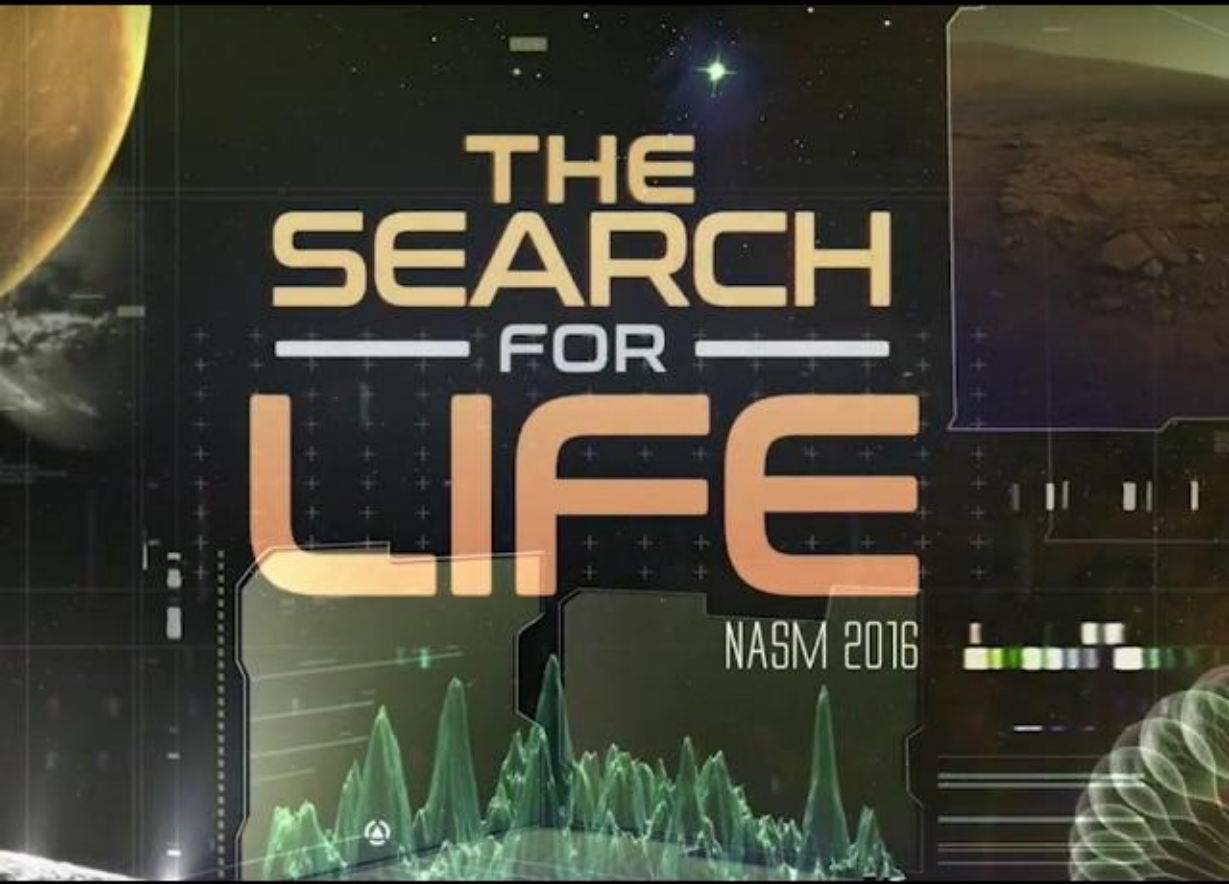
THE
SEARCH
FOR
LIFE
NASM 2016

1
00:00:12,530 --> 00:00:04,390
Technology Sounds

2
00:00:20,890 --> 00:00:16,710
//applause//

3
00:00:20,890 --> 00:00:25,080
Dr. John Holdren: Life is the most complex thing in the known universe.

4
00:00:25,080 --> 00:00:29,150
Just ask anybody in the White House. Abundant on Earth,

5
00:00:29,150 --> 00:00:33,250
hugely successful in colonizing every available

6
00:00:33,250 --> 00:00:37,310
niche. It seems that once started, life is

7
00:00:37,310 --> 00:00:41,400
unstoppable. But does that mean there's life on other planets,

8
00:00:41,400 --> 00:00:45,510
elsewhere in the universe? So far we have not seen signs

9
00:00:45,510 --> 00:00:49,610
of life elsewhere, and not for lack of trying.

10
00:00:49,610 --> 00:00:53,790
Is there other life or traces of former life out there?

11
00:00:53,790 --> 00:00:57,960
Is there now or has there ever been intelligent life

12
00:00:57,960 --> 00:01:02,130
anywhere but on our Earth? With a hundred billion

13
00:01:02,130 --> 00:01:06,180

galaxies, the order of a hundred billion galaxies,

14
00:01:06,180 --> 00:01:10,250
each containing the order of a hundred billion stars, most of which we

15
00:01:10,250 --> 00:01:14,410
now know have their own planets,

16
00:01:14,410 --> 00:01:18,600
the probability of life having evolved elsewhere

17
00:01:18,600 --> 00:01:22,780
seems very, very high. Indeed, on the numbers,

18
00:01:22,780 --> 00:01:26,840
it seems highly likely that intelligent life has

19
00:01:26,840 --> 00:01:30,930
evolved in the universe at some other time, at some other

20
00:01:30,930 --> 00:01:35,080
place, and maybe is out there now.

21
00:01:35,080 --> 00:01:39,270
How will we find out for sure? Tonight, we're going to take you on a

22
00:01:39,270 --> 00:01:43,470
journey from Earth, through the solar system, to planets around

23
00:01:43,470 --> 00:01:47,540
other stars in the search for life.

24
00:01:47,540 --> 00:01:51,630
Let's start with the Earth, and I note that some have asked whether there's intelligent

25
00:01:51,630 --> 00:01:55,780
life on Earth I believe there is, but let me turn

26
00:01:55,780 --> 00:01:59,940
it over now to Gavin Schmidt. Gavin?

27
00:01:59,940 --> 00:02:04,150
//applause//

28
00:02:04,150 --> 00:02:08,220
Dr. Gavin Schmidt: Earth is the only example we have

29
00:02:08,220 --> 00:02:12,310
so far of a planet with a biosphere. As we get

30
00:02:12,310 --> 00:02:16,400
further away, Earth shrinks from a recognizably inhabited

31
00:02:16,400 --> 00:02:20,570
place, to a blue dot and then to just a tiny point

32
00:02:20,570 --> 00:02:24,700
in orbit around the sun. The further out we go,

33
00:02:24,700 --> 00:02:28,730
the harder it is to tell that there is life on Earth.

34
00:02:28,730 --> 00:02:32,800
But there has been life on Earth for more than three billion years.

35
00:02:32,800 --> 00:02:36,880
The universe has existed for 13.8 billion years

36
00:02:36,880 --> 00:02:40,990
since the Big Bang, and our solar system has been around for the last

37
00:02:40,990 --> 00:02:45,130
4.6 billion years of those. But

38
00:02:45,130 --> 00:02:49,320

remarkably quickly after the solar system formed and rocky planets

39
00:02:49,320 --> 00:02:53,360
condensed and cooled, there was liquid water on the surface of our

40
00:02:53,360 --> 00:02:57,440
planet. For a planet 4.5 billion years old,

41
00:02:57,440 --> 00:03:01,540
we have evidence of water from only .2 billion years later.

42
00:03:01,540 --> 00:03:05,690
But it took life perhaps another

43
00:03:05,690 --> 00:03:09,870
500 million years to appear. Early life

44
00:03:09,870 --> 00:03:14,080
forms weren't much to look at, but life itself has been here

45
00:03:14,080 --> 00:03:18,160
a long time. We don't yet know how life got started,

46
00:03:18,160 --> 00:03:22,310
there are many theories, but we do know that it got going

47
00:03:22,310 --> 00:03:26,400
under some very challenging conditions.

48
00:03:26,400 --> 00:03:30,590
The sun was 30 percent dimmer than today, but with more

49
00:03:30,590 --> 00:03:34,630
solar flares. There was no oxygen, and therefore

50
00:03:34,630 --> 00:03:38,670
no ozone layer to protect the surface from harsh ultraviolet

51
00:03:38,670 --> 00:03:42,750
rays. But Earth did have the ingredients necessary

52
00:03:42,750 --> 00:03:46,870
to support life. A solvent like water, an energy

53
00:03:46,870 --> 00:03:51,050
source, and abundant nutrients.

54
00:03:51,050 --> 00:03:55,240
For 1.5 billion years, this primitive life survived

55
00:03:55,240 --> 00:03:59,290
in the oceans, protected by the water's opacity.

56
00:03:59,290 --> 00:04:03,470
But around 2.5 billion years ago,

57
00:04:03,470 --> 00:04:07,490
bacteria started to use sunlight directly to fuse

58
00:04:07,490 --> 00:04:11,510
water and carbon dioxide to make sugars, which were then used as food.

59
00:04:11,510 --> 00:04:15,590
But for every molecule of carbon dioxide they used,

60
00:04:15,590 --> 00:04:19,730
and there was a lot of carbon dioxide in the atmosphere,

61
00:04:19,730 --> 00:04:23,940
they released a molecule of oxygen. Those bacteria were followed

62
00:04:23,940 --> 00:04:28,130
by photosynthesizing algae, mosses, and plants.

63
00:04:28,130 --> 00:04:32,170

And eventually, after a number of false starts,

64
00:04:32,170 --> 00:04:36,240
the oxygen built up in the atmosphere until around 500 million years ago,

65
00:04:36,240 --> 00:04:40,360
it got close to present day concentrations, giving a start

66
00:04:40,360 --> 00:04:44,470
to the huge variety of land animals, insects, and

67
00:04:44,470 --> 00:04:48,640
plants we see today. Meanwhile, the

68
00:04:48,640 --> 00:04:52,830
climate was not static. The planet went through cycles of snowballs

69
00:04:52,830 --> 00:04:56,910
and hot houses, driven by plate tectonics, volcanism, greenhouse

70
00:04:56,910 --> 00:05:00,980
gases and impacts. Indeed, it was only

71
00:05:00,980 --> 00:05:05,030
after the last snowball Earth event that set the stage--

72
00:05:05,030 --> 00:05:09,110
that the stage was set for the evolution of multicellular life in the

73
00:05:09,110 --> 00:05:13,210
Edicarian 600 million years ago. The new

74
00:05:13,210 --> 00:05:17,350
species that were rapidly born, evolved and died

75
00:05:17,350 --> 00:05:21,400
changed the planet forever. The surface became completely covered,

76
00:05:21,400 --> 00:05:25,580
you could say infected, infested, with life.

77
00:05:25,580 --> 00:05:29,620
And that life affected the climate, changing the

78
00:05:29,620 --> 00:05:33,670
composition of the atmosphere, the reflectivity of the surface, and the cycling

79
00:05:33,670 --> 00:05:37,720
of water, radically transforming the view from space.

80
00:05:37,720 --> 00:05:41,770
Life co-created the broad

81
00:05:41,770 --> 00:05:45,890
array of special, unique ecosystems and microclimates that

82
00:05:45,890 --> 00:05:50,010
characterize the Earth today, visible even from a million miles away.

83
00:05:50,010 --> 00:05:54,190
But remember, for most of the time

84
00:05:54,190 --> 00:05:58,210
that life existed on Earth, it did not have a land fingerprint,

85
00:05:58,210 --> 00:06:02,310
and the oxygen that we now rely on wasn't detectable

86
00:06:02,310 --> 00:06:06,400
for perhaps half that time. Under those conditions,

87
00:06:06,400 --> 00:06:10,520
or any others in Earth's history, how can we know what would have been

88
00:06:10,520 --> 00:06:14,710

seen from further away? This is where our

89
00:06:14,710 --> 00:06:18,890
understanding of current climates, and of processes that control

90
00:06:18,890 --> 00:06:22,950
composition, clouds and dynamics come into play.

91
00:06:22,950 --> 00:06:27,060
We can simulate the impacts of climate on life, and the impacts of

92
00:06:27,060 --> 00:06:31,200
life on climate at each stage of our planet's history.

93
00:06:31,200 --> 00:06:35,380
Simulations which include the physics of clouds,

94
00:06:35,380 --> 00:06:39,560
oceans, ice, and of atmospheric particles like dust.

95
00:06:39,560 --> 00:06:43,610
We can take those results and then project how those

96
00:06:43,610 --> 00:06:47,680
climates would look from space, from beyond even the solar system.

97
00:06:47,680 --> 00:06:51,810
But we can go further, we can even

98
00:06:51,810 --> 00:06:55,970
simulate the climates of Venus and Mars three billion years ago,

99
00:06:55,970 --> 00:07:00,160
when they were both very different places. Places that

100
00:07:00,160 --> 00:07:04,210
perhaps also had the seeds of life. And Jen can discuss that.

101
00:07:12,400 --> 00:07:08,280
//applause//

102
00:07:12,400 --> 00:07:16,600
Dr. Jen Eigenbrode: If life ever existed in our solar system

103
00:07:16,600 --> 00:07:20,800
then it found a way to adapt to extreme conditions.

104
00:07:20,800 --> 00:07:24,880
Conditions that may be more extreme than what we have on Earth.

105
00:07:24,880 --> 00:07:28,940
I am constantly amazed to find that life has adapted

106
00:07:28,940 --> 00:07:33,080
to every niche, no matter how harsh the environment.

107
00:07:33,080 --> 00:07:37,260
Take for example, the extraordinary springs of Dallol in the

108
00:07:37,260 --> 00:07:41,450
Danakil Desert of Ethiopia. These springs are hot,

109
00:07:41,450 --> 00:07:45,530
salty, rich in heavy metals, and they're

110
00:07:45,530 --> 00:07:49,680
acidic. Microorganisms thrive in these pools,

111
00:07:49,680 --> 00:07:53,830
even the pools of pH less than one. That's more acidic than battery acid.

112
00:07:53,830 --> 00:07:58,010
Life adapted.

113
00:07:58,010 --> 00:08:02,180

Another example, the Atacama Desert in the rain shadow of the Andes

114
00:08:02,180 --> 00:08:06,230
Mountains. It is the driest land desert on Earth. This

115
00:08:06,230 --> 00:08:10,290
Martian-like landscape has been shaped by the wind and salty aerosols

116
00:08:10,290 --> 00:08:14,370
for millions of years. It has been one of the most

117
00:08:14,370 --> 00:08:18,480
challenging places to find evidence of life.

118
00:08:18,480 --> 00:08:22,610
And yet it's there, a few cells here and there. Life adapted.

119
00:08:22,610 --> 00:08:26,840
One last example, and this one really

120
00:08:26,840 --> 00:08:30,930
me, Chernobyl. This diverse life

121
00:08:30,930 --> 00:08:35,090
in this agricultural region is punctuated by the presence of

122
00:08:35,090 --> 00:08:39,280
fungi that live off the radiation from the 1986

123
00:08:39,280 --> 00:08:43,480
meltdown of reactor four. These fungi

124
00:08:43,480 --> 00:08:47,550
use the radiation, the gamma radiation, in the same way

125
00:08:47,550 --> 00:08:51,640
plants use sunlight to grow. Life adapted on Earth.

126
00:08:51,640 --> 00:08:55,780
Could life have arisen and adapted to the extreme

127
00:08:55,780 --> 00:08:59,960
conditions of other places in the solar system?

128
00:08:59,960 --> 00:09:04,160
We're going to find out. We will search for biomolecules,

129
00:09:04,160 --> 00:09:08,180
the organic compounds that make up life, its food and waste products.

130
00:09:08,180 --> 00:09:12,340
We may need to extend that search to other types of signatures,

131
00:09:12,340 --> 00:09:16,470
to build confidence in that detection. We might search for active

132
00:09:16,470 --> 00:09:20,650
cells, and catch extraterrestrial life in action.

133
00:09:20,650 --> 00:09:24,790
We might search for fossilized cells

134
00:09:24,790 --> 00:09:28,840
in ancient rocks and ice. Gavin explained that

135
00:09:28,840 --> 00:09:32,900
Earth is the only known biosphere. However, Mars is a

136
00:09:32,900 --> 00:09:37,000
close neighbor. Although it looks like a rusty,

137
00:09:37,000 --> 00:09:41,210
barren planet today, its history was very similar to Earth's in the beginning.

138
00:09:41,210 --> 00:09:45,390

Did life arise on Mars around the same time that life

139
00:09:45,390 --> 00:09:49,430
arose on Earth? Why are these

140
00:09:49,430 --> 00:09:53,490
two planets so vastly different today?

141
00:09:53,490 --> 00:09:57,600
Both Earth and Mars had a liquid core when they

142
00:09:57,600 --> 00:10:01,720
formed. Movement of this molten iron

143
00:10:01,720 --> 00:10:05,890
generate a magnetic field that shield the atmosphere and surface from being

144
00:10:05,890 --> 00:10:09,980
blasted by ionizing radiation. Earth maintains its

145
00:10:09,980 --> 00:10:14,020
magnetic field, but not so for Mars. Convection of the

146
00:10:14,020 --> 00:10:18,120
Martian core slowed or stopped four billion years ago.

147
00:10:18,120 --> 00:10:22,290
Without the protection of the magnetic field, the powerful solar

148
00:10:22,290 --> 00:10:26,480
wind streaming continuously from the young sun crashed into the

149
00:10:26,480 --> 00:10:30,660
red planet, piling up in front of it like a bow wave of a ship, except in this case,

150
00:10:30,660 --> 00:10:34,710
the wave is charged particles that electrically strip away the

151
00:10:34,710 --> 00:10:38,820
Martian atmosphere. This process continued

152
00:10:38,820 --> 00:10:42,990
for eons regulated by the sun's activity, and slowly stripped

153
00:10:42,990 --> 00:10:47,110
away gases from the volcanoes and the rocks.

154
00:10:47,110 --> 00:10:51,280
With the magnetic field and atmosphere mostly gone, the rocky

155
00:10:51,280 --> 00:10:55,330
surface of Mars was bombarded by ionizing radiation from the

156
00:10:55,330 --> 00:10:59,390
galaxy and the sun. This radiation

157
00:10:59,390 --> 00:11:03,540
comes in the form of photons, such as UV, x-ray,

158
00:11:03,540 --> 00:11:07,720
and gamma rays, as well as charged particles. However, unlike what we experience

159
00:11:07,720 --> 00:11:11,930
here on Earth, all of these forms have an enormous amount of energy.

160
00:11:11,930 --> 00:11:16,000
When ionizing radiation encounters

161
00:11:16,000 --> 00:11:20,140
molecules, it changes them. Radiation damage

162
00:11:20,140 --> 00:11:24,330
to molecules means damage to life and the

163
00:11:24,330 --> 00:11:28,530

signatures that we seek. We know that life

164
00:11:28,530 --> 00:11:32,570
adapts. If life ever existed on Mars,

165
00:11:32,570 --> 00:11:36,650
did it adapt to the harsh radiation environment at or near its

166
00:11:36,650 --> 00:11:40,760
surface? Life has surprised us on Earth and perhaps

167
00:11:40,760 --> 00:11:44,880
life will surprise us on Mars too.

168
00:11:44,880 --> 00:11:49,060
I have spent the last four years exploring Mars through the imagers and the

169
00:11:49,060 --> 00:11:53,240
instruments of the Curiosity rover. We have discovered that Mars is not

170
00:11:53,240 --> 00:11:57,310
really red, it's grey with a rusty skin.

171
00:11:57,310 --> 00:12:01,390
Mars is not really dry, either. Liquid

172
00:12:01,390 --> 00:12:05,570
water on Mars formed rivers, deltas, lakes,

173
00:12:05,570 --> 00:12:09,760
maybe seas. It has been cold and warm, acidic and

174
00:12:09,760 --> 00:12:13,960
alkaline. Its surface and atmospheric chemistry evolved.

175
00:12:13,960 --> 00:12:18,020
It has organic matter and the key nutrients needed

176
00:12:18,020 --> 00:12:22,140
for life. We have only scratched the

177
00:12:22,140 --> 00:12:26,340
surface of Mars and begun to decipher its story.

178
00:12:26,340 --> 00:12:30,540
Did life ever live there? Is there life

179
00:12:30,540 --> 00:12:34,580
on Mars now? And could life live here

180
00:12:34,580 --> 00:12:38,660
in the future? Beyond Mars, we will

181
00:12:38,660 --> 00:12:42,760
search for life in the ocean worlds of the moons of Jupiter and Saturn.

182
00:12:42,760 --> 00:12:46,910
Jupiter has a magnetic field

183
00:12:46,910 --> 00:12:51,020
20,000 times stronger than Earth's. The field

184
00:12:51,020 --> 00:12:55,230
produces a donut-shaped belt around the planet in which charged particles get trapped.

185
00:12:55,230 --> 00:12:59,300
Europa is a water ice-covered ocean

186
00:12:59,300 --> 00:13:03,370
world, and one of great interest as a possible abode for life.

187
00:13:03,370 --> 00:13:07,460
It sits right smack in the middle of Jupiter's magnetic belt,

188
00:13:07,460 --> 00:13:11,630

which means that it is being bombarded by intense amounts of radiation.

189
00:13:11,630 --> 00:13:15,810
Although the Europan surface

190
00:13:15,810 --> 00:13:19,860
is inhospitable, it may offer a glimpse of

191
00:13:19,860 --> 00:13:23,980
the chemistry of what lies beneath. Europa's thick crust

192
00:13:23,980 --> 00:13:28,120
is sufficient for protecting the underlying

193
00:13:28,120 --> 00:13:32,300
global ocean from radiation. And it is hypothesized

194
00:13:32,300 --> 00:13:36,500
that Europa may have hydrothermal vents stemming from its rocky

195
00:13:36,500 --> 00:13:40,540
interior. And if so, these are ideal sites for life,

196
00:13:40,540 --> 00:13:44,600
and they support the potential of life in the ocean.

197
00:13:44,600 --> 00:13:48,690
Now let's go to Saturn, where the moons are embedded in

198
00:13:48,690 --> 00:13:52,830
the rings, where we think life may exist on some of these moons.

199
00:13:52,830 --> 00:13:56,990
Like Europa, Enceladus is an icy

200
00:13:56,990 --> 00:14:01,130
ocean world. And in 2005, the Cassini spacecraft witnessed

201
00:14:01,130 --> 00:14:05,200
geysers of gas arising from the surface. These

202
00:14:05,200 --> 00:14:09,260
plumes are direct conduits to a deep ocean. We might search

203
00:14:09,260 --> 00:14:13,380
for signs of life by flying through these plumes.

204
00:14:13,380 --> 00:14:17,510
And then there's Titan. A rocky moon

205
00:14:17,510 --> 00:14:21,700
with seas of liquid methane and an atmosphere of organic smog.

206
00:14:21,700 --> 00:14:25,900
Titan is drenched in hydrocarbons, and it's cold enough

207
00:14:25,900 --> 00:14:29,990
to freeze most of them. Life as we know it is largely

208
00:14:29,990 --> 00:14:34,100
made of hydrocarbons. Although it may be a stretch of our imagination

209
00:14:34,100 --> 00:14:38,290
to think that life might live here, it is considered

210
00:14:38,290 --> 00:14:42,490
potentially habitable. Did life arise on

211
00:14:42,490 --> 00:14:46,570
Titan? There are

212
00:14:46,570 --> 00:14:50,680
possibilities for extraterrestrial life in our solar system. However, as

213
00:14:50,680 --> 00:14:54,840

Aki will explain, there even more possibilities of life outside of it.

214
00:15:03,210 --> 00:14:59,010
//applause//

215
00:15:03,210 --> 00:15:07,260
Dr. Aki Roberge: If we're going to look for life that's really Earth-like, we need to look for planets

216
00:15:07,260 --> 00:15:11,350
around other stars. Exoplanets, for short. When I started

217
00:15:11,350 --> 00:15:15,490
undergrad, we only knew of nine planets in the solar system. Actually, eight

218
00:15:15,490 --> 00:15:19,690
now. //audience laughter// And in grad school we thought exoplanets

219
00:15:19,690 --> 00:15:23,900
would be rare. Twenty years ago we discovered the first planet around another

220
00:15:23,900 --> 00:15:27,990
star. Since that time, we've gone from a few planets in the solar system

221
00:15:27,990 --> 00:15:32,180
to literally thousands of exoplanets orbiting other stars.

222
00:15:32,180 --> 00:15:36,350
And we have only searched a tiny portion of the galaxy with the Kepler

223
00:15:36,350 --> 00:15:40,540
'space mission. We think there's at least one exoplanet

224
00:15:40,540 --> 00:15:44,610
for every star in the galaxy, which would mean over 100 billion planets in the

225
00:15:44,610 --> 00:15:48,690
Milky Way alone. So that's at least 14 planets for every human

226
00:15:48,690 --> 00:15:52,830
on Earth. And the Milky Way is only one of a myriad

227
00:15:52,830 --> 00:15:57,000
of galaxies in the universe. We've found that the planet formation process

228
00:15:57,000 --> 00:16:01,180
is more robust and easy than we thought, and exoplanets

229
00:16:01,180 --> 00:16:05,210
are common. They can form around all different

230
00:16:05,210 --> 00:16:09,260
kinds of stars, even ones not like the sun. There are even planets around binary

231
00:16:09,260 --> 00:16:13,340
stars, just like Tatooine in Star Wars. To our delighted

232
00:16:13,340 --> 00:16:17,450
surprise, exoplanets are not only common, but diverse.

233
00:16:17,450 --> 00:16:21,630
The first planets discovered are unlike anything we have in the solar system.

234
00:16:21,630 --> 00:16:25,830
They are hot Jupiters, massive, gassy planets orbiting closer

235
00:16:25,830 --> 00:16:29,890
to their stars than Mercury orbits our sun.

236
00:16:29,890 --> 00:16:33,970
So in the solar system we have two basic classes of planets. We have

237
00:16:33,970 --> 00:16:38,090
massive gas giants like Jupiter, and small rocky planets like Earth.

238
00:16:38,090 --> 00:16:42,090

But there's all sizes of planets out there. From super Jupiters

239
00:16:42,090 --> 00:16:46,270
to Neptunes, to rocky planets several times more massive

240
00:16:46,270 --> 00:16:50,470
than Earth, all the way down to true Earth-size planets.

241
00:16:50,470 --> 00:16:54,510
So with all this richness of planetary real estate,

242
00:16:54,510 --> 00:16:58,630
it encourages us to start thinking more ambitiously. To search for

243
00:16:58,630 --> 00:17:02,790
those rocky planets that are actually like Earth. We may have

244
00:17:02,790 --> 00:17:06,920
already found some, but we can't actually tell right now what their surfaces are really

245
00:17:06,920 --> 00:17:11,090
like. So as Gavin mentioned, Earth's abundant

246
00:17:11,090 --> 00:17:15,120
surface life makes it unique in the solar system. And this is probably

247
00:17:15,120 --> 00:17:19,230
the only kind of life that we can detect from really far away.

248
00:17:19,230 --> 00:17:23,410
There might be other kinds of life on other kinds of worlds out there, but we

249
00:17:23,410 --> 00:17:27,590
probably won't be able to recognize it. So astronomers are really

250
00:17:27,590 --> 00:17:31,790
focused on finding the true Earth twins out there, and we will look for them

251
00:17:31,790 --> 00:17:35,880
in the habitable zones of nearby stars. So,

252
00:17:35,880 --> 00:17:40,030
the habitable zone is the region around a star where an Earth-like planet

253
00:17:40,030 --> 00:17:44,200
is just the right temperature to have liquid water on its surface, the key ingredient

254
00:17:44,200 --> 00:17:48,380
for Earth life. So for the sun, the habitable zone stretches from

255
00:17:48,380 --> 00:17:52,410
just outside Venus' orbit to Mars. For bigger, brighter stars,

256
00:17:52,410 --> 00:17:56,470
the habitable zone moves out, to cool off, like moving away from a campfire.

257
00:17:56,470 --> 00:18:00,590
And then for smaller, dimmer stars, the habitable zone moves in

258
00:18:00,590 --> 00:18:04,820
to keep the planet warm. Now this spectrum

259
00:18:04,820 --> 00:18:09,010
is how astronomers want to look for life on other worlds. It's the light from the

260
00:18:09,010 --> 00:18:13,080
Earth as if it were really far away, separated by color. Don't panic, we'll go through it.

261
00:18:13,080 --> 00:18:17,190
So this rise in brightness on the

262
00:18:17,190 --> 00:18:21,290
far left is literally our blue sky. And this narrow dip

263
00:18:21,290 --> 00:18:25,540

comes from oxygen, which is produced by plants. These several deep

264
00:18:25,540 --> 00:18:29,750
dips come from water vapor. And then over here is a methane

265
00:18:29,750 --> 00:18:33,810
feature. So methane in our atmosphere

266
00:18:33,810 --> 00:18:37,840
largely comes from bacteria in the guts of our livestock, and in swamps.

267
00:18:37,840 --> 00:18:41,960
So the Earth's atmosphere is full of bio signatures, gases

268
00:18:41,960 --> 00:18:46,150
that wouldn't be present in our atmosphere without life.

269
00:18:46,150 --> 00:18:50,340
Now, the technical challenge of ever seeing something like this is one of the hardest things

270
00:18:50,340 --> 00:18:54,380
scientists have ever thought of trying, and here's why. The Earth is

271
00:18:54,380 --> 00:18:58,420
10 billion times fainter than the sun. So, if the

272
00:18:58,420 --> 00:19:02,520
Luxor Sky Beam, the brightest man-made light in the world, is the sun,

273
00:19:02,520 --> 00:19:06,630
the Earth is four candles on your dinner table. But

274
00:19:06,630 --> 00:19:10,750
astronomers actually observe things that faint all the time. The real problem

275
00:19:10,750 --> 00:19:14,930
is those four candles are sitting right next to the bright lights. If we're

276
00:19:14,930 --> 00:19:19,010
looking at the solar system from 33 light years away, which is not that far,

277
00:19:19,010 --> 00:19:23,030
it's pretty nearby, the separation between the Earth and the sun

278
00:19:23,030 --> 00:19:27,120
.1 arc seconds, or the width of a human hair from the distance of two

279
00:19:27,120 --> 00:19:31,260
football fields. So imagine trying to see those candles if they were right on top of

280
00:19:31,260 --> 00:19:35,440
the Luxor Sky Beam. We have to suppress the light

281
00:19:35,440 --> 00:19:39,630
from the star before we can see the faint blue dot next to it.

282
00:19:39,630 --> 00:19:43,700
There are a couple of different technologies people have come up with to do this. One of

283
00:19:43,700 --> 00:19:47,790
them is a star shade, a gigantic deployed screen that would fly tens of thousands of

284
00:19:47,790 --> 00:19:51,810
kilometers in front of a telescope. You'd be aligned with a star

285
00:19:51,810 --> 00:19:55,900
to block its bright light. But this telescope is a relatively

286
00:19:55,900 --> 00:20:00,090
small one. If we really want to get a spectrum like the Earth

287
00:20:00,090 --> 00:20:04,140
one I showed, we need a bigger telescope. So, NASA has

288
00:20:04,140 --> 00:20:08,220

begun a concept study for a super-duper Hubble called LUVOIR,

289
00:20:08,220 --> 00:20:12,360
which will search for dozens of Earth-like planets and probe their atmospheres.

290
00:20:12,360 --> 00:20:16,570
In addition, it would enable a wide range of general astronomy,

291
00:20:16,570 --> 00:20:20,780
just like Hubble did. With powerful future missions,

292
00:20:20,780 --> 00:20:24,870
we could see the pale blue dot of Carl Sagan's imagining, and have a fighting

293
00:20:24,870 --> 00:20:28,990
chance of finding life out there among the stars. So to

294
00:20:28,990 --> 00:20:33,180
put this grand endeavor into perspective, we turn to Piers.

295
00:20:41,440 --> 00:20:37,380
//applause//

296
00:20:41,440 --> 00:20:45,470
Dr. Piers Sellers: The universe is really big and really old.

297
00:20:45,470 --> 00:20:49,590
Life has been on Earth for about four

298
00:20:49,590 --> 00:20:53,670
billion years. Now we know that in the universe, physics and chemistry

299
00:20:53,670 --> 00:20:57,840
are the same everywhere. A Hydrogen atom here

300
00:20:57,840 --> 00:21:02,040
is just the same as a Hydrogen atom on the other end of the universe.

301
00:21:02,040 --> 00:21:06,120
The laws of physics and chemistry work the same everywhere.

302
00:21:06,120 --> 00:21:10,230
Now we strongly suspect, based on an example of one,

303
00:21:10,230 --> 00:21:14,410
our Earth, that the laws of biology work the same everywhere too.

304
00:21:14,410 --> 00:21:18,600
And by that I mean the laws that Charles Darwin discovered for us.

305
00:21:18,600 --> 00:21:22,780
We think that based on these laws, that

306
00:21:22,780 --> 00:21:26,970
evolution can drive life. To greater complexity,

307
00:21:26,970 --> 00:21:31,170
and ultimately to intelligence. It's the smart thing to do.

308
00:21:31,170 --> 00:21:35,240
Now look at this tree of life. We can see intelligent

309
00:21:35,240 --> 00:21:39,320
animals that we're familiar with. Humans,

310
00:21:39,320 --> 00:21:43,440
elephants, dolphins. These creatures are very

311
00:21:43,440 --> 00:21:47,620
closely related to us. But look over here on the far right.

312
00:21:47,620 --> 00:21:51,830
There's one other intelligence, an invertebrate

313
00:21:51,830 --> 00:21:55,910

intelligence, that evolved completely separately from the rest of us.

314
00:21:55,910 --> 00:21:59,950
They split off from us before brains were even thought of,

315
00:21:59,950 --> 00:22:04,070
when all creatures had were just a few nerve cells.

316
00:22:04,070 --> 00:22:08,270
Octopuses have an intelligence that's comparable to quite a lot of

317
00:22:08,270 --> 00:22:12,450
mammals, and it evolved completely separately.

318
00:22:12,450 --> 00:22:16,500
These guys are like little aliens

319
00:22:16,500 --> 00:22:20,600
living with us on our own planet. If you look at an

320
00:22:20,600 --> 00:22:24,700
octopus, you can see that its brains are actually distributed all over

321
00:22:24,700 --> 00:22:28,820
its body. Most of its brains are in its feet, or in its legs,

322
00:22:28,820 --> 00:22:33,000
and they're connected to the nerve center in its head by a neural

323
00:22:33,000 --> 00:22:41,260
network. It's a distributed intelligence.

324
00:22:41,260 --> 00:22:45,380
But it turns out that they think pretty much the same way that mammals do.

325
00:22:45,380 --> 00:22:49,580
They have a short-term memory and a long-term memory,

326
00:22:49,580 --> 00:22:53,770
they learn, and they get mad. They basically tackle the

327
00:22:53,770 --> 00:22:57,800
business of living in a complex environment the same way that we mammals do.

328
00:22:57,800 --> 00:23:01,860
We think that we understand

329
00:23:01,860 --> 00:23:05,960
how an octopus thinks. So the secret of intelligence

330
00:23:05,960 --> 00:23:10,110
is in the software, it's not in the hardware.

331
00:23:10,110 --> 00:23:14,300
It's very likely that an alien intelligence would be

332
00:23:14,300 --> 00:23:18,490
comprehensible to us in the same way that an octopus'

333
00:23:18,490 --> 00:23:22,560
thoughts are more or less comprehensible to us too.

334
00:23:22,560 --> 00:23:26,670
We should be able to communicate with them if we met them.

335
00:23:26,670 --> 00:23:30,860
So, you'd think there'd be plenty of opportunities for life to evolve

336
00:23:30,860 --> 00:23:35,070
somewhere else, and maybe swing by the Earth, or at least call on the radio.

337
00:23:35,070 --> 00:23:39,270
But we haven't found any alien monoliths,

338
00:23:39,270 --> 00:23:43,370

or beer cans, or cigarette ends,

339
00:23:43,370 --> 00:23:47,520
and we have not heard them tweeting on the radio either.

340
00:23:47,520 --> 00:23:51,710
So, where are they? That's what Johnny von Neumann asked.

341
00:23:51,710 --> 00:23:55,910
Where are they? There are lots of theories about that,

342
00:23:55,910 --> 00:23:59,980
but I'm going to concentrate on the more plausible ones.

343
00:23:59,980 --> 00:24:04,090
First of all, there's the water trap. Maybe the worlds

344
00:24:04,090 --> 00:24:08,210
that have water on them are all ocean, for the most part.

345
00:24:08,210 --> 00:24:12,410
And if that's the case you can't discover combustion, you can't

346
00:24:12,410 --> 00:24:16,600
make metals, so you can't make a radio or a spaceship.

347
00:24:16,600 --> 00:24:20,660
If our dolphin friends lived on an ocean planet, they would be stuck where

348
00:24:20,660 --> 00:24:24,790
they are, in the Stone Age, forever.

349
00:24:24,790 --> 00:24:28,960
We might discover intelligent life here, but they could be incredibly

350
00:24:28,960 --> 00:24:33,160
boring. Talking endlessly about the flavors of different kinds of plankton,

351
00:24:33,160 --> 00:24:37,350
and that sort of thing. Or maybe on a

352
00:24:37,350 --> 00:24:41,450
planet that has dry land but no metals,

353
00:24:41,450 --> 00:24:45,610
same problem. You can't develop a technology.

354
00:24:45,610 --> 00:24:49,790
And how about the difficulty of interstellar travel?

355
00:24:49,790 --> 00:24:53,990
Maybe it's just too hard. It looks like a real challenge for us,

356
00:24:53,990 --> 00:24:58,060
it could be a couple of hundred years before we try that. Maybe it's just too hard.

357
00:24:58,060 --> 00:25:02,090
And then there's the great sci-fi standbys, hostile

358
00:25:02,090 --> 00:25:06,200
races evolve, they wipe out everyone else, that's sort of an ugly end.

359
00:25:06,200 --> 00:25:10,400
I think we should move on quickly, this is meant to be a fun evening.

360
00:25:10,400 --> 00:25:14,600
And then there's another theory, which is that we could be the first.

361
00:25:14,600 --> 00:25:18,800
We could be the first intelligence to evolve

362
00:25:18,800 --> 00:25:22,900
in this part of the galaxy. Someone has to be. We could be

363
00:25:22,900 --> 00:25:27,050

the elder race. So here's a time history of Earth.

364
00:25:27,050 --> 00:25:31,240
When you look at all the time that life has been here. Nearly four

365
00:25:31,240 --> 00:25:35,450
billion years, humans have only been around for a couple of

366
00:25:35,450 --> 00:25:39,560
hundred thousand years, civilization for about 6,000 years,

367
00:25:39,560 --> 00:25:43,680
depending how you count it, and our technical era

368
00:25:43,680 --> 00:25:47,810
only for 200 years. When you look at this picture,

369
00:25:47,810 --> 00:25:52,030
it is obvious that the most likely first alien life forms

370
00:25:52,030 --> 00:25:56,100
that we discover will not be intelligent. They will be somewhere back

371
00:25:56,100 --> 00:26:00,250
here, equivalent to life on Earth during the first three billion years

372
00:26:00,250 --> 00:26:04,280
of evolution. Similarly,

373
00:26:04,280 --> 00:26:08,480
nearby life on an exoplanet is probably plodding its way

374
00:26:08,480 --> 00:26:12,680
up the evolutionary ladder. Remember how long

375
00:26:12,680 --> 00:26:16,750
it took us to get where we are. Where we could even think about life

376
00:26:16,750 --> 00:26:20,820
elsewhere. So, what are the chances

377
00:26:20,820 --> 00:26:24,950
of us finding anything, or anybody, soon?

378
00:26:24,950 --> 00:26:29,100
Here's a timeline of missions for exploring the solar system

379
00:26:29,100 --> 00:26:33,250
with some notional ideas of what we'll be doing in the next

380
00:26:33,250 --> 00:26:37,450
50 years. I think that over the next 30 to 50

381
00:26:37,450 --> 00:26:41,530
years, we will have thoroughly explored every nook and cranny of the solar system,

382
00:26:41,530 --> 00:26:45,650
and seen or determined where there is life here, or past life,

383
00:26:45,650 --> 00:26:49,800
or not. I think there's a good chance we'll nail that one flat.

384
00:26:49,800 --> 00:26:53,960
And then there's a chance of looking for bio signatures

385
00:26:53,960 --> 00:26:58,080
in the atmospheres of exoplanets.

386
00:26:58,080 --> 00:27:02,130
Here's the missions, again, pretty notional, and it's all the 30

387
00:27:02,130 --> 00:27:06,180
to 50-year timeframe, in the future that we could see looking at exoplanets

388
00:27:06,180 --> 00:27:10,280

where we'd be looking for traces of life in their

389
00:27:10,280 --> 00:27:14,470
atmospheres. It turns out

390
00:27:14,470 --> 00:27:18,660
that we Earthlings have the prime real estate in our solar system,

391
00:27:18,660 --> 00:27:22,730
as far as having a habitable environment is concerned.

392
00:27:22,730 --> 00:27:26,810
Most of the rest of the solar system looks like a really tough place to live.

393
00:27:26,810 --> 00:27:30,960
But, you never know. We need to

394
00:27:30,960 --> 00:27:35,170
thoroughly check out our own backyard as well as the planets around other stars.

395
00:27:35,170 --> 00:27:39,370
We'd look like idiots if we failed to check for life

396
00:27:39,370 --> 00:27:43,490
close to home, and failed for lack of trying.

397
00:27:43,490 --> 00:27:47,610
Now back to the beginning. John Holdren's question.

398
00:27:47,610 --> 00:27:51,820
Why do we even care about this stuff? We think it goes

399
00:27:51,820 --> 00:27:56,120
beyond just intellectual curiosity. It's in our nature

400
00:27:56,120 --> 00:28:00,190
because we humans grew up as part of nature, and need to pay attention to it.

401
00:28:00,190 --> 00:28:04,290
I want you to imagine what humans could do in a couple of

402
00:28:04,290 --> 00:28:08,450
hundred years or so. Imagine a probe

403
00:28:08,450 --> 00:28:12,650
from Earth entering the solar system of another star

404
00:28:12,650 --> 00:28:16,840
after a journey of decades, maybe a century.

405
00:28:16,840 --> 00:28:20,900
Note the MSBR logo.

406
00:28:20,900 --> 00:28:25,020
What would it find? My advice to you is eat

407
00:28:25,020 --> 00:28:29,160
healthy, don't smoke, don't jaywalk,

408
00:28:29,160 --> 00:28:33,350
and you might find out. It'd be good to find out we're not alone.

409
00:28:33,350 --> 00:28:37,560
Thank you for your attention.