Resolving the Mid- and Far IR background

1. Science aim/goal:

Determine the cosmic history of structure formation by measuring the integrated light from resolved galaxies and by spectral mapping surveys.

2. (i) Scientific Importance:

The CIB intensity provides an integral on the hidden star formation activity throughout cosmic time, and the history of the assembly of galaxies, their evolutionary history, and related energy releases over cosmic time. The correlations of the radio-IR and IR-star formation rate it provides a mean of determining the cosmic star formation rate, the cosmic radio background, and the neutrino background from core collapse supernovae The CIB also provides a strict upper limit on any energy releases from Population III stars, and exotic sources such as decaying particles, exploding black holes, or dark stars powered by the annihilation of dark matter (see review by Dwek & Krennrich 2013, DK13).

At far-IR wavelengths, in the Rayleigh-Jeans (RJ) part of the spectrum, the CIB consists mostly of the energy emitted by star forming galaxies. It therefore contains the imprint of all energy released in the process of structure formation, and the fraction and its fraction that was absorbed and reradiated by dust.
At mid-IR wavelengths (the Wienn side of the spectrum) the CIB intensity is dominated by gravitational energy releases from accretion disks in AGNs. Furthermore, at these wavelengths, the EBL is the main source of opacity for 10 - 50 TeV gamma rays from blazars (e.g DK13 and references therein), currently observed by the Very Energetic Radiation Imaging Telescope Array System (VERITAS) or the High Energy Stereoscopic System (H.E.S.S.). Determining the CIB at these wavelengths will play a crucial role in determining the intrinsic blazar spectrum and the physical mechanisms for the production of very high energy gamma rays.

The ~10 - 1000 μm spectrum of galaxies contains a host of fine structure lines which are easily excited and are produced by the most abundant metals with low ionization potential. They suffer very little attenuation and are therefore an excellent measure of the intrinsic line intensity. They are important coolants of the interstellar medium (ISM) of normal and starburst galaxies, and gauges of the metallicity and the amount of elemental depletions in their ISM. Select lines from some key elements are (wavelengths in micron): (1) Iron: [FeI] 24.04, 34.71, 54.31, 111.18; [FeII] 17.93 24.52, 25.98, 35.35, 35.78, 51.30, 87.38; [FeIII] 22.93 33.04, 51.68, 105.37; (2) Oxygen: [OI] 63.18, 145.52; [OIII] 51.81, 88.36; (3) Carbon [CI] 371 609; [CII] 157.74; and (4) Nitrogen [NII] 121.90, 205.18; [NIII] 57.32.

In survey mode, these lines will provide important statistical information on structure formation, star formation activities, and ISM processes over large volumes of the universe. The most prominent lines in galaxies are from CI, CII, NII, OI and OII. The observed line spectrum is complex, since it contains overlapping, rotationally-broadened lines from multiple galaxies at different redshifts. Kogut et al. (2013) developed an efficient algorithm for line identification and source redshift determination. The reliability of line identification depends on the beam size, which determines the number of sources, and the spectral resolution of the instrument, which determines the ability to distinguish between overlapping lines.

The multiband SED from individual galaxies will be used to determine their star formation rate, gas, metallicity, and dust abundance as a function of redshift, enabling The RJ region of a galaxy's SED depends linearly on dust temperature which can be estimated from the peak of the galaxy's spectral energy distribution, taking the IR opacity of the galaxy into account (Kovacs 2010). The dust temperature and opacity will be determined from spectral fits to the Wienn and RJ regions of the spectrum (e.g. Kovacs 2010).

The line emission from galaxies will be used to determine their redshift, the abundance of metals, and the galaxy's stellar mass from the broadening of its line. All this information will be used to reconstruct the evolution of the galaxy's stellar population, metal and dust enrichment .

The IR surveyor will be able to cover large areas of the sky, to unprecedented depths beyond redshifts of ~ 7 with high sensitivity. The wide coverage will be able to detect rare objects, such as rare massive galaxies that assembled at very high redshift/

2. (ii) Measurements Required:

Deep field multi-band survey from 10 μm to 1 mm, covering tens of square degrees will be sufficient to obtain galaxy number counts to the required depth and uncertainties.

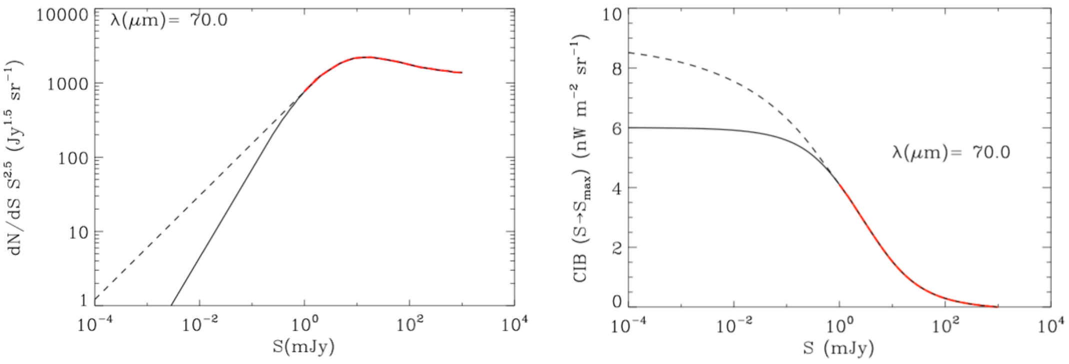
Spectral line mapping of unresolved sources. Requires moderate spectral resolution of R ≈ 700 – 4000 with angular resolution between 20 arcsec to 10 arcmin.
Wavelength coverage will be determined by the required redshift range.

2. (iii) Uniqueness to 10μm to few mm wavelength facility:

The required sensitivity cannot be achieved by either ground-based or airborne observations.

2. (iv) Longevity/Durability: (with respect to expected 2025-2030 facilities) JWST, ALMA, WFIRST, SOFIA, EELT, etc.

The combined wavelength coverage, spectral capabilities, sky coverage, and sensitivity will be complementary to expected future facilities.



3. Figure 1: Left panel: Two different extrapolation of the Euclidean-normalized differential number counts given by Bethermin et al. (2011). The red portion of the curve represents the contribution of resolved sources. The solid line is an extrapolation of the source counts using, in part, stacking analysis. It predicts few faint sources, and suggest that the CIB (right panel) has converged to a value of 6 nW m^{-2} sr^{-1}. The dashed line gives an alternative extrapolation of the number counts, producing more faint sources. In this scenario, the CIB is still increasing. Both extrapolations are within the errors of the number counts and stacking analysis. Observations at the confusion limit of a ≥ 10m telescope will be able to distinguish between the two scenarios.

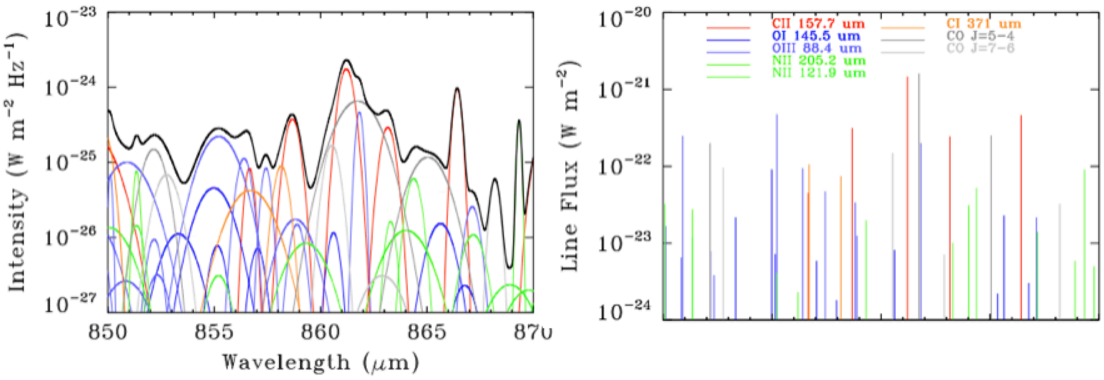


Figure 2: *Left panel:* Simulated spectra of galaxies in a wavelength band covering the central wavelengths of the [C II] line emitted from galaxies in the 4.4 < z < 4.5 redshift range. The [C II] line is depicted by the red curve. Other curves correspond to different spectral lines. All lines were spectrally broadened, reflecting galaxy rotation. The right panel depicts the spectral lines before they were rotationally broadened.

4. Table: Please fill the table below. Required value can be interpreted as the minimum value essential for the science goal and desired value as the best-case scenario. If necessary, state ranges. If any entries are not applicable leave as N/A. Use table footnotes to expand on the comment field to justify any numbers that may not be easily comprehensible. [feel free to remove these explanatory lines for additional space].

Parameter	Unit	Required value	Desired Value	Comments
Wavelength/band	μm	12, 25, 50, 70,100,250,350 500, 850, 1000, 2000		Galaxy number counts
Number of targets				
Survey area	deg.^{2}	10		
Angular resolution	arcsec			
Spectral resolution	Δλ/λ			
Bandwidth				
Continuum Sensitivity (1 σ)	μJy	1		
Spectral line sensitivity (1 σ)	W m^{-2}	1.d-23		Spectral lines survey
Signal –to-noise				
Dynamic range				
Field of Regard				
Cadence				
Any other requirement				

5. Key references: (Optional, at most three, reviews preferred)

Dwek, E. and Krennrich, F., 2013, Astroparticle Physics, 43, 112
Kogut, A., Dwek, E., and Moseley, H. S. , 2015, ApJ, 806, 234