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CORONAL MAGNETISM EXPLORER: ESA SOLAR PHYSICS MISSION WHITE PAPER

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ABSTRACT

Magnetism dominates the structure and dynamics of the solar corona. To understand the true nature of the solar corona and the long-standing coronal heating problem, ultimately, requires measuring the vector magnetic field of the corona at a sufficiently high resolution (spatially and temporally) across a large Field-of-View (FOV). Despite the importance of the magnetic field in the physics of the corona and despite the tremendous progress made recently in the remote sensing of solar magnetic fields, reliable measurements of the coronal magnetic field strength and orientation do not exist. This is largely due to the weakness of coronal magnetic fields, previously estimated to be on the order of 1-10 G, and the difficulty associated with observing the extremely faint solar corona emission. With the Coronal Magnetism Explorer (CME) mission we plan to finally observe in detail and over the long-term, uninterrupted measurements of the coronal magnetic vector field using a new and very affordable instrument design concept. This will be profoundly important in the study local atmospheric coronal heating processes, as well as, in measuring the nature of magnetic clouds, in particular, within geo-effective Earth-bound Coronal Mass Ejections (CMEs) for more accurate forecasting of severe space weather activity.

Keywords: Sun, Telescopes

1. INTRODUCTION

Coronal physics has progressed enormously over the last decade with the advent of new observations from ground and space based instruments. However, many critical questions regarding the structure, heating, and dynamics of the corona will remain open until we can reliably and routinely measure the properties of coronal magnetic fields. Most solar activity, including high-energy electromagnetic radiation, solar energetic particles, flares, and coronal mass ejections, derives its energy from coronal magnetic fields. The corona is also the source of the solar wind with its embedded magnetic field that engulfs the Earth. These phenomena are collectively responsible for perturbations on the Earth?s environment known as space weather that affect communications, space flight, and power transmission. Measuring magnetic fields in the solar corona is a necessary step towards understanding and predicting the Sun?s generation of space weather.

Direct measurement of the magnetic fields in the corona is very difficult, and past results are inconclusive because of large uncertainties. For example, the strongest field detected by early magnetograph observations of the Zeeman effect in the green Fe XIV coronal emission line (CEL) was 13±20 G (Harvey 1969). More recent spectropolarimetric measurements using the near-infrared line Fe XIIIL λ 10747 could only set an upper limit of 40 G on the coronal field strength (Kuhn 1995). Linear polarization measurements of the Hanle effect in CELs were more successful in mapping the direction of coronal magnetic fields (Mickey 1973; Querfeld & Smartt 1984; Arnaud & Newkirk 1987); however, these measurements are not sensitive to the strength of the magnetic field (Casini & Judge 1999; Lin & Casini 2000).

More recently, Coronal Multi-channel Polarimeter (CoMP: Tomyzk et al., 2008) measured a noise level of a few Gauss and this was achieved with 4.5 arcsecond pixels in 2.4 hours of integration using a 20 cm aperture coronagraph with a background level of 16.4 μB. Given that we are photon noise limited, the performance demonstrated here can only be improved with more photons. In order to address this, the next generation COSMO ground-based facility (successor to CoMP) will lead to the construction of larger solar coronagraphs (1.5 m aperture) for ensuring better S/N in the polarimetric accuracy to acquire sufficient measurements of Stokes V and the circular polarization for magnetic field strengths with a necessary reduction in the effective integration time for the measurement. Similarly, the Diffraction Limited- Near Infra-Red SpectroPolarimeter (DL-NIRSP) on DKIST (which aims to receive first light in Jan 2021) will perform a similar measurement of the coronal magnetic field over a small FOV (limited to mosaicking of $\sim 21\times 14''$ mosaic tiles). However, catching CME eruptions and measuring the magnetic cloud of a CME will require continuous monitor of the corona and to understand the nature of the corona will require synoptic measurements without interruption. Therefore there is a need to place an instrument like CoMP in space to ensure long term uninterrupted measurements at an affordable cost. Furthermore we need to further reduce the integration times while retaining a large FOV to track evolution in the fast evolving CMEs.

2. SCIENCE OBJECTIVES

Coronal atmospheric diagnostics: The goals of understanding the physical mechanisms behind coronal plasma heating and solar wind acceleration are still pertinent. This is due to the potential for different mechanisms, e.g., waves dissipation, turbulence, magnetic reconnection, instabilities, to contribute by varying amounts to the energy flux of geometrically distinct magnetic regions (i.e., active regions, closed quiescent loops, open field lines). Recent interest in the forecasting of Space Weather had added a fresh impetus for making progress in these problems of heating and wind acceleration. In particular, the ability to makes predictions of both slow and fast solar wind stream properties, and understanding their variability, are key aspects for determining particle fluxes into the near Earth environment and a contributor to the evolving kinematics of coronal mass ejections through the heliosphere.

Recently, a potential basal contribution to the energy budget has been identified in imaging and spectroscopic observations and interpreted in terms of Alfvenic wave energy (Tomczyk et al., 2007, McIntosh et al., 2012, Thurgood et al., 2014). Alfvenic waves have long been assumed to play a significant role in heating plasma, their incompressible nature enabling them to transfer energy over large distances. CoMP was the first instrument to provide evidence for the Alfvenic wave energy flux through the solar atmosphere (Tomczyk et al., 2007), and subsequent investigation has revealed the ubiquity and persistence of this wave flux in Doppler velocities (Tomczyk McIntosh, 2009; Morton et al., 2015, 2016).

These observations have come in conjunction with some success in producing a heating of coronal plasma from wave-driven turbulence models (Suzuki Inutsuka, 2005, Cranmer et al., 2007, Evans et al., 2009), along with reproducing some of the basic properties of slow and fast solar wind. However, there are a number of challenges that these models have to overcome (Cranmer 2009, Ofman 2010), requiring more stringent observational constraints on the mechanisms for delivering energy, mass and momentum in the source regions in the low corona. Moreover, current forecasting models employ empirical techniques that have provide relative levels of success, although they are limited in their predictive power due to the neglect of the physical mechanisms ultimately responsible for plasma heating and wind acceleration. For example, the Wang, Sheeley Arge (WSA) model relies upon a static, potential coronal field and an empirical formula to estimate wind speed, while the Magnetohydrodynamics-Around-a-Sphere (MAS) model generates a wind by adding an ad-hoc heating function. Success in advancing knowledge of the underlying physics and improving forecasting will depend on the determining the energy, momentum and mass flux through different magnetic regions, quantifying the relative contributions of the plethora of potential mechanisms and detailed knowledge of the free energy in the coronal magnetic field.

Initial results from CoMP have shown promise for synoptic Doppler imaging of the extended corona to contribute to our understanding of the coronal magnetic field and Alfvenic energy flux through the solar atmosphere, with the potential to constrain key features of both sets of models. Recent CoMP results demonstrates the capability to make unique insights into wave phenomenon, e.g., wave excitation damping/mode conversion; Alfvenic turbulence; relative energy fluxes through distinct regions of the corona; energy flux from the lower solar atmosphere to the solar wind (Tomczyk McIntosh, 2009; Verth et al., 2010; De Moortel et al., 2014; Morton et al., 2015,2016). Additionally, CoMP has demonstrated such instruments have the potential for the exploitation of waves through magneto-seismology, in combination with spectroscopic techniques, to determine local plasma conditions, e.g., measurements of the magnetic field and relative angle with respect to the solar surface. Further, this combination can also provide estimates of the outflow of plasma low in the corona (Morton et al., 2015), allowing constraints to be placed on mass and energy flux along open-field lines and from regions potentially contributing to the slow solar wind.

While CoMP has demonstrated the potential for spectro-polarimetric coronagraphs to reveal unique insights into Alfvnic waves and their constraining their contribution to coronal heating and wind acceleration, there are somethings unachievable by ground-based observations. For example, extended sequences of observations are required to probe the Alfvenic waves over the broad frequency range observed out in the solar wind (). The ability to provide reliable measurements on a regular (daily/hourly) basis will also aid forecasting. The following provides only a small selection of potential science and operational questions that could be answered by a space-based imaging spectro-polarimeter coronagraph.

1. What are the key physical mechanisms contributing to coronal heating in different magnetic geometries?
   (i) What is the relative wave energy flux through different magnetic regions?
   (ii) Are the waves able to deposit their energy in the solar corona? And what are the physical rates for energy deposition?
   (iii) Is there evidence for the development of Alfven wave turbulence in the lower corona?

2. What is the role of waves in the acceleration of the solar wind?
   (i) What is the evolution of these waves in outer layers of the solar atmosphere, between the solar corona and the solar wind?
   (ii) How does the wave energy flux vary over the course of the solar cycle?

3. Which regions are key contributors to solar wind streams?

4. Is it feasible to exploit MHD waves via magneto-seismology to provide routine and meaningful characterisation of the plasma and magnetic field conditions in the corona?

Magnetic fields in solar eruptions:

Coronal mass ejections (CMEs) consist of large structures containing plasma and magnetic fields that are expelled from the Sun into the heliosphere. CMEs are a key aspect of coronal and interplanetary dynamics. They inject large quantities of mass and magnetic flux into the heliosphere, causing major transient disturbances at Earth. White-light CME observations mainly provide information on the mass content of the CME but very little on the magnetic structure. They are thought to remove built-up magnetic energy and plasma from the solar corona and most of the ejected material comes from the low corona. However, cooler, dense material of chromospheric / photospheric origin is sometimes involved. The CME plasma is entrained on an expanding magnetic field exhibiting helical field lines with changing pitch angles, commonly referred to, as a flux rope. The onset of CMEs has been associated with many solar disk phenomena such as flares, prominence eruptions, coronal dimming, arcade formation, X-ray sigmoids and both thermal / non-thermal CME radio emission in the form of shocks. However, the vast majority of the ejected energy assumes the form of mechanical energy carried by the CME and not the associated solar flare. Even in the most energetic. CMEs can exhibit a variety of forms with some having the classical "three-part" usually interpreted as compressed plasma ahead of a flux rope followed by a cavity surrounded by a bright filament/prominence. Other CMEs display a more complex geometry and appear as narrow jets. Some arise from pre-existing coronal streamers (streamer blowouts), while others appear as wide almost global eruptions such as Halo CMEs. Their speeds, accelerations, masses, and energies extend over 2-3 orders of magnitude and their angular widths exceed by factors of 3-10 the sizes of flaring active regions. Many CMEs have also been observed to be unassociated with any obvious solar surface and most flares occur independently of CME eruptions and it now seems likely that any flare accompanying a CME is part of an underlying magnetic process rather than being a direct cause of the CME. Recent models describing the onset and early evolution of CMEs provide a variety of mechanisms behind their formation. More significantly, CMEs can drive interplanetary shocks which are a key source of solar energetic particles and they are known to be the major contributor to severe space weather at the Earth (i.e. they are geo-effective). (D. F. Webb & T. A. Howard, 2012, "Coronal Mass Ejections: Observations", Living Rev. Solar Physics, 9, 3)

The Earth orbits through a sea of magnetised plasma flowing from the Sun called the solar wind. Travelling at high speed through the solar wind, CMEs are clouds of high-density plasma associated with eruptions/flares at the Sun. Large CMEs may cause widespread damage to Earth technology. In predicting the occurrence and evolution of CMEs the extended inner corona is a critical region which demands greater understanding. Current observations of this region are very limited. EUV imagers/spectrometers provide high-quality data, but their field of view is limited to heights of a few tenths so solar radii, severely restricting efforts to understand the source region of CMEs and the solar wind. The lack of measurements of coronal magnetic fields is a long-standing problem: there are only four existing direct estimates of the coronal magnetic field.

Science questions to address:

1. What triggers the release of free energy in closed magnetic fields leading to CME initiation?
2. Are there two physically different processes that launch CMEs (i.e. one for flare-driven and one for prominence eruptions) or do all CMEs belong to a dynamical continuum with a single physical initiation process?
3. How is the free energy apportioned between the flare energy and the CME mechanical energy?
4. How significant are pre-eruption minor energy releases as a true precursor to a CME? Or are they only separate eruptions?
5. Can we better quantify the propelling and retarding forces that impact upon CMEs, in the corona and interplanetary medium, in order to more accurately predict the arrival at Earth?
6. Why do the fastest CMEs and seemingly more energetic events produce only low levels of solar energetic particles (SEPs)?
7. Do magnetic clouds exist within CMEs in the corona and what are their magnetic properties? Do they all consist of a flux rope structure?
8. Is there any relationship between magnetic complexity in a source region and CME productivity?
9. Does the magnetic cloud structure of a CME have a definite leading and trailing field orientation? Can we accurately forecast how geo-effective a CME in the corona will become?

3. MISSION CONCEPT

Here we propose a suitable mission concept called Solar CubeSat's for Linked imaging Spectropolarimetry (SULIS: for more information see: http://sulis.space). SULIS is a mission concept consisting of formation-flying cubesat pairs that provide very high (eclipse-like) quality observations of the solar atmosphere. SULIS was selected as the only large-scale solar-system UKRI-STFC priority project in 2018 and will be a UK-led mission with international participation. One of the two main instruments aboard SULIS has been developed under an STFC PPRP grant, the other is an US-funded instrument. The previous PPRP grant stated our intention to promote the instrument for a future space mission: this is now being implemented as SULIS. The goal of SULIS is to capitalize on the diagnostic properties of coronal forbidden emission lines in the visible/near-IR, to determine the 3D vector magnetic field routinely, and to measure electron temperatures, ion densities, elemental abundances, charge states, bulk flow speeds, and non-thermal heating (i.e. wave heating). Observations of forbidden coronal emission lines in the visible/near-IR have been neglected in current solar missions. SULIS directly addresses this shortcoming.

The region from the base of the corona out to a height of 3 solar radii (Rs) is important - it is where Coronal Mass Ejections (CMEs) and the solar wind are formed and accelerated. Yet there are no routine quality measurements of this region: there are no direct measurements of the coronal magnetic field, and no quality measurements of the plasma properties. Through multiple CubeSats, the SULIS mission (http://sulis.space) will directly address this missing link. SULIS will (i) give routine maps of the 3D coronal magnetic field, (ii) provide eclipse-quality imaging/spectroscopy of the coronal plasma, and (iii) demonstrate a number of new technologies. SULIS will compliment operational space weather missions (e.g ESAs potential L5 mission, NASA?s L1 follow-on to DISCOVR and ASPIICS/PROBA-3) and pave the way for future missions.

SULIS mission concept: Three pairs of CubeSats will fly in formation: the first pair in Earth polar orbit and the other two pairs drifting ahead of and behind Earth in a 1AU orbit (fig 1). The sunward cubesat of each pair will act as an external occulter for the other CubeSat, which will observe the corona. This unique configuration provides eclipse-quality observation, and the 3 widely-separated viewpoints allows 3D reconstruction of the coronal magnetic field, plasma and CMEs.

Instrument 1: (Coronagraph): A coronagraphic high-resolution multichannel spectrometer together with a state-of-the-art broadband hyperspectral imager for observing the off-disk extended corona. The high-resolution spectrometer element of this instrument has been developed through an STFC PRD grant (ST/N002962/1 2016-19), an advanced build is currently being prepared for the July 2 Argentinian eclipse (fig 2). An accompanying novel hyperspectral imager is included, linked to the development of the PanCam instrument on ExoMars (ST/G003114/1). The visible coronagraph will be hosted on the anti-sunward coronagraph CubeSat of each pair. The proposed instrument will simultaneously collect high-resolution spectral data of several coronal emission lines along a spatial slit, which will scan across the corona. No other space- or ground-based mission will routinely collect data of this clarity in the range of 1.5 - 3Rs from the Sun.

Instrument 2 (Spectropolarimeter): 99-slit, massively-multiplexed coronal spectropolarimeter for measuring the low-corona 3D magnetic field. The spectropolarimeter enables determination of magnetic fields, temperatures, and densities from emission line polarization. Inversion of the Fe XIII 1.075m and He I 1.083m spectra give magnetic fields through the saturated Hanle effect.

Current telescopes and instrument can only measure the coronal magnetic field strength over a small field of view. Furthermore, the observations require very long integration times that preclude the study of dynamic events even when only a small field of view is required. A new instrument concept that employees large-scale multiplexing technology to enhance the efficiency of current coronal spectropolarimeter by more than two orders of magnitude is outlined in (H. Lin, 2016). This will allow for the instrument to increase of the integration time at each spatial location by the same factor, while also achieving a large field of view coverage. We will present the conceptual design of a 100-slit coronal spectropolarimeter that can observe six coronal emission lines simultaneously. Instruments based on this concept will allow us to study the evolution of the coronal magnetic field even with coronagraphs with modest aperture.

The proof-of-concept instrument, mxSPEC, was assembled at the full-disk port of the Dunn Solar Telescope (DST) in 2014 using DST inventory optics, a He I 1083 nm DWDM bandpass isolation filter (BIF) with 1.4 nm bandpass, and a 10 frames per second (fps) Raytheon Virgo 2K 2048 × 2048 IR camera. In this setup, the DST aperture was reduced to 135 mm, and mxSPEC observed the full solar disk with 1″ pixel^{-1} spatial sampling. mxSPEC was equipped with a photolithographically etched 49-slit mask. The slits are separated by 750 ?m distance, with a slit width of 12.5 ?m. The Sun illuminates 34 to 35 of the 49 slits at any given time, while the IR camera sees 41 of the 49 slits. Thus, only 60 scan steps, or less than 8 seconds (including processing overhead) are required to obtain a 2460 2048 50 (x, y, ?) hyper-spectral data cube. The spectrograph yields a 250 m /pixel spectral sampling size ($\lambda ? \delta\lambda$ = 40,000), and a ±225 km s^{-1} Doppler velocity coverage centered on the nearby Si I 1072.7 nm line (Lin et al., 2014).

In order to observe six spectral lines spanning over two octaves in wavelength we have designed a new wide-field catadioptric coronagraph based on an off-axis Gregorian telescope, and a 100-slit refractive Czerny-Turner spectrograph that can observe three spectral lines simultaneously. The system is equipped with two spectrographs to support simultaneous observations of six spectral lines. The catadioptric off-axis Gregorian coronagraph consists of an aspheric aperture corrector (AC, aperture ψ = 300 mm) followed by an off-axis parabolic primary mirror (M1, ψ = 300 mm, Focal Length FL = 800 mm, Off-Axis Distance OAD = 300 mm) and a concave off-axis elliptical secondary mirror (M2, ? = 120 mm, FL = 244.6 mm, OAD = 160 mm, conic C = ?0.158). A full-disk occulter is placed at the M1 focus to block disk light. The effective focal length at the Gregorian focus is 1850 mm. An entrance aperture stop (AS) placed between AC and M1, and a Lyot stop (LS) placed on the image of AS formed by M2 limit the effective aperture of the telescope. With an effective focal length of 1850 mm at the Gregorian foci, and a 1:1 magnification between the entrance and exit slit focal planes, the spatial sampling size is 1″ per pixel. The slit masks, SG1SM and SG2SM of the spectrographs have 100 parallel slits with width of 9 ?m, separated by a distance of 432 ?m. It takes only 48 scan steps to complete the scanning of the 1.2 × 1 degree FOV.

The most important aspect of a coronagraph design is the scattered light performance of the optical system. With the simple optical system, mxCSM will have very high photon throughput. Using a circular polarization amplitude of 1 × 10$^{?3}$ for a 10 G magnetic field, the estimated 3? detection limits of the line-of-sight component of the coronal magnetic field B3? of mxCSM for the Fe XIII 1075 nm line are 35 G, 12 G, and 4 G, respectively, with spatial resolution of 1″, 3″ and 10″ and temporal resolution of 2 h per map if the scattered light background is $10{\times}10^{?6} I_{sun}$. This is sufficient to measure the coronal magnetic field in most active regions up to $1.4R_{sun}$, based on the experience from the SOLARC coronagraph. In comparison, it would take a conventional single slit spectropolarimeter a minimum of 26.7 h of observation to obtain one full-polarization map of the 1.2×1.0 degree field.

3.1. *Importance*

There is no bigger question in solar physics other than "What is the nature of coronal heating?". Measuring magnetic vector fields of the global solar corona via coronagraphs will give us the necessary insight into the nature of coronal heating. This mission aims to do exactly that.

The mission is of particular importance because there currently is no plan to have a space-based coronagraph as a follow-up to full-disk, uninterrupted synoptic studies of CME and eruptions beyond 2020. The measurement of the geo-effectiveness of CME eruptions leading to space weather is becoming increasingly important given our increasing reliance on satellite communications. To understand the geo-effective nature of CMEs with enough warning requires measuring the magnetic field of CMEs close to the source rather than near Earth via in-situ measurements. This mission will achieve that purpose while give unique insights into the atmospheric properties of the corona at the typical thermal timescales of 80 s for coronal structural evolution (such as coronal loops).

The use of CubeSats for an ambitious space mission sets a benchmark for future cost-effective missions. The technological innovations of SULIS will advance power efficiency, communications and control for CubeSats and constellations, with impact on future space applications, and will address the central problem of CubeSat clusters, i.e. formation flying control, scientific instrumentation integration, and a novel laser optical communications demonstration for data transfer. Precision maneuvering is of substantial interest within the international spaceflight community, e.g., the AAREST9 mission. Potential for Societal and Economic Impact SULIS will strengthen the collaborative relationship between STFC and the UK space industry. The UK?s growing space sector is a core part of the government?s Industrial Strategy. The risk of severe space weather is part of the UK National Risk Register12. Government departments must plan for this risk, and SULIS will provide crucial understanding and early warning for protecting infrastructure. SULIS will see the application of laser optical communications in space. In general, Visible Light Communications (VLC) offers a sustainable and green technology, with a market that will rise from $267.6M(2014)to113$ billion by 202213. VLC offers a wide range of applications including short range optical wireless networks for healthcare14, medium range inter-vehicular and vehicle-to-infrastructure communications.

SULIS will enable us to better understand the drivers of space weather. The cost of space weather impact is enormous: The failure of the Hydro-Quebec system in 1989 during a solar storm took 9 hours to restore 80% of operations leaving 5 million people without power costing C2 billion in economic losses. The definitive extreme space weather scenario is the famous 1859 Carrington event. Lloyd?s of London (2013) estimated the cost of a similar event today would be 1-2 trillion, based on calculations examining disruption to the global supply chain15. Insurers? pricing models offer a robust methodological approach to economic cost quantification.

3.2. *Timeliness*

If the mission flies from 2024 (as proposed by the NGSPM- SOT) that will be particularly timely given that we will be returning to solar maximum in the next cycle. So we will expect to detect a large number of CME eruptions and flaring activity. Placing two instruments similar to CoMP in space, i.e. one in a Sun synchronous oribit and one at Lagrangian point L5 has the following advantages

1. A multi-FOV perspective (via instrument #1 and #2) of CME eruptions will enable tracking from the coronal mode (#1) FOV to a wider field interplanetary mode (#2).
2. The multi-view point will directly address the 180 ambiguity in the linear polarization measurement.
3. The instruments can combine data to measure the circular polarization (Stokes V) and magnetic field strength of the same source / CME twice as fast.
4. Placing the instrument in space reduces the scattering of the polarization signal which has limited measurements of the weak fields from the ground. Thereby ensuring further reductions in the integration time.
5. The mission will enable context as well as support studies and therefore compliment both COSMO and DL-NIRSP from the ground. t

4. OBSERVABLES & INSTRUMENTATION

Using a very sensitive infrared spectropolarimeter to observe the strong near-infrared coronal emission line Fe XIII λ10747 above active regions, we have succeeded in measuring the weak Stokes V circular polarization profiles resulting from the longitudinal Zeeman effect of the magnetic field of the solar corona.

The CoMP (Coronal Multi-channel Polarimeter: see 1) instrument can observe the coronal magnetic field with a full FOV in the low corona ($\sim$1.03 to 1.5 R_{Sun}), as well as obtain information about the plasma density and motion. Like Solar-C, CoMP records the intensity and the linear and circular polarization (Stokes I,Q,U,V) of the forbidden lines of Fe XIII at 1074.7 nm and also at 1079.8 nm. In addition to detecting the POS field direction and the LOS field strength, CoMP also measures the LOS plasma velocity from Doppler observations in the wings of the line intensity (Stokes I), and the POS density from the ratio of the lines at 1074.7 and 1079.8 nm. These observations have a spatial sampling of 4.5$''$ per pixel and required 30 minutes of integration time to acquire a measure of the LOS magnetic field strength. The LOS field strength measurements shown at lower right, are significantly worse than those shown in the Solar-C data due to the smaller coronagraph aperture (20 cm vs. 46 cm on Solar-C), shorter integration time and smaller pixel size.

4.1. *Feasibility*

The instruments proposed are designed and outlined in detail in (). The cost of construction is clearly outlined and the components are largely off-the-shelf.

5. SUMMARY

We have presented a conceptual design for a new instrument, optimized for high-temporal resolution spectroscopic measurements of the intensity and polarization of multiple CELs over a very large field of view for research in coronal magnetism. For comparison, the time required for the 25 cm aperture, 6-line, 100-slit coronal spectropolarmeter coronagraph presented in this paper to observe the 1 degree FOV is comparable to that of a 6-m coronagraph equipped with current single-slit, single-wavelength spectropolarimeter. But mxCSM can be constructed with only a fraction of the cost required for the construction of a 6-m class coronagraph.

The high system throughput of this design also makes it an ideal design for future space missions where size and weight of the instruments are severely limited.

6. MEMBERS OF THE PROPOSING TEAM

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