Class exercise

- Typical velocity of convective motion seen in the Doppler shifts was about ~1 km/s (range from 0.5 to 2 km/s)
- So to travel 300 km takes:

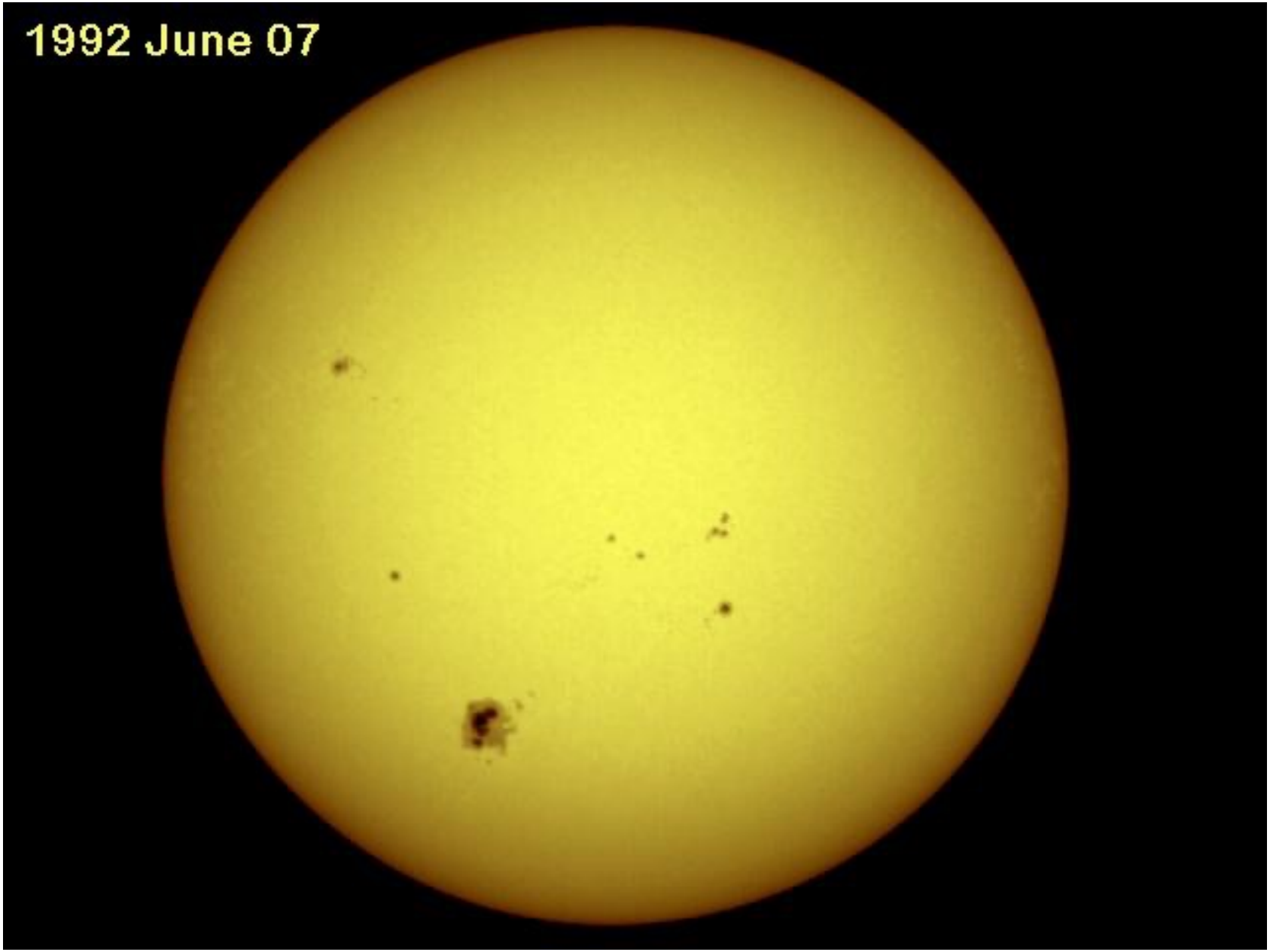
$$t = \frac{d}{v}$$

$$= \frac{300 \times 10^3}{1 \times 10^3}$$

$$= 300 \text{ seconds} = 5 \text{ minutes}$$

Solar Activity

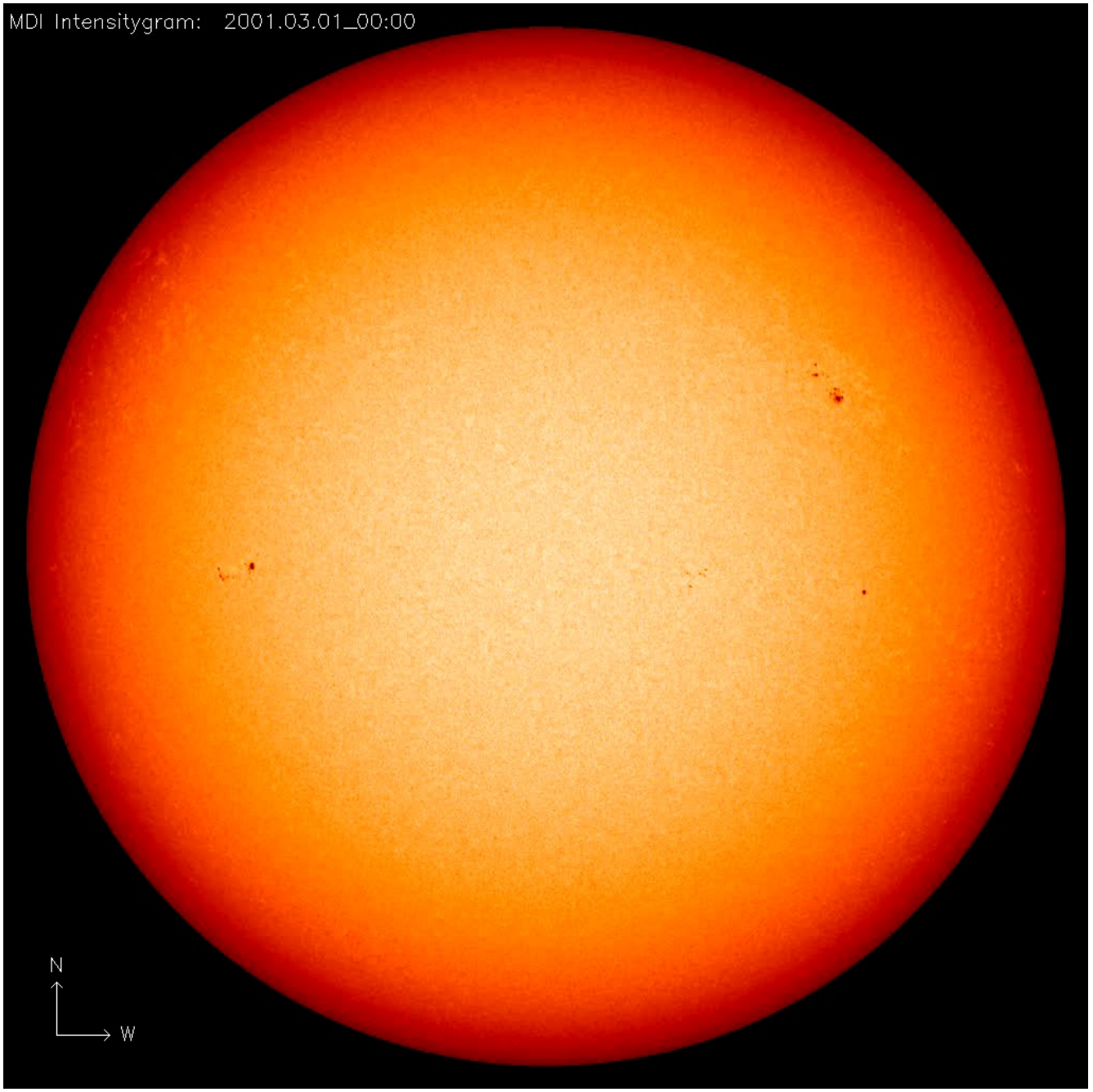
- Sunspots
- Solar Cycle
- Magnetic Model



http://solarscience.msfc.nasa.gov/

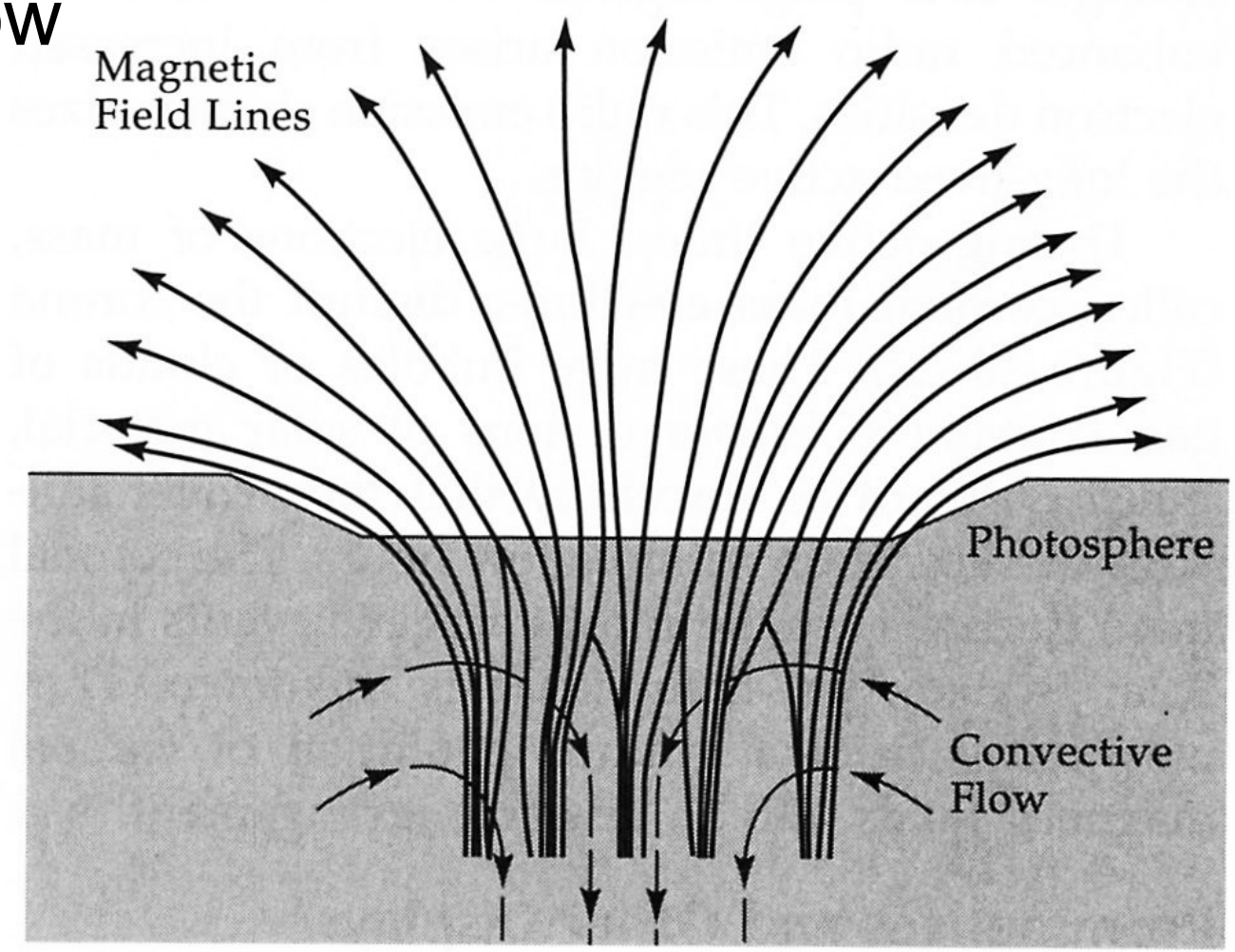
Sunspots

- Cooler regions (T~4 000 K) of the photosphere
- Hence appear darker than their surroundings
- Rotate with the Sun and reveals differential rotation – equator rotates more rapidly than higher latitudes

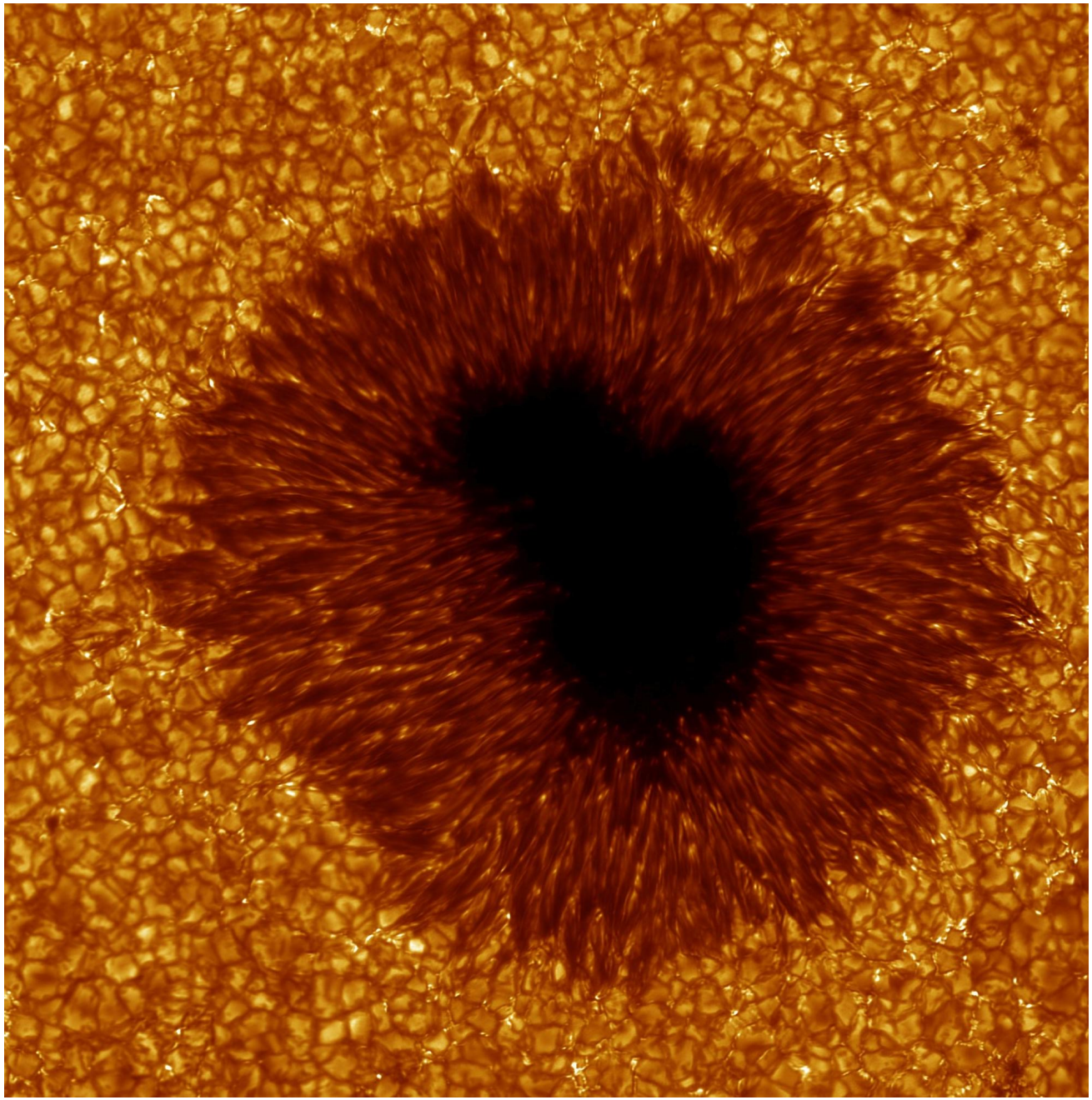


SOHO (ESA & NASA) Satellite: soho.esac.esa.int/gallery

- Spot physically lower than surroundings
- Strong (B~0.1T) vertical magnetic field prevents heat transfer from convective flow

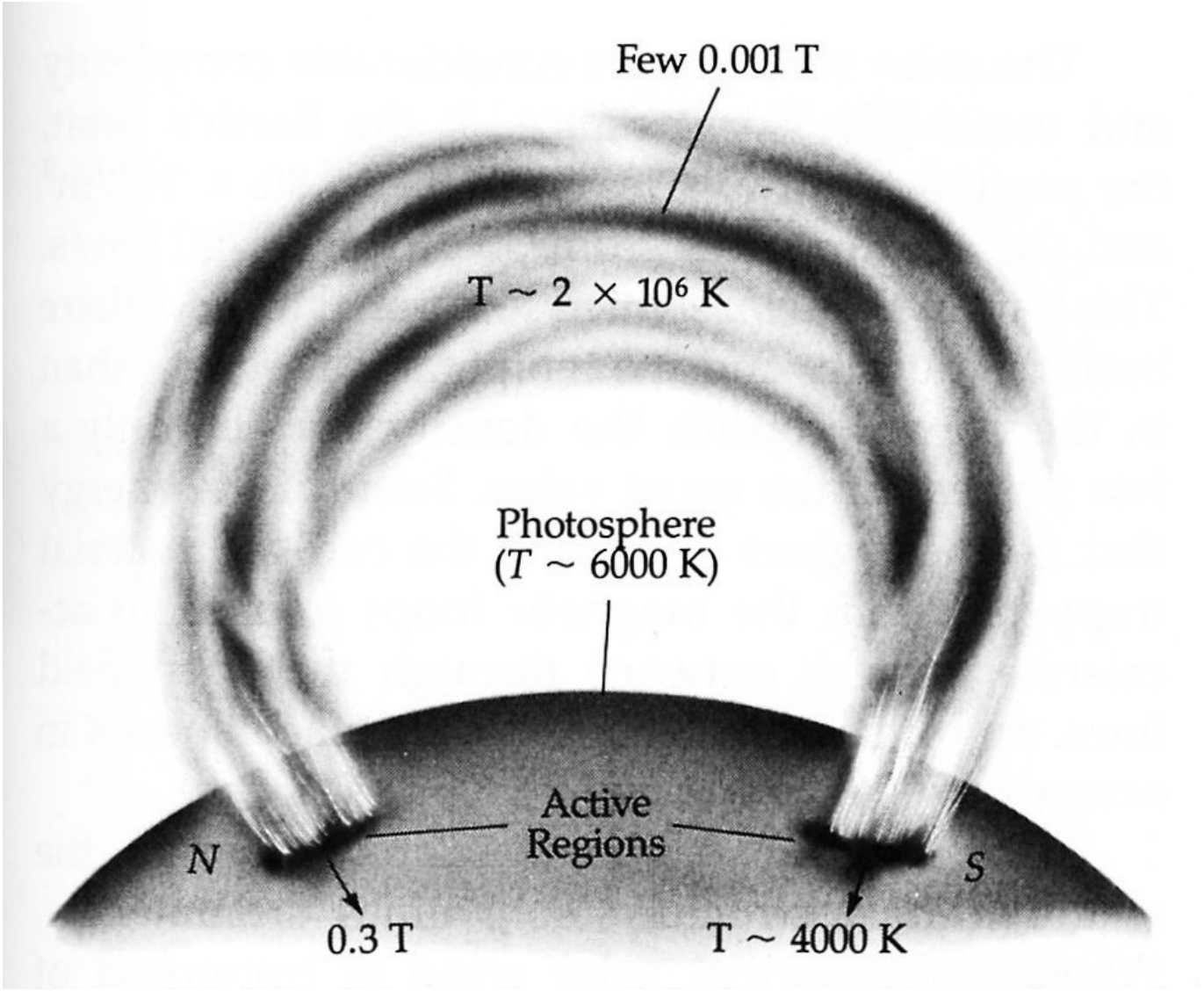


Zeilik &
Gregory
Fig 10-21



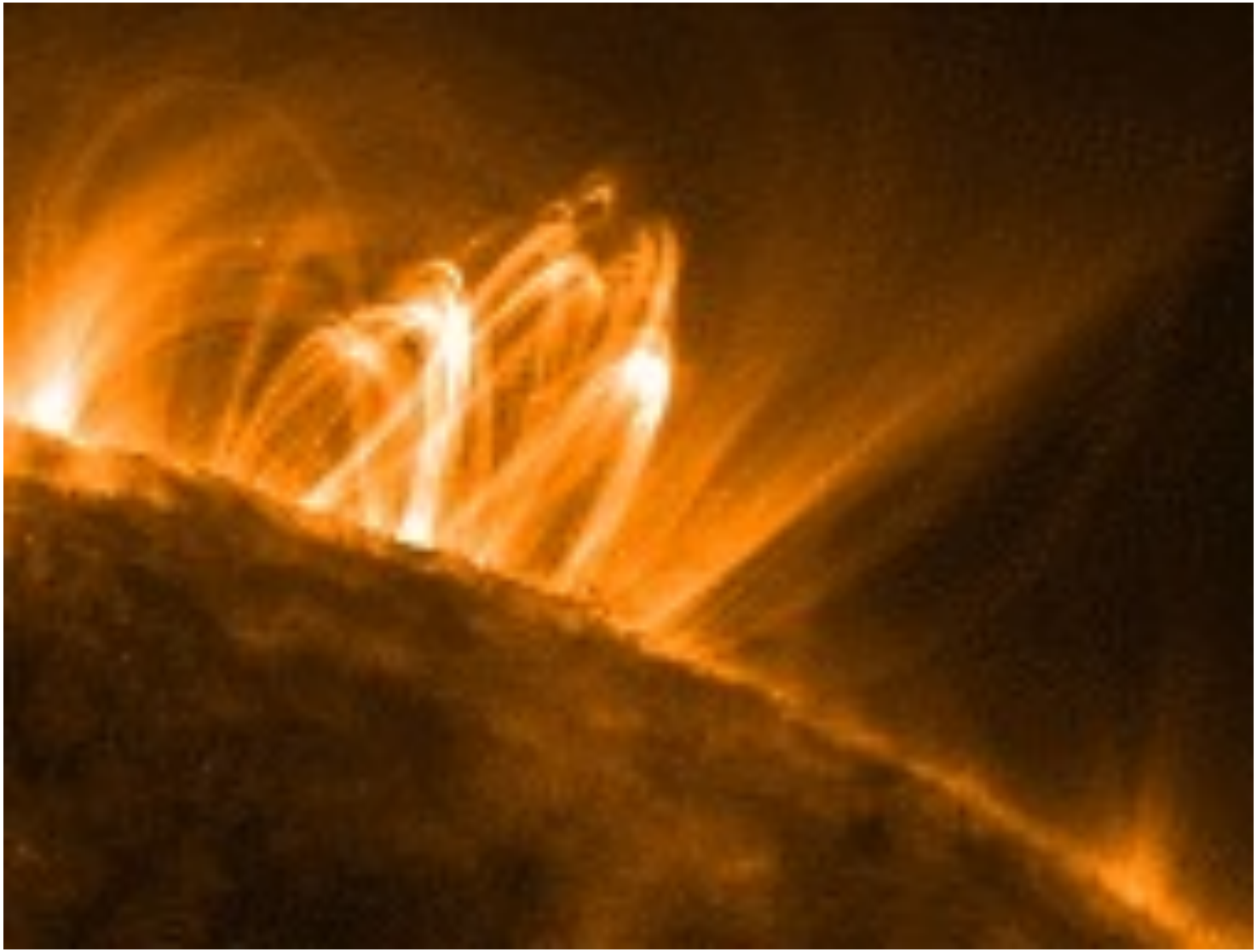
Close-up of sunspot. Credit: Royal Swedish Academy of Sciences www.solarphysics.kva.se

- Sunspots usually in ‘bipolar pairs’ with N at one end and S at the other



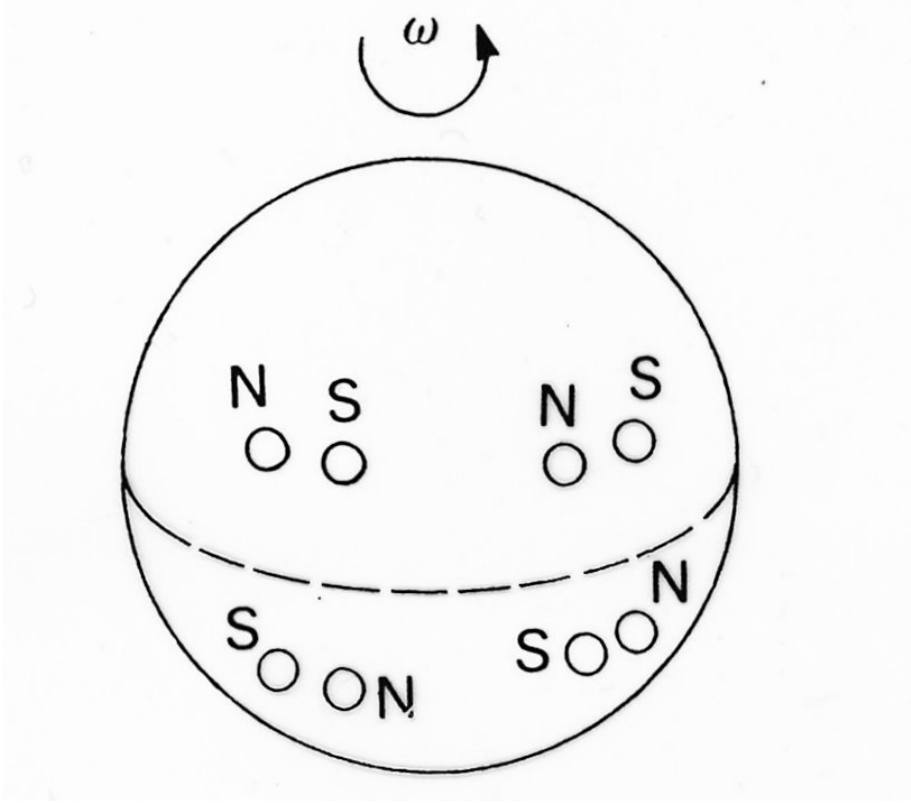
Zeilik & Gregory Fig 10-16

- Linked by loop of hot, magnetic plasma

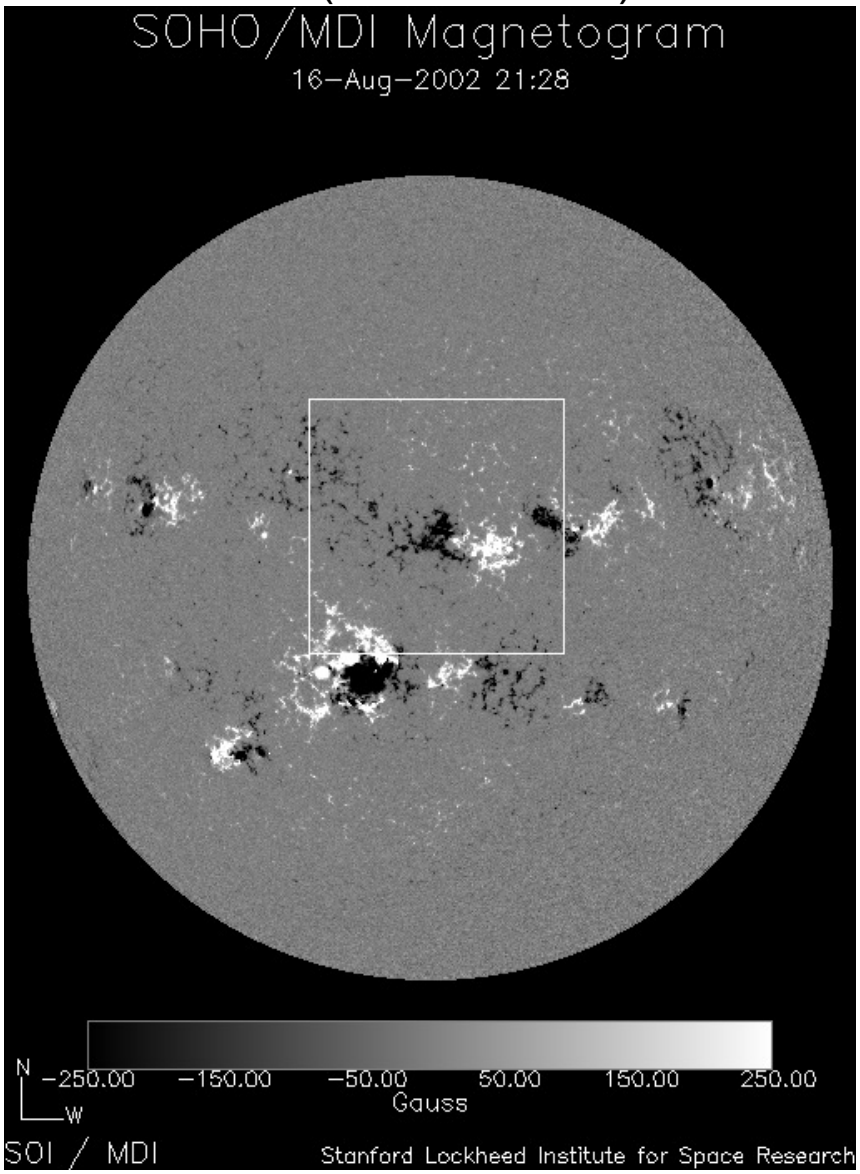


TRACE Satellite Stanford-Lockheed Institute for Space Research & NASA (trace.lmsal.com/POD/images)

- All the pairs in one hemisphere have the same polarity, but in the other it is opposite

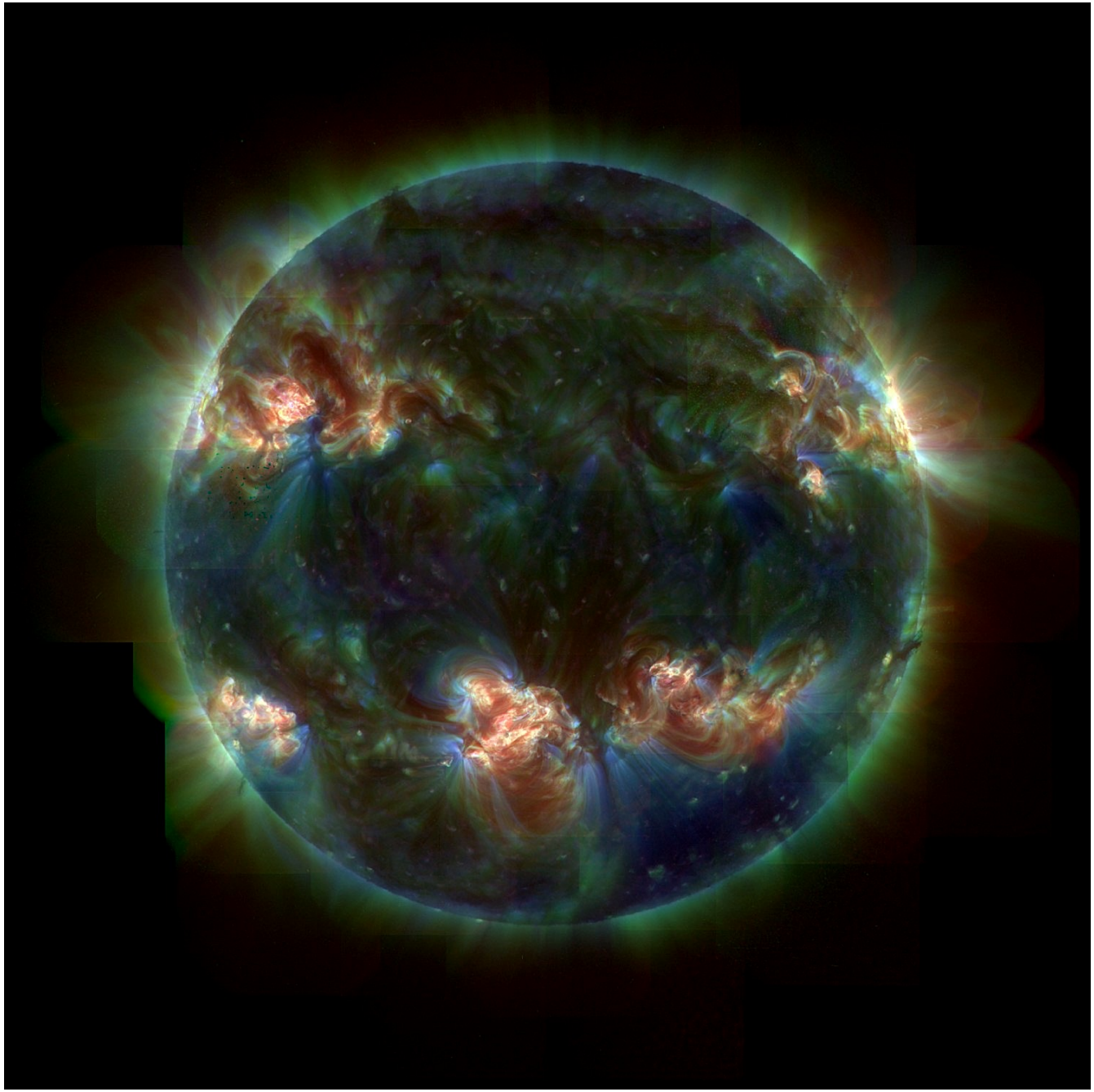


SOHO (ESA & NASA)



White – magnetic towards us

Black – magnetic field away from us

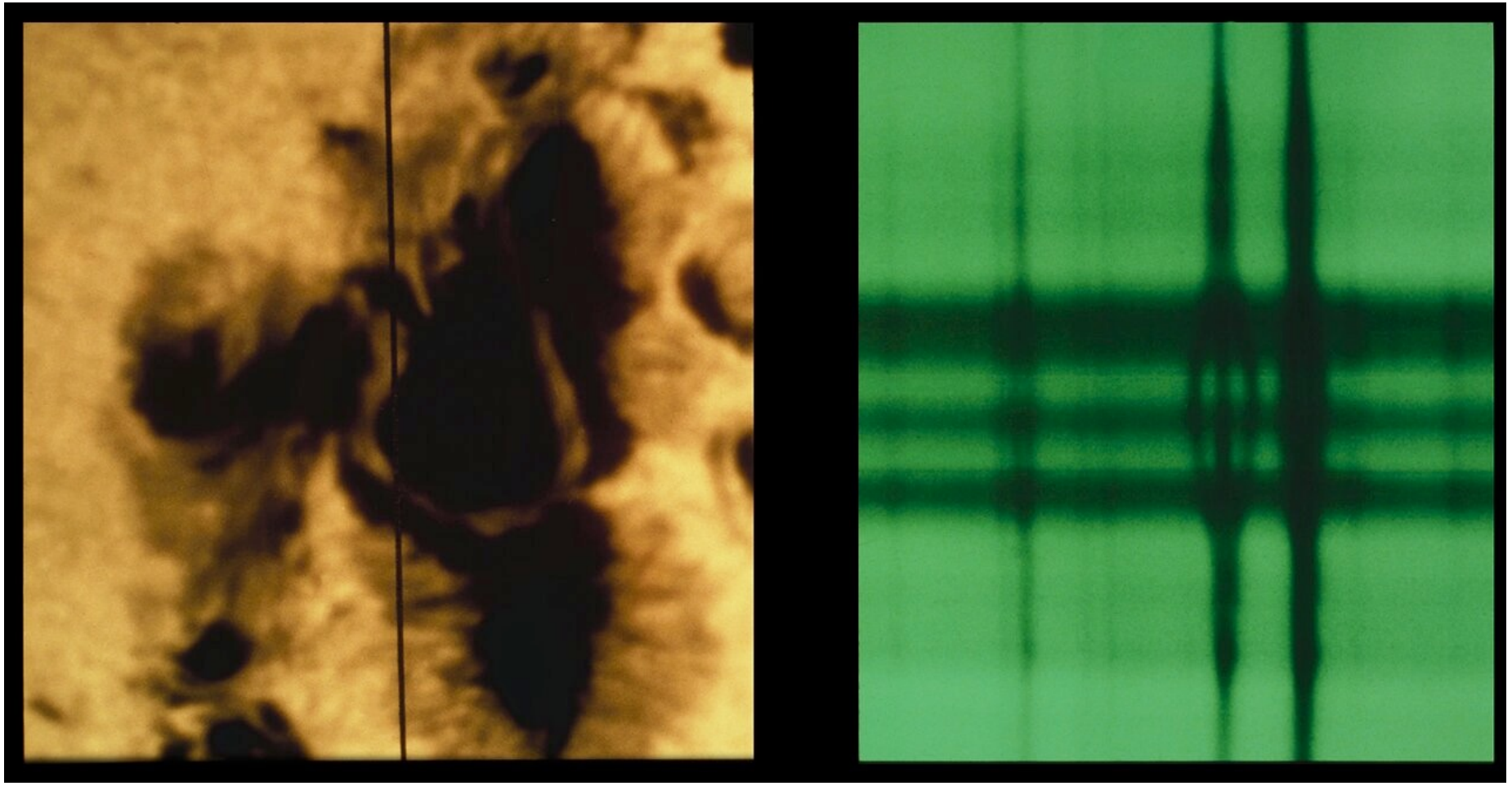


TRACE Satellite Stanford-Lockheed Institute for Space Research & NASA (trace.lmsal.com/POD/images)

Additional Learning

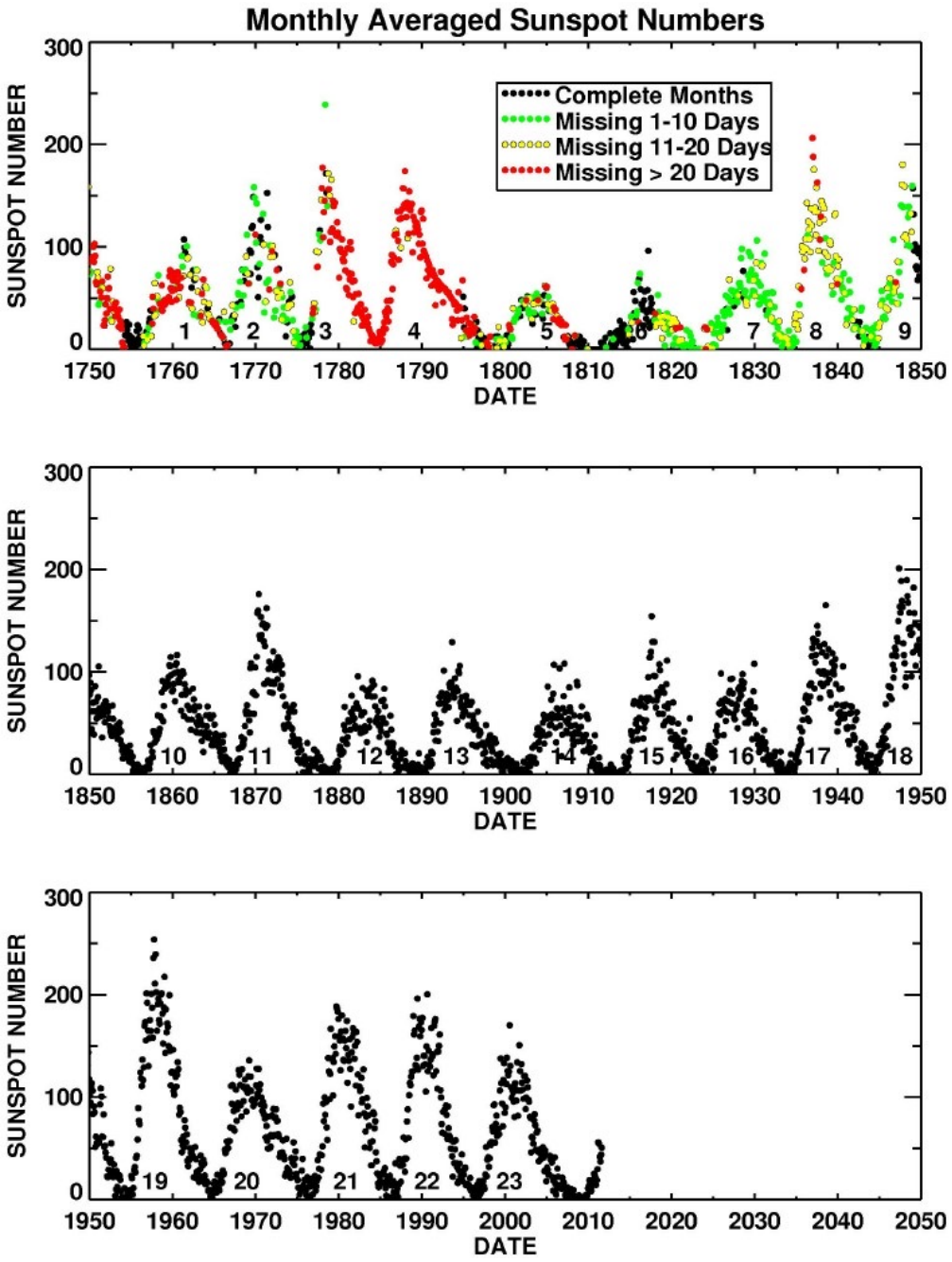
- Read up a little on the Zeeman effect to learn how the magnetic field strength and direction can be measured via spectroscopy (either textbook is fine)

Zeeman Effect



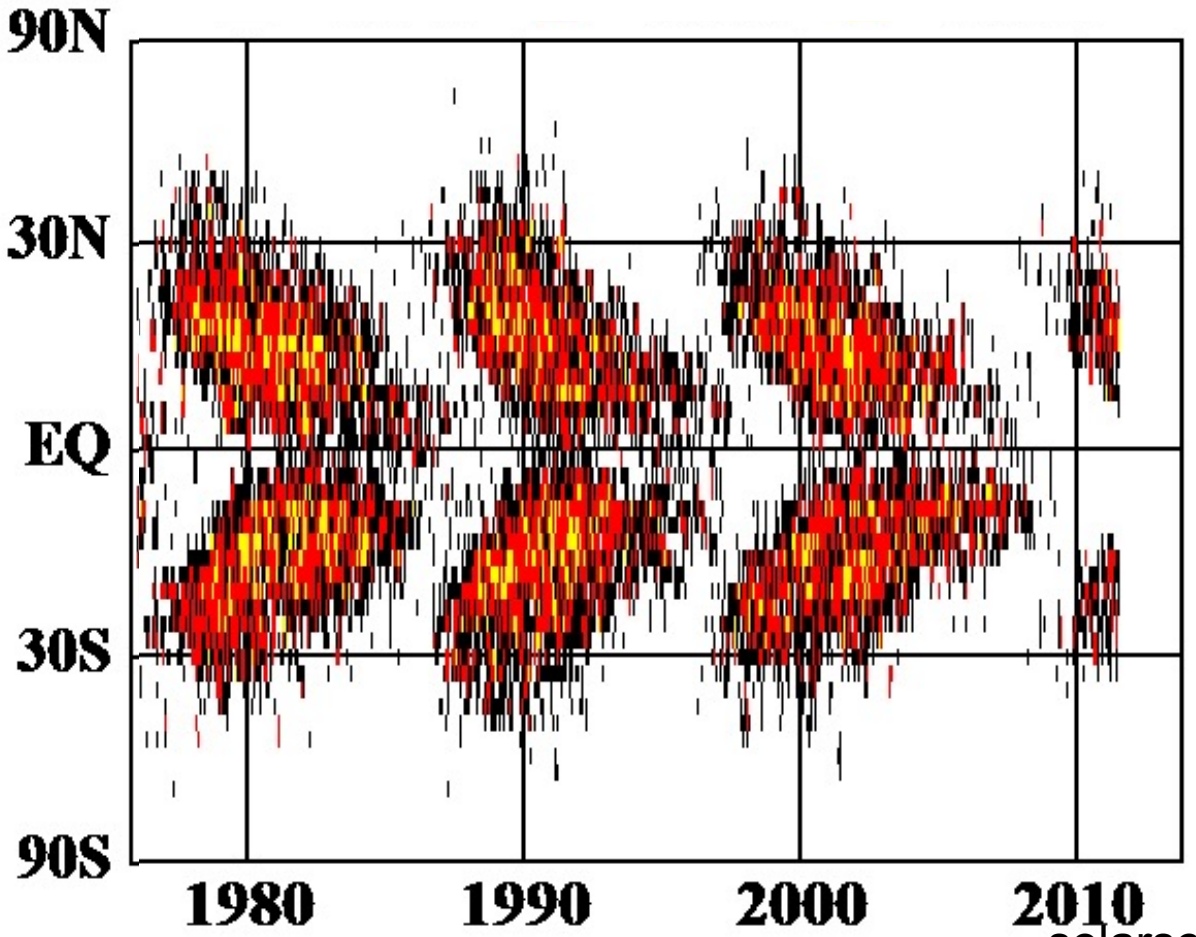
Solar Cycle

- Level of magnetic activity reaches a maximum every 11 years



solarscience.msfc.nasa.gov

- Spots start the cycle at high latitudes and end it at equatorial latitudes - Butterfly Diagram



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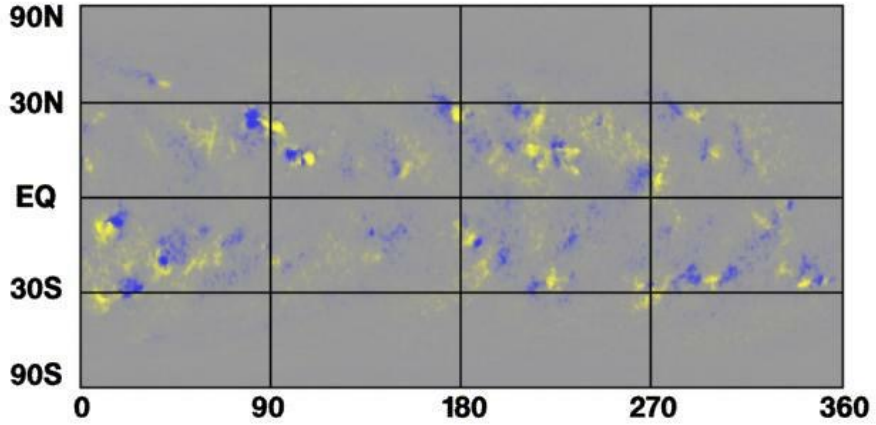
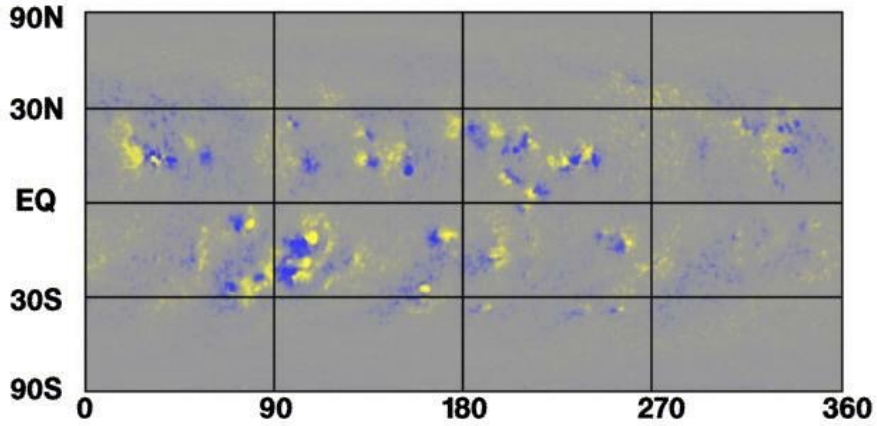
- Polarity of the sunspot pattern switches from one 11 year cycle to next
- Hence it is really a 22 year cycle before the pattern repeats itself

Cycle 21



Cycle 22



solarscience.msfc.nasa.gov

Class Exercise

- Find out where we are right now in the solar cycle – are we at maximum, minimum or somewhere in between?

- Visit the www.solarmonitor.org website to see the status of sunspot activity today.

SPACE WEATHER PREDICTION CENTER
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Monday, September 28, 2020 11:17:20 UTC

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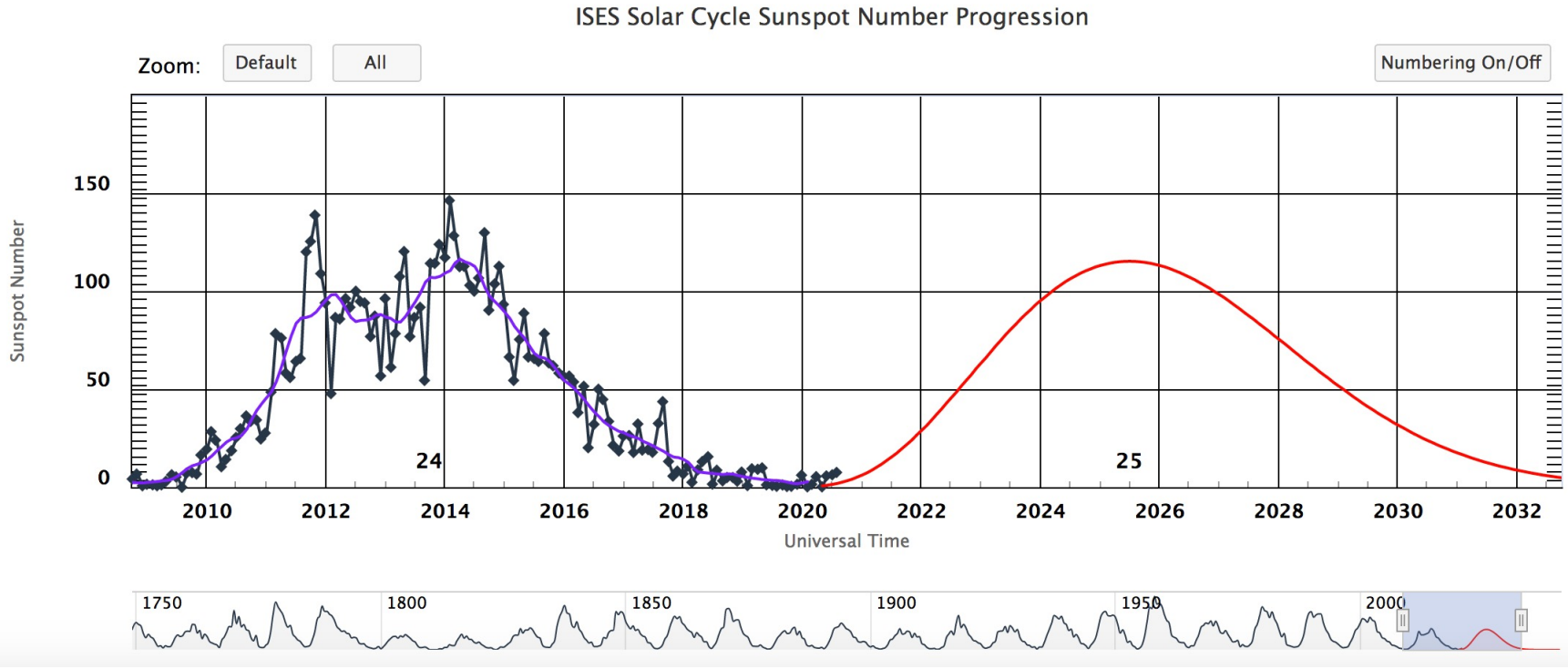
Home > Products and Data > Forecasts > Solar Cycle Progression

Search

CURRENT SPACE WEATHER CONDITIONS on NOAA Scales

R none | S none | G none

SOLAR CYCLE PROGRESSION



www.SolarMonitor.org

Date Search | 28 September 2020 | NOAA Search

⇐20200927 ⇐Week ⇐Rotation | Today | Rotation⇒ Week⇒ 20200929⇒

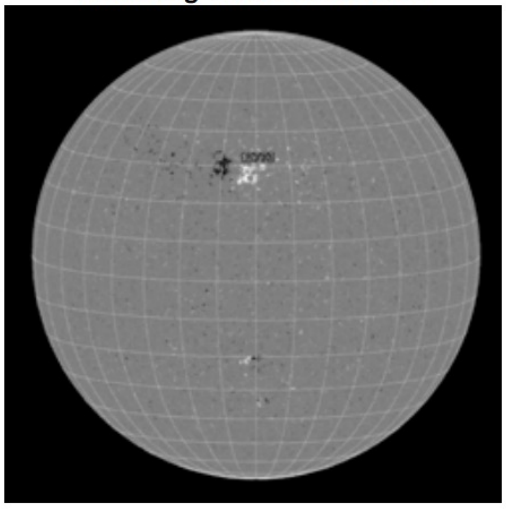
Main | Far-side | SDO short-wave | SDO long-wave

NOAA
1 Active Region

Flare Forecast

Coronal Holes

HMI Mag 20200928 05:58



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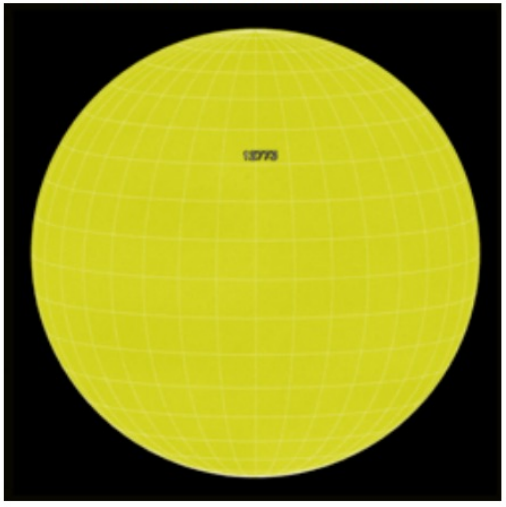

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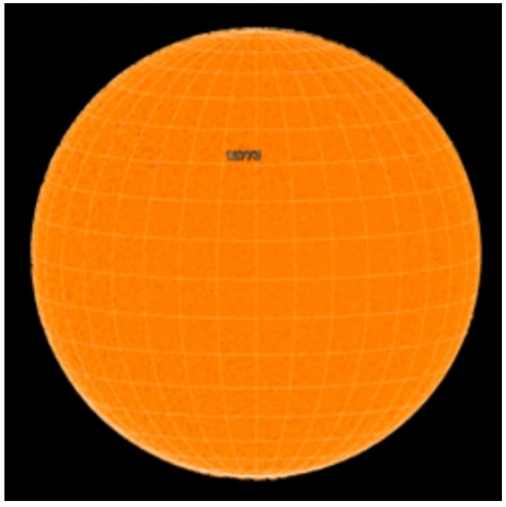

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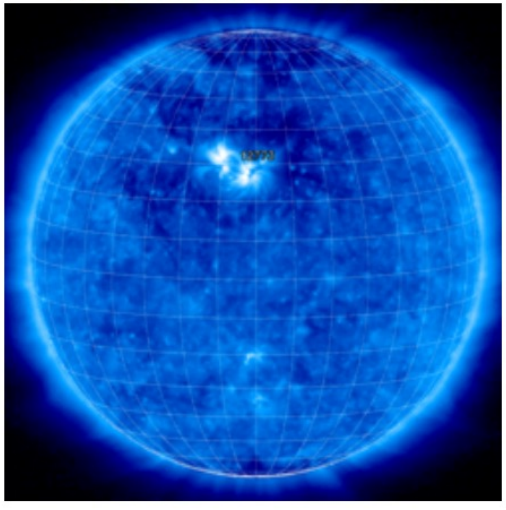

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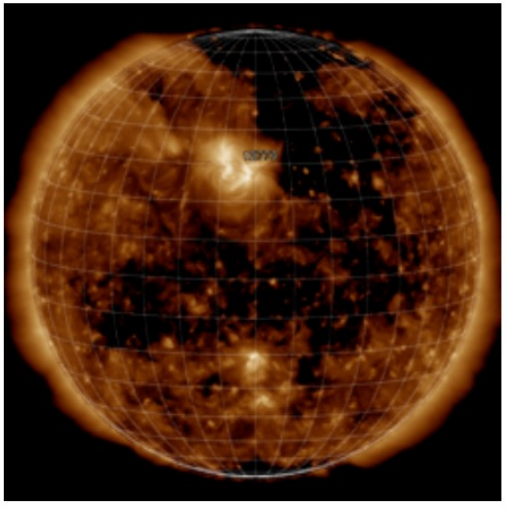

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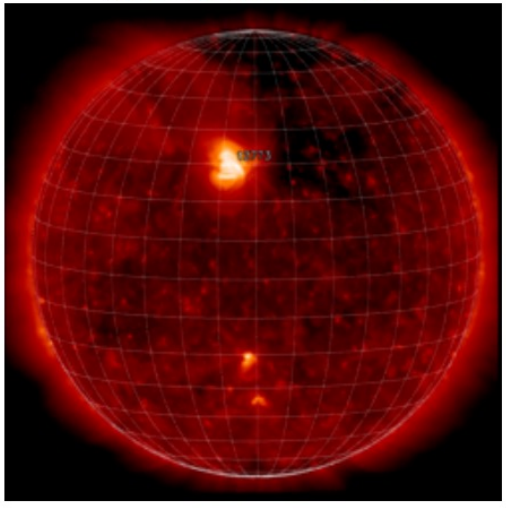
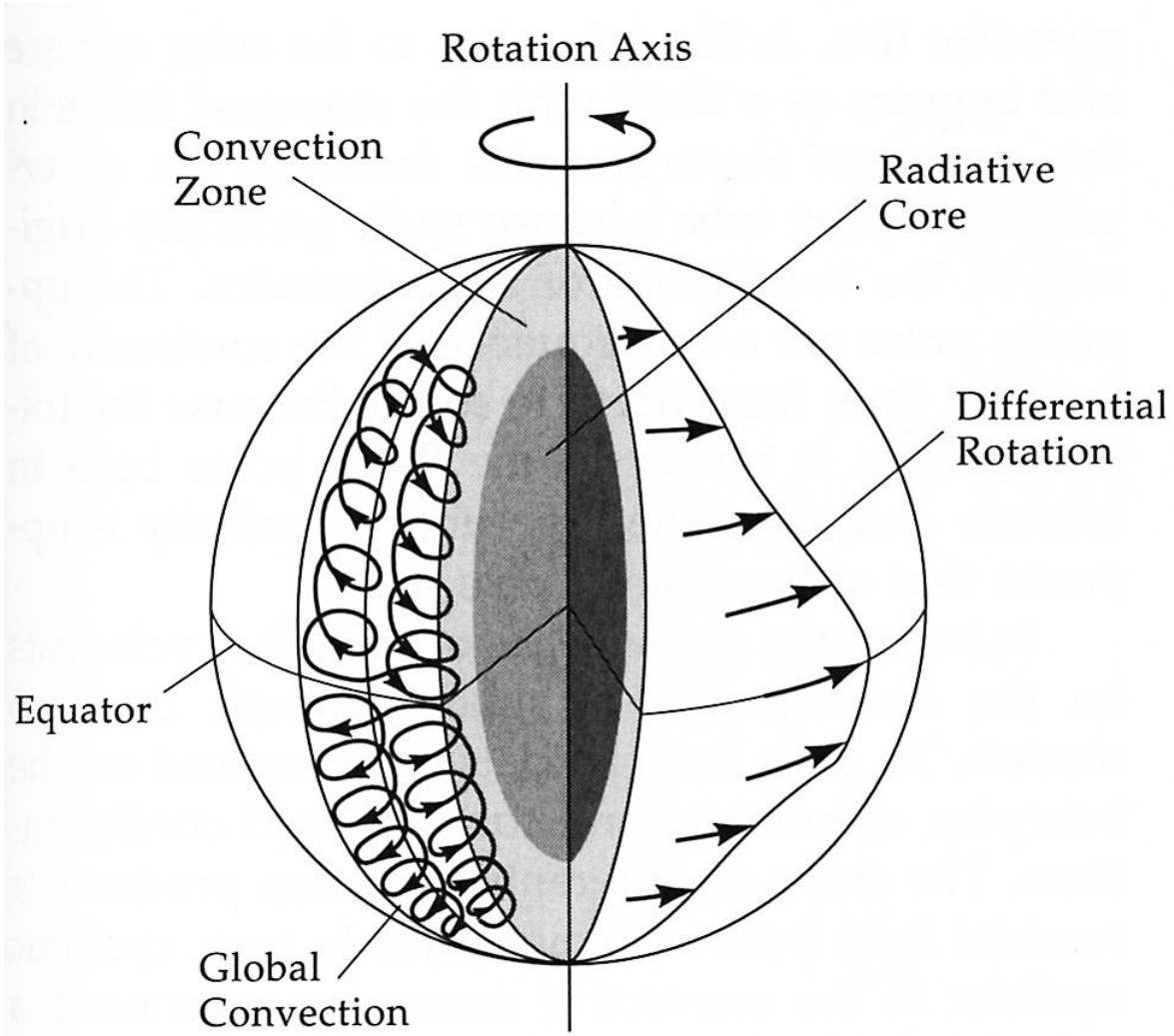
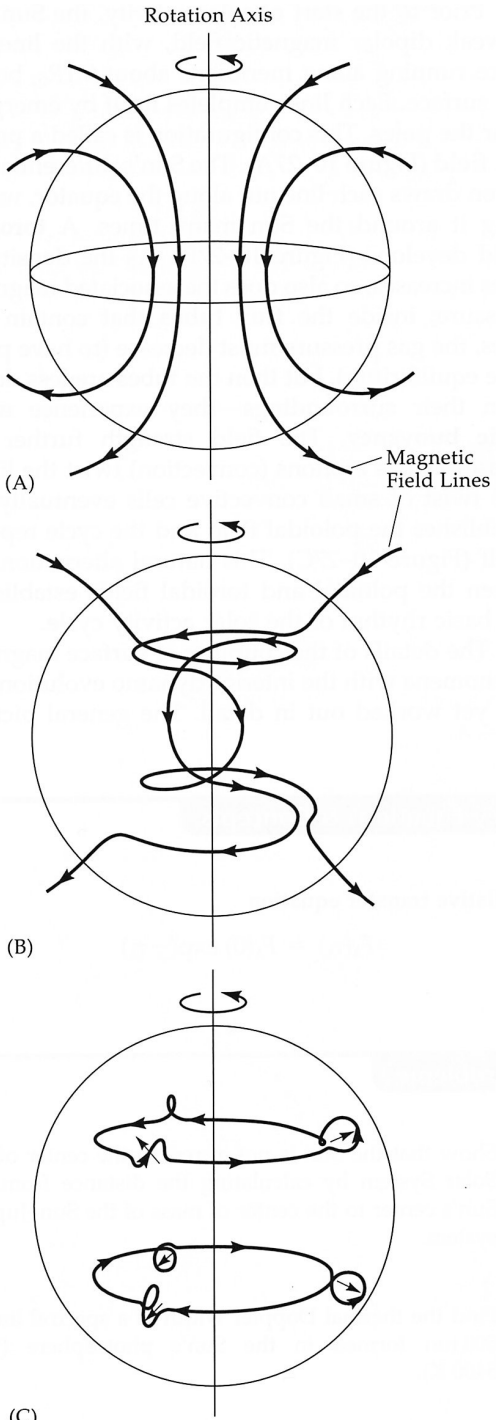


GOES
ACE
SDO/EVE
Events

Model for Solar Activity

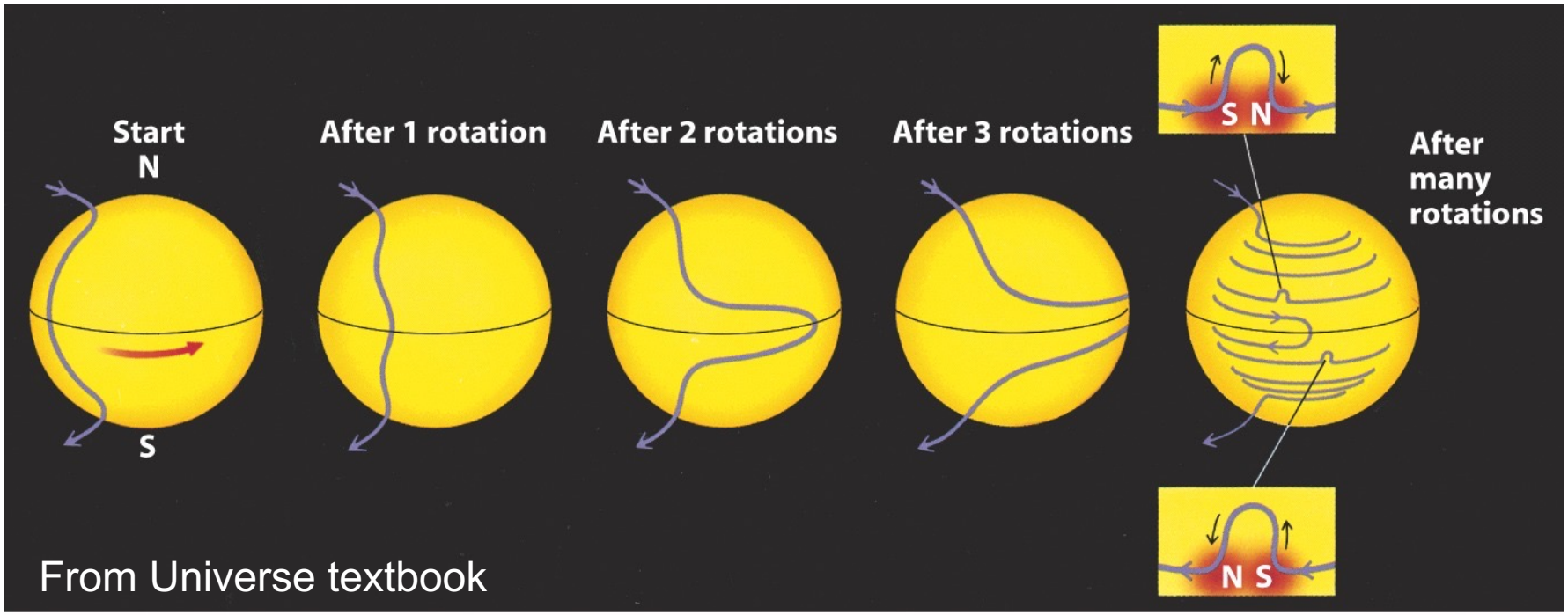
- Combination of differential rotation and convection generates strong magnetic field around the equatorial regions
- Field lines get wound up and very twisted
- Field lines arch up into the atmosphere causing sunspots





Zeilik &
Gregory
Fig 10-26

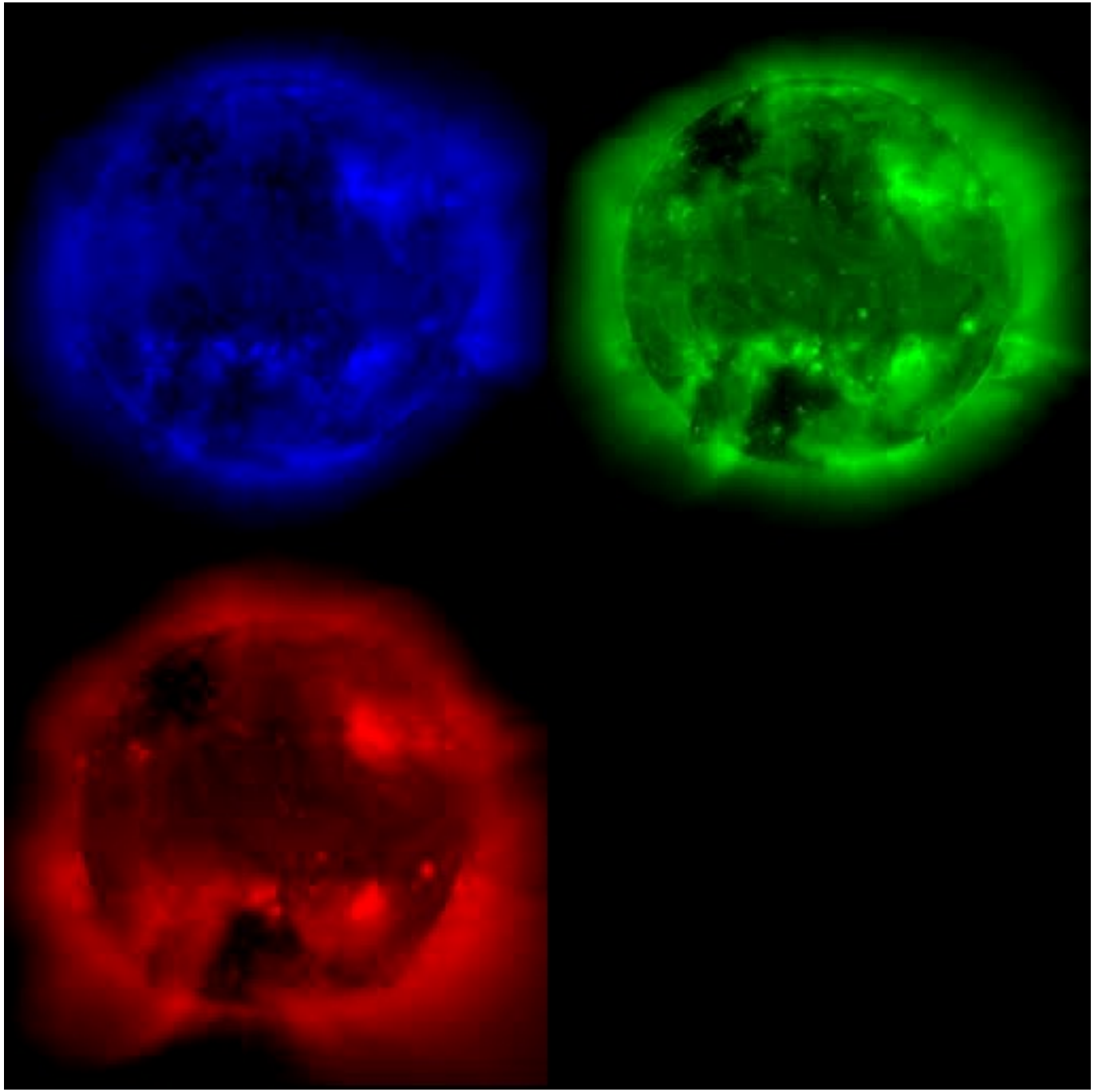
- Explains pattern of bipolar pairs

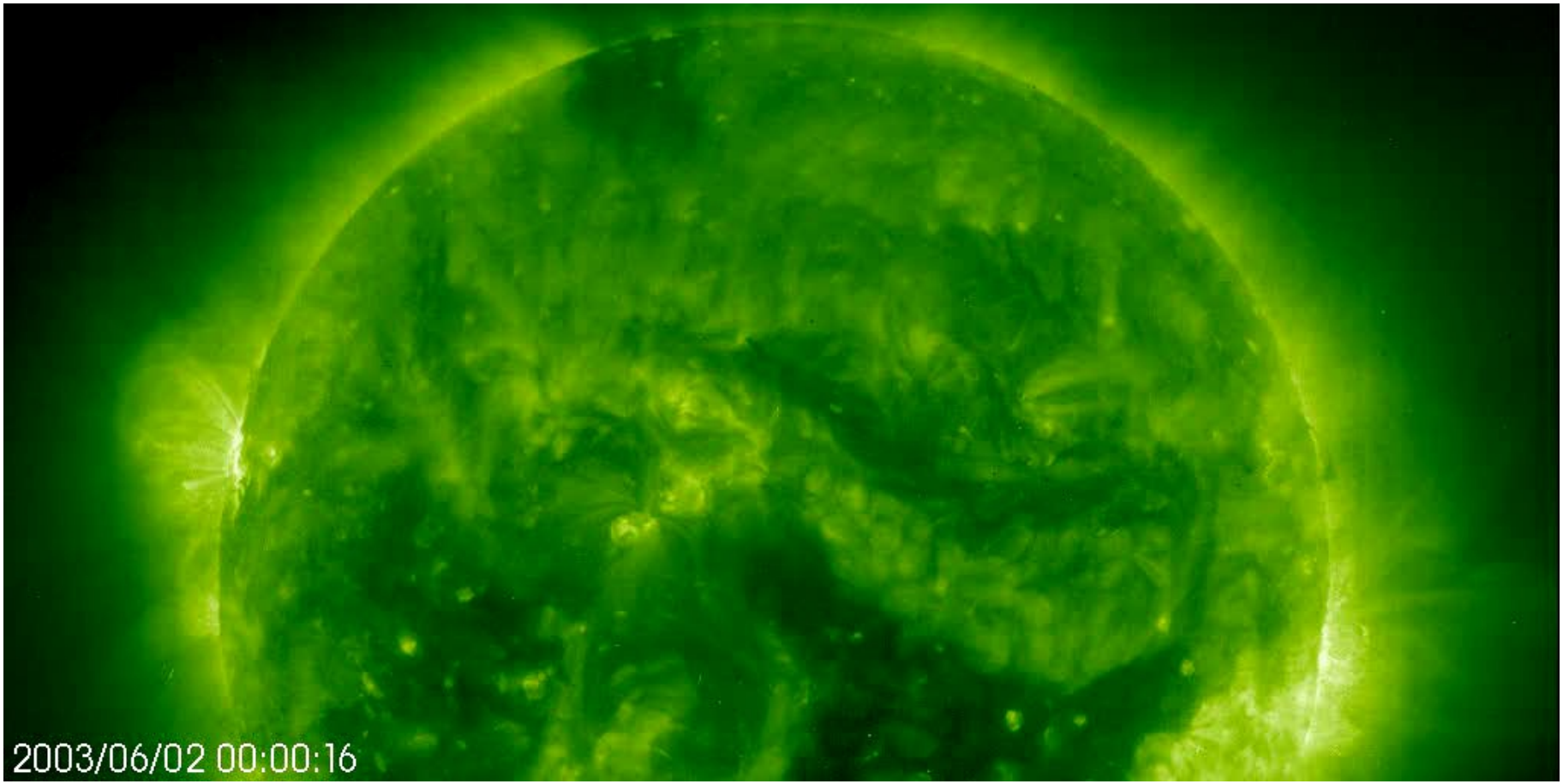


- Global magnetic field flips over every 11 years
- Movie at https://youtu.be/B4UtVo7-yJA

Summary

- The Sun's complex magnetic field generates and controls the activity seen
- Differential rotation and convection generates a strong magnetic field via dynamo action
- The high energy activity has an effect on the planets including Earth in the form of space weather and aurora
- (see more movies at soho.esac.esa.int/gallery/movies.html)

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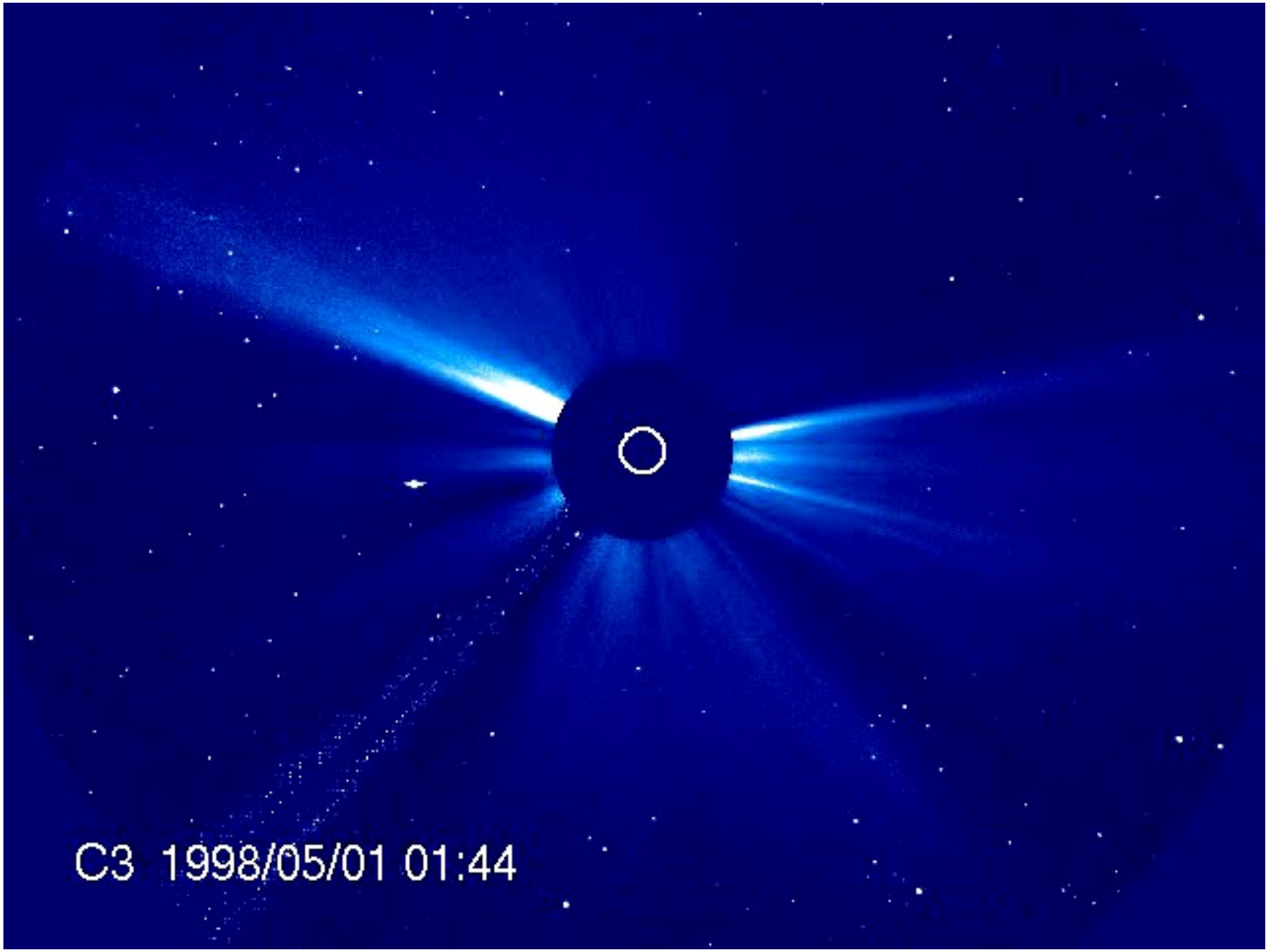
C3 1998/05/01 01:44

Class Exercise

- Consider a sunspot near the Sun's equator with a period of rotation of 27 days and a higher latitude sunspot that has a period of 30 days. If both start at the same longitude, how long before the equatorial spot overtakes the higher latitude one, i.e. when they are both at the same longitude again?