



1
00:00:00,000 --> 00:00:02,050
There's a rhythm emanating from the Sun

2
00:00:02,050 --> 00:00:04,620
to the edges of the solar system.

3
00:00:04,620 --> 00:00:09,920
Roughly every 11 years, our star ramps up to a turbulent state expelling violent eruptions.

4
00:00:09,920 --> 00:00:13,120
After a peak, it calms down to a quieter phase,

5
00:00:13,120 --> 00:00:15,320
before starting all over again.

6
00:00:15,320 --> 00:00:17,680
This is known as the solar cycle.

7
00:00:17,680 --> 00:00:22,150
This ebb and flow of solar activity affects the entire solar system

8
00:00:22,150 --> 00:00:25,370
including spacecraft electronics and astronauts

9
00:00:25,370 --> 00:00:29,670
that can be affected by particle radiation if they're not sufficiently protected.

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00:00:29,670 --> 00:00:34,690
Understanding the solar cycle is one of the oldest problems in solar physics

11
00:00:34,690 --> 00:00:40,540
and now, predicting it is more critical than ever as we venture to the Moon and Mars, and beyond.

12
00:00:40,540 --> 00:00:43,690
So, here are ways we've learned about tracking it.

13
00:00:43,690 --> 00:00:46,760

[Text: 1: Count sunspots]

14

00:00:46,760 --> 00:00:49,090

So, welcome to the dome.

15

00:00:49,090 --> 00:00:50,830

Today, we're going to observe the Sun

16

00:00:50,830 --> 00:00:53,750

and see if it has some sunspots.

17

00:00:53,750 --> 00:00:55,640

Every morning when the skies are clear,

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00:00:55,640 --> 00:00:59,460

Olivier looks through this telescope in search of sunspots.

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00:00:59,460 --> 00:01:03,750

These are dark blotches on the Sun that are the main source of solar eruptions.

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00:01:03,750 --> 00:01:06,750

They appear and disappear on the Sun's surface.

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00:01:06,750 --> 00:01:08,540

So, we're not looking at the Sun.

22

00:01:08,540 --> 00:01:13,790

In fact, we're looking at the shadow of the instrument.

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00:01:13,790 --> 00:01:18,200

Then we put the paper always at the same place

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00:01:18,200 --> 00:01:21,050

and then we can start drawing.

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00:01:21,050 --> 00:01:26,500

Olivier and a team of sun observers record the pattern of sunspots by pencil.

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00:01:26,500 --> 00:01:31,010

The first known record of sunspots date back to around a thousand years ago in China.

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00:01:31,010 --> 00:01:36,580

After the invention of the telescope in the 17th century, routine observations were made.

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00:01:36,580 --> 00:01:39,980

Today, sunspot drawers still use the same technique.

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00:01:39,980 --> 00:01:44,870

While we've created satellites that can see the Sun in much more detail in recent decades,

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00:01:44,870 --> 00:01:49,330

drawing by hand keeps the centuries-long record consistent.

31

00:01:49,330 --> 00:01:52,980

The sunspot number record goes back farther than any other instrument

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00:01:52,980 --> 00:01:57,560

allowing scientists to analyze the Sun's behavior over many, many solar cycles.\h

33

00:01:57,560 --> 00:02:02,760

Sunspot numbers are collected from observatories around the world and are averaged.

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00:02:02,760 --> 00:02:07,560

During every 11-year cycle, the number of sunspots rise from zero to a peak

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00:02:07,560 --> 00:02:09,640

and then go back down to zero again.

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00:02:09,640 --> 00:02:16,060

Scientists use these numbers to determine when a new solar cycle begins and how active a cycle is.

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00:02:16,060 --> 00:02:22,740

Solar maximum, the period of highest activity, can vary wildly from cycle to cycle.

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00:02:22,740 --> 00:02:27,520

The more sunspots there are, the higher the frequency of solar storms of all types\h—

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00:02:27,520 --> 00:02:32,860

some that create aurora and some that can affect power grids on Earth.

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00:02:32,860 --> 00:02:35,560

But sunspot number isn't the only indicator we see;

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00:02:35,560 --> 00:02:38,600

these numbers are often combined with other signs.

42

00:02:38,600 --> 00:02:39,430

[Text: 2: Track location of sunspots]

43

00:02:39,430 --> 00:02:40,920

At the beginning of each cycle,

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00:02:40,920 --> 00:02:45,460

sunspots appear on the Sun in the midlatitudes for a brief few hours to days.

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00:02:45,460 --> 00:02:49,430

At solar minimum, there are often days without any spots at all.

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00:02:49,430 --> 00:02:51,240

As the Sun becomes more active,

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00:02:51,240 --> 00:02:56,110

sunspots form closer to the equator and can stick around for weeks to months.

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00:02:56,110 --> 00:03:00,210

These sunspot patterns give clues to what drives the solar cycle —

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00:03:00,210 --> 00:03:03,080

the twisting of the Sun's magnetic field.

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00:03:03,080 --> 00:03:07,260

Like Earth, the Sun has a magnetic field with a north and south pole.

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00:03:07,260 --> 00:03:11,990

But unlike Earth, the Sun's magnetic field becomes extremely complex.

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00:03:11,990 --> 00:03:14,120

This is because the Sun is made of plasma\h—

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00:03:14,120 --> 00:03:17,110

a charged gas that generates electric currents.

54

00:03:17,110 --> 00:03:22,360

As the Sun rotates, plasma around the equator moves faster than near the poles,

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00:03:22,360 --> 00:03:26,780

causing the magnetic fields to become stretched, elongated and then twisted.

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00:03:26,780 --> 00:03:30,610

Then Kinks in the magnetic fields burst through the surface

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00:03:30,610 --> 00:03:33,200

as sunspots larger than the size of Earth.

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00:03:33,200 --> 00:03:35,380

As the solar cycle unfolds,

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00:03:35,380 --> 00:03:39,330

more sunspots appear and the magnetic field becomes more tangled.

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00:03:39,330 --> 00:03:43,840

At the peak of the solar cycle, the Sun's magnetic field flips —

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00:03:43,840 --> 00:03:46,760

the north pole switches to the south and vice versa.

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00:03:46,760 --> 00:03:49,950

The cycle then ramps down ready to start a new cycle.

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00:03:49,950 --> 00:03:56,010

Scientists can eventually see the result of this flip within sunspots using satellites.

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00:03:56,010 --> 00:03:58,460

[Text: 3: Spot new sunspots]

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00:03:58,460 --> 00:04:02,590

This black and white image of the Sun shows the magnetic field on the surface.

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00:04:02,590 --> 00:04:05,220

Most sunspots appear in pairs.

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00:04:05,220 --> 00:04:09,150

Like a magnet, one side is positive and the other is negative.

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00:04:09,150 --> 00:04:11,870

After they form, they gradually disappear again

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00:04:11,870 --> 00:04:16,810

leaving behind remnants of magnetic fields that move towards the Sun's poles.

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00:04:16,810 --> 00:04:24,070

Eventually each pole accumulates enough magnetic fields forcing the Sun's poles to flip at the peak of the cycle.

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00:04:24,070 --> 00:04:29,560

Then new sunspot groups appear with the polarities in the opposite direction.

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00:04:29,560 --> 00:04:36,000

Scientists look for a consistent string of these new sunspots in order to declare the next solar cycle.

73

00:04:36,000 --> 00:04:39,550

But the transition between cycles is slow and messy.

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00:04:39,550 --> 00:04:46,270

Cycles often overlap creating freckles of old and new sunspots on the Sun at the same time.

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00:04:46,270 --> 00:04:52,140

Scientists can only determine we're in the new cycle when the number of new sunspots overtake old ones,

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00:04:52,140 --> 00:04:56,140

which can be six months to a year after the new cycle has begun.

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00:04:56,140 --> 00:04:58,280

While these spots give a visible tracker,

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00:04:58,280 --> 00:05:03,610

in recent years scientists have discovered another signal that is hard to see from Earth.

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00:05:03,610 --> 00:05:04,040

[Text: 4: Measure strength of Sun's poles]

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00:05:04,040 --> 00:05:07,330

The strength of the Sun's poles during solar minimum

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00:05:07,330 --> 00:05:10,910

can help predict how active the next cycle will be.

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00:05:10,910 --> 00:05:17,100

After the poles have reversed at the peak, scientists keep a close eye on it for the next few years.

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00:05:17,100 --> 00:05:22,010

If the magnetic fields accumulated at the poles become strong during this time,

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00:05:22,010 --> 00:05:25,320

it's likely the next solar cycle will be an active one.

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00:05:25,320 --> 00:05:30,280

If the buildup is weak, the next solar cycle won't be as active.

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00:05:30,280 --> 00:05:35,370

While we use these indicators to track the Sun, predictions are still hard.

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00:05:35,370 --> 00:05:41,610

After all, we've only detailed satellite observations of the last four solar cycles

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00:05:41,610 --> 00:05:45,660

and scientists are still learning about what causes the Sun's cycle.