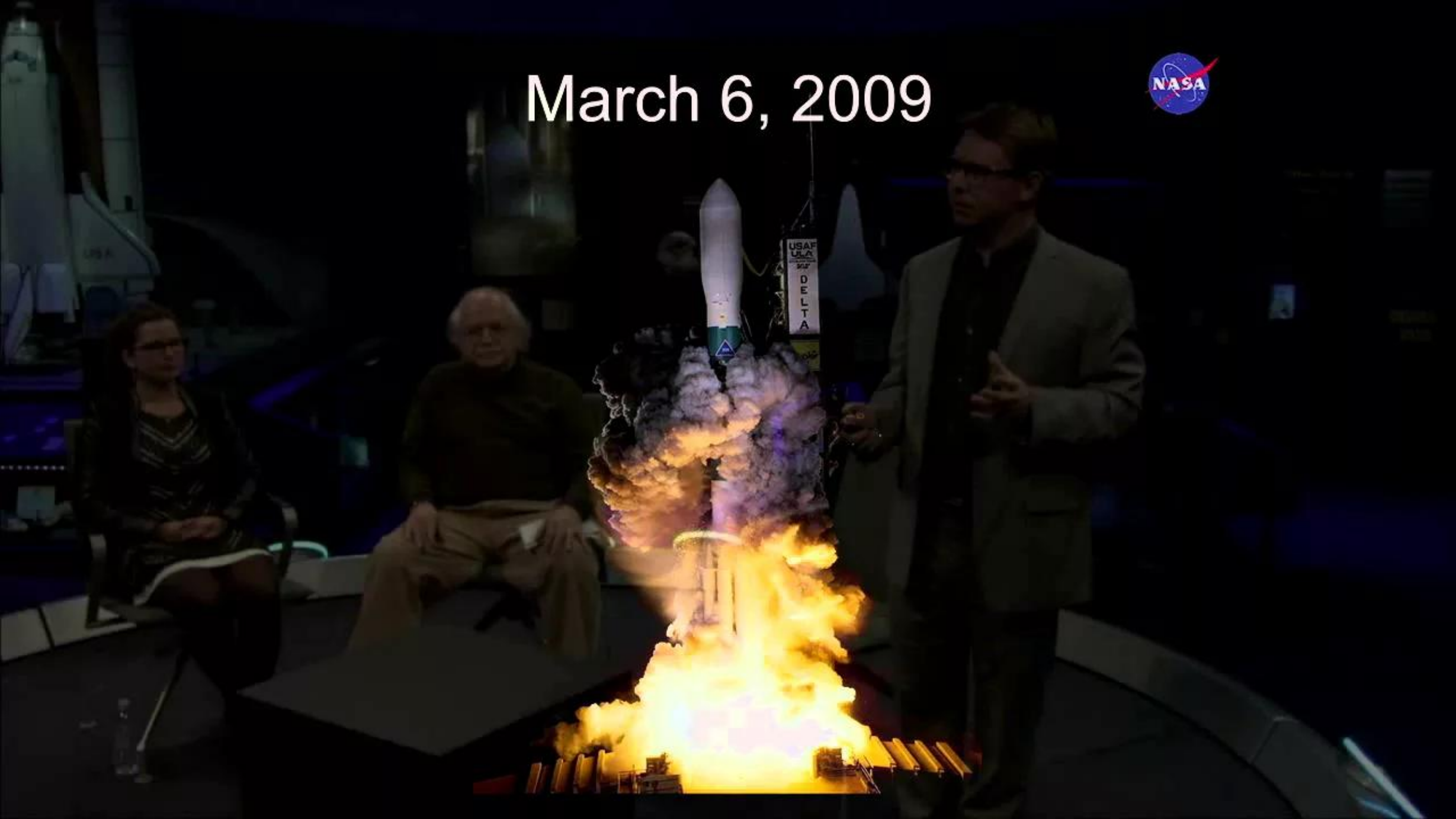
# March 6, 2009



1
00:00:11,710 --> 00:00:15,350
WELCOME TO THE MOVING BEYOND
EARTH GALLERY.

2
00:00:15,350 --> 00:00:20,860
AND ESPECIALLY TO THE WHAT'S NEW
IN AEROSPACE PROGRAM THAT WE'VE

3
00:00:20,860 --> 00:00:24,740
BEEN HOSTING HERE NOW THIS YEAR.

4
00:00:24,740 --> 00:00:28,400
AND WE'RE VERY EXCITED ABOUT.

5
00:00:28,400 --> 00:00:32,230
WE ALSO WANT TO WELCOME OUR
ELECTRONIC AUDIENCE, THE NASA

6
00:00:32,230 --> 00:00:34,210
NETWORK AUDIENCE.

7
00:00:34,210 --> 00:00:40,050
AND TALK ABOUT A SUBJECT WHICH
ACTUALLY IS VERY DEAR, I THINK,

8
00:00:40,050 --> 00:00:45,440
TO MY HEART AND THAT IS
UNDERLYING ALL OF THIS, IS THERE

9
00:00:45,440 --> 00:00:47,420
LIFE IN THE UNIVERSE?

10
00:00:47,420 --> 00:00:50,100
THE ANSWER TO THAT, WHAT WOULD
YOU SAY?

11
00:00:50,100 --> 00:00:54,030
WHO WOULD LIKE TO ANSWER THAT
QUESTION WITH A ONE WORD?

12
00:00:54,030 --> 00:00:56,070
IS THERE LIFE IN THE UNIVERSE?

13
00:00:56,070 --> 00:00:58,329
JUST BLURT IT OUT.

14
00:00:58,329 --> 00:00:59,589
YES.

15
00:00:59,589 --> 00:01:00,920
WHERE IS IT?

16
00:01:04,809 --> 00:01:01,940
HERE.

17
00:01:04,809 --> 00:01:07,210
WE HAVE TWO GREAT SPEAKERS
TODAY.

18
00:01:07,210 --> 00:01:12,740
WE HAVE TOM BARKLEY WHO IS FROM
THE AREA ENVIRONMENTAL RESEARCH

19
00:01:12,740 --> 00:01:13,740
INSTITUTE.

20
00:01:13,740 --> 00:01:17,549
HE IS A SCIENTISTS WORKING ON
NASA'S COUPLER AND TAKE TWO

21
00:01:17,549 --> 00:01:18,549
MISSIONS.

22
00:01:18,549 --> 00:01:24,131
THAT MEANS THAT HE FINDS THESE
EXTRA SOLAR PLANETS AROUND AN

23

00:01:24,131 --> 00:01:29,180
ABUND ANZ OF STARS.

24
00:01:29,180 --> 00:01:32,130
THERE ARE SO MANY STARS OUT
THERE WITH PLANETS.

25
00:01:32,130 --> 00:01:34,560
BUT THEN WHAT DO YOU DO WHETHER
YOU FIND THEM?

26
00:01:34,560 --> 00:01:39,250
WE ALSO HAVE HANNAH
RUTH-WAKEFORD, A FELLOW AT THE

27
00:01:39,250 --> 00:01:41,140
GODDARD SPACE FLIGHT CENTER.

28
00:01:41,140 --> 00:01:46,550
SHE'S WORKING IN THE PLANETARY
SYSTEMS LABORATORY TO SAY OKAY,

29
00:01:46,550 --> 00:01:51,340
ONCE YOU FIND PLANET, DOES IT
HAVE AN ATMOSPHERE?

30
00:01:51,340 --> 00:01:53,390
IS IT SUITABLE FOR LIFE?

31
00:01:53,390 --> 00:01:56,990
SO IT'S HARD FOR ME TO GET MY
MIND AROUND THE FACT THAT NOT

32
00:01:56,990 --> 00:01:59,939
ONLY ARE WE LOOKING FOR PLANETS,
BUT WE ARE APPLYING

33
00:01:59,939 --> 00:02:03,979
ENVIRONMENTAL TECHNIQUES AND
INTERPRETIVE STUDIES TO THESE

34
00:02:03,979 --> 00:02:05,950
EXTRA SOLAR SYSTEM.

35
00:02:05,950 --> 00:02:09,820
AND SO SOONER OR LATER, WE'RE
GOING TO HAVE AN ANSWER.

36
00:02:09,820 --> 00:02:11,520
WHY ARE WE DOING THIS NOW?

37
00:02:11,520 --> 00:02:18,310
BECAUSE IT'S BEEN 20 YEARS SINCE
OUR UNDERSTANDING OF ARE THERE

38
00:02:18,310 --> 00:02:22,661
OTHER PLANETS AROUND OTHER STARS
AND OTHER SOLAR SYSTEM IN THE

39
00:02:22,661 --> 00:02:24,770
UNIVERSE BEYOND OUR OWN?

40
00:02:24,770 --> 00:02:28,940
20 YEARS AGO, 25 YEARS AGO WE
LIKED WOULD SAY, SURE.

41
00:02:28,940 --> 00:02:30,920
BUT WE REALLY DON'T KNOW.

42
00:02:30,920 --> 00:02:32,660
TODAY, SURE.

43
00:02:32,660 --> 00:02:34,550
WE REALLY DO KNOW.

44
00:02:34,550 --> 00:02:36,640
AND THAT'S BEEN A TOTALLY
EXCITING THING.

45
00:02:36,640 --> 00:02:41,000
WE'RE GOING TO BE LOOKING AT THE
TWO PRIMARY ELEMENTS OF THE

46
00:02:41,000 --> 00:02:44,070
SEARCH, THE SEARCH ITSELF AND
THEN WHAT DO YOU DO WITH THE

47
00:02:44,070 --> 00:02:45,480
SEARCH?

48
00:02:45,480 --> 00:02:48,000
IN THIS PROGRAM TODAY.

49
00:02:48,000 --> 00:02:52,420
SO I'D LIKE TO TURN FIRST TO TOM
WHO IS GOING TO TELL US ABOUT

50
00:02:52,420 --> 00:02:53,420
THAT SEARCH.

51
00:02:53,420 --> 00:02:54,910
>> ALL RIGHT.

52
00:02:54,910 --> 00:02:55,910
THANK YOU.

53
00:02:55,910 --> 00:02:57,990
SO I'D LIKE TO SAY MY NAME IS
TOM BARKLEY AND I'M COMING OUT

54
00:02:57,990 --> 00:03:01,600
OF A RESEARCH CENTER BASED IN
THE HEART OF SILICON VALLEY IN

55
00:03:01,600 --> 00:03:03,430
CALIFORNIA.

56

00:03:03,430 --> 00:03:09,000
WHAT I DO IS I LOOK FOR PLANETS
OR STARS OTHER THAN THE SUN.

57
00:03:09,000 --> 00:03:11,560
WE CALL THESE PLANETS EXTRA
SOLAR PLANETS.

58
00:03:11,560 --> 00:03:13,440
AT LEAST WE DID A FEW YEARS AGO.

59
00:03:13,440 --> 00:03:16,350
EXTRA SOLAR IS TOO LONG SO NOW
WE CALL THEM EXSO PLANETS.

60
00:03:16,350 --> 00:03:21,290
THEY'RE I HAVE DIFFERENT FROM
OUR OWN.

61
00:03:21,290 --> 00:03:24,890
STARS VERY DIFFERENT FROM THE
SUN.

62
00:03:24,890 --> 00:03:26,740
FAR OUT IN THE MILKY WAY.

63
00:03:26,740 --> 00:03:30,510
I'LL PUT UP SOME SLIDES.

64
00:03:30,510 --> 00:03:34,930
I THINK I CAN SHOW YOU A LITTLE
BIT ABOUT THE HISTORY OF FINDING

65
00:03:34,930 --> 00:03:39,390
THE PLANETS AND HOW NASA IS
INVESTED IN THIS SEARCH.

66
00:03:39,390 --> 00:03:43,740
SO THE FIRST PLANETS WERE FOUND
BY FIRST ORBITTING A STAR LIKE

67
00:03:43,740 --> 00:03:50,480
OUR SUN THIS MONTH AGO ORBITTING
A STAR.

68
00:03:50,480 --> 00:03:52,640
THESE WERE FOUND ON THE GROUND.

69
00:03:52,640 --> 00:03:56,380
BUT SINCE THEN, NASA'S BEEN
SPENDING MOST OF LET SOURCES AND

70
00:03:56,380 --> 00:04:00,820
TIME SEARCHING FOR PLANETS FROM
SPACE, USING SPACE TELESCOPES.

71
00:04:00,820 --> 00:04:05,320
THIS STARTED WITH THE GREAT WORK
HORSE OF NASA, THE HUBBLE SPACE

72
00:04:05,320 --> 00:04:08,530
TELESCOPE WHICH IS VERY FAMOUS
FOR ITS BEAUTIFUL IMAGES.

73
00:04:08,530 --> 00:04:10,280
THIS STARTED THE REVOLUTION.

74
00:04:10,280 --> 00:04:15,720
THEN THERE WAS A TELESCOPE THAT
I'M GOING TO DISCUSS IN A LITTLE

75
00:04:15,720 --> 00:04:19,881
BIT DURING THIS TALK THAT REALLY
CHANGED OUR UNDERSTANDING OF OUR

76
00:04:19,881 --> 00:04:21,850
PLACE IN THE UNIVERSE.

77
00:04:21,850 --> 00:04:25,291

AND GOING ON FROM THERE, THERE'S
A K-2 MISSION WHICH IS THE NEW

78
00:04:25,291 --> 00:04:29,061
LIFE AND IN THE FUTURE SOMETHING
KNOWN AS THE TEST MISSION, THE

79
00:04:29,061 --> 00:04:33,770
SURVEY SATELLITE WHICH FOR THOSE
IN THIS ROOM CAN LEARN ABOUT

80
00:04:33,770 --> 00:04:37,979
THIS AFTER THIS TALK IN THE BACK
HERE AND FOLLOWING UP WITH THE

81
00:04:37,979 --> 00:04:42,139
NEXT GREAT OF JAMES WEBB
TELESCOPE AND THEN BEYOND THAT,

82
00:04:42,139 --> 00:04:45,160
THERE ARE WHAT SOME OF THE KIDS
IN THE AUDIENCE WILL BE WORKING

83
00:04:45,160 --> 00:04:47,300
ON IF THEY BECOME SCIENTISTS.

84
00:04:47,300 --> 00:04:53,180
WITH THIS TALK, REALLY WHAT I
WANT YOU TO DO IS BY THE END OF

85
00:04:53,180 --> 00:04:55,870
IT, KNOW HOW WE'RE GOING TO
HOPEFULLY FIND ALIENS.

86
00:04:55,870 --> 00:04:56,909
THAT'S THE PLAN.

87
00:04:56,909 --> 00:04:59,379
SO IF YOU STAY UNTIL THE END,
YOU SHOULD KNOW HOW WE'RE GOING

88
00:04:59,379 --> 00:05:00,790
TO DO THIS.

89
00:05:00,790 --> 00:05:04,500
MAKE NO MISTAKE, THE PEOPLE WHO
SAID THEY WANT TO GO AND

90
00:05:04,500 --> 00:05:05,500
FIND

91
00:05:05,500 --> 00:05:07,599
ALIENS, THEY WERE CRAZY.

92
00:05:07,599 --> 00:05:17,259
BUT NOW THERE IS A WAY TO FIND
LIFE IN THE UNIVERSE.

93
00:05:17,259 --> 00:05:22,810
THE WAY WE FIND PLANETS IS USING
THE TRANSIT TECHNIQUE.

94
00:05:22,810 --> 00:05:26,130
THE WAY TRANSIT WORKS IS YOU
HAVE A STAR.

95
00:05:26,130 --> 00:05:28,930
YOU HAVE PLANETS PASSING IN
FRONT OF THAT STAR.

96
00:05:28,930 --> 00:05:31,979
THAT PLANET BLOCKS A LITTLE BIT
OF THE LIGHT COMING FROM THE

97
00:05:31,979 --> 00:05:32,979
STAR.

98
00:05:32,979 --> 00:05:37,400
THE STAR GETS DIM AND THE

SPACECRAFT APPEARS DIMMER.

99
00:05:37,400 --> 00:05:38,930
SOME OF THE LIGHTS GO OFF.

100
00:05:38,930 --> 00:05:41,129
WE KNOW A PLANET IS THERE.

101
00:05:41,129 --> 00:05:44,840
WE'RE FORTUNATE ENOUGH TO SEE
PLANETS IN OUR OWN SOLAR SYSTEM,

102
00:05:44,840 --> 00:05:46,610
TRANSIT THE STAR.

103
00:05:46,610 --> 00:05:50,440
JUST ONCE THERE WERE ABOUT 200
YEARS, VENUS TRANSITS THE SUN

104
00:05:50,440 --> 00:05:52,729
FROM OUR PERSPECTIVE.

105
00:05:52,729 --> 00:05:55,040
WE'RE LIVING IN A TIME WHEN THAT
JUST HAPPENED.

106
00:05:55,040 --> 00:05:58,250
IF YOU MISSED IT, WELL, I HOPE
YOU'RE LIVING A HEALTHY LIFE.

107
00:05:58,250 --> 00:06:02,540
YOU'RE GOING TO LIVE ANOTHER 200
YEARS TO SEE ANOTHER ONE.

108
00:06:02,540 --> 00:06:05,659
BUT AT 2012, VENUS TRANSITS THE
SUN.

109
00:06:05,659 --> 00:06:08,770

THIS IS A VIDEO FOR THOSE OF
THAT YOU CAN LOOK LEFT OR RIGHT

110
00:06:08,770 --> 00:06:11,730
IN THE ROOM OF THE TRANSIT OF
VENUS.

111
00:06:11,730 --> 00:06:16,219
YOU CAN SEE IT MOVING ACROSS THE
FACE OF THE SUN.

112
00:06:16,219 --> 00:06:20,340
THE SUN ISN'T A UNIFORM
BRIGHTNESS.

113
00:06:20,340 --> 00:06:24,189
IT IS ACTUALLY VERY ACTIVE AND
DYNAMIC.

114
00:06:24,189 --> 00:06:26,910
A LOT OF THINGS ARE HAPPENING ON
THE SURFACE HERE.

115
00:06:26,910 --> 00:06:27,910
YOU SEE THE EDGES.

116
00:06:27,910 --> 00:06:29,539
IT APPEARS DIMMER TO OUR EYES.

117
00:06:29,539 --> 00:06:33,970
YOU SEE IT REPEATS THE PLANET
COMING IN ACROSS THE LIMB OF THE

118
00:06:33,970 --> 00:06:35,599
STAR.

119
00:06:35,599 --> 00:06:38,360
THERE IS A LOT OF STUFF GOING ON
THE SURFACE.

120
00:06:38,360 --> 00:06:42,789
THIS IS CONVECTION THIS IS HOT
PLASMA, HOT GAS MOVING UP AND

121
00:06:42,789 --> 00:06:46,219
MOVING DOWN AS THE PLANET PASSES
IN FRONT OF THE STAR.

122
00:06:46,219 --> 00:06:50,729
THIS IS ACTUALLY WHAT CAUSES A
NOISE OR DETECTION.

123
00:06:50,729 --> 00:06:54,189
IT'S LIMITED BY HOW MUCH STUFF
IS HAPPENING ON THE SURFACE OF

124
00:06:54,189 --> 00:06:55,590
THE STAR.

125
00:06:55,590 --> 00:06:56,750
SO THIS IS WHAT WE DO.

126
00:06:56,750 --> 00:06:58,630
WE TAKE THE LIGHT OF THE STAR.

127
00:06:58,630 --> 00:07:02,550
WE WAIT FOR A PLANET TO PASS IN
FRONT OF THE STAR.

128
00:07:02,550 --> 00:07:04,810
HERE'S MORE OF A REAL DATA.

129
00:07:04,810 --> 00:07:07,139
THIS IS WHAT OUR SPACECRAFT
TAKES.

130
00:07:07,139 --> 00:07:08,620
MANY PEOPLE WON'T SHOW REAL
DATA.

131
00:07:08,620 --> 00:07:12,309
IT'S, YOU KNOW, A LITTLE BIT
MORE DIFFICULT TO INTERPRET.

132
00:07:12,309 --> 00:07:15,360
BUT WHAT YOU'RE SEEING HERE IS A
TIME SERIES.

133
00:07:15,360 --> 00:07:18,100
WE MEASURE THE BRIGHTNESS OF THE
STAR EVERY 30 MINUTES.

134
00:07:18,100 --> 00:07:23,999
AND THEN IN THIS CASE, EVERY FEW
DAYS YOU SEE A REGULAR DIP.

135
00:07:23,999 --> 00:07:26,930
THIS REGULAR DIP IS BECAUSE A
PLANET IS PASSING IN FRONT.

136
00:07:26,930 --> 00:07:31,080
AND BY THE DEPTH OF THE DIP, YOU
CAN TELL HOW BIG THE PLANET IS.

137
00:07:31,080 --> 00:07:33,680
BUT SIMPLY BECAUSE YOU HAVE A
BIGGER PLANET, YOU BLOCK MORE

138
00:07:33,680 --> 00:07:34,949
STAR LIGHT.

139
00:07:34,949 --> 00:07:38,690
YOU HAVE A SMALLER PLANET, YOU
BLOCK A TINY FRACTION OF THE

140
00:07:38,690 --> 00:07:39,699
STAR LIGHT.

141

00:07:39,699 --> 00:07:44,059
AND HOW OFTEN THE DIP HAPPENS,
YOU CAN TELL HOW OFTEN THE

142
00:07:44,059 --> 00:07:46,159
PLANET GOES AROUND THE STAR.

143
00:07:46,159 --> 00:07:48,840
WE CALL THIS THE ORBITAL PERIOD.

144
00:07:48,840 --> 00:07:50,169
SO WHAT ARE ORBITAL PERIODS?

145
00:07:50,169 --> 00:07:55,409
DOES ANYONE KNOW HOW OFTEN WE GO
AROUND OUR STAR?

146
00:07:55,409 --> 00:07:59,069
A SIMPLE WORD FOR IT, A YEAR.
365 DAYS.

147
00:07:59,069 --> 00:08:01,189
THAT'S HOW LONG IT TAKES US TO
GO AROUND.

148
00:08:01,189 --> 00:08:05,009
PLANET GOES AREN'T STAR IN JUST
12 HOURS.

149
00:08:05,009 --> 00:08:07,800
WE KNOW OTHER ONES THAT GO
AROUND THEIR STAR IN CENTURIES.

150
00:08:07,800 --> 00:08:12,360
THERE'S A HUGE RANGE OF YEARS
ORBITAL PERIODS FOR OTHER

151
00:08:12,360 --> 00:08:16,949
PLANETS.

152
00:08:16,949 --> 00:08:19,430
SO IN ORDER TO DETECT THESE
TRANSITS, WE BUILT A SPECIAL

153
00:08:19,430 --> 00:08:25,150
KIND OF SPACECRAFT, DETECTOR
THAT VERY BIG.

154
00:08:25,150 --> 00:08:27,449
YOU NEED TO LOOK AT A LOT OF
STARS.

155
00:08:27,449 --> 00:08:28,669
THINK ABOUT HOW TRANSIT WORKS.

156
00:08:28,669 --> 00:08:30,259
YOU HAVE A STAR IN THE MIDDLE.

157
00:08:30,259 --> 00:08:31,439
YOU HAVE A PLANET FURTHER OUT.

158
00:08:31,439 --> 00:08:34,570
THE PLANET GOES AROUND IN A
CIRCLE OR AN ELLIPSE.

159
00:08:34,570 --> 00:08:38,810
YOU NEED TO HAVE IT LINED UP
JUST RIGHT TO SEE IT.

160
00:08:38,810 --> 00:08:43,300
IF IT'S ANGLED AWAY FROM YOU,
YOU SEE NO PLANET.

161
00:08:43,300 --> 00:08:46,621
YOU NEED TO LOOK AT AN AWFULLY
LARGE NUMBER OF STARS TO SEE

162
00:08:46,621 --> 00:08:49,320
JUST ONE TRANSIT.

163
00:08:49,320 --> 00:08:53,930
IF YOU WERE TO DETECT EARTH, YOU
NEED TO LOOK AT ABOUT 200 EARTH

164
00:08:53,930 --> 00:08:58,280
ANALOG SYSTEMS IN ORDER TO
DETECT ONE EARTH.

165
00:08:58,280 --> 00:09:02,760
NOT BECAUSE THE CHANCE OF LINING
UP IS ABOUT ONE IN 200.

166
00:09:02,760 --> 00:09:05,970
THIS MOVIE HERE IS SHOWING THE
SPACECRAFT WE BUILT WITH THIS

167
00:09:05,970 --> 00:09:09,230
LARGE DETECTOR TO DETECT
PLANETS.

168
00:09:09,230 --> 00:09:11,540
THE OTHER THING YOU NEED, YOU
NEED TO BE -- YOU NEED TO LOOK

169
00:09:11,540 --> 00:09:15,080
AT THE FIELD FOR A VERY LONG
TIME.

170
00:09:15,080 --> 00:09:17,580
SO WE LOST THE SPACECRAFT IN
2009.

171
00:09:17,580 --> 00:09:21,570
WE SPENT ABOUT 3 1/2 YEARS
LOOKING AT THE SAME FIELD.

172
00:09:21,570 --> 00:09:22,690
THIS IS A FIELD IN THE SKY.

173
00:09:22,690 --> 00:09:25,960
YOU SEE THE MILKY WAY RUNNING
THROUGH THE MIDDLE HERE.

174
00:09:25,960 --> 00:09:29,470
AND JUST ABOVE THE MILKY WAY,
YOU SEE THIS STRANGE PUDDLE THAT

175
00:09:29,470 --> 00:09:32,080
IS LIKE A SQUARE WITH THE CORNER
CUT OUT.

176
00:09:32,080 --> 00:09:34,010
THAT'S THE SHAPE OF OUR CAMERA.

177
00:09:34,010 --> 00:09:38,740
THE PICTURE HERE IS THE PHOTO WE
TOOK OF THE SKY WITH OUR -- WHEN

178
00:09:38,740 --> 00:09:42,240
OUR CAMERA WENT FIRST INTO SPACE
TO DETECT THINGS.

179
00:09:42,240 --> 00:09:46,350
AND JUST ZOOMED IN THE BOTTOM
LEFT, YOU SEE SOME FUZZY BLOCKS.

180
00:09:46,350 --> 00:09:47,940
THESE FUZZY BLOCKS ARE STARS.

181
00:09:47,940 --> 00:09:49,780
THIS IS WHAT WE LOOK AT.

182
00:09:49,780 --> 00:09:52,700
YOU KNOW, PEOPLE DON'T OFTEN
SHOW DATA COMING FROM OUR

183
00:09:52,700 --> 00:09:53,850
SPACECRAFT.

184
00:09:53,850 --> 00:09:56,290
AND THAT'S BECAUSE WE TAKE
IMAGES THAT LOOK LIKE THIS THAT

185
00:09:56,290 --> 00:09:58,990
ARE, TO ME, A BEAUTIFUL BUT
AREN'T AS BEAUTIFUL TO THE

186
00:09:58,990 --> 00:10:00,120
PUBLIC, TO YOU GUYS.

187
00:10:00,120 --> 00:10:01,460
THEY'RE NOT HUBBLE IMAGES.

188
00:10:01,460 --> 00:10:03,270
THEY DON'T HAVE BEAUTIFUL
COLORS.

189
00:10:03,270 --> 00:10:07,020
THEY DON'T HAVE BEAUTIFUL
FEATURES.

190
00:10:07,020 --> 00:10:08,190
TO ME THIS IS AMAZING.

191
00:10:08,190 --> 00:10:10,880
WE TAKE THESE UGLY IMAGES.

192
00:10:10,880 --> 00:10:12,260
WE ADD UP THE STAR LIGHT.

193
00:10:12,260 --> 00:10:14,000
WE FIND PLANETS.

194
00:10:14,000 --> 00:10:17,100
THE WAY WE DO THIS HERE IN THE
TOP LEFT IS ONE OF THE FUZZY

195
00:10:17,100 --> 00:10:18,100
BLOBS.

196
00:10:18,100 --> 00:10:20,370
AND ONE OF THE READ THE STARS WE
OBSERVE.

197
00:10:20,370 --> 00:10:22,870
WE MEASURE IT AND MEASURE IT AND
MEASURE IT AND REPEAT MEASURING

198
00:10:22,870 --> 00:10:26,380
IT FOR YEARS AND YEARS ON END
ALL THE TIME.

199
00:10:26,380 --> 00:10:27,880
WAITING FOR A PLANET TO PASS IN
FRONT.

200
00:10:27,880 --> 00:10:31,830
AND WHEN IT DOES, THIS IS REAL
DATA OF THE FIRST ROCKY PLANET

201
00:10:31,830 --> 00:10:34,220
WE EVER FOUND OUTSIDE OF OUR OWN
SOLAR SYSTEM.

202
00:10:34,220 --> 00:10:39,210
IT WAS KNOWN AS KEPLAR 10-B.
IT WAGS LIKE EIGHT TIMES AS MUCH

203
00:10:39,210 --> 00:10:40,750
AS THE EARTH AND IT IS VERY HOT.

204
00:10:40,750 --> 00:10:42,780
IT IS A HOT WORLD.

205
00:10:42,780 --> 00:10:43,780
IT'S NOTHING LIKE THE EARTH.

206
00:10:43,780 --> 00:10:47,470
FOR THE FIRST TIME, WE KNEW
THERE ARE PLACES OUT THERE THAT

207
00:10:47,470 --> 00:10:50,910
ARE ROCKY LIKE OUR OWN.

208
00:10:50,910 --> 00:10:56,510
SO LET ME TAKE YOU A LITTLE BIT
INTO THE HISTORY OF WHERE WE

209
00:10:56,510 --> 00:10:57,510
ARE.

210
00:10:57,510 --> 00:11:01,620
I THINK BECAUSE WE'VE NOW KNOWN
OF THE PLANETS FOR 20 YEARS, YOU

211
00:11:01,620 --> 00:11:03,910
KNOW, MANY OF YOU IN THE
AUDIENCE WOULDN'T HAVE BEEN BORN

212
00:11:03,910 --> 00:11:05,460
WHEN WE DIDN'T KNOW A PLANET.

213
00:11:05,460 --> 00:11:10,140
AND MANY OF YOU OTHER PEOPLE IN
THE AUDIENCE SPENT TIME WITHOUT

214
00:11:10,140 --> 00:11:11,560
EXTRA PLANETS EXISTING.

215
00:11:11,560 --> 00:11:13,950
IT'S NICE TO LOOK BACK AND SEE
WHERE WE ARE.

216
00:11:13,950 --> 00:11:19,610
UP UNTIL 1995, WE HAD OUR OWN

PLANET FROM OUR OWN SOLAR

217
00:11:19,610 --> 00:11:23,260
SYSTEM, EIGHT OR NINE, DEPENDING
ON YOUR VIEW OF PLUTO.

218
00:11:23,260 --> 00:11:26,700
AND WE HAD A FEW OTHER HINTS
THAT THERE MIGHT BE OTHER

219
00:11:26,700 --> 00:11:28,700
PLANETS OUT THERE.

220
00:11:28,700 --> 00:11:34,900
IN THE EARLY '90s, WE FOUND A
FEW PLANETS ORBITING NEUTRON

221
00:11:34,900 --> 00:11:37,650
STARS.

222
00:11:37,650 --> 00:11:49,380
BUT IN 1995, WE FOUND THE FIRST
PLANET ORBITING A STAR OTHER

223
00:11:49,380 --> 00:11:50,380
THAN THE SUN.

224
00:11:50,380 --> 00:11:51,820
THEN THE FLOODGATES REALLY
OPENED.

225
00:11:51,820 --> 00:11:55,970
THIS IS WHERE WE WENT TO FROM
THE HISTORY.

226
00:11:55,970 --> 00:11:57,490
I'M SHOWING A GRAPH HERE.

227
00:11:57,490 --> 00:12:01,180

I'M ONLY GOING TO SHOW ONE OR
TWO GRAPHS DURING THIS TALK.

228
00:12:01,180 --> 00:12:03,870
I THINK IT'S IMPORTANT TO
UNDERSTAND WHERE WE ARE VIA A

229
00:12:03,870 --> 00:12:04,870
GRAPH.

230
00:12:04,870 --> 00:12:08,610
SO THE X FACTORS HERE, THE
HORIZONTAL AXIS SHOWS THE

231
00:12:08,610 --> 00:12:09,610
ORBITAL PERIOD.

232
00:12:09,610 --> 00:12:14,240
THIS IS THE YEAR OF THE PLANET.

233
00:12:14,240 --> 00:12:19,560
THE Y AXIS, THE VERTICAL AXIS
SHOWS HOW BIG THE PLANET IS.

234
00:12:19,560 --> 00:12:21,800
YOU CAN SEE THE LINE OF EARTH.

235
00:12:21,800 --> 00:12:24,740
THAT'S ONE TIMES THE SIZE OF
EARTH.

236
00:12:24,740 --> 00:12:25,740
YOU CAN SEE THE LINE OF NEPTUNE.

237
00:12:25,740 --> 00:12:28,250
THAT IS FOUR TIME THE SIZE OF
EARTH.

238
00:12:28,250 --> 00:12:31,580

YOU CAN ALSO SEE THE LINE OF
JUPITER THAT, IS 11 TIMES THE

239
00:12:31,580 --> 00:12:33,200
SIZE OF EARTH.

240
00:12:33,200 --> 00:12:38,220
UNTIL 2009 THIS IS A PICTURE OF
OUR SOLAR SYSTEM.

241
00:12:38,220 --> 00:12:41,410
YOU CAN SEE WHERE WHEN MOST OF
THE PLANETS FALL, THE HIGH UP.

242
00:12:41,410 --> 00:12:42,810
THEY'RE AT THE TOP OF THE GRAPH.

243
00:12:42,810 --> 00:12:46,240
THAT MEANS THAT THEY'RE THE SIZE
OF JUPITER, THAT BIG THING.

244
00:12:46,240 --> 00:12:47,470
SOME OF THEM ARE VERY CLOSE IN.

245
00:12:47,470 --> 00:12:49,810
THEY'RE HOT JUPITERS, THEY'RE
NOTHING LIKE OUR OWN SOLAR

246
00:12:49,810 --> 00:12:50,910
SYSTEM.

247
00:12:50,910 --> 00:12:52,200
SOME ARE VERY FAR OUT.

248
00:12:52,200 --> 00:12:58,500
THEY'RE LIKE OUR OWN JUPITER
WHICH IS FIVE TIME THE DISTANCE

249
00:12:58,500 --> 00:13:01,390

OF EARTH FROM THE SUN.

250
00:13:01,390 --> 00:13:04,170
AND THEN THERE WAS A HINT, IF
YOU LOOK GOING INTO THE LOWER

251
00:13:04,170 --> 00:13:07,720
LEFT, THERE ARE SOME SMALLER
PLANETS THERE, PERHAPS SOME

252
00:13:07,720 --> 00:13:14,080
NEPTUNE SIZE THINGS, MAYBE A FEW
BIGGER THAN EARTH BUT VERY FEW.

253
00:13:14,080 --> 00:13:18,650
SO 2009 WE REALLY DIDN'T KNOW IS
THERE SPECIAL, ARE THERE PLACES

254
00:13:18,650 --> 00:13:21,830
LIKE EARTH OUT THERE THAT WE
HAVEN'T FOUND YET OR ARE THERE

255
00:13:21,830 --> 00:13:23,750
SIMPLY VERY FEW ROCKY PLAN
--

256
00:13:23,750 --> 00:13:26,000
PLANETS THAT WE KNOW OF?

257
00:13:26,000 --> 00:13:31,000
THIS IS WHAT HAPPENED 2009 TO
2013.

258
00:13:31,000 --> 00:13:35,620
THIS IS THE REVOLUTION OR
UNDERSTANDING OF OUR PLACE IN

259
00:13:35,620 --> 00:13:36,990
THE UNIVERSE.

260
00:13:36,990 --> 00:13:39,990
WE SUDDENLY WENT FROM KNOWING
THAT THERE'S NOT KNOWING OF

261
00:13:39,990 --> 00:13:43,040
ANYWHERE THAT LOOKS QUITE LIKE
OUR OWN SYSTEM TO KNOWING THAT

262
00:13:43,040 --> 00:13:45,120
THERE ARE PLACES THE SIZE OF
EARTH EVERYWHERE.

263
00:13:45,120 --> 00:13:48,410
MOST OF THE STARS WITH YOU LOOK
AT IN THE NIGHT SKY WILL HAVE

264
00:13:48,410 --> 00:13:49,450
PLANETS ORBITING THEM.

265
00:13:49,450 --> 00:13:50,450
ISN'T THAT INCREDIBLE?

266
00:13:50,450 --> 00:13:52,580
YOU THINK THERE ARE PLANETS OUT
THERE.

267
00:13:52,580 --> 00:13:54,750
IT SHOULD HAVE BEEN ASSUMED.

268
00:13:54,750 --> 00:13:56,130
WHY SHOULD WE BE SPECIAL?

269
00:13:56,130 --> 00:13:59,380
HEY, WE HAVE LIFE AND LIFE IS
PRETTY SPECIAL TO ME.

270
00:13:59,380 --> 00:14:02,190
SO THERE ARE PLANETS OUT THERE
EVERYWHERE.

271
00:14:02,190 --> 00:14:07,580
SO EVEN MORE INCREDIBLY TO ME,
THE MOST COLORFUL ONES ARE TWICE

272
00:14:07,580 --> 00:14:08,790
THE SIZE OF EARTH.

273
00:14:08,790 --> 00:14:12,790
THERE IS NOTHING LIKE THESE IN
OUR OWN SOLAR SYSTEM.

274
00:14:12,790 --> 00:14:14,660
STUDYING THEM AND UNDERSTANDING
THEM IS A REAL CHALLENGE.

275
00:14:14,660 --> 00:14:19,660
WE DON'T HAVE PROXIES OF THEM IN
OUR OWN SOLAR SYSTEM.

276
00:14:19,660 --> 00:14:23,790
THIS IS THE SIMILAR PICTURE ON A
SLIGHTLY DIFFERENT SCALE.

277
00:14:23,790 --> 00:14:30,760
EARTH, REMEMBER, HAS ORBIT THE
STAR EVERY 365 DAYS.

278
00:14:30,760 --> 00:14:32,690
ONE LINE HERE.

279
00:14:32,690 --> 00:14:35,650
SO WE'RE STARTING TO FIND
TENTATIVE HINTS OR MAYBE EVEN

280
00:14:35,650 --> 00:14:38,070
CANDIDATES, NOT CONFIRMED
PLANETS BUT CANDIDATE PLANETS

281

00:14:38,070 --> 00:14:41,160
THAT ARE THE SIZE OF EARTH AND
ORBIT ON THE SAME ORBITAL

282
00:14:41,160 --> 00:14:42,560
PERIOD.

283
00:14:42,560 --> 00:14:45,220
PERHAPS THERE ARE PLACES SIMILAR
TO EARTH.

284
00:14:45,220 --> 00:14:49,490
NOW A GOOD QUESTION TO ASK IS
WHY DO WE CARE ABOUT EARTH SO

285
00:14:49,490 --> 00:14:50,490
MUCH?

286
00:14:50,490 --> 00:14:51,490
WHAT IS SO SPECIAL ABOUT EARTH?

287
00:14:51,490 --> 00:14:55,510
WELL, AS SCIENTISTS, YOU
SHOULDN'T TAKE A SAMPLE SIZE OF

288
00:14:55,510 --> 00:14:59,410
ONE WHICH IS ONE PLANET WE KNOW
IS LIFE AND EXTRAPOLATE TO THE

289
00:14:59,410 --> 00:15:01,100
ENTIRE UNIVERSE.

290
00:15:01,100 --> 00:15:04,920
WE SHOULDN'T TAKE EARTH INTO OUR
ONE SAMPLE AND SAY EVERYONE OUT

291
00:15:04,920 --> 00:15:06,680
THERE SHOULD BE LIKE EARTH.

292

00:15:06,680 --> 00:15:09,160
BUT EARTH IS THE ONE PLACE WE
KNOW WITH LIFE.

293
00:15:09,160 --> 00:15:12,680
SO IT SEEMS LIKE THE ONLY PLACE
TO START IS TO LOOK FOR PLACE

294
00:15:12,680 --> 00:15:14,610
THAT'S REMIND US OF EARTH.

295
00:15:14,610 --> 00:15:16,750
SO WHAT DO WE KNOW ABOUT EARTH
THAT WE THINK IS SPECIAL?

296
00:15:16,750 --> 00:15:21,310
ONE, IT HAS LIQUID WATER ON THE
SURFACE.

297
00:15:21,310 --> 00:15:25,840
ALL LIFE WE KNOW OF ON EARTH
REQUIRES LIQUID WATER AT SOME

298
00:15:25,840 --> 00:15:29,830
STAGE IN THEIR DEVELOPMENT TO
LIVE.

299
00:15:29,830 --> 00:15:32,519
SO WE LOOK FOR OTHER PLANETS, WE
LOOK FOR PLACE THAT'S CAN HOST

300
00:15:32,519 --> 00:15:34,010
LIQUID WATER.

301
00:15:34,010 --> 00:15:35,890
WE CALL THIS REGION THE HABITUAL
ZONE.

302
00:15:35,890 --> 00:15:39,800
IT'S NOT TOO HOT THAT WATER WILL

BOIL OFF AND PERHAPS YOU'LL HAVE

303
00:15:39,800 --> 00:15:42,000
A RUN AWAY GREEN HOUSE LIKE
VENUS.

304
00:15:42,000 --> 00:15:46,480
IT'S ALSO NOT TOO COLD THAT
YOU'LL FREEZE OUT ALL THE WATER

305
00:15:46,480 --> 00:15:48,020
AND TURN INTO A GIANT SNOWBALL.

306
00:15:48,020 --> 00:15:49,050
IT'S JUST RIGHT.

307
00:15:49,050 --> 00:15:51,360
IT'S THE GOLDILOCKS ZONE.

308
00:15:51,360 --> 00:15:55,720
THE OTHER THING ABOUT EARTH IS
THAT IT'S JUST THE RIGHT SIZE.

309
00:15:55,720 --> 00:16:00,480
IF YOU'RE TOO BIG, YOU HAVE HUGE
ENVELOPES OF GAS AROUND YOU LIKE

310
00:16:00,480 --> 00:16:01,940
JUPITER.

311
00:16:01,940 --> 00:16:03,570
MOSTLY HYDROGEN AND HELIUM.

312
00:16:03,570 --> 00:16:05,290
HUGE AMOUNTS OF GAS THERE.

313
00:16:05,290 --> 00:16:10,000
AND WHILE MAYBE THERE ARE FLYING
WHALES OR SOMETHING IN GIANT

314
00:16:10,000 --> 00:16:13,560
PLANETS LIKE JUPITER, THERE IS
NOTHING LIKE LIFE ON EARTH.

315
00:16:13,560 --> 00:16:16,550
SO THAT'S WHY WE LOOK FOR PLACES
THAT ARE JUST THE RIGHT SIZE,

316
00:16:16,550 --> 00:16:17,820
SMALLER THAN JUPITER BUT BIGGER
THAN MARS.

317
00:16:17,820 --> 00:16:19,790
MARS DOESN'T HAVE ANY LIFE.

318
00:16:19,790 --> 00:16:22,870
IT HAS A LITTLE ATMOSPHERE BUT
NOT VERY MUCH.

319
00:16:22,870 --> 00:16:28,050
NOT ENOUGH TO RETAIN ANY LIQUID
WATER, AT LEAST FOR A LONG TIME.

320
00:16:28,050 --> 00:16:30,560
SO EARTH IS THAT NICE REGION IN
THE MIDDLE BETWEEN NOT BEING TOO

321
00:16:30,560 --> 00:16:32,790
BIG OR SMALL.

322
00:16:32,790 --> 00:16:41,180
SO IT IS WITH GREAT EXCITEMENT
IN APRIL OF LAST YEAR THAT WE

323
00:16:41,180 --> 00:16:45,880
DETECTED THE FIRST PLANET THAT'S
THE SIZE OF EARTH AND ORBITS IN

324

00:16:45,880 --> 00:16:51,120
THIS REGION CALLED THE HABITUAL
ZONE OR GOLDILOCKS ZONE.

325
00:16:51,120 --> 00:16:53,260
THIS PLANET WAS KEPT FOR 186.

326
00:16:53,260 --> 00:16:56,740
IT'S ONE OF FIVE PLANETS
ORBITTING A STAR THAT IS SMALLER

327
00:16:56,740 --> 00:17:00,600
AND COOLER THAN THE EARTH,
SMALLER AND COOLER THAN THE SUN.

328
00:17:00,600 --> 00:17:02,630
WE CALL IT A DWARF STAR.

329
00:17:02,630 --> 00:17:08,470
SO THIS PLANET IS THE SAME SIZE
AS EARTH.

330
00:17:08,470 --> 00:17:10,919
IT ORBITS IN THE HABITUAL ZONE.

331
00:17:10,919 --> 00:17:14,370
BUT THE FIRST TIME WE'VE KNOWN
THERE ARE PLACES OUT THERE THAT

332
00:17:14,370 --> 00:17:17,149
MAYBE WITH THE RIGHT KIND OF
ATMOSPHERE COULD HAVE LIQUID

333
00:17:17,149 --> 00:17:25,539
WATER ON THEIR SURFACE.

334
00:17:25,539 --> 00:17:29,230
THIS IS KIND OF A STORY OF WHERE
WE'VE COME FROM WITH THIS.

335
00:17:29,230 --> 00:17:32,509
IT'S A RELATIVELY SHORT STORY
GIVEN THE -- YOU KNOW, HOW LONG

336
00:17:32,509 --> 00:17:35,850
WE'VE BEEN AROUND AND HOW LONG
HUMAN KIND WE'VE BEEN DOING

337
00:17:35,850 --> 00:17:36,850
SCIENCE.

338
00:17:36,850 --> 00:17:39,279
IT'S VERY SHORT THE HISTORY OF
LEARNING ABOUT PLACES THAT

339
00:17:39,279 --> 00:17:41,010
REMIND US OF HOME.

340
00:17:41,010 --> 00:17:45,980
IN 2011, WE FOUND THE FIRST
PLANET THAT WAS EARTH SIZE AND

341
00:17:45,980 --> 00:17:50,000
WAS ORBITING ANOTHER STAR LIKE
THE SUN.

342
00:17:50,000 --> 00:17:54,700
AND THEN IN LATER THAT YEAR, WE
DISCOVERED THE FIRST PLANET IN

343
00:17:54,700 --> 00:17:55,740
THE HABITUAL ZONE.

344
00:17:55,740 --> 00:17:57,230
JUST A FEW YEARS AGO.

345
00:17:57,230 --> 00:18:02,649
JUST FOUR YEARS AGO WE FOUND
22-B FOR THE FIRST TIME ORBITING

346
00:18:02,649 --> 00:18:04,480
THE HABITUAL ZONE.

347
00:18:04,480 --> 00:18:06,210
PROBABLY MAYBE A WATER WORLD.

348
00:18:06,210 --> 00:18:10,420
MAYBE HAS SOME HYDROGEN AND
HELIUM GAS.

349
00:18:10,420 --> 00:18:11,830
IT'S DIFFICULT TO TELL.

350
00:18:11,830 --> 00:18:17,400
IT CERTAINLY UNLIKE THE SIMILAR
TO OUR ENVIRONMENT ON EARTH.

351
00:18:17,400 --> 00:18:20,299
AND THEN LAST YEAR WE FOUND
186-S.

352
00:18:20,299 --> 00:18:23,440
THAT WAS A BIG MOMENT, A BIG
DISCOVERY.

353
00:18:23,440 --> 00:18:27,320
LATER THIS YEAR, EARLIER THIS
YEAR IN JULY THIS YEAR, WE TOOK

354
00:18:27,320 --> 00:18:31,639
THE FIRST PLANET THAT
APPROXIMATELY EARTH SIZE AND

355
00:18:31,639 --> 00:18:33,980
ORBIT A STAR LIKE THE SUN.

356
00:18:33,980 --> 00:18:38,629
THIS IS KEPLER 452-B.

WE WERE VERY EXCITED AND SO WAS

357
00:18:38,629 --> 00:18:43,100
THE MEDIA AND REPORTED VERY
HEAVILY.

358
00:18:43,100 --> 00:18:47,410
SO WHAT THE DIFFERENCE IS AND
WHY WE'RE EXCITED ABOUT 452-B

359
00:18:47,410 --> 00:18:52,289
THIS IS THE PLANET ORBITING A
STAR LIKE OUR SUN AND THE ONE I

360
00:18:52,289 --> 00:18:53,750
SHOWED YOU EARLIER.

361
00:18:53,750 --> 00:18:57,370
IT'S BECAUSE THEY ORBIT VERY
DIFFERENT TYPES OF STARS AND

362
00:18:57,370 --> 00:19:01,500
DIFFERENT ENVIRONMENTS, THIS IS
A PLAN THAET IS A LITTLE BIT

363
00:19:01,500 --> 00:19:02,500
BIGGER THAN EARTH.

364
00:19:02,500 --> 00:19:03,690
IT'S ABOUT 60% BIGGER.

365
00:19:03,690 --> 00:19:09,309
IT ORBITS OUR EARTH LIKE THE
SUN.

366
00:19:09,309 --> 00:19:12,149
NOW THEY'RE EARTH SIZE AND
ORBITING IN THE HABITUAL ZONE.

367

00:19:12,149 --> 00:19:13,480
THAT IS WONDERFUL.

368
00:19:13,480 --> 00:19:15,259
THAT IS ABSOLUTELY AMAZING.

369
00:19:15,259 --> 00:19:16,259
NOW WE KNOW THAT.

370
00:19:16,259 --> 00:19:21,919
IN ARE ALSO PLACES LIKE 186-S
THAT ARE THE HABITUAL ZONE OF

371
00:19:21,919 --> 00:19:22,919
SMALLER STARS.

372
00:19:22,919 --> 00:19:24,450
AND SMALLER STARS ARE VERY
EXCITING.

373
00:19:24,450 --> 00:19:28,889
MOST OF OUR GALAXY IS MADE OF UP
SMALL, COOL RED DWARFS.

374
00:19:28,889 --> 00:19:33,380
ABOUT 70% OF THE STARS IN OUR
GALAXY ARE MADE OF SMALL STARS.

375
00:19:33,380 --> 00:19:36,299
SO IF WE'RE GOING TO LOOK FOR
LIFE AND IF WE'RE GOING TO LOOK

376
00:19:36,299 --> 00:19:41,090
FOR PLACES OUT THERE, THE MOST
COMMON PLANET, MOST COMMONPLACE

377
00:19:41,090 --> 00:19:45,490
TO HAVE WATER ARE GOING TO BE
THESE PLANET ORBITING SMALL,

378
00:19:45,490 --> 00:19:47,159
COOL STARS.

379
00:19:47,159 --> 00:19:51,559
SO WE'VE GONE FROM KNOWING THAT
THERE ARE PLANETS, OR PLANETS WE

380
00:19:51,559 --> 00:19:56,139
KNOW VERY LITTLE ABOUT THEM AND
PLANETS EVERYWHERE.

381
00:19:56,139 --> 00:20:00,320
HOWEVER, MOST OF THE PLANETS
FOUND BY THE MISSION ARE

382
00:20:00,320 --> 00:20:01,640
RELATIVELY SMALL.

383
00:20:01,640 --> 00:20:03,640
RELATIVELY FAR AWAY.

384
00:20:03,640 --> 00:20:05,860
AND DIFFICULT TO FOLLOW UP.

385
00:20:05,860 --> 00:20:08,019
SO NOW WE WANT TO BUILD A NEW
MISSION.

386
00:20:08,019 --> 00:20:12,980
NASA'S NEXT BIG MISSION IS KNOWN
AS TEST.

387
00:20:12,980 --> 00:20:16,700
NOW WE KNOW PLANETS ARE ORBITING
MOST STARS.

388
00:20:16,700 --> 00:20:18,580
LET'S LOOK AT OUR NEAREST
NEIGHBORS.

389
00:20:18,580 --> 00:20:20,090
LET'S LOOK AT STARS NEARBY.

390
00:20:20,090 --> 00:20:23,679
STARS WE CAN FOLLOW UP FROM THE
GROUND AND FROM OTHER SPACE

391
00:20:23,679 --> 00:20:26,720
MISSIONS MUCH MORE EASILY THAN
THE FAINT DISTANT STARS WE DID

392
00:20:26,720 --> 00:20:28,480
WITH THIS ONE.

393
00:20:28,480 --> 00:20:30,909
THIS IS WHAT TEST IS GOING TO
DO.

394
00:20:30,909 --> 00:20:33,700
IT WILL LAUNCH IN 2017.

395
00:20:33,700 --> 00:20:39,869
TO DEMONSTRATE THAT, LET ME SHOW
WLAU IS BASICALLY A TOP DOWN

396
00:20:39,869 --> 00:20:43,749
VIEW WITH US IN THE CENTER AND
THEN THE CIRCLES SHOWING YOU AS

397
00:20:43,749 --> 00:20:48,960
YOU ZOOM OUT OF OUR GALAXY, ZOOM
OUT FROM US WHAT OUR LOCAL

398
00:20:48,960 --> 00:20:52,009
NEIGHBORHOOD STAR IS GOING TO BE
LIKE AND HOW WE DETECT PLANETS.

399
00:20:52,009 --> 00:20:56,320

YOU'LL SEE SEVERAL DOTS THAT
SHOW WHERE WE EXPECT TO SEE

400
00:20:56,320 --> 00:20:58,230
PLANETS FROM TESS.

401
00:20:58,230 --> 00:21:04,629
YOU SEE THEY'RE VERY DIFFERENT
POPULATIONS.

402
00:21:04,629 --> 00:21:05,629
LET ME ZOOM OUT HERE.

403
00:21:05,629 --> 00:21:07,210
ALL THE RED DOTS ARE TESS.

404
00:21:07,210 --> 00:21:10,139
THESE ARE PLANETS WE'RE GOING TO
FIND WITH THE FUTURE TELESCOPE,

405
00:21:10,139 --> 00:21:12,360
NEAREST NEIGHBORS, ONCE WE CAN
FOLLOW EASILY.

406
00:21:12,360 --> 00:21:17,549
THEN YOU SEE THEY LOOKED AT ONE
PART OF THE SKY.

407
00:21:17,549 --> 00:21:21,740
YOU SEE THAT CONE COMING OUT
FROM THAT REGION FROM US.

408
00:21:21,740 --> 00:21:24,809
THEY FOUND ALL THE OTHER
PLANETS.

409
00:21:24,809 --> 00:21:27,429
SO THERE ARE PLANETS EVERYWHERE.

410

00:21:27,429 --> 00:21:33,259
TESS IS GOING TO FIND THEM AND
HOPEFULLY ONE DAY UNDERSTAND

411
00:21:33,259 --> 00:21:36,100
WHAT THEY'RE MADE OF.

412
00:21:36,100 --> 00:21:39,390
WE HAVE THIS BEAUTIFUL CONE
GOING OUT INTO THE GALAXY.

413
00:21:39,390 --> 00:21:47,690
AND THEN ON THE FURTHER OUT ON
THE LONGER TERM PROSPECT, WE

414
00:21:47,690 --> 00:21:51,450
DETECT PLANETS RIGHT NOW BY
LOOKING FOR PROXY METHODS.

415
00:21:51,450 --> 00:21:55,259
WE LOOK FOR PLANETS BLOCKING
STAR LIGHT, PRIMARILY NASA.

416
00:21:55,259 --> 00:22:00,679
BUT WHAT WE REALLY WANT TO DO IS
IMAGE THE PLANETS THEMSELVES.

417
00:22:00,679 --> 00:22:01,999
DIRECTLY IMAGING OF PLANETS.

418
00:22:01,999 --> 00:22:05,470
THIS IS SOMETHING WE CAN DO FOR
A SMALL NUMBER OF GIANT PLANETS

419
00:22:05,470 --> 00:22:07,360
RIGHT NOW.

420
00:22:07,360 --> 00:22:10,039
ONE DAY HOPEFULLY WHEN YOU KIDS
ARE IN THE AUDIENCE AND MAYBE IN

421
00:22:10,039 --> 00:22:15,340
20 YEARS WE'LL BE ABLE TO IMAGE
PLANETS ORBITING STARS ON THE

422
00:22:15,340 --> 00:22:17,540
EARTH SIDE AND PERHAPS IN THE
HABITUAL ZONES.

423
00:22:17,540 --> 00:22:21,769
THIS IS AN IMAGE HERE SHOWING
YOU HOW WE DIRECTLY IMAGE THE

424
00:22:21,769 --> 00:22:23,240
PLANET AND OUR OWN SOLAR SYSTEM.

425
00:22:23,240 --> 00:22:28,990
THIS IS TAKING AN IMAGE OF
EARTH.

426
00:22:28,990 --> 00:22:29,990
THIS IS EARTH.

427
00:22:29,990 --> 00:22:34,500
THIS IS THE UPDATED IMAGE THAT
WAS TAKEN A COUPLE YEARS AGO.

428
00:22:34,500 --> 00:22:39,119
SO WITH THIS DIRECT IMAGING OF
OTHER PLANETS, WE CAN MUCH MORE

429
00:22:39,119 --> 00:22:42,679
EASILY SEE THE ATMOSPHERES AND
UNDERSTAND WHAT'S GOING ON.

430
00:22:42,679 --> 00:22:44,059
THE TECHNOLOGY IS NOT THERE YET.

431
00:22:44,059 --> 00:22:46,509

I'M LOOKING FORWARD TO THE
FUTURE HOPEFULLY BY THE END OF

432
00:22:46,509 --> 00:22:50,249
MY CAREER WHETHER WE START TO
UNDERSTAND THESE.

433
00:22:50,249 --> 00:22:51,570
OKAY.

434
00:22:51,570 --> 00:22:55,529
WITH THAT, THANKS.

435
00:22:55,529 --> 00:22:58,820
[ APPLAUSE ]
>> I'M SURE WE HAVE SOME

436
00:22:58,820 --> 00:23:05,090
QUESTIONS HERE IN THE AUDIENCE
AND ALSO ON THE NASA NETWORK.

437
00:23:05,090 --> 00:23:08,870
IF ANYONE HERE HAS A QUESTION,
PLEASE COME OVER AND KATIE IS

438
00:23:08,870 --> 00:23:10,010
GOING TO HELP HER WITH.

439
00:23:10,010 --> 00:23:14,340
THAT BUT WE'LL START WITH THE
ONLINE QUESTIONS.

440
00:23:14,340 --> 00:23:17,710
THE ONLINE -- I READ IT, RIGHT?

441
00:23:17,710 --> 00:23:18,760
YEAH.

442
00:23:18,760 --> 00:23:20,059

WHY CAN'T I READ IT?

443
00:23:20,059 --> 00:23:23,879
WHAT FUTURE PROJECTS ARE GEARED
TOWARD THE DISCOVERY OF MORE

444
00:23:23,879 --> 00:23:24,879
EXSO PLANETS?

445
00:23:24,879 --> 00:23:30,789
AND IS THE TELESCOPE ABLE TO
DETECT PLANETARY TRANSITS?

446
00:23:30,789 --> 00:23:31,840
DUSTIN.

447
00:23:31,840 --> 00:23:36,740
>> I'LL ADDRESS THIS ONE A BIT.

448
00:23:36,740 --> 00:23:41,369
SO THE NEXT THING TO DETECT A
PLAN SET ALL ABOUT FINDING OUR

449
00:23:41,369 --> 00:23:44,040
NEAREST NEIGHBORS AND FOLLOWING
UP MUCH MORE EASILY.

450
00:23:44,040 --> 00:23:48,649
YOU'LL HEAR A LITTLE BIT ABOUT
WHY THESE PLAN RETS SPECIAL.

451
00:23:48,649 --> 00:23:52,580
JAMES WEBB, WHILE IT COULD
DETECT TRANCE FIT WE WANTED TO,

452
00:23:52,580 --> 00:23:55,840
JAMES WEBB BUILT A VIEW WHERE IT
LOOKS IS SMALL.

453

00:23:55,840 --> 00:23:59,190
REMEMBER I SAID TRANSIT, YOU
NEED TO BE LINED UP JUST RIGHT.

454
00:23:59,190 --> 00:24:00,889
YOU NEED TO LOOK AT A LOT OF
STARS.

455
00:24:00,889 --> 00:24:03,039
JAM WEBB, YOU DON'T LOOK AT A
LOT OF STARS.

456
00:24:03,039 --> 00:24:04,669
YOU LOOK AT A FEW STARS.

457
00:24:04,669 --> 00:24:08,760
SO WHAT WE'RE GOING TO DO IS
FIND TRANSIT FROM USING THE

458
00:24:08,760 --> 00:24:09,760
TELESCOPE.

459
00:24:09,760 --> 00:24:13,490
WE'RE GOING TO FOLLOW THEM UP
WITH JAMES WEBB TO TRY TO STUDY

460
00:24:13,490 --> 00:24:17,630
ATMOSPHERES, STUDY LIGHT
REFLECTING OFF THESE PLANETS.

461
00:24:17,630 --> 00:24:21,110
PICK THE BEST PLANET AND USE
JAMES WEBB TO LOOK AT THEM.

462
00:24:21,110 --> 00:24:23,409
JAMES WEBB IS ALL ABOUT
FOLLOWING UP RATHER THAN

463
00:24:23,409 --> 00:24:27,580
DISCOVERY.

464
00:24:27,580 --> 00:24:29,500
>> WE HAVE ANOTHER ONLINE
QUESTION.

465
00:24:29,500 --> 00:24:33,870
AND SO FAR NOBODY HERE HAS COME
UP WITH A QUESTION.

466
00:24:33,870 --> 00:24:35,539
WHAT IS THAT QUESTION?

467
00:24:35,539 --> 00:24:39,690
WHAT MUST YOU STUDY TO BECOME A
PERSON WHO STUDIES EXSO PLANETS?

468
00:24:39,690 --> 00:24:40,740
GEOLOGIST?

469
00:24:40,740 --> 00:24:48,330
I WANT TO FOLLOW THIS CAREER
PATH.

470
00:24:48,330 --> 00:24:51,809
>> CAN YOU GO THROUGH A NUMBER
OF DIFFERENT CAREER PATHS TO GET

471
00:24:51,809 --> 00:24:54,009
TO THE STAGE THAT WE ARE RIGHT
NOW.

472
00:24:54,009 --> 00:24:58,669
I STUDIED PLANETARY AND SPACE
PSYCHICS AT UNIVERSITY.

473
00:24:58,669 --> 00:25:01,710
SO I DID KIND OF FOLLOW THE
GEOLOGIST PATH ROUTE.

474

00:25:01,710 --> 00:25:03,330
LOTS OF PEOPLE CAN DO CIVICS.

475
00:25:03,330 --> 00:25:05,769
CAN YOU DO MATH.

476
00:25:05,769 --> 00:25:07,739
YOU CAN GO THROUGH ENGINEERING.

477
00:25:07,739 --> 00:25:09,360
FOLLOW THIS KIND OF CAREER PATH.

478
00:25:09,360 --> 00:25:13,200
REALLY KIND OF SELECT YOUR WAY
THROUGH UNIVERSITY AND THROUGH

479
00:25:13,200 --> 00:25:19,129
SCHOOL TO DO THE SCIENCES AND TO
DO THE CORE THINGS THAT WE

480
00:25:19,129 --> 00:25:20,129
STUDY.

481
00:25:20,129 --> 00:25:21,129
IT'S PHYSICS.

482
00:25:21,129 --> 00:25:22,129
IT'S CHEMISTRY.

483
00:25:22,129 --> 00:25:25,539
AND WITH THE BIOLOGY AS WE'RE
DOING RIGHT NOW, SO WE'RE

484
00:25:25,539 --> 00:25:30,879
LOOKING AT METEORITES, HINTS AT
LIFE, THAT'S DONE THROUGH

485
00:25:30,879 --> 00:25:31,879
BIOLOGY.

486
00:25:31,879 --> 00:25:35,700
SO ALL OF THE SCIENCES, MATHS
AND ENGINEERING SUBJECTS ARE A

487
00:25:35,700 --> 00:25:41,070
PERFECT WAY TO PAVE YOU'RE FIELD
TOWARDS THESE STUDIES.

488
00:25:41,070 --> 00:25:42,850
WE HAVE TIME FOR ONE MORE
QUESTION.

489
00:25:42,850 --> 00:25:45,500
ONE FROM THE AUDIENCE, YES, SIR?

490
00:25:45,500 --> 00:25:46,500
>> HI.

491
00:25:46,500 --> 00:25:50,990
RECENTLY THERE'S BEEN A LOT OF
NEWS ABOUT THIS POTENTIAL THING

492
00:25:50,990 --> 00:25:55,409
OR THE TRANSIT IN FRONT OF --
CAN YOU TALK A LITTLE BIT ABOUT

493
00:25:55,409 --> 00:25:56,409
THAT?

494
00:25:56,409 --> 00:26:00,260
>> THE QUESTION IS ABOUT DYSON'S
SPHERES.

495
00:26:00,260 --> 00:26:06,480
AND THE INFRARED DETECTABILITY
OF VERY ADVANCE CIVILIZATIONS

496
00:26:06,480 --> 00:26:12,669

THAT HAVE SOMEHOW DESTROYED
PLANETARY MASSES AND DISTRIBUTED

497
00:26:12,669 --> 00:26:17,899
IT AROUND THE STARS, HOST STARS
TO COLLECT ALL THE ENERGY FROM

498
00:26:17,899 --> 00:26:22,580
THAT STAR IN ORDER FOR THE
CIVILIZATION TO SURVIVE.

499
00:26:22,580 --> 00:26:25,090
HAVE I DEPICTED IT CORRECTLY?

500
00:26:25,090 --> 00:26:27,429
WELL, YOU HAVE BEEN LOOKING FOR
THEM?

501
00:26:27,429 --> 00:26:28,530
>> SO, YEAH.

502
00:26:28,530 --> 00:26:33,330
IN THE NEWS RECENTLY -- WHAT WAS
ANNOUNCED IS THE STRANGEST STAR

503
00:26:37,030 --> 00:26:34,330
IN OUR GALAXY.

504
00:26:37,030 --> 00:26:39,129
THIS IS AMONGST THE STRANGEST.

505
00:26:39,129 --> 00:26:42,309
WHAT WE SEE IS WE LOOK FOR
TRANSITS.

506
00:26:42,309 --> 00:26:46,869
WHAT WE SAW IS A WHOLE BUNCH OF
THINGS PASSING IN FRONT OF THE

507

00:26:46,869 --> 00:26:48,870
STAR AND THEN NOTHING.

508
00:26:48,870 --> 00:26:53,879
THEN 800 DAYS LATER, SOMETHING
PASSED IN FRONT OF THE STAR.

509
00:26:53,879 --> 00:26:56,379
WE CAN'T EXPLAIN WHAT'S GOING
ON.

510
00:26:56,379 --> 00:26:59,950
WE HAVE SOME IDEAS THAT IT PROPS
COULD BE SOMETHING OR IT COULD

511
00:26:59,950 --> 00:27:02,419
HAVE BEEN TWO PLANETS THAT HIT
EACH OTHER AND YOU SEE

512
00:27:02,419 --> 00:27:03,419
FRAGMENTS.

513
00:27:03,419 --> 00:27:05,480
IT'S NOT CLEAR YET.

514
00:27:05,480 --> 00:27:08,289
THE REASON WHY THERE IS
DISCUSSION OF DYSON SPHERES IS

515
00:27:08,289 --> 00:27:12,530
THE BASICALLY A WHOLE BUNCH OF
DETECTORS OF PHOTO PANELS YOU

516
00:27:12,530 --> 00:27:16,019
PUT AROUND THE STAR IF YOU'RE
WAY MORE ADVANCED THAN WE ARE.

517
00:27:16,019 --> 00:27:20,140
IT'S BECAUSE IT LOOKED A LITTLE
BIT LIKE WHAT YOU MIGHT EXPECT

518
00:27:20,140 --> 00:27:21,140
THESE TO LOOK LIKE.

519
00:27:21,140 --> 00:27:23,610
I MEAN WE HAVE NO IDEA WHAT
ALIEN WAS DO.

520
00:27:23,610 --> 00:27:26,590
BUT IF YOU NEED ENOUGH ENERGY,
MAYBE YOU PUT THESE AROUND.

521
00:27:26,590 --> 00:27:31,730
SO ABSOLUTELY ALIENS IS THE LAST
THING YOU SHOULD GO FOR.

522
00:27:31,730 --> 00:27:34,659
IF YOU RUN OUT OF THEORIES, THEN
YOU MIGHT REACH TO ALIENS.

523
00:27:34,659 --> 00:27:38,649
JUST BECAUSE THAT'S WHAT IT MAY
LOOK LIKE, IT ALSO LOOKS LIKE A

524
00:27:38,649 --> 00:27:41,190
BUNCH OF OTHER THINGS MAY LOOK
LIKE AND ALMOST CERTAINLY GOING

525
00:27:41,190 --> 00:27:42,360
TO BE THOSE THINGS.

526
00:27:42,360 --> 00:27:45,460
THAT DOESN'T MEAN WE SHOULDN'T
KEEP LOOKING.

527
00:27:45,460 --> 00:27:49,010
NONE OF US ARE IN THIS FIELD, I
THINK, WITHOUT US WANTING TO ONE

528

00:27:49,010 --> 00:27:53,099
DAY DETECT LIFE ELSEWHERE IN THE
UNIVERSE.

529
00:27:53,099 --> 00:27:56,340
>> THAT QUESTION IS A REALLY
GOOD SEGUE TO OUR NEXT SPEAKER.

530
00:27:56,340 --> 00:28:03,009
AND NOW WE'RE GOING TO TURN TO
HANNAH RUTH-WAKEFORD FROM

531
00:28:03,009 --> 00:28:10,679
ENGLAND AND SHE IS GOING TO BE
TALKING A LITTLE BIT MORE ABOUT

532
00:28:10,679 --> 00:28:14,700
WHAT DO YOU DO WITH A PLANET
ONCE YOU FOUND IT?

533
00:28:14,700 --> 00:28:16,919
>> GREAT, HI, EVERYBODY.

534
00:28:16,919 --> 00:28:22,129
I CURRENTLY WORK AT NASA'S SPACE
FLIGHT CENTER IN MARYLAND.

535
00:28:22,129 --> 00:28:25,690
SO JUST OUTSIDE OF D.C.
AND WHAT I'M DOING IS I'M

536
00:28:25,690 --> 00:28:29,390
LOOKING TO CHARACTERIZE THESE
TYPES OF PLANETS USING THE

537
00:28:29,390 --> 00:28:31,179
HUBBLE SPACE TELESCOPE.

538
00:28:31,179 --> 00:28:36,759
WHAT I'M DOING IS LOOKINGVAPOR OF THE UPPER

ATMOSPHERES AND REALLY TRYING TO

539
00:28:36,759 --> 00:28:38,190
WORK OUT WHAT THEY MIGHT BE
LIKE.

540
00:28:38,190 --> 00:28:42,350
SO I HAVE A COUPLE OF SLIDES TO
SHOW YOU WHICH IS TAKING YOU

541
00:28:42,350 --> 00:28:45,940
THROUGH HOW WE DO THAT.

542
00:28:45,940 --> 00:28:52,539
HOW THAT INFORMS US WHAT THE
PLANETS MIGHT BE LIKE.

543
00:28:52,539 --> 00:28:56,559
TOM SHOWED YOU THIS PICTURE HERE
OF THE DISTRIBUTION OF PLANETS.

544
00:28:56,559 --> 00:28:59,850
THERE REALLY ARE VERY, VERY
ALIEN PLANETS IN.

545
00:28:59,850 --> 00:29:03,759
THERE NOTHING LIKE WE'RE SEEING
IN OUR OWN SOLAR SYSTEM.

546
00:29:03,759 --> 00:29:06,400
WHAT I'M GOING TO HIGHLIGHT IS
THIS REGION OF PLANETS IN THE

547
00:29:06,400 --> 00:29:07,649
TOP CORNER.

548
00:29:07,649 --> 00:29:10,679
THESE ARE THE HOT JUPITERS.

549

00:29:10,679 --> 00:29:14,609
THEY'RE CALLED HOT JUPITERS
BECAUSE THEY ARE THE SAME SIZE

550
00:29:14,609 --> 00:29:16,980
OR MASS AS JUPITER.

551
00:29:16,980 --> 00:29:23,191
BUT THEY ORBIT THE STARS 20
TIMES CLOSER TO THEM THAN THE

552
00:29:23,191 --> 00:29:25,359
EARTH DOES TO THE SUN.

553
00:29:25,359 --> 00:29:29,630
THAT'S ACTUALLY FOUR TIMES TO
EIGHT TIMES CLOSER THAN EVEN

554
00:29:29,630 --> 00:29:31,440
MURCURY AND OUR OWN SOLAR
SYSTEM.

555
00:29:31,440 --> 00:29:36,759
THEY HAVE INCREDIBLY HOT
ATMOSPHERES.

556
00:29:36,759 --> 00:29:41,029
AND THE WAY THAT WE LOOK AT
THESE ATMOSPHERES IS BY LOOKING

557
00:29:41,029 --> 00:29:43,660
AT THE STAR LIGHT THAT PASSES
THROUGH THEM BEFORE IT REACHES

558
00:29:43,660 --> 00:29:44,660
US.

559
00:29:44,660 --> 00:29:48,720
SO BECAUSE THESE ARE SUCH ALIEN
WORLDS, TO GET THEM YOUR HEAD A

560
00:29:48,720 --> 00:29:52,450
LITTLE BIT, IMAGINE WE SH RUFRPG
THE EARTH DOWN TO THE SIDE OF A

561
00:29:52,450 --> 00:29:53,539
PEA.

562
00:29:53,539 --> 00:29:58,369
NOW ON THIS SCALE, LARGEST
PLANET IN OUR SOLAR SYSTEM,

563
00:29:58,369 --> 00:30:01,570
JUPITER, WOULD BE ABOUT THE SIZE
OF A LARGE ORANGE.

564
00:30:01,570 --> 00:30:06,480
THAT'S 11 TIMES THE WIDTH OF THE
EARTH.

565
00:30:06,480 --> 00:30:10,039
THESE HOT JUPITERS, THESE
PLANETS THAT WE'RE FINDING,

566
00:30:10,039 --> 00:30:13,690
WE'RE DISCOVERING, ORBITING VERY
CLOSE TO THE STARS ARE ON

567
00:30:13,690 --> 00:30:17,379
AVERAGE 1 1/2 TIMES THE SIZE OF
THAT.

568
00:30:17,379 --> 00:30:21,309
SO ABOUT THE SIZE OF A
WATERMELON.

569
00:30:21,309 --> 00:30:25,389
SO THEY'RE VERY LARGE PLANETS
ORBITING VERY CLOSE TO THEIR

570
00:30:25,389 --> 00:30:30,119
STARS AND THEIR ATMOSPHERES ARE
BEING HEATED BY THEIR STARS.

571
00:30:30,119 --> 00:30:33,739
THEY'RE CONSTANTLY BOMBARDED
WITH THE RADIATION FROM THE

572
00:30:33,739 --> 00:30:34,739
STAR.

573
00:30:34,739 --> 00:30:37,489
AND THEY'RE ACTUALLY HOTTER THAN
SITTING UNDER THIS ENGINE OVER

574
00:30:37,489 --> 00:30:40,150
HERE AS IT TAKES OFF.

575
00:30:40,150 --> 00:30:43,700
THEY'RE INCREDIBLY HOT PLACES.

576
00:30:43,700 --> 00:30:47,419
NOW WHEN WE'RE LOOKING AT THESE,
WE'RE LOOKING AT THEM IN

577
00:30:47,419 --> 00:30:48,419
TRANSIT.

578
00:30:48,419 --> 00:30:51,450
SO BECAUSE THEY'RE PASSING IN
FRONT OF THEIR STAR, WHAT WE CAN

579
00:30:51,450 --> 00:30:55,100
DETECT IS STAR LIGHT THAT HAS
SHOWN THROUGH THAT ATMOSPHERE

580
00:30:55,100 --> 00:30:56,779
BEFORE IT REACHES US.

581
00:30:56,779 --> 00:30:59,139
AND WE SEE SOMETHING LIKE THIS
ON THE EARTH.

582
00:30:59,139 --> 00:31:02,419
THIS IS AN IMAGE TAKEN FROM THE
INTERNATIONAL SPACE STATION IN

583
00:31:02,419 --> 00:31:04,059
ORBIT AROUND OUR PLANET.

584
00:31:04,059 --> 00:31:07,260
AND IT IS ABLE TO LOOK THROUGH
THE EDGE OF THE EARTH'S

585
00:31:07,260 --> 00:31:08,260
ATMOSPHERE.

586
00:31:08,260 --> 00:31:09,700
AND THAT'S WHAT YOU'RE SEEING
HERE.

587
00:31:09,700 --> 00:31:12,691
IF YOU LOOK THROUGH THE EDGE OF
THE EARTH'S ATMOSPHERE, YOU CAN

588
00:31:12,691 --> 00:31:15,389
SEE THE STAR LIGHT WHICH IS
PASSED THROUGH IT BEFORE

589
00:31:15,389 --> 00:31:17,669
REACHING THE CAMERA.

590
00:31:17,669 --> 00:31:20,970
AND WE ARE DOING THE SAME THING
WITH THESE ALIEN PLANETS.

591
00:31:20,970 --> 00:31:24,169
WE'RE LOOKING FOR THAT VERY

SMALL AMOUNT OF STAR LIGHT WHICH

592
00:31:24,169 --> 00:31:29,029
PASSED THROUGH THE ATMOSPHERE
BEFORE IT REACHES OUR TELESCOPE.

593
00:31:29,029 --> 00:31:34,710
AND TO PUT THIS ON SCALE, THIS
IS A SCALE DIAGRAM OF A STAR

594
00:31:34,710 --> 00:31:38,899
THAT WE'RE LOOKING AT AND A HOT
JUPITER, A REALLY BIG PLANET

595
00:31:38,899 --> 00:31:43,340
ORBITING IT AND AROUND THAT
BLACK CIRCLE IS A BLUE

596
00:31:43,340 --> 00:31:47,889
ATMOSPHERE TO SCALE OF WHAT
WE'RE ABLE TO IMAGE.

597
00:31:47,889 --> 00:31:50,470
YOU CAN VERY, VERY, BARELY SEE
THAT.

598
00:31:50,470 --> 00:31:53,860
BUT WE'RE ABLE TO DETECT THE
LIGHT THAT HAS PASSED THROUGH

599
00:31:53,860 --> 00:31:57,259
THIS VERY, VERY SMALL AMOUNT OF
ATMOSPHERE COMPARED TO THE SIZE

600
00:31:57,259 --> 00:31:59,649
OF THE PLANET.

601
00:31:59,649 --> 00:32:02,690
AND THE WAY THAT WE DO THAT IS
IN THE TRANSIT.

602
00:32:02,690 --> 00:32:07,629
AND WHAT WE DO IS WE BREAK UP
THAT TRANSIT LIGHT THAT, LIGHT

603
00:32:07,629 --> 00:32:11,009
FROM THE STAR INTO ALL OF ITS
DIFFERENT COLORS.

604
00:32:11,009 --> 00:32:13,840
IF WE BREAK UP THOSE -- THAT
LIGHT INTO THE DIFFERENT COLORS,

605
00:32:13,840 --> 00:32:18,019
IF WE JUST VIEW IT IN THE BLUE,
WE GET A MEASUREMENT OF THE

606
00:32:18,019 --> 00:32:21,460
AMOUNT OF LIGHT BEING BLOCKED
OUT BY THAT PLANET.

607
00:32:21,460 --> 00:32:26,399
IF WE THEN MEASURE IT ACROSS ALL
OF THE DIFFERENT COLORS, THE

608
00:32:26,399 --> 00:32:33,669
GREEN, ORANGE, RED, WE CAN BUILD
UP A PICTURE OF HOW THE SIZE,

609
00:32:33,669 --> 00:32:38,179
THE RELATIVE SIZE OF WHAT WE'RE
SEEING OF THE PLANET IS CHANGING

610
00:32:38,179 --> 00:32:41,210
BECAUSE DIFFERENT PARTS OF THE
ATMOSPHERE, DIFFERENT THINGS IN

611
00:32:41,210 --> 00:32:46,429
THE ATMOSPHERE LIKE WATER VAPOR
OR HERE SODIUM AND POTASSIUM ARE

612
00:32:46,429 --> 00:32:48,970
BLOCKING OUT THAT LIGHT.

613
00:32:48,970 --> 00:32:51,749
SO IF THEY'RE BLOCKING OUT THAT
LIGHT IN THE ATMOSPHERE, IT

614
00:32:51,749 --> 00:32:54,590
LOOKS LIKE IT'S BIGGER.

615
00:32:54,590 --> 00:32:58,359
SO IF WE BUILD UP THIS PICTURE
OF THESE PLANETS OVER THESE

616
00:32:58,359 --> 00:33:02,230
DIFFERENT COLORS, WE CAN GET AN
IDEA OF WHAT IS IN THE

617
00:33:02,230 --> 00:33:05,529
ATMOSPHERE ABSORBING THAT LIGHT.

618
00:33:05,529 --> 00:33:08,869
SO WHEN WE'RE LOOKING AT THE
EARTH'S ATMOSPHERE, LOTS OF

619
00:33:08,869 --> 00:33:13,409
BEAUTIFUL WATER VAPOR CLOUDS,
THAT WATER VAPOR BLOCKS THE

620
00:33:13,409 --> 00:33:18,269
SUN'S LIGHT DOWN TO THE SURFACE
OF THE EARTH HERE JUST BEYOND

621
00:33:18,269 --> 00:33:20,359
THE RED PART OF WHAT OUR EYES
CAN SEE.

622
00:33:20,359 --> 00:33:24,629

SO IF WE LOOK AT THESE PLANETS
IN THAT REGION, JUST BEYOND THAT

623
00:33:24,629 --> 00:33:28,809
RED PART OF WHAT OUR EYES CAN
SEE, AND WE SEE THAT PLANET

624
00:33:28,809 --> 00:33:33,169
APPEARS TO BE BIGGER, THEN WE
CAN DETERMINE THAT THERE IS

625
00:33:33,169 --> 00:33:36,889
WATER VAPOR IN THAT PLANET'S
ATMOSPHERE BLOCKING THAT

626
00:33:36,889 --> 00:33:39,450
SUNLIGHT, THAT STAR LIGHT FROM
US.

627
00:33:39,450 --> 00:33:43,970
SO THIS IS AN IDEA OF WHAT
DIFFERENT TYPES OF PLANETS MAY

628
00:33:43,970 --> 00:33:47,479
HAVE IN THEIR ATMOSPHERE ACROSS
THE OPTICAL AND INTO THIS

629
00:33:47,479 --> 00:33:51,359
INFRARED REGION WHERE THIS WATER
VAPOR AND YOU CAN SEE ON THE

630
00:33:51,359 --> 00:33:57,899
VERY, VERY HOT PLANETS IS
BLOCKING THIS LIGHT.

631
00:33:57,899 --> 00:34:02,259
AND WE'RE ABLE TO DETECT THESE
DIFFERENT MODULES FROM THE

632
00:34:02,259 --> 00:34:04,549

ATMOSPHERE BY HOW MUCH LIGHT
THEY'RE BLOCKING AND WHERE

633
00:34:04,549 --> 00:34:06,980
THEY'RE BLOCKING IT.

634
00:34:06,980 --> 00:34:13,280
NOW I'VE GOT SOME EXAMPLES HERE
OF A SIMULATED SUNSET IN THE

635
00:34:13,280 --> 00:34:15,780
ATMOSPHERE, ONE OF THE HOT
JUPITERS.

636
00:34:15,780 --> 00:34:19,200
THIS IS WHAT THE SUNSET WOULD
LOOK LIKE FROM THIS PLANET.

637
00:34:19,200 --> 00:34:22,440
BECAUSE WE MEASURED WHAT THE
DIFFERENCE THINGS IN THE

638
00:34:22,440 --> 00:34:25,520
ATMOSPHERE ARE THAT ARE BLOCKING
THAT LIGHT.

639
00:34:25,520 --> 00:34:28,490
AND THIS IS THE MEASUREMENT THAT
WE'VE TAKEN WITH THE HUBBLE

640
00:34:28,490 --> 00:34:30,270
SPACE TELESCOPE.

641
00:34:30,270 --> 00:34:33,539
AND THIS SHOWS US THAT IT IS
SCATTERING LOTS OF BLUE LIGHT

642
00:34:33,539 --> 00:34:35,720
JUST LIKE THE EARTH'S ATMOSPHERE
DOES.

643
00:34:35,720 --> 00:34:38,679
IT'S SCATTERING LOTS OF LIGHT,
THEN IT'S GOING TO APPEAR VERY

644
00:34:38,679 --> 00:34:41,149
RED IN SUNSET.

645
00:34:41,149 --> 00:34:44,971
AND IT'S MUCH, MUCH BIGGER THAN
THE EARTH'S SUNSET WHICH YOU CAN

646
00:34:44,971 --> 00:34:48,470
SEE IN THE BOTTOM CORNER BECAUSE
IT IS SO MUCH CLOSER TO THE

647
00:34:48,470 --> 00:34:49,470
STAR.

648
00:34:49,470 --> 00:34:53,200
THE CLOSER IT, IS THE BIGGER THE
STAR APPEARS TO BE IN ITS SKY.

649
00:34:53,200 --> 00:34:57,289
SO YOU CAN SEE ALL OF THE COLORS
OF THE SUNSET ACROSS THE DISK OF

650
00:34:57,289 --> 00:35:00,100
THE STAR BECAUSE IT'S SO CLOSE.

651
00:35:00,100 --> 00:35:04,130
BUT HERE ARE REALLY ALIEN
SUNSET.

652
00:35:04,130 --> 00:35:09,349
THIS IS A SUNSET ON A PLANET
CALLED HG 209458 B.

653
00:35:09,349 --> 00:35:12,859

VERY FANCY NAME.

654
00:35:12,859 --> 00:35:17,490
THIS IS A VERY ALIEN GREEN
SUNSET BECAUSE IT'S GOT LOTS OF

655
00:35:17,490 --> 00:35:19,910
SODIUM IN ITS ATMOSPHERE.

656
00:35:19,910 --> 00:35:22,710
THE SODIUM STREET LAMP YOU SEE
OUTSIDE ARE ORANGE.

657
00:35:22,710 --> 00:35:25,150
THIS HAS GOT SODIUM IN THE
ATMOSPHERE, IT'S BLOCKING OUT

658
00:35:25,150 --> 00:35:26,150
THOSE COLORS.

659
00:35:26,150 --> 00:35:29,430
SO IF IT IS ABSORBING THE
COLORS, YOU'LL SEE ALL OF THE

660
00:35:29,430 --> 00:35:31,099
OTHER COLORS.

661
00:35:31,099 --> 00:35:34,150
YOU'RE GOING TO BE SEEING THESE
BLUES AND THESE GREENS.

662
00:35:34,150 --> 00:35:38,970
AND, AGAIN, THE EARTH'S SUNSET
IN THE CORNER THERE TO SCALE.

663
00:35:38,970 --> 00:35:42,210
AND ANOTHER REALLY STRANGE
PLANET THAT WE LOOK AT THIS IS

664

00:35:42,210 --> 00:35:47,720
WHAT IS 12-B AND IT ORBITS THE
STAR IN JUST OVER A DAY.

665
00:35:47,720 --> 00:35:52,610
THE YEAR JUST A BIT LONGER THAN
OUR DAYS HERE ON EARTH.

666
00:35:52,610 --> 00:35:54,690
IT'S VERY CLOSE TO ITS STAR.

667
00:35:54,690 --> 00:35:57,819
YOU CAN SEE IT MUCH, MUCH BIGGER
IN THE SKY.

668
00:35:57,819 --> 00:35:59,960
IT'S GOT A VERY GRAY SUNSET.

669
00:35:59,960 --> 00:36:02,470
IT'S A VERY CLOUDY PLANET.

670
00:36:02,470 --> 00:36:07,250
LOTS OF VERY, VERY HOT MOLTEN
MATERIAL IN THE ATMOSPHERE.

671
00:36:07,250 --> 00:36:09,780
WHICH IS SCATTERING ALL
DIFFERENT COLORS OF LIGHT.

672
00:36:09,780 --> 00:36:16,290
SO IT BE A VERY GRAY SCALE
SUNSET.

673
00:36:16,290 --> 00:36:20,570
THESE ARE THE ACTUAL DATA POINTS
THAT WE'RE GETTING FROM HUBBLE.

674
00:36:20,570 --> 00:36:25,089
SO LET'S GO BACK TO OUR FRUIT
BASKET OF PLANETS.

675
00:36:25,089 --> 00:36:28,980
WE WANT TO BE LOOKING AT THESE
EARTH LIKE PLANETS AND TALKING

676
00:36:28,980 --> 00:36:33,760
ABOUT THESE PLANETS WHICH ARE
TWO-TIME THE SIZE OF THE EARTH.

677
00:36:33,760 --> 00:36:36,490
SO OUR LITTLE BLUE PLANET.

678
00:36:36,490 --> 00:36:40,450
WE'RE DETECTING THE OTHER
PLANETS WE DON'T SEE IN THE

679
00:36:40,450 --> 00:36:41,450
SOLAR SYSTEM.

680
00:36:41,450 --> 00:36:46,620
THE NEPTUNE 4 EARTH SIZE PLANETS
AND SMALLER.

681
00:36:46,620 --> 00:36:50,000
AND THESE KIND OF GO UP TO ABOUT
THE SIZE OF AN APPLE.

682
00:36:50,000 --> 00:36:53,460
SO THIS IS OUR FAMILY OF PLANETS
THAT WE'RE DISCOVERING IN OUR

683
00:36:53,460 --> 00:36:54,830
GALAXY.

684
00:36:54,830 --> 00:36:59,340
THESE EARTH SIZE ONES TO THESE
SUPER EARTHS, THE TWO-TIME THE

685
00:36:59,340 --> 00:37:04,619

SIZE TO SIX TIMES THE SIZE AND
THEN THESE JUPITERS AND HOT

686
00:37:04,619 --> 00:37:05,619
JUPITERS.

687
00:37:05,619 --> 00:37:09,340
IT'S A HUGE RANGE OF PLANETS OUT
THERE THAT ARE NOTHING LIKE WHAT

688
00:37:09,340 --> 00:37:11,569
WE'VE GOT AT HOME.

689
00:37:11,569 --> 00:37:13,700
WHEN WE'VE GOT PLANETS IN OUR
SOLAR SYSTEM, WE CAN THROW

690
00:37:13,700 --> 00:37:14,700
THINGS AT THEM.

691
00:37:14,700 --> 00:37:18,020
AND THAT'S WHAT WE'RE FANTASTIC
AT DOING.

692
00:37:18,020 --> 00:37:19,020
SEE WHAT WE CAN GET.

693
00:37:19,020 --> 00:37:20,640
WE CAN'T DO THAT WITH THESE.

694
00:37:20,640 --> 00:37:22,430
SO WE HAVE TO LOOK.

695
00:37:22,430 --> 00:37:26,240
WHAT WOULD WE EXPECT LIFE TO BE?

696
00:37:26,240 --> 00:37:30,170
WHAT IN THE ATMOSPHERE IS GOING
TO TELL US THAT THERE'S LIFE?

697
00:37:30,170 --> 00:37:33,040
AND WE'RE LOOKING AT THESE HOT
JUPITERS WHERE WE GOT A HUGE

698
00:37:33,040 --> 00:37:37,230
EXTENSION OF THE ATMOSPHERE DOWN
TO THE SUPER EARTHS.

699
00:37:37,230 --> 00:37:38,579
THEY'RE MUCH SMALLER.

700
00:37:38,579 --> 00:37:41,289
THERE SEARCH LESS ATMOSPHERE.

701
00:37:41,289 --> 00:37:45,530
SO IT'S MUCH, MUCH HARDER TO DO
BECAUSE LESS LIGHT IS ABLE TO

702
00:37:45,530 --> 00:37:49,480
PASS THROUGH THAT ATMOSPHERE
COMPARED TO THE REALLY, REALLY

703
00:37:49,480 --> 00:37:51,569
EXPANDED PLANETS.

704
00:37:51,569 --> 00:37:54,640
SO WE'VE GOT ALL OF THESE
TELESCOPES AT OUR DISPOSAL.

705
00:37:54,640 --> 00:37:57,530
IN THE FUTURE, TECH WILL FIND US
MORE AND MORE PLANETS THAT WE

706
00:37:57,530 --> 00:38:00,780
CAN FOLLOW UP AS TOM SAID AND
JAMES WEBB SPACE TELESCOPE IS

707
00:38:00,780 --> 00:38:02,420

GOING TO ALLOW US TO
CHARACTERIZE THEM.

708
00:38:02,420 --> 00:38:04,920
LOOK AT THAT ATMOSPHERE.

709
00:38:04,920 --> 00:38:07,750
SEE WHAT THEY MIGHT BE MADE UP
OF.

710
00:38:07,750 --> 00:38:13,119
SO, BACK TO OUR OLD VOYAGER 2
PALE BLUE DOT.

711
00:38:13,119 --> 00:38:17,210
THIS IS WHAT THE EARTH LOOKS
LIKE FROM AFAR.

712
00:38:17,210 --> 00:38:21,020
SUSPENDED IN A SUNBEAM ON A PILE
OF DUST.

713
00:38:21,020 --> 00:38:24,830
IF WE WERE TO LOOK AT WHAT THE
SPECTRUM IS LIKE, LOOK AT WHAT

714
00:38:24,830 --> 00:38:28,750
THE ABSORPTION, WHAT THINGS ARE
BLOCKING THAT LIGHT FOR THE

715
00:38:28,750 --> 00:38:32,770
EARTH, WE SEE SOMETHING VERY
MUCH LIKE THIS.

716
00:38:32,770 --> 00:38:35,280
WHAT DOES THAT MEAN?

717
00:38:35,280 --> 00:38:39,140
WE OUGHT TO KNOW WHAT EACH OF
THOSE DIFFERENT LINES MEAN.

718
00:38:39,140 --> 00:38:41,130
WHAT IS BLOCKING THAT LIGHT?

719
00:38:41,130 --> 00:38:45,210
YOU CAN SEE THERE ARE LOTS OF
DIFFERENT PARTS OF THE

720
00:38:45,210 --> 00:38:48,250
ATMOSPHERE.

721
00:38:48,250 --> 00:38:54,369
SO THIS VEGETATION CAUSES A VERY
SPECIFIC WAVE LENGTHS, COLOR

722
00:38:54,369 --> 00:38:56,619
SIGNATURE IN THE ATMOSPHERE.

723
00:38:56,619 --> 00:39:01,460
THE OZONE AND OXYGEN AND THE
AMOUNT OF WATER VAPOR WE HAVE IN

724
00:39:01,460 --> 00:39:05,690
OUR ATMOSPHERE AND THERE IS ME
SAYING I'M OUTGASSING FROM

725
00:39:05,690 --> 00:39:09,410
VOLCANOS.

726
00:39:09,410 --> 00:39:14,000
SEE IF WE CAN FIND INDICATORS
FOR A BALANCE AND OFF BALANCE SO

727
00:39:14,000 --> 00:39:17,290
WE PRODUCE AND THEY PRODUCE A
LOT OF THINGS.

728
00:39:17,290 --> 00:39:23,050
THAT IS NOT EQUAL TO WHAT WOULD

NATURALLY BE THERE.

729
00:39:23,050 --> 00:39:28,020
SO WE CAN LOOK FOR THE CHANGES,
THESE THINGS THAT ARE NOT IN

730
00:39:28,020 --> 00:39:29,020
BALANCE.

731
00:39:29,020 --> 00:39:32,270
AND WHAT KIND OF LIFE ARE WE
TALKING ABOUT.

732
00:39:32,270 --> 00:39:35,020
LIFE IS INCREDIBLY RESILIENT.

733
00:39:35,020 --> 00:39:40,760
IT WILL TRY AND TRY AND TRY
WHEREVER IT CAN TO EXIST.

734
00:39:40,760 --> 00:39:45,190
THE TYPE OF LIFE WE'LL BE
TALKING ABOUT IS THESE EXTREME

735
00:39:45,190 --> 00:39:46,190
FILES.

736
00:39:46,190 --> 00:39:49,480
THESE THINGS THAT LIVE IN THE
WORST AND MOST HARSHEST PLACES

737
00:39:49,480 --> 00:39:50,480
YOU CAN IMAGINE.

738
00:39:50,480 --> 00:39:54,210
THEY LIVE IN VERY, VERY SALTY
PLACES.

739
00:39:54,210 --> 00:39:59,430

THEY LIVE IN VERY, VERY HOT
PLACES, COLD PLACES, UNDERWATER

740
00:39:59,430 --> 00:40:02,309
AND IN PRESSURE ENVIRONMENTS.

741
00:40:02,309 --> 00:40:07,280
THIS IS FULL IN ANARCTICA.

742
00:40:07,280 --> 00:40:13,859
THIS IS BECAUSE SUBSURFACE
BIOLOGICAL MATERIAL IS BEING

743
00:40:13,859 --> 00:40:19,109
GROWING UNDERNEATH THE ICE AND
THEN IS PUSHED OUT TO DIFFERENT

744
00:40:19,109 --> 00:40:20,109
COLORS.

745
00:40:20,109 --> 00:40:21,690
IT'S A DIFFERENT TYPE OF LIFE
THAN WHAT WE EXPECT.

746
00:40:21,690 --> 00:40:26,109
THERE IS THIS ONE REALLY SPECIAL
ONE CALLED THE HARD TO GRADE.

747
00:40:26,109 --> 00:40:29,609
THE WATER THERE AND IF HE WERE
THIS SIZE, IT WOULD BE

748
00:40:29,609 --> 00:40:30,779
ABSOLUTELY TERRIFYING.

749
00:40:30,779 --> 00:40:32,990
HE IS INCREDIBLY TINY.

750
00:40:32,990 --> 00:40:34,609

INCREDIBLY TINY.

751
00:40:34,609 --> 00:40:41,480
BUT HE IS AN ORGANISM WHICH CAN
SURVIVE EVEN IN SPACE.

752
00:40:41,480 --> 00:40:45,350
AND THEY HAVE BEEN SHOWN TO LAST
TEN DAYS IN HIBERNATION IN

753
00:40:45,350 --> 00:40:46,619
SPACE.

754
00:40:46,619 --> 00:40:51,180
THESE TYPES OF -- THIS TYPE OF
LIFE IS INCREDIBLY RESILIENT.

755
00:40:51,180 --> 00:40:55,819
AND THIS IS WHAT WE MIGHT BE
TALKING ABOUT.

756
00:40:55,819 --> 00:40:59,690
SO WE REALLY JUST NEED TO
IMAGINE ONE OF THE DIFFERENT

757
00:40:59,690 --> 00:41:03,849
PLACES LIFE MIGHT THRIVE, WHERE
MIGHT WE WANT TO EXPLORE NEXT?

758
00:41:03,849 --> 00:41:11,359
WE HAVE BEAUTIFUL TRAVEL POSTERS
TO MARS, TITAN, THE LARGEST MOON

759
00:41:11,359 --> 00:41:14,299
AROUND SATURN HAS A HUGE
ATMOSPHERE.

760
00:41:14,299 --> 00:41:17,319
IT HAS A NICE THICK ATMOSPHERE
WHERE IF YOU SLAPPED YOUR ARM

761
00:41:17,319 --> 00:41:25,829
YOU MIGHT BE ABLE TO FLY.

762
00:41:25,829 --> 00:41:29,680
THESE TYPE OF VERY STRANGE
ORGANISMS MIGHT BE THERE.

763
00:41:29,680 --> 00:41:31,650
WE JUST DON'T KNOW.

764
00:41:31,650 --> 00:41:35,350
BUT THEN ALSO THINK ABOUT THESE
EXSO PLANETS WE'RE DISCOVERING.

765
00:41:35,350 --> 00:41:39,779
THINK ABOUT THE ALIEN WORLDS,
WHAT WE CAN LEARN FROM THE

766
00:41:39,779 --> 00:41:42,930
ATMOSPHERES AND WHERE WE MIGHT
BE GOING IN THE FUTURE.

767
00:41:42,930 --> 00:41:47,089
SOME YOU MIGHT BE ONES THAT ARE
HERE TO DISCOVER THAT EXSO EARTH

768
00:41:47,089 --> 00:41:49,890
AND SOME OF YOU MIGHT BE THE
ONES THAT ARE ABLE TO BUILD US

769
00:41:49,890 --> 00:41:54,119
THE INSTRUMENTS AND THE SHIPS SO
THAT WE CAN ACTUALLY LIVE OUT

770
00:41:54,119 --> 00:41:55,950
THESE TRAVEL POSTER IDEAS.

771
00:41:55,950 --> 00:41:59,369

BUT WE NEED THE FUTURE AND WE
NEED THE ENGINEERS AND THE

772
00:41:59,369 --> 00:42:02,640
SCIENTISTS TO BE WORKING ON
THIS.

773
00:42:02,640 --> 00:42:06,029
AND THERE'S SO MANY THINGS THAT
WE CAN ANSWER ABOUT OURSELVES

774
00:42:06,029 --> 00:42:07,960
AND ABOUT OUR OWN SOLAR SYSTEM.

775
00:42:07,960 --> 00:42:09,109
SO THANK YOU.

776
00:42:09,109 --> 00:42:13,170
ANY QUESTIONS?

777
00:42:13,170 --> 00:42:19,401
[ APPLAUSE ]
>> I'D LIKE TO START WITH

778
00:42:19,401 --> 00:42:25,579
DIALOGUE OR MAYBE A TRIALOGUE
BETWEEN THE THREE OF US ABOUT

779
00:42:25,579 --> 00:42:28,780
THIS INCREDIBLE SET OF
PERSPECTIVES.

780
00:42:28,780 --> 00:42:34,740
I MEAN, 20 YEARS AGO WE COULDN'T
HAVE POSSIBLY HAD THIS

781
00:42:34,740 --> 00:42:37,020
CONVERSATION.

782

00:42:37,020 --> 00:42:41,559
AND WHAT WAS IT THAT MADE A
DIFFERENCE?

783
00:42:41,559 --> 00:42:47,579
NOT ONLY IN DETECTING PLANETS
BUT IN CHARACTERIZING PLANETS OR

784
00:42:47,579 --> 00:42:51,589
BEING ABLE TO CHARACTERIZE THE
ENVIRONMENTS FOR LIFE.

785
00:42:51,589 --> 00:42:59,940
AND I'M JUST WONDERING FROM BOTH
OF YOU AS YOU TRAIN AS STUDENTS

786
00:42:59,940 --> 00:43:05,570
AND SCHOLARS, WHAT WAS IT THAT
EXCITED YOU MOST SAYING YOU CAN

787
00:43:05,570 --> 00:43:08,300
MAKE A CONTRIBUTION TO THIS
FIELD?

788
00:43:08,300 --> 00:43:10,980
NOW SO IT'S SORT OF A COMPLEX
QUESTION.

789
00:43:10,980 --> 00:43:13,980
WHY COULDN'T YOU DO IT MORE THAN
20 YEARS AGO?

790
00:43:13,980 --> 00:43:16,660
WHAT HAPPENED IN THE LAST 20
YEARS THAT CHANGED THINGS?

791
00:43:16,660 --> 00:43:20,900
I KNOW ASTRONOMERS HAVE BEEN
TRYING TO FIND PLANETS AROUND

792

00:43:20,900 --> 00:43:25,130
OTHER STARS FOR MUCH MORE THAN
20 YEARS.

793
00:43:25,130 --> 00:43:28,000
AND I KNOW FOR SURE THAT THEY
THOUGHT THAT THEY HAD FOUND A

794
00:43:28,000 --> 00:43:30,589
FEW PLANETS BY 1950.

795
00:43:30,589 --> 00:43:34,390
AND, YET, ALL OF THOSE PLANETS
THAT THEY THOUGHT THEY FOUND

796
00:43:34,390 --> 00:43:38,119
ONLY TWO OF THEM, OF COURSE, AT
THAT TIME, THEY DIDN'T TURN OUT

797
00:43:38,119 --> 00:43:39,980
TO BE REAL.

798
00:43:39,980 --> 00:43:42,210
AND NOW WE HAVE THOUSANDS.

799
00:43:42,210 --> 00:43:43,460
WHAT HAPPENED IN THE LAST 20
YEARS?

800
00:43:43,460 --> 00:43:49,529
>> WELL, 20 YEARS AGO I WOULDN'T
HAVE DONE THIS BECAUSE I WOULD

801
00:43:49,529 --> 00:43:51,210
HAVE BEEN IN FIRST GRADE.

802
00:43:51,210 --> 00:43:54,690
BUT WHAT'S HAPPENED IS SCIENCE
FICTION IS NOW FACT.

803
00:43:54,690 --> 00:43:56,660
WE DIDN'T HAVE THE PLANETS
BEFORE.

804
00:43:56,660 --> 00:43:59,380
WE DIDN'T HAVE -- IN FACT, THEY
DIDN'T COME UP WITH HOT

805
00:43:59,380 --> 00:44:00,380
JUPITERS.

806
00:44:00,380 --> 00:44:03,890
THEY WERE SO STRANGE.

807
00:44:03,890 --> 00:44:09,619
WE'VE BEEN DISCOVERING THESE AND
DISCOVERING WHAT IMAGINATION CAN

808
00:44:09,619 --> 00:44:12,119
STRETCH TO AT THE SAME TIME.

809
00:44:12,119 --> 00:44:15,960
SO WHEN I WAS DOING MY STUDIES,
I DIDN'T EVEN KNOW ABOUT EXSO

810
00:44:15,960 --> 00:44:17,400
PLANETS IN HIGH SCHOOL.

811
00:44:17,400 --> 00:44:21,490
IT WASN'T PART OF THE CURRICULUM
AT ALL.

812
00:44:21,490 --> 00:44:24,940
AND NOW IT S EVERY SINGLE CHILD
IS BEING BORN IS BORN INTO A

813
00:44:24,940 --> 00:44:27,520
WORLD WHERE THESE PLANETS ARE
KNOWN AND THEY EXIST.

814
00:44:27,520 --> 00:44:31,470
AND THAT DIDN'T HAPPEN 20 YEARS
AGO.

815
00:44:31,470 --> 00:44:35,230
AND THEY'RE BEING TAUGHT, AND
THAT IS SO IMPORTANT, IT'S SO

816
00:44:35,230 --> 00:44:38,180
IMPORTANT THAT THEY ARE BEING
TAUGHT IN SCHOOLS AND PEOPLE

817
00:44:38,180 --> 00:44:42,180
KNOW THAT, YOU KNOW, WE CAN
PLACE OUR SOLAR SYSTEM, WE'RE

818
00:44:42,180 --> 00:44:43,180
TRYING.

819
00:44:43,180 --> 00:44:45,800
TO WE'RE TRYING TO ANSWER THE
BIG QUESTIONS AND SCIENCE IS

820
00:44:45,800 --> 00:44:49,599
ACTUALLY ABLE AND IN A PLACE
WHERE IT CAN ACTUALLY CONTRIBUTE

821
00:44:49,599 --> 00:44:50,849
TO THAT.

822
00:44:50,849 --> 00:44:55,230
SO AS I WAS COMING THROUGH
UNIVERSITY, I WENT THAT'S REALLY

823
00:44:55,230 --> 00:44:56,230
COOL.

824
00:44:56,230 --> 00:44:58,450

I CAN ACTUALLY DO WHAT THEY DO
ON SCIENCE FICTION.

825
00:44:58,450 --> 00:45:00,510
THEY'RE GOING TO OTHER PLANETS.

826
00:45:00,510 --> 00:45:03,599
I'M GOING TO SEE IF THEY'RE
GOING TO PLACE THAT'S CAN EXIST.

827
00:45:03,599 --> 00:45:06,030
AND THAT REALLY EXCITED ME.

828
00:45:06,030 --> 00:45:07,319
>> MARVELOUS.

829
00:45:07,319 --> 00:45:08,349
WHAT IS YOUR EXPERIENCE?

830
00:45:08,349 --> 00:45:12,069
>> I THINK ONE OF THE REASONS
WHY WE CAN FIND PLANETS NOW IS A

831
00:45:12,069 --> 00:45:17,460
SMALL NUMBER OF PIONEERS 20 AND
30 YEARS AGO DARED TO BELIEVE

832
00:45:17,460 --> 00:45:21,260
THERE WERE PLANETS OUT THERE AND
RISKED THEIR CAREERS AND THEIR

833
00:45:21,260 --> 00:45:25,299
REPUTATIONS AND ALSO SPENT MOST
OF THEIR LIFE NOT FINDING

834
00:45:25,299 --> 00:45:28,779
PLANETS BUT BELIEVING THEY'RE
OUT THERE AND JUST WILLING THEM

835

00:45:28,779 --> 00:45:29,779
TO EXIST.

836
00:45:29,779 --> 00:45:31,520
AND THEN THEY WERE FOUND.

837
00:45:31,520 --> 00:45:34,870
ONCE THEY WERE FOUND, ALL OF US
CAN RIDE THAT WAVE OF THERE

838
00:45:34,870 --> 00:45:38,551
BEING PLENTY OF INTEREST AND
MASSIVE INTEREST AND NASA'S

839
00:45:38,551 --> 00:45:41,390
INTEREST AND THE GOVERNMENT
INTEREST AND THE FOUNDATION

840
00:45:41,390 --> 00:45:47,119
SUPPORTING THE WORK.

841
00:45:47,119 --> 00:45:49,760
BUT WITHOUT PEOPLE BELIEVING IT
WE WOULDN'T BE WHERE WE ARE

842
00:45:49,760 --> 00:45:50,760
TODAY.

843
00:45:50,760 --> 00:45:53,369
>> ONE WHAT ARE THE TECHNOLOGY
THAT'S MADE A DIFFERENCE?

844
00:45:53,369 --> 00:45:58,800
WHAT WAS NOT AVAILABLE MORE THAN
20, 30 YEARS AGO THAT IS

845
00:45:58,800 --> 00:46:00,170
AVAILABLE NOW?

846

00:46:00,170 --> 00:46:04,559
NOT ONLY THE TECHNOLOGIES BUT
THE MODEL SET MAYBE.

847
00:46:04,559 --> 00:46:10,060
DO YOU HAVE SOME SORT OF VIEW ON
THAT?

848
00:46:10,060 --> 00:46:11,589
>> CERTAINLY TECHNOLOGY
IMPROVES.

849
00:46:11,589 --> 00:46:16,370
I THINK IT'S A MIND SET TO DO
THIS.

850
00:46:16,370 --> 00:46:22,010
SO ARE PEOPLE PROPOSING MISSIONS
THAT WOULD HAVE DETECTED PLANETS

851
00:46:22,010 --> 00:46:25,869
WAY BEFORE THEY WERE DETECTED,
THERE WASN'T THIS BELIEF THAT

852
00:46:25,869 --> 00:46:26,869
THEY WOULD FIND ANYTHING.

853
00:46:26,869 --> 00:46:28,430
THEY THOUGHT IT WAS TOO RISKY.

854
00:46:28,430 --> 00:46:31,160
ONCE WE KNEW THEY WERE THERE,
THEN WE COULD TAKE THE MUCH

855
00:46:31,160 --> 00:46:34,970
SMALLER RISK OF BUILDING THESE
VERY EXPENSIVE MISSIONS TO FIND

856
00:46:34,970 --> 00:46:36,549
MANY, MANY PLANETS.

857
00:46:36,549 --> 00:46:37,549
>> OKAY.

858
00:46:37,549 --> 00:46:38,660
QUESTION FROM THE AUDIENCE?

859
00:46:38,660 --> 00:46:42,610
>> IN TERMS OF THE TOPOGRAPHY
USED TO DEFINE EXSO PLANETS,

860
00:46:42,610 --> 00:46:44,859
DOES IT COME FROM THE VISUAL
SPECTRUM?

861
00:46:44,859 --> 00:46:49,520
IF IT'S NOT, WHAT OFFERS THE
MOST INSIGHT INTO WHAT THE

862
00:46:49,520 --> 00:46:51,480
PLANETS ARE MADE OF?

863
00:46:51,480 --> 00:46:55,251
>> HE ASKED WHICH PART OF THE
SPECTRUM, WHICH PART OF THAT

864
00:46:55,251 --> 00:46:57,930
COLOR SPECTRUM IS REALLY
IMPORTANT AND WHICH PART WILL

865
00:46:57,930 --> 00:46:59,640
GIVE US THE MOST INFORMATION?

866
00:46:59,640 --> 00:47:02,829
AT THE MOMENT, WE'RE USING THE
HUBBLE SPACE TELESCOPE WHICH

867
00:47:02,829 --> 00:47:03,859
DOES HAVE THE OPTICAL.

868
00:47:03,859 --> 00:47:06,789
IT ALSO HAS THIS NEAR INFRARED
PART.

869
00:47:06,789 --> 00:47:08,520
AND THAT'S CAMERA FREE.

870
00:47:08,520 --> 00:47:11,700
IF YOU'RE HERE TODAY, CAN YOU GO
OUTSIDE AND SEE THE PREVIOUS TO

871
00:47:11,700 --> 00:47:15,740
THE CAMERA 2 WHICH IS USED TO
LOOK AT THE FRAN RED PART WHERE

872
00:47:15,740 --> 00:47:17,750
WATER ABSORPTION OCCURS.

873
00:47:17,750 --> 00:47:22,700
SO MOST OF MY PHD WAS USING THAT
TO LOOK AT WATER ABSORPTION IN

874
00:47:22,700 --> 00:47:23,880
THE UPPER ATMOSPHERE.

875
00:47:23,880 --> 00:47:27,609
IF WE WANT TO GO FURTHER INTO
THE INFRARED, WE'RE USING SPACE

876
00:47:27,609 --> 00:47:29,910
TELESCOPES TO DO THAT.

877
00:47:29,910 --> 00:47:33,970
AND IT HAS TWO BANDS IN THE
INFRARED WHICH WE'RE ABLE TO

878
00:47:33,970 --> 00:47:35,529
LOOK FOR THESE DIFFERENT THINGS.

879
00:47:35,529 --> 00:47:39,250
SO WHAT JAMES WEBB IS GOING TO
DO FOR THE JAMES WEBB TELESCOPE

880
00:47:39,250 --> 00:47:46,210
THAT, IS GOING TO GIVE COVERAGE
FROM THE OPTICAL, THE END OF THE

881
00:47:46,210 --> 00:47:49,569
RED END OF THE OPTICAL ALL THE
WAY UP TO 30 MICONS.

882
00:47:49,569 --> 00:47:54,420
THAT IS HEAT SIGNATURE THAT
WE'VE GOT.

883
00:47:54,420 --> 00:47:57,391
SO THAT'S GOING TO REALLY EXPAND
OUR UNDERSTANDING OF THE

884
00:47:57,391 --> 00:47:58,579
ATMOSPHERES.

885
00:47:58,579 --> 00:48:01,950
WHAT IS ABSORBING THEM IN THIS
CRITICAL REGION?

886
00:48:01,950 --> 00:48:11,750
WE MAY BE ABLE TO TELL WHAT YOU
CLOUDS WE'RE GOING TO LOOK AT.

887
00:48:11,750 --> 00:48:16,190
>> WE HAVE A QUESTION FROM THE
ONLINE AUDIENCE.

888
00:48:16,190 --> 00:48:25,170
AND THAT IS BASED ON YOUR SIZE
ORBIT CHART, EARTH LOOKS TO BE A

889
00:48:25,170 --> 00:48:27,940
COMPLETE OUTLIER.

890
00:48:27,940 --> 00:48:31,680
IS THIS AN INDICATION OF CURRENT
TECHNICAL LIMITATION OF

891
00:48:31,680 --> 00:48:33,280
OBSERVATION?

892
00:48:33,280 --> 00:48:34,880
JOHN?

893
00:48:34,880 --> 00:48:38,599
>> I WOULD SAY IT'S VERY LIKELY
A LIMITED OBSERVATION.

894
00:48:38,599 --> 00:48:43,559
I CAN'T SAY THAT FOR SURE
BECAUSE WE HAVEN'T TRULY FOUND

895
00:48:43,559 --> 00:48:47,869
ANYTHING WE WOULD SAY IS EARTH
ANALOG, A EARTH TWIN.

896
00:48:47,869 --> 00:48:50,730
NOTHING THAT WOULD FILL THAT.

897
00:48:50,730 --> 00:48:54,912
BUT IT'S BECAUSE OF TECHNICAL
LIMITATIONS, IN ORDER TO FIND

898
00:48:54,912 --> 00:48:59,069
EARTH, YOU NEED TO LOOK AT FROM
THE RIGHT ANGLE AT THE RIGHT

899
00:48:59,069 --> 00:49:03,019
STAR FOR YEARS, SEVERAL YEARS ON
END.

900
00:49:03,019 --> 00:49:06,630
AND THEN YOU'D BE ABLE TO HAVE
TO MUDDLE YOUR SPACECRAFT DOING

901
00:49:06,630 --> 00:49:11,099
DURING THAT TIME AND REALLY
DEVELOP YOURAL GA RHYTHMS TO

902
00:49:11,099 --> 00:49:13,880
DETECT THE TINY SIGNALS.

903
00:49:13,880 --> 00:49:15,140
SO THIS IS SOMETHING WE'VE BEEN
DOING.

904
00:49:15,140 --> 00:49:19,040
THE MAIN MISSION LASTED ABOUT
3 1/2 YEARS.

905
00:49:19,040 --> 00:49:23,830
AND THE TIME SINCE 2013, ABOUT
18 MONTHS, WE'VE BEEN REALLY

906
00:49:23,830 --> 00:49:26,700
WORKING ON IMPROVING OUR
UNDERSTANDING OF HOW THE

907
00:49:26,700 --> 00:49:29,170
SPACECRAFT IS WORKING.

908
00:49:29,170 --> 00:49:30,170
IT'S IN SPACE.

909
00:49:30,170 --> 00:49:32,630
YOU CAN'T GO AND MEASURE HOW
SOMEBODY REACTS TO TEMPERATURE.

910
00:49:32,630 --> 00:49:34,230

YOU HAVE TO REMOTE CENSOR IT.

911
00:49:34,230 --> 00:49:36,820
WE'RE IMPROVING OUR REMOTE
SENSING AND MODELS OF HOW

912
00:49:36,820 --> 00:49:38,069
SPACECRAFT WORK.

913
00:49:38,069 --> 00:49:41,190
WE'RE TRYING TO UNDERSTAND WHAT
THE ONBOARD THINGS ARE DOING AND

914
00:49:41,190 --> 00:49:42,330
WHAT IS COMING FROM THE STAR.

915
00:49:42,330 --> 00:49:45,390
NOT HELPING US TO IMPROVE THIS.

916
00:49:45,390 --> 00:49:47,309
>> YOU MIGHT TALK A LITTLE BIT
ABOUT BIAS.

917
00:49:47,309 --> 00:49:50,980
I DON'T MEAN BIAS IN TERMS OF
OUR OPINIONS.

918
00:49:50,980 --> 00:49:55,069
BUT OUR BIAS IN TERMS OF THE
FACT THAT WE TEND TO DISCOVER

919
00:49:55,069 --> 00:50:00,160
PLANETS GOING AROUND OTHER STARS
IN VERY SHORT PERIODS BECAUSE

920
00:50:00,160 --> 00:50:02,040
WE'RE NOT LOOKING FOR VERY LONG
TIME.

921

00:50:02,040 --> 00:50:03,400
YOU BROUGHT UP THAT.

922
00:50:03,400 --> 00:50:06,060
I THINK YOU NEED TO EMPHASIZE
THAT.

923
00:50:06,060 --> 00:50:10,039
THAT SHORT PERIOD TRANSITS,
SHORT PERIOD VARIATIONS AND

924
00:50:10,039 --> 00:50:14,990
RADIO VELOCITY ARE MORE SENSIBLE
THAN LONG PERIODS, THEY TAKE

925
00:50:14,990 --> 00:50:16,569
LONGER TO DISCOVER.

926
00:50:16,569 --> 00:50:20,089
AND WE'VE ONLY BEEN DOING IT FOR
A FEW YEARS, 20 YEARS IS NOT

927
00:50:20,089 --> 00:50:23,230
MUCH IN AT LEAST ASTRONOMICAL
TIME.

928
00:50:23,230 --> 00:50:25,190
YOU HAVE ANY THOUGHTS ABOUT
THAT?

929
00:50:25,190 --> 00:50:28,430
>> WELL, AS YOU SAID, IT'S MUCH
EASIER FOR US TO DETECT THE BIG

930
00:50:28,430 --> 00:50:29,430
PLANETS.

931
00:50:29,430 --> 00:50:32,299
THE BIGGER THE PLANET AND CLOSER
IT IS TO THE STAR, THE MORE

932
00:50:32,299 --> 00:50:34,089
LIGHT IS BLOCKING OUT.

933
00:50:34,089 --> 00:50:37,530
AND ALSO AT THE SAME TIME, THE
CLOSER IT IS TO THE STAR, THE

934
00:50:37,530 --> 00:50:38,859
SMALLER IT IS.

935
00:50:38,859 --> 00:50:42,580
THE SMALLER THE TIME IS BETWEEN
IT PASSING IN FRONT ONE TIME AND

936
00:50:42,580 --> 00:50:44,780
COMING AROUND AND PASSING IN
FRONT AGAIN.

937
00:50:44,780 --> 00:50:49,380
SO WE CAN CONFIRM THAT SOMETHING
IS PERIODICALLY BLOCKING OUT

938
00:50:49,380 --> 00:50:50,799
THAT LIGHT MUCH, MUCH QUICKER.

939
00:50:50,799 --> 00:50:53,580
IF IT TAKES THREE DAYS TO COME
BACK AROUND AND BLOCK OUT THAT

940
00:50:53,580 --> 00:50:57,480
LIGHT AGAIN, WE CAN IN A WEEK
TELL THAT YOU IT'S BLOCKED OUT

941
00:50:57,480 --> 00:51:00,000
THAT LIGHT A NUMBER OF TIME.

942
00:51:00,000 --> 00:51:02,690
AND THAT'S REALLY IMPORTANT FOR

WHEN WE'RE CONFIRMING THESE.

943
00:51:02,690 --> 00:51:07,369
THE MENTION WAS TO STAIR AT THE
STARS FOR THREE YEARS SO THAT

944
00:51:07,369 --> 00:51:11,690
OVER THE THREE YEARS CAN YOU
BUILD UP FREE TRANSIT EVENTS,

945
00:51:11,690 --> 00:51:15,190
FREE PERIODS WHERE IT'S BLOCKING
THAT LIGHT FOR THESE MUCH, MUCH

946
00:51:15,190 --> 00:51:18,799
SMALLER PLANETS IN THESE MUCH,
MUCH WIDER ORBITS.

947
00:51:18,799 --> 00:51:22,289
WE NEED TO CONFIRM THAT THE
THING THAT IS BLOCKING OUT THE

948
00:51:22,289 --> 00:51:24,410
LIGHT IS ACTUALLY GOING TO DO IT
AGAIN.

949
00:51:24,410 --> 00:51:29,280
SO IT IS, THEREFORE, KIND OF
INFORMED TO BE A PLANET ON AN

950
00:51:29,280 --> 00:51:30,970
ORBIT, A REGULAR ORBIT.

951
00:51:30,970 --> 00:51:34,770
SO IT'S EASIER FOR US TO DO THE
BIGGER ONES.

952
00:51:34,770 --> 00:51:38,750
AND THEN AT THE SAME TIME, IT'S
EASIER FOR US TO DETECT SMALLER

953
00:51:38,750 --> 00:51:42,299
PLANETS ORBITING SMALLER STARS.

954
00:51:42,299 --> 00:51:44,549
BECAUSE IT'S A RELATIVE SIZE.

955
00:51:44,549 --> 00:51:47,510
WE'RE MEASURING THE AMOUNT OF
LIGHTS BEING BLOCKED OUT BY THE

956
00:51:47,510 --> 00:51:51,470
RELATIVE SIZE OF THE PLANET TO
THE STAR.

957
00:51:51,470 --> 00:51:53,990
SO IF THE STAR IS SMALLER, THE
AMOUNT, SAME AMOUNT OF LIGHT

958
00:51:53,990 --> 00:51:56,910
THAT IS BEING BLOCKED OUT BY
BIGGER PLANET ON A BIGGER STAR

959
00:51:56,910 --> 00:51:57,910
CAN BE MEASURED.

960
00:51:57,910 --> 00:52:02,279
SO THESE SMALLER STARS ARE VERY
IMPORTANT FOR THESE KINDS OF

961
00:52:02,279 --> 00:52:04,119
STUDIES AS WELL.

962
00:52:04,119 --> 00:52:07,030
BECAUSE WE'RE ABLE TO GET THE
SMALLER AND SMALLER PLANETS.

963
00:52:07,030 --> 00:52:10,059
BUT IF YOU WANT TO LOOK AT ONES

WHERE THE ORBIT IS LONGER, YOU

964
00:52:10,059 --> 00:52:11,869
HAVE TO LOOK AT THE STAR FOR
LONGER.

965
00:52:11,869 --> 00:52:14,440
SO IT TAKES A LOT OF TIME.

966
00:52:14,440 --> 00:52:17,589
>> WHETHER PLANETS STARTED OR AT
LEAST TRANSIT STARTED TO BE

967
00:52:17,589 --> 00:52:20,309
OBSERVES WITH KEPLER, THEY
CALLED THEM PLANETARY

968
00:52:20,309 --> 00:52:21,829
CANDIDATES.

969
00:52:21,829 --> 00:52:25,119
THEY HAD TO WAIT TO SEE IF THE
TRANSIT CAME BACK.

970
00:52:25,119 --> 00:52:26,529
IS THAT RIGHT?

971
00:52:26,529 --> 00:52:27,529
>> THAT'S RIGHT.

972
00:52:27,529 --> 00:52:30,700
YOU KNOW, WE FIND THE PLANETS
THAT ARE EASIEST FIRST AND THEN

973
00:52:30,700 --> 00:52:31,800
THEY GET HARDER.

974
00:52:31,800 --> 00:52:34,609
SO WHEN WE FIRST FIND PLANETS,

WE FIND PLAN THAETS ARE BIG AND

975
00:52:34,609 --> 00:52:35,720
CLOSE TO THEIR STAR.

976
00:52:35,720 --> 00:52:38,609
AND WE WORK ON THOSE FIRST AND
THEN WE GET TO MORE DIFFICULT

977
00:52:38,609 --> 00:52:39,609
ONES.

978
00:52:39,609 --> 00:52:43,650
IT'S NO COINCIDENCE THE TWO BEST
PLANETS WERE FOUND FROM KEPLER

979
00:52:43,650 --> 00:52:45,790
ARE ONE THAT ARE EARTH SIZE.

980
00:52:45,790 --> 00:52:48,900
IT'S IN THE HABITUAL ZONE AND
ORBITS A VERY SMALL STAR.

981
00:52:48,900 --> 00:52:52,480
THE OTHER ONE IS A STAR THAT IS
THE SAME SIZE AS THE SUN.

982
00:52:52,480 --> 00:52:53,829
IT IS A HABITUAL ZONE.

983
00:52:53,829 --> 00:52:55,349
THE PLANET SEARCH BIGGER.

984
00:52:55,349 --> 00:52:58,330
YOU'RE SKIRTING AROUND THIS EDGE
OF WHERE WE CAN FIND THINGS

985
00:52:58,330 --> 00:53:02,789
QUECHLT FIND BIGGER PLANETS

ORBITS SUNLIGHT STARS AND OTHERS

986
00:53:02,789 --> 00:53:04,329
ORBITING SMALLER SIZE.

987
00:53:04,329 --> 00:53:10,090
FINDING THE EARTH'S TRUE TWIN IS
VERY CHALLENGING INDEED.

988
00:53:10,090 --> 00:53:11,670
I BELIEVE WE'RE GOING TO GET
THERE.

989
00:53:11,670 --> 00:53:16,050
BUT IT'S A LOT OF WORK AND WE
HONE OUR SKILLS WHERE WE CAN DO

990
00:53:16,050 --> 00:53:17,350
IT MOST EASILY.

991
00:53:17,350 --> 00:53:18,579
THE SAME WITH ATMOSPHERES.

992
00:53:18,579 --> 00:53:22,430
WE START WITH THE ATMOSPHERES OF
THE GIANT PLANETS AND THEN ONCE

993
00:53:22,430 --> 00:53:25,000
WE CAN DO THIS WE MOVE TO THE
MORE CHALLENGING REGIME OF

994
00:53:25,000 --> 00:53:28,930
SMALLER WORLDS AND PROBING
ATMOSPHERES OF THESE WORLDS.

995
00:53:28,930 --> 00:53:30,890
BUT THAT COMES LATER.

996
00:53:30,890 --> 00:53:32,359

>> I CAN'T WAIT.

997
00:53:32,359 --> 00:53:36,529
WE HAVE A QUESTION FROM THE
ONLINE AUDIENCE.

998
00:53:36,529 --> 00:53:41,000
HAVE EITHER OF THE SPEAKERS BEEN
INSPIRED IN THEIR CAREER PATHS

999
00:53:41,000 --> 00:53:47,359
BY SCIENCE FICTION BOOKS, TV
SHOWS, OR MOVIES, "DR.

1000
00:53:47,359 --> 00:53:49,460
WHO"
PERHAPS?

1001
00:53:49,460 --> 00:53:53,690
THEY BOTH COME FROM A CERTAIN
PART OF THE WORLD.

1002
00:53:53,690 --> 00:53:58,250
>> I WAS INSPIRED WHEN I WAS
GROWING UP BY "STAR GATE."

1003
00:53:58,250 --> 00:54:00,809
I'M KIND OF GOT THAT THERE.

1004
00:54:00,809 --> 00:54:05,780
"STAR GATE" IS A SHOW ABOUT
TRAVELING TO DIFFERENT PLANETS.

1005
00:54:05,780 --> 00:54:09,930
AND THAT REALLY -- I GREW UP IN
THE TIME WHEN THAT WAS ON

1006
00:54:09,930 --> 00:54:10,930
TELEVISION.

1007
00:54:10,930 --> 00:54:13,099
SO THAT REALLY -- AND THERE IS A
FEMALE ON THE SHOW.

1008
00:54:13,099 --> 00:54:15,030
I SAID I CAN DO THAT.

1009
00:54:15,030 --> 00:54:21,060
SO I BASICALLY STOPPED SAYING I
CAN'T DO THAT AND JUST WENT FOR

1010
00:54:21,060 --> 00:54:22,430
IT REALLY.

1011
00:54:22,430 --> 00:54:23,430
>> WONDERFUL.

1012
00:54:23,430 --> 00:54:25,170
>> I MEAN, ABSOLUTELY.

1013
00:54:25,170 --> 00:54:27,450
SCIENCE FICTION INSPIRES OUR
DISCOVERY.

1014
00:54:27,450 --> 00:54:31,799
I THINK THE BEST EXAMPLE OF THIS
WAS THE -- THERE ARE BOOKS

1015
00:54:31,799 --> 00:54:34,230
WRITTEN ABOUT SCIENCE ORBITING
TWO STARS.

1016
00:54:34,230 --> 00:54:35,380
THERE ARE SEVERAL OF THESE.

1017
00:54:35,380 --> 00:54:40,359
POLARIS IS A BOOK IN THE '30s, I
BELIEVE, A LONG TIME AGO.

1018
00:54:40,359 --> 00:54:43,750
LATER ON, THERE WAS "DR.

1019
00:54:43,750 --> 00:54:47,750
WHO"
UNIVERSE AND THEN THE STAR WARS

1020
00:54:47,750 --> 00:54:48,750
UNIVERSE.

1021
00:54:48,750 --> 00:54:51,740
ALL PLANETS ORBITING TWO STARS.

1022
00:54:51,740 --> 00:54:53,460
SO THEY SAID THEY'RE OUT.

1023
00:54:53,460 --> 00:54:57,640
THERE AND A LOT OF SCIENTISTS
SAID WELL MAYBE, PROBABLY NOT.

1024
00:54:57,640 --> 00:54:58,640
IT'S VERY DIFFICULT.

1025
00:54:58,640 --> 00:55:01,210
THAT ENVIRONMENT YOU CAN'T FORM
BANDS AROUND.

1026
00:55:01,210 --> 00:55:02,210
WHO KNOWS?

1027
00:55:02,210 --> 00:55:03,210
GUESS WHAT?

1028
00:55:03,210 --> 00:55:07,869
IN 2012, KEPLER FOUND THE FIRST
PLANET ORBITING A DOUBLE STAR.

1029
00:55:07,869 --> 00:55:10,910

THIS IS TWO STARS AND THEY GO
AROUND THE OUTSIDE.

1030
00:55:10,910 --> 00:55:16,150
THIS IS SCIENCE FICTION
PREDICTING SCIENCE FACT OR

1031
00:55:16,150 --> 00:55:17,150
THAT'S WHAT WE'RE DOING.

1032
00:55:17,150 --> 00:55:19,480
AND I THINK THAT THAT'S THE BEST
EXAMPLE.

1033
00:55:19,480 --> 00:55:22,369
HOPEFULLY THERE WILL BE MORE
SCIENCE FICTION THAT WILL TURN

1034
00:55:22,369 --> 00:55:25,599
TO FACT AS WE GO ALONG.

1035
00:55:25,599 --> 00:55:30,170
>> I REMEMBER AS A STUDENT BEING
ASKED TO TRY TO COMPUTE A STABLE

1036
00:55:30,170 --> 00:55:32,200
ORBIT AROUND TWO STARS.

1037
00:55:32,200 --> 00:55:36,070
AND IT HAD TO BE THE TWO STARS
WERE VERY CLOSE TOGETHER IN THE

1038
00:55:36,070 --> 00:55:37,829
PLANET WAS VERY FAR AWAY.

1039
00:55:37,829 --> 00:55:43,000
BUT WE HAVE ONE MORE QUESTION
FROM THE ONLINE AUDIENCE.

1040

00:55:43,000 --> 00:55:49,740
IN TESS, IS TESS LIKE A LARGER
SCALE KEPLER JUST FOCUSING ON

1041
00:55:49,740 --> 00:55:51,920
CLOSER STARS?

1042
00:55:51,920 --> 00:55:54,790
CAN YOU CHARACTERIZE TESS?

1043
00:55:54,790 --> 00:55:57,820
>> ACTUALLY, TESS IS MORE LIKE A
SMALLER VERSION OF KEPLER IN

1044
00:55:57,820 --> 00:55:59,650
MANY WAYS.

1045
00:55:59,650 --> 00:56:03,849
YOU CAN IMAGINE SOMETHING VERY
BIG HONING IN ON A SMALL AREA OF

1046
00:56:03,849 --> 00:56:04,849
SPACE.

1047
00:56:04,849 --> 00:56:07,190
IF YOU SHRINK IT DOWN, CAN YOU
LOOK AT LARGER AREAS.

1048
00:56:07,190 --> 00:56:09,529
THAT'S WHAT TESS IS.

1049
00:56:09,529 --> 00:56:11,660
YOU SHRINK DOWN THE CAMERAS FROM
KEPLER.

1050
00:56:11,660 --> 00:56:13,710
YOU INCREASE THE FIELD OF VIEW.

1051
00:56:13,710 --> 00:56:15,019

THINK OF A MICROSCOPE.

1052
00:56:15,019 --> 00:56:21,569
YOU ZOOM IN ON A MICROSCOPE.

1053
00:56:21,569 --> 00:56:24,080
YOU GET THE MAXIMUM

1054
00:56:24,080 --> 00:56:25,080
MAGNIFICATION.

1055
00:56:25,080 --> 00:56:27,299
THAT'S SIMPLY SOMEWHAT HOW TESS
WORKS.

1056
00:56:27,299 --> 00:56:33,339
>> I WANT TO THANK BOTH HANNAH
AND -- OH, LORD --

1057
00:56:33,339 --> 00:56:34,559
TOM.

1058
00:56:34,559 --> 00:56:35,779
SORRY.

1059
00:56:35,779 --> 00:56:40,820
FOR A WONDERFUL HOUR HERE,
BECOMING, I THINK, COMFORTABLE

1060
00:56:40,820 --> 00:56:45,410
WITH ALL OF THE PLANETS THAT
EVIDENTLY EXIST OUT THERE.

1061
00:56:45,410 --> 00:56:49,720
AND I CERTAINLY WANT TO THANK
BOEING FOR MAKING THIS PROGRAM

1062
00:56:49,720 --> 00:56:51,030
POSSIBLE.

1063
00:56:51,030 --> 00:56:55,540
AND FOR THE STAFF HERE THAT
KNOWS HOW TO MAKE LOOKING BEYOND

1064
00:56:55,540 --> 00:56:59,079
EARTH OR MOVING BEYOND EARTH
THIS GALLERY A GLOBAL

1065
00:56:59,079 --> 00:57:00,079
PHENOMENON.

1066
00:57:00,079 --> 00:57:04,930
SO THANK YOU VERY MUCH FOR
COMING.