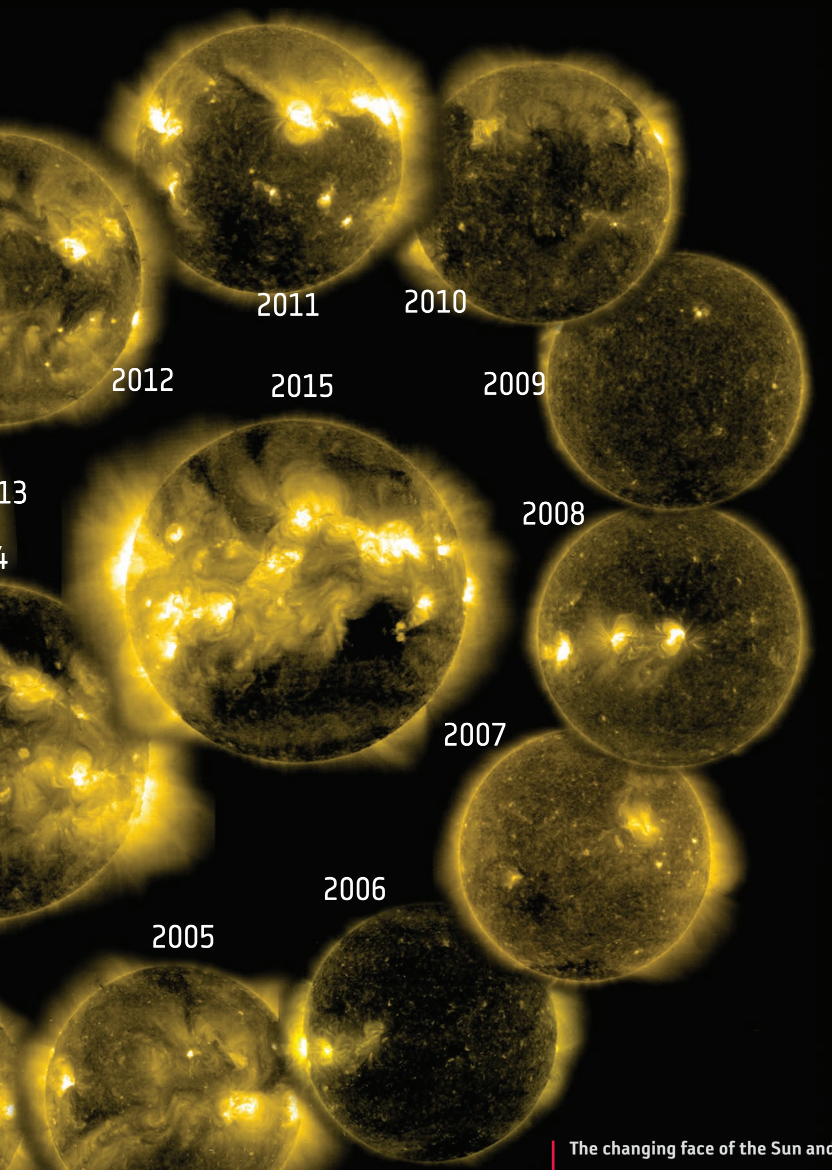

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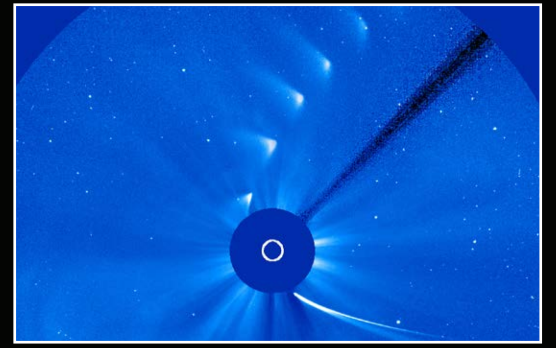

The demise of Comet ISON as it came within 1.2 million km of the Sun on 28 November 2013, fading from view in the following days. The small white circle in the centre of many SOHO images indicates the position and size of the Sun behind the telescope's occulting 'coronagraph mask', seen as the wider disc. The mask blocks out the dazzling light that otherwise drowns out this region, allowing details of the corona to be seen.

FACTS AND FIGURES

Dimensions	4.3 x 2.7 x 3.7 m ; solar array span 9.5 m
Launch	2 December 1995 (arrival at orbit February 1996)
Launch mass	1850 kg, including 610 kg payload
Launch vehicle	NASA Atlas IIAS from Cape Canaveral, Florida, US
Telemetry	200 kbit/s (realtime operation); 40 kbit/s (onboard storage mode)
Orbit	circling Lagrangian point L1, 1.5 million km from Earth in the direction of the Sun
Payload	Developed and built by 12 international consortia involving 39 institutes from 15 countries CDS: Coronal Diagnostic Spectrometer (Rutherford Appleton Lab., UK) CELIAS: Charge, Element and Isotope Analysis System (Max-Planck-Institut für extraterrestrische Physik, DE/Univ. of Bern, CH/Univ. of Kiel, DE) COSTEP: Comprehensive Suprathermal and Energetic Particle Analyser (Univ. of Kiel, DE) EIT: Extreme-ultraviolet Imaging Telescope (Institut d'Astrophysique Spatiale, FR) ERNE: Energetic and Relativistic Nuclei and Electron experiment (Univ. of Turku, FI) GOLF: Global Oscillations at Low Frequencies (Institut d'Astrophysique Spatiale, FR) LASCO: Large Angle and Spectrometric Coronagraph (Naval Research Lab., US) MDI: Michelson Doppler Imager (Stanford Univ., US) SUMER: Solar Ultraviolet Measurements of Emitted Radiation (Max-Planck-Institut für Sonnensystemforschung, DE) SWAN: Solar Wind Anisotropies (Institut Pierre Simon Laplace, Lab. Atmosphères, Milieux, Observations Spatiales, FR) UVCS: Ultraviolet Coronagraph Spectrometer (Harvard-Smithsonian Center for Astrophysics, US) VIRGO: Variability of Solar Irradiance and Gravity Oscillations (Physikalisch-Meteorologisches Observatorium/World Radiation Center, Davos, CH)
Satellite control and science operations centre	NASA Goddard Space Flight Center, Greenbelt, US
Ground stations	NASA's Deep Space Network
Planned mission	2 years; 7 extensions running to end-2018

SOHO is a project of international cooperation between ESA and NASA
http://sci.esa.int/soho/
Realtime images: **soho.esac.esa.int**

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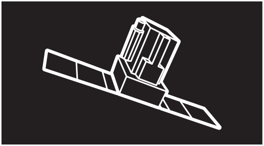

A NEAR-LOSS AND A DRAMATIC RECOVERY

The mission almost ended on 25 June 1998 when control was lost during a routine manoeuvre. It took three months to restore operations in one of the most dramatic recovery operations in space history, including 2.5 weeks to thaw frozen hydrazine propellant in the tank and pipes. Unexpectedly, all 12 instruments survived despite the extreme temperatures they suffered during the time contact was lost.

But the drama was not over yet: all three gyroscopes later failed, the last in December 1998. New control software that does not rely on gyros was developed and installed in February 1999, allowing the spacecraft to return to full scientific operations. This made SOHO the first spacecraft to be stabilised in three axes without gyros.

All images: SOHO (ESA & NASA)

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→ TWO DECADES OF DISCOVERIES

FACING THE SUN

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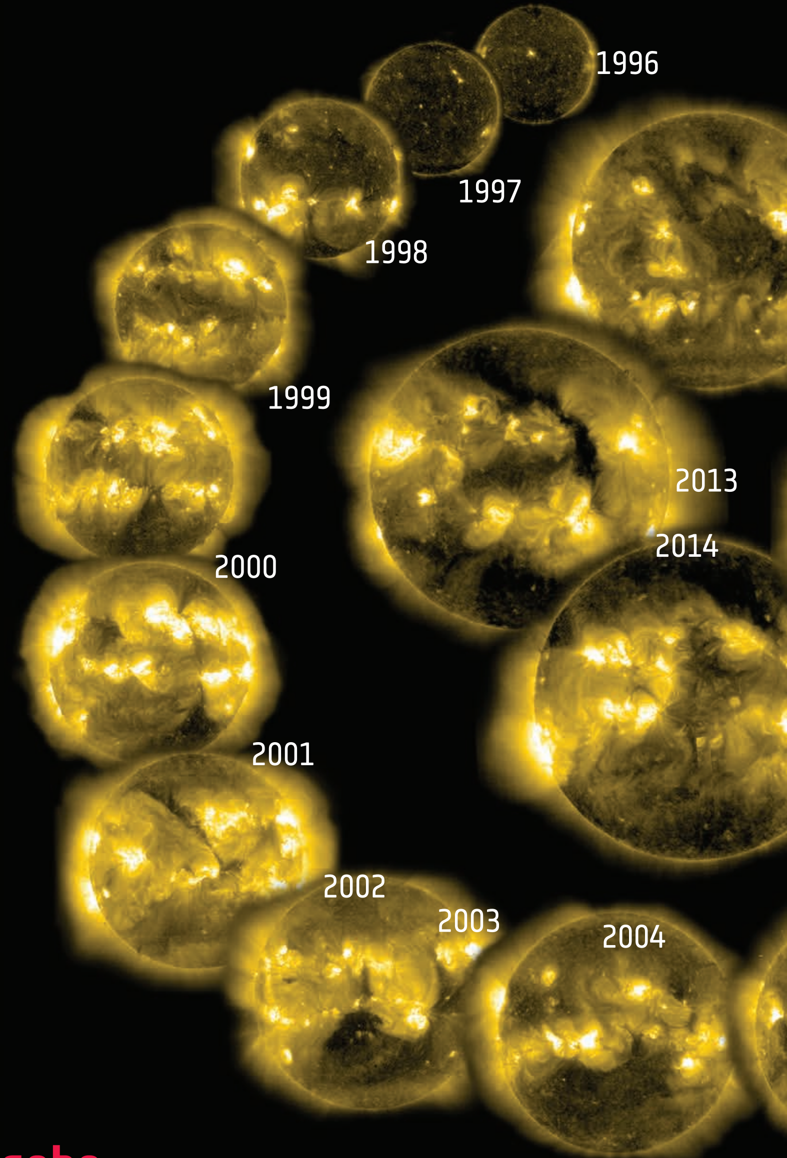
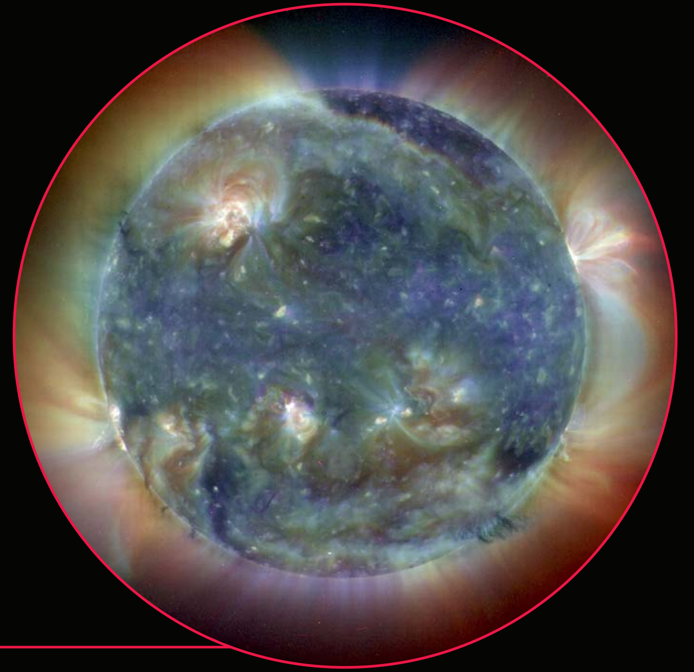


STARQUAKES: SEEING INSIDE THE SUN

Just as seismology reveals Earth's interior by studying seismic waves from earthquakes, solar physicists use 'helioseismology' to probe the solar interior by studying the frequency and oscillations of sound waves reverberating through it. SOHO pioneered the new field of 'local area helioseismology', providing the first images of structures and gas flows below the Sun's surface and even images of activity on the far side. It discovered 'sunquakes' and a slow subsurface current of gas flowing from the equator towards the poles.

Deeper inside the Sun, about a third of the way towards the centre at the transition between its turbulent outer shell – the convection zone – and the more orderly radiative zone, SOHO found that the speed of the rotating gas changes abruptly. The measurements indicated that, near the equator, the outer layers rotate faster than the inner layers, while at mid-latitudes and near the poles the situation is reversed. This boundary region is of particular interest because it is where the solar dynamo that creates the Sun's ever-changing magnetic field is believed to operate.

SOHO also shed light on the 'solar neutrino problem' – a major discrepancy between the rate at which neutrinos were predicted to be created by nuclear fusion in the deep solar interior and the rate measured at Earth. SOHO confirmed that the standard model of the Sun is correct, ruling out that possible explanation. Instead, the discrepancy had to be explained by the physics of the neutrino, as confirmed by better neutrino measurements a few years later.



Composite image combining EIT images from three wavelengths to reveal solar features unique to each wavelength. Blue areas indicate 'cooler' regions at 1 million °C, green 'warmer' regions at 1.5 million °C, and red 'hot' regions at 2 million °C.

THE SOLAR HEATING MYSTERY

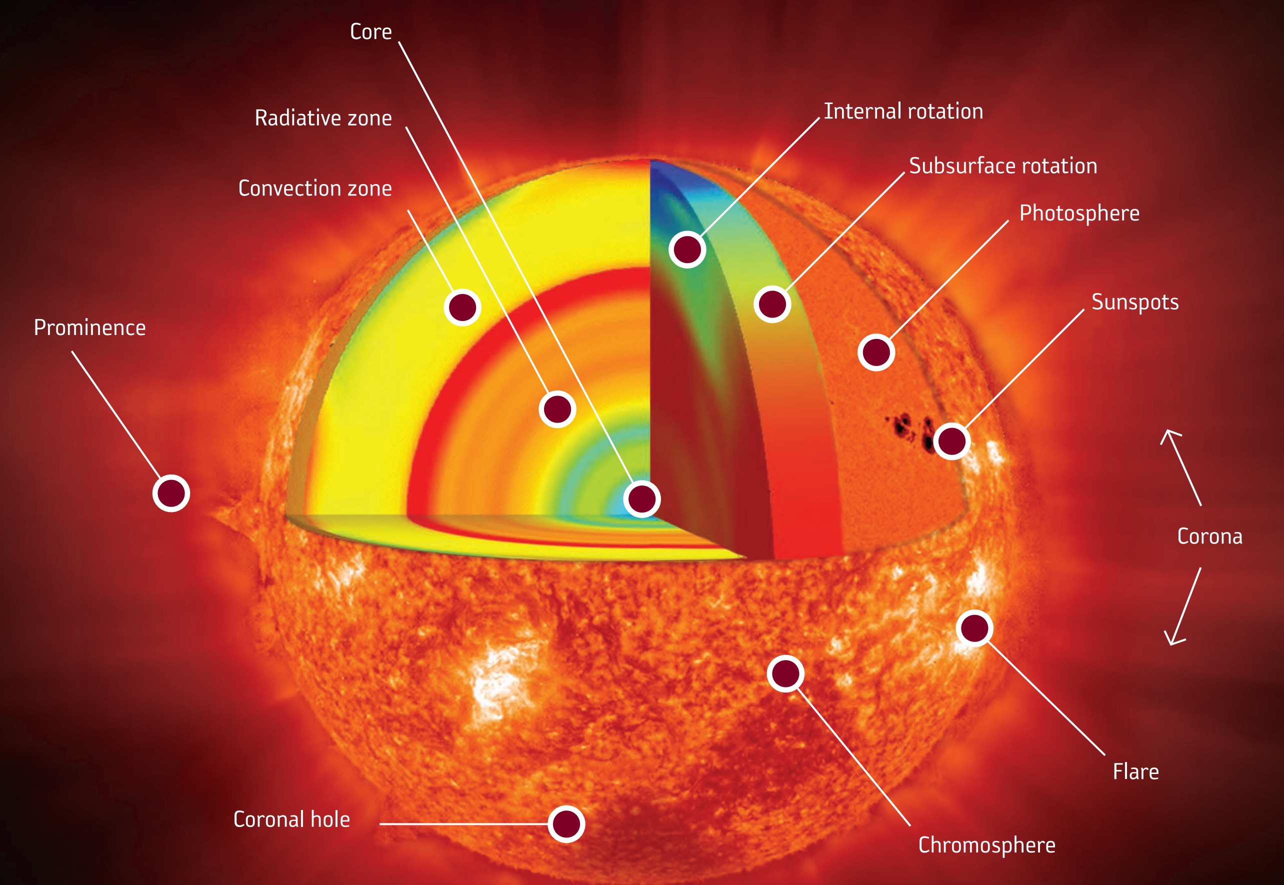
Why the Sun's corona is heated to the extremely high 1–2 million °C when the visible surface (the photosphere) is 'only' about 5500°C has long been a mystery of solar physics.

SOHO has revealed an extremely dynamic atmosphere where plasma flows and small-scale transient events play an important role. They also discovered new dynamic phenomena such as solar tornadoes and global coronal waves – disturbances associated with coronal mass ejections that can travel around the entire solar globe – and provided evidence for the upwards transfer of magnetic energy from the surface to the corona through a magnetic carpet – a weave of magnetic loops extending above the Sun's surface.

GONE WITH THE SOLAR WIND

A prime goal was to observe where the solar wind – electrically charged atomic particles streaming from the Sun – is produced and how it is accelerated to beyond 3 million km/h. Scientists have made great strides in answering this fundamental question. They measured the acceleration profiles of both the 'slow' and 'fast' solar wind and found that the fast solar wind streams into interplanetary space by 'surfing' on waves produced by vibrating magnetic field lines. Mapping the outflow of the plasma from coronal holes – darker, cooler and less dense areas of the Sun's corona where the Sun's magnetic field reaches into space, allowing hot gas to escape – revealed a clear connection between the flow speed and the structure of the chromosphere.

SOHO also revealed that heavy solar wind ions in coronal holes flow faster and are heated hundreds of times more strongly than protons and electrons.



THE ANATOMY OF OUR SUN

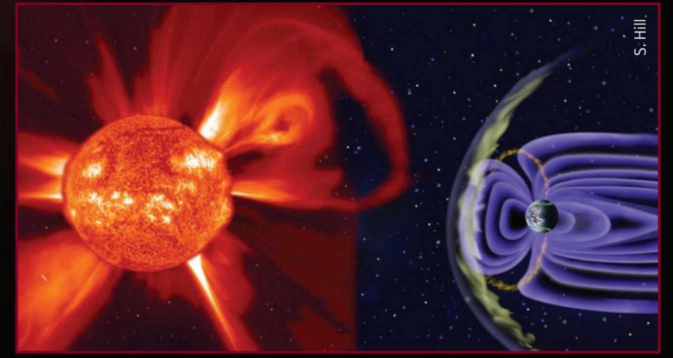
Left cutaway: The Sun's interior explored with sound waves. Red depicts layers where sound travels faster than predicted by theory, implying that the temperature is higher than expected, while blue indicates slower speeds and lower temperatures. The prominent red layer marks the transition between the turbulent outer convection zone and the more stable inner radiative zone. Right cutaway: The Sun's internal rotation, where red depicts fast rotation and blue slower rotation. Outer layers: Visible light images show sunspots, cool dark features in the photosphere, which lies below the chromosphere. Flares, resulting from the release of a buildup of magnetic energy, and coronal mass ejections (CMEs, giant clouds of electrically charged atomic particles launched into space) often occur in magnetically active regions around sunspot groups.

THE SUN–EARTH CONNECTION

With its near-continuous monitoring of the Sun, SOHO has revolutionised our understanding of the Sun–Earth connection and dramatically boosted space weather forecasting.

The major driver of space weather are CMEs, the most powerful eruptions in the Solar System, which propel billions of tonnes of electrified gas into space at millions of kilometres per hour. If CMEs hit Earth, in addition to causing intense auroral displays in polar regions by electrically charging atoms in our upper atmosphere, they can cause major geomagnetic storms, which can damage satellites, disrupt telecommunications, endanger astronauts, lead to corroded oil pipelines and cause current surges in power lines.

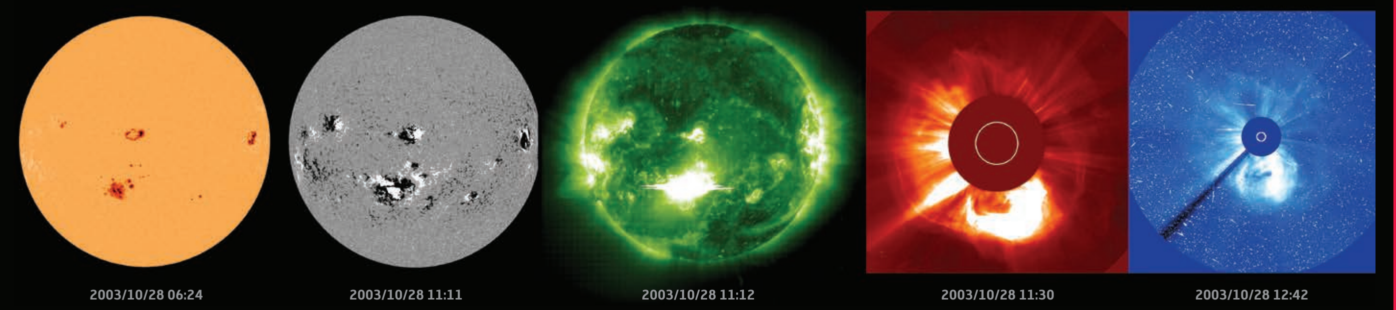
SOHO is a pioneer in detecting when such a solar storm is incoming. It has studied more than 20000 CMEs to date, pinpointing their sources on the Earth-facing hemisphere of the Sun, and determining their speed and direction to provide up to three days' warning – sufficient to take mitigating action on Earth. From its vantage point matching Earth's orbit, the observatory can also make *in situ* measurements when a CME and its energetic particles arrive.



A CME blasts from the Sun (left, EIT and LASCO images) and a few days later hits Earth's magnetosphere (right, artist 's impression); images and Sun–Earth distance not to scale.

INCOMING!

For two weeks in October-November 2003, the Sun featured three unusually large sunspot groups, which gave rise to 11 X-class flares - the most energetic class of flare - including the strongest ever recorded.

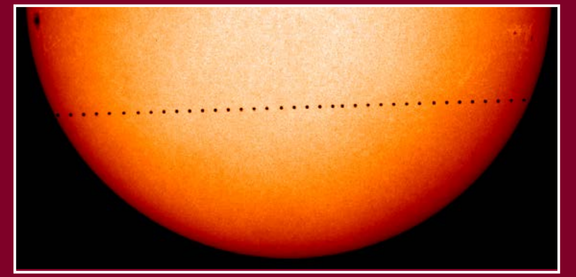


First left: giant sunspot groups seen by MDI on 28 October 2003 in visible light. Second: MDI magnetogram on the same day, illustrating the magnetic complexity of these active regions. Third: EIT image at the time of an X-ray flare, seen as the bright emission just below the centre of the disc. The linear horizontal feature is an artefact due to saturation of the CCD detector.

Fourth: LASCO C2 image at minutes after the flare, with a 'halo CME' completely surrounding the occulting disc. Fifth: LASCO C3 image of the expanding halo CME, where energetic particles hitting the CCD detector appear like 'snow'. The flare location and the halo were a clear indication that the CME was heading towards Earth.

SHINE LIKE A STAR

The Sun's surface brightness is an important part of SOHO's long-term studies, because changes could influence Earth's climate. SOHO monitors the total brightness as well as variations in the extreme ultraviolet flux, both of which are important for understanding the effect of solar variability on climate. The measurements show that the brightness changes by only 0.1% between the minimum and maximum of a solar cycle.



SOHO occasionally has the chance to watch a planet cross in front of the Sun, such as this transit of Mercury in 2006, seen by MDI.

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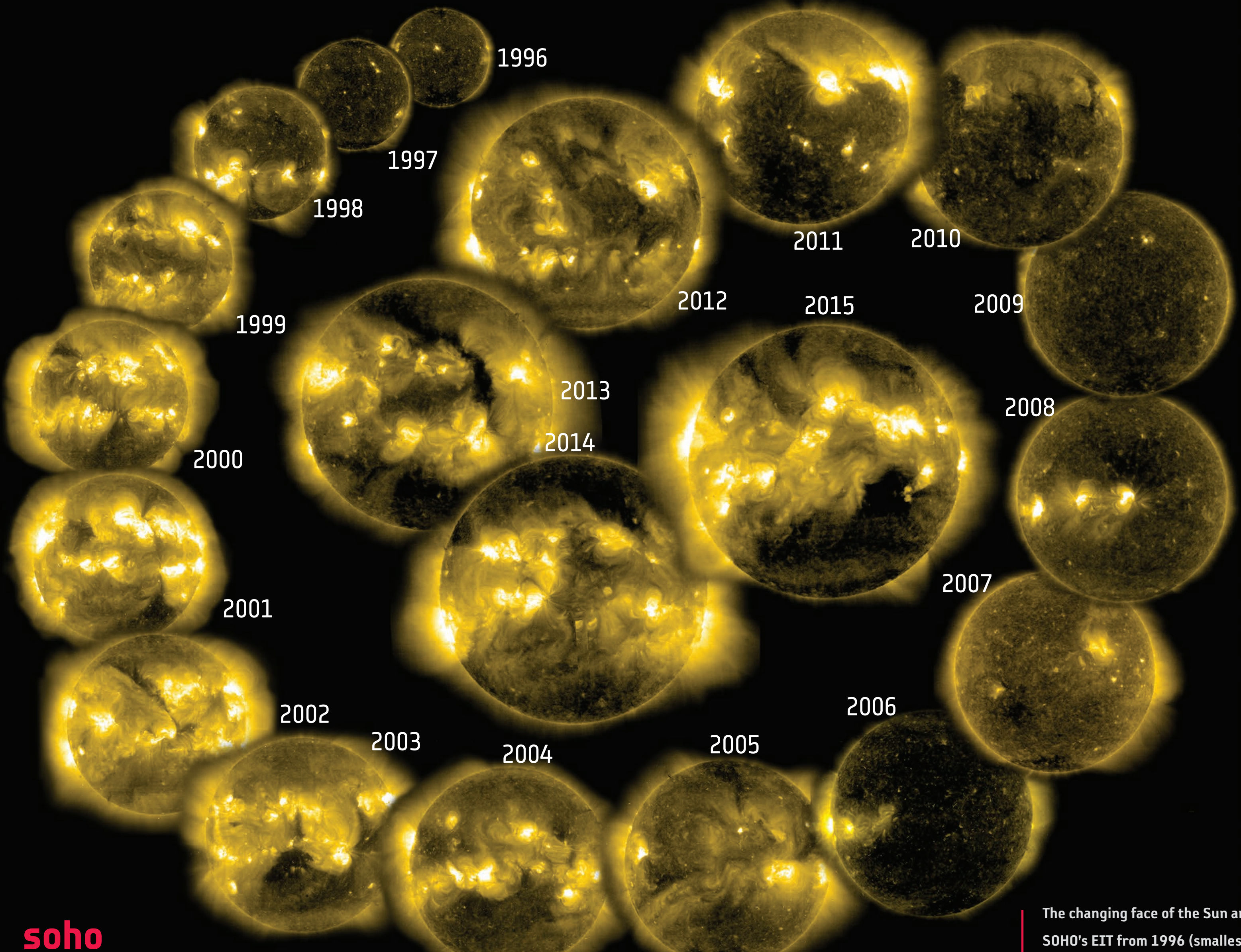

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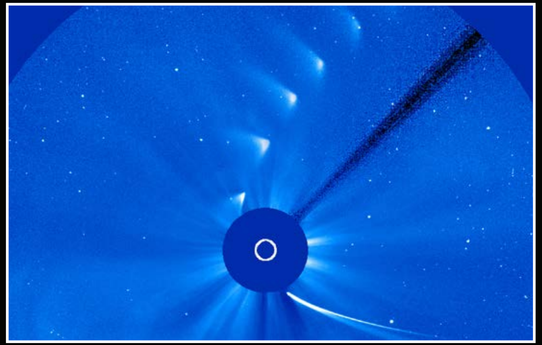

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