NESSC Undergraduate Summer School on Fundamental Physics of the Sun-Earth System

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NESSC UNDERGRADUATE SUMMER SCHOOL ON FUNDAMENTAL PHYSICS OF THE SUN-EARTH SYSTEM

Proposed REU Summer School

We propose to organize the first yearly summer school on fundamental physics of the Sun-Earth system, specifically designed for undergraduate students. The one-week school will take place in the late Spring of each year and be organized under the governance of the New England Space Science Consortium (NESSC, see `http://nessc.unh.edu`) at the University of New Hampshire (UNH). It will take advantage of the large number of higher-education institutions engaged in space physics in New England by selecting internationally recognized experts in their fields from the local community. In particular, the summer school will benefit from the presence of the Space Science Center of the University of New Hampshire with research which spans observational, theoretical and computational space physics and researchers whose areas of expertise range from the lower corona to Earth's ionosphere. Over seven days, the summer school will offer about 25 hours of lectures, as well as an introduction to IDL and the participation in small dedicated research projects.

The proposed school will introduce undergraduate students to solar and space physics and educate them about the present knowledge of the field. We will introduce our students to the existing and the future capabilities of the *Solar-Terrestrial Relations Observatory* (STEREO), the *Solar Dynamics Observatory* (SDO), the *Radiation Belt Storm Probes* (RBSP), the *Advanced Technology Solar Telescope* (ATST), *Solar Orbiter*, *Solar Probe* and the *Magnetosphere Multiscale Mission* (MMS). Our goal is also to use ground-based observatories and both NASA and ESA missions to inspire and motivate the students, as well as to educate them about the Sun, the heliosphere and Earth's magnetosphere and the dynamic processes that affect the Earth, life, and society.

Rationale and Goals

It is clear that there is a need for undergraduate education in space physics in the USA. As noted in the recently released decadal survey for solar and space physics "*solar and space physics is most often taught or introduced in summer schools at the graduate level, so that opportunities to become aware of the discipline have been more limited at the undergraduate and pre-college levels.*" [page D-2, *Solar and Space Physics: A Science for a Technological Society*, 2012]. As noted in another section, "one exception is NSF's Research Experiences for Undergraduates (REU) Program" (*ibid*, 4-18). In fact, it is clear that to have the largest impact and to influence someone's career choices, one must target undergraduate or high schools students. The "classical" REU sites offer one of the main opportunities for an undergraduate student to be introduced to solar and space physics. The demographic survey of the field supported by NSF reported that "nearly three-quarters of recent PhD recipients (receiving their degree since 2000) participated in some form of undergraduate research" (*ibid*, D-7), illustrating the impact of REU and undergraduate research on our field.

The rationale of the current proposal is that there is a large population of undergraduate students which is not "captured" by the existing REU programs, but who might become interested in space physics if introduced to the discipline. Students participating in REU research in space physics must, almost by definition, (i) be interested in research, (ii) be aware of the existence of the field of space physics and (iii) be fully available for 8 to 12 straight weeks during the summer.

This last point is particularly important, since it makes it nearly impossible for a REU student to hold another summer job (concurrently or after their research experience). We note that, while REU stipends are generous ($4000-$5000 over the length of the appointment), students working to pay for their studies might be looking for the most lucrative opportunities. About 60% of high-school and college-age students were in the labor force in July 2012 according to the bureau of labor statistics and 75% of students work for pay while enrolled in college [*Financing College in Hard Times: Work and Student Aid*, 2011]. In addition to students participating in REU programs, there are also a number of undergraduate students performing research during the academic year or summer at their university. Solar and space physics is often represented by only a couple (or only one) faculty members in a physics and/or astronomy department. While the faculty member(s) may be interested in developing research projects with undergraduate students, it is time-consuming and challenging to give potential undergraduate researchers the broad academic background necessary to perform research in our field. In addition, space physics is typically not taught in these institutions.

To fulfill these needs, **we propose a full-week summer course specifically designed for undergraduate students**. A one-week school in space physics at the end of Spring/beginning of the summer, as is proposed here, should be able to capture working students and introduce them to space physics. We expect the school also to reach to Science, Technology, Engineering and Mathematics (STEM) students not (yet) interested in research; for example, students interested in K-12 science teaching or in aerospace engineering. A last, and probably largest category of students for our summer school will be those from institutions lacking dedicated solar and space physics classes but who are interesting in performing research in the future with a solar or space physics faculty part of a broader physics and astronomy department.

The goals of the summer school are: 1) to give a first introduction to space physics to undergraduate students enrolled in STEM majors. Ideally, these students would not have classes in space physics available at their university, 2) to give the opportunity to working students to learn about space physics without committing to the 10 weeks of a REU program, 3) to teach, prior to or at the start of their research appointment, the foundation of space physics in a more academic setting to students interested in research, and, 4) to increase the technical capabilities and further the understanding of the Sun-Earth system of the selected students. **The summer school will be open only to enrolled undergraduate students** –excluding graduated seniors– **in STEM fields** and we will reach to students having graduated from community colleges and transferring to a 4-year institution.

Relation to Existing Summer Schools

There exist about a dozen summer schools focusing on solar and space physics (a list can be found page D-5 of the Heliophysics Decadal survey). Nominally, many of these schools are open to undergraduate students as well as graduate students and post-doctoral researchers. For example, the Heliophysics summer school sponsored by NASA/Living with a Star (LWS) and held in Boulder, CO targets early career scientists from undergraduates to post-docs. The CISM summer school targeted early graduate students (starting graduate school). The 4-week joint Space Weather Summer school by the University of Alabama in Huntsville (UAH) and the German Aerospace Center (DLR) is open to undergraduate and graduate students. However, **there is no summer school in solar and space physics designed specifically for undergraduate students**. An advanced undergraduate student with a strong background in mathematics and physics might be able to follow and gain from one of the existing summer schools. In fact, some advanced UNH undergraduate students participated in one of the summer schools discussed above. However, these students had already been working for more than a year on space physics and had encountered a broad variety of topics in the field. For most undergraduate students, a curriculum covering Hall MHD, turbulence and coronal heating (as is the case for some of these schools) in one week to 10 days will not result in a deep understanding of the field. The space weather summer school of DLR and UAH lasting 4 weeks might be able to cover some of these topics successfully for undergraduate students but it requires a much larger commitment from the student (6 weeks in the middle of the summer, including German language classes). Other summer schools open to undergraduate and graduate students in space physics (e.g., PARS, AMISR) focus on specific instrumentations (radars for example) and do not intend to give a broad overview of the field to undergraduate students.

Existing summer schools fill an important need for advanced education for students who wish to pursue a research career in solar or space physics. They offer opportunities for graduate students coming from institutions without a large number of space physics researchers to be introduced to space physics. This is why the decadal survey recommended the replacement of the CISM summer school and the development of workshops for graduate students [p. 4-17, *Solar and Space Physics: A Science for a Technological Society*, 2012]. We propose to develop a summer school to **introduce undergraduate students to solar and space physics**, to give them a global view of the field and to introduce them to current missions and observational capabilities.

Relation to Existing and Proposed REU Sites

This proposal differs from existing and other proposed REU sites (including the ones proposed at UNH) as it focuses on the organization of a summer school. Most of the existing REU programs in solar and space physics include a more academic component. Some REU programs organize a series of weekly 1-hour seminars (for example, at the University of Hawaii, at Harvard/SAO and at the Catholic University of America); others hold informal classes about IDL during the first week in addition to bi-weekly seminars and weekly group meetings (Montana State University); while others organize a full 1-week summer school (at the University of Colorado). This illustrates that undergraduate students enrolled in REU programs require some academic and practical training. To the best of our knowledge, all these classes are only open to the REU students participating in the program (as well as local students, possibly).

Our proposed summer school would provide a similar training but to students who either perform research at their home institution or who do not desire to do research yet but are interested by the field. In addition, we will welcome students who participated or will participate in a REU program at institutions where the academic grounding is limited to weekly seminars. The proposed schedule (see below) would make it possible for a student to attend our school and then participate in a REU program in the same year at Harvard/SAO, MIT Haystack, the University of Minnesota, Montana State University and the University of Colorado-Boulder or one of the Neck Northeast Astronomy Consortium (KNAC) school. We also expect some students to come for one week before returning to their home university and perform research in the remaining of the summer with the necessary theoretical background.

Overview of the Space Science Summer School

Inspiration and Origins

The proposed summer school is inspired from the NASA/LWS Heliophysics summer school run in Boulder, the University of Arizona/National Solar Observatory (NSO) summer school in solar physics previously run at the NSO facility, and the SPD/ESPD summer school run in 2008 in Maui, Hawaii. As detailed above, these programs were or are geared toward graduate students and beginning post-doctoral scientists. The Boulder program explicitly calls for applications from advanced graduates students and recent PhDs. We propose a program aimed at undergraduate students that will be specifically designed for this age group; it will begin with basic discussions needed to understand the field, and evolve over the course of the week to cover fundamentals in the field with an introduction to existing and future ground-based and satellite observations. In so doing, we intend to provide (i) a general introduction to space physics, (ii) a formal grounding in space science research of today and in the future.

Space science is rarely taught at the undergraduate level and students who might otherwise consider a career in the subject are not exposed to ideas, the subject, or the techniques. We believe that, by teaching topics of scientific research from the space physics discipline, we can create a vehicle that exposes students to the general field as well as the exciting research within the field and thereby capture future scientists who might otherwise select a different career path for want of exposure. One small part of the inspiration behind the NESSC summer school comes from the fact that we have sent motivated UNH undergraduates to the NSO summer school when it was possible. Because the NSO summer school was very advanced by undergraduate standards, we chose only students who already had research experience and who had already attended the space science seminars offered within the department. Those students flourished and returned stronger and more motivated, inspired, and with a degree of seriousness and personal responsibility for their research efforts that eclipsed anything they had shown before. We want to offer that same opportunity to a greater number of motivated students in a forum tailored to their needs and background.

School Topics and Organization

We propose that the first summer school should instruct in plasma physics throughout the solar system (similar to the topic of the first Boulder summer school in 2007). A possible topic for the second year is "Space Storms: Causes and Consequences" (also inspired from the Boulder summer school). Each year, the governing board will formally decide on the topic for the summer school. **The central topic of the summer school will rotate on a evolving 2-year cycle, allowing interested undergraduate students to repeat the class once**. We expect most students to be incoming juniors and seniors (including students who just graduated from community colleges). Hence, there is no need to have a 3-year cycle as in the Boulder summer school targeted for graduate students. Overall, the program is intended to challenge students but, at the same time, to give them in one week a broad introduction to the field of solar and space physics.

We propose to create a governing board to provide direction for future summer schools and select the lecturers in the program (see below for more details). Most board members will come from New England universities (UNH, Boston University, Harvard Smithsonian Center for Astrophysics, Dartmouth). Membership may rotate as those who have served give way to others with new energy and new ideas. The organization for the summer school is coordinated by Noé Lugaz at UNH. Charles

Smith, Nathan Schwadron, Charles Farrugia, Terry Forbes and Benjamin Chandran from UNH will serve in the governing board. Other members include Merav Opher at Boston University, Kelly Korreck, Kathy Reeves and John Raymond at Harvard/SAO.

Evolution and exploration of new ideas are key defining principles in the operation of this program. For instance, we do not now intend to write a book as has been very well accomplished by the Boulder school, but future activities will be determined by the membership and volunteers within the program. Lecture materials will be made available via the World Wide Web and this will form the beginning of any education-related efforts by this program.

Curriculum development for an undergraduate audience requires coordination by the teaching faculty. Getting researchers to cooperate as part of a unified program, recognizing the need for an orderly development of the subject and a consistent use of notation is notoriously difficult. Nonetheless, it is required and will be supported by the governing board.

A Summer School in New England

New England has a proud tradition of small, liberal arts colleges that produce excellent students and it is known nationally as a region with a high concentration of distinguished colleges and universities. We propose to reach to find students from across the country from four-year colleges, community colleges and universities without a dedicated space science program to attend a summer school in New England for one week. We propose to actively recruit from these types of institutions in the hope that the students will take back to their home schools an improved knowledge of space science and thereby act as ambassadors for space science to their home institutions.

The New England Space Science Consortium (NESSC) was formed in recognition of the potential for broad collaboration by a large number of space science researchers within the New England area. The NESSC has come to represent a successful and well-supported grass roots effort that brings together between 25 and 40 scientists once each semester for a day of scientific presentation and debate. More information about the NESSC can be found at `http://nessc.unh.edu`. We propose to build on this existing vehicle of collaboration. We feel confident that a suitable number of appropriate applicants can be found from in New England, assuring a successful program. **There is no intent or desire to limit applications to this program to New England schools alone**. We note only that the local colleges and universities can guarantee success with initial student applications. UNH students who will be already living and working in Durham will provide an additional pool of students requiring no additional funding from this proposal. We will advertise nationally (see section on student recruitment).

Students Activities: Space Science Summer School Curriculum

The stated goal of the summer school will be to provide both fundamental and advanced education in space science. We recognize that undergraduate students do not usually have the tools and background to understand the advanced topics that are common in the field of space physics, such as magnetic reconnection, turbulence, etc... Therefore, **the first part of every school will be spent in developing the fundamental tools needed to understand the science of the Sun-Earth system**. For instance, the first lectures in the summer school will be an extensive discussion of magnetic field, particle motions and the plasma state. From these fundamentals, we will introduce the general topics and area of investigation in our field, such as magnetosphere, ICME, solar wind and only after this, will we build, in time, to reach the cutting edge of the subject, on advanced topics such as reconnection, turbulence or particle acceleration.

We expect the third year to repeat the general focus of the first summer school; hence the curriculum will evolve as we learn from teaching undergraduate students in a one-week summer school. The full process is viewed as a learning program for all involved, including the lecturers who volunteer to teach in the program. As the program grows, our vision of how best to accomplish the stated goals will grow as well.

Below, we show an **example of a possible curriculum** for the first two years. This curriculum is inspired from that of the first two years of the Boulder summer schools. The summer school governing board will be in charge of selecting the topics for the school, to draft a curriculum and to select the lecturers (including, of course, themselves). The proposed curriculum will further evolve into the final one depending on the availability and particular interests of the selected lecturers. If the governing board decides on a more traditional 2-year separation between solar-heliospheric physics (from the Sun to L1, including shocks and energetic particles) and heliospheric-magnetospheric physics (from the heliosphere to the radiation belt, including solar wind and its coupling to the magnetosphere), the curriculum will be reorganized but the basic units should be similar. Depending on the speciality of the available lecturers, we may also have lectures about the ionosphere, composition, etc...Once again, the schedule below is only an example of the potential curriculum, and it will evolve as the governing board meets and discusses the organization of the school.

Time - Day	**Sunday**	**Monday**	**Tuesday**	**Wednesday**
8:30am–9:30am 9:45am–10:45am 11:00am–noon	Travel	Welcome Intro to the Sun-Earth system	Magnetic Field Structures	Corona and Heliosphere
noon–1:30pm		lunch	lunch	lunch
1:30pm–2:30pm		Plasma	Instruments	Free Afternoon
3:00pm–5:30pm	Arrival	Intro to IDL (1)	Intro to IDL (2)	Free Afternoon
Time - Day	**Thursday**	**Friday**	**Saturday**	**Sunday**
8:30am–9:30am 9:45am–10:45am 11:00am–noon	Solar Wind	CMEs	Solar wind magnetosphere coupling	Space Weather
noon–1:30pm	lunch	lunch	lunch	lunch
1:30pm–2:30pm	Turbulence	Reconnection	Visit of Morse Hall	End of School
3:00pm–5:30pm	Project (1)	Project (2)	Social Activities	Departure

Table 1: Example of curriculum for Year 1 of the summer school on plasma physics in the inner solar system.

There will be 25 hours of lectures (corresponding approximately to a 1.5 credit class) as well as 5 hours of IDL tutorial and 5 hours of research projects and a visit of the Morse Hall. Morning lectures will be mostly introductory, presenting the different domains and central processes in space physics. The first-day lectures ("Introduction to Heliophysics" and "Plasma") will provide a general introduction to magnetic fields, particle motion in the presence of electro-magnetic fields and the concept of plasma. The second-day morning lecture ("Magnetic Field Structures" or "Introduction to Space Storms") will give an introduction to the topics covered in the rest of the summer school. The last morning of the summer school will be dedicated to an introduction of the concept of space

Time - Day	**Sunday**	**Monday**	**Tuesday**	**Wednesday**
8:30am–9:30am 9:45am–10:45am 11:00am–noon	Travel	Welcome Intro to the Sun-Earth system	Introduction to Space Storms	Shocks
noon–1:30pm		lunch	lunch	lunch
1:30pm–2:30pm		Plasma	Reconnection	Free Afternoon
3:00pm–5:30pm	Arrival	Intro to IDL (1)	Intro to IDL (2)	Free Afternoon
Time - Day	**Thursday**	**Friday**	**Saturday**	**Sunday**
8:30am–9:30am 9:45am–10:45am 11:00am–noon	Magnetosphere	Particle and Acceleration and Transport	Storms and Substorms	Space Weather
noon–1:30pm	lunch	lunch	lunch	lunch
1:30pm–2:30pm	Instruments	Turbulence	Visit of Morse Hall	End of School
3:00pm–5:30pm	Project (1)	Project (2)	Social Activities	Departure

Table 2: Example of curriculum for Year 2 of the summer school on causes and consequences of space storms.

weather, including economical and societal impacts. Overall, **our proposed schedule includes about 10 hours of lectures on fundamental concepts for understanding the Sun-Earth system** and about 15 hours of lectures on current areas of research, such as CMEs, magnetosphere or solar storms. The 1-hour afternoon lectures will be dedicated to the most advanced topics (turbulence, reconnection, current instruments) which will be presented in relation to the concepts discussed in the morning lectures (see next paragraph for details). Wednesday afternoon will be free and some local activities will be planned. Saturday afternoon will be used for a visit of Morse Hall, including the machine shop and a short discussion of the design and fabrication of instruments for space missions, as well as social activities (group outing and dinner).

The developed curriculum must take into consideration that some students will repeat the summer school once, so there must be limited overlap from one year to the next. However, some (or most) students will not repeat (because of graduation or to perform research during the next summer) and we want them to have as broad an understanding of the field of solar and space physics as possible. The first-day of lecture will be very similar in the two years in order to introduce the required concepts (magnetic field and the plasma state) but all the other lectures and projects will differ. **The afternoon lectures** have the same title in the two years but they **will be tailored specifically to reflect the focus of the current year's summer school**. For example, the reconnection lecture in Year 1 will focus on the importance of reconnection for the initiation of coronal mass ejections, while, in Year 2, it will focus on the reconnection in the magnetosphere resulting in (sub)storms. Students in Year 1 might be introduced to the Solar Probe mission as well as ground-based solar observatories through the IDL tutorials, instrument lecture and projects, and introduced to MMS and ground-based magnetometers data in Year 2. Because each year will be a self-contained school, it is possible for a student to participate in two consecutive years, irrespectively of when he first attended.

The IDL tutorials, held in the first two afternoons, will be practical, focusing on reading, manipulating and saving remote-sensing images (for example with SolarSoft) and opening, processing and analyzing *in-situ* measurements. The projects will introduce existing instruments and data to the students and will consist in performing analysis on real data.

We propose to have 10 or more UNH researchers –including advanced PhD students, post-doctoral researchers, research scientists, research and teaching faculty members– **participating in the afternoon projects**. Each researcher will work with 2–3 students on a pre-defined and pre-selected project for 2 afternoons. Five potential afternoon projects are developed below. These projects are real, actual science projects, not just simple exercises. These and other projects will be based on the analyses of recent events observed by the latest instruments with state-of-the-art techniques. The major difference with "traditional" REU projects is that the research projects at our summer school will focus only on the analysis of one event and include neither the extended physical interpretation nor the statistical analysis, which would be expected to warrant a publication. Other projects may use radio observations, interplanetary scintillation (IPS) observations, ground-based coronagraphic observations and ground-based magnetometers measurements and radar observations. The required data is typically available in near-real time.

• **The initiation of coronal mass ejections**: This will include an introduction to HMI or GONG magnetogram data as well as SDO/AIA extreme-ultraviolet (EUV) and STEREO/COR coronagraphic observations. Using SolarSoft and the Helioviewer, the students will determine the source region of the CME. They will create a 3-D visualization of the coronal magnetic field using GONG or HMI data and the potential field source surface (PFSS) model. Using coronagraphic observations, they will determine the CME direction using the Graduated Cylindrical Sell (GCS) model of *Thernisien et al.* [2009], which is part of SolarSoft. Finally, they will compare the direction of the CME in the corona to the source region and determine if there is any angular deflection due to the presence of open field regions.

• **The heliospheric propagation of coronal mass ejections**: This will include an introduction to STEREO/SECCHI observations of CMEs. Using SolarSoft and the satplot routine introduced by JPL [*de Jong et al.*, 2010], the students will track a recent CME and derive its velocity and direction using existing methods (for example the Fixed-Φ method of *Rouillard et al.* [2008] or the Harmonic Mean method of *Lugaz* [2010]). More complex methods will be used to determine the CME kinematics, which will be compared with model runs from CCMC or NOAA/SWPC as well as drag methods available online [e.g., see *Vršnak et al.*, 2012].

• **Determining the orientation of CMEs and CME-driven shocks at 1 AU**: This will include an introduction to ACE and *Wind* in-situ data. Using existing IDL routines, the student will determine the orientation of a recent fast CME using the minimum variance analysis (MVA) technique [*Sonnerup and Scheible*, 1998] and possibly more complex methods such as Grad-Shafranov [*Hu and Sonnerup*, 2001]. The CME-driven shock speed and normal will be determined using the Rankine-Hugoniot relations and the students will determine whether or not the shock was driven by the observed CME. For advanced students, this and the previous project could be combined into a global Sun-to-Earth analysis of a CME event.

• **The acceleration of SEPs**: This will include an introduction to particle detection from instruments onboard STEREO/ACE/GOES as well as the Lunar Reconnaissance Orbiter (LRO) mission. The students will use the real-time information available at UNH about radiation and dose through the EMMREM and CRATER projects. The particle flux will be related to the CME speed, estimated position and to the Sun-Earth connectivity from the Parker's spiral as obtained from ENLIL or the Wang-Sheeley Arge model at NOAA/SWPC or NASA/CCMC. Time permitting, the students will also study the composition of the energetic particles.

• **Particle energization during a geomagnetic storm**: This will include an introduction to RBSP data as well as geomagnetic indices, such as Dst and Kp and concepts such as the L-shell. The students will analyze observations by RBSP during a (sub)storm and calculate the first adiabatic invariant of the particles.

Research Environment: Space Science Summer School Operations and Tentative Schedule

Committees

We will establish three committees:

1. A governing board to assist in management and decision making.
2. A joint faculty that volunteers to teach the first year.
3. A list of faculty affiliates willing to teach in future years.

The first two committees are most critical to the initiation of the school. We have a core group of researchers from institutions in New England willing to initiate the program and to form the basis of the governing board and the faculty to teach during the first year. We have also contacted individuals involved in REU programs in New England: Drs. Korreck and Reeves, current and future PI of the Harvard/SAO REU program to serve in the governing board as well Pr. Wolfson of Middlebury college and a member of the faculty of the Keck Northeast Astronomy Consoritum (KNAC), a consortium of eight liberal arts colleges and universities. We have also contacted individuals involved in the organization of summer schools for graduate students: Dr. Forbes chair of the SPD summer school committee, Dr. Roussev, director of the 2008 SPD summer school and Dr. Opher, who organized a summer school in Boston in the summer of 2012.

For the first two years of the summer school, the lecturers will be primarily chosen from UNH as well as from the governing board. About 10-12 lecturers must be chosen every year (note that there are already 10 researchers listed as collaborators to this proposal).

Research Environment

The school will be held at **the University of New Hampshire (UNH)**. UNH is a land-, sea- and space-grant university based in Durham, NH in the center of New England. Demeritt Hall is the recently renovated home of the Physics Department and it will be the location where the lectures and IDL laboratories are held. We plan on scheduling the summer school after the end of the finals at UNH (typically the end of the second full week of May) and we will have access to the classrooms in the Demeritt Hall. Morse Hall is the building of the **Institute for the Study of Earth, Oceans and Space (EOS)**. EOS is UNH largest research enterprise with over $35 million each year in research support. Morse Hall has two conference rooms that can accommodate 30-40 persons as well as a number of smaller rooms. WE plan on holding the individual research projects in Morse Hall in the offices of the advising researchers. The Space Science Center is one of the EOS research centers has about a dozen tenured or tenure-track faculty (also members of the Physics Department at UNH), a dozen research faculty (also affiliated with the Physics Department) and more than a dozen research scientists, and about 20 graduate students.

Many of the faculty members have experienced doing research with and/or teaching to undergraduate students. UNH has a year-long research for undergraduate program as part of **the Hamel Center for Undergraduate Research** (established 25 years ago), as well as summer undergraduate research fellowship (SURF) and a undergraduate research conference (URC) held in April for the past 14 years.

The interdisciplinary science and engineering (ISE) symposium for undergraduate students is traditionally held at Morse Hall and the neighboring Kingsbury Hall. Most of the senior personnels in this proposal have advised undergraduate students for research projects at UNH or at other institutions. Many have also taught at summer schools for graduate students (at the Boulder summer school, at the CISM summer school and at the Boston University summer school on plasma processes in Space Physics). We will work with the Hamel Center for Undergraduate Research to best design the research projects.

UNH Based Teachers and Mentors:

Noé Lugaz, Research Scientist III, Space Science Center (SSC), UNH
Dr. Lugaz's research focuses on coronal mass ejections (CMEs), one of the most important drivers of space weather. His main interests are numerical simulations of the propagation and interaction of CMEs with magneto-hydrodynamic (MHD) codes, the analysis of coronagraphic and heliospheric images of CMEs and the development of new techniques. While at the University of Hawaii from 2007 to 2012, Dr. Lugaz worked with four undergraduate students, as part of the Institute for Astronomy (IfA) REU program. In 2009 and 2011, he was the sole advisor of two undergraduate students, resulting in 3 publications [*Lugaz et al.*, 2010, 2012; *Lugaz and Kintner*, 2012] and presentations as first author at the AGU fall and spring meetings by one of his student. He also co-developed and co-taught a class on solar and stellar magnetism at the University of Hawaii in the Fall 2010 and served as teaching assistant for a senior-level class on space environment taught by Pr. Gombosi in 2005-2006.

Charles W. Smith, Research Professor, SSC and Department of Physics, UNH
Dr. Smith's work focuses on space plasma theory with a focus on the analysis of *in situ* measurements by spacecraft, with interests ranging from interplanetary turbulence, kinetic plasma processes, to shocks and CMEs. He has worked with more than 30 undergraduate students since moving to UNH in 2003. Throughout the years, he has published a number of articles with students as first or co-authors [e.g. *Smith et al.*, 2006; *MacBride et al.*, 2008; *Coburn et al.*, 2012]. He was a faculty teacher at the first NASA/ Living With a Star (LWS) summer school in Boulder, CO.

Nathan Schwadron, Associate Professor, SSC and Department of Physics, UNH
Dr. Schwadron's research focuses on the solar wind and heliospheric magnetic field, energetic particles and pick-up ions and the outer heliosphere. He has taught at the CISM summer school while at Boston University (BU). At BU, he taught an introductory class for undergraduate students on solar, planetary and space sciences. He has worked with over 10 undergraduate students, in particular through a NASA funded program about IBEX.

Charles J. Farrugia, Research Professor, SSC and Department of Physics, UNH
The research of Dr. Farrugia focuses on the solar wind-magnetosphere coupling, magnetosphere-ionosphere coupling and interplanetary shock and coronal mass ejections (ICMEs). While in Malta, he worked as a professional teacher in mathematics and science in high school and, later on for undergraduate students at the University of Malta from 1993 to 1996. He earned a Diploma of Education from the University of London, England. Drs. Galvin and Farrugia traditionally teach a class entitled "Introduction to Space Plasma Physics" to senior undergraduate students at UNH through the physics department.

Terry Forbes, Research Professor, SSC and Department of Physics, UNH
Dr. Forbes is the Chair of the summer school committee of the Solar Physics Division of the American Astronomical Society (AAS/SPD). His research focuses on the initiation of coronal mass ejections, solar flares and magnetic topology. He is a frequent faculty teacher at summer schools in the US, for example in 2007, 2008, 2010 and 2011 at the LWS summer school in Boulder, CO or in 2006 at the

SPD summer school in Durham, NH.

Benjamin D. G. Chandran, Professor, Department of Physics and EOS, UNH Dr. Chandran's research interests lie in the study of plasma turbulence in coronal and heliospheric physics as well as in astrophysics. Dr. Chandran has served as a member of the steering committee of the SHINE workshop, has been a frequent lecturer at summer school (for example, recently in the Boston University summer school on plasma physics and at the Boulder summer school and multiple times at the National Undergraduate Fellowship (NUF) Summer School on Plasma Physics at Princeton University). He has advised 5 undergraduate students, resulting in a number of publications [e.g., see Chandran and Rodriguez, 1997; Rasera *et al.*, 2008].

Teachers and/or Members of the Boards from Other Institutions:

Richard Wolfson, Middlebury College

Pr. Wolfson is the Benjamin F. Wissler Professor of Physics at the 4-year liberal arts Middlebury college in Vermont. His research focuses on coronal mass ejections and the solar corona. Pr. Wolfson is a member of the **Keck Northern Astronomy Consortium (KNAC)** a NSF-funded REU astronomy program, comprising of eight small liberal arts colleges and universities in the Northeast (Colgete and Wesleyan Universities, Haverford, Middlebury, Smarthmore, Vassar, Wellesley and Willams colleges). There are currently three faculty members in the consortium whose research speciality is in solar or space physics. More information about the KNAC can be found at `http://astro.swarthmore.edu/knac/`. Dr. Wolfson's work with undergraduate students resulted in a number of publications [e.g., see *Wolfson et al.*, 2007, 2012]. Pr. Wolfson will help us reach to liberal arts colleges in the Northeast, including to the KNAC members.

Merav Opher, Assistant Professor, Department of Astronomy, Boston University

The focus of Dr. Opher's research is on the outer heliosphere, coronal mass ejections, shock waves. In the summer of 2012, she has organized a summer school for graduate students on plasma processes in the heliosphere. She has supervised 6 graduate students and 1 undergraduate students and taught undergraduate electro-magnetism classes while a faculty at George Mason University.

Kelly K. Korreck, Astrophysicist, CfA

Dr. Korreck's research is on the solar corona, including coronal heating, particle acceleration during flares and CMEs as well as X-Ray and EUV experimentations. She has served as the PI of the Harvard Smithsonian REU program in solar physics. While at the University of Michigan, she has advised about 10 undergraduate students as part of the Undergraduate Research Opportunities Program (UROP).

John Raymond, Astrophysicist, CfA

Dr. Raymond's research focuses on the solar corona and solar wind, with particular interest in the solar wind acceleration problem, coronal heating, CME shocks and particle acceleration during CMEs and flares.

Kathy Reeves, Astrophysicist, CfA

Dr. Reeves' research focuses on coronal mass ejections and reconnection, primarily in the corona. She is serving as the PI of the Harvard Smithsonian REU proposal in solar physics.

Tentative Schedule

We propose to hold the school during the last 10 days of May. Most universities in the United States have their last day of final exams for the Spring semester in a period of May 1 to May 20. This is true for the following universities (randomly checked): Brown, Harvard, Cornell, Yale, Penn, BU, NYU, Temple, Rutgers, the Universities of Michigan, Colorado, Alabama, Florida, New Hampshire, Massachusetts (all campuses), Texas (all campuses), SUNY (all campuses), California-Berkeley, the Salem State University, the Burlington, Middlebury, Williams, Bowdoin and Smith colleges, as well as most community colleges (all of the ones in New Hampshire, Maine,Vermont, Rhode Island and Massachusetts).

There are exceptions, primarily universities using the quarter system (all campuses of the University of California except Berkeley and Merced, Dartmouth, the Universities of Washington and Oregon) but also a few universities which have a last day of final exams later in May (May 24: CUNY, MIT).

Our goal in scheduling our summer school is to make it as close as possible to the end of the year of most universities. This is chosen so that students do not have to schedule their summers around the summer school. For example, by having the school at the end of May, students will be able to work for two and an half months to three months (June to August) in a research or a work to pay for school. Students enrolled in a REU program at most universities would also be able to attend before starting their research experience.

Student Recruitment and Selection

We plan to recruit 15 undergraduate students to participate per year in our program. In addition, there will be about 10-15 UNH students, which will attend the lectures and for which we request no funding. In our recruitment activities, **we will target students from undergraduate institutions with little access to space science classes, with a particular focus on underrepresented students**. We intend to design a flyer, which will be sent to physics department in universities and colleges in New England and in the US, including community colleges in Massachusetts, New Hampshire and Maine (and beyond). The state of New Hampshire has a program allowing students enrolled in public community colleges to automatically transfer into a state university after graduation, based on a minimum required GPA (New Hampshire Transfer Connection Programs). We will contact physics departments in the community colleges in New Hampshire to recruit students enrolled in such a program, in order for them to be introduced to space physics before the start of their junior year. We will also take advantage of an ongoing partnership between UNH and the Elizabeth City State University (ECSU, which is an historical black college –HBCU–). This partnership exists primarily through a REU program organized at UNH in Earth System Science and a joint NASA Innovation in Climate Education (NICE) program. Through this existing partnership, we intend to attract underrepresented minorities in STEM disciplines to our summer school. We also plan to recruit through the American Astronomical Society/Solar Physics Division (SPD) solarnews and Space Physics and Aeronomy (SPA) newsletters. We will also rely upon our faculty colleagues at other institutions where we have existing collaborative contacts to identify and encourage students to apply to our summer school.

Students will be asked to submit an application with two letters of recommendation from faculty or work-related contacts asking them to assess their interest in STEM fields, potential interest in research and interest in the physics of the Sun-Earth system. The applicants will also submit a resume. There will be a summer school website housed on the EOS server, which will provide a description of the program, the schedule, the teachers and potential research topics so the students will be able to identify their area of interest. Student applications will be due March 1st to coincide with other research programs at UNH. The governing board will meet to provide recommendations for acceptance to the program. The committee will rank students with regard to scientific background and interest in space science, while also keeping a balance in gender and underrepresented backgrounds in mind. Students will be notified of acceptance within four weeks.

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This will be the 7th school of the series of Byurakan International Summer Schools (BISS) founded in 2006 and being held once every 2 years, one of the most important and regular astronomical summer/winter schools in the world. According to the analysis of the IAU Division C (Education, Outreach and Heritage), BISS is among the top-3 astronomical schools in the world (together with IAU ISYAs and Vatican schools, VOSS), as well as the NEON/OPTICON schools are among the best ones. Event listing ID: 1331127.Â The objective is to cover a wide range of fundamental to functional phenomena, to serve as a critical evaluation of the use of Magnetism to address societal challenges. NESSC, Utrecht (stad) (Utrecht). 414 likes Â· 7 talking about this Â· 15 were here. reading the past, projecting future climate.Â Because of this, the oceans on our planet have drastically reduced the impact of the changing climate. But how is it even possible that the oceans keep on absorbing CO2? The efficiency of CO2 uptake by the oceans is governed by ocean alkalinity. Because of ocean alkalinity, ocean water is able to buffer against acidic inputs, like those from the uptake of carbon dioxid...e. A new review article, written by NESSC-researcher Jack Middelburg (Earth Sciences, Utrecht University), Karline Soetaert (NIOZ) and Mathilde Hagens (Wageningen University & Research) looks in detail at the mechanism beh Electromagnetism and electromechanical systems; use of sensing, control and actuation to demonstrate key physical relationships through the transducer relationships linking pressure, temperature and other physical stimuli to changes in electric and magnetic fields. Prerequisites: Grade of C or better in MATH 152 or MATH 172, or equivalent; grade of C or better in PHYS 206 or equivalent; grade of C or better in PHYS 216/ENGR 216 or ENGR 216/PHYS 216; grade of C or better and concurrent enrollment in PHYS 207; also taught at Galveston campus.Â Laboratory experiments in modern physics and physical optics with an introduction to current, state-of-the-art recording techniques. Prerequisites: PHYS 225; PHYS 309. PHYS 328.