1
00:00:05,059 --> 00:00:03,649
cow is a fundamental physics experiment

2
00:00:08,600 --> 00:00:05,069
it's an atomic physics pyramid we're

3
00:00:10,609 --> 00:00:08,610
going to build or develop a system which

4
00:00:12,529 --> 00:00:10,619
allows us to create a ultra cold quantum

5
00:00:13,970 --> 00:00:12,539
gas on orbit and we're gonna be able to

6
00:00:15,829 --> 00:00:13,980
take this gas down to temperatures that

7
00:00:17,540 --> 00:00:15,839
are so low we actually see something

8
00:00:19,279 --> 00:00:17,550
called a bose-einstein condensate and

9
00:00:21,200 --> 00:00:19,289
that bose-einstein condensate is at a

10
00:00:23,720 --> 00:00:21,210
temperature of around 100 Pico kelvins

11
00:00:25,609 --> 00:00:23,730
it's 100 times 10 to the minus 12 Kelvin

12
00:00:27,290 --> 00:00:25,619
and those temperatures matter actually

13
00:00:29,060 --> 00:00:27,300

behaves entirely differently at room

14
00:00:30,890 --> 00:00:29,070
temperature matter behaves like

15
00:00:32,390 --> 00:00:30,900
particles like billiard balls knocking

16
00:00:34,220 --> 00:00:32,400
into each other but at temperatures

17
00:00:35,869 --> 00:00:34,230
below the bose-einstein condensate

18
00:00:37,520 --> 00:00:35,879
temperature matter actually behaves as

19
00:00:38,959 --> 00:00:37,530
something called a matter wave and the

20
00:00:40,099 --> 00:00:38,969
temperatures that we're gonna see on the

21
00:00:41,810 --> 00:00:40,109
International Space Station we're gonna

22
00:00:44,209 --> 00:00:41,820
see macroscopic matter waves which is

23
00:00:47,090 --> 00:00:44,219
kind of a new phenomenon which is

24
00:00:49,160 --> 00:00:47,100
enabled by going to ISS so how does this

25
00:00:51,049 --> 00:00:49,170
instrument work so the instrument works

26
00:00:52,279 --> 00:00:51,059
by a process called laser cooling so

27
00:00:53,479 --> 00:00:52,289
it's a little bit counterintuitive where

28
00:00:55,340 --> 00:00:53,489
you fire lasers I think that you

29
00:00:57,259 --> 00:00:55,350
actually cool it down but it actually

30
00:00:59,180 --> 00:00:57,269
works that way because lasers are made

31
00:01:00,860 --> 00:00:59,190
up of particles of light or called

32
00:01:02,779 --> 00:01:00,870
photons and those photons actually have

33
00:01:05,180 --> 00:01:02,789
a momentum associated with them and so

34
00:01:07,580 --> 00:01:05,190
you can actually push on particles with

35
00:01:09,290 --> 00:01:07,590
photon momentum to slow them down and so

36
00:01:11,210 --> 00:01:09,300
we have two stages of this laser cooling

37
00:01:13,430 --> 00:01:11,220
phenomena and then finally we have this

38
00:01:15,350 --> 00:01:13,440

RF cooling phenomena where we get it

39
00:01:17,570 --> 00:01:15,360
down to an even colder temperature so it

40
00:01:19,400 --> 00:01:17,580
uses an optical system a laser system in

41
00:01:20,870 --> 00:01:19,410
an RF system to be able to get down to

42
00:01:22,460 --> 00:01:20,880
these incredibly cool temperatures when

43
00:01:24,670 --> 00:01:22,470
you take atoms and you cool them down to

44
00:01:27,590 --> 00:01:24,680
a very low temperature you can actually

45
00:01:31,370 --> 00:01:27,600
work with their quantum wave function

46
00:01:35,210 --> 00:01:31,380
instead of the the classical particle of

47
00:01:37,040 --> 00:01:35,220
each atom and by sending them on two

48
00:01:38,810 --> 00:01:37,050
different paths at the same time quantum

49
00:01:42,370 --> 00:01:38,820
mechanically that that's possible I can

50
00:01:45,350 --> 00:01:42,380
make very precise measurements of well

51
00:01:47,300 --> 00:01:45,360
accelerations due to gravity of

52
00:01:49,190 --> 00:01:47,310
interactions with particles that we may

53
00:01:50,300 --> 00:01:49,200
know about and we don't want to see or

54
00:01:52,580 --> 00:01:50,310
particles that we don't know about and

55
00:01:53,750 --> 00:01:52,590
do want to see we study it to understand

56
00:01:55,940 --> 00:01:53,760
the fundamental physics of the universe

57
00:01:57,110 --> 00:01:55,950
so people potentially believe that a

58
00:01:58,400 --> 00:01:57,120
beginning of time the universe could

59
00:01:59,930 --> 00:01:58,410
have been formed by these ultra cold

60
00:02:02,000 --> 00:01:59,940
quantum gases so we're gonna understand

61
00:02:03,980 --> 00:02:02,010
more about how matter behaves at these

62
00:02:07,370 --> 00:02:03,990
temperatures so we you know there's a

63
00:02:08,749 --> 00:02:07,380

difference between Newtonian physics in

64
00:02:09,649 --> 00:02:08,759
quantum physics and so it's kind of the

65
00:02:11,330 --> 00:02:09,659
same thing there's a difference between

66
00:02:12,860 --> 00:02:11,340
matter at room temperature and matter at

67
00:02:14,120 --> 00:02:12,870
these ultra cold temperatures there are

68
00:02:15,800 --> 00:02:14,130
potential technology for

69
00:02:17,720 --> 00:02:15,810
applications as well but the purpose of

70
00:02:19,130 --> 00:02:17,730
our experiment is to understand the

71
00:02:20,840 --> 00:02:19,140
fundamental physics of what's going on

72
00:02:22,610 --> 00:02:20,850
these incredible cold temperatures and

73
00:02:25,310 --> 00:02:22,620
how these macroscopic matter waves

74
00:02:27,650 --> 00:02:25,320
actually interact with each other we

75
00:02:30,290 --> 00:02:27,660
know that our theories of gravity and

76
00:02:32,450 --> 00:02:30,300
our theory of particle physics don't get

77
00:02:34,160 --> 00:02:32,460
along at high energies everything works

78
00:02:36,020 --> 00:02:34,170
fine at low energies but it doesn't work

79
00:02:37,340 --> 00:02:36,030
at high energies this is a known problem

80
00:02:39,830 --> 00:02:37,350
and is a big problem the biggest problem

81
00:02:41,750 --> 00:02:39,840
that we have in physics and so we're

82
00:02:44,000 --> 00:02:41,760
hoping to get a hint as to what's

83
00:02:46,070 --> 00:02:44,010
happening at higher energies by looking

84
00:02:47,420 --> 00:02:46,080
for small deviations from the laws of

85
00:02:49,460 --> 00:02:47,430
physics as we think we understand them

86
00:02:51,230 --> 00:02:49,470
now at low energies and so looking for

87
00:02:52,730 --> 00:02:51,240
gravity to tug on one kind of atom

88
00:02:55,910 --> 00:02:52,740

differently than it tugs on another kind

89
00:02:58,430 --> 00:02:55,920
of atom is like great way to probe this

90
00:03:00,530 --> 00:02:58,440
kind of physics well the ISS gives us a

91
00:03:02,060 --> 00:03:00,540
microgravity platform which allows us to

92
00:03:03,890 --> 00:03:02,070
test gravity in ways that are very hard

93
00:03:05,300 --> 00:03:03,900
to do and more less impossible on the

94
00:03:08,210 --> 00:03:05,310
ground on the ground gravity is very

95
00:03:10,490 --> 00:03:08,220
strong it accelerates your atoms very

96
00:03:12,080 --> 00:03:10,500
fast you have only a fraction of a

97
00:03:14,690 --> 00:03:12,090
second before they the wall of your

98
00:03:16,670 --> 00:03:14,700
vacuum chamber on the ISS you could hold

99
00:03:20,330 --> 00:03:16,680
the atoms and run the theater for ometer

100
00:03:23,120 --> 00:03:20,340
four seconds tens of seconds and get a

101
00:03:25,580 --> 00:03:23,130
much more sensitive measurement it also

102
00:03:28,370 --> 00:03:25,590
is a nice environment where we can

103
00:03:30,470 --> 00:03:28,380
cancel systematic errors here I need to

104
00:03:32,480 --> 00:03:30,480
subtract the known acceleration of

105
00:03:35,330 --> 00:03:32,490
gravity from the earth and get a small

106
00:03:37,550 --> 00:03:35,340
signal from it on the ISS the small

107
00:03:39,080 --> 00:03:37,560
signal is most of our signal plus we can

108
00:03:40,760 --> 00:03:39,090
turn the experiment around put the earth

109
00:03:43,070 --> 00:03:40,770
on the other side of the experiment and

110
00:03:44,480 --> 00:03:43,080
so any systematic error that you know it

111
00:03:46,580 --> 00:03:44,490
gives us a signal in one direction

112
00:03:49,100 --> 00:03:46,590
relative to our apparatus will rotate

113
00:03:51,170 --> 00:03:49,110

with our experiment but the signal from

114
00:03:52,670 --> 00:03:51,180
gravity does not and so we can actually

115
00:03:54,920 --> 00:03:52,680
subtract that out better we're delving

116
00:03:56,420 --> 00:03:54,930
into a temperature range that we've

117
00:03:57,860 --> 00:03:56,430
never seen before so we actually don't

118
00:03:59,710 --> 00:03:57,870
know what we're gonna see so it's kind

119
00:04:01,940 --> 00:03:59,720
of the reason why you do scientific

120
00:04:02,960 --> 00:04:01,950
exploration is for discovery and so by

121
00:04:05,150 --> 00:04:02,970
definition what we're doing is

122
00:04:08,570 --> 00:04:05,160
discovering a new physics as a result of

123
00:04:10,400 --> 00:04:08,580
this it also enables us to use our

124
00:04:12,260 --> 00:04:10,410
expertise at JPL to create a system

125
00:04:13,490 --> 00:04:12,270
which ordinarily a mission like this

126
00:04:14,480 --> 00:04:13,500
would be a lot more expensive but

127
00:04:15,740 --> 00:04:14,490
because we can put it on the

128
00:04:17,060 --> 00:04:15,750
International Space Station because we

129
00:04:18,770 --> 00:04:17,070
were able to put it in shirtsleeves