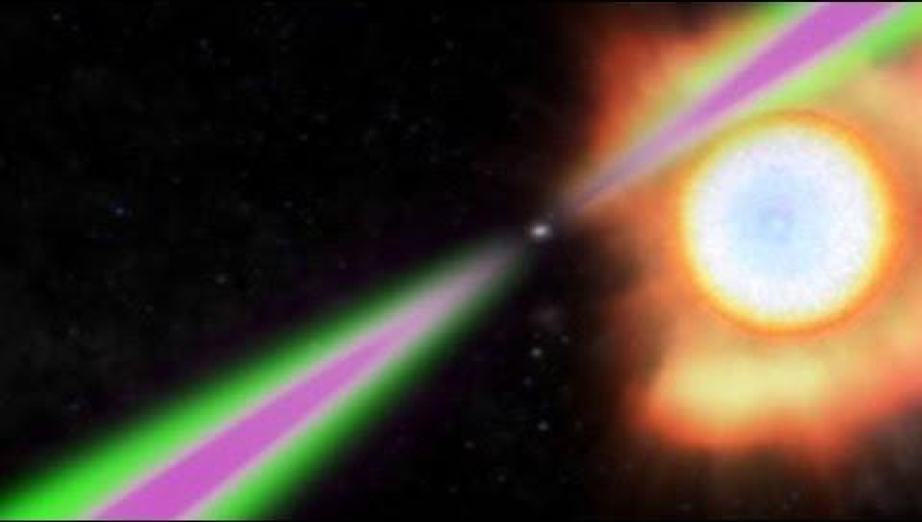

1
00:00:01,630 --> 00:00:11,030
[Music]

2
00:00:15,669 --> 00:00:13,030
when a massive star explodes as a

3
00:00:18,230 --> 00:00:15,679
supernova its core may be crushed into

4
00:00:21,990 --> 00:00:18,240
one of two types of compact remnant a

5
00:00:24,310 --> 00:00:22,000
black hole or a neutron star

6
00:00:26,630 --> 00:00:24,320
neutron stars are the size of a city but

7
00:00:28,870 --> 00:00:26,640
contain more mass than our sun

8
00:00:31,029 --> 00:00:28,880
they rotate rapidly host powerful

9
00:00:33,190 --> 00:00:31,039
magnetic fields and produce beams of

10
00:00:34,229 --> 00:00:33,200
radiation that emit a wide range of

11
00:00:36,470 --> 00:00:34,239
energy

12
00:00:38,709 --> 00:00:36,480
when we detect pulses as the beams sweep

13
00:00:39,910 --> 00:00:38,719

over earth the object is known as a

14
00:00:41,990 --> 00:00:39,920
pulsar

15
00:00:44,069 --> 00:00:42,000
they can spin many times per second on

16
00:00:45,990 --> 00:00:44,079
their axes the fastest pulsars spin over

17
00:00:48,709 --> 00:00:46,000
700 times per second

18
00:00:50,630 --> 00:00:48,719
and that rapidly spinning massive object

19
00:00:52,470 --> 00:00:50,640
generates extremely strong

20
00:00:54,630 --> 00:00:52,480
magnetic fields and accelerates

21
00:00:55,910 --> 00:00:54,640
particles to high energies and we see

22
00:00:57,590 --> 00:00:55,920
that

23
00:01:00,069 --> 00:00:57,600
those accelerated particles emitting

24
00:01:02,069 --> 00:01:00,079
energy in the form of gamma rays x-rays

25
00:01:03,510 --> 00:01:02,079
and radio waves and when that beam

26
00:01:06,070 --> 00:01:03,520
sweeps past the line of sight to the

27
00:01:08,950 --> 00:01:06,080
earth we see it pulse on and that's why

28
00:01:10,950 --> 00:01:08,960
they're named pulsars

29
00:01:13,510 --> 00:01:10,960
the most sensitive tool for observing

30
00:01:16,230 --> 00:01:13,520
pulsars and gamma-ray light is nasa's

31
00:01:18,149 --> 00:01:16,240
fermi gamma-ray space telescope

32
00:01:20,710 --> 00:01:18,159
fermi scans the entire sky for

33
00:01:23,830 --> 00:01:20,720
high-energy sources and has found many

34
00:01:25,990 --> 00:01:23,840
previously undetected gamma-ray emitters

35
00:01:27,749 --> 00:01:26,000
scientists have identified many of these

36
00:01:31,109 --> 00:01:27,759
but for some the source of the gamma

37
00:01:33,190 --> 00:01:31,119
rays remains unknown

38
00:01:35,109 --> 00:01:33,200

i got interested a couple years ago in

39
00:01:37,190 --> 00:01:35,119
trying to find the limits of what fermi

40
00:01:40,469 --> 00:01:37,200
can discover how extreme these objects

41
00:01:42,550 --> 00:01:40,479
can be and in order to do that i focused

42
00:01:44,630 --> 00:01:42,560
on this set of objects that are

43
00:01:46,069 --> 00:01:44,640
relatively bright and well measured by

44
00:01:47,910 --> 00:01:46,079
fermi

45
00:01:50,230 --> 00:01:47,920
and found that virtually all of them

46
00:01:51,749 --> 00:01:50,240
have now been identified at present when

47
00:01:53,590 --> 00:01:51,759
i started this project there were only

48
00:01:55,510 --> 00:01:53,600
six objects which hadn't been we hadn't

49
00:01:58,550 --> 00:01:55,520
figured out what they were yet despite

50
00:01:59,990 --> 00:01:58,560
intense searches at radio with radio

51
00:02:02,310 --> 00:02:00,000
wavelengths which is the standard way in

52
00:02:04,149 --> 00:02:02,320
which people find pulsars and also

53
00:02:06,469 --> 00:02:04,159
looking at the gamma rays themselves no

54
00:02:08,229 --> 00:02:06,479
pulsations had been seen so something

55
00:02:10,309 --> 00:02:08,239
was unique about these six objects and i

56
00:02:12,150 --> 00:02:10,319
thought hmm that's where the discovery

57
00:02:13,750 --> 00:02:12,160
space is going to be if we can track

58
00:02:16,550 --> 00:02:13,760
down what those are we have a good

59
00:02:18,790 --> 00:02:16,560
chance of finding something new

60
00:02:20,150 --> 00:02:18,800
we took this small set of six objects

61
00:02:21,990 --> 00:02:20,160
and attacked them with a number of wave

62
00:02:23,350 --> 00:02:22,000
bands but i think the thing that helped

63
00:02:25,830 --> 00:02:23,360

us make the greatest progress was

64
00:02:27,510 --> 00:02:25,840
looking in the optical invisible light

65
00:02:29,030 --> 00:02:27,520
now this may seem a little bit unusual

66
00:02:31,670 --> 00:02:29,040
for studying the high-energy gamma-ray

67
00:02:33,750 --> 00:02:31,680
universe but it turns out that many of

68
00:02:35,350 --> 00:02:33,760
these objects seem to have optical

69
00:02:37,509 --> 00:02:35,360
counterparts and if you can figure out

70
00:02:39,589 --> 00:02:37,519
what the visible light counterpart of an

71
00:02:40,949 --> 00:02:39,599
object is you've a long ways along the

72
00:02:42,949 --> 00:02:40,959
track to understanding what it's all

73
00:02:45,030 --> 00:02:42,959
about

74
00:02:47,030 --> 00:02:45,040
it was roger romani's optical

75
00:02:49,670 --> 00:02:47,040
observations that discovered a

76
00:02:51,670 --> 00:02:49,680
counterpart to the gamma-ray source that

77
00:02:53,430 --> 00:02:51,680
showed a binary period that was

78
00:02:55,830 --> 00:02:53,440
indicative of this potentially being a

79
00:02:58,229 --> 00:02:55,840
binary millisecond pulsar it brightened

80
00:03:00,869 --> 00:02:58,239
and it dimmed and brightened

81
00:03:03,910 --> 00:03:00,879
and so this looked like we were

82
00:03:07,670 --> 00:03:03,920
looking at possibly something which was

83
00:03:09,110 --> 00:03:07,680
irradiated by a companion pulsar

84
00:03:11,350 --> 00:03:09,120
and that every time you're looking at

85
00:03:13,830 --> 00:03:11,360
the bright face you see a bright optical

86
00:03:15,509 --> 00:03:13,840
source and when it rotates away from you

87
00:03:16,630 --> 00:03:15,519
and you see the dark face you don't see

88
00:03:18,710 --> 00:03:16,640

anything

89
00:03:20,390 --> 00:03:18,720
we managed to get enough observations of

90
00:03:23,270 --> 00:03:20,400
the object to piece together its orbital

91
00:03:26,070 --> 00:03:23,280
period and found uh remarkably that it

92
00:03:28,149 --> 00:03:26,080
was an incredibly heated object blue

93
00:03:30,390 --> 00:03:28,159
white on one side deep deep red on the

94
00:03:32,550 --> 00:03:30,400
other that was orbiting around something

95
00:03:34,070 --> 00:03:32,560
invisible with an orbital period about

96
00:03:34,789 --> 00:03:34,080
one and a half hours

97
00:03:36,710 --> 00:03:34,799
now

98
00:03:38,710 --> 00:03:36,720
that's faster than any spin powered

99
00:03:41,190 --> 00:03:38,720
pulsar ever known and indicates that

100
00:03:43,190 --> 00:03:41,200
it's a really really tight system and

101
00:03:45,750 --> 00:03:43,200
that the gamma rays are blasting the

102
00:03:48,229 --> 00:03:45,760
companion at point-blank range

103
00:03:49,830 --> 00:03:48,239
our colleagues of germany managed to use

104
00:03:51,990 --> 00:03:49,840
the orbital period that we'd measured to

105
00:03:54,149 --> 00:03:52,000
search in the gamma rays directly and

106
00:03:56,390 --> 00:03:54,159
with a computational tour to force

107
00:03:58,070 --> 00:03:56,400
managed to find the pulse signal of the

108
00:04:00,710 --> 00:03:58,080
pulsar directly in the gamma rays

109
00:04:02,789 --> 00:04:00,720
themselves

110
00:04:04,229 --> 00:04:02,799
what i'm doing is blind searches for

111
00:04:06,869 --> 00:04:04,239
pulsars so

112
00:04:08,470 --> 00:04:06,879
that we try to find pulses that have not

113
00:04:10,550 --> 00:04:08,480

been seen before

114
00:04:12,309 --> 00:04:10,560
so you don't know how fast the pulse is

115
00:04:14,869 --> 00:04:12,319
spinning where exactly it is sitting in

116
00:04:17,110 --> 00:04:14,879
the sky to do that you have basically to

117
00:04:19,349 --> 00:04:17,120
try every possible combination of

118
00:04:20,789 --> 00:04:19,359
parameters if they match your data

119
00:04:22,390 --> 00:04:20,799
output stream

120
00:04:24,469 --> 00:04:22,400
so the problem is that the number of

121
00:04:26,950 --> 00:04:24,479
possible combinations is tremendously

122
00:04:28,550 --> 00:04:26,960
high so the straightforward brute force

123
00:04:29,990 --> 00:04:28,560
approach isn't possible the

124
00:04:32,150 --> 00:04:30,000
computational power you would need would

125
00:04:33,510 --> 00:04:32,160
be in excess of what's available in the

126
00:04:35,990 --> 00:04:33,520
whole planet

127
00:04:38,710 --> 00:04:36,000
so our work is to invent more efficient

128
00:04:41,749 --> 00:04:38,720
methods to do that

129
00:04:44,390 --> 00:04:41,759
the basic method is analogous to zooming

130
00:04:47,189 --> 00:04:44,400
it's similar to changing your

131
00:04:49,270 --> 00:04:47,199
uh objectives of your microscope in

132
00:04:51,909 --> 00:04:49,280
favor of one of higher magnification so

133
00:04:53,909 --> 00:04:51,919
you look at one interesting point on the

134
00:04:55,590 --> 00:04:53,919
slide and then you zoom in on that and

135
00:04:56,710 --> 00:04:55,600
then you further zoom in if it still is

136
00:04:59,189 --> 00:04:56,720
interesting

137
00:05:00,070 --> 00:04:59,199
to find the pulsations in the gamma-ray

138
00:05:02,230 --> 00:05:00,080

data

139
00:05:04,310 --> 00:05:02,240
uh required us about

140
00:05:05,590 --> 00:05:04,320
5000 cpu

141
00:05:07,189 --> 00:05:05,600
days so

142
00:05:08,950 --> 00:05:07,199
so if you do it on your laptop you need

143
00:05:11,830 --> 00:05:08,960
5000 days

144
00:05:14,390 --> 00:05:11,840
um but if you have five thousand laptops

145
00:05:16,629 --> 00:05:14,400
you only one day and so

146
00:05:18,710 --> 00:05:16,639
that's the path we took because we have

147
00:05:20,310 --> 00:05:18,720
a computing cluster that's called atlas

148
00:05:23,430 --> 00:05:20,320
at the albert einstein institute in

149
00:05:25,909 --> 00:05:23,440
hanover and that computing facility we

150
00:05:28,629 --> 00:05:25,919
used for this analysis and it was

151
00:05:30,310 --> 00:05:28,639
immediately clear this is a detection so

152
00:05:32,390 --> 00:05:30,320
it's not it cannot be a noise

153
00:05:35,029 --> 00:05:32,400
fluctuation because it's so

154
00:05:37,029 --> 00:05:35,039
so loud in the data

155
00:05:39,909 --> 00:05:37,039
a pulsar that was a strong gamma ray

156
00:05:41,749 --> 00:05:39,919
source yet showed no radio signature

157
00:05:43,430 --> 00:05:41,759
intrigued researchers

158
00:05:45,830 --> 00:05:43,440
among them was paul ray of the naval

159
00:05:47,270 --> 00:05:45,840
research laboratory he and his team

160
00:05:50,390 --> 00:05:47,280
thought they might have a solution to

161
00:05:52,310 --> 00:05:50,400
the puzzling lack of radio emission

162
00:05:53,830 --> 00:05:52,320
when we first discovered the system i

163
00:05:55,990 --> 00:05:53,840

looked back at our archival radio

164
00:05:58,390 --> 00:05:56,000
observations and none of them showed

165
00:06:00,790 --> 00:05:58,400
detections of this pulsar we think that

166
00:06:03,029 --> 00:06:00,800
nearly all pulsars do emit radio waves

167
00:06:05,189 --> 00:06:03,039
the radio beam is emitted from most

168
00:06:06,790 --> 00:06:05,199
pulsars from a region above the polar

169
00:06:08,550 --> 00:06:06,800
cap of the star and that means it's a

170
00:06:09,350 --> 00:06:08,560
tightly concentrated flashlight type

171
00:06:11,590 --> 00:06:09,360
beam

172
00:06:13,350 --> 00:06:11,600
in a system like this where there's wind

173
00:06:15,189 --> 00:06:13,360
being blown off the companion star

174
00:06:17,670 --> 00:06:15,199
there's a lot of obscuring material

175
00:06:19,110 --> 00:06:17,680
along the line of sight it might be that

176
00:06:21,510 --> 00:06:19,120
it is a radio pulsar and we just

177
00:06:23,670 --> 00:06:21,520
couldn't see it and the one way to

178
00:06:25,510 --> 00:06:23,680
confront that is to use a higher radio

179
00:06:27,350 --> 00:06:25,520
frequency that's more penetrating that's

180
00:06:29,350 --> 00:06:27,360
less affected by the scattering in the

181
00:06:30,950 --> 00:06:29,360
in the intervening material and so we

182
00:06:33,189 --> 00:06:30,960
went and made an observation with the

183
00:06:34,469 --> 00:06:33,199
robert c byrd green bank telescope run

184
00:06:36,950 --> 00:06:34,479
by the national radio astronomy

185
00:06:38,790 --> 00:06:36,960
observatory in west virginia at a much

186
00:06:40,870 --> 00:06:38,800
higher frequency than typical radio

187
00:06:42,870 --> 00:06:40,880
observations and it was in one of those

188
00:06:45,430 --> 00:06:42,880

observations that we first saw the

189
00:06:48,230 --> 00:06:45,440
signal from the system and it appears

190
00:06:51,350 --> 00:06:48,240
that it is most of the time obscured by

191
00:06:53,990 --> 00:06:51,360
the material from its companion

192
00:06:56,550 --> 00:06:54,000
a combination of radio optical and gamma

193
00:06:58,710 --> 00:06:56,560
ray data allowed astronomers to assemble

194
00:07:00,870 --> 00:06:58,720
a complete picture of the system it

195
00:07:03,350 --> 00:07:00,880
turned out to be a rare black widow

196
00:07:05,350 --> 00:07:03,360
binary where a rejuvenated pulsar is

197
00:07:07,749 --> 00:07:05,360
gradually evaporating a low-mass

198
00:07:10,390 --> 00:07:07,759
companion star they get this name

199
00:07:12,230 --> 00:07:10,400
because they are in very close systems

200
00:07:14,150 --> 00:07:12,240
with the companion star being close

201
00:07:16,230 --> 00:07:14,160
enough to the neutron star that the

202
00:07:18,870 --> 00:07:16,240
neutron star is irradiating the

203
00:07:21,110 --> 00:07:18,880
companion so the neutron stars producing

204
00:07:23,670 --> 00:07:21,120
a wind of energetic particles and

205
00:07:26,150 --> 00:07:23,680
magnetic fields and also all the gamma

206
00:07:29,430 --> 00:07:26,160
rays that are radiated all this hits the

207
00:07:32,550 --> 00:07:29,440
companion star and heats it up to very

208
00:07:34,790 --> 00:07:32,560
high temperatures but only on one side

209
00:07:38,150 --> 00:07:34,800
so the side that's towards the neutron

210
00:07:39,749 --> 00:07:38,160
star gets blasted by this pulsar wind

211
00:07:41,909 --> 00:07:39,759
and it has been whittled away over

212
00:07:43,510 --> 00:07:41,919
billions of years to where it now is

213
00:07:44,390 --> 00:07:43,520

only about eight times the mass of

214
00:07:46,469 --> 00:07:44,400
jupiter

215
00:07:48,790 --> 00:07:46,479
this whole system is about the size of

216
00:07:49,990 --> 00:07:48,800
the earth moon system so it's very

217
00:07:52,309 --> 00:07:50,000
compact

218
00:07:54,869 --> 00:07:52,319
we see the pulsar at the center

219
00:07:56,629 --> 00:07:54,879
spinning and emitting beams of radio and

220
00:07:58,629 --> 00:07:56,639
gamma rays the radio waves are

221
00:08:00,790 --> 00:07:58,639
represented by the green and the gamma

222
00:08:03,350 --> 00:08:00,800
rays are represented by the magenta

223
00:08:05,830 --> 00:08:03,360
that radiation that impinges on the star

224
00:08:07,670 --> 00:08:05,840
is blowing off clouds of ionized

225
00:08:09,510 --> 00:08:07,680
material that are collecting around the

226
00:08:11,589 --> 00:08:09,520
system and that's what obscures the

227
00:08:13,670 --> 00:08:11,599
radio emission so we see that most of

228
00:08:16,309 --> 00:08:13,680
the time the radio and represented in

229
00:08:18,150 --> 00:08:16,319
green only makes it to that obscuring

230
00:08:19,350 --> 00:08:18,160
material and not through it while the

231
00:08:22,469 --> 00:08:19,360
gamma rays which are much more

232
00:08:24,390 --> 00:08:22,479
penetrating go right through

233
00:08:27,270 --> 00:08:24,400
it turns out that in as far as it's a

234
00:08:30,150 --> 00:08:27,280
pulsar it's not so very unusual what's

235
00:08:32,389 --> 00:08:30,160
unusual about it is this binary system

236
00:08:34,790 --> 00:08:32,399
and the binary system seems to have

237
00:08:36,949 --> 00:08:34,800
through its history allowed this neutron

238
00:08:39,670 --> 00:08:36,959

star pulsar to accrete enormous amounts

239
00:08:42,149 --> 00:08:39,680
of mass the measurements to date suggest

240
00:08:44,550 --> 00:08:42,159
that it's very heavy indeed and heavy

241
00:08:46,230 --> 00:08:44,560
neutron stars push the absolute extreme

242
00:08:48,230 --> 00:08:46,240
of the densest matter in our visible

243
00:08:50,230 --> 00:08:48,240
universe i say this because many people

244
00:08:52,550 --> 00:08:50,240
think of black holes as being exotic in

245
00:08:54,630 --> 00:08:52,560
the most extreme objects known but after

246
00:08:56,550 --> 00:08:54,640
all a black hole is collapsed to the

247
00:08:59,430 --> 00:08:56,560
point where nothing is visible it's

248
00:09:00,949 --> 00:08:59,440
black a neutron star is an object that's

249
00:09:02,790 --> 00:09:00,959
on the hairy edge of becoming a black

250
00:09:03,829 --> 00:09:02,800
hole yet is still visible in our

251
00:09:06,230 --> 00:09:03,839
universe

252
00:09:08,550 --> 00:09:06,240
hence the study of these ultra massive

253
00:09:11,030 --> 00:09:08,560
neutron stars gives us the opportunity

254
00:09:12,470 --> 00:09:11,040
to study the most extreme matter in our

255
00:09:15,190 --> 00:09:12,480
visible universe

256
00:09:18,070 --> 00:09:15,200
if this fellow is as heavy as he seems

257
00:09:21,350 --> 00:09:18,080
he pushes that study to a new horizon to