48,810 --> 00:01:53,510

Herschel had just discovered invisible infrared radiation.

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00:01:53,510 --> 00:01:57,978

Humanity now knew there were forms of radiation that could not be seen.

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00:01:57,978 --> 00:01:59,950

They could be anywhere.

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00:01:59,950 --> 00:02:01,810

All around us.

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00:02:01,810 --> 00:02:03,109

How many were there?

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00:02:03,109 --> 00:02:04,450

What were they up to?

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00:02:04,450 --> 00:02:06,140

What were they hiding?

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00:02:06,140 --> 00:02:09,189

Obviously, we had to find out.

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00:02:09,189 --> 00:02:15,439

A type of energy that travels through the universe in the form of waves is called electromagnetic

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00:02:15,439 --> 00:02:16,879

radiation.

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00:02:16,879 --> 00:02:22,240

The entire range of it, from high-energy gamma

rays to low-energy radio waves, is called

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00:02:22,240 --> 00:02:27,170

the electromagnetic spectrum.

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00:02:27,169 --> 00:02:32,149

Although our eyes can see only visible light,
we can build tools, like infrared-detecting

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00:02:32,150 --> 00:02:35,730

cameras, to see other forms of radiation.

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00:02:35,729 --> 00:02:41,489

These tools are man-made "eyes" that view
invisible radiation for us, and transform

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00:02:41,490 --> 00:02:45,469

it into pictures.

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00:02:45,469 --> 00:02:48,990

Objects can emit all kinds of radiation.

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00:02:48,990 --> 00:02:56,490

Observing the entirety of that radiation gives
us a true picture of an object.

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00:02:56,490 --> 00:03:04,430

When we turn these tools on space, they open
up the entire cosmos to us, in its full glory.

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00:03:04,430 --> 00:03:09,950

When we look at the night sky, we see stars
and planets, galaxies and nebulae, in the

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00:03:09,949 --> 00:03:11,349

form of visible light.

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00:03:11,349 --> 00:03:18,449

But if we could see in infrared light, the
sky would appear very different.

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00:03:18,449 --> 00:03:25,479

For one thing, infrared light's long wavelengths
penetrate clouds of gas and dust.

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00:03:25,479 --> 00:03:29,568
The shorter wavelengths of visible light are stopped and scattered as they fight through

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00:03:29,568 --> 00:03:32,129
collections of particles.

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00:03:32,129 --> 00:03:38,139
So by detecting infrared light, we can see through clouds of gas and dust to warm objects

54
00:03:38,139 --> 00:03:39,399
inside --

55
00:03:39,400 --> 00:03:42,670
like just-forming stars.

56
00:03:42,669 --> 00:03:46,599
Objects that don't glow with any visible light of their own -- like planets -- are

57
00:03:46,599 --> 00:03:49,879
still often warm enough to radiate infrared light,

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00:03:49,879 --> 00:03:53,240
perhaps allowing us to glimpse them.

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00:03:53,240 --> 00:03:58,659
And by observing how infrared light from a planet's star passes through its atmosphere,

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00:03:58,659 --> 00:04:02,359
we acquire clues about the planet's composition.

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00:04:02,360 --> 00:04:08,030
The dust left behind by distant planets as they form will also glow in infrared, helping

62
00:04:08,030 --> 00:04:11,348
to show us how planets are born.

63
00:04:11,348 --> 00:04:15,268
So infrared helps us see objects like these

in our own galactic backyard.

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00:04:15,269 --> 00:04:20,978

But it can also help us observe the first objects that formed in the universe after

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00:04:20,978 --> 00:04:22,998

the Big Bang.

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00:04:22,999 --> 00:04:28,120

Imagine you gave a letter to the post office in a galaxy billions of light-years away,

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00:04:28,120 --> 00:04:29,949

and addressed it to Earth.

68

00:04:29,949 --> 00:04:32,879

It would travel for an incredibly long time.

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00:04:32,879 --> 00:04:37,759

When it finally arrived at its destination, the person who opened it would be getting

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00:04:37,759 --> 00:04:41,110

news from billions of years earlier.

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00:04:41,110 --> 00:04:45,990

The light from the first stars to shine in the universe is something like that.

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00:04:45,990 --> 00:04:52,098

It left the stars ages ago and is still out there in space, traveling the vast distances

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00:04:52,098 --> 00:04:53,990

between galaxies.

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00:04:53,990 --> 00:04:59,819

If we could see it, we could see those galaxies as they were in the early universe.

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00:04:59,819 --> 00:05:03,550

Essentially, we would be seeing back in time.

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00:05:03,550 --> 00:05:06,538
But we haven't been able to see it.

77
00:05:06,538 --> 00:05:07,538
Why?

78
00:05:07,538 --> 00:05:10,478
Because the universe is expanding.

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00:05:10,478 --> 00:05:16,438
As light travels across space, it's stretched
like taffy by the expansion.

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00:05:16,439 --> 00:05:21,949
The first stars gave off mostly visible and
ultraviolet light, but the stretching changes

81
00:05:21,949 --> 00:05:24,978
those waves into infrared light.

82
00:05:24,978 --> 00:05:27,788
This is called "redshifting."

83
00:05:27,788 --> 00:05:32,899
The only way to see that light as it arrives
in our region of the universe is to look for

84
00:05:32,899 --> 00:05:35,278
that faint infrared glow.

85
00:05:35,278 --> 00:05:41,680
By capturing it, we will be able to create
images of the first galaxies to form in the

86
00:05:41,680 --> 00:05:43,259
universe.

87
00:05:43,259 --> 00:05:48,169
By witnessing the birth of the first stars
and galaxies, we deepen our knowledge of how

88
00:05:48,168 --> 00:05:51,348
the universe as we know it came to be.

89

00:05:51,348 --> 00:05:56,498
How did we get from those first blazing stars
to the islands of billions of stars we see

90
00:05:56,499 --> 00:05:58,360
today?

91
00:05:58,360 --> 00:06:03,119
What will we learn about how galaxies grow
and evolve?

92
00:06:03,119 --> 00:06:09,650
How did the chaos of the early universe transform
into order and structure?

93
00:06:09,649 --> 00:06:14,549
NASA is currently building the James Webb
Space Telescope.

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00:06:14,550 --> 00:06:20,309
With its huge, infrared-capturing mirror and
distant orbit far beyond the Moon, Webb will

95
00:06:20,309 --> 00:06:26,300
allow us to view the cosmos as we've never
seen it before.

96
00:06:26,300 --> 00:06:32,860
Webb will search for signs of water vapor
on planets around other stars.

97
00:06:32,860 --> 00:06:37,759
It will take pictures of the universe's
infancy.

98
00:06:37,759 --> 00:06:45,229
Webb will reveal the hidden stars and solar
systems forming within cocoons of dust.

99
00:06:45,228 --> 00:06:50,329
The answers to some of the universe's biggest
mysteries -- and more questions we haven't

100
00:06:50,329 --> 00:06:51,418
thought yet to ask --

101

00:06:51,418 --> 00:06:56,389

are waiting out there for us, in the form
of infrared radiation.

102

00:06:56,389 --> 00:07:12,610

All we have to do is look.

103

00:07:12,610 --> 00:07:26,090

[music]