Galaxy Evolution Spectroscopic Probe (GESP)

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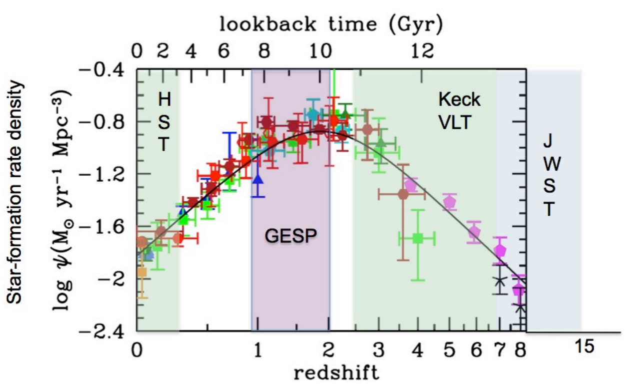
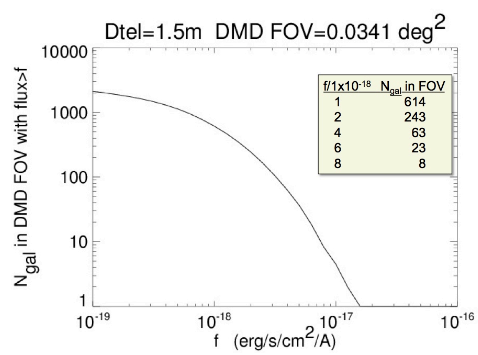
SCIENCE DRIVERS

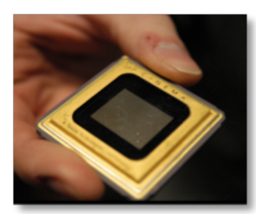
We know the star-formation history of the universe (see figure below at left), but we don't know the physical processes that drove it. "The evolution of the star-formation rate density says little about the inner workings of galaxies, i.e., their "metabolism" and the basic process of ingestion (gas infall and cooling), digestion (star formation), and excretion (outflows)…[What is needed] are studies of the physics of the ISM, self-regulated accretion and star formation, stellar feedback, and SN-driven galactic winds." (Madau & Dickinson, ARAA, 2014).

Understanding galaxy evolution requires study of the underlying physical processes, and that requires rest far-UV spectra, which are richest in diagnostics. HST, ground-based telescopes, and JWST have or will obtain rest far-UV spectra of galaxies over a wide range in redshift but will leave an enormous gap between redshifts, z~0.2 to z~2.5, equivalent to 2/3rds of the lifetime of the universe! GESP observations will fill the most important hole in redshift coverage (where the turnover occurs) needed to understand galaxy evolution at redshift, z~1-2. Using rest far-UV spectra (100-200 nm), GESP will study the physics of the ISM, accretion and star formation, stellar feedback, and galactic winds. In concert with X-ray telescopes and Subaru/Hyper Suprime Cam + Prime Focus Spectrograph, GESP will answer: what are the roles of stellar feedback, AGN feedback, and dark energy in driving galaxy evolution?





TECHNICAL CAPABILITIES



GESP will make a spectroscopic survey of the rest-frame far-UV spectra of ~1x10^5 galaxies at z~1-2. But because of the redshift, the far-UV spectrum (100-200 nm) is shifted to longer wavelengths by a factor, 1+z, so that observed spectrum of a z=1 galaxy appears in the near-UV (200-400 nm).

Making a large near-UV spectroscopic survey in a 3-year mission requires a multi-object slit spectrograph capable of recording the spectra of hundreds of galaxies in a single exposure. We have a choice of slit generators: a Digital Micromirror Device (DMD) as shown at right, or the MicroShutter Array, which is being flown on JWST's NIRspec instrument. Either slit generator has instantly adjustable slits, which eliminate confusion with nearby sources and block unwanted zodiacal background that would otherwise swamp the light from these faint galaxies.

A large spectroscopic survey also requires high sensitivity. Using *Galex* data incorporated in the COSMOS survey (Jouvel et al. 2011), we have calculated the number of galaxies in the 0.0341 deg^2 field of view of a 1.5m GESP with a DMD slit generator. As shown in the right-hand figure on page 1, the number of galaxies available for spectroscopy falls off steeply at fluxes higher that $1x10^{-18}$ erg/s/cm^2/Å. We estimate that a 1.5m GESP could obtain rest far-UV spectra of 243 galaxies with near-UV fluxes of $\geq 2x10^{-18}$ erg/s/cm^2/Å or more in a single 10-hr exposure. The spectra, with 6-Å resolution (3 Å in the rest frame) have a S/N $\gtrsim$ 6 in the continuum. The Lyman α emission line could have a much higher flux. As UV spectra have strong features, they are easily registered and co-added with other like galaxies. These spectra will be compared to simulations to constrain models of galaxy evolution.

Although the main focus of GESP is in the UV, GESP will also simultaneously obtain near-IR spectra (800-1600 nm) of the same galaxies "passed" by the slits. The near-IR spectra will show the spectra of z=1-2 galaxies as emitted in the optical, a spectral region rich in nebular diagnostics.

GESP will have a high observing efficiency by observing galaxies already observed Subaru's Hyper-Suprime Cam (HSC) and Prime Focus Spectrograph (PFS). Thus, the position, optical flux, and redshift of each target galaxy will be known ahead of time, so target-acquisition time will be minimal. Also, a custom deep-space orbit for GESE ensures that a PFS field will usually be available to GESP.

Parameter	Value
Wavelength Coverage	NUV (200-400 nm) Near-IR (800-1600 nm)
Spectral resolving power	~500 (obs), ~1000 (rest)
Field of view	0.0341 deg^2 (DMD) 0.0843 deg^2 (MSA)
Primary operational mode	Survey
Sensitivity	$2x10^{-18}$ erg/s/cm^2/ Å

NEW TECHNOLOGIES

GESP will take advantage of new technologies and engineering techniques that will improve performance and in some cases lower risk.

GESP TECHNICAL, SCHEDULE, COST RISKS

Key Component	Source	Technical	Schedule	Cost
Telescope PM	Schott 1.5m AOS polish	Low Low	6 months 9 months	$2.5 M $0.7 M
Detector	e2v 4Kx4K CCD	Low	12 months	$2.0 M catalog item
Slit Generator	TI 2Kx1K DMD GSFC MSA	Low- moderate	9 months 1 yr testing	$0.2 M actual SAT
Large convex grating	Zeiss	Low	9 months	$0.2 M (eng. grade)

PROBE-CLASS MISSION NEEDED

There is no current or planned mission able to make the massive UV spectroscopic survey needed to understand galaxy evolution. Using a design-to-cost approach, we find that GESP is a relatively low-risk, high-return mission concept that can be developed for less than $1B.