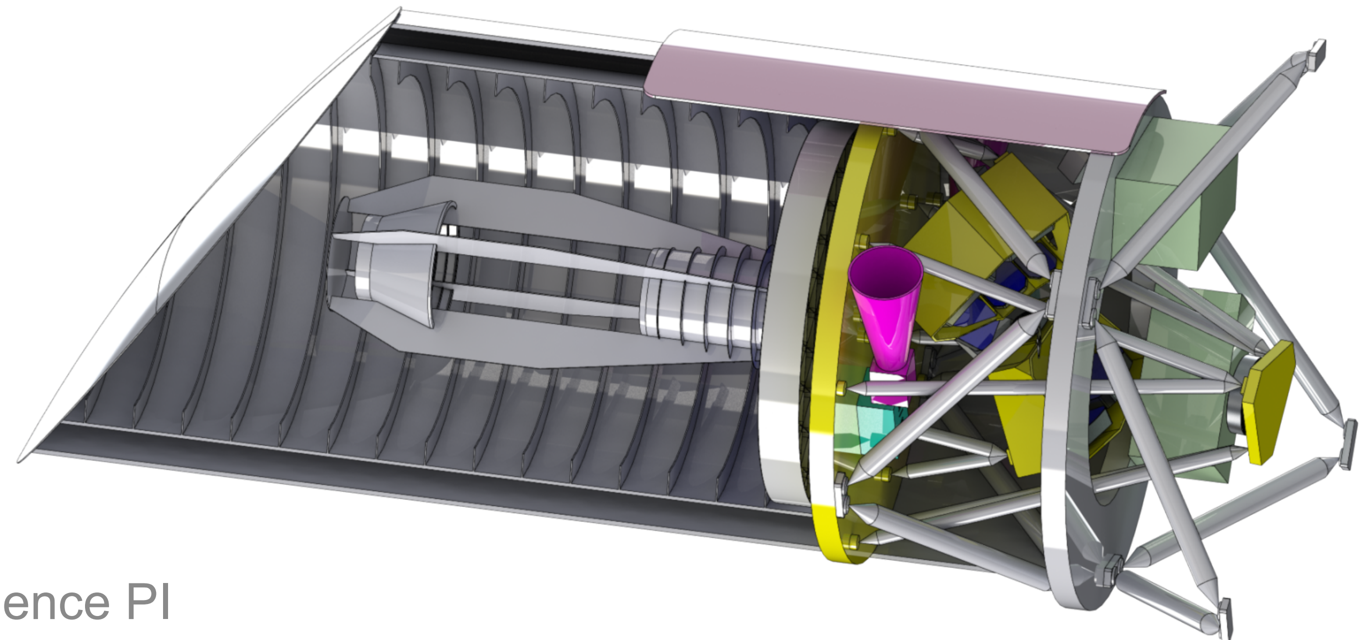
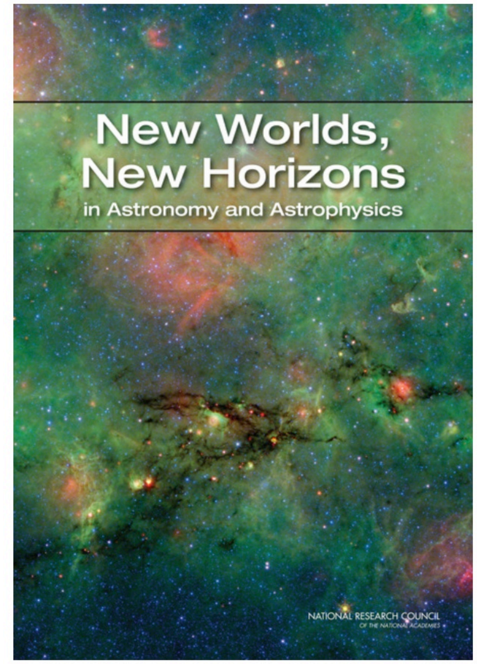
Galaxy Evolution Spectroscopic Explorer (GESE)



Sally Heap – Science PI
Lloyd Purves – Mission Systems Engineer
Qian Gong – Optics
Tony Hull - Telescope

1. GESE Science is Great and
and Doable on a Tight Budget!

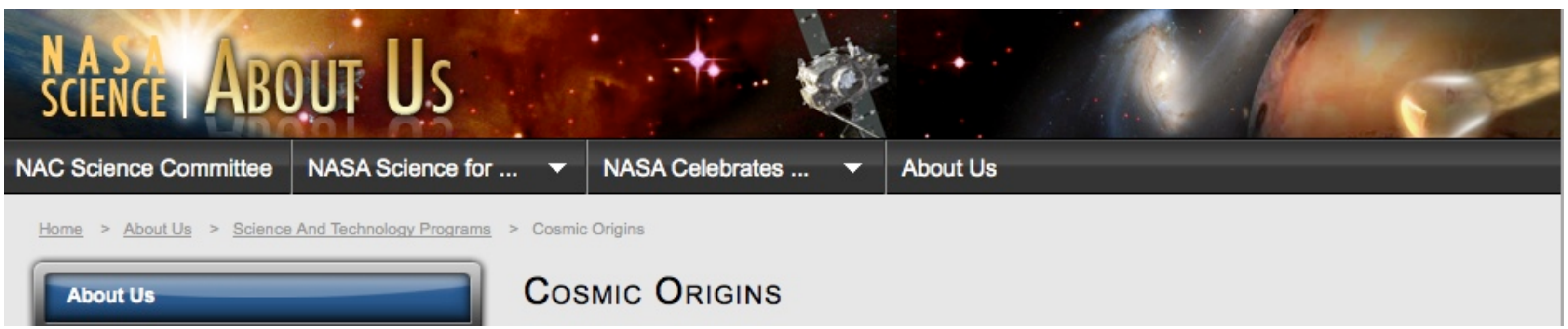
GESE is traceable to:



* 2010 Decadal Survey

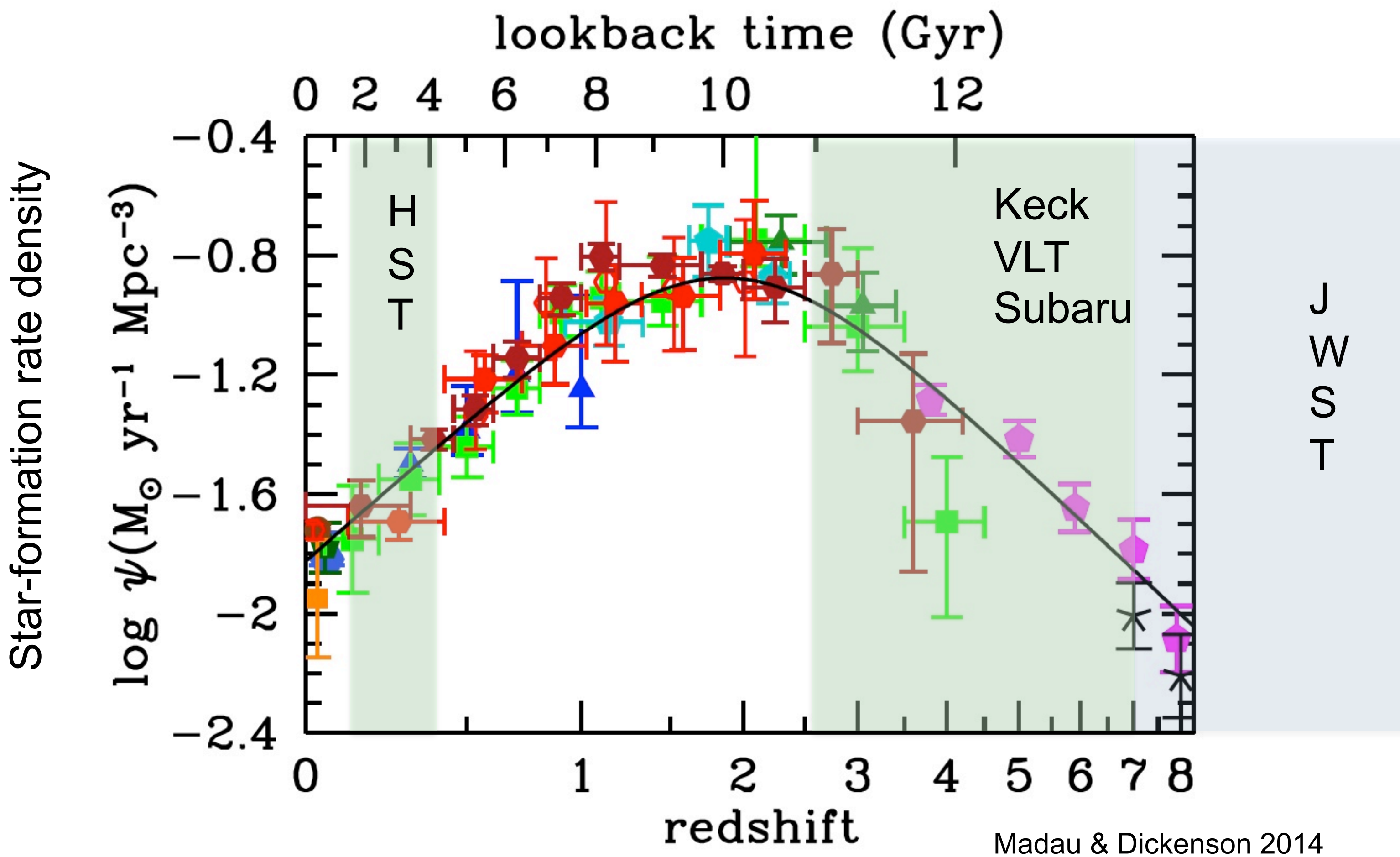
"A future UV space mission ... will move the subject of galaxy evolution ... to one of integrated measurements of the buildup of dark matter, gas, stars, metals, and structure over cosmic time. [It] will lay the foundation for the ultimate aim of a complete *ab initio* theory of galaxy formation and evolution." p. 7-14

* NASA's Cosmic Origins Program



"Our big question: **How did the universe originate and evolve to produce the galaxies**, stars and planets **we see today**?"

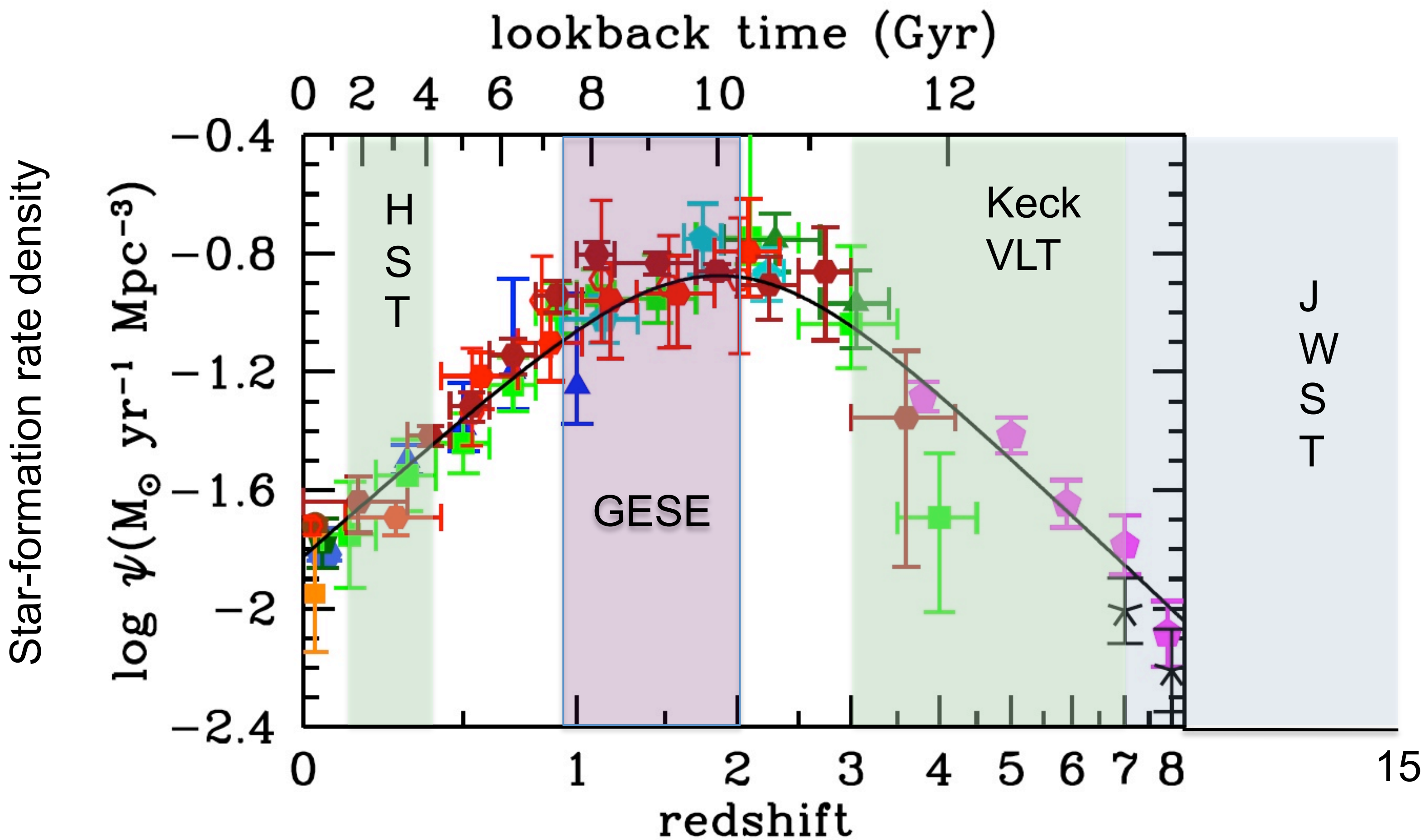
What processes drive galaxy evolution in the critical era of z~1-2?



Madau & Dickenson 2014

- The peak star formation rate density occurs at z=1-2
- There is no current or planned coverage of rest-frame FUV spectra of galaxies at z=1-2

GESE will identify processes driving galaxy evolution in the critical era of z~1-2



GESE will fill the hole in redshfit coverage of galaxies at z=1-2 when star formation reached its peak and started to turn down

Understanding galaxy evolution involves study of the underlying physical processes

[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). Ultimately, it also says little about the mapping from dark matter halos to their baryonic components. Its roots are in optical-IR astronomy, statistics, stellar populations, and phenomenology, rather than in the physics of the ISM, self-regulated accretion and star formation, stellar feedback, and SN-driven galactic winds." …… Madau & Dickinson, "Cosmic Star-Formation History" ARAA (2014)

Understanding the underlying physical processes requires rest far-UV spectra

Using new UV spectra, GESE will study the physics of the ISM, self-regulated accretion and star formation, stellar feedback, and SN-driven galactic winds.

GESE has a Science Partner: Subaru/PFS

	GESE	Subaru/PFS
Scientific Goal	Galaxy evolution	Galaxy evolution
Primary targets	z~0.8-2.0 galaxies	z~1-2 galaxies
Wavelength coverage	**0.2-0.4 μ**	**0.4-1.3 μ**
Coverage of Lyα	z~0.7-2.2	z>2.2
Telescope	1.5 m	8.2 m
Orbit	Geo or drift-away	Ground-based
Primary mission	3 years (~26,000 hr)	75 nights
Exposure time	5 hr	~0.3-3 hr
Galaxy spectra per exposure	50-100	2000
Spectra density	600-1200 spec/deg^2	1800 spec/deg^2
Sensitivity	few x10^{-18} erg/s/cm^2/A	few x10^{-18} erg/s/cm^2/A

The value of GESE grows in combination with Subaru/PFS spectra and Subaru/HSC images to produce a UV-optical-IR spectrum (200-1300 nm)

As Science Partner, Subaru/PFS contributes:

- Target list of galaxies with redshifts, coordinates, etc.
- Target field in g-band for correlating with GESE g-band image
- Physical parameters of target galaxies such as stellar mass, which are vital for interpreting GESE UV spectra
- Experience in spectral surveys from SDSS as well as Subaru Prime Focus Spectra (PFS)
- Advice (and perhaps collaboration) in science data processing, archival and distribution of data
- Scientific advice from eminent astrophysicists (Jim Gunn, David Spergel, and Michael Strauss)

Together, GESE + Subaru/PFS spectra will give diagnostics of the basic processes driving galaxy evolution at *z*~1-2

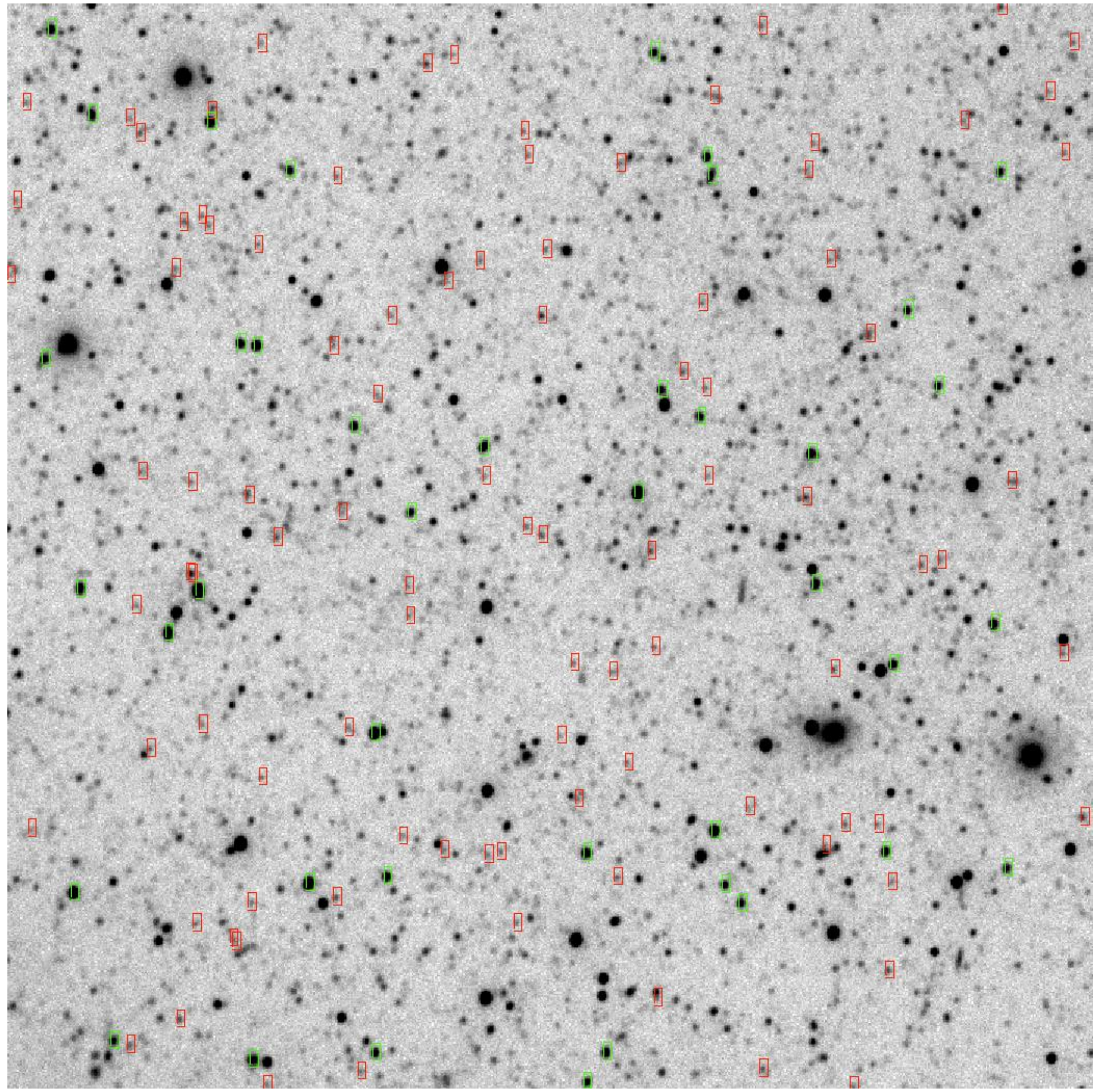
Drivers of Galaxy Evolution	Rest-UV Diagnostic	Optical-IR Diagnostic
Infall/Accretion	SFR ← far-UV spectrum	M^*, Z_{HII}
Star Formation	Far-UV flux	Hα flux
Stellar Feedback		
-- Stellar winds	Far-UV line spectrum	
-- Photo-ionization & heating	Far-UV line spectrum	Optical line spectrum
-- Galactic outflows	Far-UV line spectrum	

The target list from Subaru/PFS and MSA from Goddard make all the difference

Galex NUV image of central COSMOS field

Red boxes: galaxies with
- z=0.8-2.0
- g <23.5
- (g-r) < +0.6

Green boxes: nearby bluish galaxies
- z<0.4
- g < 21



GESE FOV (1045” x 1045”)

GESE Science Flow-Down:

Science requirement → Measurement requirements

To achieve its aims, GESE needs to collect UV spectra of over 10^5 galaxies:

• To distinguish among the possible drivers of galaxy evolution;

• To cover a wide variety of environments, e.g. field vs. cluster galaxies;

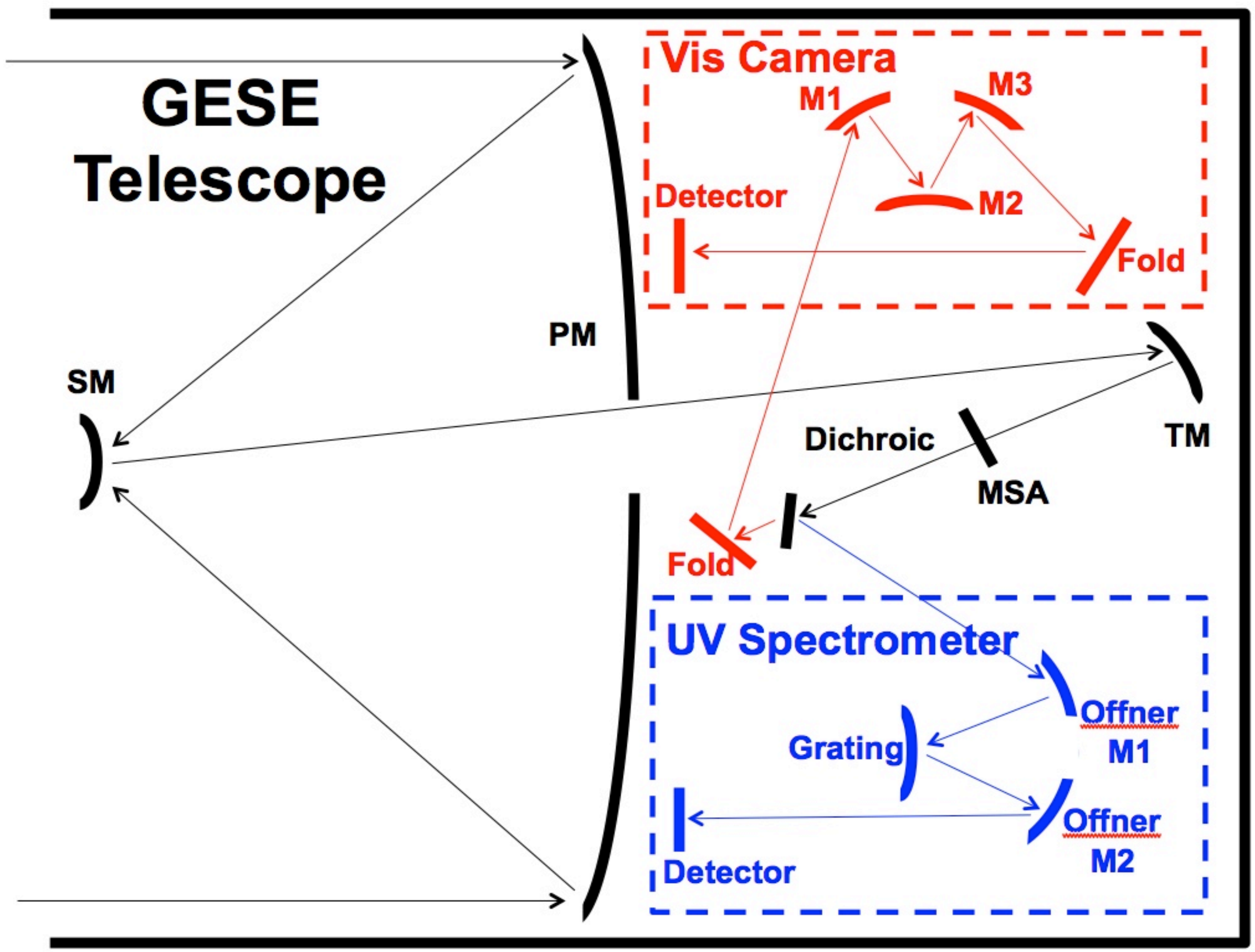
• To stack the spectra of faint galaxies to derive the properties of various types of galaxies, e.g. galaxies showing Lyman α in pure emission vs. P Cygni line vs. pure absorption.

GESE Science Flow-Down:
Measurement Requirements → Functional Requirements

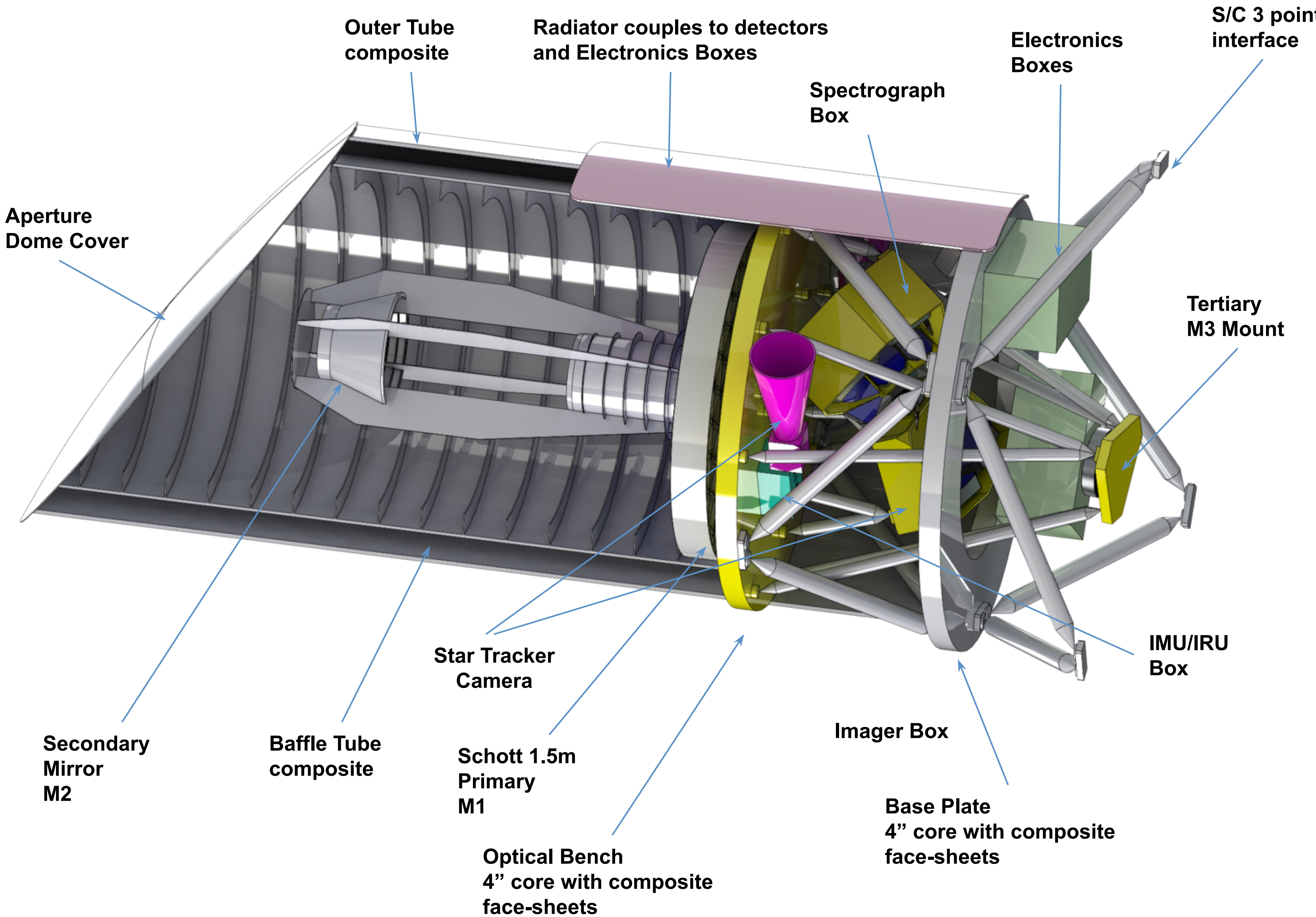
Measurement requirement	Functional requirement
Obtain $>10^5$ far-UV spectra of z~1-2	Obtain spectra at the rate of 4 galaxy spectra per hr in 3-year mission
Sensitivity ~ few x10^{-18} erg/s/cm^2/A to obtain spectra in 5-hr exposure	1.5-m space telescope
Spectra of >50 galaxies per exposure	Multi-object slit spectrograph via microshutter array as slit generator
Measure spectral line features	R≥500 spectra
Restframe far-UV sensitivity	Near-UV spectra at 200-400 μm
Find target galaxies	Optical camera for comparison against Subaru optical image

2. GESE Design is relatively simple, mature, and high TRL

The GESE Design is simple



The GESE Design is mature



The GESE Design is high TRL

- CCD detectors
  - Plan: e2v 4kx4k photon-counting CCD (in dev.)
  - Fall-back: 4kx4k UV/visual CCD’s (e2v catalog item)

- Multi-Object Slit Device
  - Plan: Next-generation MicroShutter Array (MSA, in dev.)
  - Fall-back: Digital Micromirror Device (DMD)

- Large convex grating
  - Plan: Custom grating from Zeiss (proposed to APRA)
  - Grating is an engineering issue, not a technology issue

3. GESE can be made into a competitive Explorer proposal, using new, low-cost techniques being applied to developing space missions.

New Low-Cost Techniques: Materials & Methods

Methods strongly drive cost, simplicity and low risk

* A geosynchronous or Earth-trailing orbit avoids periodic thermal changes

* Both test and operation of GESE are at room temperature, reducing cost and simplifying the error budget

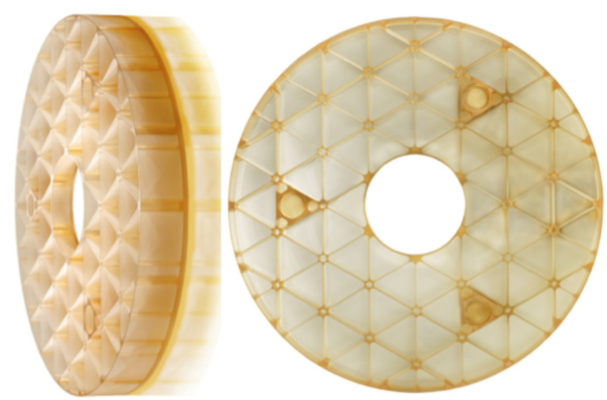
* Architecture is for passive dimensional stability. Low thermal expansion materials are planned for the optical path
  - Only one mechanism for SM actuation, primarily backup in flight.
  - Schott's ZERODUR® mirror material has very low thermal expansion
  - The CFRP metering structure has very low thermal expansion

* The GESE optical design is also forgiving of perturbations

New Low-Cost Techniques: Telescope Architecture

- From the earliest design stage we have taken steps to minimize telescope cost.
- Our design is specific to the primary science, uncomplicated by ancillary science.
- The architecture emphasizes passive telescope operation, and insensitivity to environmentally induced solid-body perturbations and distortions of the mirrors.
- Our adoption of ZERODUR with CFRP metering helps us to reach these goals.
- Such mirrors can be procured rapidly and at attractive cost.
- They also offer extensive lightweighting and superb passive thermal stability which yield simplifications that propagate all aspects of the telescope.

1.2-m ZERODUR Mirror substrate lightweighted to 88% by SCHOTT is similar to the 1.55-m M1 of GESE. This prototype substrate was produced in < 2 months. Modern deterministic optical finishing controls lightweight mirror mid-spatial frequencies.



New Low-Cost Techniques:

Falcon 9 LV ~ half the cost of an Atlas V for the same performance

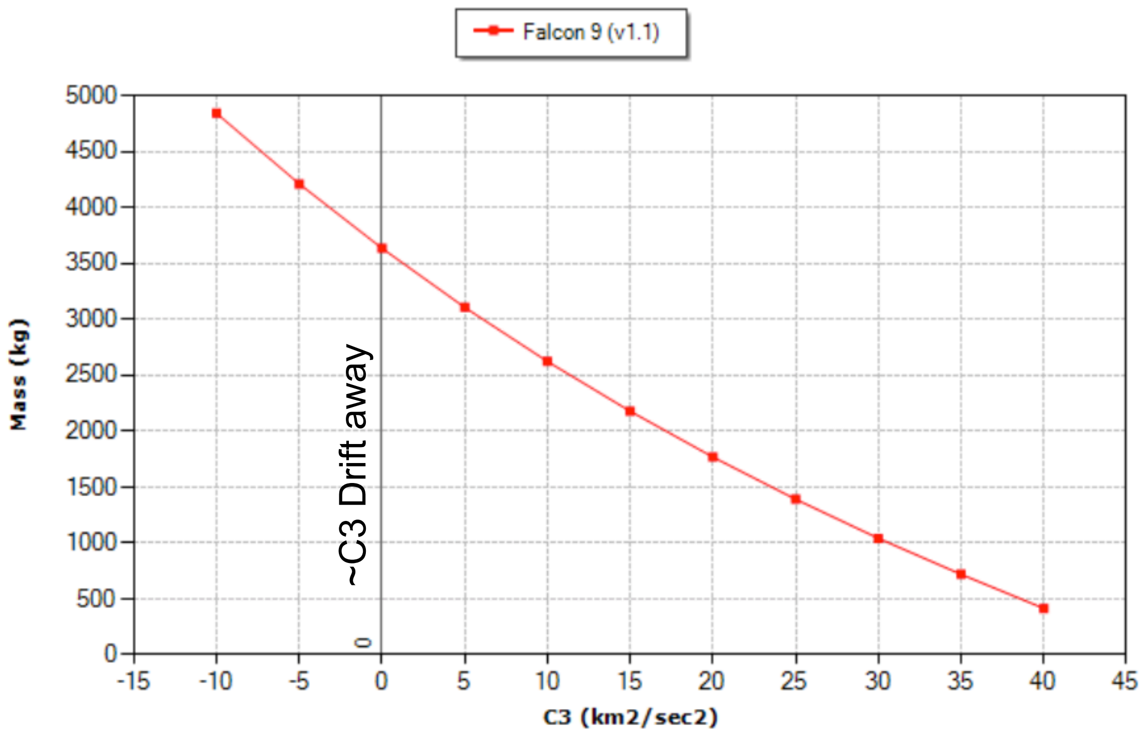


FIG. 2

Composite Fairing

13.1m (43 ft) height,

5.2m (17.1 ft) diameter