WFIRST Science Investigation Teams And Adjutant Scientists

Selections made in response to solicitation NNH15ZDA001N-WFIRST
Program Officer: Dominic Benford
Selecting Official: Paul L. Hertz
Updated 5 January 2016

This documents the selected Science Investigation Teams (SITs) and Adjutant Scientist for the Wide-Field InfraRed Survey Telescope (WFIRST), which will result in the formation of a Formulation Science Working Group (FSWG) for the mission. Twelve proposals have been selected in whole or in part.

Investigations are selected addressing the following topical areas:

A. Galaxy Redshift Survey investigations, using baryon acoustic oscillation (BAO) and/or redshift space distortion (RSD) techniques;
B. Type Ia Supernovae (SNe Ia) investigations;
C. Weak Lensing and Cluster Growth investigations;
D. Exoplanet Microlensing investigations;
E. Exoplanet Coronagraphy investigations;
F. Guest Investigator (GI)/Guest Observer (GO) science: investigations using the archival data from the surveys conducted in support of the science investigations listed above and/or new observations with WFIRST, in order to optimize the science return from the GI/GO programs;
G. Adjutant Scientist position for the WFI (WAS)
H. Adjutant Scientist position for the CGI (CAS).

TITLE: COSMOLOGY WITH THE WFIRST HIGH LATITUDE SURVEY
TOPICS: A AND C

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SUMMARY OF INVESTIGATION:
Cosmic acceleration is the most surprising cosmological discovery in many decades. Testing and distinguishing among possible explanations requires cosmological measurements of extremely high precision that probe the full history of cosmic expansion and structure growth. The WFIRST-AFTA mission, as described in the Science Definition Team (SDT) reports (Spergel 2013, 2015), has the ability to improve these measurements by 1-2 orders of magnitude compared to the current state of the art, while simultaneously extending their

redshift grasp, greatly improving control of systematic effects, and taking a unified approach to multiple probes that provide complementary physical information and cross-checks of cosmological results.

We have assembled a team with the expertise and commitment needed to address the stringent challenges of the WFIRST dark energy program through the Project's formulation phase. After careful consideration, we have elected to address investigations A (Galaxy Redshift Survey) and C (Weak Lensing and Cluster Growth) of the WFIRST SIT NRA with a unified team, because the two investigations are tightly linked at both the technical level and the theoretical modeling level. The imaging and spectroscopic elements of the High Latitude Survey (HLS) will be realized as an integrated observing program, and they jointly impose requirements on instrument and telescope performance, operations, and data transfer. The methods for simulating and interpreting weak lensing and galaxy clustering observations largely overlap, and many members of our team have expertise in both areas.

The team PI, Olivier Dore, is a cosmologist with a broad expertise in cosmic microwave background and large scale structures. Yun Wang and Chris Hirata will serve as Lead Co-Investigators for Topics A and C, respectively. Many members of our team have been involved with the design and requirements of a dark energy space mission for a decade or more, including the Co-Chair and three additional members of the 2013-2015 WFIRST-AFTA SDTs. Our team includes authors of the two most comprehensive reviews of observational methods for probing dark energy (Wang 2010, Weinberg, ..., Hirata, 2013) and the Chair and Vice-Chair of the Astro2010 Science Frontier Panel on Cosmology and Fundamental Physics, whose report played a central role in the NWNH recommendation of WFIRST as the highest priority large space-based program. Our team of Co-Is includes world leading experts on image processing and weak lensing, on design and analysis of galaxy redshift surveys, on space-based slitless spectroscopy analogous to that planned for WFIRST, on photometric calibration, on photometric redshifts from large imaging surveys, on detector characterization, and on cosmological forecasting and parameter estimation from combinations of cosmic microwave background (CMB) and large scale structure (LSS) data or from combination of Galaxy Redshift Survey, Weak Lensing and Cluster Growth.

Through this team of co-Is, we have close connections to most of the major current or planned cosmological experiments that will provide the context for the WFIRST dark energy program, including the WMAP and Planck CMB missions, the Sloan Digital Sky Survey (SDSS), the Dark Energy Survey (DES), the Subaru Hyper-Suprime Camera (HSC) and Prime Focus Spectrograph (PFS) projects, the Dark Energy Spectroscopic Instrument (DESI), the Euclid mission and the LSST Dark Energy Science Collaboration. Our team of U.S. and international collaborators brings extensive expertise in cosmological simulations, detailed simulations of observational data sets, and the theoretical modeling and cosmological interpretation of weak lensing and galaxy clustering data.

TITLE: OPTIMIZING THE WFIRST TYPE IA SUPERNOVA SURVEY
TOPIC: B

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SUMMARY OF INVESTIGATION:
Observations of Type Ia supernovae (SN Ia) led to the discovery that the Universe's expansion is currently accelerating. WFIRST-AFTA is well positioned to provide a generation-defining measurement of the nature of dark energy through its multiple probes, with the WFIRST SN survey projected to have twice the impact as its other probes.

Our experienced team includes some of the original discoverers of the accelerating universe, two of the selected ROSES WFIRST preparatory science teams, and the key scientific expertise for the most current and precise SN cosmology results. Our expertise in SN cosmology, SN physics, space-based imaging and spectroscopy, and calibration provide the best foundation upon which a WFIRST SN SIT can be formed.

As dark energy is central to NASA's Physics of the Cosmos program, we directly address major objectives of NASA’s science program. Moreover, WFIRST is NASA's top priority in the next decade, and preparations now are critical for its eventual success.

We present a comprehensive plan to investigate multiple strategies for both optimization and risk mitigation. We have built a simulation framework based on publicly available tools for

these evaluations at no cost to this program. Our team has produced the first realistic, full end-to-end simulation of the DRM SN survey, finding that it is suboptimal. After a cursory search of the available parameter space, we were able to find alternative strategies that are significantly better than the DRM strategy.

Of course the most optimal strategy will depend on (1) our ability to properly calibrate our data, (2) the data analysis tools available, and (3) our understanding of astrophysical systematic uncertainties. We plan to use much of the next five years to develop strategies to properly calibrate our data, generate software to analyze data from the pixel level to cosmology, and further understand all systematic uncertainties. With the results of these investigations combined with an expanded survey strategy optimization and further knowledge of the WFIRST instrumentation, we will be able to suggest the best strategy for the WFIRST SN survey.

TITLE: INVESTIGATING THE NATURE OF DARK ENERGY USING TYPE IA SUPERNOVAE WITH WFIRST-AFTA SPACE MISSION
TOPIC: B

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SUMMARY OF INVESTIGATION:

Scientifically, the WFIRST supernova program is unique: it makes possible a dark energy measurement that no other space mission or ground-based project is addressing, a measurement that will set the standard in determining the expansion history of the universe continuously from low to high redshifts ($0.1 < z < 1.7$). In the context of the WFIRST Science

Definition Team several participants in this proposal have developed a first version of a supernova program, described in the WFIRST SDT Report. While this program was judged to be a robust one, and the estimates of the sensitivity to the cosmological parameters were felt to be reliable, due to limitations of time the analysis was clearly limited in depth on a number of issues. The objective of this proposal is to further develop this program. Technically this is the WFIRST measurement that arguably requires the most advanced project development, since it requires near-real-time analysis and follow-up with WFIRST, and since it is using the IFU spectrograph in the WFI package, the IFU being the WFIRST instrument that does not yet have a completely consistent set of specifications in the design iteration of the SDT report.

In this proposal for the WFIRST Scientific Investigation Team, focused primarily on the supernova dark energy measurements, we address these crucial technical needs by bringing the larger supernova community's expertise on the science elements together with a smaller focused team that can produce the specific deliverables. Thus the objectives of this 5 year proposal are the following:

1. Development of scientific performance requirements for the study of Dark Energy using Type Ia supernovae

2. Design an observing strategy using the Wide Field Instrument (WFI) and the Integral Field Spectrometer Unit (IFU)

3. Development of science data analysis techniques and data analysis software

4. Development of ground and space calibration requirements and estimating realistic correlated errors, both statistical and systematic

5. Development of simulations and data challenges to validate the above

6. Development of complete plans in coordination with WFIRST project, for all aspects of science simulations, precursor observations, ground calibration, observational needs, data processing, anciliary data collection/incorporation, analysis, dissemination and documentation of the proposed science investigation.

The 5 year program also intends to provide the following deliverables:

1. Documentation describing detailed scientific performance requirements
2. Documentation describing a design of an observing program
3. Documentation of science data analysis techniques
4. Simulations and data challenges to validate the above items
5. Algorithms used to perform processing of science data to serve as a basis for the WFIRST pipeline

To achieve these objectives the plan is to set up a Supernova Project Office, seven Supernova Working Groups, and two Supernova Software Deliverables Teams.

During the recent years of work with the Science Definition Team, it has been clear that the WFIRST Project Office requires a continuous series of scientific answers to the stream of design and requirements questions that arise in the development of the mission. One of the highest priorities of the Supernova Project Office will be to coordinate with the WFIRST Project Office and be the one-stop-shopping source of answers to such questions.

The second topic of this proposal is Weak Lensing (WL). The intrinsic broad wavelength coverage and excellent flux calibration of the IFU spectra will provide an important training for the photometric redshift measurements, beyond what is possible from the ground, required for the WL survey. At this time the IFU design details are not fully developed, and our studies will ensure that the WL photo-z requirements are folded into a realistic final IFU design.

TITLE: PREPARING FOR THE WFIRST MICROLENSING SURVEY: SIMULATIONS, REQUIREMENTS, SURVEY STRATEGIES, AND PRECURSOR OBSERVATIONS
TOPIC: D

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SUMMARY OF INVESTIGATION:

As one of the four primary investigations of the Wide Field Infrared Survey Telescope (WFIRST) mission, the microlensing survey will monitor several square degrees of the Galactic bulge for a total of roughly one year. Its primary science goal is to "Complete the statistical census of planetary systems in the Galaxy, from the outer habitable zone to free floating planets, including analogs of all of the planets in our Solar System with the mass of Mars or greater."

WFIRST will therefore (a) measure the mass function of cold bound planets with masses greater than that of roughly twice the mass of the moon, including providing an estimate of the frequency of sub-Mars-mass embryos, (b) determine the frequency of free-floating planets with masses down to the Earth and below, (c) inform the frequency and habitability of potentially habitable worlds, and (d) revolutionize our understanding of the demographics of cold planets with its exquisite sensitivity to, and large expected yield of, planets in a broad and unexplored region of parameter space.

In order for the microlensing survey to be successful, we must develop a plan to go from actual survey observations obtained by the WFIRST telescope and hardware to the final science products. This plan will involve many steps, the development of software, data reduction, and analysis tools at each step, and a list of requirements for each of these components.

The overarching goal of this proposal is thus to develop a complete flowdown from the science goals of the microlensing survey to the mission design and hardware components. We have assembled a team of scientists with the breadth of expertise to achieve this primary goal. Our specific subgoals are as follows.

Goal 1: We will refine the input Galactic models in order to provide improved microlensing event rates in the WFIRST fields.

Goal 2: We will use the improved event rate estimates, along with improvements in our simulation methodology, to provide higher-fidelity estimates of the science yield of bound planets, free floating planets, and potentially habitable planets.

Goal 3: We will perform trade studies to determine the effect of different mission architectures on the yield, and optimization studies to determine the effect of different survey strategies on the yield within a given mission architecture. These studies will include considerations of the field location, number of fields and cadences, and filter properties and filter cadence choices.

Goal 4: We will determine the precision with which the parameters of the detected planetary systems can be determined using all available constraints, and in particular provide the survey strategies and instrument requirements to enable the measurement host star masses and distances.

Goal 5: We will determine the hardware, software, and calibration requirements needed to achieve our primary science goals.

Goal 6: We will identify and carry out (where possible) precursor observations needed to inform our survey strategy and data reduction methodologies, verify our science output, and maximize the WFIRST scientific return.

Goal 7: Where applicable, we will begin development of data reduction and analysis tools, and work with members of the WFIRST Science Centers to ensure that these tools are applicable to microlensing. We will issue data challenges, both to verify our methodologies, but also to draw people to the microlensing field.

TITLE: OPTIMIZING WFIRST CORONAGRAPH SCIENCE
TOPIC: E

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SUMMARY OF INVESTIGATION:
We propose an in-depth scientific investigation that will define how the WFIRST coronagraphic instrument will discover and characterize nearby planetary systems and how it will use observations of planets and disks to probe the diversity of their compositions, dynamics, and formation.

Given the enormous diversity of known planetary systems it is not enough to optimize a coronagraph mission plan for the characterization of solar system analogs. Instead, we must design a mission to characterize a wide variety of planets, from gas and ice giant planets at a range of separations to mid-sized planets with no analogs in our solar system. We must consider updated planet distributions based on the results of the Kepler mission, long-term radial velocity (RV) surveys and updated luminosity distributions of exo-zodiacal dust from interferometric thermal infrared surveys of nearby stars. The properties of all these objects must be informed by our best models of planets and disks, and the process of using WFIRST observations to measure fundamental planetary properties such as composition must derive from rigorous methods.

Our team brings a great depth of expertise to inform and accomplish these and all of the other tasks enumerated in the SIT proposal call. We will perform end-to-end modeling that starts with model spectra of planets and images of disks, simulates WFIRST data using these models, accounts for geometries of specific star / planet / disk systems, and incorporates detailed instrument performance models. We will develop and implement data analysis techniques to extract well-calibrated astrophysical signals from complex data, and propose observing plans that maximize the mission's scientific yield. We will work with the community to
build observing programs and target lists, inform them of WFIRSTs capabilities, and supply simulated scientific observations for data challenges.

Our work will be informed by the experience we have gained from building and observing with high contrast, ground-based, exoplanet imaging instruments (GPI, SCExAO), working with prototype WFIRST CGI coronagraphs, and developing wavefront control algorithms. We are already discovering and interpreting the spectra of exoplanets around nearby stars with these systems and will apply the many lessons learned to our WFIRST work. Our previous experiences managing large instrumental and scientific collaborations, working on JWST, and as members of the WFIRST-AFTA, Exo-C, Exo-S, and TPF-C science definition teams will allow us to work closely with the project to provide all required deliverables in a timely, efficient and complete manner. Ultimately, we will ensure that the needed elements are in place to make WFIRST-CGI a revolutionary scientific instrument.

TITLE: HARNESSING THE POWER OF THE WFIRST-CORONAGRAPH: A COORDINATED PLAN FOR EXOPLANET AND DISK SCIENCE
TOPIC: E

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SUMMARY OF INVESTIGATION:

We propose to form a WFIRST Coronagraph Science Investigation Team (WFIRST-C SIT) for the purpose of defining the coronagraph scientific performance requirements, designing an exoplanet and debris disk observing program, and developing data analysis techniques including faint source detection and spectral retrieval. Our team will accomplish these tasks by:

1. Providing detailed characterization of the candidate target stars in terms of stellar/substeller companions, circumstellar debris, and astrophysical background in order to inform the final target selection by the community. As part of this effort, we will make a plan for coordination between WFIRST and Large Binocular Telescope Interferometer (LBTI) target selection, to obtain both scattered light and thermal emission observations of exozodiacal dust in the same systems. This will be important precursor science for future exoEarth direct imaging missions.

2. Creating simulated spatial-spectral data cubes representative of what the WFIRST coronagraph may see around the candidate targets, including known and hypothetical exoplanets, dynamically consistent interplanetary dust distributions, and astrophysical background contamination. The code framework to make the high-fidelity input models exists within our team, and we currently have a complete spectral data cube that allows us to generate images at any wavelength between 0.3 microns and 2.5 microns. To generate the

simulated datasets for WFIRST, we will make use of instrument simulation tools provided by the coronagraph design team, spanning the range of expected coronagraph performance characteristics. We will also add functionality to these tools, or build our own, as required.

3. Designing and conducting a “blind retrieval challenge” study to distribute these data amongst source detection and spectral modeling teams in the exoplanet and wider astrophysics community. Given the variety of sources expected in each planet-finding field, we expect that Galactic and extra-galactic astrophysicists may be called upon to aid exoplanet scientists in this venture. We will compile the submitted results of the blind analyses, and we will assess their findings in comparison to the original input data.

4. Assessing the scientific yield from all the science programs under different target prioritization schemes. We will also assess the scientific yield that would be offered by combining an initial coronagraphic survey with follow-up characterization observations obtained with a WFIRST starshade.

5. Using the blind study and yield assessment results to inform the WFIRST coronagraph and IFS calibration, operational, and data processing requirements.

The results of this community-wide blind study are expected to be pivotal in designing a uniquely capable WFIRST exoplanet and disk imaging mission, especially through (1) motivating the community to develop improved analysis techniques and (2) providing a conduit for feedback from the community on observational procedures.

TITLE: WFIRST EXTRAGALACTIC POTENTIAL OBSERVATIONS (EXPO) SCIENCE INVESTIGATION TEAM
TOPIC: F

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SUMMARY OF INVESTIGATION:

The Wide-Field InfraRed Survey Telescope (WFIRST) holds tremendous promise as a space observatory for extragalactic astrophysics beyond cosmological surveys. The WFIRST Extragalactic Potential Observations (EXPO) Science Investigation Team will identify the most pressing and scientifically compelling Guest Investigator and Guest Observer projects with WFIRST to address a range of exciting outstanding issues in galaxy formation, from the epoch of reionization to galaxy-galaxy lensing, the discovery of exotic supernovae and luminous active galaxies, and charting the chemical evolution of galaxies. The identified EXPO GI projects will help maximize the scientific return of the WFIRST cosmological surveys, and supply innovative ideas and methods for archival research that leverages the WFIRST dataset. The EXPO team will also evaluate the science payoff of translating previous successful space telescope surveys to the era of WFIRST, helping us to realize the full power of WFIRST for extragalactic astronomy through the competed GO programs. The WFIRST-EXPO team consists of world-wide experts in designing and executing space-based extragalactic programs, multi-object spectroscopic campaigns in the optical and infrared, and theoretical modeling of galaxy formation, exotic supernovae, and reionization.

In support of WFIRST before Critical Design Review, WFIRST-EXPO will 1) develop and publicly release tools to generate mock catalogs for planning extragalactic astrophysics investigations with the HLS (GI) and GO community programs, 2) simulate images for modeling medium- and ultra-deep extragalactic GO programs, 3) develop and publicly release work flows for planning and evaluating the science return of potential extragalactic GI/GO programs, 4) perform case studies of medium- and ultra-deep imaging and spectroscopic GO/GI programs, 5) evaluate WFIRST design choices that influence extragalactic science

return, and 6) serve as liaisons to James Webb Space Telescope, Large Synoptic Survey Telescope, Thirty Meter Telescope /Giant Magellan Telescope / European-Extremely Large Telescope, Subaru/Prime Focus Spectrogram, Atacama Large Millimeter/sub-millimeter Array, and 21cm experiments for coordinating synergistic WFIRST surveys for extragalactic astrophysics.

The work conducted and products delivered by WFIRST-EXPO are of central importance in helping WFIRST develop as a premier observatory for broad astrophysical research. The focus of WFIRST-EXPO is on establishing the capabilities of WFIRST to serve both as a GO facility for conducting astrophysical investigations and as an essential archival resource for GI programs. These objectives are closely aligned with the WFIRST Science Investigation Team solicitation and mirror broader NASA goals for advancing astrophysical research through spaced-based facilities.

TITLE: WINGS: WFIRST INFRARED NEARBY GALAXY SURVEY
TOPIC: F

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SUMMARY OF INVESTIGATION:

WFIRST's combination of wide field and high resolution will revolutionize the study of nearby galaxies. We propose to produce and analyze simulated WFIRST data of nearby galaxies and their halos to maximize the scientific yield in the limited observing time available, ensuring the legacy value of WFIRST's eventual archive. We will model both halo structure and resolved stellar populations to optimize WFIRST's constraints on both dark matter and galaxy formation models in the local universe.

WFIRST can map galaxy structure down to ~35 mag/square arcsecond using individual stars. The resulting maps of stellar halos and accreting dwarf companions will provide stringent tests of galaxy formation and dark matter models on galactic (and even sub-galactic) scales, which is where the most theoretical tension exists with the Lambda-CDM model. With a careful, coordinated plan, WFIRST can be expected to improve current sample sizes by 2 orders of magnitude, down to surface brightness limits comparable to those currently reached only in the Local Group, and that are >4 magnitudes fainter than achievable from the ground due to limitations in star-galaxy separation.

WFIRST's maps of galaxy halos will simultaneously produce photometry for billions of stars in the main bodies of galaxies within 10 Mpc. These data will transform studies of star formation histories that track stellar mass growth as a function of time and position within a galaxy. They also will constrain critical stellar evolution models of the near-infrared bright, rapidly evolving stars that can contribute significantly to the integrated light of galaxies in the near-infrared. Thus, with WFIRST we can derive the detailed evolution of individual galaxies, reconstruct the complete history of star formation in the nearby universe, and put crucial constraints on the theoretical models used to interpret near-infrared extragalactic observations.

We propose a three-component work plan that will ensure these gains by testing and optimizing WFIRST observing strategies and providing science guidance to trade studies of observatory requirements such as field of view, pixel scale and filter selection. First, we will perform extensive simulations of galaxies' halo substructures and stellar populations that will be used as input for optimizing observing strategies and sample selection. Second, we will develop a pipeline that optimizes stellar photometry, proper motion, and variability measurements with WFIRST. This software will: maximize data quality & scientific yield; provide essential, independent calibrations to the larger WFIRST efforts; and rapidly provide accurate photometry and astrometry to the community. Third, we will derive quantitative performance metrics to fairly evaluate trade-offs between different survey strategies and WFIRST performance capabilities. The end result of this effort will be: (1) an efficient survey strategy that maximizes the scientific yield of what would otherwise be a chaotic archive of observations from small, un-coordinated programs; (2) a suite of analysis tools and a state-of-the-art pipeline that can be deployed after launch to rapidly deliver stellar photometry to the public; (3) a platform to independently verify the calibration and point spread function modeling that are essential to the primary WFIRST goals, but that are best tested from images of stellar populations.

These activities will be carried out by a Science Investigation Team that has decades of experience in using nearby galaxies to inform fundamental topics in astrophysics. This team is composed of researchers who have led the charge in observational and theoretical studies of resolved stellar populations and stellar halos. With our combined background, we are poised to take full advantage of the large field of view and high spatial resolution WFIRST will offer.

TITLE: ARCHIVAL RESEARCH CAPABILITIES OF THE WFIRST DATA SET
TOPIC: F

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SUMMARY OF INVESTIGATION:

WFIRST's unique combination of a large (~0.3 deg^2) field of view and HST-like angular resolution and sensitivity in the near infrared will produce spectacular new insights into the origins of stars, galaxies, and structure in the cosmos. We propose a WFIRST Archive Science Investigation Team (SIT-F) to define an archival, query, and analysis system that will enable scientific discovery in all relevant areas of astrophysics and maximize the overall scientific yield of the mission. Guest investigators (GIs), guest observers (GOs), the WFIRST SIT's, WFIRST Science Center(s), and astronomers using data from other surveys will all benefit from the extensive, easy, fast and reliable use of the WFIRST archives.

We propose to develop the science requirements for the archive and work to understand its interactions with other elements of the WFIRST mission. To accomplish this, we will conduct case studies to derive performance requirements for the WFIRST archives. These will clarify what is needed for GIs to make important scientific discoveries across a broad range of astrophysics. While other SITs will primarily address the science capabilities of the WFIRST instruments, we will look ahead to the science enabling capabilities of the WFIRST archives. We will demonstrate how the archive can be optimized to take advantage of the extraordinary science capabilities of the WFIRST instruments as well as major space and ground observatories to maximize the science return of the mission.

We will use the "20 queries" methodology, formulated by Jim Gray, to cover the most important science analysis patterns and use these to establish the performance required of the

WFIRST archive. The case studies will be centered on studying galaxy evolution as a function of cosmic time, environment and intrinsic properties. The analyses will require massive angular and spatial cross correlations between key galaxy properties to search for new fundamental scaling relations that may only become apparent when exploring a database of 108 galaxies with multiband photometry and grism spectroscopy.

The case studies will require (i) the creation of a unified WFIRST object catalog consisting of data cross-matched to external catalogs, (ii) an easy-to-access, scalable database, utilizing the latest data discovery and querying techniques, (iii) in situ analyses of large and/or complex data, (iv) identification of links to supporting data and enabling queries spanning WFIRST and other databases, (v) combining simulations with modeling software. To accomplish these objectives, we will prototype a system capable of executing complex user-defined scripts including database access to a shared computational facility with tools for joining WFIRST to other surveys, also enabling comparisons to physical models.

Our organizational plan divides the work into several general areas where our team members have specific expertise: (a) apply the 20 queries methodology to derive performance and functionality requirements, (b) develop a practical interactive server-side query system, built on our SDSS experience, (c) apply advanced cross-matching techniques, (d) create mock WFIRST imaging and grism data, (e) develop high level cross correlation tools, (e) optimize scripting systems using high-level languages (iPython), (f) perform close integration of cosmological simulations with observational data, (g) apply advanced machine learning techniques.

Our efforts will be coordinated with the WFIRST Science Center (WSC), the other SITs, and the broader community in a manner consistent with direction and review of the Project Office. We will publish our results as milestones are reached, and issue progress reports on a regular basis. We will represent SIT-F at all relevant meetings including meetings of the other SITs (SITs A-E), and participate in "Big Data" conferences to interact with others in the field and learn new techniques that might be applicable to WFIRST.

TITLE: COSMIC DAWN WITH WFIRST
TOPIC: F

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SUMMARY OF INVESTIGATION:
Central objectives: WFIRST-AFTA has tremendous potential for studying the epoch of "Cosmic Dawn" the period encompassing the formation of the first galaxies and quasars, and their impact on the surrounding universe through cosmological reionization. Our goal is to ensure that this potential is realized through the middle stages of mission planning, culminating in designs for both WFIRST and its core surveys that meet the core objectives in dark energy and exoplanet science, while maximizing the complementary Cosmic Dawn science.

Methods: We will consider a combined approach to studying Cosmic Dawn using a judicious mixture of guest investigator data analysis of the primary WFIRST surveys, and a specifically designed Guest Observer program to complement those surveys. The Guest Observer program will serve primarily to obtain deep field observations, with particular attention to the capabilities of WFIRST for spectroscopic deep fields using the WFI grism. We will bring to bear our years of experience with slitless spectroscopy on the Hubble Space Telescope, along with an expectation of JWST slitless grism spectroscopy. We will use this experience to examine the implications of WFIRST's grism resolution and wavelength coverage for deep field observations, and if appropriate, to suggest potential modifications of these parameters to optimize the science return on WFIRST.

We have assembled a team of experts specializing in (1) Lyman Break Galaxies at redshifts higher than 7 (2) Quasars at high redshifts (3) Lyman-alpha galaxies as probes of reionization (4) Theoretical simulations of high-redshift galaxies (5) Simulations of grism observations (6) post-processing analysis to find emission line galaxies and high redshift galaxies (7) JWST observations and calibrations. With this team we intend to do end-to-end simulations starting

with halo populations and expected spectra of high redshift galaxies and finally extracting what we can learn about (a) reionization using the Lyman-alpha test (b) the sources of reionization - both galaxies and AGN and (c) how to optimize WFIRST-AFTA surveys to maximize scientific output of this mission.

Along the way, we will simulate the galaxy and AGN populations expected beyond redshift 7, and will simulate observations and data analysis of these populations with WFIRST.

Significance of work: Cosmic Dawn is one of the central pillars of the “New Worlds, New Horizons” decadal survey. WFIRST’s highly sensitive and wide-field near-infrared capabilities offer a natural tool to obtain statistically useful samples of faint galaxies and AGN beyond redshift 7. Thus, we expect Cosmic Dawn observations will constitute a major component of the GO program ultimately executed by WFIRST. By supporting our Science Investigation Team to consider the interplay between the mission parameters and the ultimate harvest of Cosmic Dawn science, NASA will help ensure the success of WFIRST as a broadly focused flagship mission.

TITLE: RESOLVING THE MILKY WAY WITH WFIRST
TOPIC: F

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SUMMARY OF INVESTIGATION:
High-resolution studies of nearby stellar populations have served as a foundation for our quest to understand the nature of galaxies. Today, studies of resolved stellar populations constrain fundamental relations – such as the initial mass function of stars, the time scales of stellar evolution, the timing of mass loss and amount of energetic feedback, the color-magnitude relation and its dependency on age and metallicity, the stellar-dark matter connection in galaxy halos, and the build up of stellar populations over cosmic time -- that represent key ingredients in our prescription to interpret light from the Universe and to measure the physical state of galaxies.

More than in any other area of astrophysics, WFIRST will yield a transformative impact in measuring and characterizing resolved stellar populations in the Milky Way. The proximity and level of detail that such populations need to be studied at directly map to all three pillars of WFIRST capabilities - sensitivity from a 2.4 meter space based telescope, resolution from 0.1″ pixels, and large 0.3 degree field of view from multiple detectors.

Our WFIRST GO Science Investigation Team (F) will develop WFIRST (notional) GO programs related to resolved stellar populations to fully stress WFIRST's Wide Field Instrument. The programs will include surveys of key sightlines in the Milky Way center, disk and star forming regions, star clusters, and the stellar halo populations including newly discovered substructure and Ultra Faint Dwarf galaxies from the High Latitude Survey. Specific science goals for each survey will be validated through a wide range of observational data sets, simulations, and new algorithms. As an output of this study, our team will deliver optimized strategies and tools to maximize stellar population science with WFIRST. This will include: new grids of IR-optimized stellar evolution and synthetic spectroscopic models; pipelines and algorithms for optimal data reduction at the WFIRST sensitivity and pixel scale; wide field simulations of MW environments including new astrometric studies; strategies and automated algorithms to find substructure and dwarf galaxies in the Milky Way through the WFIRST High Latitude Survey; and documentation.

Our team will work closely with the WFIRST Science Center to translate our notional programs into inputs that can help achieve readiness for WFIRST science operations. This includes building full observing programs with target definitions, observing sequences, scheduling constraints, data processing needs, and calibration requirements.

Our team has been chosen carefully. Team members are leading scientists in stellar population work that will be a core science theme for WFIRST and are also involved in all large future astronomy projects that will operate in the WFIRST era. The team is intentionally small, and each member will "own" significant science projects. The team will aggressively advocate for WFIRST through innovative initiatives. The team is also diverse in geographical location, observers and theorists, and gender.

TITLE: WIDE FIELD INSTRUMENT ADJUTANT SCIENTIST
TOPIC: G

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SUMMARY OF INVESTIGATION:
As Wide Field Instrument Adjutant Scientist, my goal will be to maximize the science capability of the mission in a cost-contained environment. I hope to work with the HQ, project and the FSWG to assure mission success. I plan to play a leadership role in communicating the WFIRST science capabilities to the astronomy community , obtain input from both science teams and the broader community that help derive performance requirements and calibration metrics. I plan to focus on developing the observing program for the deep fields and focus on using them to calibrate instrument performance and capabilities. I plan to organize workshops that will bring together WFIRST team members with astronomers working on LSST, Euclid, JWST, and the ELTs to maximize combined science return. I am also eager to explore the astrometric and stellar seismology capabilities of the instrument with a goal of maximizing science return without affecting science requirements.

TITLE: WFIRST CGI ADJUTANT SCIENTIST
TOPIC: H

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SUMMARY OF INVESTIGATION:
One of the most exciting developments in exoplanet science is the inclusion of a coronagraph instrument on WFIRST. After more than 20 years of research and development on coronagraphy and wavefront control, the technology is ready for a demonstration in space and to be used for revolutionary science. Good progress has already been made at JPL and partner institutions on the coronagraph technology and instrument design and test. The next five years as we enter Phase A will be critical for raising the TRL of the coronagraph to the needed level for flight and for converging on a design that is robust, low risk, and meets the science requirements. In addition, there is growing excitement over the possibility of rendezvousing an occulter with WFIRST/AFTA as a separate mission; this would both demonstrate that important technology and potentially dramatically enhance the science reach, introducing the possibility of imaging Earth-like planets in the habitable zone of nearby stars. In this proposal I will be applying for the Coronagraph Adjutant Scientist (CAS) position. I bring to the position the background and skills needed to be an effective liaison between the project office, the instrument team, and the Science Investigation Team (SIT). My background in systems engineering before coming to Princeton (I was Chief Systems Engineer for the Gravity Probe-B mission) and my 15 years of working closely with NASA on both coronagraph and occulter technology make me well-suited to the role. I have been a lead coronagraph scientist for the WFIRST mission from the beginning, including as a member of the SDT. Together with JPL and NASA HQ, I helped organize the process for selecting the coronagraphs for the CGI, one of which, the shaped pupil, has been developed in my lab. All of the key algorithms for wavefront control (including EFC and Stroke Minimization) were originally developed by students or post-docs in my lab at Princeton. I am thus in a unique position to work with both the scientists and engineers to coordinate the performance requirements and calibration metrics and to optimize the instrument to achieve the maximal scientific output. I am also one of the few engineers/scientists in the community to research both coronagraph and occulter technology. I have been PI on all of the leading Technology Development for Exoplanet Missions (TDEM) for occulters as well as being a member of the Exo-S study. This puts me in a unique position to be able to fulfill the role of CGI adjutant scientist as well as ensure that the WFIRST/AFTA spacecraft is "occulter ready" in anticipation of a decadal review. For much of my career I have straddled the boundary between science and engineering, working closely with astronomers and physicists on key technology to enable world-class science. I am enthusiastic about bringing that experience to the CAS position. I also have proven communication and leadership skills that will allow me to fulfill the duties associated with enhancing the communication between the SIT and FSWG and the instrument team, to coordinate and lead the FSWG meetings, and to interact with the astronomical community and the WFIRST Science Center.