Dark Energy & GEST: the Galactic Exoplanet Survey Telescope

- Cosmology with a Exoplanet Search Mission
- a MIDEX Proposal currently under review
  - $180M NASA OSS Cost cap
- Related option
  - STEP (Survey for Terrestrial ExoPlanets) is under consideration as Advanced Mission Concept

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NASA’s Exoplanet Goals

“The time is right to make the search for Earth-like planets around other stars a major priority for astronomy. This is a goal worthy of a civilization.” -- HST and Beyond (Dressler 1996)

- The cornerstone of NASA’s exoplanet search program is the Terrestrial Planet Finder (TPF)
- The McKee-Taylor Decadal Survey Report: support for TPF is “predicated on the assumption that space- and ground-based searches will confirm the expectation that terrestrial planets are common”
- **GEST** can do this
Exoplanet Search Mission Requirements

- Telescope aperture $\geq 1\text{m}$
- Continuous view of Galactic bulge for $\geq 6$ months per year
  - other targets when bulge is near the Sun: Cosmology is free!
- Wide field of view: $\sim 2$ sq. deg.
- Near diffraction limited imaging: FWHM $\leq 0.3''$
  - Implies large pixel count: $\sim 0.6$ Gpix for $0.2''$ pixels
- Detectors sensitive in near-IR
  - Highly reddened Galactic bulge fields
- Data rate $\geq 14$ Mbits/sec continuous (uncompressed)
A Wide FOV Space Telescope Finds Earths Strong planetary signals

Uniquely sensitive at a > 0.7AU

Taxpayers like exoplanets!
The **GEST** Midex Proposal

**The GEST Team**

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**Industrial Partners**

- Lockheed Martin Space Systems (LMSS)
  - LMSS-Sunnyvale: Spacecraft
  - MIT’s Lincoln Labs: Instrument
  - Telescope:
    - Arizona & Composite Optics
Galactic Exoplanet Survey Telescope

- 1m telescope
- 2.1 sq. deg. FOV
- shutter for camera
- 0.2”/pixel => 6×10^8 pixels
- continuous view of Galactic bulge
  - for 8 months per year
  - 60 degree Sun avoidance
- <0.025” pointing stability & drift
  - maintained >95% of the time
- observe in dither pattern on grid with 0.05” steps => accurate photometry
- MIDEX level budget (almost: donations are accepted)

Polar Orbit for GEST MIDEX proposal
Three Mirror Anastigmat
• 2.4×1.2 degree FOV
• allows filter wheel
  – 3-4 very wide filters
• non-circular field => more events!
• better baffling
**GEST Instrument**

- High sensitivity in near-IR: 50% better than EEV
- Diffraction limited optics at ~0.8 µm
- 32 Lincoln Labs 3k × 6k CCDs
  - 10 µm pixels; 600 Mpix total
- Passively cooled to -90°C
GEST Focal Plane Layout

Layout of 32 CCD FPA

shutter concept

Readout not simultaneous: minimizes readout electronics
Survey for Terrestrial ExoPlanets

  - Proposal for 1-year study phase
  - Cost cap $300M, but there is no budget separate budget for a mission
- 1.5m telescope aperture
- CCDs & HgCdTe detectors (passively cooled)
- Higher sensitivity gives statistics on Jupiters + Earths in the same system
- High Earth Orbit: inclined GEO or higher
- Lincoln Labs electronic shutter
- No moving parts except for filters
Lincoln Labs Integrated Electronic Shutter for Back-Illuminated CCD Imager

**Objectives**
- Transfer smear reduction
- High-speed photography
- Target tracking
- Range gating
- Real-time adaptive optics

**Performance**
- Short adjustable exposure time (< 100 ns)
- High extinction ratio (> 5000 for $\lambda < 580$ nm)

**Electronic Shutter Pixel Cross Section**

- $V_{SD} = 3 \text{ V}$
- $V_{IA} = 18 \text{ V}$
- $V_{SD} = 3 \text{ V}$

- $V_{SD} = 3 \text{ V}$
- $V_{IA} = 18 \text{ V}$
- $V_{SD} = 3 \text{ V}$

- $V_{SD} = 18 \text{ V}$
- $V_{IA} < 12 \text{ V}$
- $V_{SD} = 18 \text{ V}$

- $n+$ Buried Channel
- Contoured $p+$ Buried Layer
- High Resistivity $p-$ Substrate
- Shutter Open
- Shutter Closed
- Light Input
- CCD Gate
Lincoln Labs Electronic Shutter

INTEGRATED CCD ELECTRONIC SHUTTER

EXTINCTION RATIO

WAVELENGTH nm

- EXPERIMENT, 17 \( \mu \text{m} \) Si
- CALCULATED, 17 \( \mu \text{m} \) Si
- CALCULATED, 50 \( \mu \text{m} \) Si
- CALCULATED, 100 \( \mu \text{m} \) Si
GEST/STEP Cosmology Program

- High Redshift SN search
- Deep, wide weak lensing survey
- Comes for free
  - Use spare time when Galactic bulge is close to the Sun
  - But telescope parameters are optimised for planets
- A joint exoplanet/cosmology mission might be sensible
  - But it doesn’t fit easily into existing NASA programs
High-Z SN with GEST or STEP

- 1000’s of $0.6 < z < 1.7$ SN
- measure $\Omega_\Lambda$ to a few %
- photometric redshifts
- STEP: optical & IR photometry
- GEST Light curves
  - Only rest frame U-band
  - A small number of IR obs. From HST/WFC3 or NGST
- SN type classification from light curve shape
- Spectra for a subset of SN
Spectrographs for **GEST** SN Search

**OSIRIS**: OH-suppressing IR Imaging Spectrograph – under construction

Not quite dedicated to GEST follow-up, unfortunately.
Dark Energy Results from part-time SN Survey

- Results from 1 month of GEST data taken over 6 months
- Statistical errors can be made smaller by a factor of 3 if the SN search gets 10 months of observations
Weak Lensing with GEST

- 500-1000 sq. degrees surveyed
- 0.2 arcsec. pixels $\Rightarrow$ $\sim$ 0.15 arcsec. resolution with dithering
- measure galaxy shapes down to 0.3-0.5 arcsec. half light radius
- measure shapes to $I=26$
- $\sim 10^8$ galaxy shapes over course of mission
- 3-4 filters $\Rightarrow$ photo $z$’s $\Rightarrow$ subdivide into $z$ bins

GEST will measure

- variance of the shear distribution $\Rightarrow \Omega_M \sigma_8$
- variance of the size distribution (magnification effect) $\Rightarrow \Omega_M$
- skewness of the shear distribution $\Rightarrow$ independent measure of $\Omega_M$
- relationship between galaxies and shear $\Rightarrow$ bias parameter $b$
- redshift dependence of above parameters
Comparison to SNAP and HST/HUFI

- $80 \times$ imaging area of HST/HUFI
  - $20 \times$ better throughput for cosmology
  - Planet search not possible from HST orbit
  - $\sim 2 \times$ HST/HUFI cost
  - Allows HST exhibit in Air & Space Museum!
- About as good as SNAP for statistical error bars
  - But SNAP emphasizes systematics
  - STEP might get optical & IR light curves comparable to SNAP
  - Spectra from ground (for $z \sim 1$) and HST or NGST