Solar Physics Division of the American Astronomical Society

The Coronal Courant

A Solar Zine for the Solar Scene

Image Credit: NASA/Goddard/SDO/AIA

Volume 1, Issue 2 *Shining Light on the Sun* **May 11, 2010**

From APOD (Astronomy Picture of the Day): http://apod.nasa.gov/apod/ap100423.html

Explanation: Don't panic, the Sun has not gone wild. But this wild-looking portrait of the nearest star to planet Earth was made on March 30th by the recently launched Solar Dynamics Observatory (SDO). Shown in false-color, the composite view covers extreme ultraviolet wavelengths and traces hot plasma at temperatures approaching 1 million kelvins. At full resolution, SDO image data is intended to explore solar activity in unprecedented detail. In fact, SDO will send 1.5 terabytes of data back each day, equivalent to a daily download of about half a million MP3 songs. New SDO data releases include a high-resolution movie of the large, eruptive prominence seen along the solar limb at the upper left. (Robert Nemiroff—MTU, Jerry Bonnell—UMCP)

SDO main web site: **http://sdo.gsfc.nasa.gov/**
SDO Science: **http://sdo.gsfc.nasa.gov/mission/science/science.php**
SDO First Light News: **http://sdo.gsfc.nasa.gov/resources/newsroom/newsroom.php**

E-mail address:

solarstudentnews@aol.com

We're on the Web!
http://spd.aas.org

MISSION STATEMENT

The Coronal Courant is a newsletter/zine for students. The target audience will be both students within the solar community as well as students with no access to solar physics education. We hope to serve the more advanced undergraduates and graduate level students who have started to build specific interests and expertise, as well as students from high school level on up through early undergraduate years where students may not have declared their interests yet.

The purpose of this newsletter/zine is to provide scientific and technical articles, descriptions of the scientific experience, news and announcements pertaining to students, career information, listing of student activities (student talks, papers, summer projects, and theses), mission and satellite descriptions, data analysis and modeling techniques, a picture gallery, web link directories, fun stuff, and whatever else people want to submit. In other words, we offer a little of this, a little of that, and something for everyone!!!

Both faculty and students are invited to submit.

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The Making of a Scientist - Part 2
Loren W. Acton, Research Professor of Physics

In the last issue we left our hero (namely, me) with a fresh B.S. in Engineering Physics, all prepared after summer break to leave for Colorado with a wife, one-year-old daughter and a generous full-ride fellowship – good for one year. Carrying on with my guiding principle of recounting small events (which made a big difference for me career-wise), I want to tell you about my summer job with GE (known as *Generous Electric Company* by the students) at the Hanford Atomic Products operation outside Richland, Washington. Although the "product" at Hanford was bomb-grade plutonium, there was a strong unclassified laboratory program in support of the main effort. I was assigned to a lab doing experimental mass spectrometry of heavy atoms. The big career value of that summer's work for me was learning a lot about vacuum systems and how to use an oscilloscope. This hands-on lab experience gave me a significant head start when I delved into experimental solar physics.

UNIVERSITY OF COLORADO

Shortly after joining the CU Department of Physics in the autumn of 1959, I realized that the research field in which I was interested-- upper atmospheric physics and sun-earth relations-- was being handled in a different department, the Department of Astro-Geophysics. So, almost immediately, I switched departments, only to be confronted with a real shocker – having to take the Ph.D. Comprehensive Exams! At that time, the policy in the very small A-G Department was for every student (all grads) to take the three comps (Physics, Astrophysics, Geophysics) every year until they passed or gave up. I still believe this a good, although humbling, policy. There is no better way to introduce the new student to how much they need to learn. I well remember my feeling of abject ignorance upon being asked to derive the Rankine-Hugoniot relations across a shock wave! When a student passed one of the exams, that exam did not have to be taken again. I finally passed the Astrophysics comp on my fourth try, and as I recall, that was a record.

In my opinion, the CU Department of Astro-Geophysics in that era provided the world's best opportunity for a student. The High Altitude Observatory and the A-G Department were one and the same. The faculty was young and truly outstanding in this burgeoning field of study, and there were about the same number of faculty as students. As the field was new and still fairly small, the "big names" in science were constantly visiting or coming to spend the summer. In the first two years I was privileged to meet James Van Allen, Eugene Parker, Subrahmanyan Chandrasekhar, Sydney Chapman and others. Whenever one of these luminaries came to town, Connie and Jim Warwick would invite us grad students to their home to meet and chat. I well remember we students gathered around Harlow Shapley, inventor of the Cepheid-variable cosmic

> **One of my life-changing moments took place early in my time at CU when I realized that**
>
> ***"I" could do science MYSELF --- that the U.S.A. would actually pay me to build and fly experiments of my own conception and design.***
>
> ***Wow! What a deal!***

yardstick, as he quizzed us on what could be learned from a single point of light in the sky. One of my life-changing moments took place early in my time at CU when I realized that "I" could do science MYSELF --- that the U.S.A. would actually pay me to build and fly experiments of my own conception and design. Wow! What a deal!

The early 60's were an exceptionally exciting and fruitful time for solar and astrophysics because of the flood of new observations from space. Because of my interest in solar flare effects on the earth's ionosphere, I wanted part of this action and was fortunate to land a chance to do my thesis research at the U. S. Naval Research Laboratory (NRL) in Washington, DC. Herb Friedman and his NRL colleagues were the first to record solar x-rays on a photographic emulsion behind a Be window, which was flown at White Sands Missile Range in 1949 on a captured German V-2 rocket. For the following eleven years, the NRL group dominated the study of solar x-ray and extreme ultra-violet emission (see accompanying article on solar x-ray history).

My assignment was to use the solar soft x-ray measurements from the soon-to-be-launched Solar Radiation 4 (SR4) satellite for my thesis research – a terrific opportunity! Unfortunately, shortly after my family (wife and 2 children) and I moved across the U.S. in the dead of winter to Oxon Hill, MD (near NRL), the SR4 launch attempt failed. The satellite fell on Cuba. Not to worry, in a few weeks a backup satellite was to be launched from Vandenburg AFB on the west coast. Unfortunately that one fell into the Pacific Ocean! I was left to create a dissertation from the difficult telemetry of SR3, a slowly spinning and tumbling satellite.

"Never hesitate to talk to the movers and shakers."

In 1964 we moved to California where I acquired a position as Graduate Study Scientist at the Lockheed Palo Alto Research Laboratory. In 1965 I completed my thesis and proposed my first rocket experiment to NASA, thanks to encouragement from Henry J. Smith, who was then NASA Chief of Solar Physics. (Lesson: Never hesitate to talk to the movers and shakers.) This proposal led to a long series of rocket experiments. My first three, flown for the purpose of recording the high energy tail of the solar x-ray spectrum, are pictured in the figure below. At the time these flew in 1967 and 1968, they carried the largest, by far, proportional counters that had been flown in space.

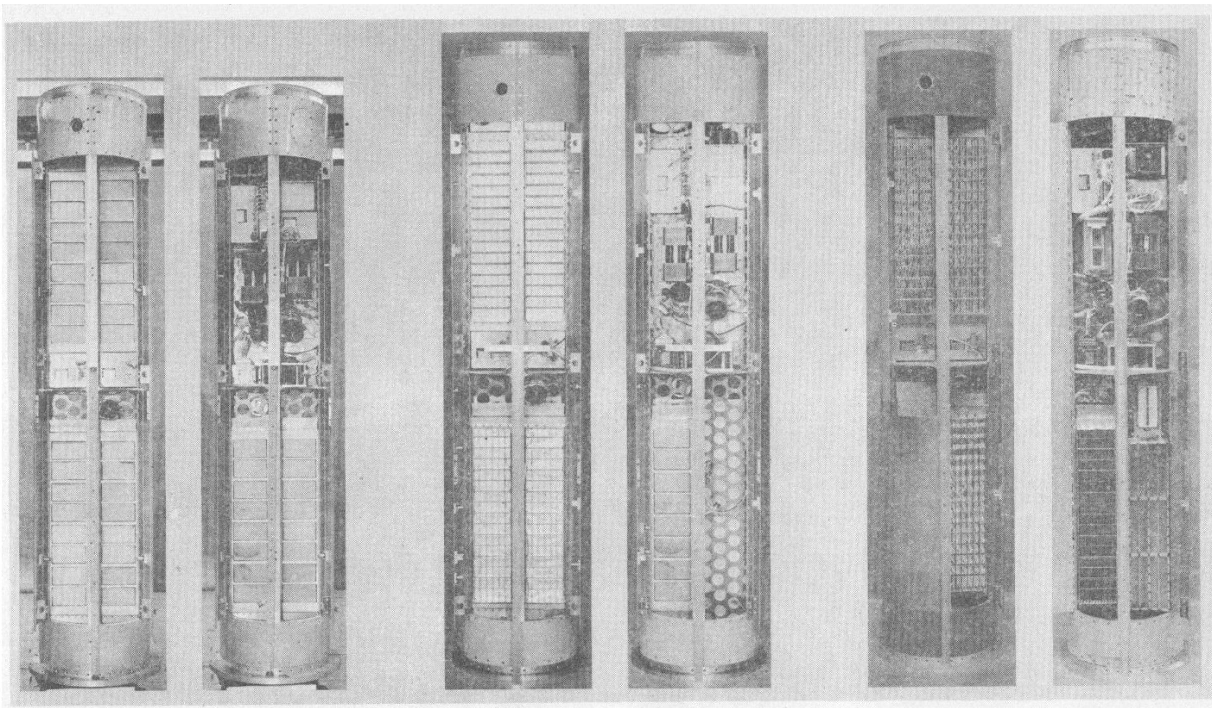


Fig. 1 Front and back views of the 3 solar payloads flown on NASA Aerobees 4.168, 4.169 and 4.248. The payloads are just short of 2 meters long with payload-bay type doors on both sides.

I had intended to stay at Lockheed for only a couple years since my preferred and anticipated job of choice was at a university. However, for an experimentalist, the advantage of the tremendous technical and engineering resources in this big aerospace lab, coupled with really fine scientific colleagues, held me there for 29 years. As most of you know, the Lockheed-Martin Advanced Technology Center in Palo Alto remains a very big player in solar physics. I am quite proud that this is, in a small sense, part of my legacy to the field.

In the course of a series of nine rocket experiments, I developed increasing interest (and improved competence) in high resolution solar spectroscopy and imagery. I finally gained enough confidence to compete in the big time, satellite experiments. We were fortunate to win with the Mapping X-ray Heliometer (MXRH) on OSO-8, the X-ray Polychromator (XRP) on SMM, and much later, the Soft X-ray Telescope (SXT) on *Yohkoh*. Frankly, I am not proud of my sparse publication record from all of these missions. However, without the experience gained from the rockets, I would never have been successful in proposing the XRP and SXT, missions, each of which paid good scientific dividends even though I was not the author of many of the papers.

Next issue,

How in the world did Acton end up flying on Challenger?

What's the Worst That can Happen? Space Weather Impacts in 2012

Mark B. Moldwin, Atmospheric, Oceanic and Space Sciences, University of Michigan

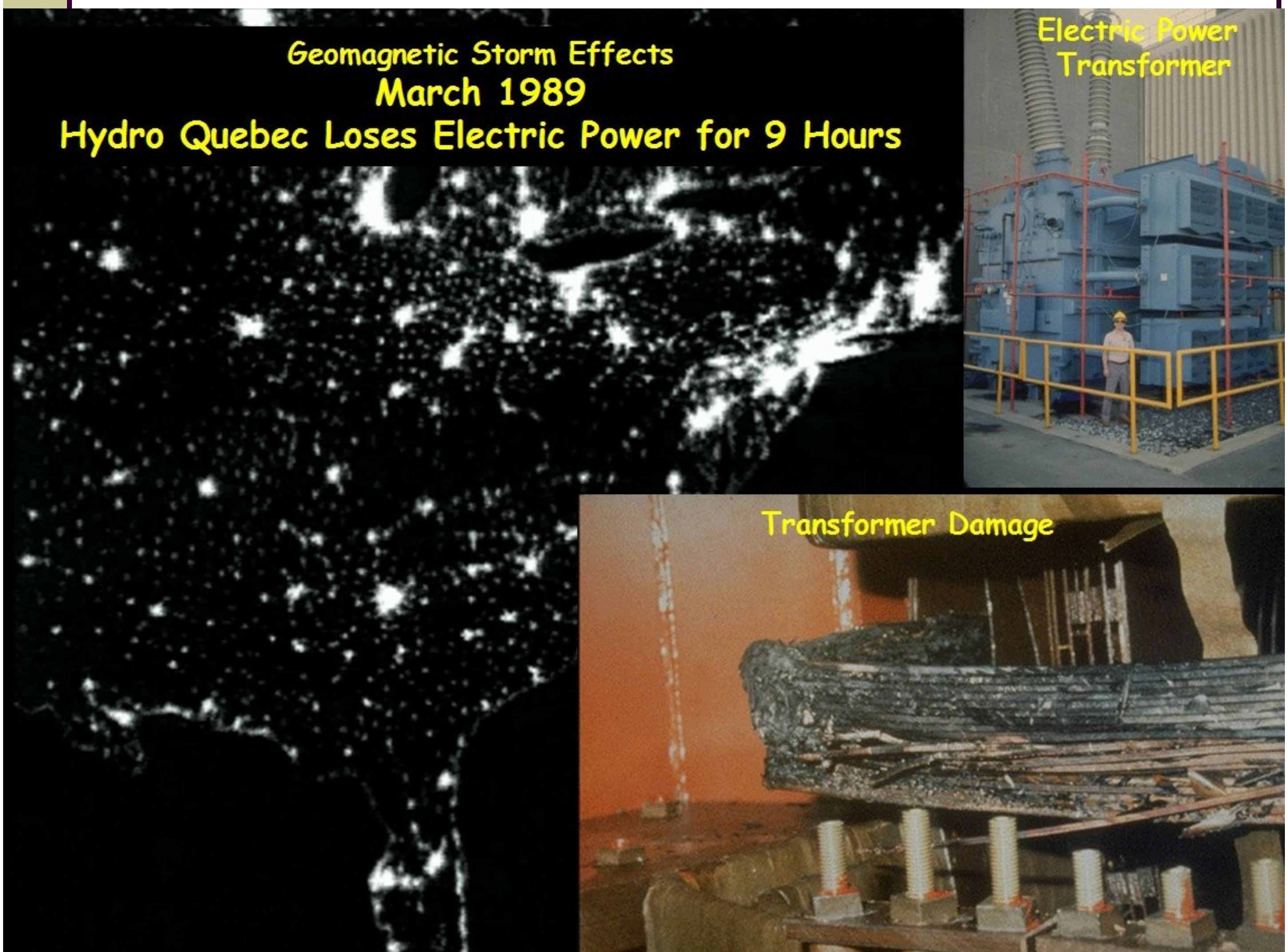
The field of space weather studies the technological and societal impacts of the solar terrestrial relationship. This emerging field of space science has become increasingly important due to modern society's dependence on global communication systems and continental scale power distribution systems. Solar storms (such as coronal mass ejections and solar flares) can cause geomagnetic impacts that can damage or destroy satellites, perturb satellite communication and navigation systems, sicken or kill astronauts and cause power blackouts.

Though the current solar minimum is unprecedented in the space age in terms of its low solar activity and subsequent low geomagnetic activity, the forecast is for solar maximum to arrive in a few years. As part of a National Research Council's (NRC) Space Studies Board workshop on the economic impact of space weather, the worst-case scenarios on different technological systems were investigated [*NRC*, 2008]. The most intense geomagnetic storm ever measured occurred in 1859 and is often called the Carrington Event after British astronomer Richard Carrington's observation of a white light flare and suggestion that the subsequent geomagnetic storm were connected. This observation ushered in the field of space physics (see http://measure.igpp.ucla.edu/solar-terrestrial-luminaries/timeline.html for a on-line history of the scientists and discoveries of space physics as well as links to seminal papers including the original Carrington paper). The space weather effects of the 1859 Carrington storm included disruption of telegraph signals, observation of aurora at mid and even tropical latitudes [*Green et al.,* 2006] and geomagnetic deflections of over 2000 nT [*Tsurutani et al.,* 2003].

What would happen if a solar storm of this magnitude (or other large storms observed in the pre-space age era) hit Earth today? This essay concentrates on the possible impact on the electric distribution system since this effect could be the worst natural disaster in modern history with costs estimated over a trillion US dollars and impacts reaching across every industry and every segment of society.

First a short summary of how geomagnetic storms impact ground electrical systems. Electric currents driven by the interaction of the solar wind and interplanetary magnetic field with the Earth's magnetic field flows through the magnetosphere and ionosphere. These time varying and spatially localized electrical currents close in the upper atmosphere in the auroral regions. An effect of these time changing currents flowing in the ionosphere is the induction of an EMF along electrical transmission wires on Earth via Amperes' and Faraday's Law (time changing currents creating time varying magnetic fields that induce voltages in long conductors). If a Carrington Storm hit when North America was undergoing a cold snap or heat wave that was taxing the electrical generation and distribution system (or non-intuitively even during periods of light load when many generation systems are off-line and hence long-distance power transfers are more important), the enhanced voltages induced in the grid could cause overloading of transformers. Because of the interconnection of the North American power grid, a transformer failure has the potential to cascade through the system as power is shunted from one line to another to attempt to get around the failed transformer. This can cause failures of transformers across the system. The March 1989 space weather storm caused a massive power blackout in Canada when Hyrdro Quebec transformers failed [*Bolduc*, 2002]. The accompanying figure shows one of the damaged transformers as well as the size of these massive machines. In 2003 there was a cascading failure of power transmission due to a tree branch in Ohio that caused the largest blackout in US history affecting nearly 50 million people with power lost from Detroit to New York City (see https://reports.energy.gov/ for report on the causes and consequences of this failure).

A Carrington-class storm has the potential to trigger such a cascade and cause the destruction of hundreds of major transformers. To repair the damaged electrical grid could take many years to completely restore power. This estimate is based on the inventory of transformers and the production capacity of transformers worldwide. It currently takes approximately 12 months for the manufacture of one of these major transformer systems. Even if production was ramped up in response to the crisis, the amount of time required to replace these systems by the electrical power industry is estimated to be years since the transformers cannot be repaired in the field, but must be replaced.



How would your life change if your community went without power for a day, week, month, or year? The dependence on reliable electricity by modern civilization cannot be overstated. Critical systems (hospitals, banking centers, telecommunication centers etc.) have redundant and back-up systems, but many commercial and residential buildings do not. In addition, many redundant and back up systems fail in an emergency as happened to the Olive View UCLA Hospital in Sylmar California during the fires of 2008. The fires knocked out the power lines into the hospital, the back-up generators failed, and the co-generation plant also failed. Fortunately hospital staff was able to evacuate critical care patients to other facilities until power was restored. What would have happened if the power outages were more spatially widespread as is possible during a worst-case geomagnetic storm?

What is the economic cost of such a space weather disaster? It has been estimated, using simple models of the economic impact of lost productivity, that a North American power grid blackout would impact GDP by about $30 billion per day. A blackout that required even less than a week to recover from would surpass the economic impact of Hurricane Katrina that is estimated to have caused $120 billion in economic losses. A blackout lasting two weeks would surpass the $500 billion economic impact of the 1906 San Francisco earthquake, the largest US natural disaster in terms of economic impact. With estimates as long as 4 to 6 years for full recovery, the total economic impact of a severe space weather perfect storm on the US economy easily reaches into the trillions of dollars and would have profound impact on the daily lives of 100s of millions of people with economic ripples felt world-wide.

So with the next solar maximum predicted to arrive around 2012 (give or take a few years) the basic premise of the current disaster block-buster "2012" movie predicting the end of civilization due to a solar storm is perhaps not too far off base, though the plate tectonic response due to the solar storm – the premise of the movie – is pure Hollywood. The reality, though less physically destructive, could have profound worldwide impacts.

Bolduc, Léonard, GIC observations and studies in the Hydro-Québec power system, Journal of Atmospheric and Solar-Terrestrial Physics, Volume 64, Issue 16, November 2002, Pages 1793-1802, doi:10.1016/S1364-6826(02)00128-1

Green, J., Boardsen, S. and Odenwald, S., Eyewitness Accounts of the 1859 Superstorm, Advances in Space Research, 38, p.145-154, 2006

Tsurutani, B. T., W. D. Gonzalez, G. S. Lakhina, and S. Alex (2003), The extreme magnetic storm of 1–2 September 1859, *J. Geophys. Res.*, 108(A7), 1268, doi:10.1029/2002JA009504.

NRC, Severe space weather events – understanding societal and economic impacts: A workshop report, National Research Council of the National Academies, National Academies Press, Washington DC, 2008

Transformer Picture Credit: NASA Science News (01/21/2009)

Celestial Atlas (17th Century): Harmonia Macrocosmica

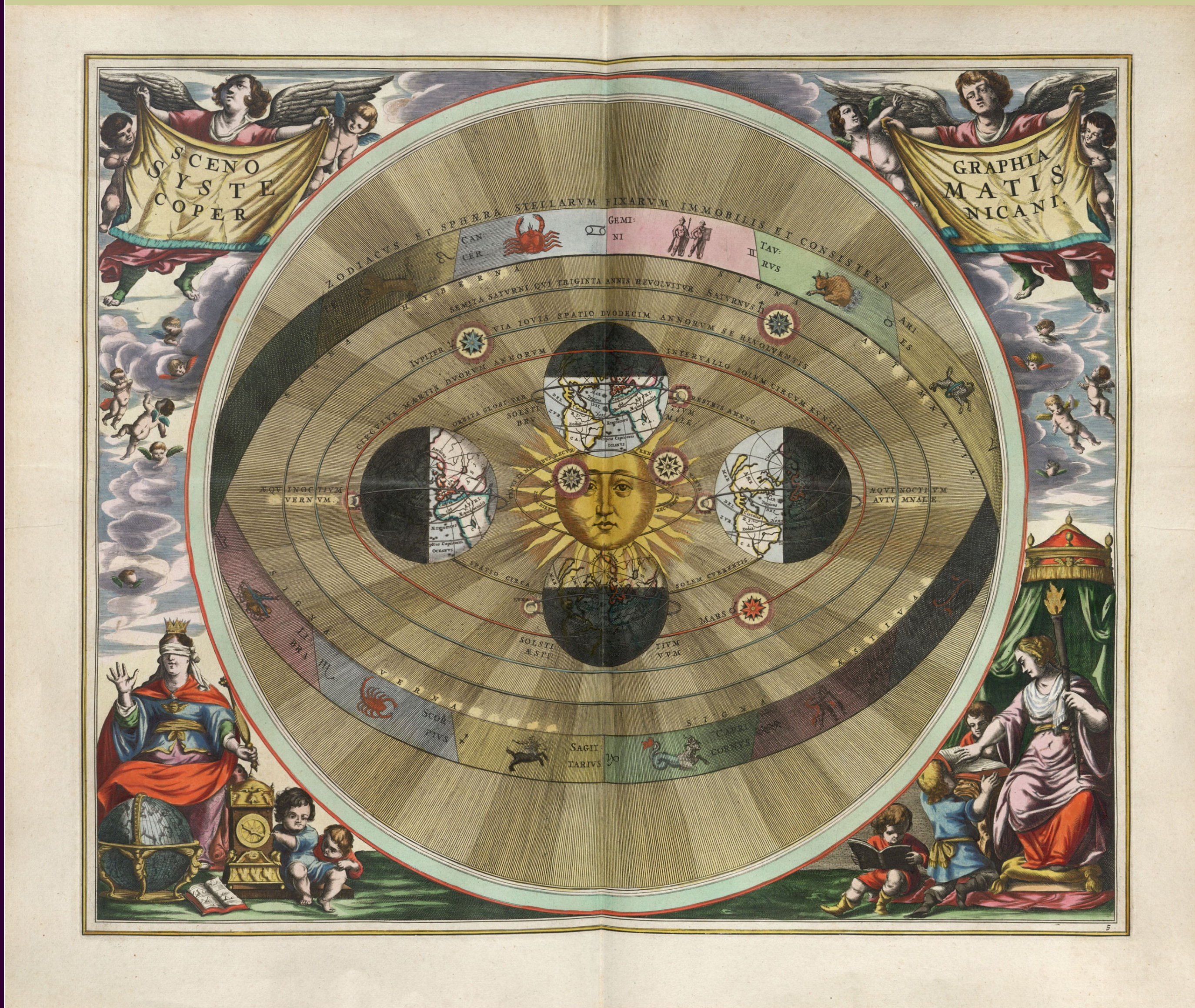
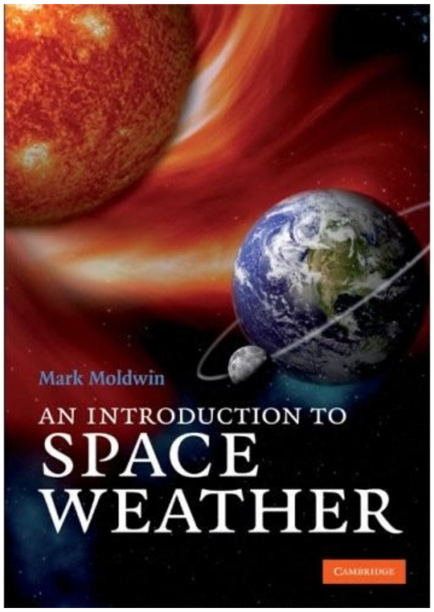


Plate 5: **SCENOGRAPHIA SYSTEMATIS COPERNICANI - Scenography of the Copernican world system**
http://www.phys.uu.nl/~vgent/cellarius/cellarius_plates.htm for all the plates in the atlas.

Andreas Cellarius was a Dutch-German mathematician, cosmographer, and cartographer (1596-1665).
http://www.phys.uu.nl/~vgent/cellarius/cellarius.htm
This plate of Andreas Cellarius' Harmonia Macrocosmica represents the Copernican view of a heliocentric world system. The four earths show the seasons. Six planets surround the sun. Each planet's length of orbital evolution is indicated. The outer circle contains the zodiac. The blindfolded woman (lower left corner) is likely to be Astraea ("Star-maiden"). She represents justice. The woman holding a torch (lower right corner) likely represents Calliope, the muse of heroic poetry.

(reference: Robert van Gent's "Andreas Cellarius, Harmonia Macrocosmica," 2006)

New and Recent Books



An Introduction to Space Weather *by Mark Moldwin*

ISBN-13: 9780521861496 (hardback) ISBN-13: 9780521711128 (paperback)
Adobe eBook Reader ISBN-13: 9780511388965

http://www.cambridge.org/uk/catalogue/catalogue.asp?isbn=9780521861496

Faculty Colleagues: request a examination copy from Cambridge

Space weather is an emerging field of space science focused on understanding societal and technological impacts of the solar-terrestrial relationship. The Sun, which has tremendous influence on Earth's space environment, releases vast amounts of energy in the form of electromagnetic and particle radiation that can damage or destroy satellite, navigation, communication and power distribution systems. This textbook introduces the relationship between the Sun and Earth, and shows how it impacts our technological society. One of the first undergraduate textbooks on space weather aimed at non-science majors, it uses the practical aspects of space weather to introduce space physics and give students an understanding of the Sun-Earth relationship. Definitions of important terms are given throughout the text. Key concepts, supplements, and review questions are given at the end of each chapter to help students understand the materials covered. This textbook is ideal for introductory space physics courses.

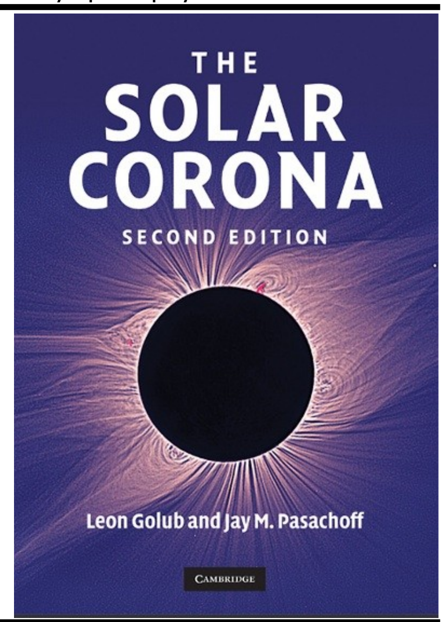
The Solar Corona *by Leon Golub and Jay M. Pasachoff*

Second Edition ISBN-13: 9780521882019

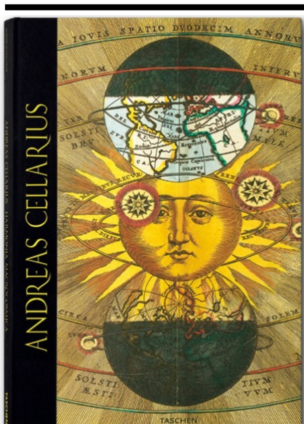
http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521882019

(Cambridge University Press)

Lecturers can request examination copies for course consideration.



Intended for graduate students and astronomers seeking an introduction to coronal physics, this textbook strikes a balance between the observational and theoretical aspects of the subject. This second edition takes into account the major observational and theoretical developments of recent years to provide an up-to-date treatment of our understanding of the solar corona. After reviewing the latest observations of the solar corona, the authors explain how the studies have advanced and shaped our understanding of coronal physics. The textbook introduces a wide variety of exciting physics, including dynamo theory and magnetohydrodynamics, and shows how the transient effects of the solar cycle affect space weather. Each subject area is introduced using basic physics, and refers readers to fundamental papers on the topic, key new studies in each area, and extensive discussions in recent review articles.



Andreas Cellarius, Harmonia Macrocosmica by *Robert van Gent*

ISBN: 978-3-8228-5290-3 Hardcover, 32 x 53 cm (12.6 x 20.9 in.), 240 pages

This collection of celestial maps by Dutch-German mathematician and cosmographer **Andreas Cellarius** (c. 1596 – 1665) brings back to life a masterpiece from the Golden Age of celestial cartography. First published in 1660 in the *Harmonia Macrocosmica*, the complete 29 double-folio maps and dozens of unusual details reproduced here depict the world systems of **Claudius Ptolemy, Nicolaus Copernicus**, and **Tycho Brahe**, the motions of the sun, the moon, and the planets, and the delineation of the constellations in various views. Cellarius's atlas, superbly embellished with richly decorated borders depicting cherubs, astronomers, and astronomical instruments, features some of the most spectacular illustration in the history of astronomy.

(Don't be fooled by the small image; this book is almost 2 feet tall !)

http://www.taschen.com/pages/en/catalogue/classics/all/00335/facts.andreas_cellarius_harmonia_macrocosmica.htm

Solar Eclipses

By Jay M. Pasachoff
Chair, International Astronomical Union Working Group on Solar Eclipses

Image: Jay M. Pasachoff, Sara Dwyer, Rachel Wagner-Kaiser

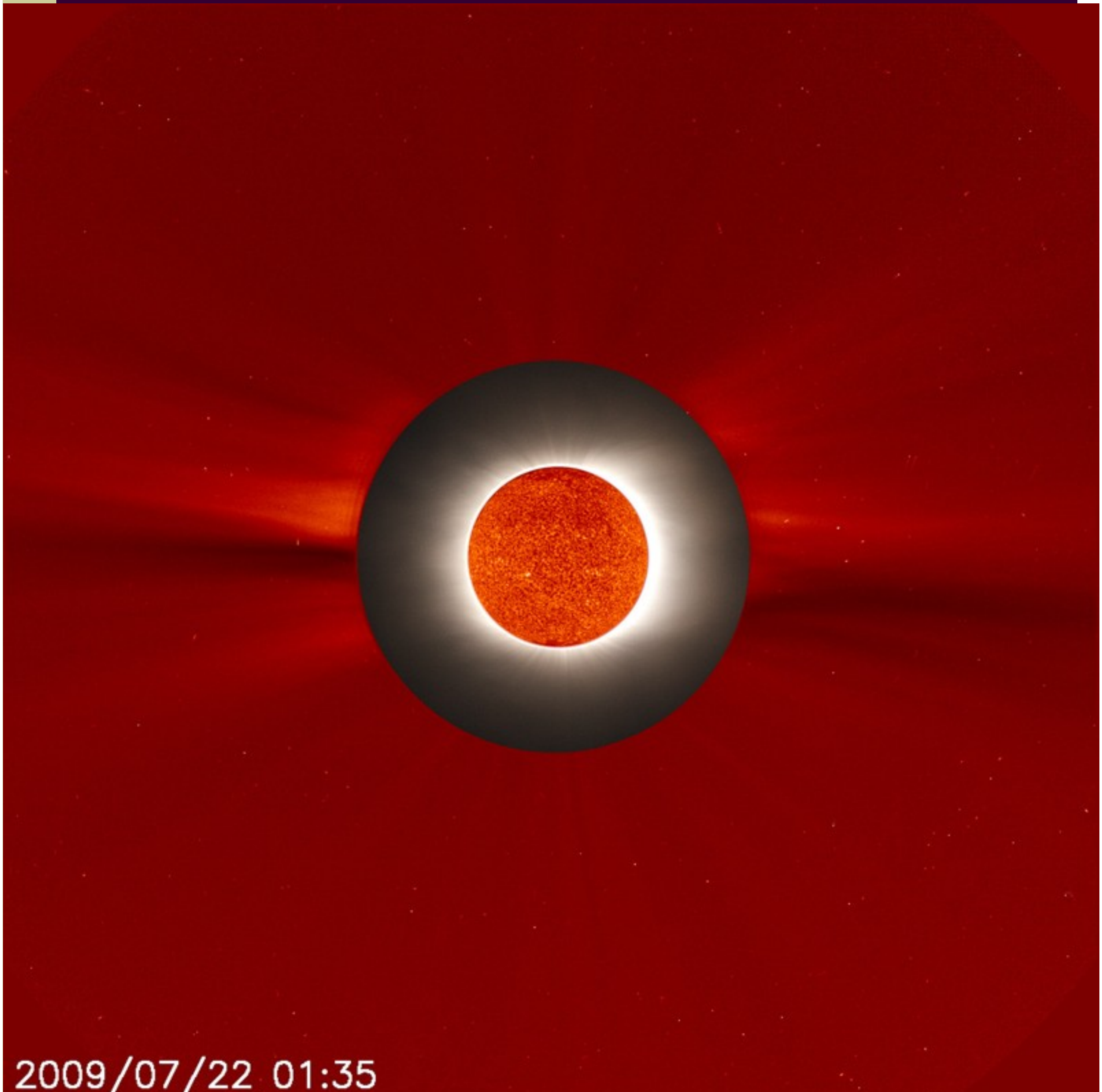
Image: The diamond ring effect marking the beginning of totality viewed from Tianhuangping, China, on 22 July 2009. Image by Jay M. Pasachoff, Sara Dwyer (Williams College '11), and Rachel Wagner-Kaiser (Vassar College '10 and Keck Northeast Astronomy Consortium), with support of the Committee for Research and Exploration of the National Geographic Society.

A total solar eclipse is visible from a long, narrow arc across the globe about every 18 months, and an annular solar eclipse is visible similarly about every 18 months, with partial eclipses visible for hundreds of miles to the sides of the umbra and antumbra. 2010 had an annular solar eclipse on January 15th, which was observed from Kenya to the Maldive Islands to the southern tip of India and on to Burma and China. A total solar eclipse will be visible from the Pacific Ocean on July 11th, with Easter Island the main populated and accessible location; there is to be 4 minutes 40 seconds of totality there. Some atolls near Tahiti and in the Cook Islands are also in totality, and some cruise ships will also be in the path. Totality reaches southern Patagonia in Chile and Argentina at sunset, but with the sun so low in the sky and winter weather, ground-based observing there is not hopeful, though there may be an airplane overflight. An airplane expedition is also planned out of Tahiti to get 9 minutes of totality.

Scientific observations of the solar corona are planned, as they have been for the past total eclipses, though current-day eclipse observations make use of new technologies, such as infrared sensitivity or computer compositing to improve dynamic range and resolution, or of liaisons with near-simultaneous space observations. This summer's eclipse will have the added benefit of being able to compare the observations with those from Solar Dynamics Observatory. Eclipse observations are used to fill in the missing doughnut of coverage of the inner corona on coronagraph observations from the ESA/NASA Solar and Heliospheric Observatory and from NASA's STEREO. For a discussion of eclipse science, see my International Year of Astronomy review article "Solar Eclipses as an Astrophysical Laboratory," *Nature, June 11,* ***459***, 789-795, http://www.nature.com/nature/journal/v459/n7248/pdf/nature07987.pdf.

The year 2011 will have four partial solar eclipses, though no total or annular solar eclipses. On 4 January 2011, a partial eclipse will be visible throughout Europe, northern Africa, and the western half of Asia. On 1 June 2011, a partial eclipse will be visible in the Arctic, extending to northern Alaska and northern Canada while reaching in Asia as far south as northern Japan. On 1 July 2011, a partial eclipse will be visible only in a tiny area in the ocean near Antarctica, and it is therefore probable that nobody sees that one. On 25 November 2011, partial phases will be visible from all of Antarctica and will reach New Zealand and southernmost South Africa. See Fred Espenak's NASA Eclipse Web Site at http://eclipse.gsfc.nasa.gov/OH/OH2011.html for maps.

A variety of eclipse maps and other information is available at our IAU Eclipse Web Site at http://www.eclipses.info. Links include a zoomable Google map eclipse tool assembled by Xavier Jubier from Espenak's data.



http://www.williams.edu/astronomy/eclipse/eclipse2009/2009total/index.html
A total solar eclipse image from Tianhuangping, China (outside Hangzhou at 900 m altitude) during the 22 July 2009 eclipse, merged with a SOHO Extreme- ultraviolet Imaging Telescope (EIT) disk image in the helium 304 Å emission line and a Large-Angle Spectrometric Coronagraph (LASCO) image of the outer corona. The corona was very sparse because of the exceedingly low phase of the sunspot cycle, really a cycle in the solar magnetic field. Williams College Eclipse Expedition: Jay M. Pasachoff, Bryce A. Babcock, Katherine DuPré, Sara Dwyer, Rachel Wagner-Kaiser, Yung Hsien Ng Tam, Huajie Cao; EIT image courtesy EIT Team, NASA's Goddard Space Flight Center; LASCO image courtesy of LASCO Team, Naval Research Laboratory; compositing by Steele Hill, NASA's Goddard Space Flight Center. The expedition was carried out with support of the Committee for Research and Exploration of the National Geographic Society.

Five Myths about Magnetic Topology

Anthony Yeates, Postdoctoral researcher
Division of Mathematics, University of Dundee, UK

The Sun's corona is a very highly conducting plasma, so that it may largely be treated as "ideal" from the point of view of magnetohydrodynamics, the study of electrically conducting fluids. In this limit of zero resistivity, Alfvén's celebrated frozen-flux theorem assures us that the magnetic field moves with the plasma. A key consequence is that the "magnetic topology", meaning the connectivity and mutual linkage of magnetic field lines, is conserved (e.g. Fig. 1).

In this article I want to highlight five common misconceptions about coronal magnetic topology. The first is about the coronal magnetic structure at a given time, while the remainder concern "magnetic reconnection": the process by which small local deviations from a perfectly ideal evolution can lead to changes in topology. These deviations often arise where the magnetic field varies within a small distance, leading to significant electric currents and Ohmic (resistive) dissipation despite the very low resistivity. Although these non-ideal regions may be localized, the changes of topology can have a global impact. Full references may be found in the books [1-3].

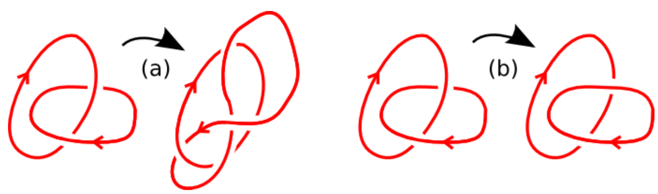


Figure 1: Examples of magnetic field lines in (a) an ideal evolution where the topology is preserved, and (b) a non-ideal evolution where the topology has changed.

1. Knowing the photospheric magnetic field determines the coronal magnetic field

It is well appreciated that we can very rarely measure the magnetic field in the corona directly, but have to use theoretical extrapolations from photospheric measurements. Unfortunately, it is simply not true that the photospheric magnetic field determines the coronal magnetic field uniquely, even if all three vector components are measured. Additional assumptions about the plasma in the coronal volume have to be made.

A reasonable approximation is to neglect non-magnetic forces, such as pressure gradients or gravity, in favor of the much stronger magnetic forces. Yet even this doesn't determine the magnetic field structure. One way to get a unique solution is to assume vanishing current density in the corona, called a potential field (Fig. 2a). This is a mathematically well-posed problem, but is limited in that it has the minimum possible magnetic energy for the given boundary conditions. Free magnetic energy above that of the potential field is needed to power, for example, flares and coronal mass ejections. The more general alternative is a "force-free" equilibrium, which allows for electric currents but still requires that the magnetic force balances itself. However, this is no longer a well-posed boundary value problem given an observed photospheric field. Techniques are being developed to make such force-free extrapolations in practice, but tests find that different numerical codes lead to different solutions [4].

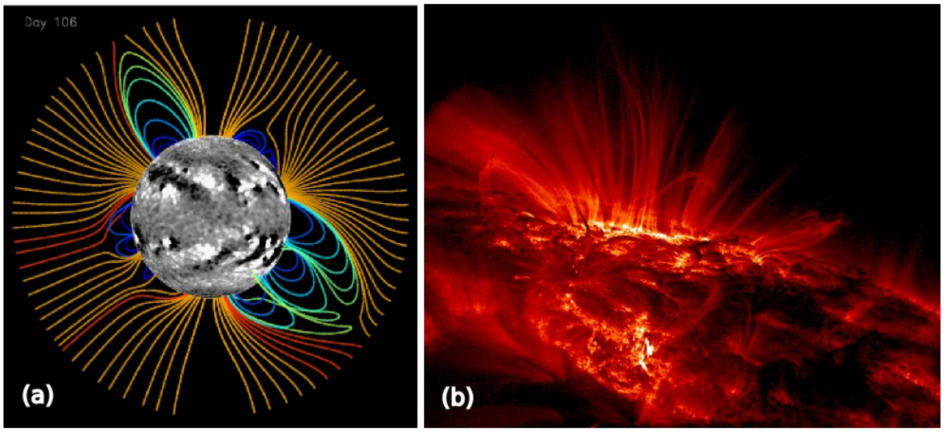


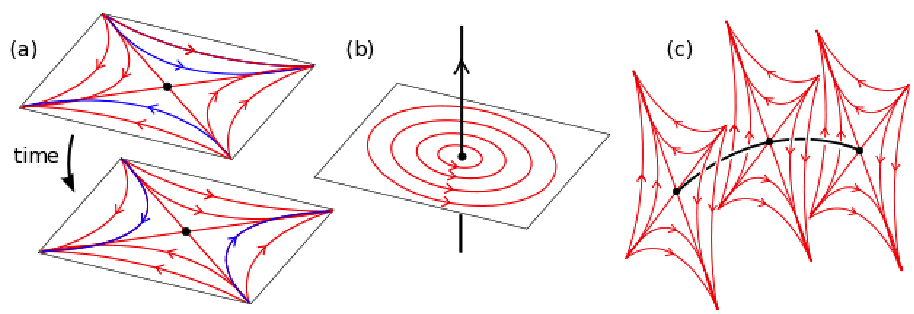
Figure 2: (a) A potential-field source surface extrapolation of the 3-d coronal magnetic field from a photospheric magnetogram (here taken at NSO/Kitt Peak). Grey shading shows the radial photospheric magnetic field of the magnetogram (white positive/out of the Sun, black negative/into the Sun), and colored lines are selected coronal magnetic field lines. (b) Million-degree coronal loops as imaged in the 171Å passband of the Transition Region And Coronal Explorer (TRACE) satellite. These outline (some of) the magnetic field lines in the corona, and can be used to constrain magnetic field models.

Lest you should think that all is doom and gloom, I should point out that we can often derive qualitative information about the coronal magnetic field from imaging observations (e.g. Fig. 2b). For example, alternative force-free models of coronal regions have been produced where observations of coronal X-ray loops are used to constrain the shape of field lines [5], rather than trying to extrapolate solely from the photospheric boundary.

2. Reconnection occurs only at magnetic null points

A common perception of magnetic reconnection is based on the classical 2-d Sweet-Parker model [6]. In a 2-d (planar) magnetic field, changes in field line connectivity can occur only at null points, where the magnetic field vanishes. Generic 2-d nulls are either hyperbolic (X-type) or elliptic (O-type), according to the local structure of the magnetic field (Figs. 3a, 3b). The Sweet-Parker model gives a rough scaling law predicting the rate of reconnection at an X-point, i.e., how much magnetic flux can change its connectivity per unit time. It is well known that the resulting estimate is much too low to explain the release of energy in solar flares, so that theorists have been developing 2-d models with faster reconnection rates ever since the original work of Sweet and Parker.

Figure 3: Magnetic null points: (a) a classical 2-d X-point with reconnecting field lines shown in blue, (b) a 2-d



O-point magnetic field arising from a line current, and (c) an X-line in 3-d.

But this 2-d picture of reconnection at an X-point may be rather misleading, because the real corona is 3-d. The most direct 3-d analogy of the 2-d X-point is the “X-line” (Fig. 3c) where the field vanishes along a whole line (shown in black) and the surrounding field in any cross-section looks like the 2-d case. Such X-lines are unlikely to occur in the corona because they would be unstable. However, in 3-d, changes of topology can occur anywhere, not just at null points or X-lines [7]. A 3-d field has greater freedom to change its connectivity. Whereas in 2-d the locations of reconnection are determined by the locations of X-points, the locations of reconnection in 3-d are determined by the dynamics prior to the onset of reconnection. In particular, the locations where strong currents (or unusually high resistivity) develop. This may well be determined by the locations of null points (in 3-d, reconnection can happen at both hyperbolic *and* elliptic nulls), because the nearby magnetic field often has strong spatial gradients. On the other hand, there is no requirement that reconnection in 3-d be limited to such locations; indeed, numerical experiments show the development of turbulent reconnection in magnetic fields with no null points at all (Fig. 4).

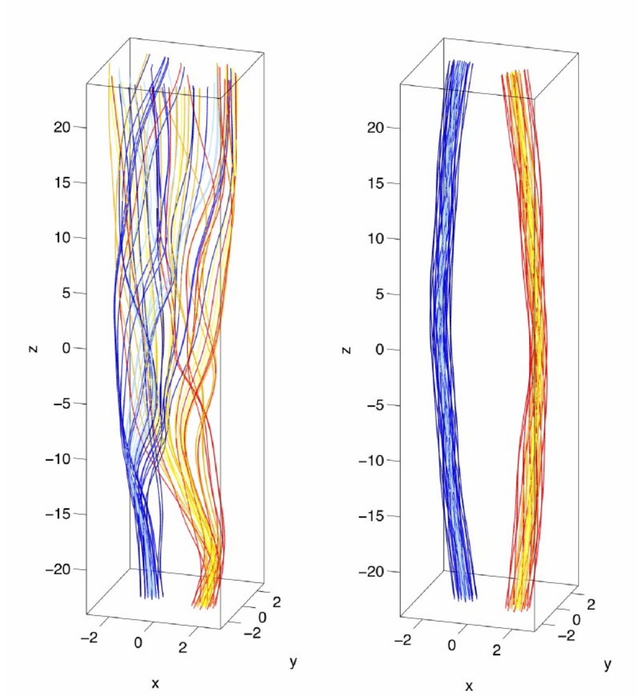


Figure 4: A 3-d numerical experiment [8], here at Dundee, where there is a change of topology despite the absence of any null points. An initial tangle of field lines (*left*) undergoes a turbulent relaxation (via the magnetohydrodynamic equations) with significant reconnection. The final state (*right*) has two neatly separated magnetic flux tubes with opposite twists.

3. Non-ideal processes always change the magnetic topology

Although a change of magnetic topology requires a non-ideal evolution of the plasma, not all non-ideal evolutions lead to a change in topology. In fact, this is already the case in 2-d, as can be illustrated by the simple example of a line current (Fig. 3b). Here we imagine a thin wire carrying an electric current (shown in black) that is decaying by Ohmic dissipation (resistivity). The magnetic field produced by this current has the form of concentric circles in the plane normal to the wire, corresponding to an O-point. As the current decays, the amount of magnetic flux decreases, but the topology of magnetic field lines - concentric circles - is preserved. This dissipation process is not normally considered to be “reconnection”.

4. Reconnection releases energy locally

A major application of reconnection theory in solar physics is to explain how the Sun's magnetic field heats the solar corona to millions of degrees. Popular theories suggest that localized currents build-up inevitably in the coronal magnetic field as it is tangled by continual motions of its foot-points inside the Sun. This leads to many small reconnection events (sometimes called “nanoflares”) that contribute to coronal heating.

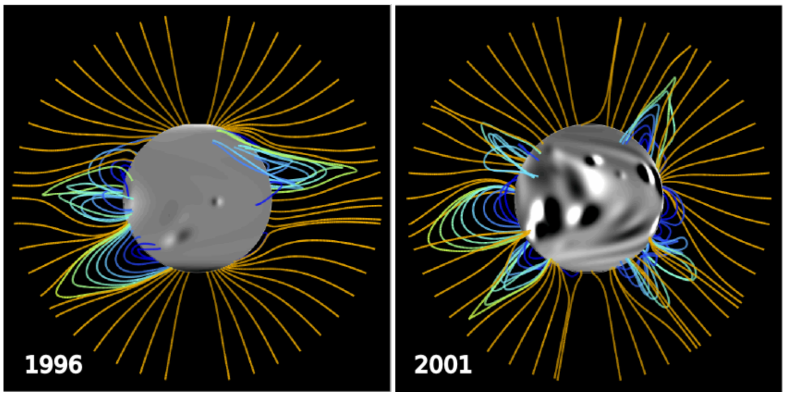
The misconception here is that these reconnection events heat the corona locally. Actually, since these non-ideal regions are small and the resistivity is still very low, the amount of direct Ohmic heating is likely to be small. Far more important is the *global* effect of reconnection. A change of connectivity can enable the release of large amounts of energy that was stored in the magnetic field. This is intimately related to the conservation of magnetic topology in an almost-ideal evolution. Conserving a particular topology of field lines means that there is a certain minimum degree of tangling of the field, and therefore a minimum energy that can be reached by an ideal evolution. However, if reconnection occurs, it can change the topology in such a way that a lower energy state becomes reachable. This excess energy that was stored in the magnetic field - over a potentially large volume - can then be released, either into heating, kinetic energy or the acceleration of energetic particles.

5. Reconnection is always a very fast process of energy release

Finally, the effects of reconnection can be more varied than many people imagine. In solar physics we tend to think of reconnection as a rapid process leading to spectacular flares and sudden releases of energy. This is not the whole story.

Reconnection can also occur on much longer timescales, with a lower rate of energy output. Because they don't produce spectacular explosions of hot plasma and sudden ejections of energetic particles, these more gradual changes of magnetic topology may go unobserved. We can infer their existence in various ways. For example, coronal holes - low density, magnetically open regions of the corona that appear dark in X-ray or EUV images - are often seen to rotate at a different speed from features in the underlying photosphere [9]. Since a coronal hole's magnetic field is rooted in the photosphere, the field lines concerned must be continually reconnecting at the coronal hole boundary in order to change their photospheric foot-points as the Sun rotates. On a slightly longer timescale, eclipse observations reveal significant changes in the global magnetic field structure over the 11-year solar cycle. At solar minimum the corona is dominated by the large polar coronal holes, while at maximum there is a much more complex magnetic field originating from the many active regions across the solar surface (Fig. 5).

Figure 5: Global force-free models of the corona in 1996 (left) and 2001 (right), showing the difference in the



Sun's magnetic field between solar minimum and solar maximum. These models don't use a single-time extrapolation, but take into account the time evolution of the coronal field as it is driven by the emergence of new active regions and by surface motions [10].

This nicely draws together the problems of finding the coronal magnetic structure (myth 1) and of understanding reconnection. The Sun's magnetic field exists not just as a sequence of independent "snapshots", but as a continuous evolution. Understanding how the magnetic topology evolves over time is one of the key challenges facing solar physics in the twenty-first century.

I thank Antonia Wilmot-Smith for helpful criticism and for supplying Fig. 3. TRACE is a mission of the Stanford-Lockheed Institute for Space Research, and part of the NASA Small Explorer program.

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"Here Comes the Sun" … again and again

If you are a student, chances are your professor will first introduce the topic of solar physics to the tune of the George Harrison Beatle's song, "Here Comes the Sun," recorded in 1969. Since we haven't heard the original for some time, you will build an association between school, your professor, or your class, and this song. Listening to other versions of this song is the only antidote :

Saturday Night Live, 1976

Selected Live Performances from YouTube:

George Harrison (1972)

George Harrison with Paul Simon (1976)

George Harrison with Ringo Starr, Elton John, Eric Clapton, and Phil Collins (1987)

George Benson - notice the guy playing tamborine with his foot

Richie Havens (1974) - great rhythms
Richie Havens (1971) with conga drums

American Idol Contestant - give her credit for trying and for wearing yellow

Bon Jovi (2001) - tribute to George Harrison

Nina Simone - (not a live performance)

R'n'G (1997) - same title, different song (Rap)

That's Fiction Not Friction … Solar Sci-Fi

In this 2005 disaster movie, Solar Attack, the largest CME ever ignites the excessive levels of methane in the atmosphere that have been growing due to global warming. The planet is about to be destroyed and can only be saved by one man, a man who already happens to be working for a private space company. Colleagues don't believe his theories. Cooperation from the Russians is needed. Lou Gosset Jr. makes a great American president.

Solar Attack Trailer

"Astronomy Without Borders" - Developing Countries

International Astronomical Union Report:

Astronomy for the Developing World (pdf)
Building from the IYA2009
Strategic Plan 2010-2020

TUNISIA'S ASTRO-BUS

Children waiting to board the Astro-Bus at a village in Tunisia. The Astro-Bus is an initiative of La Cité des Sciences, Tunis. The bus transports a small telescope, a mini-planetarium and an exhibition. It travels around Tunisia throughout the year introducing the excitement of astronomy to children, even in the remotest villages.
(from the report)

Fig 25 in the report

Take the Bill Gates Challenge

Bill Gates, in his role as a philanthropist, in conjunction with the work of the Bill and Melinda Gates Foundation has been on a college lecture tour presenting his talk:
"Giving Back: Finding the Best Way to Make a Difference" (video lecture from Stanford)
Bill Gates College Tour on Facebook (can watch Berkeley and Harvard talks from facebook)

"Are the brightest minds working on the most important problems?"

The most important problems include: addressing inequities in the poorest countries, problems more global in nature, healthcare, education, reduction of poverty, equal opportunity for all, energy, and others. Bill Gates invites students to dialogue and to get involved.
Bill Gates invites students to post on the foundation facebook page:

- "What problem are you working on?"
- "What draws you to it?"
- "How will you draw other people to it?"

Science and Politics—Science Idol

The Union of Concerned Scientists held a contest in which proven artists entered cartoons depicting some commentary about scientific integrity. 10,000 voters chose the 12 finalist cartoons which ended up in the 2010 Scientific Integrity Calendar.

The 12 winning cartoons:
http://www.ucsusa.org/scientific_integrity/science_idol/2009-science-idol-finalists.html

Observing the Sun in Ancient Peru

Mitzi Adams, NASA Marshall Space Flight Center

In 1982, I visited the country of Peru for the first time, to participate in an Earthwatch project, *Astronomers of Machu Picchu*. I was twenty-seven years old and this was my first trip out of the United States. This particular trip was headed by Drs. Raymond White (The Senior) and David Dearborn. These two individuals made three trips to Machu Picchu for Earthwatch over the course of about eight years, taking with them two teams per year with approximately twenty people per team. As a result of the work of Dearborn and White, we now know much about the astronomy performed at Machu Picchu, especially from a structure called The Torreon.

Before I tell you about the Torreon, we should first discuss the people who built it, the Inca. An origin of the Inca peoples is from the Lake Titicaca region. According to one version of their creation legend, the people were not civilized, so "our father the Sun took pity on them and sent down from the sky his own daughter and son to teach them the worship of the Sun, to give them laws to live by, and to show them how to build villages, grow crops, and tend livestock." The Sun told his children to go north from Lake Titicaca. Wherever the Sun's daughter and son stopped, they thrust a rod of gold into the ground. The place where the rod would disappear into the ground would become their home. When these children of the Sun reached the valley of Cusco on the hill called Rainbow, the golden rod disappeared into the ground. From that time on, "The Inca" and his sister/wife, "The Coya", ruled over the people and the people worshipped them as children of the Sun. The first Inca was called Manco Capac and the first Coya was Mama Ocllo, children of the Sun and Moon.

Illustration 1: Lake Titicaca, the highest navigable lake.

That is the legend, now what do we know from historical records and from the archaeology? The Inca did indeed originate from the area around Lake Titicaca where there was a civilization known as the Tiahuanacos. These people were good with stone, a talent the Inca people inherited, and they worshipped the Sun and the Moon. From historical records set down by the invading Europeans (the Inca had no written language), the Inca people traced their rulers back only eleven generations. Because of roads and other construction, these people must have been filtering into and influencing the Cusco area for much longer than that. Once the "historical" Inca empire was established, Pachacuti Inca (the ninth Inca ruler) greatly expanded its boundaries. Then, at the time of the arrival of Francisco Pizarro in 1532, the Incas were engaged in a civil war, caused by a dispute over the throne between two half-brothers, Atahualpa and Huascar. Huascar was defeated by Atahualpa and Atahualpa was captured by the Spanish, ransomed for a room full of gold, and finally, executed; thus ended the golden age of the Inca people, a civilization which lasted only about 150 years.

Another half-brother of Atahualpa, Manco, continued the war against the Spanish and the last surviving son of Manco, Topa Amaru, was captured and executed in 1572. Before Topa died however, he converted to Christianity and denied his ancestral religion. Topa though, left us with a better understanding of the tie between Inca and Sun.

Topa described how the ruling Inca would frequently consult with the Sun, represented by a large disk of gold, the Punchao, which had been located in a room of the Coricancha (Temple of the Sun) in Cusco. Topa Amaru said,

Illustration 2: This image shows the still-standing Coricancha (with Spanish buildings) in Cusco, Peru

"...afterwards I should come forth and tell the Indians that Punchao had spoken to me and had said what I wanted to tell them, because in this way, the Indians would comply better with what I was ordering them to do. And that what should be revered was what was inside the Sun Punchao, which is the hearts of my ancestors the Incas."

The interior of the Punchao apparently literally carried a dough, made up of the hearts of previous Inca rulers. The Sun was very important to these people and the relationship of the Sun with the ruling Inca and Coya gave them the right (in the eyes of their people) to rule.

So how did the Inca, his 'astronomers', and his people observe the Sun? Today, we pay little attention to the motions of the Sun (or the Moon) in the sky throughout the year. At the time of the Inca however, keeping a calendar was a very important duty. To practice agriculture, farmers need to know when to plant and when to harvest...and also the farmer, through the Inca ruler and his 'astronomers' might also make sacrifices to appropriate Gods, at the appropriate time, to ensure a good harvest.

Illustration 3: The main square in Cucso, Peru is still host to parades and celebrations of all kinds.

And so it was, that in Cusco at the time of the solstice, the Inca sat in the main square surrounded by his people, watching the Sun rise in the east, travel across the sky, and set in the west. The people sang to him (the Sun AND the Inca) all day and served chicha (a maize beer) at the end of the day.

Everyone has heard of Machu Picchu, the Inca site never found by the Spanish, which was rediscovered by Hiram Bingham in 1911. But Machu Picchu is a long way from Cusco. What was it like at Machu Picchu? Did the Inca observe and worship the Sun at Machu Picchu? Most probably, Machu Picchu was a holiday retreat for the Inca and his family. They may not have spent the solstices there because the ruler needed to be seen by a large amount of people, but from observations made at Machu Picchu, the Royal Family could have predicted when the solstice would occur. The figure below (left) shows the Torreon, a building that reminds us today of an observatory. Note the large stone in the middle of the room, which features a knife edge.

Illustration 4: At Machu Picchu, there are an abundance of steps. From these, one can look down into the Torreon.

Illustration 5: Inside the structure of the Torreon, is a large rock, perhaps an altar, with a "knife edge".

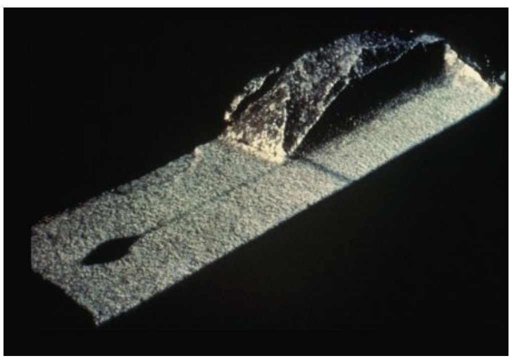

Illustration 6: On the June Solstice, researchers hung a plumb bob from outside the eastward facing window. The shadow is perfectly aligned with the edge of the stone.

On the outside of all the windows of the Torreon are "knobs" on which objects could have been hung. If one hangs a device for casting a shadow, the shadow will fall exactly along the edge of the stone in the middle of the Torreon on the day of the solstice. The image to the left shows how that works. In addition, through the eastward-facing window, the Pleiades would be visible, rising before the Sun, on the days preceding the solstice. The Pleiades were highly significant to the Incas -- they represented a storehouse for grain (Collca).

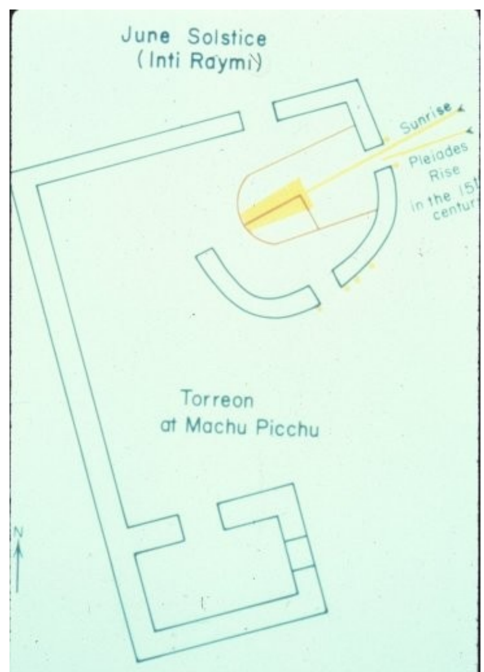

Illustration 7: This schematic shows the orientation of the Torreon with respect to the rise of the Pleiades and the Sun.

The tail of the Scorpion was another Collca, which marked the approach of the other (summer in the southern hemisphere) solstice. As long as a Collca was in the sky, the Inca believed that there would be no hunger.

Modern-day Peru has television and computers and cell-phones, although many in the highlands still live as did their ancestors. Undoubtedly though, there are many more Inca and Pre-Inca observatories in the mountains and forests of Peru. Using modern technology, perseverance, and a lot of foot work on the ground we will learn more about the history of these fascinating cultures and how they observed the Sun.

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HISTORICAL REVIEW OF SOLAR X-RAY STUDIES

(From Loren Acton's Ph.D. thesis, Univ. of Colorado, 1964)

It was early realized, from radio propagation studies, that the upper atmosphere of Earth was diurnally ionized – providing reflecting and/or absorbing layers which affected long distance radio communication.

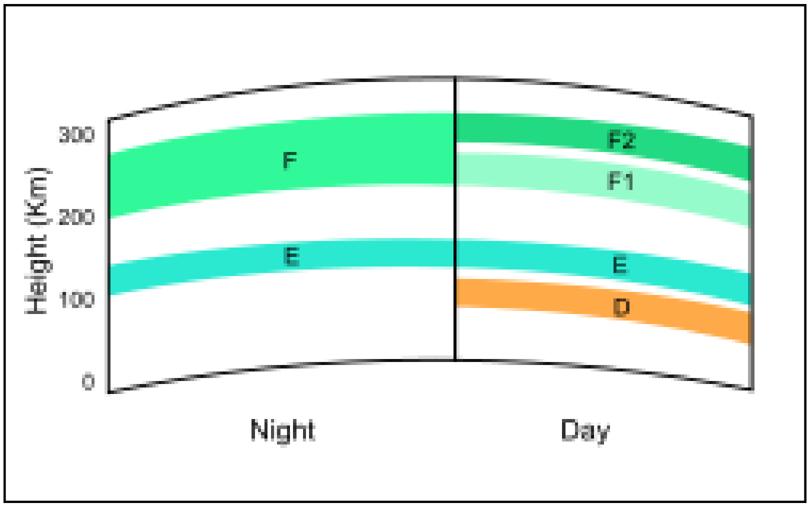

Fig. 1 Ionospheric layers. At night the E layer and F layer are present. During the day, a D layer forms and the E and F layers become much stronger. Often during the day the F layer will differentiate into F1 and F2 layers. http://en.wikipedia.org/wiki/Ionosphere

E. O. Hulburt (1938) of the U. S. Naval Research Laboratory (NRL) was the first to suggest that solar x-rays might play a role in the formation of the ionosphere. In the concluding remarks of his paper which was concerned with the formation of the ionospheric layers he states, "... E is caused by a moderately penetrating solar radiation which approximately travels in straight lines into the terrestrial atmosphere and is absorbed exponentially. The radiation might be ultraviolet light, x-rays or particles of zero average charge; ..." It was NRL, under Hulburt's leadership that first began to investigate the ultraviolet end of the solar spectrum in 1946, using captured V-2 rockets to carry their experimental apparatus above the absorbing atmosphere of the earth.

The first positive measurement of solar x-rays was obtained by NRL with photographic film placed behind a 0.076 cm thick Be window and flown to an altitude exceeding 100 km on 6 August 1948 with a V-2 rocket (Burnight, 1949). Subsequent flights in 1948, 1949 and February 1950 carried similar film packets and also carried thermoluminescent phosphors (Tousey, Watanabe and Purcell, 1951) behind various absorbing filters. These very early and relatively primitive experiments were successful in establishing the fact that the sun was an x-ray source, that the intensity of the solar x-ray flux was a function of solar activity and that the spectrum of the x-radiation hardened during solar flares.

The first quantitative measurements of the solar x-ray flux was made with beryllium window photon counters on 29 September 1949 (Friedman, Lichtman and Byram, 1951). This flight pioneered the use of this kind of soft x-ray detector. These instruments are of basic importance to the progress of solar x-ray astronomy and their perfection and development was a continuing program at NRL. Byram, Chubb and Friedman (1956) summarized the results of six rocket experiments covering the period September 1949 to December 1953. They conclusively demonstrated the variation of the x-ray flux with solar activity. In addition, on the basis of photon counter response as a function of rocket altitude they conclude that, while to a first approximation the ~8-60 A data can be fit with a 7 x 10^5 K Planckian distribution, a more refined analysis indicates that the shorter wavelength photons probably come from a hotter source at a temperature of one to two million Kelvin. These observations were the first to be reduced to absolute flux values under the graybody approximation (Kreplin, 1961).

The interpretational phase of solar x-ray astronomy was advanced greatly during this period by the theoretical work of E1wert (1952a, b, c, 1953, 1954, 1956, 1957, 1958, 1961). For many years his work dominated the theoretical aspects of solar x-ray astronomy in the same manner that the work of the NRL dominated the experimental aspects.

By 1956 it was well established that the solar x-ray intensity was enhanced and the spectrum hardened during solar flares. However, controversy still raged as to whether Lyman-alpha or x-rays were responsible for the sudden ionospheric disturbances (SID) which accompanied some solar flares (Warwick and Zirin, 1957). In an attempt to gain the experimental information necessary to solve this problem NRL launched Project Rockoon in the summer of 1956, the first experiment deliberately planned to observe the x-ray and Lyman-alpha radiation of flares (Chubb, Friedman, Kreplin and Kupperian, 1957). The late phases of one small flare were observed. They found no detectable Lyman-alpha enhancement but the hardest x-rays observed up to that time (~3 A) were detected.

In the summer of 1957 Project Sunflare I yielded better observations which led to the same conclusion, namely, that hardening and intensification of the x-ray spectrum was the probable cause of SIDs (Friedman, Chubb, Kupperian, Kreplin and Lindsay, 1958). One of the rockets of this series obtained observations of x-rays which penetrated to within 63.5 km of the surface of the earth (<1.5 A). This record for photon energy was soon surpassed, however, when Peterson and Winckler (1958, 1959) on 20 March 1958 detected solar flare photons with energies of the order of 500 keV from a balloon floating over Cuba at an atmospheric depth of 10 gm cm^{-2}. Recognition of the time coincidence of this x-ray burst and a radio burst at 10,000 Mc/s led to their brilliant interpretation of this event. They argued that the x-ray burst and the radio burst were the bremsstrahlung and synchrotron emission, respectively, of a group of energetic, non-thermal electrons created during or by the flare.

Up to this point no direct observations had been obtained of the distribution of x-ray sources over the disk of the sun. In an ambitious attempt to gain some information on this point NRL set out to launch six instrumented rockets from shipboard in the South Pacific during the course of the solar eclipse of 12 October 1958. This effort was partially successful and it was shown that x-ray emission was predominantly associated with solar centers of activity and that 12% of the x-ray flux in the 44-60 A region was still observable at totality (Kreplin, 1961).

1959 was an eventful year in x-ray astronomy. For the first time NRL received some serious scientific competition when the Soviets (Mandel'shtam, et. al., 1961a) and shortly thereafter the British (Pounds and Bowen, 1962) flew rockets carrying solar x-ray experiments. This was also the year that the first satellite x-ray experiments (Vanguard III and Explorer VII) were attempted by NRL. Both met with failure due to orbital problems and interference from trapped radiation. In the summer of 1959 NRL launched 12 rockets carrying several kinds of x-ray and Lyman-alpha photometers as a part of their Project Sunflare II flare patrol program (Kreplin, 1961). They were successful in observing several flares and obtained the first spectral information on the harder component of flare x-ray emission (Chubb, Friedman and Kreplin, 1960, 1964).

Conclusive evidence demonstrating the localization of solar x-ray emitting regions over centers of activity was obtained by NRL in 1960 with their first x-ray photographs of the sun, made with a simple pin hole camera (Blake, Chubb, Friedman and Unziker, 1963). Also in 1960 Vette and Casal (1961) obtained time resolved observations of two hard (>20 keV) solar x-ray bursts with their balloon borne experiment -- the first balloon equipment specifically designed to observe these events.

Early that year NRL orbited the first successful x-ray monitoring satellite, Solar Radiation 1 (SR1), which obtained data off and on for four and one-half months. A strip-chart record of a flare observed by SR1 is illustrated in the figure. This experiment established once and for all that x-rays, rather than Lyman-alpha, are responsible for SIDs. The scattered, real-time, SR1 observations also shed light on defining what sort of solar active features produce x-ray enhancements (Kreplin, Chubb and Friedman, 1962).

Fig. 2 Solar Radiation 1 (aka Galactic Radiation and Background or GRAB). The spacecraft was 50.8 cm in diameter.

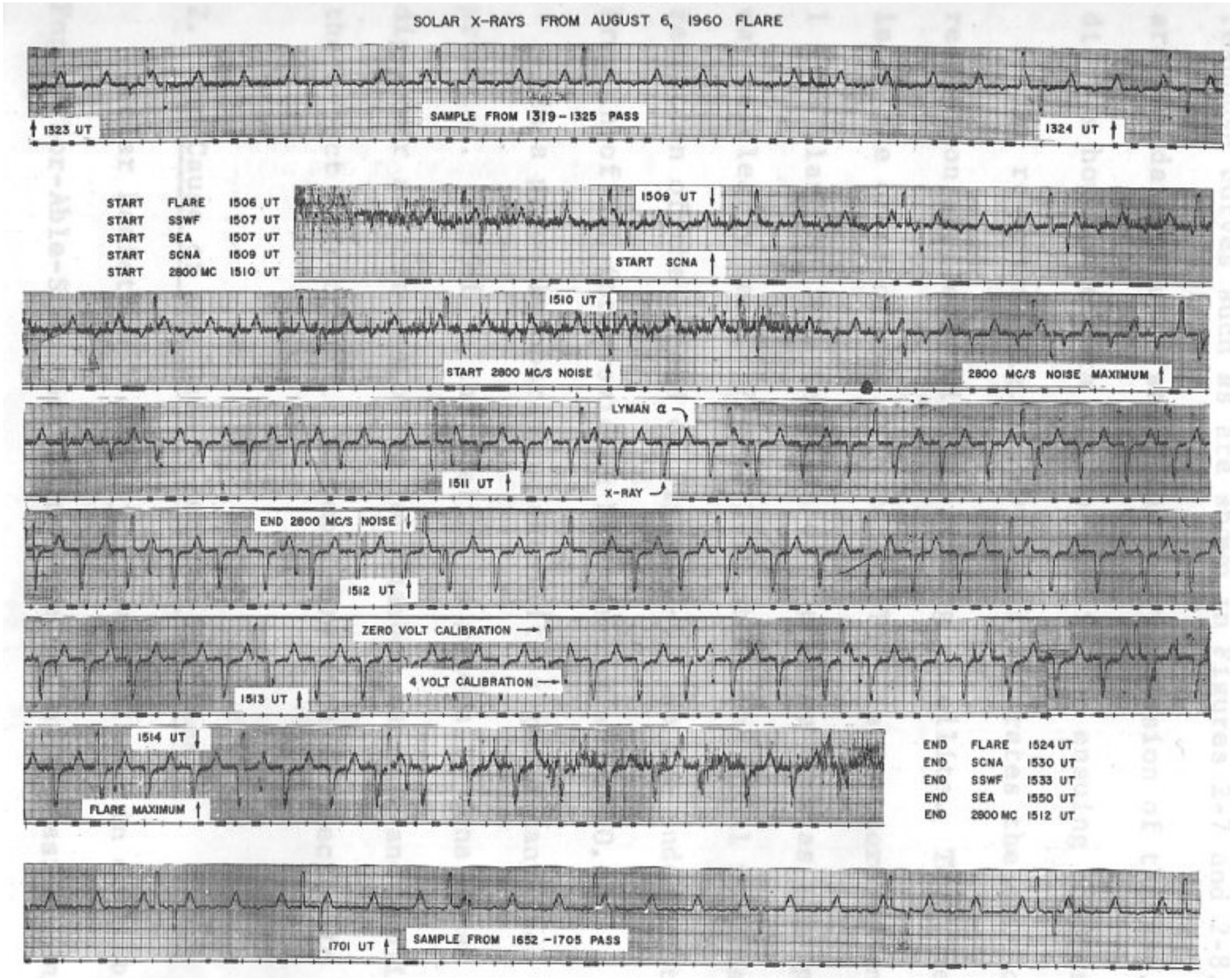

Fig. 3 Telemetry record obtained from Solar Radiation 1 coincident with the occurrence of a limb flare on 6 August 1960. On this record the Lyman-alpha signals (which show no enhancement) are the upward going blips. The 1-8 A x-ray signals are the downward going blips which begin to increase in the third plan from the top. The top and bottom panels are quiet-sun times and show no x-ray signal although the Lyman-alpha signal is constant throughout. (Figure courtesy of USNRL.)

In August and December of 1960 the Soviet Union launched their second and third spaceships. These satellites carried several kinds of solar x-ray detectors and obtained x-ray measurements for about two days in each case (Mandel'shtam, et. al., 1961b; Yeframov, et. al., 1963).

1961 saw the launching of Solar Radiation 3 (NRL) and Injun 1 (State Univ. of Iowa). Also, on 28 September 1961, Anderson and Winckler (1962) obtained truly exceptional observations of a hard (> 20 keV) x-ray burst. Their data were obtained with balloon borne experimental apparatus which was designed to measure aurorally associated x-ray emission. These observations provided the best time resolved spectral information to date. Subsequently, the general interest in the problems connected with solar x-ray emission grew apace and many satellite and rocket experiments attempted including proportional counter experiments carried aloft on the UK satellite Ariel (Culhane, Willmore, Pounds and Sanford, 1964), and the x-ray monitoring apparatus carried by the first solar-oriented satellite, OSO-1 (White, 1964; Lindsay, 1964). With these spectroscopic and imaging experiments the exploratory phase of solar x-ray and extreme ultra-violet studies was essentially over. We are still attempting to understand the details.

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Student Receptions (SPD Miami)

Getting to know us …..

Coming to Miami a little early? Spend some time chatting with your friendly, neighborhood astronomers and solar physicists at the Graduate and Undergraduate Student Reception. **The reception starts at 5:30 PM Sunday, May 23 and leads into the AAS General Reception at 7:00 PM**.

There will be representatives from several universities to talk with undergraduates about grad programs and research opportunities along with scientists from various disciplines to talk about the kinds of jobs they do, how they spend their days, and the excitement of working in cutting edge research. Did we mention there'll be munchies, too?

Zoe Frank
LMSAL
(for the SPD E/PO Committee)

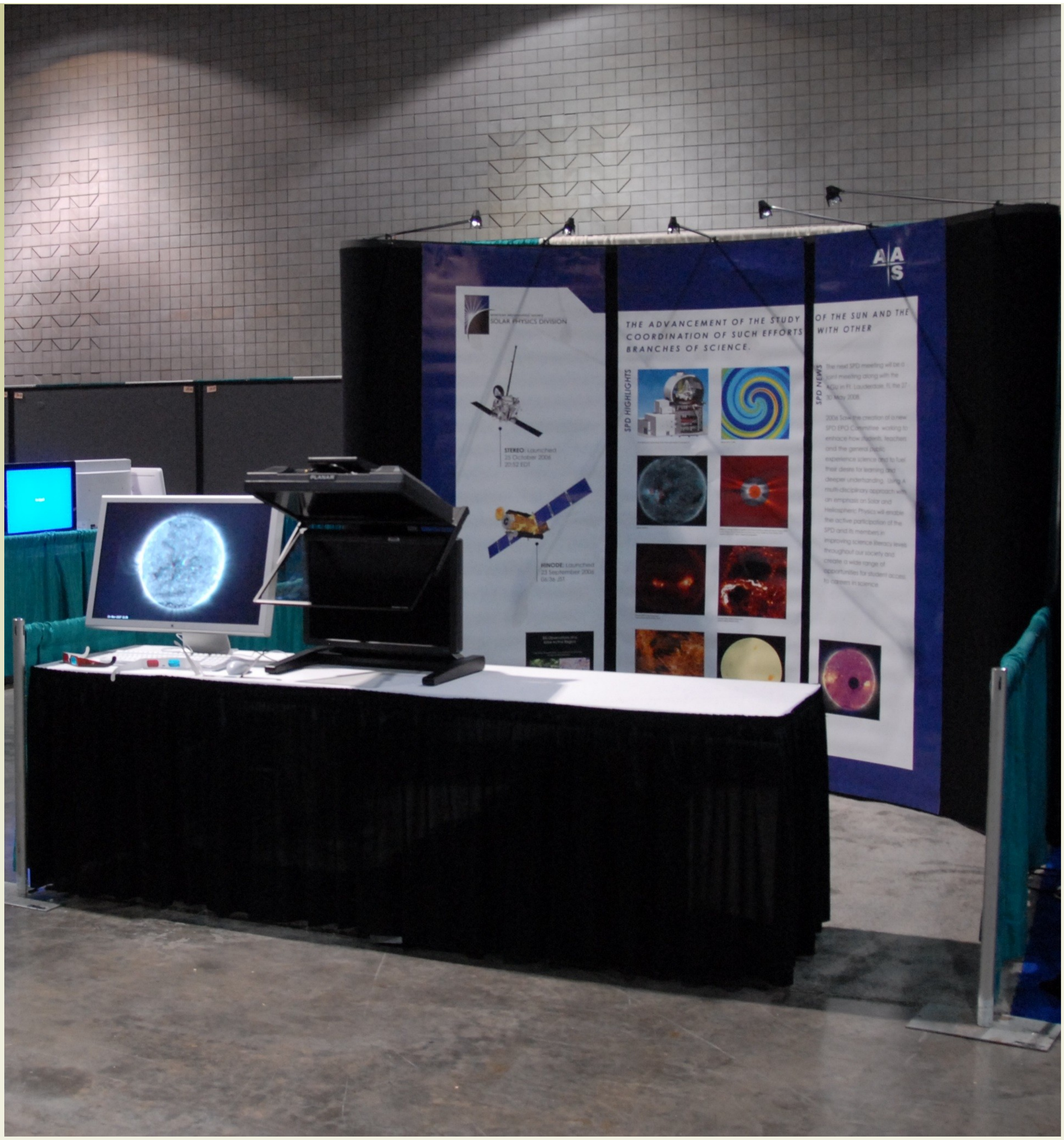
SPD Booths

Reaching Out

Every three years the Solar Physics Division meets jointly with our parent organization, the American Astronomical Society. During these joint spring meetings, the SPD takes the opportunity to present a display booth in the exhibits area of the meeting. Normally, exhibits are for advertising products. Our "products" are our work and the images and information we gather daily about our Sun, our closest star. The SPD display booth is a soapbox we can stand on to teach other science communities about our fascinating Sun. Our Sun is a tiny, nondescript star, easily overlooked in a view of the Universe (i.e., The Big Picture). There are so many interesting objects out there that don't have the problem of providing so many photons that your CCD saturates… But, hey, this little star is close enough that sometimes we can see starspots on it without a telescope at all (oh OK, sunspots). Our SPD display booth is commercial, a pop-up box about our star. It's an advertisement to the rest of the AAS community. The SPD is a relatively small group of colleagues with an international base and the booth is about who we are and what we do within the AAS. Over the years, the booth has been a display of the newest images of the Sun and enabling technology, a movie theater, video workstation, classroom, lecture hall, information center, meeting point, interview desk, and voting booth. It has provided space for collaboration, discussion, teaching, and learning. Also, over the years, many students have lent hands, hearts, and minds to helping out at the booth. The SPD will again have a display booth at the upcoming Miami meeting. This is an invitation to students to first, come by the booth and see what we have to offer; second, spend an hour, or even half an hour, on the "inside" of the booth. Talk with the other scientists who pass by. Let them know why you are interested in our Sun and our solar system… and ask about their work. The SPD booth is a way to interface with more meeting attendees than you otherwise might. It's a way for the same scientists to remember your face, your name, when they stop to read your poster, too. Please note, the booth is an advertisement for YOUR field. We are always looking for artwork, ideas, and other input for the booth. Please contact Zoe Frank (zoe[at]lmsal.com) with comments or ideas for the booth. Zoe will likely be nearby the booth during the meeting, too, and hopes to see you there.

Zoe Frank
LMSAL
(for the SPD E/PO Committee)

SPD Booths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