WFIRST and the Astronomical Landscape of the 2020s

D. Law, dlaw[at]stsci.edu, M. S. Peeples, molly[at]stsci.edu, and K. M. Gilbert, kgilbert[at]stsci.edu

Abstract

The *Wide Field Infrared Survey Telescope* (*WFIRST*), a NASA mission in formulation for launch in the mid-2020s, will provide a powerful tool for exploration and discovery. In June 2017, the Institute hosted a workshop that brought together scientists interested in exploring the big questions in astrophysics that will be addressed by *WFIRST* and other major astronomical facilities of the 2020s. Opportunities for synergies between the facilities of the next decade were identified over a broad range of astrophysics.

WFIRST at the Institute

WFIRST will provide fundamental new constraints on our understanding of dark energy and extra-solar planets, as well as many topics in general astrophysics. *WFIRST* will have a 2.4-meter-diameter primary mirror and will carry two instruments: a Wide Field Instrument (WFI), which will obtain photometry and spectra in the near-infrared (0.5–2.0 microns) with a field of view 100 times that of *Hubble,* and a Coronagraph Instrument (CGI) which will operate in the 0.4–1.0 micron range and reach contrast levels several orders of magnitude better than currently reached with ground- or space-based observatories*.* *WFIRST* will combine dedicated surveys with a Guest Observer program. Both the surveys and Guest Observer programs will provide a wealth of data for archival Guest Investigator programs.

The Institute is one of the Science Operations Centers for *WFIRST*. The Institute will schedule and archive all *WFIRST* observations, and will calibrate and produce pipeline-reduced data products for the WFI (**www.stsci.edu/wfirst**). Additional *WFIRST* information can be found on the websites of our partners at GSFC (**wfirst.gsfc.nasa.gov/**) and IPAC (wfirst.ipac.caltech.edu/).

Future Synergies with *WFIRST*

In June 2017, the Institute hosted a meeting dedicated to exploring the scientific reach of *WFIRST* in the evolving astronomical landscape. At this conference, *Astronomy in the 2020s: Synergies with WFIRST* (**stsci.edu/~dlaw/WFIRST2020s/**), participants spent three days discussing how today's cutting-edge topics are likely to evolve over the next ten years, and the best ways for *WFIRST* to work with other astronomical facilities to answer scientific questions. It was clear from these talks and conversations that *WFIRST*'s power lies not only in its novel design and survey strategies, but also in how its wealth of data will leverage new capabilities and complement its contemporary observatories.

An overarching theme from the meeting was that astronomy in the 2020's will have a high demand for systematic spectroscopic follow-up of sources detected photometrically by large-area imaging surveys such as *WFIRST*, the Large Synoptic Survey Telescope (LSST), and *Euclid*. Although the spectroscopic capabilities of *WFIRST* are considerable, there will be a strong need for a large-aperture *Webb* and/or Extremely Large Telescope (ELT) follow-up of individual objects ranging from spectroscopic confirmation of redshift z = 10–15 galaxy candidates (as discussed by Rychard Bouwens) to metallicities of microlensing events (as discussed by Scott Gaudi). Likewise, Leonidas Moustakas pointed out that while strong gravitational lenses in galaxy clusters will be found in

WFIRST's High Latitude Survey, high signal-to-noise spectroscopy from ground-based ELTs will be critical to determining the 3-d structure of these lens systems and maximizing their efficacy for learning about cosmology or the properties of the magnified background images. More broadly, massively-multiplexed, large area, moderate-to-high resolution spectroscopic follow-up of entire classes of new and exciting objects will also be a crucial aspect of astronomy in the 2020s. Although this general need has been recognized for some time, this meeting marked progress towards a potential practical implementation in the form of the Southern Spectroscopic Survey Instrument (SSSI) as discussed by Jeff Newman.

In the era of precision cosmology, systematics are the limiting factor in dictating the uncertainties of key cosmological parameters. The 2000s have shown us that the best constraints on these parameters combine multiple different methods. Supernova surveys (from the *WFIRST* Supernova Survey and LSST), weak gravitational lensing and baryon acoustic oscillation measurements (from the *WFIRST* High Latitude Survey, LSST, *Euclid*, and the Dark Energy Spectroscopic Instrument; DESI), and cosmic microwave background measurements from *Planck* will place different constraints on cosmological growth and structure. LSST project scientist Zeljko Ivezic pointed out that three of the major dark-energy focused surveys of the 2020s are highly complementary: the space-based *WFIRST* and *Euclid* will excel in image quality/depth and image quality/area respectively, while LSST will excel in depth/coverage area.

The cosmological surveys of the 2020s will largely be executing similar experiments from observations in overlapping fields. A potentially powerful possibility that was discussed by Peter Melchior is that of joint pixel processing, in which data from different facilities is jointly processed at the raw *pixel*-level (as opposed to the final catalog level) using probabilistic algorithms. Weak gravitational lensing measurements would benefit by calibrating out systematics owing to PSF variations and local optical distortions of different instruments. Such low-level data analysis coordination would have wide-ranging benefits, from aiding strong gravitational lens modeling to establishing priors on photometric deblending positions for exoplanet microlensing observations. Despite the potential strengths of such joint processing, the workshop identified significant challenges facing its implementation since it lies outside the funded mandate for each individual survey. Progress will require early coordination between involved parties encompassing data access, storage formats, and funding streams.

There was general agreement on the utility of overlap between *WFIRST* and *Webb*. Although *WFIRST* will only see to about the same depth as *Hubble*, its 100x larger area will allow us to catalog millions of galaxies out to $z \sim 6$ and beyond. With its enormous, but deep, extragalactic surveys, *WFIRST* will be ideal for finding targets suited for spectroscopic follow-up with *Webb*, such as supernovae and the brightest galaxies at the epoch of reionization. The redder wavelengths accessible with *Webb* will start to fill in and spectroscopically confirm the fainter galaxies in the cosmic web.

More locally, synergies with *WFIRST* have already begun: as shown by Robyn Sanderson, with *Hubble* providing a long baseline and *Gaia* offering a strong astrometric reference frame, *WFIRST* proper motions and ELT-based radial velocities will be able to constrain the 3-d motion of stars in the Milky Way and the Local Group, enabling the discovery and characterization of new halo substructures out to hundreds of kiloparsecs.

It was evident at the conference that the *WFIRST* coronagraph will have natural synergies with "narrow field" facilities from the ground. Al Wootten specifically called out the revolutions being made in the fields of protoplanetary disks with Atacama Large Millimeter/submillimeter Array (ALMA), which can now resolve individually cleared lanes in protoplanetary disks. In combination with *WFIRST* coronagraphic observations, this promises to greatly expand our understanding of the formation and evolution of planetary systems.

Videos of presentations from the conference *Astronomy in the 2020s: Synergies with WFIRST,* including those mentioned above, can be found in the Institute's webcast archive.

Summary

While *WFIRST* is powerful on its own, the takeaway message from the *Astronomy in the 2020s* meeting is that the power of any individual observatory can be magnified when combined and coordinated with the other major astronomical facilities of the 2020s. The challenge that lies before us now is to identify those areas in which it overlaps and complements other facilities, and design our programs, pipelines, and data archives in a manner that best leverages those synergies.

References

wfirst.gsfc.nasa.gov/

www.stsci.edu/wfirst

wfirst.ipac.caltech.edu/