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6. Kodaikanal Solar Observatory – Science & Technology

Scientists from the Indian Institute of Astrophysics (IIA), an autonomous institute of the Department of Science and Technology (DST), used over 100 years of archival solar observations from the Kodaikanal Solar Observatory (KSO) to uncover new clues about how the Sun's surface convection patterns respond to its 11-year activity cycle. Researchers analysed approximately 34,000 Ca II K spectroheliograms recorded between 1907 and the present, covering more than nine solar cycles. Key findings reveal that surface convection features closely follow the 11-year solar cycle, with a notable time lag of 1.25-1.5 years between changes in convection-cell widths (at solar maximum) and subsequent changes in network brightness.

1. About the Study

Study Basis

1. Analysed **~34,000 Ca II K spectroheliograms** recorded between **1907 and present**
2. Covering **more than nine solar cycles**
3. One of longest continuous solar observation datasets globally

Ca II K Spectroheliograms

1. Images of the Sun taken in the **calcium-II K spectral line**
2. Useful for studying magnetic activity and solar networks
3. Ca II K wavelength (~393 nm) in violet part of spectrum
4. Reveals chromospheric features including active regions, filaments, network structures

Supergranulation and EUV Network

1. Study examined **large-scale convection cells (supergranules)** forming the chromospheric network
2. Network extends into transition region as **Extreme UltraViolet (EUV) network**
3. Linking surface convection to higher atmospheric layers

2. Key Findings of the Study

Linked to Solar Activity

1. Surface convection features closely follow **11-year solar cycle**
2. Especially in regions located about **11°–22° north and south of the equator**
3. Demonstrating latitude-specific solar activity response

Different Latitudes Behave Differently

1. No single latitude perfectly reflects solar activity
2. Sun's surface responds differently across regions
3. Complex latitude-dependent dynamics

Time Lag Observed

1. Changes in **convection-cell widths** occur around **solar maximum**
2. Changes in **network brightness** appear **1.25–1.5 years later**
3. Suggesting cascade of effects through solar atmosphere layers

Variable Response Across Latitudes

1. Time lag differs across latitudes
2. Suggesting complex interactions between solar magnetic fields and convection patterns

Role of Magnetic Flux

1. Supergranular properties influenced by -
    1. Local magnetic flux concentrations
    2. Changing solar activity levels
2. Magnetic field-convection interaction central to observed patterns

3. About Supergranulation

Definition

1. Large convective cells on the Sun's surface
2. **Average size - ~30,000 km** (Earth's diameter ~12,750 km for comparison)
3. **Lifetime - ~24 hours**
4. Horizontal flow cells carrying hot plasma from solar interior to surface

Magnetic Network Formation

1. Boundaries contain **concentrated magnetic fields**
2. Forming **chromospheric network** visible in Ca II K observations
3. Network traces supergranular boundaries across solar surface

Role in Magnetic Flux Transport

1. Play important role in **transporting magnetic flux** across solar surface
2. Horizontal flows sweeping magnetic elements to supergranular boundaries
3. Contributing to solar magnetic field evolution

Other Solar Convection Structures

1. **Granules -** Smaller convection cells (~1,000 km, lifetime ~10 minutes)
2. **Supergranules -** ~30,000 km, ~24 hours (studied here)
3. **Giant cells -** Hypothetical very large convection cells (~200,000 km)

4. About Kodaikanal Solar Observatory (KSO)

Location and Administration

1. Situated in **Palani Hills of Tamil Nadu**
2. Operated by **Indian Institute of Astrophysics (IIA)**
3. IIA - Autonomous institute under **Department of Science and Technology (DST)**

Establishment

1. Founded in **1899** for systematic solar observations
2. Originally established by British colonial government
3. One of world's oldest continuously operational solar observatories

Long-Term Solar Records

1. Maintains one of world's **longest continuous series of solar observations**
2. Spanning **over 100 years**
3. Invaluable for studying multi-decadal solar variability

Multi-Wavelength Observations

1. Conducts simultaneous observations in different wavelengths -
    1. **Ca II K (393 nm) -** Chromospheric magnetic activity
    2. **H-alpha -** Solar flares, prominences, filaments
    3. **White light -** Sunspot observations
2. Dataset uniquely suited for multi-wavelength solar studies

Global Research Resource

1. Century-long records providing insights into long-term solar behavior
2. Covering multiple solar cycles (11-year periodicity)

3. Freely accessible to international solar physics community

5. The 11-Year Solar Cycle

Definition

1. Approximately **11-year cycle** of solar activity variation
2. Measured by sunspot number, magnetic activity, solar radiation
3. **Solar maximum -** Peak sunspot activity, intense magnetic activity
4. **Solar minimum -** Fewest sunspots, lowest activity

Solar Cycle Indicators

1. **Sunspots -** Dark, cool regions on solar surface due to strong magnetic fields
2. **Solar flares -** Intense bursts of electromagnetic radiation
3. **Coronal Mass Ejections (CMEs) -** Large plasma and magnetic field expulsions
4. **Solar wind -** Stream of charged particles from Sun varying with cycle

Impact on Earth

1. **Geomagnetic storms -** CMEs disrupting Earth's magnetic field
2. **Aurora borealis/australis -** Enhanced during solar maximum
3. **Satellite drags -** Increased upper atmosphere density during maximum
4. **Radio communication disruption -** Ionospheric changes affecting signals
5. **Power grid failures -** Geomagnetically induced currents
6. **Climate -** Solar irradiance variations affecting Earth's energy balance (studied for monsoon connections)

6. Significance of the Study

Improves Solar Cycle Understanding

1. New insights into how supergranulation, EUV network evolve during 11-year solar activity cycle
2. Revealing latitude-dependent response patterns previously unknown

Supports Solar Activity Prediction

1. Understanding correlation between supergranulation and sunspot activity
2. Improving future solar cycle forecasts
3. Critical for space weather prediction

Helps Study Solar Irradiance

1. Findings relevant for understanding variations in solar ultraviolet radiation
2. Affecting Earth's upper atmosphere, ozone layer, ionosphere
3. Implications for satellite operations, GPS accuracy

Advances Solar Physics

1. Contributes to resolving long-standing puzzle of origin, evolution of supergranulation
2. One of unsolved problems in solar physics

Value of Long-Term Data

1. Demonstrates scientific importance of century-long observations
2. Validating investment in maintaining historical observational archives
3. Encouraging preservation of other long-term datasets globally

Future Research Potential

1. **National Large Solar Telescope (NLST) -** High-resolution observations expected to further improve understanding of supergranular dynamics
2. NLST - India's planned large solar telescope (planned for Merak, Ladakh — high-altitude site for superior seeing conditions)

Conclusion

IIA scientists' analysis of 34,000 Ca II K spectroheliograms from Kodaikanal Solar Observatory (founded 1899) across nine solar cycles reveals supergranulation closely follows the 11-year solar activity cycle — with convection-cell width changes at solar maximum and network brightness responding 1.25-1.5 years later — demonstrating KSO's century-long dataset as globally irreplaceable resource advancing solar physics, space weather prediction, and solar irradiance understanding critical for Earth's atmospheric, communication, and satellite systems.

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