Multiscale methods offer a powerful approach to solar image processing and analysis. In this paper, wavelet-based methods are applied to a sequence of TRACE 195 passband images and LASCO C2/C3 white-light images to unambiguously identify faint features associated with the 2002 April 21 X-class flare and CME. Morphological properties, such as feature width, height, velocity and acceleration are then extracted, and compared to recent results from traditional image processing techniques.

SH42B-0544 1330h POSTER

Moving Magnet Features around Sunspots

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Moving magnetic features (MMF's) associated with small-scale emerging fluxes near the sunspot penumbra are believed to play an important role in mass and energy flow near sunspots. Since their discovery 30 year ago, only a few theoretical interpretations have been proposed on the real identity of MMF's: they may be associated with field lines detached from a decaying spot, or with closed magnetic loops. MMF's have remained a difficult subject for observations, requiring high spatial resolution movies for at least several hours. Coronal emission does not show immediate response to the birth and disappearance of individual MMF's; and the role of MMF's in the dynamics of upper layers of the atmosphere remains unclear. We present the results of recent, multi-wavelength observations designed to study the dynamics of MMF's from the time of their emergence to the moment when they merge into network or moat. Vector magnetograms made with the Dunn Telescope at Sunspot, NM, are co-aligned with MDI magnetograms, and TRACE 1600 Å and Fe IX/X 171 Å images, showing field orientation at the site of emergence, and the response of the chromosphere and corona to dynamic changes in the MMF's. These data allow meaningful statistics on MMF's and their relation to sunspot evolution.

SH42B-0545 1330h POSTER

First Results from SOLIS

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SOLIS (Synoptic Optical Long-term Investigations of the Sun) is a project to replace antiquated synoptic observing equipment at the National Solar Observatory. SOLIS includes a suite of three instruments on an equatorial mount originally installed at a site in Tucson and will be moved to Kitt Peak before the end of 2003. The major SOLIS instrument is a vector spectromagnetograph that maps magnetic fields across the full solar disk using a slit spectrograph and one arc sec pixels. Daily observations include several line-of-sight component magnetograms in the photosphere and chromosphere and, for the first time, full-disk vector magnetograms. At a medium scan speed (~10 minutes for the full disk) noise is less than 1 Mx/cm^2. This low noise, combined with negligible instrumental polarization and well resolved spectral line profiles, yields moderate resolution magnetograms of unprecedented quality. Sample observations show magnetic flux nearly everywhere in the photosphere from the disk center to the solar limb. The flux is organized in large scale patterns that heretofore had been visible only in strong flux elements or after substantial spatial smearing. Good results have been obtained from the other SOLIS instruments: a full-disk filter imager at several narrow wavelengths and a grating spectrograph that provides high-accuracy line spectra of integrated sunlight. SOLIS data are freely available via the Internet and users may submit observing time requests for special observations. The National Solar Observatory is operated by AURA, Inc. under a cooperative agreement with the National Science Foundation. Additional support for the development of SOLIS from NASA and ONR is gratefully acknowledged.

SH42B-0546 1330h POSTER

The Origin of Sunspots - A New Hypothesis

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Recent observations of sunspots, the high temperature of the corona and CMEs strongly suggest that they are all caused by highly energetic solid bodies falling into the Sun. This hypothesis is consistent with the rapid (3000 mph) downward flow of gases in sunspot interiors observed by SOHO, their lower temperatures, and the presence of large quantities of water in their spectra. The high velocity of the incoming body entrains the surface gases, carrying them rapidly downward. The vaporization of the bodies cools the local gases and the water released from the bodies produces the observed spectra. Solar flares and CMEs comprise the material splashed from the impact perimeter. The paired sunspots and the multiple secondary spots are the result of the partial breaking up of the incoming body in the solar atmosphere before it reaches the surface. The persistence of the sunspots is due to a quasi-stable toroidal circulation induced in the surface layer, similar to a smoke-ring or an inverse Hadley cell. An impact was recently captured in a sequence of ultraviolet images by the TRACE spacecraft. In the clip, the initial dark scene is suddenly illuminated by the splash or flare due to the primary impactor, which is not seen because it is dark. The resulting illumination makes it possible to observe the associated secondary bodies, which leave dark trails of gases as they vaporize and cool their surroundings. These were described as 'tadpoles' because they each leave undulating dark tails in contrast to the bright background. Their downward motion has created great difficulty for the current hypothesis, that sunspots are generated from within the sun, implying that all material should be moving outward. The estimated velocity of the 'tadpoles,' 400 miles/sec implies that they fell from the vicinity of Jupiter's orbit. Interestingly, the average sunspot cycle is close to the period of Jupiter, not the period of a body falling from Jupiter in a Sun grazing orbit. I suggest that the modulation of sunspot activity, illustrated by the well-known butterfly diagram, is due to millions of bodies which have been ejected from Jupiter's Great Red Spot (-20 latitude) in recent millennia. The differences in their orbits and the consequent modulation of the resulting impacts on the Sun are likely due to variations in the ecliptic and eccentricity, both of which follow Jupiter's period. The difference between Jupiter's period (11.8 earth years) and the average sunspot cycle (11.3) years, and the systematic variation of sunspot latitude during a cycle, may be due to relativistic effects on their sun grazing orbits (advance of perihelion) combined with the barycentric motion of the Sun caused primarily by Jupiter. The influx of numerous high velocity solid bodies is also consistent with the localized, non-thermal heating of the corona to millions of degrees. Yohkoh images show only the hottest part of the corona and SOHO's ultraviolet spectra of these regions have provided clear evidence for their non-thermal nature. These show the continually changing locations of heat deposition due to incoming bodies. The implication of the 'Maunder Minimum' and recent studies of the sunspot cylce on climate is that powerful bursts of energetic charged particles from the Sun are a significant factor in maintaining the temperature of the Earth at its current level. This accentuates the importance of understanding their origin, particularly when their future decline remains a possibility.

SH42C MCC: Level 1 Thursday 1330h

Radio Remote Sensing of the Corona and Heliosphere I Posters

Presiding: **N Gopalswamy,** NASA Goddard Space Flight Center

SH42C-0547 1330h POSTER

Radiations at Twice the Plasma Frequency Detected Upstream of the Earth's Shock by the CLUSTER/WHISPER Sounder

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Radiations at twice the plasma frequency, Fpe, have been commonly observed in the foreshock regions upstream of the Earth's bow shock and far beyond. These electromagnetic radiations are thought to be produced in the electron foreshock and most probably close to the interplanetary magnetic field line tangent to the shock surface. They are often seen simultaneously with suprathermal electrons that are energized at the shock and are backstreaming from it. The objective of the current presentation is to show and discuss a 2Fpe radiation event recorded on the CLUSTER spacecraft by the WHISPER experiment. In particular, the observed strong modulations of the 2Fpe signal intensity have been used to determine the apparent location of the radiation source. Surprisingly the source extension seems to be limited in this case. This could be due to the current solar wind behaviour. The interplanetary magnetic field direction and the solar wind density were indeed varying abruptly.

SH42C-0548 1330h POSTER

IPS investigation of CMEs in the solar wind

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Interplanetary scintillation (IPS) measurements of natural radio sources act as a useful tool for clarifying global properties of solar wind plasma, particularly of the transient streams associated with coronal mass ejections, since they allow us to probe the solar wind at multiple points within a relatively short time. Taking this advantage, we have investigated the 3D structure and radial evolution of CMEs in the interplanetary medium from IPS measurements made with the 327 MHz four-station system of the Solar-Terrestrial Environment Laboratory (STEL), Nagoya University. In the present study, the model fitting analysis has been preformed to derive 3D properties of CMEs from IPS data. As a result, the majority of analyzed CME events is found to have a loop-shaped global structure with an anisotropic angular extent. The remainder of the CME events is found to be well explained by a bubble-shaped model with a nearly uniform angular extent. The elongated structure of CMEs tends to be oriented nearly parallel to the heliographic equator, although some of CME events show a large tilt to the equator. The radial variation of CME speed has been deduced for selected events by combining IPS data with coronagraph and in situ data. It is found that CMEs are decelerated significantly as they propagate through the solar wind. The interaction between CMEs and the ambient solar wind is considered to play an important role in forming the observed features (i.e. the 3D structure and deceleration) of CMEs.

SH42C-0549 1330h POSTER

Alfven Wave Effects in Radio Scattering Observations of the Inner Solar Wind

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Microwave radio scattering and scintillation observations reveal a variety of distinctive characteristics in the density fluctuation spectrum and scintillation velocity field of the solar wind inside 25 solar radii. Any plasma wave or turbulence model of the corona and solar wind must be consistent with these radio results as well as with in situ spacecraft measurements outside 60 solar radii. High-frequency Alfven (ion-cyclotron) waves have some distinctive properties whose signatures appear to be showing up in the radio data. Obliquely propagating Alfven waves have substantial compressibility at high frequency that can explain the observed flattening of the density spectrum at 10-100 km scales, provided that there is an additional power-law component of passive density fluctuations riding on the magnetic turbulence. Proton cyclotron and electron Landau damping of the waves can account for the inner scale in the density spectrum as well as the observed break in spacecraft magnetic spectra, although an active Kolmogorov cascade is required to counteract spectrum erosion from wave damping. Such a cascade implies an energy input from wave dissipation that is substantial and much greater than that associated with cyclotron sweep of a passive spectrum. Interplanetary scintillation velocity measurements show a large parallel random component and small perpendicular random component, which is consistent with Alfven waves and inconsistent with fast-mode waves. The parallel velocity spread could result from a combination of wave dispersion and line-of-sight variations in the Alfven speed. All of the above effects will be discussed on the basis of numerical modeling results obtained assuming an evolving angular spectrum of Alfven waves described by a kinetic Vlasov dispersion code.

SH42C-0550 1330h POSTER

Comparison Between Interplanetary Scintillation Observation and In-Situ Measurement From 1991 to 2002

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Interplanetary scintillation (IPS) is a phenomenon that is unique and allows one to measure solar wind velocities over a wide spatial range of interplanetary space where in-situ measurements are impossible or difficult. We have been observing the solar wind velocity structure using the IPS facility (327 MHz) in Japan throughout solar cycles 22-23. To observe the continuously-changing solar wind structure, we apply a newly developed computer-assisted tomography (time-series tomography) to IPS data and then compare the velocity structure obtained by this new method with various in-situ measurements (i.e. WIND, ACE, Ulysses etc.) in the years from 1991 to 2002, to check the reliability of the time-series tomography. As a result, a high-level of agreement between IPS and in-situ measurements has been seen throughout cycles 22-23. We, therefore, conclude that this new technique is highly reliable. We, next, statistically study the variation of the solar wind structure during this period using parameters such as the NS asymmetry, variation of the ratio of fast to slow solar wind component and behavior of the fast solar wind during the solar maximum. We report the results of these analyses in this paper.

SH42C-0551 1330h POSTER

Propagation Effects on the Directivity Characteristics of Solar and Interplanetary Type II and Type III Radio Bursts

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Type II and type III radio bursts are excited by the CME driven shocks and flare accelerated electrons, respectively. These radio emissions contain advance information regarding the space weather critical CMEs and flare related particles. However, some uncertainities arise due to the dipole and quadrupole nature of the fundamental and second harmonic emission patterns of these bursts. For example, if the mode of emission is the second harmonic, it is less likely that the radio signals associated with the approaching CMEs or flare particles reach the observer if he/she is located in the nulls of the quadrupole. We will address this issue by (1) investigating the directivity patterns that arise from the conversion of Langmuir waves into radio emission at the fundamental and second harmonic of the electron plasma frequency in realistic situations especially including the weak magnetic fields, (2) determining the modifications to these emission patterns due to propagation effects by tracing the rays corresponding to the fundamental and second harmonic emission patterns in the presence of realistic density structures in the solar atmosphere; (propagation effects include scattering, absorption, refraction and ducting), and (3) comparing the directivity patterns and raytracing calculations with type II and type III burst intensity profiles obtained simultaneously by the widely separated Ulysses and Wind spacecraft.

SH42C-0552 1330h POSTER

A new Design for a Very low Frequency Satellite Based Radio Interferometer

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The non-transparency and severe propagation effects of the Earth's ionosphere do not allow electromagnetic waves lower than a few tens of MHz to be studied from the ground. To study the universe in this last, yet unexplored, part of the spectrum with the sensitivity and the resolution demanded by the scientific objectives, a dedicated space borne radio interferometer working at these frequencies is needed. Designs for space based Very Low Frequency (VLF, $<$ 30 MHz) interferometers have been discussed in literature for the past many years. All the proposed designs are based on transmitting the Nyquist sampled time series from each of the receptors of the interferometer to the Earth and doing offline correlations, as in VLBI. The inherently large data rates and the comparatively narrow telemetry bandwidth to the Earth limit these designs to providing narrow radio frequency (RF) bandwidths of observation and few bits per sample (125 kHz at 1 bit/sample, Jones et al. 2000, Geophys. Mono. Series, 119, 339-349). This adversely impacts the scientific capabilities of the mission. In principle, this hurdle can be overcome by reducing the volume of data to be transmitted to the Earth by doing appropriate real time data analysis on board. The phenomenal increase in the capabilities of space qualified hardware in the recent past now have brought close to meeting the requirements of a practical implementation of this concept. We present a new design for a space based VLF interferometer based on this approach, which can provide $\sim$2 orders of magnitude larger RF bandwidth coverage. In addition to on-board data processing, this design incorporates several other new features as well. We propose to use three dipole elements per satellite rather than two, to capture all the independent information impinging on the satellite. The design will implement a Radio Frequency Interference (RFI) mitigation scheme designed to identify and discard the parts of the band with strong RFI in real time. We strongly recommend an overlap in frequency range with upcoming ground based low frequency instruments like the Low Frequency Array (LOFAR) to benefit from the detailed information about the sky made available by them and to have a better handle on calibration. The hardware needed to implement this design is expected to become available in very near future, making this the design of choice for a VLF space interferometer.

SH42C-0553 1330h POSTER

Communications, Navigation, and Timing Constraints for the Solar Imaging Radio Array (SIRA)

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The Solar Imaging Radio Array (SIRA) is a proposed NASA mission to measure solar radio emissions in the 30kHz to 30MHz region of the electromagnetic spectrum. The baseline design consists of 16 separated spacecraft in an irregular pattern several kilometers across. Each spacecraft is equipped with a pair of crossed dipole antennas that together form a 16-element radio interferometer for Fourier-type image reconstruction (120 baselines in the UV-plane). The required close coordination between this formation of spacecraft places many unique constraints on the SIRA communications, navigation, control, and timing architectures. Current specifications call for knowledge of the relative locations of the spacecraft to approximately meter-level accuracy in order to maintain primary instrument resolution. Knowledge of the relative timing differences between the clocks on the spacecraft must likewise be maintained to tens of nanoseconds or better. This in turn sets a minimum bound on the regularity of communications updates between spacecraft. Although the actual positions of the spacecraft are not tightly constrained, enough control authority and system autonomy must be present to keep the spacecraft from colliding due to orbital perturbations. Each of these constraints has an important effect on the design of the architecture for the entire array. This paper examines the engineering requirements and design tradeoffs for the communications, navigation, and timing architectures for SIRA. Topics include the choice of navigation sensor, communications methodology and modulation schemes, and clock type to meet the overall system performance goals while overcoming issues such as communications dynamic range, bandwidth limitations, power constraints, available antenna beam patterns, and processing limitations. In addition, this paper discusses how the projected use of smaller spacecraft buses with their corresponding payload and cost limits has important consequences for the overall system design.

SH42C-0554 1330h POSTER

A Quantitative Model for Terrestrial Foreshock Langmuir Waves and Radio Emission

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Radio emissions near the first and second harmonics of the electron plasma frequency, as well as the Langmuir waves that produce them, are well known phenomena upstream from Earth's bow shock. Here, we present theoretical predictions for the spatial distribution and flux levels of the foreshock radio emissions generated in Earth's foreshock. The theoretical model combines electron reflection and acceleration at Earth's bow shock with stochastic growth theory for the steady-state production of Langmuir waves and nonlinear wave processes for the emission of electromagnetic radiation at harmonics of the electron plasma frequency. We demonstrate that the model predictions agree remarkably well, both qualitatively and quantitatively, with observations.

SH42C-0555 1330h POSTER

Probing Solar Energetic Particles with SIRA

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The space-based SIRA (Solar Imaging Radio Array) will provide a powerful capability to track high energy particles from solar flare and CME sites through interplanetary/heliospheric space all the way to Earth. Together with two other overlapping planned radio interferometers, i.e., FASR (Frequency-Agile Solar Radiotelescope) and LOFAR (Low-Frequency Array) the entire plasma frequency range from 30 GHz all the way down to the plasma frequency cutoff of 30 kHz at 1 AU will be covered. These instruments will track the magnetic trajectory of high energy particles, beam-driven radio emission, and localize the acceleration sites in the corona or interplanetary shocks. We simulate some CME and type III events, as they will be mapped with these instruments, using realistic scattering functions of radio waves on coronal and heliospheric density inhomogeneities.

SH42C-0556 1330h POSTER

Type II Radio Bursts and Energetic Solar Eruptions

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Type II radio bursts at decameter-hectometric (DH) and kilometric wavelengths are indicative of CME-driven shocks in the interplanetary medium. Only a subset of these type II bursts continue from the DH to the km regimes. We report on a study of these long-lasting type II bursts using data from the Wind/WAVES experiment in conjunction with white-light coronal mass ejection (CME) data from SOHO. We find the majority of these events (80 percent) are also associated with metric Type II bursts. We also studied the properties of the associated CMEs and found them to be the most energetic when compared to CMEs associated with bursts in any single wavelength regime.

SH42C-0557 1330h POSTER

The Potential for Characterizing the Heliosphere and Disturbances with LOFAR Faraday Rotation Observations

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A linearly polarized radio wave propagating along a magnetic field line may be represented as a combination of two components with right and left-hand circular polarizations. In a magnetized plasma such as the heliosphere these two circular polarizations experience different indices of refraction, leading to a phase lag between the two components. This phase lag results in Faraday Rotation - an overall rotation of the angle of the original linearly polarized wave. The extent of Faraday Rotation is proportional to the component of the magnetic field along the direction of propagation, the electron number density, and the square of the wavelength of the radiation. Faraday Rotation may be used to probe the three-dimensional electron number density and magnetic field topology of both the background heliosphere and of transients such as coronal mass ejections (CMEs). It is particularly interesting to note that the rotation is proportional to the total electron number density, in contrast to the signals from Interplanetary Scintillation (IPS), which are only a function of density fluctuations. Prior work in this topic typically involves monitoring variation in the polarization of either extragalactic sources or of transmitted telemetry from spacecraft such as Helios. These observations have been successfully used to study turbulence and propagating transients in the inner heliosphere. We have begun a study of the potential for the Low Frequency Array (LOFAR) to characterize both the background heliosphere and transients. LOFAR is a possible aperture synthesis radio interferometer for the 10-240 MHz range consisting of hundreds of thousands of individual receivers. The array will operate as a fully digitally steered instrument, in which the signals from the antennae may be combined to simultaneously image multiple regions in the sky. Among the factors which make LOFAR appealing to Faraday Rotation studies are the large wavelengths of the observations, the high sensitivity of the instrument, and the ability to track multiple objects. We will present our initial work on simulations of the ability of LOFAR to observe both the background heliosphere and simple transient structures such as flux ropes. For the background heliosphere we will demonstrate how various models for extrapolating photospheric magnetic fields produce different signatures. In the case of transients we examine how clearly we can extract fundamental properties such as helicity and field strength. This work is sponsored by NSF grant ATM-0317957

SH42C-0558 1330h POSTER

Radio and hard X-ray signatures of flare accelerated electrons

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While imaging and spectral radio observations in the decimetric-dekametric domain provide signatures of non-thermal electrons in the middle and upper corona , hard X-rays as well as microwaves trace flare accelerated electrons in the low corona and the chromosphere. Radio observations combined with hard X-ray observations thus allow to analyse the signature of energetic electrons in a whole range of coronal heights. We shall present here the results of multiwavelength studies primarily based on the analysis of HXR and decimetric/metric spatially resolved observations from RHESSI and the Nançay Radioheliograph. We shall outline how these combined observations provide information on the magnetic structures at different spatial scales in which energetic electrons are accelerated and injected as well as on the link between the production of energetic electrons interacting at the Sun and the injection of escaping electrons giving rise to the radio emissions at the lowest frequencies.

SH42C-0559 1330h POSTER

Coronal Mass Ejections, Flares and Type II Radio Bursts

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An investigation of 210 interplanetary type II radio bursts and the associated white-light coronal mass ejections (CMEs) is presented. The radio bursts were detected by the Wind/WAVES experiment in the 1-14 MHz (decameter-hectometric, DH) range, while the CMEs were observed by the Solar and Heliospheric Observatory (SOHO). The study period, 1997-2002, encompasses the current solar cycle (23) between minimum and beyond maximum. We could only find 108 solar flares associated with DH type IIs. We obtained the difference onset times (solar flare - DH type II) and found that DH type IIs start at the same time as the flares. On the other hand the difference between CME and DH type II onset times is indicates that the type II bursts occur well after the CME onset. The present study suggests that the CMEs are more likely to be the source of the shocks responsible for the type II bursts. We extend the study to metric type II bursts and obtained similar results.

SH42D MCC: 2010 Thursday 1340h

Coronal Magnetic Fields: Models to Measurements III

Presiding: **T H Zurbuchen,** University of Michigan**; G Fisher,** University of California, Berkeley

SH42D-01 1340h INVITED

Diagnostics of the Solar Coronal Magnetic Field: 1878 - 2010

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The solar corona is today a subject of intense scientific scrutiny as the birthplace of space weather and the location of the largest explosions in the solar system. The dynamics and structure of the lower solar corona are controlled by its magnetic field. Diagnosing the magnetic field is a difficult task of astrophysics that has been pursued for 125 years. This brief review will examine optical and radio methods used to study the inner coronal magnetic field. The National Solar Observatory is operated by AURA, Inc. under a cooperative agreement with the National Science Foundation.

SH42D-02 1400h

Measuring Coronal Magnetic Fields with Coronal Emission Line Polarimetry

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Magnetic field is the dominating field in the solar corona, responsible for the majestic coronal structures and dynamic events. However, no direct measurements of the coronal magnetic fields are routinely available and we can only infer the coronal magnetic field structures from observed intensity images. Although several methods for the diagnostics of coronal magnetic fields have been demonstrated, measurement of the coronal magnetic fields remains a very challenging observational task. This paper reports on a concerted effort at the Institute for Astronomy (IfA) to establish routine vector coronal magnetic field measurement capabilities using spectropolarimetric observation of the near infrared Fe XIII 1074.7 nm coronal emission line. The IfA effort includes observations of two-dimensional circular polarization maps of the emission line which carry information about the coronal magnetic field strength. High resolution observation of the linear polarization maps which yield the projected direction of the coronal magnetic field in the plane of the sky will also be obtained. The latest results from these experiments will be presented.

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Multi-Channel Polarimeter for Coronal Magnetic Filed Measurements

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We are currently building a filter-based polarimeter optimized for the measurement of magnetic fileds in the solar corona through observations of the coronal emission lines of Fe XIII at 1074.7 and 1079.8 nm. The instrument consists of a polarimeter allowing complete Stokes I,Q,U,V measurement followed by a Lyot birefringent filter with dual passbands of 0.14 nm width. Both the polarimeter and filter employ liquid crystals for rapid electro-optical tuning. This instrument will be deployed at the One Shot coronagraph at NSO Sac Peak. Measurement of the longitudinal Zeeman effect will yield information on the strength of the line-of-sight component of the magnetic field while the observation of resonance scattering will constrain the plane-of-sky field direction. Precise measurement of plasma velocity will also be possible. Such measurements are critical for addressing many outstanding problems in coronal physics. The operation and performance of the instrument will be described. We will also describe the methodology for the coronal magnetic field measurement. Preliminary measurements with the instrument at the One Shot coronagraph will be presented.