Highly Energetic Physical Processes and
Mechanisms for Emission from Astrophysical Plasmas
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Astrophysics in the New Millennium

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I am going to use this opportunity to make some very general remarks. I believe we are about to enter an era that is very different from those we have experienced before, and is probably closest to what those of us who have been around long enough experienced in the 1970s. That was a time of explosive expansion in space astronomy and astrophysics. The intervening two decades have seen major advances in many specific areas, but, since the 1970s period, progress has been more episodic, triggered by the occasional appearance of some new observational tool, new computational tool, or theoretical insight.

I think the new millennium is going to be qualitatively different from the past two decades. Consider some of the new observational tools that are about to be at our disposal over the next few years (or, in one case, in the next week), in addition to those that exist now, like the *Hubble Space Telescope*, *Rossi X-ray Timing Explorer*, SAX, *Yohkoh*, and the *Compton Gamma Ray Observatory*.

In X-ray astronomy, there is *Chandra*, now approved for launch in this month, XMM, to be launched in December, and Astro-E in 4–5 years. This is an extraordinary and unprecedented array of new instruments for our discipline. In my own area of X-ray spectroscopy, the improvement in capability is roughly three orders of magnitude. One thing that I find particularly pleasing is that these complementary missions are, respectively, primarily U.S., European, and Japanese in origin, so this is truly an international armada.

In other areas, FUSE is now up and working well in the UV, HETE-2 and possibly SWIFT will attack the gamma-ray burst phenomenon with new intensity in the near future. SIRTF, Integral, and GLAST are moving forward, and advanced technology development is underway for NGST and Constellation-X. Since particle acceleration is a topic of this meeting, I also want to mention my colleague Sam Ting's Alpha Magnetic Spectrometer experiment which had a successful test flight on the Shuttle and will eventually be installed on the International Space Station.

There are also significant advances in ground-based facilities relevant to the study of energetic processes in astrophysical plasmas. There is the VLT, Keck I and II, Gemini, Magellan, ALMA, the new international fusion of efforts in millimeter-wave astronomy, and the AUGER project to study the highest energy cosmic rays. There are also new instrumentation and capabilities, such as interferometry and adaptive optics, which Gene Parker already noted were very important for solar observations.

I'm sure I've forgotten some relevant missions or projects, for which I apologize, but this is a mind-boggling list already.

The major challenge to all of us, of course, is how to make the best use of this stunning array of new tools (which, I note, also represents quite a significant

fraction of the research budgets of the participating nations). Most of the observations, initially at least, will involve redoing things that were done previously, but now with much enhanced sensitivity, angular resolution, spectral resolution, temporal resolution, or some combination of all the above. However, making the best use of these facilities will also require us to work smarter. One thing we have not yet figured out how to do easily, for example, is multiwavelength observations that require multiple facilities, whether simultaneous or not. The proposal and scheduling mechanisms discourage such coordination. Another is how best to do spectral imaging or spectral timing—we need improved analysis tools that deal with such multidimensional data "cubes". Several speakers at this meeting have expressed the need for such data, but if the data were here today, it's not clear to me we'd have the analysis tools to make the most of it.

The challenge for theorists is to make the best connection to the kinds of observations that will be performed with these new instruments. Theorists need to help us identify the key diagnostics that will test the various models and hypotheses presented over the past few days, or that might suggest new ones.

My last comment is about this meeting. As an X-ray spectroscopist, I have always looked to areas like solar physics and laboratory plasma physics to learn things that are relevant to the cosmic plasmas I was trying to study, so I've been to quite a few meetings that tried to do what has been done here. At those times I was often reminded of Winston Churchill's comment that the United States and the United Kingdom were two countries "divided by a common language". Too often the astronomers and physicists in these various disciplines were similarly divided by their common equations and talked past each other, not with one other.

I think this meeting might well be a watershed in the development of plasma astrophysics. The presentations here showed much clearer connections than I've ever seen before between, say, phenomena in the sun and the processes thought to be important in accretion around compact objects, in interstellar or supernova shock waves, or in the diffuse plasmas of galaxies and clusters. It's not easy to accomplish this kind of cross-cultural communication, to leave the comfort of your own subdiscipline, but we have made a new start here. It is especially encouraging to think that the younger attendees at this meeting, being exposed to this at an early point in their careers, might find it natural.