ASTR-7500: Topics in Solar Observation Techniques CU Boulder Course Syllabus (Spring 2016)

Instructors:
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Course Times: Tues., Thurs., 2:00–3:15 pm MST, Duane Physics room G-328

Course web page: http://lasp.colorado.edu/∼cranmer/ASTR_7500_2016/

Office hours: By appointment

SUMMARY

This web-enabled course is the third offering of the *George Ellery Hale Collaborative Graduate Education (COLLAGE) Program,* a joint effort between CU Boulder, the National Solar Observatory (NSO), New Jersey Institute of Technology (NJIT), University of Hawaii (UH), New Mexico State University (NMSU), Montana State University (MSU), and the High Altitude Observatory (HAO). We anticipate that graduate students from outside CU Boulder will take this course by registering for courses at their home institutions that are used for special topics, seminar-type discussions, or independent study.

In this course we will cover the basics of spectropolarimetric instrumentation and measurement techniques, diagnostics of the plasma properties and magnetic field of the solar atmosphere, occulting coronagraphs, and emission-line spectroscopy of the solar corona. The entire course will be web-cast to participating institutions (with additional instructors lined up to facilitate local discussion). Some material will be pre-recorded for earlier viewing, with the "flipped classroom" model being used for in-class discussion.

This course is an elective for CU Boulder APS graduate students. A recommended pre-requisite or co-requisite is Observations, Data Analysis, & Statistics (ASTR–5550).

COURSE MATERIAL

There are no required textbooks for this course. Material from the four instructors will be distributed to the students throughout the semester. For additional reading on several topics important to this course, see:

- *Solar Astrophysics,* Peter V. Foukal (Wiley-VCH, 2nd ed., 2004)
- *Introduction to Spectropolarimetry,* Jose Carlos del Toro Iniesta (Cambridge, 2007)
- *Astronomical Optics,* Daniel J. Schroeder (Academic Press, 2nd ed., 2000)
- *Optics,* Eugene Hecht (Addison-Wesley, 4th ed., 2001)
- *Astrophysical Techniques,* C. R. Kitchin (CRC Press, 6th ed., 2013)
- *Adaptive Optics for Astronomical Telescopes,* John W. Hardy (Oxford, 1998)
- *Ellipsometry and Polarized Light,* R. Azzam & N. Bashara (North-Holland, 1999)
- *The Observation and Analysis of Stellar Photospheres,* David F. Gray (Cambridge, 3rd ed., 2008)
- *Polarized Light for Scientists and Engineers,* E. Collett & B. Schaefer (PolaWave, 2012)
- *Astronomical Polarimetry,* J. Tinbergen (Cambridge, 1996)
- *Handbook of CCD astronomy,* Steve B. Howell (Cambridge, 2nd ed., 2006)

GRADING

At CU Boulder, the final grade will be broken down into contributions from problem sets (50%) and a final project & presentation (50%). More details on these components are given below.

SCHEDULE OF TOPICS

The dates listed here for each set of topics are approximate. There will be an actively maintained web page that stays up-to-date on the topics to be covered in each class session.

Introduction & overview	Jan 12 (part)
1. Off-limb Coronagraphy & Spectroscopy (S. R. Cranmer)	
1.1. Background & definitions of radiative quantities	Jan 12 (part), 14
1.2. Diffraction theory & coronagraph design	Jan 19, 21
1.3. Visible continuum emission: K & F corona diagnostics	Jan 26, 28
1.4. Emission-line spectroscopy: collisional & scattering lines	Feb 2, 4
1.5. Bridging remote-sensing & in-situ diagnostics	Feb 9
2. Applied Spectropolarimetry: Radiative Transfer (H. Uitenbroek)	
2.1. Basic concepts	Feb 11
2.2. Transfer of polarized radiation	Feb 16, 18
2.3. Spectral lines in atoms, ions, & molecules	Feb 23, 25
3. Applied Spectropolarimetry: Diagnostic Techniques (R. Centeno)	
3.1. Remote sensing & interpretation	Mar 1
3.2. Simple diagnostic & inversion methods	Mar 3
3.3. Inversion codes, merit functions, & model fitting	Mar 8
4. Astronomical Instruments & Observation Techniques (W. Cao & V. M. Pillet)	
4.1. Fundamental optics & astronomical telescopes	Mar 10, 15
4.2. Astronomical detectors	Mar 17
4.3. Imaging instruments	Mar 29
4.4. Grating-based spectrographs	Mar 31
4.5. Turbulent atmosphere & adaptive optics	Apr 5, 7
4.6. Astrophysical spectropolarimetry	Apr 12, 14
4.7. Modern telescopes & spectropolarimeters	Apr 19
5. Student project presentations	Apr 21, 26, 28

PROBLEM SETS

There will be approximately five homework assignments distributed throughout the semester. A detailed schedule of distribution and due dates will be given out in class and posted on the course web page. Hardcopy submissions are preferred, but email is fine, too. Students choosing the latter option are encouraged to write out solutions long-hand and scan them. (That way you won't be tempted to leave out intermediate steps when typing in equations.)

Problems are due on the dates given. However, since it is our top priority that students have sufficient time to learn from the problem sets, we will grant one lateness exception per student: One problem set can be turned in up to three business days late with no penalty. Other late problem sets will incur a penalty of a 5% lower grade per business day that it is late.

FINAL PROJECT & PRESENTATION

There will also be a project that will count for 50% of the final grade. This will enable you to explore a chosen topic in a bit more detail and gain some extra experience with scientific writing and expressing your ideas in front of a group. For the main project activity, feel free to choose between the following options:

- A review of a topic relevant to this course, that goes well beyond the material discussed in class. Reviews usually involve conveying the background (i.e., how did we come to understand the topic) and motivation (i.e., why is it relevant) to non-experts, as well as searching the literature to get a ∼complete sense of chronological progress.
- Some kind of mathematical or computational calculation that explores a topic relevant to the course. The types of things you could do include:
  a. exploring a wider "parameter space" of a textbook model,
  b. numerically solving an equation (that was presented in class) that has no analytic solution,
  c. constructing your own model or simulation.
- Downloading and analyzing some publicly available observational data.

  For this course, we *may* have some real, fresh-off-the-telescope solar data for you to use! This would be a great opportunity to get experience at all levels of observational solar physics—i.e., we'll try to take you through as many steps in the process (from observation planning to raw data to science results) as possible.
- Critical testing (or debunking?) of the claims made in a recent paper.

The written component of the project should end up around 10 double-spaced pages in length—i.e., roughly 2500 words—not counting the (required) bibliography. If there is a computational or observational aspect to your project, we may request to see some of the source code or data.

There will be a handful of class sessions reserved at the end of the semester for student presentations (exact number to depend on enrollment). Additional information, including lists of possible topic ideas and deadlines, will be distributed during the semester. Please feel free to discuss possible topics with the instructors at any time.

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ACADEMIC INTEGRITY

All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Additional information regarding the Honor Code policy can be found online and at the Honor Code Office.

For this course, we encourage you to discuss the assignments and topics with your fellow students. However, everything that is written up and submitted must be your own independent work. If you do collaborate with other students, a good time to split off from the group is when you start to write up your answers. If someone

were to ask you questions about your work, you should be able to explain everything about how & why you did it the way you did.

STUDENTS WITH DISABILITIES

If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu. If you have a temporary medical condition or injury, see Temporary medical conditions under the Quick Links at the Disability Services website and discuss your needs with your professor.

RELIGIOUS OBSERVANCES

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. If you have religious obligations that result in schedule conflicts, please contact us in the first two weeks of class to make alternate arrangements. For full details, see the campus policy regarding religious observances.

DISCRIMINATION AND HARASSMENT

The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. CU-Boulder will not tolerate acts of discrimination or harassment based upon protected classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "protected classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy. Individuals who believe they have been discriminated against should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or the Office of Student Conduct and Conflict Resolution (OSC) at 303-492-5550. Information about the OIEC, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be found at the OIEC website. The full policy on discrimination and harassment contains additional information.

CLASSROOM BEHAVIOR

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructors with the student's legal name. We will gladly honor your request to address you by an alternate name or gender pronoun. Please advise us of this preference early in the semester so that we may make appropriate changes to our records. For more information, see the policies on classroom behavior and the student conduct code.

The policy of the Department of Astrophysical and Planetary Sciences is to ban any use of electronic devices (cellphones, tablets, laptops) in class except as an approved accommodation granted by Disability Services, or as explicitly authorized by the instructor. *In this course* we authorize the use of tablets and laptops for note-taking, but students must do their best to seat themselves with nobody behind them.