Response to Request for Information: NNH12ZDA008L
Science Objectives and Requirements for the next NASA UV/Visible Astrophysics Mission Concepts

Richard Ignace
East Tennessee State University
Department of Physics & Astronomy
email: ignace@etsu.edu
phone: 423 439-6904

> This response to the RFI will emphasize the importance of times series studies and polarimetric capability for future NASA missions.

My own area of research concerns the general topic of stars, especially stellar winds and circumstellar disks, and have included objects such as the Wolf-Rayet stars, Luminous Blue Variables, O stars, Be stars, magnetic massive stars, and evolved cool giants and supergiants. I have been involved with multiwavelength studies of these objects, ranging from the X-ray band to the radio. I have been involved with awards of observing time that include Chandra, XMM-Newton, Suzaku, RXTE, FUSE, Spitzer, and ISO. (Ground-based efforts include data acquired with ESO's VLT, the CFHT, and the EVLA.)

Although the arena of theoretical and interpretive modeling is my primary focus, I am certainly involved in obtaining new data (as PI or co-I) and making use of archival data. As such, I have a vested interest in the strength of NASA's future plans for space-borne telescopes and associated funding programs.

In my, admittedly, narrow subdiscipline of circumstellar studies, the issue of "structure" in winds and disks has become of central importance of late. The clumping aspects of stellar winds has proven to be critical for obtaining better mass loss rates of massive stars, with consequences for understanding both stellar and galactic evolution. Magnetism of massive stars has matured greatly as a subfield. Detections are now regularly reported, and there have been significant successes from theory in explaining a number of phenomena associated with rotating magnetospheres and stellar winds (although it is clear that there is much work remaining).

Although the ability to obtain spectral energy distributions or high quality line profiles are and will continue to be important, another "style" of observing that has proven to be of immense scientific value and highly productive has been time series studies. A few examples would include:

- The Kepler and COROT missions for finding exoplanets along with the added benefit of variability studies (e.g., non-radial pulsations of B stars).
- Variability studies by the RXTE that have proven critical for our understanding of compact objects.

- CFHT and VLT studies of massive star magnetism. Although the presence of magnetism is achievable with a single detection of the Zeeman effect, characterizing the magnetic field strength and dipole orientation requires multiple spectra within a rotational phase.

The end result is that variability studies have been a mainstay of astronomical scientific investigation. No one contests this. Yet, my experience with proposing to programs such as Chandra, Spitzer, and others is the all-too-familiar threat that time-constrained observations will be frowned upon.

I understand that with advances in capability, there is much to be gained by looking at the most diverse set of sources possible. I also appreciate the challenges associated with efficient use of instrumentation when time-constrained observations are involved. However, we are now in the post-Great-Observatories era. (Yes, 3 of the 4 continue to operate, but this RFI is looking to the future.) As such, and being a researcher who straddles the line between theory and observing, I would like to emphasize the importance of having a program that encourages time series studies, especially in conjunction with reasonably high spectral resolution capability at UV and visible wavelengths. Such capability will prove crucial for addressing outstanding questions about stochastic (e.g., clumping) and ordered (e.g., corotating interaction regions, or "CIRs") structures in massive star winds, and shock physics in supersonic flows arising from physical instabilities, colliding winds in binary systems, or magnetically channeled flow. Similar considerations apply to other classes of stars, ranging from AGB types to young forming stars.

In addition to an emphasis given to time series studies, I also wish to advocate for polarimetric capability. I was the lead organizer for a conference entitled "Stellar Polarimetry: From Birth to Death" that was held in summer 2011 (proceedings now in print under Hoffman et al., 2012, AIP Conf. Proc.). That meeting certainly demonstrated the importance of photopolarimetry, spectropolarimetry, and imaging polarimetry for advancing our understanding of stellar astrophysics, ranging from forming stars through supernova and compact objects.

Unfortunately, polarization is a somewhat underutilized tool in astrophysical inquiry. There are some ground based facilities with polarimetric modes of operation. However, few NASA missions have included polarimetric instrumentation. WUPPE and WISP were small missions with a focus on UV polarimetry, but they have certainly been among the very few.

There is no doubt that polarimetric capability adds complexity to the instrument design, the reduction pipeline, and observing planning. Polarimetric capability also adds important new diagnostics for astrophysical inquiry, as evidenced for example by the NASA GEMS mission. Polarization can immediately reveal whether an unresolved source is essentially spherically symmetric or not. Using the Zeeman effect, circularly polarized lines are used to detect stellar magnetism. Time series studies of polarized radiation from stellar sources trace the time varying geometry of sources. Senstive to scattering and absorptive properties, polarization has long been important for interstellar studies and for understanding dust grains. Polarimetric data are important for studies of jets for AGN, for example because of polarized synchrotron emission. Faraday rotation is important to studies of interstellar magnetism. Polarization could also one day prove to be key in studies of exoplanets. And of course polarization has recently been prominent in cosmological studies of the cosmic background radiation.

NASA has been successful in pushing to make as many wavebands accessible for astronomical study as possible. Often, the goal is to go fainter (generally accompanied by better spatial resolution), which usually means being able to detect things that are either more distant, less luminous, or having lower surface brightness. The inclusion of polarimetric capability is less about opening a new waveband than of providing new leverage on old wavebands through the powerful diagnostics of linear and circular polarization. I simply want to make the point that the quest to go fainter is not the only way to advance the astrophysical sciences, and that polarimetry has broad appeal to the astrophysical community.