Wootton Center for Astrophysical Plasma Properties
Department of Astronomy and McDonald Observatory

2515 Speedway, C1400 • Austin, TX 78712-1205 • 512-471-3000 • FAX 512-471-6016
www.as.utexas.edu

Center Scientific Advisory Committee meeting for the Wootton Center for Astrophysical Plasma Properties

Meeting date: 4 January 2019

Location: RLM building, The University of Texas at Austin, Austin, TX

Members of Center Scientific Advisory Committee meeting (CSAC) for the Wootton Center for Astrophysical Plasma Properties (WCAPP) present:

- Chris Fontes, Los Alamos National Laboratory
- David Kilcrease, Los Alamos National Laboratory
- Don Lamb, Department of Astronomy and Astrophysics, University of Chicago
- Keith Matzen, Sandia National Laboratories, Albuquerque
- Marilyn Schneider, Lawrence Livermore National Laboratory
- Hugh Van Horn, Department of Physics and Astronomy, University of Rochester (retired)
- Alan Wootton (retired)

Nancy Brickhouse, Harvard-Smithsonian Center for Astrophysics, was unable to attend because of the partial government shutdown.

Don Lamb and Hugh Van Horn attended via video conference.
Meeting held at The University of Texas at Austin campus.

Contents

1. Summary

The Wootton Center for Astrophysical Plasma Properties (WCAPP) is engaged in an exciting research program. It is built on the PI's and Co PIs' successful ~5 year Fundamental Science Program at the Z facility at Sandia National Laboratories (SNL), that included the precursor ZAPP (Z Astrophysical Plasma Properties) program. The research focus is unique: "at parameter" experiments, with high fidelity data, resulting in publications with high impact for both astrophysical and DOE/NNSA interests. Efficient use of the Z facility is assured by fielding multiple experiments (typically 4) on one shot. In addition, the Center will continue to provide an education leading to a future source of young scientists in the important area of atomic and radiation physics of warm dense matter.

The committee meeting demonstrated that the team, a combination of experimental, theoretical and computational scientists, is well aware of the challenges involved in meeting the Center's objectives. An important and well-understood challenge is to find sufficient high-quality postdocs for the experiments, e.g. for the solar opacity, and photo ionized and accretion plasma, projects. This reflects the shortage of highly qualified young scientists in the field of atomic and radiation physics of warm dense matter; helping to remedy this shortage is one objective of the Center.

Findings and Recommendations are given in individual sections, and also in the Final Summary.

2. Introduction

The Wootton Center for Astrophysical Plasma Properties (WCAPP) is a new Center, with funding received in February 2018. It is focused on the atomic and radiation physics of matter over a wide range of temperatures and densities. Academics currently funded by the grant are from the University of Texas at Austin (UT) and the University of Reno, Nevada (UNR). The experiments are undertaken at the Sandia National Laboratories (SNL) Z Facility. In addition to the heavily involved SNL staff, there is significant participation from Lawrence Livermore National Laboratory (LLNL) and Los Alamos National Laboratory (LANL), as well as from the University of Arizona. Motivated by astrophysics, the Center will also address problems of interest for stockpile stewardship, ICF, HED physics and astrophysics. This document is a summary of the first meeting of the Center Scientific Advisory Committee (CSAC).

The panel met from 8:30 am to 4:45 pm on Friday January 4, 2019; the meeting agenda is listed in the Appendix. After an introduction from the WCAPP Director, Don Winget, Jim Bailey of SNL discussed the relation of WCAPP to SNL. There followed four presentations on current and near-term (~3 year) experimental research by: Jim Bailey of SNL (2 presentations), Mike Montgomery of UT (1) and Roberto Mancini of UNR (1). Details are again found in the Appendix.

After a general discussion with WCAPP researchers (including students) around focused questions, the committee met alone for discussions in the following areas, with responsibilities noted. (**Name**)

Near term (3 years)
Choosing important astrophysics questions to address. Is the proposed research unique, world class, likely to be approved for time on Z, and likely to succeed? This has been done initially for year one, with research proposals peer-reviewed, funded, and experimental time awarded, but we need to look at 3-year plans. **Don Lamb**

Performing the experiments (radiation measurements) at Z, with all that entails: This requires experimental time, SNL assistance (see Section 3.2, "Personnel"), diagnostics, data analysis tools, etc. Again this is in hand for the initial experiments, but we should look at the 3-year plans. **Keith Matzen**

Assessing the astrophysical consequences of the expected research. **Hugh Van Horn**

Development of relevant astrophysics / radiation physics tools. **Dave Kilcrease**

Personnel
People to do all of the above, linked to the Center, in particular academics and students, and the necessary SNL involvement. **Chris Fontes**

Planning for the Future
Should the team be looking to beyond 3 years now? If so are there any exploratory studies that should be started soon? For example, should the Center consider not only what can be done "at parameter, at *Z*" or also using laser facilities, including scaled experiments? If yes, then is this the right time, or too soon, to start an evaluation and possible exploratory experiments? **Alan Wootton**

Other areas
(including any brought to light during the meeting). **Marilyn Schneider**

3. Discussion, Findings and Recommendations

A lively and very constructive discussion, first with the Center members, and then amongst just the committee members, ensued. We summarize these discussions below, including any Findings and Recommendations.

3.1 Near term (~ 3 years)

3.1.1 Choosing important astrophysics questions to address.

To summarize, these are currently:
a) Opacities in the Sun and related stars
b) Atomic physics and x-ray heating of photoionized plasmas

c) White-dwarf photospheres and theoretical developments
d) Black hole accretion disc radiation

The panel agrees that these four areas chosen for the 3-year time frame are important scientifically, can be or already are very high impact topics, and represent an excellent fit between the academic teams, the SNL researchers, and the facility capabilities. The research focus is unique: "at parameter" experiments, producing high fidelity data, resulting in publications of high impact for both astrophysical and DOE/NNSA interests. Efficient use of the Z facility is assured by fielding multiple experiments (typically 4) on one shot. The program will continue to provide an education leading to a much-needed source of young scientists in the field of atomic and radiation physics of warm dense matter.

So near to the start of funding, the Center involvement in the four areas is of course disparate. The WCAPP team is historically and deeply involved (leading) in areas b) photoionized plasmas and c) white dwarfs, but not yet deeply involved in areas a) solar opacities or d) accretion-disc radiation. As discussed later (under 3.2 "Personnel") this is partially a direct consequence of a lack of high-quality, young post-doctoral researchers in the relevant atomic-physics areas. To remedy this lack is itself a significant motivation for undertaking the research being discussed. Keith Hawkins and Roberto Mancini are interested in a) and d), respectively, but on-site at SNL postdocs involved in these experiments is the ultimate goal.

The four projects are linked together in that they can, and usually are, deployed simultaneously on the same Z facility "shot". To assure that the individual projects continue to be allocated experimental time on the Z facility, and indeed to be justified, it is crucial to maintain a strong motivating connection between each project and the astrophysical question(s) being addressed.

Highlights of the experimental approach are the "at parameter" aspect, the dedication to reducing errors and uncertainties, and assuring reproducibility. We expect these to be continued, perhaps with scaling included where possible.

Finding: *The four projects considered for research represent a unique focus that is of great interest to academia and DOE/NNSA.*

Recommendation: *Do not expend significant effort beyond these four areas in the near term, although planning for the future is also recommended (see 3. below) in anticipation of the 5-year renewal proposal.*

This Recommendation also reflects the outcome of the discussion in Section 3.3, "Planning for the Future".

3.1.2 Performing the experiments (radiation measurements) at Z.

The first critical task for performing experiments on the Z Facility is to ensure that the WCAPP proposals for experiments to the Z Fundamental Science Program (ZFSP) review panel are of the highest quality; have a clear connection to a recognized, critically important problems in astronomy/astrophysics, will train students in capability areas important to the programs within the national nuclear weapons laboratories, and will result in e.g. Science or Nature publication if successful. Of course, it is helpful if the capabilities developed in the process of executing these experiments are also relevant for addressing problems of interest for national security.

For these experiments to be successful, it is important to have a tiered approach to staffing at both the University of Texas and Sandia. Past history suggests that the chances of success are greatly increased if UT postdocs and graduate students can spend time in residence at Sandia. The UT faculty should also plan to spend several days per year with their students in Albuquerque. At Sandia, the tiered approach suggests having oversight of the experiments from a distinguished member of the staff (e.g., Jim Bailey), detailed interactions with relatively new staff actively performing experiments on the Z facility (e.g., Guillaume Loisel and Taisuke Nagayama), and new staff at Sandia familiar with the UT program (e.g., Marc Schaeuble and Thomas Gomez). These interactions are further enhanced with support from first level managers (e.g., Greg Rochau). Ideally, there are parallel interactions between the levels of staff and students at UT and the levels of management and staff at Sandia. Developing a comprehensive communication between these multiple levels of staff and management is very important. *Relevant Findings and Recommendations concerning SNL staff involvement and communication are included in Section 3.2, "Personnel" and in Section 3.4, "Other areas".*

With respect to diagnostics, all proposed experiments should be planned to use existing diagnostics on the Z Facility. While it is appropriate to propose new diagnostics (and new diagnostics are continually being developed on Z), the timescale for developing a new diagnostic can be longer than the tenure of a graduate student.

Finally, there is a great need for data-analysis tools. Similar to the diagnostics themselves, the data-analysis tools can take years to develop, and they constantly evolve. Something as mundane as creating better ways to archive data for later analysis could have a large impact on the overall program.

3.1.3 Assessing the astrophysical consequences of the expected research.

High-energy-density plasma-physics (HEDP) experiments, such as those performable at SNL's Z-machine, extend from high to low mass densities. The former enable investigations at parameters like those inside the Sun and other stars. The astrophysical consequences of such experiments are expected to be relatively straightforward to determine. For example, current values for log g for white dwarf stars yield significantly different results from the broadening of different H lines. Since a given star can have only one value of the surface gravity, improvements in line-broadening theory (based on Z-pinch experiments) that yield a smaller dispersion in log g will enable obvious advances in determining white dwarf parameters such as the stellar mass. This in turn will advance the use of white dwarfs as tools for other astronomical measurements, such as the age of the galactic disk. Similarly, the best current structural models for the Sun disagree with results obtained from helioseismology. It has been suggested that this may be due to inaccurate opacities near the base of the solar convection zone. Here also it will be straightforward to judge the degree of improvement in models obtained using new absorption coefficients determined from Z-machine experiments: the base of the convection zone in the models will agree more closely with determinations from helioseismology. This is important because the Sun serves as our benchmark for all other stars. Yet another area in which Z-machine experiments can be expected to yield significant improvements is in our understanding of the physics involved in the lowering of the continuum and the merging of spectral lines at high mass densities. This involves very complicated, time-dependent many-body physics, and current theory is not adequate. Improvements in this area will impact broad areas of astrophysics.

At the other extreme of mass densities, High Energy Density Plasma (HEDP) experiments can reproduce parameters associated with the harsh radiation environments associated with accretion disks around compact objects such as neutron stars and black holes. Here, however, the structural uncertainties in the intrinsically two-dimensional, rotationally supported accretion disks are much larger than those associated with almost perfectly spherical stars, making it less clear how to judge the astrophysical consequences of Z-machine experiments. Nevertheless, any improvement in understanding the mechanisms responsible for determining the charge states, line strengths, and broadening mechanisms of ions in such high-energy radiation environments can only help to advance of our understanding of such disks and the compact objects they surround.

3.1.4 Development of relevant astrophysics / radiation physics tools

There are a number of existing astrophysical computational tools that were mentioned as being used in the analysis of the Center's experiments. These were: TLUSTY, a stellar and accretion disk spectroscopy diagnostic code; XSTAR, for the modeling of conditions and spectra of photoionizing plasmas; MESA, a 1D stellar evolution code; FLASH, a 3D AMR MHD code with many high energy density physics applications; CLOUDY spectral synthesis code for NLTE ionizing gas and dust; VISRAD, a 3D reflection, absorption, and emission of radiation modeling code; HELIOS-CR, a 1D radiation hydrodynamic NLTE and MHD code, the LANL ATOMIC-Boltzmann code for modeling NLTE plasmas including NLTE electron distributions. The TLUSTY code will be updated with new hydrogen spectral line shapes, developed by Center collaborator Thomas Gomez and graduate student Patricia Cho, to evaluate the implied changes in basic white dwarf parameters like mass and age. Mike Montgomery attempted to model the Sandia Z experiments using the FLASH code but was unsuccessful. Capabilities are being added to the FLASH code to enable it to simulate Z-pinch experiments. It was suggested that use of the FLASH code should therefore be revisited. Its 3D and MHD capabilities could be a great asset for modeling the Z-pinch back lighter. With these codes and improvements, it would appear that the project has adequate tools for analysis of its experiments.

3.2 Personnel

The WCAPP funds several academics at US Universities, and academic staff and students at SNL. Current funding can support 6 graduate students and 3 postdocs. The Center takes great care to only hire exceptional candidates, who are in high demand.

These candidates must be approved by all relevant members of the Center. At the moment, and on track, 4 of the 6 graduate-student positions are filled. For the postdocs, 1 of the 3 positions is filled. This reflects the shortage of highly qualified young scientists in the field of atomic physic of warm dense matter, itself a motivation for the existence of the Center. This initial and expected shortage is currently ameliorated by the involvement of Keith Hawkins (UT faculty) and Bart Dunlap (UT postdoc) with Jim Bailey in the stellar opacity work.

The process for filling the remaining 2 graduate-student positions proceeds as planned, and is expected within about a year. Filling the two remaining postdoc positions is currently a highest priority item. Hiring exceptional candidates who are willing to be retrained in the relevant areas will likely be required. Recommended methods for finding and attracting candidates include:

1. Outreach efforts at national meetings, such as the OMEGA Laser Facility Users Group Workshop, the American Physical Society (APS) Division of Plasma Physics (DPP) Conference, the International Conference on Atomic Processes in Plasmas (APIP), and the International Workshop on Radiative Properties of Hot Dense Matter (RPHDM).

2. Visiting US universities with programs that have graduate students with relevant skills. Possible institutions include Auburn and Kansas State. Visiting UK universities in London and Oxford is also a possibility.

3. Hosting a one-off meeting on relevant areas of high energy density physics at UT-Austin in order to bring potential candidates to campus and to highlight the research carried out at the WCAPP.

4. Reaching out to colleagues in the magnetic fusion community, which has students with skill sets that overlap, to some extent, those required by the WCAPP.

5. Participating in summer-student programs at the national laboratories in general, and SNL in particular, such as the Science Undergraduate Laboratory Internship (SULI) Program.

The above will be time consuming. In recognition of this, Prof. Winget has already arranged to step away from teaching for one semester this year. However, there are other time-sensitive initiatives that need his attention, for example planning for the future (Section 3.3). Prof. Winget is encouraged to seek addition leave from teaching.

Finding: *Filling the two remaining postdoc positions is currently a highest priority item.*
Recommendation: *The members of the WCAPP, with the aid of this advisory committee, can take a more active role in advertising the Center and seeking postdoctoral candidates. Prof. Winget is encouraged to seek more than a one-semester leave.*

An additional Finding and Recommendation in the Personnel area concerns the involvement of SNL staff, and is discussed in more detail in Section 3.1.2, "Performing the experiments (radiation measurements) at Z":

Finding: *An increase in the number of SNL staff who participate in WCAPP projects is desirable.*
Recommendation: *Together with CSAC members, investigate applying for any appropriate Laboratory-Directed Research and Development (LDRD) funding at SNL and (again with CSAC members) pursue the possibility of creating a "Z Professorship" that is funded partially by SNL and partially by UT.*

3.3. Planning for the Future.

It was unanimously agreed that the Center should concentrate on the current four scientific areas (see 3.1.1 above) on the Z facility for the next ~3 years. The envisaged graduate students are either in place or about to be, whereas the postdoc complement needed is, as expected and discussed above, incomplete. However, and again as noted, planning for the future should start by exploring what complementary research can be undertaken on other facilities, in anticipation of a future proposal renewal. Currently, the best options appear to be the OMEGA laser user facility, Laboratory for Laser Energetics (LLE) at the University of Rochester, and the Jupiter laser user facility at LLNL. Both LLE and LLNL senior scientists and managers are actively encouraging WCAPP involvement. Understanding what complementary research could be undertaken in the future (beyond 3 years, considered as part of a 5-year renewal submission) will require active effort by the PIs.

The relevant Findings and Recommendations are covered in Sections 3.1.1 and 3.2.

3.4 Other areas

Here we note both questions and ideas that emerged during the discussion.

• Experimental: Stellar opacity: Measure the oxygen opacity using the successful iron opacity platform with (hopefully) slight modifications. This would require developing targets and possibly new crystals for existing spectrometers.

• Experimental: Accretion Disk Platform on photoionized plasmas (G. Loisel, "Benchmark Experiment for Photoionized Plasma Emission from Accretion-Powered X-ray Sources", Phys. Rev. Lett., 119 (2017) 075001.) The initial experiments by the Sandia Group verified that the platform was reproducible, and found the plasma was under-ionized compared to current models used for astrophysical plasmas. More experiments need to be done to understand ionization and radiation transport and there is opportunity for Center scientists to take the lead.

Theoretical: What are the implications of recent experimental results (from this collaboration) to models of stars, accretion disks, age of the universe, etc., in particular:

What is the implication of the higher opacity of Fe at solar interior conditions? (J. E. Bailey, et al, "A higher-than-predicted measurement of iron opacity at solar interior temperatures", Nature 517 (2015) 56.)

What is the implication of recently measured line-widths of H- and He-like plasmas (Schauble work) to white dwarf masses and implication of those masses to understanding of stellar evolution, age of universe. This analysis has started.

What are the implication of the disagreement in ionization between models and measurements in the accretion disk platform?

• Intra-Center Communication: There was a discussion concerning how Center scientists (including students) at Reno, Austin, Albuquerque and elsewhere interacted, and whether improvements could and should be made.

Finding: *Improved communication between Center partners could enhance the research.*
Recommendation: *Find out how this is done in similar distributed Centers, and between universities (in particular UT) and high-energy facilities.*

4. Final Summary

Here we list the Findings and Recommendations.

Finding: *The four projects considered for research represent a unique focus that is of great interest to academia and DOE/NNSA.*
Recommendation: *Do not expend significant effort beyond these four areas in the near term, although planning for the future is also recommended (see 3. below) in anticipation of the 5-year renewal proposal.*

Finding: *Filling the two remaining postdoc positions is currently a highest priority item.*
Recommendation: *The members of the WCAPP, with the aid of this advisory committee, can take a more active role in advertising the Center and seeking postdoctoral candidates. Prof. Winget is encouraged to seek more than a one-semester leave.*

Finding: *An increase in the number of SNL staff who participate in WCAPP projects is desirable.*
Recommendation: *Together with CSAC members, investigate applying for any appropriate Laboratory-Directed Research and Development (LDRD) funding at SNL and (again with CSAC members) pursue the possibility of creating a "Z Professorship" that is funded partially by SNL and partially by UT.*

Finding: *Improved communication between Center partners could enhance the research.*
Recommendation: *Find out how this is done in similar distributed Centers, and between universities (in particular UT) and high-energy facilities.*

Appendix 1. Meeting Agenda

I. Introduction to Meeting by Chair of CSAC, Alan Wootton (8:30 – 8:45)

II. Introduction to WCAPP (Don Winget) (8:45 – 9:45)
   a. Why WCAPP, and what defines success
   b. Three general areas where advice is requested from the committee: science in the next 2 to 3 years, personnel needed to achieve these science goals, and longer-term science ideas that need exploratory studies in the 2- to 3-year time frame.

III. Relation of WCAPP to Sandia (Jim Bailey) (9:45 – 10:00)

IV. Current, 2 – 3 year, and any longer term, science, emphasizing astrophysical science, astrophysical tools, physics, and including institutional and personnel involvement (30 minutes for each presentation). (10:00 – 12:15*)
   a. Opacities in the Sun and related stars (Jim Bailey)
   b. Atomic physics and x-ray heating of photoionized plasmas (Roberto Mancini)
   c. White dwarf photospheres and theoretical developments (Mike Montgomery)
   d. Black hole accretion disc radiation (Jim Bailey)

**Note: Dean Paul Goldbart will arrive during these talks for a few words on WCAPP. We will divert for approximately 15minutes*

LUNCH (catered box lunches) (12:15 – 12:45)

Free time to stretch (<30 minutes) (12:45 – 1:15)

Discussions with CSAC (CSAC, PIs, and Co PIs) (1:15 – 2:45)

Focus Questions for the discussion:
   a. Near term, 2-3 years: Is the proposed research that is focused around the Z facility at SNL (physics and astrophysics, experiment and theory, and tools) unique, world class, likely to be approved for time on Z, and likely to succeed?
   b. Is the research planning, especially human effort (including for postdocs, students, additional institutions) adequate for success?
   c. Looking to beyond 3 years out, are there any exploratory studies we should be undertaking in the 2- to 3-year time frame? For example, is it the right time or too soon to be evaluating what could be done not only “at parameter on Z” but also on lasers, and including scaled experiments?

V. CSAC meets alone (2:45 – 4:00)

VI. OUTBRIEF to PI and Co PIs (4:00 – 4:30)

4:30pm adjourn

Link to the Wootton Center for Astrophysical Plasma Properties:
http://www.as.utexas.edu/~mikemon/CAPP.html

Wootton Center for Astrophysical Plasma Properties
Center Scientific Advisory Committee

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Chris Fontes	Date
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Marilyn Schneider	Date
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Alan Wootton, Chair	Date