Deep Imaging Galaxy Evolution Probe (DIGEP)
Astrophysics

Overview:

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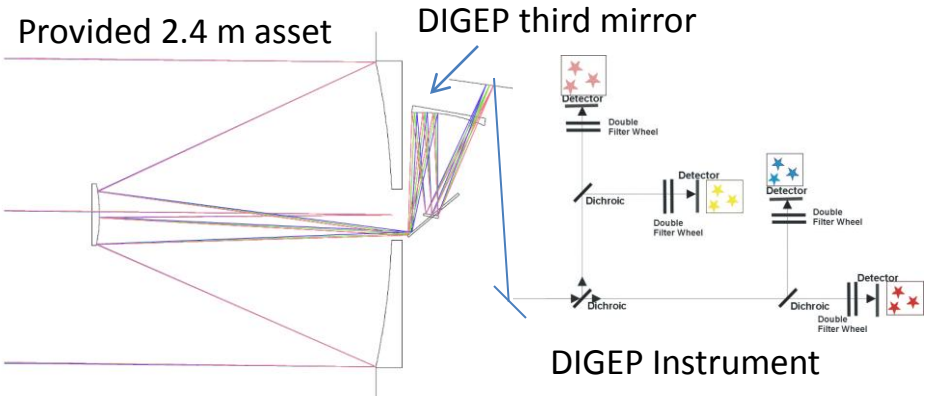
Key collaborators: Prof. Xiaohui Fan, Steward Obs., Dr. Glenn Schneider, Steward Obs., Prof. Brandt Robertson, Steward Obs., Prof. George Rieke, Steward Obs.

Goal 1) A deep near infrared imaging survey in 8 photometric bands of four 1 Sq. Deg. fields separated by ~90º on the sky. The average depth is AB 31 mag per pixel with a pixel size of 0.11 arc seconds. The 8 photometric bands are distributed log normal between 0.8 and 2.4 microns.

Goal 2) Provide a versatile near infrared imager and spectrometer for the astronomical community that can carry out diverse observations chosen in a competed proposal program open to the community.

Graphic:



Description:

The concept provides
feeds an instrument utilizing dichroics to image the same 0.25 sq. deg. area of sky on four separate focal planes, each with its own compliment of filters and grisms plus a clear aperture and blank. This concept quadruples the science output over single focal plane concepts .

DIGEP provides both a focused mission of 4 1 sq. deg. high spatial resolution deep images to 31 AB mag per pixel in 8 photometric bands between 0.8 and 2.4 μm and a versatile near infrared imager and spectrometer for competed observing proposals from the astronomical community.

DIGEP utilizes existing TRL 6 technologies and the H4RG HgCdTe detectors under development at Teledyne.

DIGEP does not require human interaction or outside collaborations.

1/4/2013

Value to NASA:

The four focal plane design with dichroics quadruples the scientific effectiveness of DIGEP over single focal plane concepts. This increase in efficiency produces a set of (4) 1 Sq. Deg. Field images in 8 photometric bands to a depth of 31 AB mag per 0.11 arc sec. pixel in only one year of observation. DIGEP can also operate in modes that utilize any combination of focal planes including sending all of the light to a single focal plane for very deep imaging in the entire 0.8-2.4 μm bandwidth.

The DIGEP concept directly addresses the NASA astrophysics goal of answering the question of How did we get here? DIGEP studies how the universe evolved to produce the galaxies stars and planets we see today. The competed general observer programs addresses the additional questions of How does the Universe work and are we alone?

Deep Imaging Galaxy Evolution Probe

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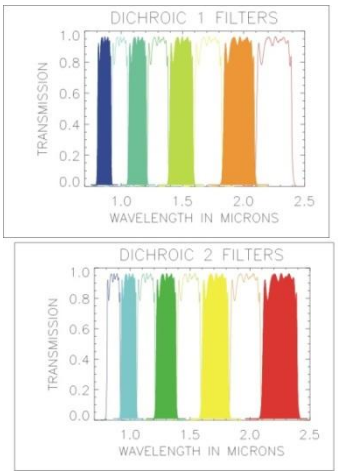
Qualifications: The principal author is the Principal Investigator for the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) on the Hubble Space Telescope (HST). He was also the PI for two funded studies of the Galaxy Evolution Origins Probe which is the basis of this concept. **Primary concept goal category:** Astrophysics
Concept Summary: This concept produces very deep, high spatial resolution, 1 degree square images in 4 widely separated fields on the sky. The images are produced in 8 near-infrared photometric bands between 0.8 and 2.4 microns. Dichroic splitting of the light from the telescope creates 4 separate focal planes, each viewing the same field of view. Each focal plane covers 1/4 of a square degree with 0.11 arc second pixels. The 8 bands are, therefore, imaged with only two integrations. Provision is also made for very broad filters including a photometric band that includes the entire wavelength range. Each of the 8 bands reachs an AB 5σ depth fainter than 31 per pixel except for the longest band which is compromised by the thermal emission from the telescope. The 8 bands provide a superb basis for photometric redshifts for the study of galaxy evolution back to the earliest epoch of galaxy formation. In addition to the 8 survey bands DIGEP includes a diverse compliment of filters and grisms for other observations. The dichroic wheels also contain clear apertures and mirrors so that all or subsets of the full spectral region can be diverted to one or more of the focal planes.
Scientific Mission: This mission covers the very important middle ground between the very deep but small fields planned for JWST and the very large but shallower fields expected from WFIRST. The deisgn reference mission (DRM) for JWST calls for deep imaging to 31 AB mag for the NIRCam instrument in the 3.3x3.3 arc minute area of the Hubble Ultra Deep Field (HUDF). The Deep Imaging Galaxy Evolution Probe (DIGEP) will cover 14,600 sq arc minutes to the same limiting magnitude. This is accomplished through the much larger focal plane of DIGEP, a misssion time of 1 year, and the unique dichoroic design that produces 4 images of the same field at a time. Attempting the same mission with a single focal plane design would require 4 years of integration leaving no time for other science. The DIGEP fields cover sufficient area to significantly reduce errors due to large scale structure and probe as deeply as the planned JWST small field. Even though smaller in mirror area (DIGEP) is more than 9 times more efficient at this mission than JWST due to DIGEP's much larger focal plane and a dichoric arrangement that produces 4 simultaneous focal planes rather than NIRCam's 2 focal planes. The primary science of the DIGEP mission is the study of galaxy evolution and the star formation history of the universe out to redshifts past 10. Current studies are limited by both the depth and the size of the fields. The four large DIGEP fields will be separated by approximately 90 degrees on the sky

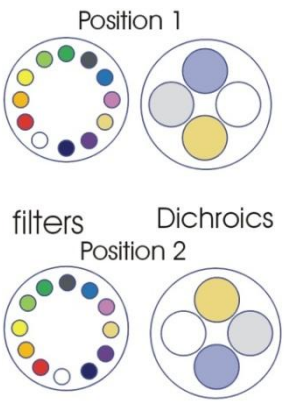
producing 4 completely spatially uncorrelated measurements of galaxy evolution and star formation history. The very large individual fields, 3600 square arc minutes as opposed to the expected 11 square arc minute JWST fields reduces large scale structure error by a factor of 18 with the 4 independent fields reducing it by another factor of 2. Large scale structure error is the dominant error in projecting the observed field meaurements to the universe as a whole. Although current theoretical opinion appears to favor a hierarchical assembly of galaxies there still appear to be galaxies that have assembled most of their mass at very early stages of the universe. The presence of quasars at very high redshift with massive 10^9 solar mass black holes is another indicatior of galaxy formation modes other than the expected hierarchical model. DIGEP provides the first statistically significant data set to study the multiple scenarios for galaxy formation, many of which may have yet to be observed in the current small fields. Based on the current near-infrared deep fields and the increased depth of the images we expect to observe on the order of 70 million galaxies, many of which will be at redshifts where we currently only have single candidates. Parallel to and part of galaxy evolution is the star formation history of the universe, the evolution from the starless dark ages to the complex universe we observe today. In short DIGEP provides the most complete baryonic history of the universe ever assembled.

Benefits of the application: This application provides the community with an 8 color survey of 4 square degrees of field to a depth equivalent to the planned JWST deep images. The spatial resolution is finer that the current WF3-IR images and the size is 120 times the area of the planned JWST deep image. This is a legacy data set for cosmological and galaxy evolution studies for a generation of astronomers and astrophysicists. The data set has the depth to reach the era of reionization, the size to minimize large scale structure variation and 8 separate photometric bands to provide accurate photometric redshift determinations. It increases the discovery space by several orders of magnitude over the current Hubble deep fields and the proposed JWST deep field. This is the logical next step in the cosmological revolution initiated by the Hubble Space Telescope and the powerful CMB imagers such as WMAP and Planck. In addition to the legacy deep survey the application also provides an extremely versatile instrument for competed General Observer programs after the one year survey mission is completed. The large number of filters and grisms in the multiple filter wheels provide wide science capabilities that range from very wide images of galactic star formation regions in lines such as Paschen alpha to even deeper imaging in selected extragalactic fields in the total light between 0.8 and 2.4 microns.

Instrument Concept Design and Operation: The DIGEP instrument is fed by one of the NRO obtained 2.4 meter telescopes. DIGEP provides the third mirror to form a three mirror anastigmat telescope providing a diffraction limited field of view in all parts of a square field of view encompassing 0.25 square degrees. A system of 3 dichroics produces four 0.25 square degree focal planes all viewing exactly the same field of view on the sky. Broadband filters

cover the 0.8 t0 2.4 micron spectral region in 8 bands. Four of these bands are observed with one dichroic setting. As shown in figure 1, every other band is observed in one setting with the dichroic transitions occuring in between the bands. The dichroics are installed on wheels so that a second set of 3 dichroics can be rotated into the beam to observe the other 4 bands. Two sets of integrations cover all 8 bands. Each dichroic wheel also contains a clear aperture and plane mirror so that all of the light in the beam can be either directly transmitted or reflected to a focal plane. There are two sets of filter wheels for each focal plane that each contain a clear aperture as well as filters. This combination of dichroics, mirrors and clear apertures provides combinations that range from observing the entire 0.8-2.4 spectral region on one focal plane to broad band observations in 3 focal planes and narrow band observations in the fourth. The conceptual layout is shown in figure 2. Note that the 8 survey filters are only a subset of an extensive filter set that is optimized for a broad suite of scientific programs.





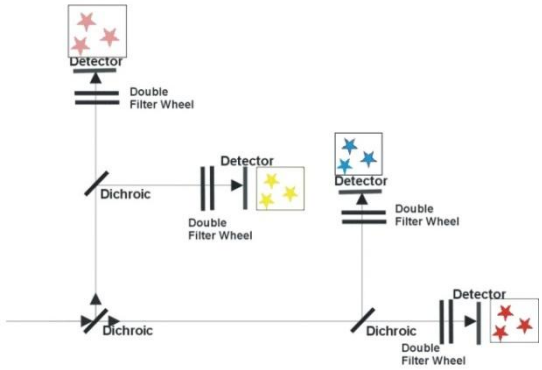


Figure 1 Figure 2

The focal planes contain 16 Teledyne H4RG detectors in a 4x4 mosaic. The plate scale is 0.11 arcseconds per pixel providing a 0.25 sq degree field of view for each focal plane. The focal planes also contain 4 additional H4RG detectors for guiding on each side of the square science focal plane. The guide detectors are readout only in the vicinity of the guide stars to minimize on board processing. The angular size of the guide arrays is 440 x 440 arc seconds so only very course initial pointing is required to acquire objects. The survey operational mode is to observe 4 different 1 sq. deg. fields roughly separated by 90° on the sky. DIGEP will take images at 4 positions for roughly 3 months before moving to the next area. The four positions that make up the sq. deg. field are dithered to provide increased spatial resolution via reduction methods such as drizzle and mitigation of bad pixels or low QE areas. Each position in the mosaic is imaged 223 times, providing excellent temporal coverage for transient events such as supernovae and AGN variability.