Massive Space Spectroscopy (MaSSpec) Astrophysics

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Overview:

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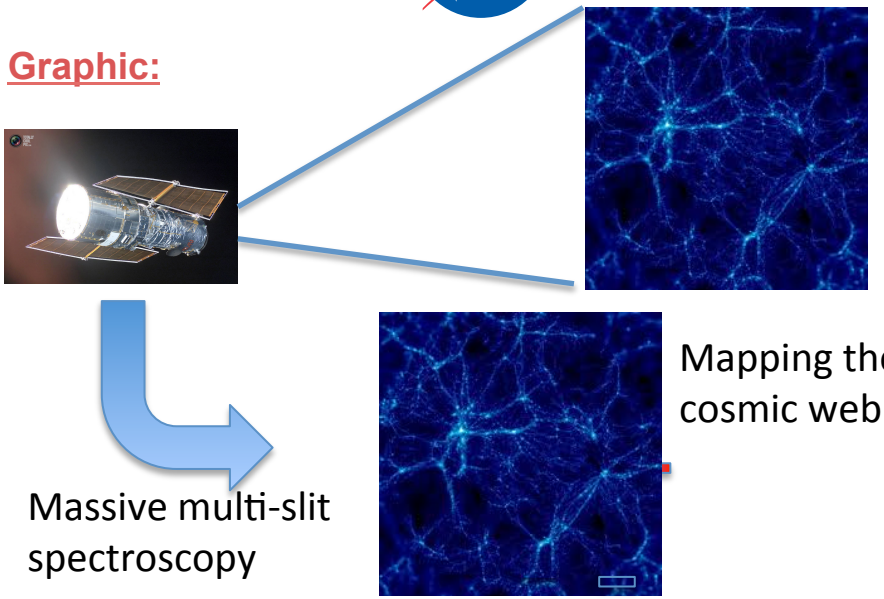
Key collaborators

Short list of goals of the proposed concept

- ❑ Comprehensive multi-slit spectroscopic survey of galaxies to redshift z~2-3
- ❑ Mapping the cosmic webs of mass and galaxies and their relation
- ❑ Comprehensive survey of galaxy properties (stellar mass, SFR, etc) out beyond redshift unity
- ❑ Census of galaxy clusters and their dynamics to redshifts beyond unity
- ❑ Galactic structure and dynamics

Graphic:



Description:

Briefly describe the concept, implementation and operations approach.

- ❑ *Wide-field, massively parallel multi-slit spectroscopy*
- ❑ *Masks enabled by micro-devices*
- ❑ *Wide-area, high-density, medium- to high-resolution spectroscopic surveying*

What observations/tests will be carried out?

- ❑ *Large-area galaxy survey to ~15 gals/sq arcmin, Galactic stars at 17-20 mag and local group sources.*

Identify and describe the readiness level of key technologies.

- ❑ *Micro-shutter technology utilized for NIRspec.*

Identify external collaboration opportunities and dependencies.

- ❑ *Redshift/velocity follow-up of LSST, WFIRST, Euclid and GAIA sources*

Identify proposed utilization of human exploration capabilities: *None*

Value to NASA:

What are the benefits of the proposed concept?

- ❑ *More comprehensive galaxy survey than possible with slit-less spectroscopy, and Galactic stellar spectroscopy and velocities*
- ❑ *Enhance science return from WFIRST, LSST, Euclid and GAIA*
- ❑ *Complement JWST NIRspec deep spectroscopy*

How does this concept advance Agency objectives across science, technology and human exploration?

- ❑ Advance understanding of cosmic structure and galaxy formation
- ❑ Advance understanding of Galactic structure
- ❑ Use of micro-shutter/micro-device technology to achieve new science goals

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MASSIVE SPACE SPECTROSCOPY (MASSPEC)

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Primary Concept Goal Category: Astrophysics

Abbreviated Concept Summary: We propose a high-throughput wide-field spectrograph with masks based on micro-shutter, digital micro-devices or equivalent technology. The instrument will be a natural complement to large-area imaging surveys, such as the Wide Field Infrared Survey Telescope (WFIRST), the Large Synoptic Survey Telescope (LSST) and Euclid, and it will overcome the severe limitations of slit-less spectroscopy currently proposed for WFIRST and Euclid. This will enable important advances in the fields of cosmology, structure formation, galaxy evolution and Galactic structure.

Goal of the Proposed Application: As reflected in the *New Worlds, New Horizons* Astronomy and Astrophysics 2010 Decadal Survey, large mission preparation is heavily focused on ambitious imaging surveys and on redshift surveys based on slit-less spectroscopy, with the primary aim of probing the nature of dark energy (e.g., WFIRST, LSST and Euclid). The present concept proposes to explore the possibility of implementing the natural complement, namely a high-throughput, massively parallel multi-slit spectroscopic observatory. Such a mission would enable qualitatively new Galactic and extragalactic science:

• *Combined mapping of the cosmic mass, galaxy and velocity fields out to redshifts beyond unity*: Spectroscopic redshifts for the majority of objects imaged by Euclid and the Dark Energy Survey (DES), and a high fraction of objects from the deeper WFIRST and LSST surveys – this eliminates uncertainty generated by photometric redshift determinations. In addition to giving a detailed map of the galaxy distribution over a vast volume, it enables higher fidelity mapping of the cosmic mass field through lensing (as opposed to statistical measures like correlation functions) than possible through imaging alone and reconstruction of the velocity field through joint modeling. The relation between these fields probes the relation between dark and luminous matter, galaxy formation, the nature of dark matter and dark energy and possible deviation from standard of gravity. These fields are the primary predictions of cosmological theories.

• *CMB lensing studies:* Trace foreground structures over vast volumes for CMB lensing with all-sky maps from WMAP, Planck and high-resolution maps from ground-based CMB surveys; measure the mass of objects during the peak epoch of galaxy formation at z~2 using the CMB as the source plane.

• *Galaxy formation and evolution:* Measure stellar mass build-up, gas diagnostics, galaxy dynamics, star formation activity and AGN/black hole development; determine spatial distributions of galaxies according to internal properties; capture light emitted by the bulk of stellar mass during the epoch of peak star formation. With this information, we can examine the relation between stars, gas and dark matter halos at these critical times, uncover the key physical mechanisms driving galaxy formation and trace the disposition of galaxies within the cosmic web as a function of their internal properties.

• *Galaxy clusters and groups:* Detect clusters and groups as over-densities in redshift space out to high redshift. This is the most reliable way to identify clusters at optical and near-infrared wavelengths. Comparison of the cluster catalog with those at X-ray and millimeter wavelengths tells us about the relation between cluster galaxy and gas

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properties. The multi-slit spectra provide velocity dispersions, an important mass proxy for clusters. Cluster abundance, as a function of mass, and its evolution is a recognized probe of structure formation, the nature of dark matter and dark energy, and of deviations from standard gravity. The survey offers optical/NIR follow-up for all other all-sky cluster surveys, e.g., eROSITA.

• *Precise baryon acoustic oscillation (BAO) measurements and redshift-space distortions out to high redshift:* improve on measures from WFIRST and Euclid.

• *Reionization physics*: study sources driving reionization of the cosmic intergalactic gas.

• *Galactic structure:* Provide velocities and stellar diagnostics for stars down to the limiting magnitude of GAIA over the full sky, filling the gap over 17-20 magnitude unattainable by GAIA alone. Probe the Galactic gravity field and stellar distributions.

Benefits of the Application: The proposed capability is a natural complement to the imaging and low-resolution, confusion-limited slit-less spectroscopic surveys now planned (e.g., WFIRST, LSST, Euclid). The ability of the proposed concept to obtain multi-slit spectra of objects at high areal density greatly extends the scientific reach of the imaging surveys. For the all-sky survey, the instrument would target ~15-20 gals/arcmin^2. This is impossible with the slit-less spectroscopy of WFIRST and Euclid, which is severely limited by confusion. The mission would capitalize investment in micro-devicetechnology on

on the lack of atmospheric lines to extend spectroscopy deeper into the IR than ground-based observations, and it would provide all-sky coverage.

The all-sky capability is an important asset for Galactic and local group studies; mass, galaxy and velocity field mapping; CMB lensing over cosmic scales at high redshift; and for studies of the disposition of objects within the cosmic matter web according to their intrinsic properties (e.g., stellar mass).

With the proposed instrument, we can detect and study the dynamics of all galaxy clusters and groups out to redshifts beyond unity. In a high-resolution mode (R~3000-5000), operating at lower areal density, the instrument can probe Galactic dynamics, obtaining velocities and stellar diagnostics for stars in the 17-20 magnitude range inaccessible to GAIA. We can measure internal dynamics of galaxies using line widths and study galaxy properties and the distribution of galaxies within the cosmic web as a function of these properties.

The application makes use of NASA NIRspec.

Top-Level Description of the Design, Operation, and Results: We propose a wide-field multi-slit spectrograph covering the maximum field possible: 0.3 deg^2 or more.

The field will be covered by an array of micro-shutters, or equivalent micro-device technology, with ~0.5x0.5 arcsec^2 footprint (to be optimized), and IR detector arrays with 0.25x0.25 arcsec^2 pixels. Spectroscopic targets are selected through broadband imaging and masks are constructed by switching the micro-devices.

The objective for the all-sky survey is to reach ~15-20 objects/arcmin^2 at a resolution of R~500. There will also be a high-resolution mode, up to R~5,000-10,000, operating at lower areal density.

The instrument would operate at the Earth-Sun L2 for a period of 5-10 years, performing an all-sky survey at R~500, a Galactic survey at higher resolution, and smaller area extragalactic surveys at higher spectral resolution. There will also be a Guest Observing (GO) mode. Observations would be performed close to the anti-sun direction and move across the sky with the orbit. We require HST pointing control and stability.

The mission archive would contain large catalogs of object spectra from these surveys,

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as well as from the GO cycles after a short proprietary period.

Strategic Position:

• *Compared to ground-based instrumentation:* Better, more efficient infrared spectroscopy and full-sky surveying.

• *Compared to other space-based instrumentation:* Overcomes limitations of slit-less spectroscopy planned for WFIRST and Euclid – reaches higher areal density of source spectra in all-sky mode; permits higher-resolution spectroscopy than possible with slit-less surveying. It has nearly 20 times the throughput (telescope étendue) of the James Webb Space Telescope's (JWST) NIRspec instrument.

The concept fills a gap in space astrophysics capabilities. It enhances planned imaging surveys by significantly increasing the density of source spectra on the sky to better match the imaging. Its large telescope étendue offers a wide-field survey instrument that complements the James Webb Space Telescope's (JWST) deep-field spectroscopy. It enables high-resolution spectra for detailed galaxy and Galactic studies, and permits detection and dynamical study of clusters and groups to high redshift.

MaSSpec Concept Characteristics

Field-of-View (FoV)	0.3 deg^2 (or larger)
Wavelength coverage	0.6-2 micron
Filters	Y, J, H, prism/grism
Broadband sensitivity	24 mag
Masks	Micro-shutters/micro-mirrors or equivalent
Spectral resolution	500-10,000
N. of Spectra/FoV	~5000
Detectors	16 * 2kx2k HgCdTe arrays
Pixel size	0.25 arcsec
Micro-device footprint	0.5 arcsec
Data rate	1-2 Mb/sec
Modes of operation	-All-sky survey (R~500) -Galactic survey (R~5000-10000) -Guest Observing
Duration	5-10 years
Orbit	Earth-Sun L2
Instrument mass	200 kg
Total wet mass (including allocation for HST pointing stability)	3550 kg

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