Jacob Parker Personal Statement

Throughout my career as a student I have had countless opportunities. Thanks to the tremendous faculty at MSU and collaborating institutions I have been able to design and manufacture experimental components, develop code for solar physics data analysis and modeling, collaborate with Marshal Space Flight Center on the ESIS sounding rocket, work as a member of the IRIS team as a science planner, preform optical testing and assembly of EUV telescopes, and attended many conferences throughout the country to present my work. This variety is what makes me excited about my future career in Solar Physics

As an Undergraduate I took the first couple years of the Mechanical Engineering curriculum before choosing to stick with Physics. Before I left the ME department behind I was able to learn enough about mechanical design and machining to build simple parts. This knowledge allowed me to be useful as a member of the MSU Sounding rocket team as a Sophomore even though a lot of the physics was over my head. Since then my role on the team has expanded significantly. As a Physics Graduate Student I manage the "mechanical" portion of the sounding rocket team which includes maintaining the schedule, managing several undergraduates and one professional engineer, as well as contributing to opto-mechanical design and testing. As we start to run out of "mechanical" tasks I have had the opportunity to learn how to use our 4-D interferometer and theodolites for optical testing, focus, and alignment. Working on the sounding rocket team gives me plenty of opportunities to get away from the computer and "turn a wrench". I hope to continue working on solar telescopes in the future in order to contribute new and exciting data to the community.

Last spring I had the opportunity to travel to Lockheed Martin in Palo Alto to participate in IRIS science planner training. Since then I have planned a month in total and have learned a lot about IRIS and its operations. My experience interacting with the professional scientists on the IRIS team has been invaluable in preparing me to be a productive member of the IRIS science team. Last year I completed my first publication using. Dana Longcope and I developed a linear MHD model to describe elliptical oscillations observed in a flare ribbon observed by IRIS. My exposure to IRIS beyond simple data analysis has given me great insight into its capabilities and limitations, as well as the parameters that go into a quality observation. I believe these skills to be essential in producing quality science from IRIS, or any instrument for that matter, in the future.

Going forward with my career I hope to continue to use and develop spectral instruments to diagnose solar magnetic reconnection. Being able to develop completely theoretical MHD models, design and build a new mirror mount, and do large numerical studies of data, all for one project is what drew me to solar physics, and it is what will keep my passion alive in the future.

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BURSTS, BOMBS, AND EXPLOSIVE EVENTS: MAGNETIC RECONNECTION IN THE LOWER SOLAR ATMOSPHERE

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ABSTRACT

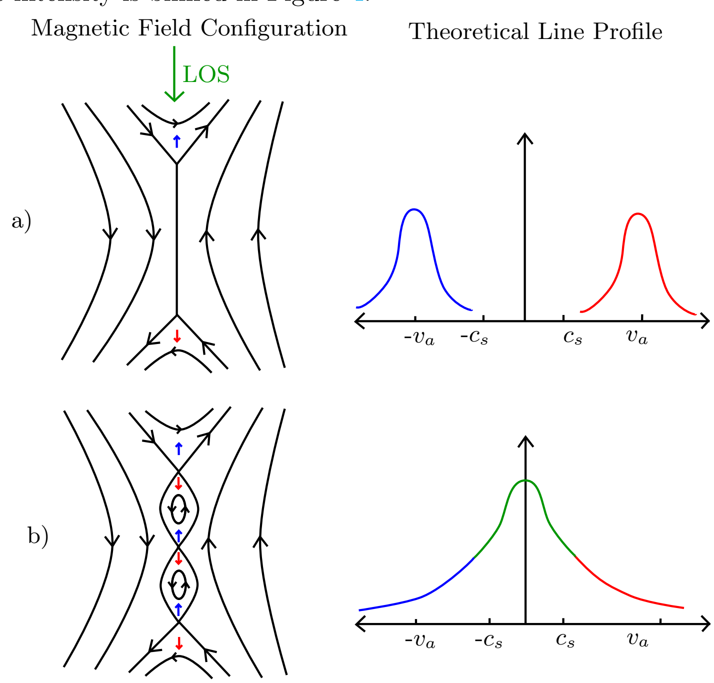
The Suns atmosphere is a dynamic and variable environment. Stressed magnetic fields generated in the interior carry large amounts of energy past the photosphere where it is released violently into surrounding plasma. Magnetic reconnection is likely responsible for this release but details on how are lacking. We propose to do a statistical study of small eruptions, reconnection events, in the lower solar atmosphere using data from IRIS and the ESIS/MOSES-3 sounding rocket. Better information on these eruptions is needed in order to challenge conclusions of the past and integrate recent findings into our understanding of magnetic reconnection and its role in transporting mass and energy throughout the Sun's atmosphere.

1. BACKGROUND

1.1. *Transient Brightenings in the Lower Solar Atmosphere*

From the photosphere to the upper reaches of the transition region the solar atmosphere changes three orders of magnitude in temperature over only a few thousand kilometers. This thin layer of the Sun, while

Figure 1. Here we present a cartoon representing an ideal presentation of magnetic reconnection and corresponding spectral observation. Panel a shows Petscheck reconnection with bi-directional outflow jets at the Alfvén Speed, v_a. Plotted along side is a theoretical line profile, for the labeled *Line Of Sight* (LOS), showing two seperate peaks in intensity at $\pm v_a$. Panel b shows the developement of magnetic islands during the onset of the tearing mode instability. The addition of stationary emitting material will fill out line center and result in a broadened, mostly centered line profile. The blue, green, red coloring of the line profiles demonstrated how line intensity is binned in Figure 4.



often less grand in appearance than the corona, plays an important role in the energy transport required to heat the corona to mega-Kelvin temperatures. Like the flickering coals of a camp fire the photosphere, chromosphere, and transition region are littered with small, short lived, brightenings. Brightenings give us clues as to how often, where, and when energy produced in the solar interior is deposited beyond the photosphere.

These small brightenings are often accompanied by fast motion. Spectroscopic observations reveal many events, over a range of heights and temperatures, that have Doppler velocities exceeding the local thermal speed. In order for plasma velocities to exceed thermal speeds there must be a conversion of a non-thermal energy source to kinetic energy. It is becoming widely accepted that this extra energy comes from the solar magnetic field. Through magnetic reconnection the Sun's magnetic field eliminates high energy discontinuities and converts that energy in to the heating and motion of local plasma. While repeated observations of non-thermal plasma motion within regions of complicated magnetic field has the solar physics community leaning toward magnetic reconnection as the cause of solar atmospheric heating the details are still the subject of much debate.

1.2. *Ellerman Bombs and Explosive Events*

Two commonly observed events in the Sun's lower atmosphere are Ellerman Bombs (EBs) and Explosive Events (EEs). EBs (Ellerman 1917) are commonly observed as intense brightenings in the wings of Hα λ6563 Å are characterized by small spatial scales (arcsecond or smaller), and short life times (a few minutes). Hα has a peak formation temperature of $\approx$ 10000 K placing EBs very low in the solar atmosphere near the photosphere. EBs are observed in regions of opposing magnetic polarity and, until recently (Nelson et al. 2017), exclusively within active regions. EBs are believed to be the result of magnetic reconnection as new flux emerges through the photosphere and reconnects with the preexisting photopsheric magnetic field. High resolution instruments such as the Crisp Imaging Spectropolarimeter (CHRISP; Scharmer et al. 2008) on the Swedish Solar Telescope (SST; Scharmer et al. 2003) and the Interface Region Imaging Spectrometer (IRIS; De Pontieu et al. 2014) have helped discover more details about EBs. They often originate between granules deep in the photosphere, have an upward extending flow or "jet", and demonstrate very fast variations (on second timescales) coupled with repeated eruptions (Watanabe et al. 2011; Vissers et al. 2013, 2015)

EEs were first analyzed by Brueckner & Bartoe (1983) using data from the High Resolution Telescope and Spectrograph (HRTS) sounding rocket. EEs are typically characterized by Doppler shifts on order 100 km s^{-1} and spatial scales of a few arcseconds (Dere et al. 1989; Dere 1994). Si IV λ1393Å rasters taken by the Solar Ultraviolet Measurement of Emitted Radiation (SUMER) sounding rocket revealed an EE with bi-directional jets near small magnetic bi-poles on the solar surface (Innes et al. 1997). This presentation was said to match the classic magneto-hydrodynamic (MHD) model of reconnection (Petschek 1964) quite well which is illustrated in Figure 1(a). Data from the first flight of the Multi-Order Solar EUV Spectrograph (MOSES; Fox et al. 2010) sounding rocket showed evidence of many explosive events in He II λ304Å. While a large number of events showed clear bi-directional jets with Doppler velocities of approximately $\pm$ 100 km s^{-1} (Rust 2017), one event showed fast jets, offset spatially, with a bright stationary core (Fox et al. 2010). Fox et al. (2010) identified a possible cause of the complicated spatial/spectral signature to be the Tearing Mode Instability (Furth et al. 1963) illustrated in Figure 1(b).

1.3. *IRIS Bombs and UV Bursts*

IRIS has been observing the transition region since late 2013. In this short period of time several discoveries have been made that have challenged our understanding of reconnection in the lower solar atmosphere. An early discovery by Peter et al. (2014) showed the presence of very cool, photospheric absorption lines in the wings of the Si IV λ1394Å line. Transient brightenings in Si IV with these types of absorption features have been labeled "IRIS Bombs" or "UV Bursts" and are thought to be caused by magnetic reconnection. The presence of the Ni II and Fe II absorption lines, with peak formation temperatures of approximately 15,000K, implies that IRIS bombs actually occur in the photosphere. Magnetic reconnection would heat plasma to at least 80,000K for Si IV formation, and emit through the cool photospheric plasma above it.

IRIS has also observed many events most similar to traditional EEs. While early work by Innes et al. (1997) showed EEs in Si IV to have bi-directional jets, later work by Innes et al. (2015) with IRIS Si IV data has shown EEs to have broad, almost triangular, line profiles with very bright cores and little to no sign of bi-directional flows. This was originally attributed to the Tearing Mode instability based on MHD

Figure 2. Example explosive event map from our software package

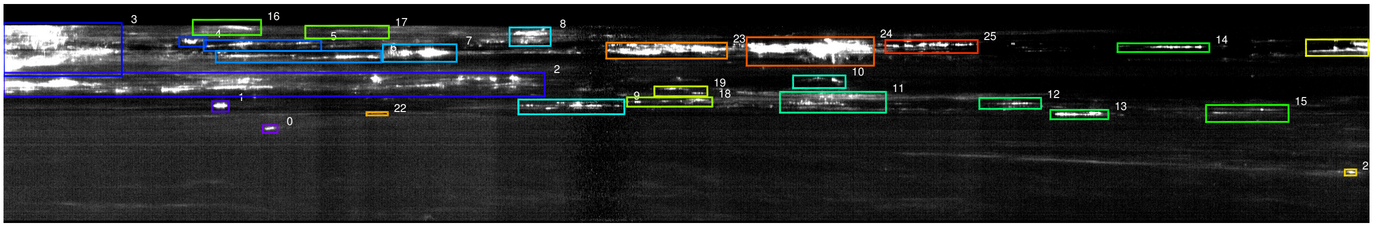
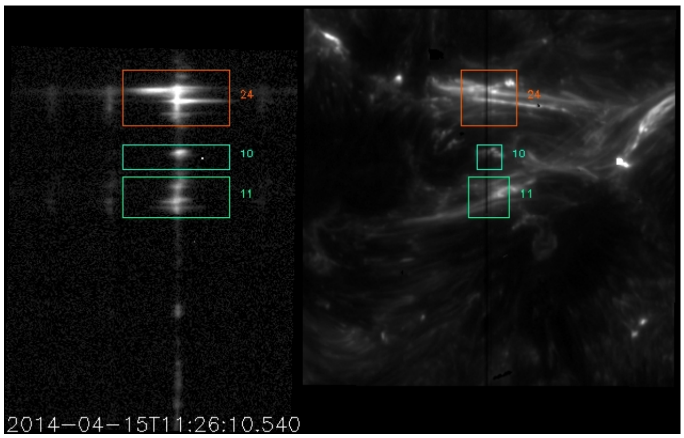


Figure 3. A single frame from an IRIS slit jaw context movie (right) side by side with corresponding slit spectra (left) shows event number 24 at a point in its evolution with a particularly sheared line profile.



simulations and synthetic line profiles. This theory has been corroborated recently by the observation of very small (≈ 0.”2) and very fast (less than a second) brightenings by SST that are co-spatial with Si IV UV Burst spectra (Rouppe van der Voort et al. 2017). These small brightenings are taken to be direct observation of Tearing Mode islands at transition region scales.

1.4. *Problem Statement*

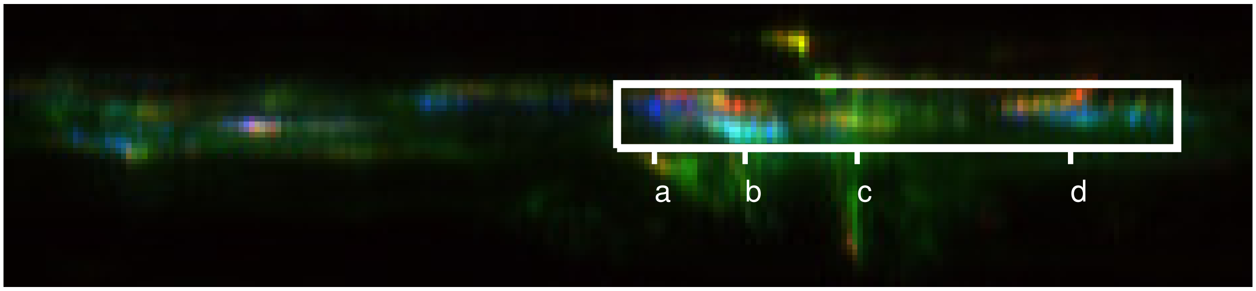
Transient brightening in the lower solar atmosphere have many names and present themselves in a variety of ways. Names aside, these events have a lot in common. Consistently we see energy releases with on order arcsecond spatial scales and second temporal scales. Spectrometers reveal that these small events have Doppler velocities exceeding local thermal speeds, and that they occur in a wide temperature band from 10^4-10^6 K. Due to their correlation with complex photospheric magnetic fields and super thermal velocities these events are all likely connected to magnetic reconnection, though not everyone is convinced (Judge 2015). Advances in instrumentation and modeling reveal the structure of the photosphere, chromosphere, and transition region to 3-D in nature, challenging the theoretical 1-D stratified solar atmospher. Throughout our study we will address the following science questions:

- Are EEs, UV Bursts, EBs, and IRIS Bombs truly different events, or are they all small reconnection events happening slightly different environments?
- If all of these events are associated with magnetic reconnection then what determines their presentation?
- What is the role of small reconnection events in transporting mass and energy to the corona?
- What can small reconnection events tell us about the role of the tearing mode instability in the onset of fast solar magnetic reconnection?

2. TECHNICAL APPROACH

The best tools currently available for studying magnetic reconnection in the lower solar atmosphere are high resolution spectrographs. We propose a multi-instrument statistical study of small transient brightenings. For this study we consider all brightenings, besides large flares, with significant super-thermal velocities

Figure 4. Color map of event number 24. This RGB image is generated by binning line profile intensity around a typical sound speed, in this case $v = 60$ km s^{-1}. Blue is the total intensity $\leq -v$, red is the total line intensity $\geq v$, and Green is the total intensity of the line core between $\pm v$. An example of this binning is illustrated in Figure 1. A transition from a separated blue/red intensity to a broader green profile is similar to a progression proposed in Figure 1.



to be Explosive Events (EEs) regardless of specific past definitions. Our study will begin with a detailed statistical study of Si IV spectra taken by IRIS and be supplemented with Ne VII and O V images taken by MOSES and the EUV Slitless Imaging Spectrograph (ESIS)

2.1. *Initial Survey and Event Selection*

We began our study by building a large database of EEs. To do this we selected a handful OBS IDs, IRIS observing programs, that best suited our needs. These OBS are all sit-and-stare observations with ≤ 4 second cadence, a medium or larger linelist, have limited spectral binning, and they must include the Si IV slit jaw data at least.

We opt to use sit-and-stare data, as opposed to slit rasters, for increased temporal resolution. While it is easier to capture EEs using a rastered slit we have found that EEs evolve on a timescale much faster than the time it takes to complete even a small raster. Therefore, the best way to capture EE dynamics is to sit and stare.

With EEs evolving on second time scales we must make a trade between image cadence and signal to noise ratio. Over the last 4 years the FUV sensitivity of IRIS has diminished significantly. An exposure length that was long enough in 2013 is not long enough now. Fortunately for us EEs tend to be bright, allowing for good data with a sub four second exposure even with decreased sensitivity.

IRIS is an extremely flexible instrument that is limited in its data production by downlink telemetry bandwidth. Two methods of reducing memory usage are truncating data in the spectral dimension and binning data at the CCD level. We choose to use a medium line list or larger because it is the smallest line list that includes both Si IV spectral lines, $\lambda 1394$ Å and $\lambda 1403$ Å, which are required for optical depth diagnostics. We also allow more binning in spatial dimension, along the slit, than we do in the spectral dimension. If we hope to resolve narrow photospheric absorption lines, like Fe II and Ni II that are only a pixel or two wide, we need to take advantage of IRIS' high spectral resolution. We often bin spectra along the slit during analysis and therefore require less spatial resolution.

Since the bulk of our analysis centers on Si IV spectra we require all OBS for this study to have at least the Si IV $\lambda 1400$ Å slit jaw images for context. Slit jaw movies show what is going on around the slit and are very useful for identifying and sorting different event spatial structure. An example of a slit jaw image is shown in Figure 3

This criteria gave us 23 OBS from April 2014 to May 2017. With more data coming down from IRIS everyday we will be able to expand this data set. As we approach solar minima we will add more observations of quiet sun targets to look for any associated trends. From these 23 OBS we have identified 581 events. To do this we used an EE software package developed at Montana State University which provides a simple GUI for event selection as well as worked with an REU student during the summer of 2017 (Bartz 2018). An example of our software in action can be seen in Figure 2. EE maps are made by integrating all material with a Doppler speed ≥ 60 km s^{-1} and making an image with slit position on the vertical axis and time on the horizontal. Then clumps of intensity in the image can be boxed via a click and drag interface. Each box represents an event. Our initial survey has shown our data set to cover a large portion of the solar disk, covering mostly active latitudes. Most events last 20 min or less and cover less than 10" of slit.

2.2. *Spectral Diagnostic IRIS*

Si IV has a peak formation temperature of $\approx 80,000$K placing it at the base of the transition region. IRIS has revealed this line to be both optically thin during small flaring events and show a variety of optical depth effects (Peter et al. 2014; Yan et al. 2015). Complex Si IV line profiles are being used to draw new conclusions about the location EEs, the type of magnetic reconnection causing them, and the fundamental structure of the lower solar atmosphere. We wish to study Si IV line profiles to determine which behaviors are statistically significant and which are anomalous events that contribute less to our overall understanding of EEs.

We will start by sorting EEs into optically thin and optically thick events. To do this we will monitor the line ratio of both Si IV lines throughout the course of each event. Si IV λ1394 Å and λ1403 Å maintain a 2:1 ratio during optically thin conditions (Mathioudakis et al. 1999). Significant deviations from this line ratio indicate an event has significant absorption or is optically thick. Optically thick line profiles will need to be handled differently when determining Doppler shifts. Absorption features would need to be masked off when analyzing line profiles. We are also interested in the distribution of line ratios across the EE database in order to address the question of whether events with or without optical depth effects are unique, or the product of how we observe them.

The next step is to identify typical velocity distributions during EEs. Observations of EEs in the past have shown them to be both bi-modal (Innes et al. 1997; Rust 2017) and have more continuous velocity distributions with 3-D structure (Fox et al. 2010; Innes et al. 2015; Rouppe van der Voort et al. 2017). We will determine what portion of events deviate from the bi-modal Petschek reconnection picture of EEs by using Doppler maps like in Figure 4. By binning spectral intensity by Doppler shift we can quickly see events that have directional flows (blue or red) and those that are more complicated and have significant line core emission (green). Identifying blue/red to green transitions over time may help us understand the onset of the tearing mode instability and the transition to fast reconnection. A more complicated method of analyzing velocity distributions would be to deconvolve thermal gaussians from the line profile. This would allow us to distinguish between highly structured velocity fields from reconnection outflows and turbulent flows.

The IRIS slit jaw movies give spatial context for each event. Spatial context allows for further event classification. For example Figure 3 shows a frame from the Si IV slit jaw movie associated with event 24 in Figure 2 next to its corresponding spectra. From this frame we can see that event 24 is associated with a visible loop. We can then correlate observed Doppler velocities with apparent motion along the loop. An alternative would be a compact brightening with no obvious spatial structure, an observation off limb, a sun spot penumbra, etc. This context is vital for interpreting spectral information as an indication of spatial structure.

Say something about future work with C II or HMI? Or is the scope getting too far out? Mention despiking the data?

2.3. *ESIS and MOSES-3*

The ESIS/MOSES-3 sounding rocket launch is currently scheduled for Fall of 2018. ESIS and MOSES both use convex diffraction gratings to focus light from different spectral orders onto separate CCDs. Each image represents a different projection through a 3-D cube with two spatial and one spectral dimension. MOSES data from the previous two launches has already been inverted successfully via a few different methods (Fox et al. 2010; Courrier & Kankelborg 2015; Smart et al. 2016, 2017; Rust 2017) demonstrating its ability to provide simultaneous spectral and spatial measurements over it's entire field of view. ESIS will improve on MOSES' design by adding additional CCDs, four cameras to start with the possibility of six for future launches. It also includes a field stop which will limit spectral contamination from objects beyond its field of view (Parker & Kankelborg 2016).

ESIS images primarily in O V λ630 Å with a portion of the detector capturing He I λ584 Å and MOSES-3 images in Ne VII λ465 Å. These lines have peak formation temperatures of 224,000 K, 10,000K, and 500,000 K respectively. The O V and Ne VII were chosen for use with ESIS and MOSES because of their formation temperature and because they are isolated enough from surround spectra to be use narrow band EUV multi-lay coatings. Comparing EEs in hotter transition region lines with those in Si IV will help place events at a height in the atmosphere and map the flow of mass and energy from photosphere to corona. Not to mention if we are lucky enough to catch an event in both O V and He I with ESIS we will see that EEs have a wide variation in temperature across a single event. Comparing Doppler shifts between cooler and hotter lines will also how material and energy are transfered from photosphere through the transition region to the corona.

A slitless spectrograph has many advantages over traditional spectrographs when viewing explosive events. A large field of view eliminates the need for slit rastering to find velocity fields. Since Doppler information is co-temporal across the field of view there is no issue of the velocity field evolving faster than one can raster. Coordination with IRIS and the ESIS/MOSES-3 sounding rocket is relatively simple. MOSES and ESIS have significantly larger fields of view than IRIS and since they capture Doppler shifts over the entire field of view there is no risk of slit misalignment. IRIS slit jaw images allow for simple co-alignment with ESIS/MOSES-3 images.

We believe that slitless spectrograph will provide unprecedented insight into reconnection events in the lower solar atmosphere. With access to Doppler velocities across an entire event with every exposure we no longer have to wonder what is happening in an object, or a portion of an object, that is off slit. We can also make velocity maps co-temporally in multiple lines at multiple temperatures, getting us one step closer to mapping energy flow through the lower solar atmosphere.

3. SCIENTIFIC IMPACT

Preforming a detailed statistical study of small energy releases in the lower solar atmosphere has a lot to offer the broader scientific community. Magnetic reconnection is a physical process of universal significance. Fusion reactors, the Earth's magnetotail, coronal heating, etc. are all impacted by magnetic reconnection. EEs are great way to study reconnection for few reasons. They are more frequent than large flares, providing better statistics. EEs tend to be compact allowing for a slit spectrograph to capture Doppler velocities over a larger portion of the event. They also occur in a narrow portion of the Sun's atmosphere where there is less "stuff" to look through. We believe that magnetic reconnection contributes largely to the variability of the Sun and , in turn, the space weather environment. A more thorough understanding of reconnection will help minimize it's impact on humanity by improving our predictive capabilities.

While many publications exist on IRIS observations of EEs, most of them focus on a few tens of events or less. Large statistical studies are going to become more and more common in our field. In a time where Heliophysics satellites are taking gigabytes of data a day we need to be focused on analysis methods that are catered to large data sets. With no shortage of observations available we can use statistically significant sample sizes prior to drawing broad conclusions. Developing the machinery to analyze EE spectra in a semi-automated will make expanding our statistics simple throughout the remainder of the IRIS mission. Questions that arise during the study will also motivate future IRIS observing plans and help increase its scientific productivity.

ESIS/MOSES-3 represent the next generation of solar spectrometers. Work on these sounding rockets gets us closer to the ultimate ideal in spectroscopy, full disk co-temporal spectral/spatial images. While we are still a ways off, advances in slitless spectroscopy will slowly dissolve our reliance on the medieval arrow slit of slit spectroscopy and give us back our field of view.

4. TIMELINE

Table 1 shows an outline of the next two plus years with milestones marked in green. Between now and November myself and the ESIS/MOSES-3 team will be getting ready for launch at White Sands Missile Range. In that time we will receive our flight optics, focus and align them, finish the electronics and cooling systems, and prepare for range operations. Work on the EE statistical study will continue to move along. While the data base is large enough for the study already we will update with new data and implement some improved noise reduction routines prior to starting the full spectral analysis.

This project will have perfect timing with my planned graduation date of Summer 2020. Close to a year of additional hardware development culminating in an experience at White Sands Missle Range will lead into two years of data analysis. This award would give me the flexibility to focus on data post launch and better address our science questions.

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Table 1. Proposed timeline. Major milestones are marked in green.

NESSF Project Timeline

#	Task	Start	Finish	2018	2019	2020
		Start	Finish	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D
	IRIS EE Study					
1	Update EE Dataset	01/18/18	03/18/18			
2	Si IV Optical Depth Analysis	03/01/18	09/18/18			
3	EE Doppler Velocity Analysis	10/01/18	01/30/19			
4	Submit IRIS EE Paper (ApJ)	02/01/19	02/01/19			
	ESIS/MOSES-III					
5	Optical Alignment and Focus	01/31/18	04/30/18			
6	Integration and Testing (MSU)	01/01/18	06/30/18			
7	Delivery and Testing (WSMR)	10/01/18	11/2018			
8	Launch	11/2018	11/2018			
9	Data Analysis/Paper writing	11/2018	08/05/19			
10	Submit ESIS/MOSES-III EE Paper	08/06/19	08/31/19			
11	Prepare for future launch with two					
	additional cameras (to be proposed)	12/01/18	TBD			
	MSU PhD Program					
12	Prepare Thesis	01/15/18	05/31/20			
13	Dissertation Defense	Summer 2020				
14	Graduation	Summer 2020				

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Areas of specialization

Image Data Analysis • Correlation
Physics • Magnetic Reconnection
Opto-mechanical Design and Simulation
Sounding Rocket Science

Research Experience

2011-2014 Undergraduate Research Assistant: Work with the *Multi-Order Solar Extreme Ultraviolet Spectrograph* (MOSES) sounding rocket on mechanical ground support and instrument calibration

2014-2016 Identifying Extra Spectral Content in MOSES images using cross-correlation and CHIANTI.

2015-2016 Created a linear MHD model of the Tearing Mode instability with equilibrium shear flow with Dana Longcope to analyze elliptical motions in a flare ribbon observed by IRIS.

2016-Present Managing the mechanical design team for the *Extreme-Ultraviolet Snapshot Imaging Spectrograph* (ESIS) a sounding rocket mission.

2017-Present Focus, Alignment, and Optical Testing of ESIS.

Present Statistical survey of the temporal evolution of explosive events observed by IRIS.

Education

2014 BS in Physics (Highest Honors), Montana State University

2016 MS in Physics, Montana State University

Fellowships

Fall 2017 Montana Space Grant Consortium Graduate Fellowship

Publications & talks

Journal articles

2017 Jacob Parker and Dana Longcope (2017), “Modeling A Propagating Sawtooth Flare Ribbon Structure as a Tearing Mode in the Presence of Velocity Shear”, *ApJ*

2018 Jacob Parker and Charles Kankelborg (2016), “Determining the Spectral Content of MOSES images”, *In preparation for Solar Physics*

Posters

2016 Jacob Parker and Charles Kankelborg (2016), “Determining the Spectral Content of MOSES images”, AAS/Solar Physics Division Meeting, Number 47. LINK

2017 Jacob Parker and Dana Longcope (2017), “Modeling A Propagating Sawtooth Flare Ribbon Structure as a Tearing Mode in the Presence of Velocity Shear”, IRIS-8/HINODE-11 Meeting LINK

Talks

2017 Jacob Parker, Dana Longcope, and Sean Brannon “Modeling A Propagating Sawtooth Flare Ribbon Structure as a Tearing Mode in the Presence of Velocity Shear”, 48th Annual SPD Conference (Portland Oregon)

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Ph.D., September 1996 Department of physics, Stanford University, Stanford, CA. Dissertation: "Multispectral observations of coronal X-ray bright points"

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Research Interests

Solar magnetic activity; Coronal loops; X-ray bright points; Image analysis; UV spectroscopy, optics, and instrument design; space instrumentation; signal and image processing; inverse problems.

Relevant Experience

2017 - present: Co-Investigator, *MUlti-slit Spectroscopic Explorer*, NASA SMEX Phase A.

2015 - present: Principal Investigator, *EUV Snapshot Imaging Spectrograph* (*ESIS*) sounding rocket investigation, NASA Heliophysics LCAS.

2014 - present: Professor, Department of Physics, Montana State University

2008 - present: Co-Investigator, *Inerface Region Imaging Spectrograph*, NASA Heliophysics Small Explorer mission. Responsible for spectrograph optics.

2001 - 2015: Principal Investigator, *Multi-Order Solar EUV Spectrograph* (*MOSES*) sounding rocket investigation, NASA Heliophysics LCAS.

2007 - 2014: Associate Professor, Department of Physics, Montana State University

2001 - 2007: Assistant Professor, Department of Physics, Montana State University

April 2001 - August 2001: Research Scientist, Department of Physics, Montana State University, Bozeman, MT.

Service

Dr. Kankelborg has served on a variety of NASA review panels, including Solar Probe Plus Standing Review Board (Aug 2009 - Sep 2010), TMC reviews for two major space missions, SR& T, GI, Moo, LCAS, and MIDEX science review. He has also served on review panels for the US National Science Foundation and the Swiss SNF.

2012-2016: NASA Sounding Rocket Working Group.

2011-2013, Judge for the National Solar Spectrograph Competition. Public outreach program for the NASA *IRIS* mission.

2009-2012: NASA Heliophysics Subcommittee.

April 2012 - 2015: Montana Space Grant Consortium Advisory Board

Referee for The Astrophysical Journal, Solar Physics, and others. Chaired poster and oral sessions at AAS/SPD meetings.

Member, American Geophysical Union

Associate Member, Solar Physics Division of the American Astronomical Society

Member, American Scientific Affiliation

Awards

Spring, 2012: MSU Society of Physics Students Undergraduate Level Instructor Award.

2012: Kavli Frontiers of Science meeting, invited participant.

2011 and 2006: George Tuthill award (outstanding graduate level instructor, selected by the physics graduate students).

2010: Charles & Nora Wiley Faculty Award for Meritorious Research.

Presidential Early Career Award for Scientists & Engineers (PECASE), awarded December 19, 2008 at the White House, "for the development of novel instrumentation for imaging spectroscopy in Solar Physics; and for mentoring undergraduate and graduate students involved in experiments on sounding rockets."

Selected Publications

Dr. Kankelborg is author or co-author of three dozen refereed and 145 total publications.

1. "Using local correlation tracking to recover solar spectral information from a slitless spectrograph", Charles C. Kankelborg Hans T. Courrier, *Journal of Astronomical Telescopes, Instruments, and Systems*, **4**, 4-11, (2018).

2. "Fast Differential Emission Measure Inversion of Solar Coronal Data", J. Plowman, C. Kankelborg, and P. Martens, *ApJ*, **771**, 2, (2013).

3. "Exploring the Interface Between the Sun's Surface and Corona", Charles Kankelborg, *Physics Today*, **65**, 72-73, (2012).

4. "Data inversion for the Multi-Order Solar Extreme-Ultraviolet Spectrograph", J. L. Fox, C. C. Kankelborg, and T. R. Metcalf, In *Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space Research V., Larar, Allen M.; Shaw, Joseph A.; Sun, Zhaobo., eds. Proc. SPIE*, volume 5157, pages 124–132, (2003).

5. "Evidence of Separator Reconnection in a Survey of X-Ray Bright Points", D. W. Longcope, C. C. Kankelborg, J. L. Nelson, and A. A. Pevtsov, *ApJ*, **553**, 429–439, (2001).

6. "Forward modeling of the coronal response to reconnection in an X-ray bright point", C. Kankelborg and D. Longcope, *Sol. Phys.*, **190**, 59–77, (1999).

Department of Physics

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January 31, 2018

To: NESSF Selection Committee

Dear Colleagues,

I am writing to recommend my PhD student, Jacob Parker, for the 2018 NASA Earth and Space Science Fellowship program. Jake is a tremendously versatile and hard working young scientist with unique potential.

I have known Jake for about 6 years, since he was an undergrad at MSU. He is among the best students I have taught and worked with in research. As an undergraduate, he routinely took 18-19 credits of upper division science and engineering courses, managed his time well, and performed admirably. He began working on my sounding rocket program during those undergraduate years, and became experienced with many aspects of our instrument development program, including EUV calibration with a hollow cathode light source, high vacuum, cleanroom, and ESD procedures. He is also adept in the machine shop. Jake is an exemplary team member who identifies what needs to be done and does it. He relates well to everyone on the project, from outside vendors to support staff, machinists, engineers, co-investigators, and NSROC personnel.

Working with graduate student Hans Courrier, Jake designed several nontrivial components that flew successfully on the MOSES-II rocket mission in 2015. He also played a major role in developing our EUV radiometric calibration setup. When he would encounter any task he did not know how to accomplish, Jake demonstrated the patience and resourcefulness to figure it out with a minimum of supervision. Jake has high personal standards, but is not impaired by perfectionism or fear of failure.

As a graduate student, Jake has continued the trend of academic success, intellectual and personal growth. He completed a very subtle data analysis that uncovered the influence of a host of weak lines in the MOSES-I sounding rocket data, and presented the results at an SPD meeting.

Jake is experienced, competent and trustworthy in the lab. He led the mechanical design team for our new instrument, ESIS which included managing and mentoring our undergraduate engineers. To take just one example of his contribution to our team: In Fall 2016, Jake uncovered a subtle boundary condition issue with our finite element analyses and thereby saved us from greatly overdesigning our mirror mounts for the EUV Snapshot Imaging Spectrometer (ESIS). Jake's combination of mechanical and electronic skills, leadershp, self discipline, and analytic ability make him perhaps the most versatile graduate student I have ever worked with. *The major progress we have made in preparing for launch during the past year owes much to his talent, resourcefulness, and perseverance.*

In addition to his hardware work and his leadership on my team, Jake completed a theoretical project last year with Prof. Dana Longcope in modeling the tearing mode instability. The effort grew out of an assignment for a plasma physics class, and has been published as a first-author paper in the *Astrophysical Journal*. Jake also serves as a science planner for the IRIS mission, on which I am a co-investigator. This activity has given him familiarity with IRIS data, as well as experience in satellite operations and multi-spacecraft coordinations.

Jake has settled on a thesis topic that will combine explosive event data from the IRIS satellite and our rocket flights. The project will require the careful analysis of a large number of events. He launched this project, mentoring his own REU student, last summer; they began with a large explosive event database developed by my former REU student Hannah Alpert and postdoc Sarah Jaeggli, and greatly extended the database coverage and added significant new analysis capabilities to the software suite. Jake's work is likely to shed new light on the reconnection process, influencing our understanding not only of the transition region, but of flares and CMEs. In the context of major coronal events, the reconnection region is difficult to observe because of low emission measure, background, and line of sight confusion. Thanks to IRIS, MOSES, and our new instrument ESIS, explosive events and related signatures of reconnection in the transition region and chromosphere are becoming a new laboratory for exploration of the initiation and evolution of the reconnection process in a solar context.

Of the students I have worked with over the past 20 years, Jake stands out as the best suited to become a principal investigator. He has taken on and completed a range of projects, demonstrating both theoretical and experimental ability. He has proven himself repeatedly as a good mentor to younger students in both physics and engineering disciplines. He has taken on a great deal of responsibility as a graduate student, in part because he possesses extraordinary self discipline, time management, and leadership skills. However, he deserves and will benefit from the NESSF fellowship that allows him to pursue wholeheartedly the scientific ideas that are driving him. The project that he has proposed is well conceived, and will establish him as a member of our solar physics community. I am absolutely confident that he will succeed, and will lead a distinguished career. I recommend him in the strongest possible terms for the NESSF Fellowship.

Sincerely,

Charles C. Kankelborg
Professor of Physics

Department of Physics

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January 31, 2018

To: NASA/NESSF Program

We affirm that this proposal is the work of the graduate student, Jacob Parker, and not that of any other team member.

Sincerely,

Charles C. Kankelborg
Professor of Physics

Jacob Parker

Jacob Parker
Graduate Student

Display Transcript

This is NOT an official transcript. Courses which are in progress may also be included on this transcript.

Transfer Credit Institution Credit Transcript Totals Courses in Progress

Transcript Data

STUDENT INFORMATION

Name : Jacob D. Parker

Curriculum Information

Current Program

College: College of Letters & Science

Major and Department: Physics, Physics

***Transcript type:WEB is NOT Official ***

DEGREES AWARDED:

Awarded: Bachelor of Science **Degree Date:** May 02, 2014

Institutional Honors: Highest Honors

Curriculum Information

College: College of Letters & Science

Major: Physics

Major Concentration: Interdisciplinary Studies

Minor: Mathematics

Awarded: Master of Science **Degree Date:** Dec 16, 2016

Curriculum Information

College: College of Letters & Science

Major: Physics

TRANSFER CREDIT ACCEPTED BY INSTITUTION -Top-

sp08-sp10: Advanced Placement Program

Subject	Course	Title	Grade	Credit Hours	Quality Points	R
ELEC	100D	Govt & Politics-Comp	TP	3.000	0.00	
HSTA	101IH	American History I	TP	4.000	0.00	
HSTA	102IH	American History II	TP	4.000	0.00	
HSTR	101IH	Western Civilization I	TP	4.000	0.00	
HSTR	102IH	Western Civilization II	TP	4.000	0.00	
LIT	110IH	Intro to Lit	TP	3.000	0.00	
M	171Q	Calculus I	TP	4.000	0.00	
PHYS	211	Gen & Mod Phys I	TP	4.000	0.00	
PSCI	210IS	Intro to American Government	TP	3.000	0.00	
WRIT	101W	College Writing I	TP	3.000	0.00	

	Attempt	Passed	Earned	GPA	Quality	GPA

		Hours	Hours	Hours	Hours	Points		
Current Term:		36.000	36.000	36.000	0.000	0.00		0.00

Unofficial Transcript

INSTITUTION CREDIT **-Top-**

Term: 2010 Fall Semester

College: College of Letters & Science
Major: Physics
Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
CHMY	151	UG	Honors College Chemistry I	A	4.000	16.00			
M	181Q	UG	Honors Calculus I	A	4.000	16.00			
ME	101	UG	Intro to Mech Engr	A	1.000	4.00			
PHSX	240	UG	Honors Gen & Mod Phys I	A	4.000	16.00			
UH	201US	UG	Texts & Critics:Knowledge	A	4.000	16.00			

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	17.000	17.000	17.000	17.000	68.00	4.00
Cumulative:	17.000	17.000	17.000	17.000	68.00	4.00

Unofficial Transcript

Term: 2011 Spring Semester

College: College of Letters & Science
Major: Physics
Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
CHBE	213	UG	Material Science	A-	3.000	11.10			
M	182Q	UG	Honors Calculus II	A	4.000	16.00			
ME	117	UG	ME Design Graphics	A	1.000	4.00			
ME	118	UG	ME Design Graphics Lab	A	1.000	4.00			
ME	202	UG	Engr Comptr Application	B+	1.000	3.30			
ME	251	UG	ME Material Sci Lab	A	1.000	4.00			
PHSX	242	UG	Honors Gen & Mod Phys II	A	4.000	16.00			
UH	202	UG	Texts & Critics:Imagination	A	4.000	16.00			

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	19.000	19.000	19.000	19.000	74.40	3.91
Cumulative:	36.000	36.000	36.000	36.000	142.40	3.95

Unofficial Transcript

Term: 2011 Fall Semester

College: College of Letters & Science
Major: Physics
Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
EGEN	201	UG	Engineering Mechanics--Statics	B	3.000	9.00			

ETME	215	UG	Manufacturing Processes	A-	3.000	11.10			
ETME	217	UG	Manufact Process Lab--ME	A-	1.000	3.70			
M	283Q	UG	Honors Multivariable Calculus	A-	4.000	14.80			
PHSX	200	UG	Research Programs in Physics	P	1.000	0.00			
PHSX	224	UG	Physics III	B+	4.000	13.20			
PHSX	261	UG	Laboratory Electronics I	A-	2.000	7.40			
PHSX	490R	UG	Undergraduate Research	A	1.000	4.00		I	

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	19.000	19.000	19.000	18.000	63.20	3.51
Cumulative:	55.000	55.000	55.000	54.000	205.60	3.80

Unofficial Transcript

Term: 2012 Spring Semester

College: College of Letters & Science

Major: Physics

Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
EGEN	205	UG	Mechanics of Mtls (equiv 305)	C+	3.000	6.90			
M	221	UG	Introduction to Linear Algebra	A	3.000	12.00			
M	284	UG	Honors Intro to Diff Equations	A	4.000	16.00			
PHSX	262	UG	Laboratory Electronics II	A	2.000	8.00			
PHSX	301	UG	Intro Theoretical Physics	B+	3.000	9.90			

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	15.000	15.000	15.000	15.000	52.80	3.52
Cumulative:	70.000	70.000	70.000	69.000	258.40	3.74

Unofficial Transcript

Term: 2012 Fall Semester

College: College of Letters & Science

Major: Physics

Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
EMAT	350	UG	Engineering Materials	B+	3.000	9.90			
GRMN	101	UG	Elementary German I	A	4.000	16.00			
M	348	UG	Techniques of Applied Math I	A	3.000	12.00			
PHSX	320	UG	Classical Mechanics	A-	4.000	14.80			
PHSX	331	UG	Meth of Computational Physics	A	1.000	4.00			
PHSX	343	UG	Intermediate Physics	B+	3.000	9.90			

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	18.000	18.000	18.000	18.000	66.60	3.70
Cumulative:	88.000	88.000	88.000	87.000	325.00	3.73

Unofficial Transcript

Term: 2013 Spring Semester

College:	College of Letters & Science
Major:	Physics
Academic Standing:	Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
EMAT	463	UG	Composite Materials	A	3.000	12.00			
M	349	UG	Techniques of Applied Math II	A	3.000	12.00			
MUSI	101IA	UG	Enjoyment of Music	A	3.000	12.00			
PHSX	423	UG	Electricity and Magnetism I	A	3.000	12.00			
PHSX	446	UG	Thermodynamics & Stat Mech	B	3.000	9.00			
PHSX	490R	UG	Undergraduate Research	A	1.000	4.00		I	

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	16.000	16.000	16.000	16.000	61.00	3.81
Cumulative:	104.000	104.000	104.000	103.000	386.00	3.74

Unofficial Transcript

Term: 2013 Fall Semester

College:	College of Letters & Science
Major:	Physics
Academic Standing:	Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
M	441	UG	Num Linear Alg & Optimization	A	3.000	12.00			
PHSX	425	UG	Electricity and Magnetism II	A	3.000	12.00			
PHSX	461	UG	Quantum Mechanics I	A-	3.000	11.10			
PHSX	494	UG	Seminar/Workshop	P	1.000	0.00			
PHSX	501	UG	Advanced Classical Mechanics	A-	3.000	11.10			

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	13.000	13.000	13.000	12.000	46.20	3.85
Cumulative:	117.000	117.000	117.000	115.000	432.20	3.75

Unofficial Transcript

Term: 2014 Spring Semester

Term Comments:	Degree Requirements Completed
College:	College of Letters & Science
Major:	Physics
Academic Standing:	Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
ACT	230	UG	Intermediate Yoga	P	1.000	0.00			
M	442	UG	Num Solution of Diff Equations	A	3.000	12.00			
PHSX	435	UG	Astrophysics	A-	3.000	11.10			
PHSX	462	UG	Quantum Mechanics II	A	3.000	12.00			
PHSX	499R	UG	Senior Capstone Seminar	A-	1.000	3.70			

Term Totals (Undergraduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	11.000	11.000	11.000	10.000	38.80	3.88
Cumulative:	128.000	128.000	128.000	125.000	471.00	3.76

Unofficial Transcript

Term: 2014 Fall Semester

College: College of Letters & Science
Major: Physics
Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
PHSX	501	GR	Advanced Classical Mechanics	A	3.000	12.00			
PHSX	506	GR	Quantum Mechanics I	A-	3.000	11.10			
PHSX	566	GR	Mathematical Physics I	A	3.000	12.00			
PHSX	594	GR	Sem: Teaching	P	1.000	0.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	10.000	10.000	10.000	9.000	35.10	3.90
Cumulative:	10.000	10.000	10.000	9.000	35.10	3.90

Unofficial Transcript

Term: 2015 Spring Semester

College: College of Letters & Science
Major: Physics
Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
PHSX	507	GR	Quantum Mechanics II	A-	3.000	11.10			
PHSX	519	GR	Electromagnetic Theory I	A	3.000	12.00			
PHSX	535	GR	Statistical Mechanics	A-	3.000	11.10			
PHSX	594	GR	Sem: Intro to Rsch	P	1.000	0.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	10.000	10.000	10.000	9.000	34.20	3.80
Cumulative:	20.000	20.000	20.000	18.000	69.30	3.85

Unofficial Transcript

Term: 2015 Summer Session

College: College of Letters & Science
Major: Physics
Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
PHSX	592	GR	Independent Study	A	1.000	4.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	1.000	1.000	1.000	1.000	4.00	4.00
Cumulative:	21.000	21.000	21.000	19.000	73.30	3.85

Unofficial Transcript

Term: 2015 Fall Semester

College:	College of Letters & Science
Major:	Physics
Academic Standing:	Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
EELE	581	GR	Fourier Optics/Imaging Theory	A	3.000	12.00			
PHSX	520	GR	Electromagnetic Theory II	B+	3.000	9.90			
PHSX	565	GR	Astrophysical Plasma Physics	A	3.000	12.00			
PHSX	594	GR	Sem:Solar Journals	P	1.000	0.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	10.000	10.000	10.000	9.000	33.90	3.76
Cumulative:	31.000	31.000	31.000	28.000	107.20	3.82

Unofficial Transcript

Term: 2016 Spring Semester

College:	College of Letters & Science
Major:	Physics
Academic Standing:	Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
PHSX	567	GR	Mathematical Physics II	A	3.000	12.00			
PHSX	591	GR	Sp:Solar Observation Technique	A	3.000	12.00			
PHSX	592	GR	Independent Study	A	3.000	12.00			
PHSX	594	GR	Sem:Solar Journals	P	1.000	0.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	10.000	10.000	10.000	9.000	36.00	4.00
Cumulative:	41.000	41.000	41.000	37.000	143.20	3.87

Unofficial Transcript

Term: 2016 Fall Semester

College:	College of Letters & Science
Major:	Physics
Academic Standing:	Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
PHSX	594	GR	Sem: Heliophysics Journals	P	1.000	0.00			
PHSX	690	GR	Doctoral Thesis	P	8.000	0.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	9.000	9.000	9.000	0.000	0.00	0.00
Cumulative:	50.000	50.000	50.000	37.000	143.20	3.87

Unofficial Transcript

Term: 2017 Spring Semester

College:	College of Letters & Science
Major:	Physics

Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
PHSX	591	GR	Sp: Solar flares and CMEs	A	3.000	12.00			
PHSX	594	GR	Sem: Heliophysics Journals	P	1.000	0.00			
PHSX	690	GR	Doctoral Thesis	P	5.000	0.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	9.000	9.000	9.000	3.000	12.00	4.00
Cumulative:	59.000	59.000	59.000	40.000	155.20	3.88

Unofficial Transcript

Term: 2017 Fall Semester

College: College of Letters & Science

Major: Physics

Academic Standing: Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	Start and End Dates	R	CEU Contact Hours
PHSX	594	GR	Sem: Heliophysics Journals	P	1.000	0.00			
PHSX	690	GR	Doctoral Thesis	P	5.000	0.00			

Term Totals (Graduate - Semester)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	6.000	6.000	6.000	0.000	0.00	0.00
Cumulative:	65.000	65.000	65.000	40.000	155.20	3.88

Unofficial Transcript

TRANSCRIPT TOTALS (GRADUATE - SEMESTER) -Top-

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Total Institution:	65.000	65.000	65.000	40.000	155.20	3.88
Total Transfer:	0.000	0.000	0.000	0.000	0.00	0.00
Overall:	65.000	65.000	65.000	40.000	155.20	3.88

Unofficial Transcript

TRANSCRIPT TOTALS (UNDERGRADUATE - SEMESTER) -Top-

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Total Institution:	128.000	128.000	128.000	125.000	471.00	3.76
Total Transfer:	36.000	36.000	36.000	0.000	0.00	0.00
Overall:	164.000	164.000	164.000	125.000	471.00	3.76

Unofficial Transcript

COURSES IN PROGRESS -Top-

Term: 2018 Spring Semester

College: College of Letters & Science

Major: Physics

Subject	Course	Level	Title	Credit Hours
PHSX	594	GR	Sem: Heliophysics Journals	1.000
PHSX	690	GR	Doctoral Thesis	5.000

Unofficial Transcript

RELEASE: 8.7.1