Annual Report
“Simultaneous Imaging Spectroscopy of the Solar Transition Region”
NASA Grant NNX14AK71G

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June, 2016

Contents

1 Introduction

The goals of this investigation are to investigate small scale energy releases due to reconnection in the solar atmosphere by means of a new technique, snapshot imaging spectrometry. Prior to proposing this investigation, we built and demonstrated the Multi-Order Solar EUV Spectrograph (MOSES), a rocket instrument that first demonstrated the new technique. We proposed to complete development of MOSES-II, which refitted MOSES to observe in Ne VII at 465 Åwavelength. We also proposed development and flight of a next generation instrument, the EUV Snapshot Imaging Spectrograph (ESIS), to be added to the existing payload. The investigation entails two rocket flights, MOSES-II and a subsequent launch of MOSES+ESIS.

We had a successful launch of MOSES-II last year, and are on track for launch of MOSES+ESIS in Summer 2018. The next sections describe in detail our accomplishments, including a successful launch, detailed design and initiation of grating procurement for ESIS. A current program schedule is provided in Appendix A.

2 MOSES-II Launch

The first part of our proposed investigation, the launch of MOSES-II, is complete. Flight 36.282 on Aug 27, 2015 met minimum (but not comprehensive) success criteria. Combustion instability of the Black Brant during ascent resulted in 120 g vibration, sustained for 14 s. This killed one of our three detector channels (spectral order $m = -1$), distorted our primary optic, and generated fast moving debris that damaged the filters on the remaining channels. The resulting loss of data, aberrations, and light leaks significantly reduced the quality of our observations, but we have been able to get some good science out of the results (§ 4).

The damage caused by the combustion instability required refurbishment and extensive testing of MOSES. Repairs were completed at MSU and at Mullard Space Science Laboratory (MSSL), the original makers of our readout electronics.[1] Appendix B details the costs attributable to the combustion instability.

3 ESIS

In the past year, we have pursued detailed alignment of the new ESIS Instrument, developed an instrument alignment plan, and initiated procurement

[1]The MOSES readout electronics are nearly a direct copy of the system for Hinode/EIS.

of custom diffraction gratings. We have a robust collaboration with Jon Cirtain's team at MSFC, who are developing the camera and data handling system for ESIS. We have a well-developed, mutually agreed set of requirements covering instrument development activities at both institutions. I travelled to MSFC for our second technical interchange meeting at MSFC in May, and brought with me our lead I&T engineer and two graduate students. Our colleagues at MSFC have CCDs in hand, and are developing software with lab cameras. The program has a good synergy with Hi-C (scheduled flight July 2016), which is using very nearly the same camera design. ESIS will have four (upgradable to six) cameras arrayed at 45-degree intervals in the focal plane, so the mechanical design is significantly different from Hi-C. The ESIS cameras and mounting structures are in a detailed design phase at MSFC. The overall status of ESIS instrument development is reflected in the program schedule, Appendix A.

3.1 Grating Procurement

Custom gratings pose technical risks for EUV spectroscopic instrumentation. There are few manufacturers, and it is generally necessary to iterate to reach a detailed specification that meets mission requirements and is manufacturable. Lead times are typically 1-2 years ARO, and the performance of the final product can be difficult to predict, both because of the grating manufacturing process itself and the vagaries of interactions with multilayer coatings. For ESIS, we are leveraging our experience with grating procurement, coating and testing for MOSES, MOSES-II, and IRIS.

In the process of procuring the ESIS gratings, we learned that it would be impossible to meet our requirement for midspatial roughness, which is a key contributor to the instrument point spread function. The manufacturer, Horiba Jobin-Yvon, was able to quote ¡ 12 nm RMS for replica gratings, or ¡ 4 nm RMS for master gratings, on a best effort basis. Our original requirement was ¡ 2.2 nm. At the proposal stage, we had no indication that this would be a problem. In particular, judging from the quality of the IRIS replicated gratings, which are replicated gratings from the same manufacturer and similar in size to the ESIS gratings, we had reason to believe that midspatial roughness would not be a cost driver and did not pursue detailed formulation of that aspect of the specification until after the award.

In consultation with the manufacturer, we have completely reworked our system resolution budget, pushing a little harder in areas where we have more control, and also accepting a factor of 2 increase in roughness. The resulting resolution budget accepts a reduction in MTF, but will still meet our proposed science goals. Consequently, we are able to proceed but must procure, coat and fly master gratings.

A second factor affecting the grating procurement is the development of our detailed instrument alignment plan. The plan we had in mind originally was based on discussions with our collaborator Roger Thomas, regarding the alignment approach for SERTS and EUNIS. After study within the MSU team and consulations with our colleagues at MSFC, we found that this approach was incompatible with the heritage optical bench in the MOSES payload, which forms the structural basis for the ESIS instrument. We simply cannot get a UV source into the right position with respect to our field stop (which is analogous to the slit in EUNIS and SERTS). The most economical approach to aligning the UV instrument requires aligning the instrument in visible light with special alignment gratings, and then transferring the alignment to the UV gratings.

Our original costing of ESIS was built around a quote for replica gratings, and did not foresee the requirement of visible gratings for alignment. We therefore faced an unforeseen cost increase of nearly \$200 k. We are working diligently to control costs overall within the program, to mitigate the impact of the grating overrun.

4 Science and Education

During the past year, we have made significant scientific progress in the following areas. These results are in various stages of publication as seen in Appendix C.

- Transition region explosive events observed in He II with MOSES-I. The bipolar jets lack emission at line center. This result differs from recent results by Guo and Innes[2] using IRIS Si IV line profiles.
- Detailed analysis of the full-frame MOSES-I data have revealed the presence of many faint lines. While undetectable individually, together these faint lines account for significant differences between the $m = 0$ and $m = \pm 1$ MOSES images. The result also constrains the quiet sun DEM covering a large part of the disk.

[2]Guo and Innes, 2015 *ApJ* **813**:86.

- Dopplergrams in He II have been obtained from the MOSES-I data by using local correlation tracking to compare images in different spectral orders.

- Preliminary dopplergrams from MOSES-II images in Ne VII show an active region jet and downflows in cooling loops.

- MOSES-I images have been corrected for differences in point spread function, thereby reducing systematic error in their interpretation.

Following are some highlights of the recent accomplishments of five graduate students who are involved in the sounding rocket mission. The scientific progress above is mainly due to their efforts. They are supported partly from this grant and partly from other sources.

Thomas Rust is expected to finish his PhD in the coming year. Tom is working on analysis of explosive events in the MOSES He II data from 2006. He has a large number of events and presented a preliminary analysis at the 2016 SPD meeting. Tom has developed an improved inversion technique for MOSES data that allows a higher fidelity recovery of the spectra. Even without relying on inversion, however, Tom has demonstrated that many events have a clearly separated bidirectional jet structure with no emission at line center. It is not yet clear whether Tom's events represent the same sort of explosive event (perhaps observed at a different stage of evolution), or whether they are a different phenomenon entirely. Tom's dissertation also describes the methodology he deveoped for optical testing, alignment and focus of MOSES-II.

Hans Courrier is also expected to finish in the coming year. He has developed, tested and demonstrated a methodology for generating dopplergrams from MOSES imaging data. His approach is to map small differences between the MOSES spectral orders by fourier local correlation tracking (FLCT). Hans published an SPIE paper on this work a year ago, and has a refereed paper in preparation. The algorithm is also likely to work for ESIS data. Hans did the detailed design of the ESIS optical system, including aberration corrected gratings. Hans is interested in searching for signatures of waves in the transition region and corona, and has recently been applying his skill with correlation tracking techniques to IRIS slit jaw images. Hans and Roy Smart (below) collaborated on analysis of MOSES-II data using Hans' FLCT approach.

Shane Atwood has demonstrated a technique that greatly reduces systematic errors in MOSES data, or in any dataset where images with different point spread functions must be compared. This resulted in an SPIE conference paper reported in last year's annual report; a refereed publication is in preparation. He also has a very original idea for obtaining line profiles from bright events observed with MOSES. Shane's other data analysis project is an investigation of transition region signatures of coronal heating with IRIS and AIA data. He will graduate in Spring 2017.

Jacob Parker is a second year graduate student. His 2016 SPD presentation demonstrated the estimation of field-integrated EUV spectra from MOSES-I data. By cross-correlating difference images from the slitless spectrograph, he was able to show that a simplified spectral synthesis with just the brightest few lines was not sufficient to account for the data. Instead, a full Chianti spectral synthesis was required. His result also leads to an estimate of differential emission measure. All this from a slitless spectrograph working at 30.4 nm. Jake will complete the PhD in 2019.

Roy Smart developed the flight software for the successful 2015 launch of MOSES-II. He entered the MSU graduate program that fall. Roy did the reduction of MOSES-II data for the preliminary analysis of the data. Roy is interested in data analysis applications of machine learning, and has demonstrated a prototype MOSES data inversion on a neural network. Roy will graduate with a PhD in 2020.

A significant portion of the engineering work on ESIS is being done by undergraduate students at MSU (listed in alphabetical order): Nick Bonham, Ben Carroll, Micah Johnson, Harper Moore, and Anna Teintze. Our undergrads are mentored by Jordan Maxwell (Staff Engineer), Keith Mashburn (Senior Engineer), Larry Springer (Program Manager) and Charles Kankelborg (PI). In the fall, Jordan Maxwell will be leaving for graduate school in Aerospace Engineering. Grad students Roy Smart and Jake Parker will take an incresing role in mentoring undergraduates.

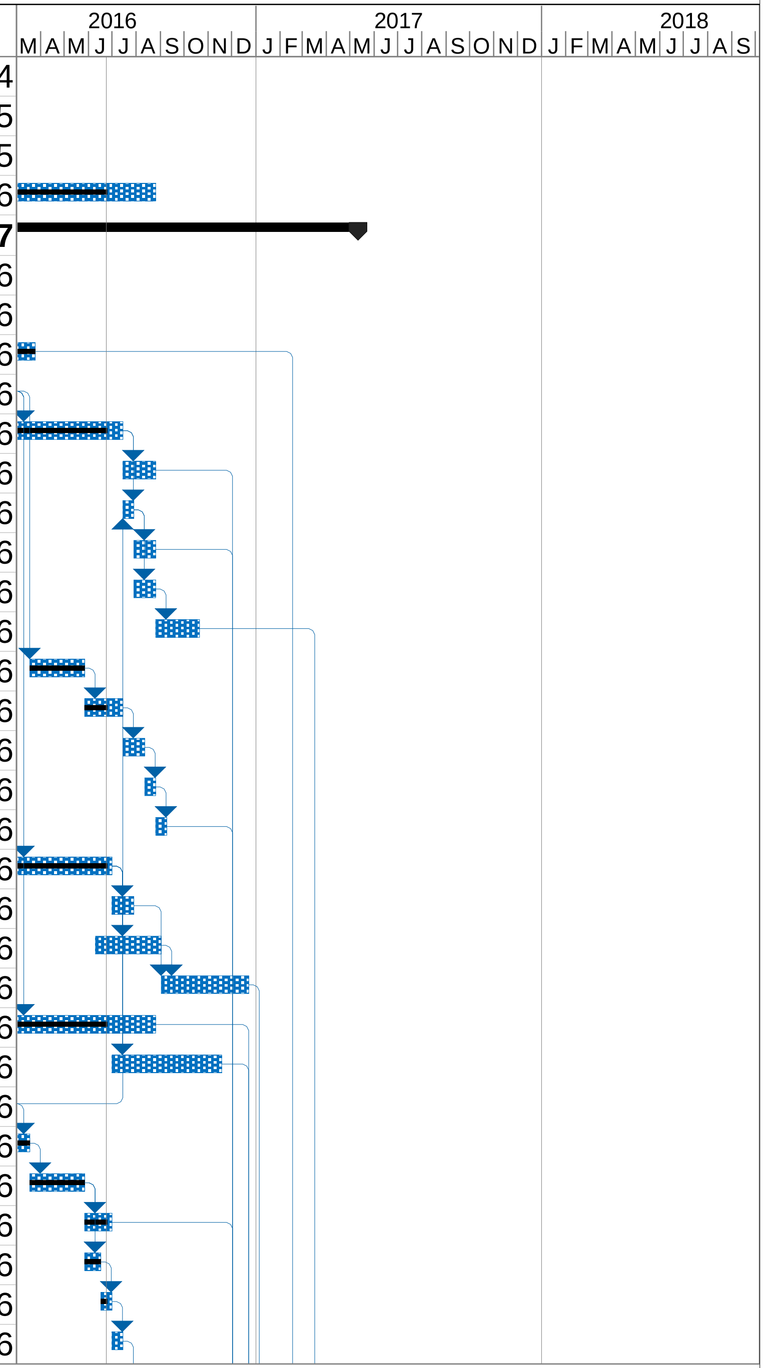
5 Acknowledgments

In addition to the current award from NASA, the MOSES-II project and our students have been supported by NASA grants NNX07AG76G and NNX12AD79G, by the Vice President for Research at MSU, and by the MSU Physics Department.

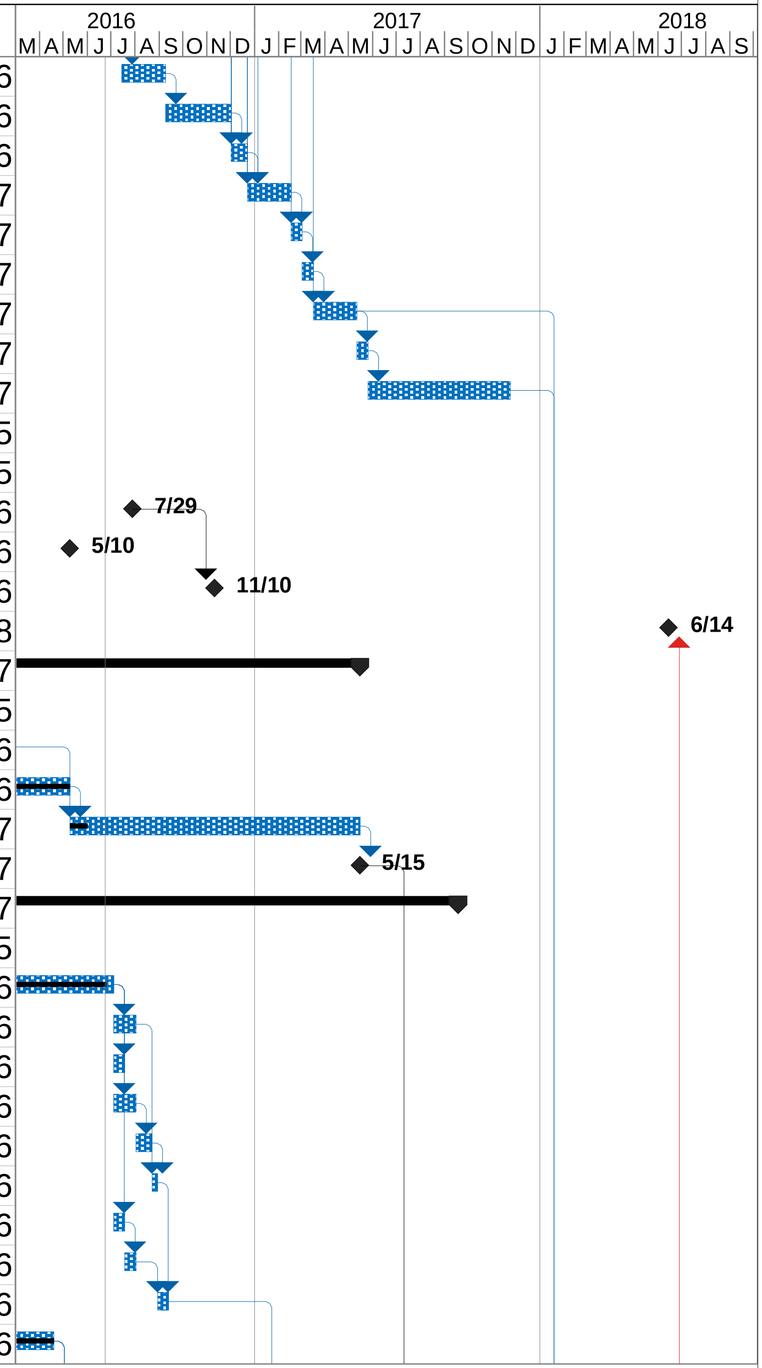
A Schedule

The next several pages show the most current, detailed program schedule.

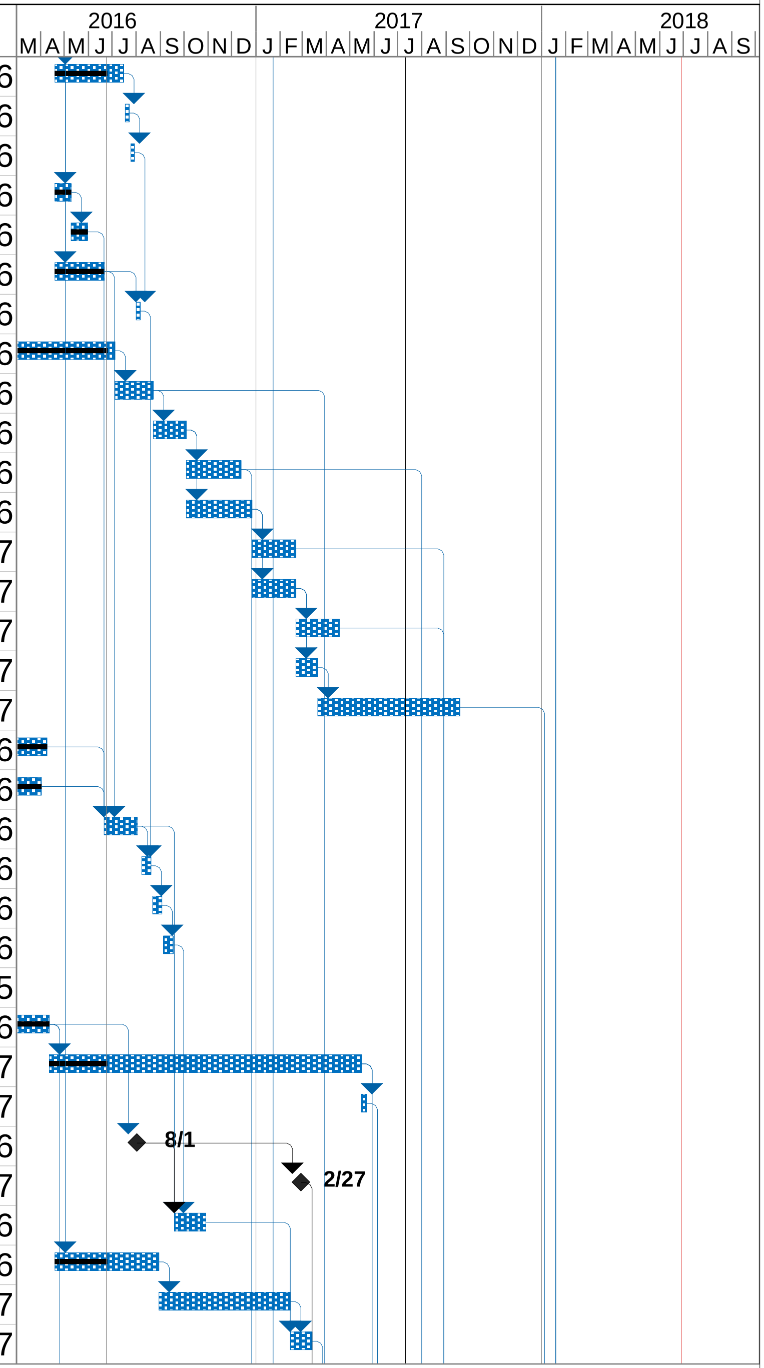
ID	Task Name	Duration	Start	Finish
1	ESIS Project Start	0 days	4/1/14	4/1/14
2	Range Operations	20 days	7/31/15	8/27/15
3	Launch	0 days	8/27/15	8/27/15
4	Data Analysis	52 wks	8/28/15	8/25/16
5	**MOSES Rework**	**445 days**	**8/28/15**	**5/11/17**
6	MOSES Post Launch Damage Asses	20 wks	8/28/15	1/14/16
7	ROE to MSSL	2 wks	1/15/16	1/28/16
8	MSSL Repair ROE	8 wks	1/29/16	3/24/16
9	Design MOSES Reconfigure	26 wks	8/28/15	2/25/16
10	Design MOSES Electronics Mounts	20 wks	2/26/16	7/14/16
11	Fab MOSES Electronics Mounts	6 wks	7/15/16	8/25/16
12	TEC Replacement Design	2 wks	7/15/16	7/28/16
13	TEC Replacement Fab	4 wks	7/29/16	8/25/16
14	LN2 System Redesign	4 wks	7/29/16	8/25/16
15	LN2 System Procure & Fab	8 wks	8/26/16	10/20/16
16	Design New Power Board	10 wks	3/18/16	5/26/16
17	Layout new Power Converter Board	7 wks	5/27/16	7/14/16
18	Fabricate new Power Board	4 wks	7/15/16	8/11/16
19	Assemble new Power board	2 wks	8/12/16	8/25/16
20	Test New Power Board	2 wks	8/26/16	9/8/16
21	Design New MOSES Harness	18 wks	2/26/16	6/30/16
22	Build Harness Mockup	4 wks	7/1/16	7/28/16
23	Order Connectors & Wire	12 wks	6/10/16	9/1/16
24	Fab New MOSES Harness	16 wks	9/2/16	12/22/16
25	MOSES Software update	26 wks	2/26/16	8/25/16
26	MOSES EGSE Update	20 wks	7/1/16	11/17/16
27	Remove MOSES Components from LOTS	4 wks	1/29/16	2/25/16
28	Inspect LOTS	3 wks	2/26/16	3/17/16
29	Clean MOSES Components & LOTS	10 wks	3/18/16	5/26/16
30	Inspect & Clean Electronics	5 wks	5/27/16	6/30/16
31	Order New HEPA & Prefilters	3 wks	5/27/16	6/16/16
32	Install Filters	2 wks	6/17/16	6/30/16
33	Clean Optics & Mounts	2 wks	7/1/16	7/14/16



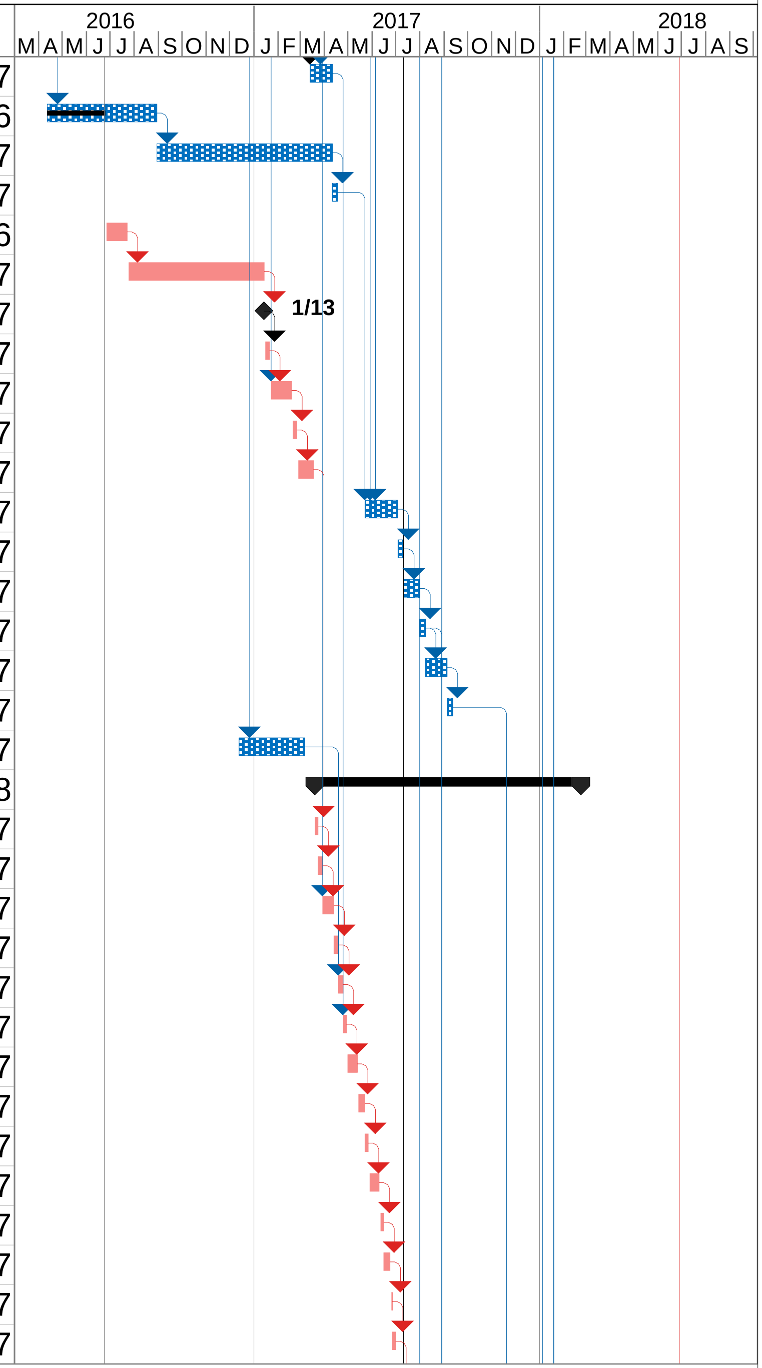
ID	Task Name	Duration	Start	Finish
34	Component Level Optical Test	8 wks	7/15/16	9/8/16
35	Mount & Align MOSES Optics on +Z	12 wks	9/9/16	12/1/16
36	Mount MOSES Electronics on -Z	3 wks	12/2/16	12/22/16
37	Integrate & Test the MOSES Harness	8 wks	12/23/16	2/16/17
38	Integrate & Test ROE	2 wks	2/17/17	3/2/17
39	Re-Verify Alignment	2 wks	3/3/17	3/16/17
40	MOSES Test	8 wks	3/17/17	5/11/17
41	Order New MOSES Filters	2 wks	5/12/17	5/25/17
42	Fab New MOSES Filters	26 wks	5/26/17	11/23/17
43	ESIS Requirements & Interfaces Definition	44 wks	4/1/14	2/2/15
44	ESIS Mission Initiation Review	0 days	10/14/15	10/14/15
45	ESIS Requirements Definition Meeting	0 days	7/29/16	7/29/16
46	ESIS TIM	0 days	5/10/16	5/10/16
47	ESIS Design Review	0 days	11/10/16	11/10/16
48	ESIS Mission readiness review	0 days	6/14/18	6/14/18
49	MSFC Electronics Development	595 days	2/3/15	5/15/17
50	Electronics Preliminary Design	26 wks	2/3/15	8/3/15
51	CCD Procurement	54 wks	2/3/15	2/15/16
52	Electronics Detailed Design	40 wks	8/4/15	5/9/16
53	Electronics Fab Assemble & Test	53 wks	5/10/16	5/15/17
54	Electronics Delivery to MSU	0 days	5/15/17	5/15/17
55	ESIS Development at MSU	685 days	2/3/15	9/18/17
56	Optics & Mechanical Preliminary Design	36 wks	2/3/15	10/12/15
57	Mirror Mount Detailed design	38 wks	10/13/15	7/4/16
58	Mirror Mount Fab & Assemble	4 wks	7/5/16	8/1/16
59	Fab Mirror Slug	2 wks	7/5/16	7/18/16
60	Mirror Mount Assy Jig design	4 wks	7/5/16	8/1/16
61	Mirror Mount Assw Jig Fabricate	3 wks	8/2/16	8/22/16
62	Mount Mirror Slug	1 wk	8/23/16	8/29/16
63	Design Primary Vibe Fixture	2 wks	7/5/16	7/18/16
64	Fab Primary Vibe Fixture	2 wks	7/19/16	8/1/16
65	Primary Mount Vibe Test	2 wks	8/30/16	9/12/16
66	Secondary Mount Design	21 wks	11/24/15	4/18/16



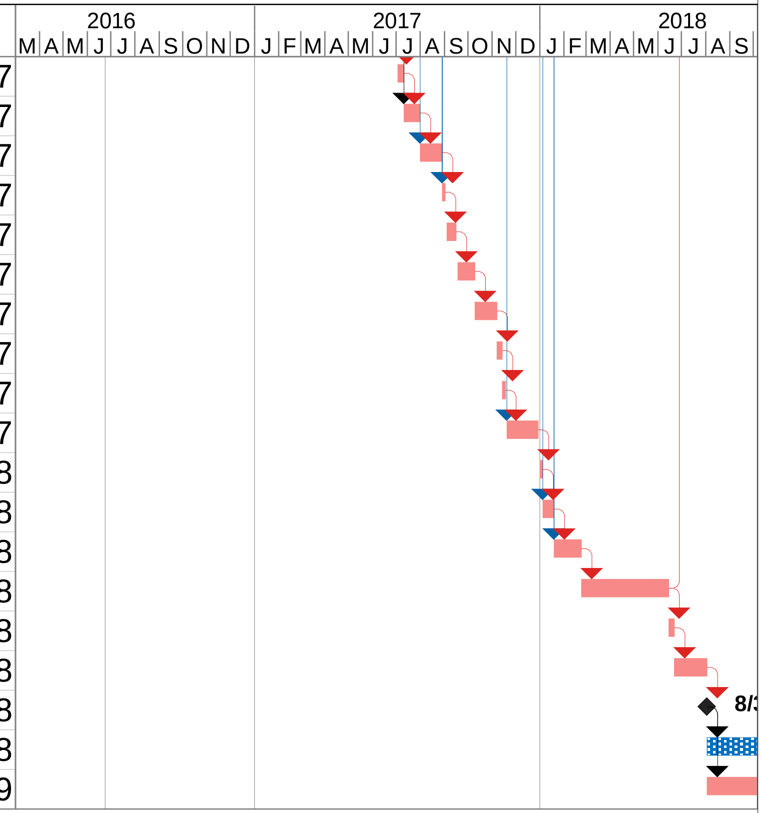
ID	Task Name	Duration	Start	Finish
67	Fab Secondary Mount	64 days	4/19/16	7/15/16
68	Anodize Secondary	1 wk	7/18/16	7/22/16
69	Assemble Secondary	1 wk	7/25/16	7/29/16
70	Grating Assy Jig Design	3 wks	4/19/16	5/9/16
71	Grating Assy Jib Fabricate	3 wks	5/10/16	5/30/16
72	Procure Grating Flats	9 wks	4/19/16	6/20/16
73	Assemble Flats on Seconsary	1 wk	8/1/16	8/5/16
74	Field Stop & Mount Design	22 wks	2/2/16	7/4/16
75	Fab & Assemble Field stop & Mount	7 wks	7/5/16	8/22/16
76	Design LN2 System	6 wks	8/23/16	10/3/16
77	Fabricate LN2 System	10 wks	10/4/16	12/12/16
78	Design Baffels	12 wks	10/4/16	12/26/16
79	Fabricate Baffels	8 wks	12/27/16	2/20/17
80	Design MASS & LISS Mounts	8 wks	12/27/16	2/20/17
81	Fab MASS & LISS Mounts	8 wks	2/21/17	4/17/17
82	Design/Move Vac Port & Skin Mods	4 wks	2/21/17	3/20/17
83	Skins to Wallops for Mods	26 wks	3/21/17	9/18/17
84	Interferometer Repair	6 wks	2/29/16	4/8/16
85	Fab new Bipods	5 wks	2/29/16	4/1/16
86	Grating Bipod Mount Tests	6 wks	6/21/16	8/1/16
87	Assemble secondary	2 wks	8/8/16	8/19/16
88	Vibrate Substrates & Mount	2 wks	8/22/16	9/2/16
89	Thermal test the secondary	2 wks	9/5/16	9/16/16
90	Grating Design Iterations	47 wks	2/3/15	12/28/15
91	Order Gratings	15 wks	12/29/15	4/11/16
92	Grating Development	57 wks	4/12/16	5/15/17
93	Acceptance Test Grating	1 wk	5/16/17	5/22/17
94	Deliver Figured Substrates	0 days	8/1/16	8/1/16
95	Deliver Visible Gratings	0 days	2/27/17	2/27/17
96	Assemble Substrates to Grating Mount	6 wks	9/19/16	10/28/16
97	Determine Vis-UV Transfer Technique	19 wks	4/19/16	8/29/16
98	Develop Vis-UV Transfer GSE	24 wks	8/30/16	2/13/17
99	Develop Alignment Transfer procedure	4 wks	2/14/17	3/13/17



ID	Task Name	Duration	Start	Finish
100	Assemble Visible Gratings in Mount	4 wks	3/14/17	4/10/17
101	Order Primary Mirror	20 wks	4/12/16	8/29/16
102	Fab Primary Mirror	32 wks	8/30/16	4/10/17
103	Acceptance Test Primary	1 wk	4/11/17	4/17/17
104	Order Sphere Primary	20 days	6/27/16	7/22/16
105	Fab Sphere Primary	25 wks	7/25/16	1/13/17
106	Deliver Sphere Primary	0 days	1/13/17	1/13/17
107	Test Mirror Figure	1 wk	1/16/17	1/20/17
108	Assemble Mount & Sphere Primary	4 wks	1/23/17	2/17/17
109	Test Mirror Figure	1 wk	2/20/17	2/24/17
110	Primary Thermal Test	3 wks	2/27/17	3/17/17
111	Primary & Grating Coat & Measure	6 wks	5/23/17	7/3/17
112	Optics Acceptance Testing	5 days	7/4/17	7/10/17
113	Assemble Coated Primary to Mount	3 wks	7/11/17	7/31/17
114	Test Mirror Figure	1 wk	8/1/17	8/7/17
115	Assemble Coated Gratings to Mounts	4 wks	8/8/17	9/4/17
116	Test Grating Figure	1 wk	9/5/17	9/11/17
117	Develop Target & Camera Mount GSE	12 wks	12/13/16	3/6/17
118	ESIS I &T	244 days?	3/20/17	2/22/18
119	Define ESIS optical Axis	4 days	3/20/17	3/23/17
120	Place Uncoated Primary on LOTS	4 days	3/24/17	3/29/17
121	Place Field Stop	2 wks	3/30/17	4/12/17
122	Install Lab Detector	4 days	4/13/17	4/18/17
123	Place Targets at CCD positions	4 days	4/19/17	4/24/17
124	Rough place all Vis Gratings on LOTS	4 days	4/25/17	4/28/17
125	Align Grating to Detector	10 days	5/1/17	5/12/17
126	Focus Lab Camera	6 days	5/15/17	5/22/17
127	Set Alignment Verif Targrt	4 days	5/23/17	5/26/17
128	Transfer Alignment to another Vis Grating	10 days	5/29/17	6/9/17
129	Verify Alignment with Target	4 days	6/12/17	6/15/17
130	Verify Alignment with Camera	6 days	6/16/17	6/23/17
131	Transfer Alignment to another Vis Grating	1 day?	6/26/17	6/26/17
132	Verify Alignmwnt with Target	4 days	6/27/17	6/30/17



ID	Task Name	Duration	Start	Finish
133	Verify Alignment with Camera	6 days	7/3/17	7/10/17
134	ESIS Elect I&T	3 wks	7/11/17	7/31/17
135	Develop ESIS Performance Test	4 wks	8/1/17	8/28/17
136	Mount Coated Primary on LOTS	4 days	8/29/17	9/1/17
137	Align & Focus Field Stop	10 days	9/4/17	9/15/17
138	Align Vis Gratings to Detectors	16 days	9/18/17	10/9/17
139	Focus All Detectors	20 days	10/10/17	11/6/17
140	Solar Simulator Test	5 days	11/7/17	11/13/17
141	Set Alignment Verif Target	4 days	11/14/17	11/17/17
142	Transfer Alignment to UV Gratings	30 days	11/20/17	12/29/17
143	Verify Alignment with Targets	4 days	1/1/18	1/4/18
144	ESIS / MOSES Preformance Test	2 wks	1/5/18	1/18/18
145	ESIS Environmental test, & SIMs	5 wks	1/19/18	2/22/18
146	Program Reserve	80 days	2/23/18	6/14/18
147	Pack & Transport to the Range	5 days	6/15/18	6/21/18
148	ESIS Range Operations	30 days	6/22/18	8/2/18
149	ESIS Launch	0 days	8/3/18	8/3/18
150	End to End Calibration	13 wks	8/3/18	11/1/18
151	ESIS Data Analysis & Publications	169 days	8/3/18	3/27/19



B Costs Resulting From Combustion Instability

Labor	
PM/Sr Engineer	8,058
I&T Sr Engineer	10,667
Engineer	10,655
Grad Students	14,240
Undergraduates	935
SUBTOTAL	44,555
Benefits	11,845
DIRECT LABOR TOTAL	56,400
Indirect on Labor	24,815
Fall grad student tuition waiver	8,100
ROE Repair (per MSSL quote)	7,975
ROE Shipping (both ways)	1,800
Indirect on shipping	792
GRAND TOTAL	99,882

C Dissemination

The following pages list relevant conference presentations and papers produced during the past year. Since the annual Solar Physics Division meeting occurs near our anniversary date, there may be some overlap with last year's list.

SAO/NASA ADS Astronomy Abstract Service

Title:	Preliminary Results of the MOSES II 2015 Flight
Authors:	Smart, Roy; Courrier, Hans; Kankelborg, Charles
Affiliation:	AA(Montana State University), AB(Montana State University), AC(Montana State University)
Publication:	American Astronomical Society, SPD meeting #47, id.#309.01
Publication Date:	05/2016
Origin:	AAS
Abstract Copyright:	(c) 2016: American Astronomical Society
Bibliographic Code:	2016SPD....4730901S

Abstract

The Multi-Order Extreme Ultraviolet Spectrograph (MOSES) is a slitless spectrograph which aims to produce simultaneous spatial-spectral imaging of the solar transition region. This is accomplished through a multilayer concave diffraction grating which produces three images for the spectral orders m = 0, ± 1. The multilayer coating provides a narrow passband, dominated by Ne VII (46.5 nm), which allows the three images to be compared in order to determine line broadenings and identify explosive events in the Solar Transition Region. Here, we examine the preliminary results of MOSES II, the instrument's second flight which was launched on a sounding rocket from White Sands Missile Range, NM in August 2015. We present the first images of the Sun in Ne VII since Skylab and the preliminary results of observed doppler shifts within an active region.

Title:	Transition Region Explosive Events in He II 304Å: Observation and Analysis
Authors:	Rust, Thomas; Kankelborg, Charles C.
Affiliation:	AA(Montana State University), AB(Montana State University)
Publication:	American Astronomical Society, SPD meeting #47, id.#101.01
Publication Date:	05/2016
Origin:	AAS
Abstract Copyright:	(c) 2016: American Astronomical Society
Bibliographic Code:	2016SPD....4710101R

Abstract

We present examples of transition region explosive events observed in the He II 304Å spectral line with the Multi Order Solar EUV Spectrograph (MOSES). With small (<5000 km) spatial scale and large non-thermal (100-150 km/s) velocities these events satisfy the observational signatures of transition region explosive events. Derived line profiles show distinct blue and red velocity components with very little broadening of either component. We observe little to no emission from low velocity plasma, making the plasmoid instability reconnection model unlikely as the plasma acceleration mechanism for these events. Rather, the single speed, bi-directional jet characteristics suggested by these data are consistent with acceleration via Petschek reconnection.Observations were made during the first sounding rocket flight of MOSES in 2006. MOSES forms images in 3 orders of a concave diffraction grating. Multilayer coatings largely restrict the passband to the He II 303.8Å and Si XI 303.3Å spectral lines. The angular field of view is about 8.5'x17', or about 20% of the solar disk. These images constitute projections of the volume I(x,y,λ), the intensity as a function of sky plane position and wavelength. Spectral line profiles are recovered via tomographic inversion of these projections. Inversion is carried out using a multiplicative algebraic reconstruction technique.

Title:	Determining the Spectral Content of MOSES Images
Authors:	Parker, Jacob; Kankelborg, Charles
Affiliation:	AA(Montana State University), AB(Montana State University)
Publication:	American Astronomical Society, SPD meeting #47, id.#2.04
Publication Date:	05/2016
Origin:	AAS
Abstract Copyright:	(c) 2016: American Astronomical Society
Bibliographic Code:	2016SPD....47.0204P

Abstract

The MOSES (Multi-Order Solar EUV Spectrograph) sounding rocket was launched February 8th, 2006. The MOSES concave grating forms solar images in multiple spectral orders, in an effort to measure line profiles from a single exposure over a wide field of view. We present a preliminary identification of spectral content in MOSES images. The cross correlation of subtracted images provide evidence of spectral content besides the normal 304 Anstrom He II line. We place confidence on the peaks in correlation by cross correlating random data that is statistically representative of MOSES data. These significant peaks indicate a contribution to intensity from several coronal lines. These lines are individually weak, but if not taken into account, they would significantly increase the residuals when inverting MOSES images to obtain spectra.

Title:	Using Correlation Tracking to Disentangle Spatial and Spectral Data in a Slitless Spectrograph
Authors:	Courrier, Hans; Kankelborg, Charles
Affiliation:	AA(Montana State University), AB(Montana State University)
Publication:	Joint American Astronomical Society/American Geophysical Union Triennial Earth-Sun Summit, meeting #1, id.403.15
Publication Date:	04/2015

Origin: AAS

Bibliographic Code: 2015TESS....140315C

Abstract

In a typical slit style spectrograph, the limited field of view afforded by the entrance slit is overcome by rastering the slit across a feature of interest to build a composite image. While it is trivial to separate spatial and spectral data in such an instrument, the cadence of the raster results in a loss of temporal data when attempting to image a feature that is much larger than the entrance slit. The Multi-Order Solar EUV Spectrograph (MOSES) is a slitless spectrograph that collects co-temporal spatial and spectral images in He II 304 Å over a 10' x 20' field of view through the use of a spherical diffraction grating. Local correlation tracking routines are used to disentangle the spatial and spectral data from images formed by the zero and both first orders of the MOSES instrument. The opposing dispersion direction of the outboard orders allows a diagnostic of the viability of the method when analyzing images obtained from the February 2006 MOSES sounding rocket flight.

Title: PSF-Corrected Inversion of MOSES Images: Validation With IRIS Data

Authors: Atwood, Shane; Kankelborg, Charles

Affiliation: AA(Montana State University), AB(Montana State University)

Publication: Joint American Astronomical Society/American Geophysical Union Triennial Earth-Sun Summit, meeting #1, id.403.06

Publication Date: 04/2015

Origin: AAS

Bibliographic Code: 2015TESS....140306A

Abstract

The Multi-Order Solar EUV Spectrograph (MOSES) forms three Helium 304 images taken at the m=-1,0,+1 spectral orders. Subtle differences between images encode line profile information. However, differences in instrument point spread function (PSF) in the three orders lead to non-negligible systematic errors in the retrieved profiles. The PSF-corrected SMART 2 algorithm is designed to equalize the PSFs and extract the spectral and doppler information. We apply the algorithm to IRIS raster images to demonstrate the technique's effectiveness.

Title: Imaging Spectroscopy of Transition Region Explosive Events from MOSES Sounding

Rocket Data

Authors: Rust, Thomas; Kankelborg, Charles
Affiliation: AA(Montana State University), AB(Montana State University)
Publication: Joint American Astronomical Society/American Geophysical Union Triennial Earth-Sun Summit, meeting #1, id.203.04
Publication Date: 04/2015
Origin: AAS

Bibliographic Code: 2015TESS....120304R

Abstract

The Multi-Order Solar EUV Spectrograph (MOSES) forms 304 Å EUV images at three spectral orders from an objective multilayer grating. The images encode spatial and spectral data over a 20 x 10 arc minute field of view. Numerous examples of compact transient brightenings are present in data obtained during a 2006 flight. We employ an inversion algorithm which incorporates the instrument point spread functions and noise model and present spectra derived thereby which show strong doppler shifts associated with these brightenings. Spatial structure (0.5" pixels) and temporal evolution (~10 s cadence) of these events will be presented.
