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# Inter-Division D-G-H-J / Commission WG
# Reference Library of Galaxy Spectral Energy Distributions

**https://www.iau.org/science/scientific_bodies/working_groups/307/**

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## INITIAL REPORT

## 1. Introduction

The original goal of the Reference Library of Galaxy Spectral Energy Distributions (RELIGAS) Working Group was to define a set of SEDs (initially photometry, not spectroscopy) that could be used by the astronomical community. Two potential deliverables were identified:
• an ensemble of already existing galaxy SED libraries
• a report that summarizes the principal properties of SED templates and models, their applicability (i.e., to particular science goals and galaxy classes), and suggests ways to improve them and identify key missing object classes.
This could potentially be finalized and delivered prior to the 2018 IAU General Assembly in Vienna.

The library of SEDs should not only be relevant to local galaxies but also applicable to (or selected from) a variety of environments and redshifts. The wavelength range was not defined, but covering the restframe FUV to FIR was identified as a goal, given the current suite of satellites and telescopes being used by the astronomical community. The intention was to include both observed and modeled SEDs in the compilations.

The main objectives of compiling the SEDs was to
• provide the community with an archive of the available libraries, that can be updated appropriately.

• provide SED reference data for the astronomical community.
• provide a reference of SED empirical templates and modeling codes, which can be used for cross-calibration and estimation of model dependencies for key quantities (e.g., stellar masses).
• identify and highlight weaknesses in existing SEDs (observational and model) to motivate community efforts (observing proposals, grants, PhD projects) to improve SEDs, their interpretation and utilization.

## 2. Recent Developments

RELIGAS Working Group members have held a series of teleconferences over the past year to clarify RELIGAS's goals and how to achieve them. Should RELIGAS be aggregating and characterizing the SEDs in the literature? Should the Working Group have its own archive, or encourage the migration of SED libraries and codes to established archives (e.g., ESA, ESO, IPAC MAST, NED)? Should the Working Group be identifying preferred SEDs for particular purposes, or provide information for astronomers to better identify the SEDs for their needs? How can RELIGAS motivate rather than duplicate the existing photometric SEDs (e.g., CANDELS, GAMA, unWISE) and resources (e.g., archives)? How can RELIGAS motivate new research of SEDs? Should RELIGAS identify preferred methods for the construction of SEDs? How can RELIGAS motivate improved archiving and documentation? Critically, how can RELIGAS motivate new research of SEDs?

An obvious goal for RELIGAS is to identify the key weaknesses in existing SEDs, and to help motivate further observational and theoretical research. Do observational SEDs cover a sufficient range in wavelength, mass, color and star formation rate? Do model SEDs include sufficient astrophysics to adequately model galaxies, including stellar populations (binary stars, AGB stars, BHB stars, IMF), nebular line emission, dust obscuration, emission by warm dust and PAHs?

A first step for RELIGAS was to summarize the existing literature on SEDs and characterize the properties of the relevant SEDs. What exactly constitutes an SED does complicate the issue, as SEDs can incorporate (or be limited to) photometry, spectrophotometry or models, span a variety of wavelength ranges, and be optimized for particular wavelength ranges.

For SEDs comprising of multi-wavelength photometry, the literature from past decade falls into two broad categories. These categories reflect different science goals, magnitude ranges, angular diameters and time available for manual tweaking. There is precision (aperture) photometry of limited numbers of individual bright nearby galaxies (e.g., Dale et al. 2017) where an individual galaxy may be detected in all (or most) of the relevant bands. There is also automated photometry of large numbers of galaxies in wide-field and deep surveys such as GAMA and CANDELS (e.g., Wright et al. 2016, Nayyeri et al. 2017), where source confusion, wavelength dependent point-spread functions and non-detections in some bands are significant issues. The Working Group is summarizing the properties of such SEDs, and determining how best to convey key details in a succinct and informative manner.

While an initial focus on photometric SEDs was considered, SED templates incorporating spectrophotometry are amongst the most widely used in the literature, being used for photometric redshifts, k-corrections, exposure time calculations and modeling object selection. The UV-optical SEDs of Coleman, Wu & Weedman (1980) and Kinney et al. (1996) are classic examples of such templates, and since 2005 the number of such

SED libraries and their scope has increased. RELIGAS has identified over a dozen such SED libraries in the literature, including libraries that with SEDs for quasars, luminous infrared galaxies and blue compact dwarfs (e.g., Polletta et al. 2007, Brown et al. 2014).

SED libraries incorporating spectrophotometry now span the 0.1 to 400 micron range, exploiting photometry and/or spectroscopy from FUSE, GALEX, HST, SDSS, 2MASS, *Akari*, *Spitzer*, WISE, ISO, IRAS and *Herschel*. However, in the UV, near-infrared and far-infrared these templates are often using models (constrained with photometry) rather than spectrophotometry, and there's a dearth of flux calibrated spectra of entire galaxies at these key wavelength ranges. Contemporary UV and near-infrared spectroscopy of nearby galaxies is often limited to individual regions within galaxies, limiting its use for SEDs.

Recent work on SEDs in part reflects the improved archiving and documentation of input imaging, photometry, spectrophotometry and code used to construct SEDs. In particular, the availability of flux calibrated imaging, photometry and/or spectra from wide-field ground-based surveys (e.g., SDSS) or satellites (e.g., *Akari*, *Spitzer*, *Herschel*). A potential weak point is ground-based optical and near-infrared spectroscopy, where some crucial data products are held by individual authors and raw data may predate systematic archiving by observatories.

The wealth of spatially resolved spectrophotometry becoming available thanks to ALMA, GEMINI, VLT-SINFONI, VLT-MUSE and in the very near future JWST, opens a new question on how to include these 3D information in the SED fitting. We will need to go beyond modeling the integrated multi-wavelength emission from galaxies, modeling individual pixels at all wavelengths simultaneously. Some widely-used panchromatic modelling techniques that build energy-balanced consistent models of all these data simultaneously, are potentially usable for the pixel-by-pixel multiwavelength SED fitting (e.g., Smith et al. 2018; Gallagher et al. 2013).

## 3. Closing remarks

Prior to 2018 IAU General Assembly in Vienna the RELIGAS will complete its overview of the literature, and provide some means of succinctly summarizing this literature for the astronomical community (i.e., tables, figures and relevant references). The Working Group will also identify several key weaknesses in the existing empirical SEDs and SED models that can plausibly be addressed in the coming years (e.g., with James Webb Space Telescope).

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