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FINAL REPORT

Science Working Group Meeting for
Definition of NASA's Mechanisms of Solar Variability Program
P.O. H-24734D

PERIOD OF PERFORMANCE: January 1, 1995 - July 16, 1995

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(NASA-CR-199262) SOLAR-B: EXPLORING THE DYNAMIC SUN Final Report, 1 Jan. - 16 Jul. 1995 (Alabama Univ.) 24 p

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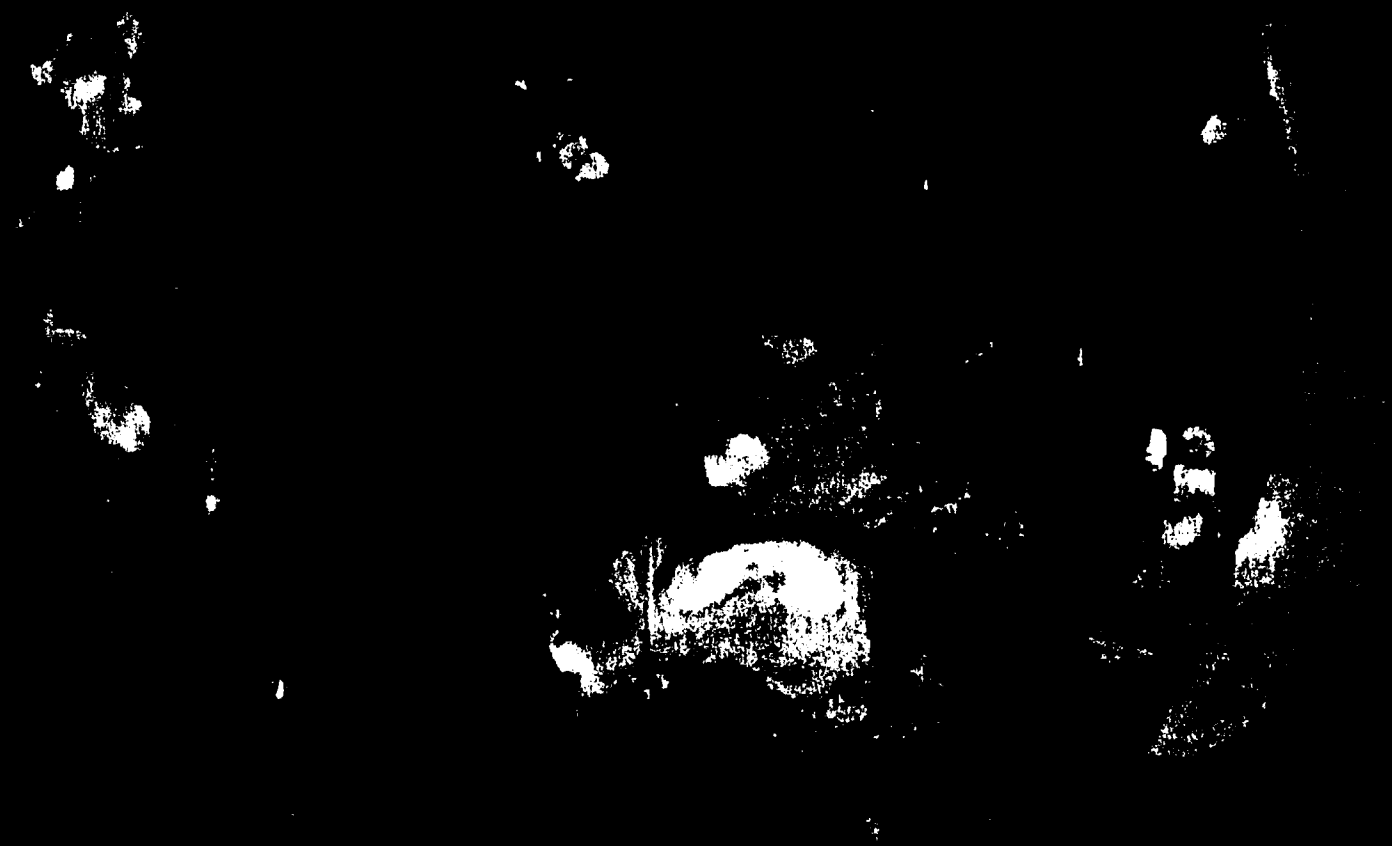
In this period of performance, January 17, 1995 - July 16, 1995 a three day meeting was held at the Space Science Laboratory, George C. Marshall Space Flight Center on February 14, 15, and 16, 1995. This meeting was to call the Science Working Group Meeting for Definition of NASA's Mechanisms of Solar Variability Program Working Group to review and update plans for NASA's MSV program. Particular attention was given to the option of NASA participating with the Japanese in the next solar space mission. Personnel from NASA/HQ, NRL and NASA/MSFC attend the meeting. UAH supported actual travel expenses for the following members of the SWG to attend the meeting:

Richard Canfield	Hugh Hudson
Leon Golub	Ken Dere
J. Harvey	Alan Title
Stephen Keil	
Bruce Lites	

The enclosed brochure is a result of this meeting.

SOLAR-B



Exploring the Dynamic Sun

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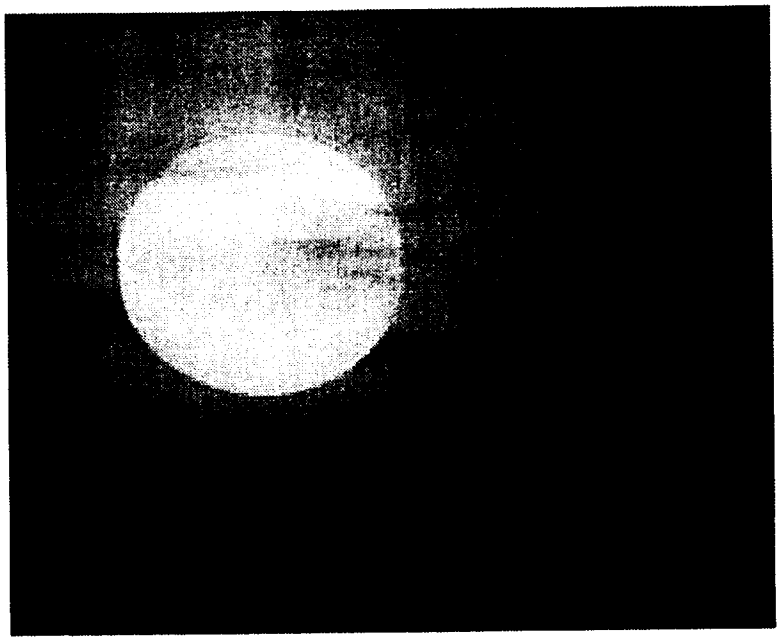
The Dynamic Sun

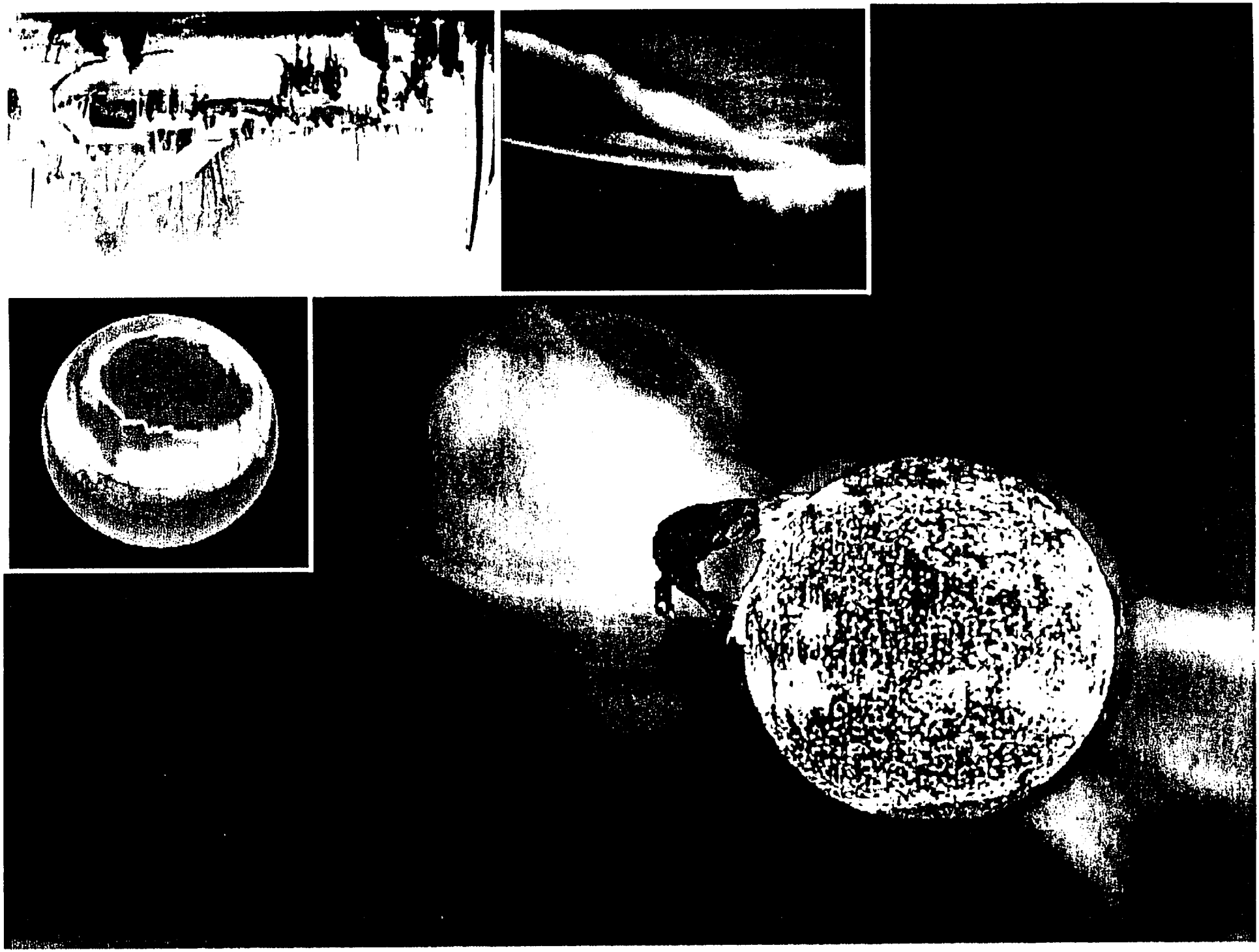


The Sun is the main source of light and energy for all life on Earth.

We seek to understand the origins of solar activity and variability which disrupt our home environment.

> *"How are the conditions for life on Earth maintained? How does the solar output vary?... What knowledge from space can improve the quality of life on Earth?... "*
>
> NASA Strategic Plan, 1994

Cover: *Yohkoh* soft X-ray image from May 8, 1992



The Sun-Earth System

Solar-B will reveal the mechanisms for solar variability, and study the origins of space weather and global change.

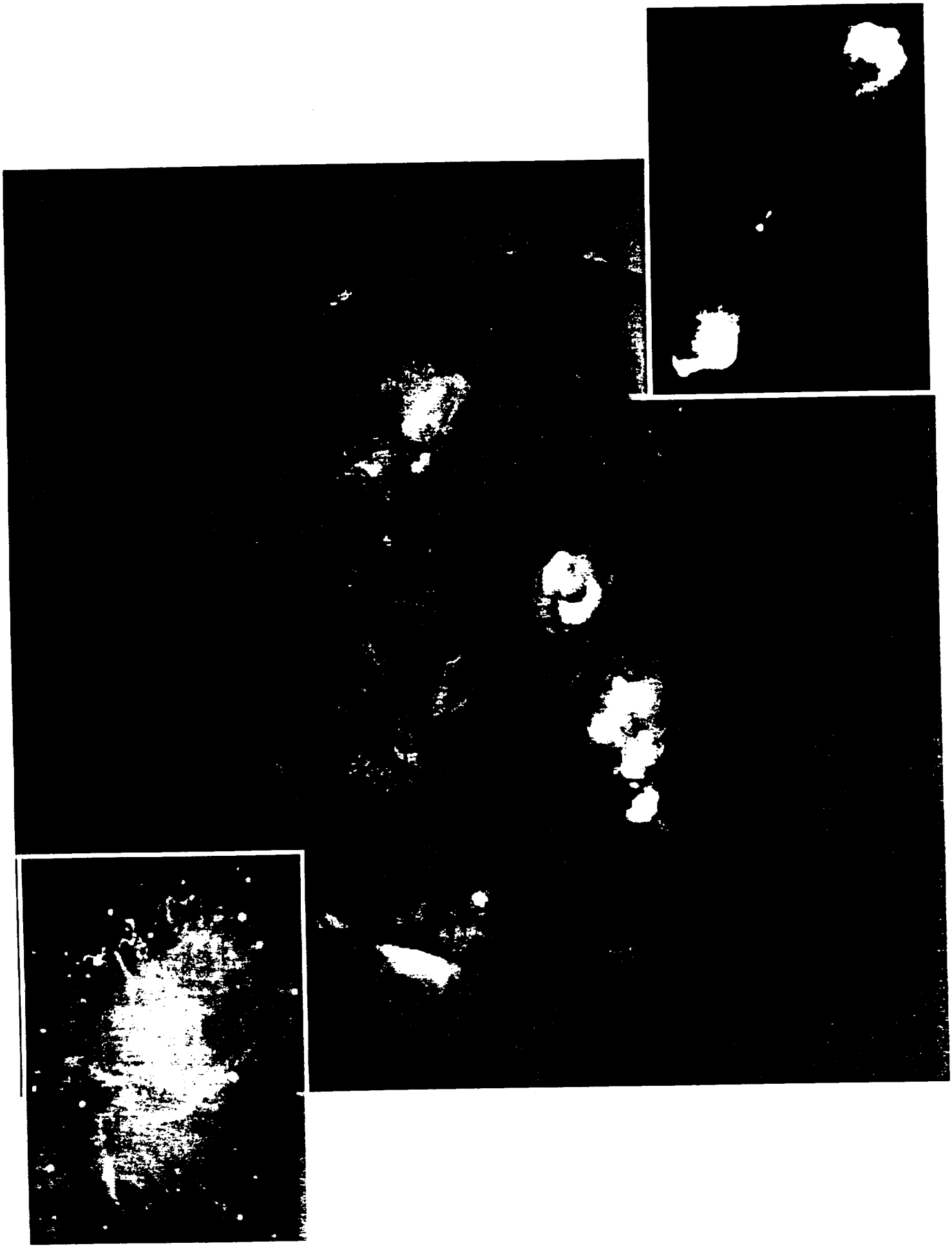
The Sun and Earth form a tightly coupled system, with solar variability driving effects ranging from space weather to climate change.

Global Climate:
The Sun's brightness is not constant and its magnetic activity influences the Earth's temperature, contributing both to global warming and little ice ages.

Upper Atmosphere:
The Sun's magnetic activity causes extreme variations in ultraviolet and X-ray radiation. These radiations control the Earth's ionosphere and the protective ozone layer.

Space Weather:
The Earth is constantly bombarded by solar material accelerated in the corona. Frequently magnetic disruptions eject massive clouds which impact the Earth causing magnetic storms. Energetic particles often create local radiation hazards in space.

Figure: Superposed *Skylab* coronagraph and He 304 Å images; ozone concentration from TOMS; Brugel painting of skaters during the "Little Ice Age"; auroral curtain seen from space.



Broader Implications: Our Dynamic Universe

Solar-B will provide detailed information about the dynamic behavior of cosmic magnetic fields.

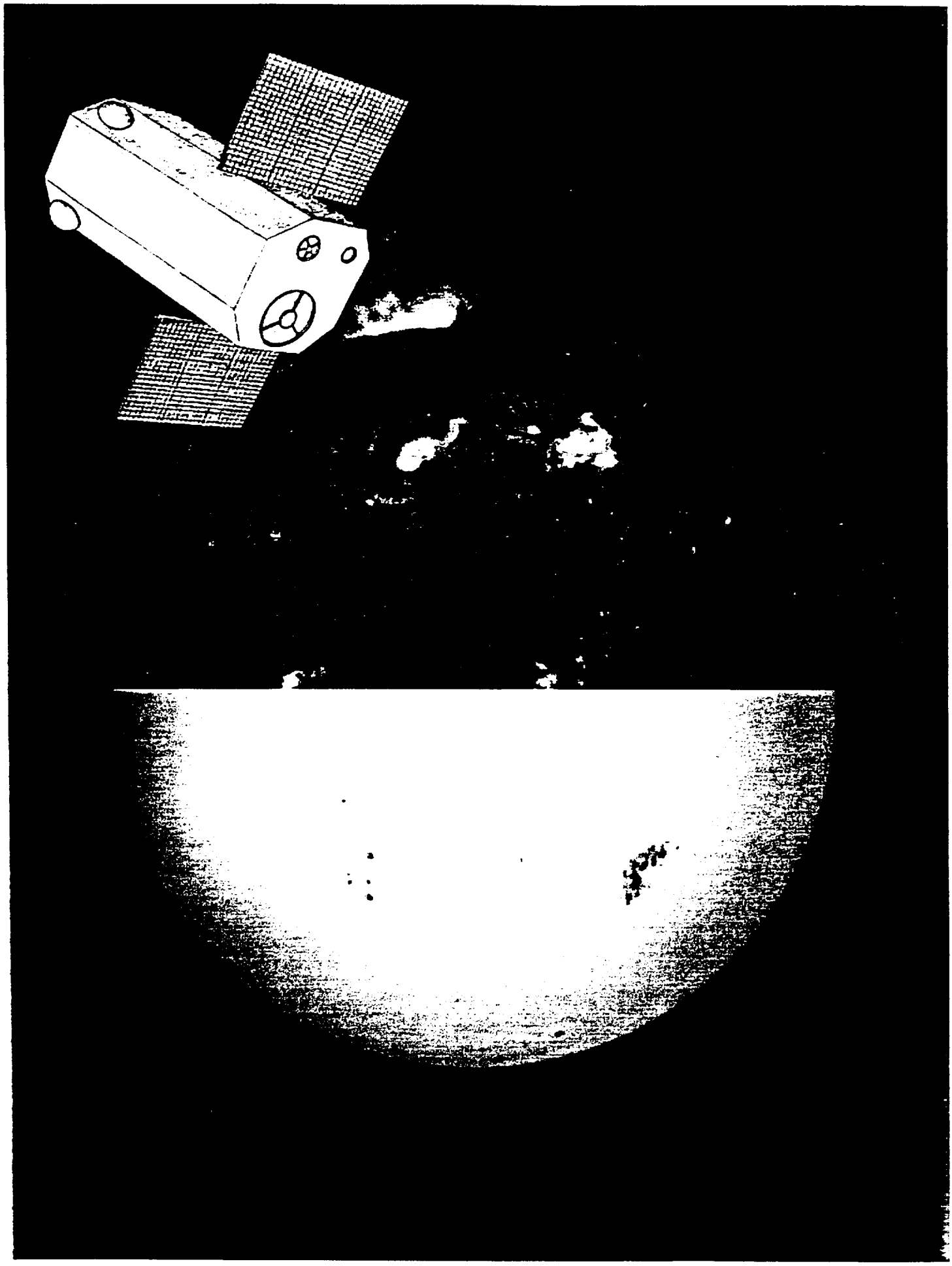
Astronomical objects — from dwarf stars to accretion disks to giant elliptical galaxies — have dynamic magnetic fields, the origins of which are not well understood.

Pulsars such as the Crab have magnetic fields a billion times stronger than the Sun's, transmitting sufficient energy to power the entire Crab nebula.

Magnetic fields in cosmic jets cause massive radio emission by interaction with high-energy particles.

Our own Sun has the most intense magnetism in the solar system. The Sun's atmosphere, the million-degree corona, its dynamic nature, and the solar wind extending out to the Earth and beyond, are all direct consequences of the Sun's magnetic activity.

Figure: Galactic radio jets from quasar 3C-175; *Yohkoh* soft X-ray image from November 12, 1991; the Crab nebula.

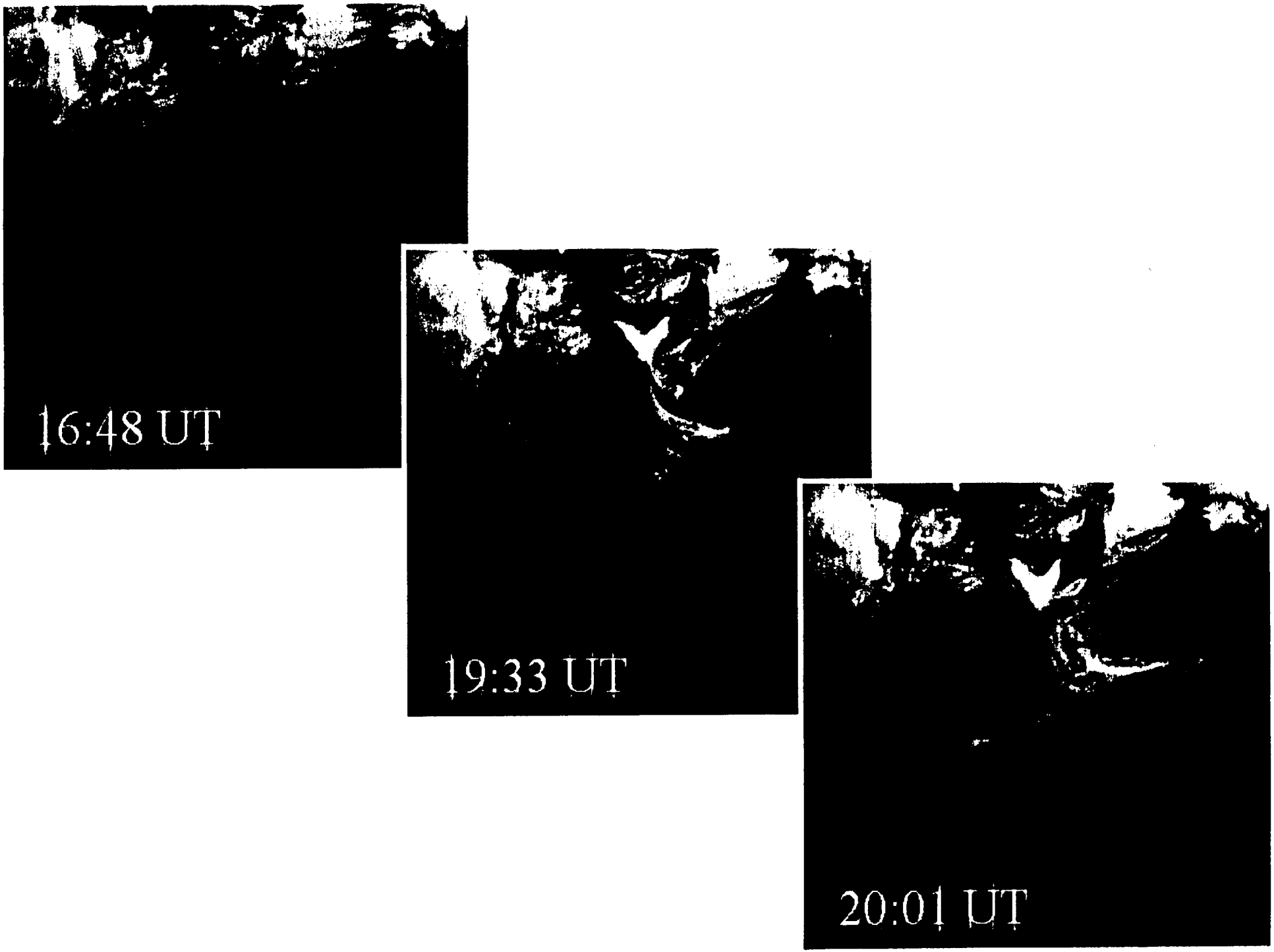


The Solar-B Mission

Solar-B is:

- An international collaboration building on the highly successful Japan/U. S. *Yohkoh* (Solar-A) experience.
- A coordinated set of optical, UV, and X-ray instruments to understand the dynamic Sun.
- A source of dramatic images of solar activity with a strong education and outreach component.

Figure: Solar-B satellite; *Yohkoh* soft X-ray image; Big Bear Solar Observatory white light image.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Understanding the Dynamic Sun

Solar-B will provide a comprehensive view of the dynamic solar atmosphere.

Observational Advances:

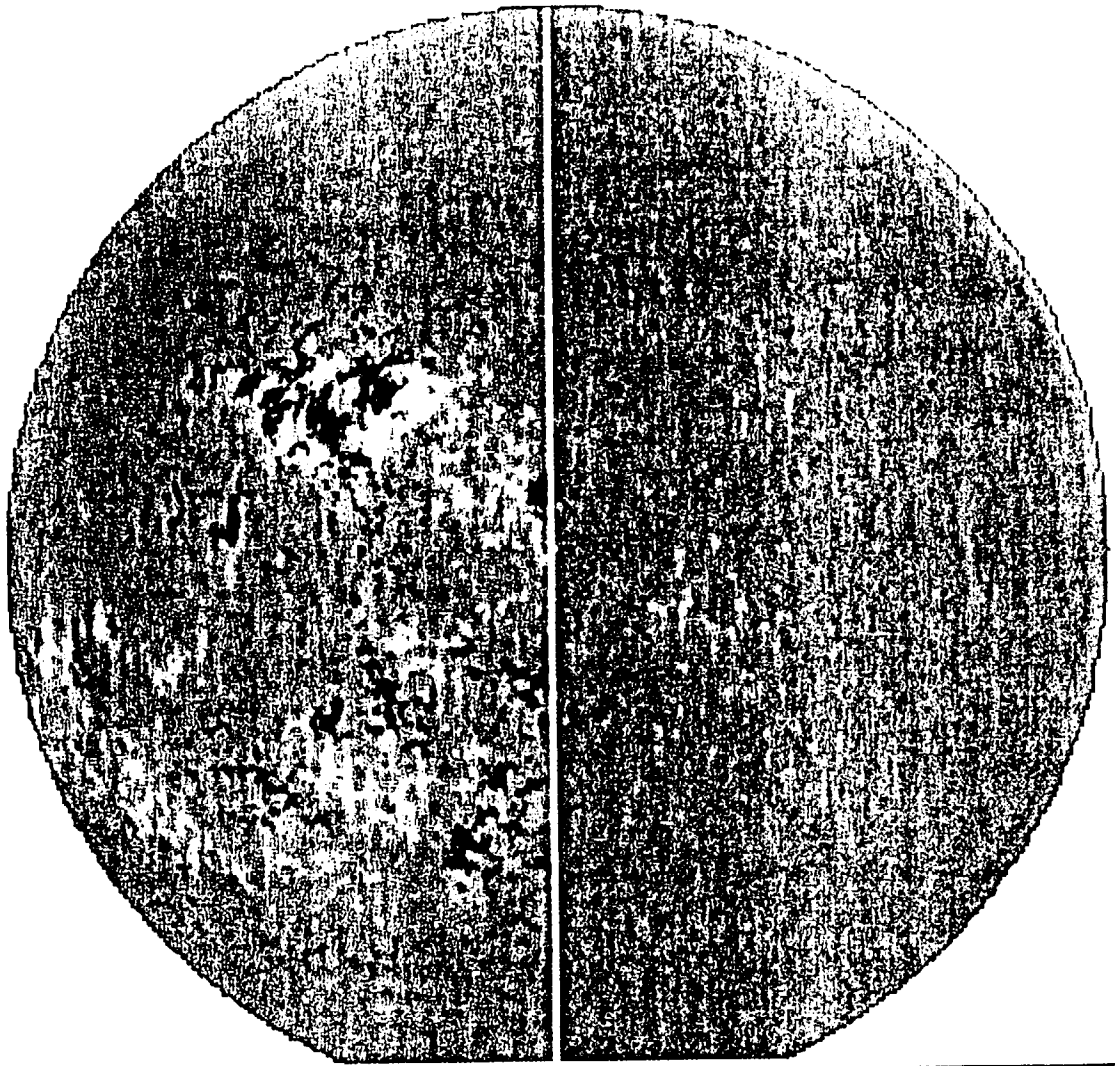
- Reveals magnetic field's photospheric roots and 3-D linkage to corona.
- Provides unprecedented spatial resolution
- Provides first complete time coverage at high resolution.

Science Objectives:

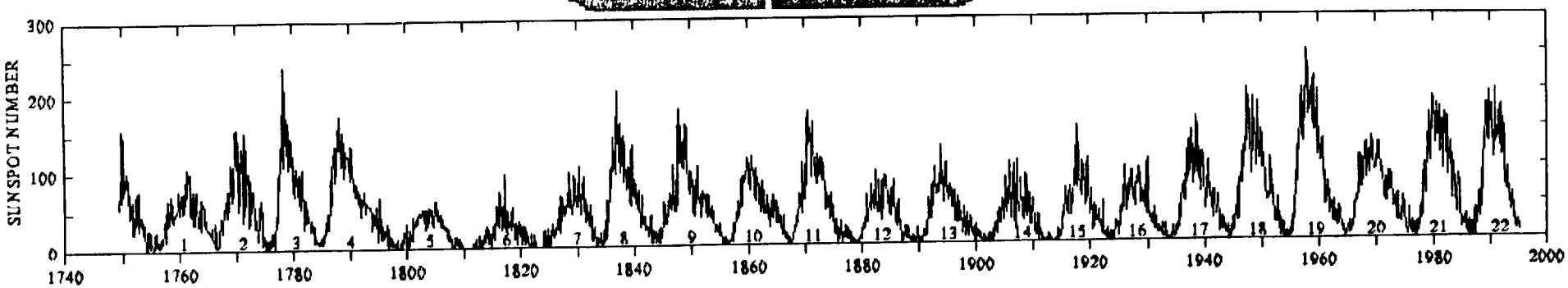
1. Creation and destruction of the Sun's magnetic field.
2. Modulation of the Sun's Luminosity.
3. Generation of UV and X radiation.
4. Solar wind and eruptions.

Figure: *Yohkoh* soft X-ray images from February 26, 1992 showing the "Scorpion" filament eruption.

Maximum Phase (1991)



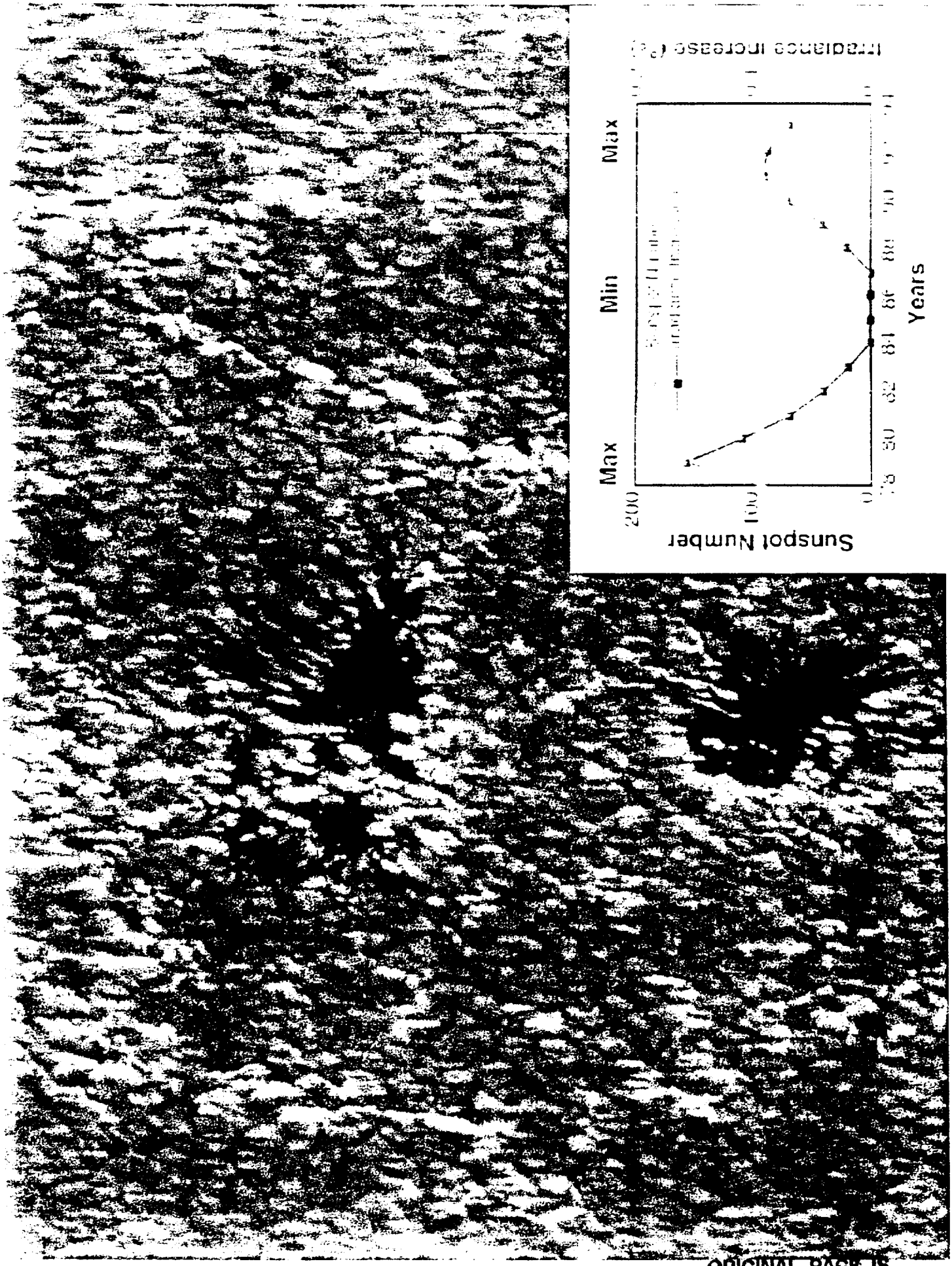
Minimum Phase (1995)



Objective: Magnetic Field Creation and Destruction

- Creation
  - — Processes hidden deep within the Sun generate surface activity in an 11-year cycle.
  - — Solar-B uses emerging field as a tracer to the deep-seated processes causing solar activity.
- Destruction
  - — The processes by which solar magnetism leaves the Sun to produce a solar cycle are unknown.
  - — Solar-B will directly show the magnetic flux removal process and its role in the cycle.

Figure: Solar magnetic field from National Solar Observatory at cycle maximum and minimum; international sunspot numbers from 1749 to 1995.



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Objective: Modulation of the Sun's Luminosity

All life on Earth depends on the Sun's radiation for its existence. Small changes in the solar heating can change our climate and weather, with enormous impact on human civilization.

Measurement of the solar "constant" shows the Sun to be less luminous at sunspot cycle minima. An extended period of abnormally low activity coincided with the "Little Ice Age" in the 17th century.

Extremely small scale features in the solar photosphere cause the solar cycle changes in the luminosity. Solar-B will make the first observations with resolution, wavelength coverage, and sampling adequate to determine the role of these features in the long-term solar luminosity changes.

Figure: G-band image of the solar photosphere from the Swedish Vacuum Solar Telescope on LaPalma showing bright faculae and dark spots; plot of solar luminosity and the sunspot cycle.

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Objective: Production of UV and X Radiation

The Sun is a powerful and highly variable source of ultraviolet and X radiation, which has major effects on our environment.

The solar UV and X radiation originates in the chromosphere and corona, where temperatures rise to over one million degrees. In flares, energetic particles and even gamma rays are produced, with coronal temperatures exceeding ten million degrees.

Solar-B will have the spatial resolution and the wavelength and temporal coverage needed to answer questions raised by *Yohkoh* and TRACE about the processes which produce the UV and X-ray emission.

Figure: *Yohkoh* soft X-ray image from November 12, 1991 overlaid on a NSO magnetogram from the same date.

Objective: Causes of the Solar Wind and Eruptions

Solar Wind:
The million-degree corona continually expands outward, becoming a supersonic wind that blows past the Earth, buffeting the geomagnetic field and dumping energy into the upper atmosphere.

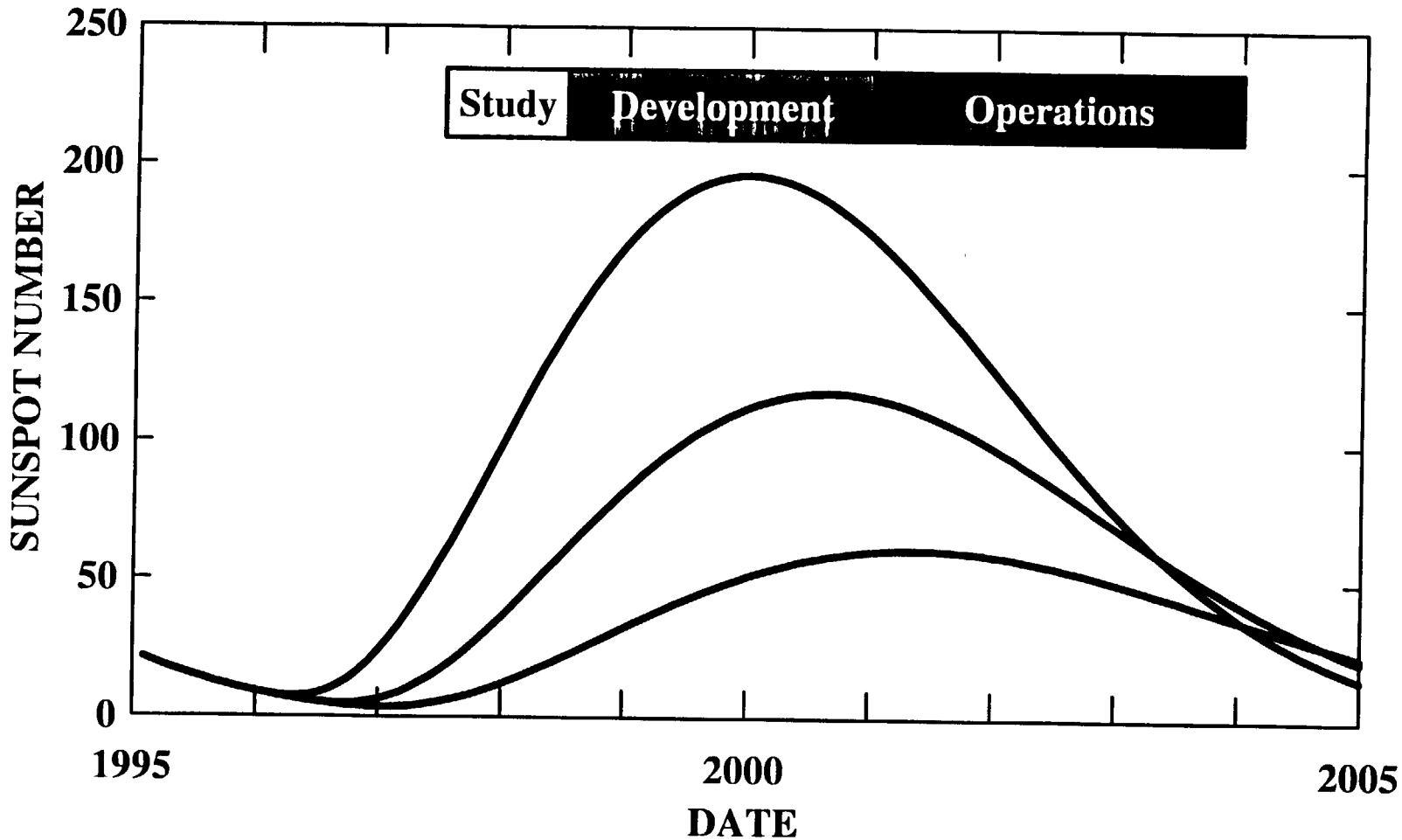
Eruptions:
Large parts of the corona are seen to explode, blast through the solar wind, and cause major magnetic and atmospheric disturbances at the Earth. The solar atmosphere is filled with eruptive events — surges, spicules, X-ray jets — representing release of magnetic energy into the corona.

Solar-B:

- opens a new window on the root causes of coronal heating, providing new understanding of solar wind energetics.
- provides accurate measurements of magnetic fields, to reveal the causes of eruptions in the solar atmosphere.

Figure: NIXT soft X-ray image superposed on HAO eclipse image of July 11, 1991; the "Grandaddy" eruptive prominence of June 4, 1946 from HAO.

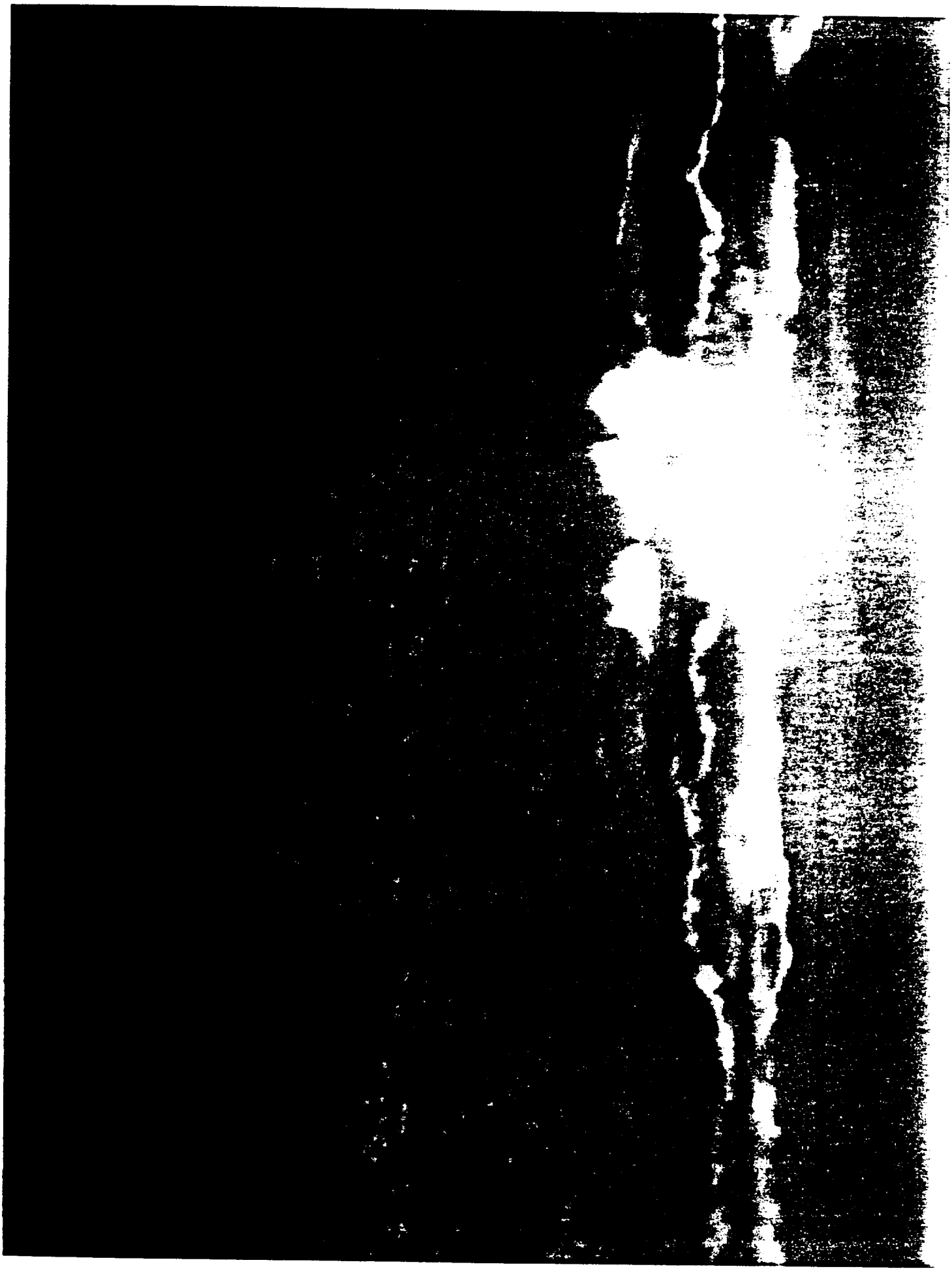
Proposed Solar-B Schedule



Programmatic Benefits to NASA

- Highly leveraged participation in a major mission.
- Reliable partner, proven cost and schedule maintenance.
- Builds on *Yohkoh*, SOHO, and TRACE.
- Continues the thrust of the Solar Connections program.

Figure: Mission schedule and the possible solar cycle behavior (large, average, and small cycle profiles).



Summary

What: Solar-B contains a set of high-resolution solar telescopes and spectrometers. The data will reveal the mechanisms of solar variability that arise in the dynamic structure of the solar atmosphere.

Why: We need such data to understand the variable Sun and its effect on terrestrial climate (global change) and space weather.

Science:

- Advances in understanding basic plasma astrophysics such as the dynamo and magnetic reconnection processes.

- Identification of the physics underlying the variations of solar luminosity as an input to global change.

- Identification of the mechanisms of solar variability.

Technology:

- Solar-B is a "faster, cheaper, better" opportunity to develop specific technologies in remote sensing instrumentation, such as ultra-precise polarimeters and optical and X-ray filters.

Outreach:

- Solar-B imaging observations will provide a basic tool for education and public understanding of plasma physics at work in nature.

- Observations of the Sun, our local star, substantially influence the public understanding of science and technology.