Models for the Panchromatic Emission of Galaxies and Active Galactic Nuclei

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Introduction

It is now clear that in order to understand the numerous processes that govern galaxy formation and evolution we need multi-wavelength observations of galaxies at all cosmic epochs. This has led to a series of surveys at all wavelengths from the X-rays to the radio of ever improving sensitivity, resolution and sky coverage. At the same time significant progress has been made in the development of models (stellar population synthesis models, radiative transfer models) that aid the interpretation of these observations. The spectra of galaxies can be decomposed into a number of components. Radiative transfer models are available for all of these components but comparing them to the data is a very computing intensive operation as each model has at least 2 or 3 parameters.

Models

Our group has been involved for a number of years in the development of such models and their comparison with observations (Efstathiou & Rowan-Robinson 1995, Efstathiou et al. 2000, Efstathiou & Siebemorgen 2009, Efstathiou et al. 2013). We have embarked on an ambitious project to model a sample of ~200 luminous infrared galaxies observed with the Infrared Spectrograph (IRS) of the Spitzer Space Telescope (that covers the wavelength range 5-35μm) and which are available from the CASSIS database. Recent studies (e.g. Efstathiou et al. 2013) have shown that the IRS spectra are crucial for constraining the parameters of the models.

A Panchromatic View of Galaxies

- **Three main types of activity in galaxies:**
  - star formation in quiescent disk galaxies,
  - bursts of star formation in starbursts and
  - accretion of matter onto a supermassive black hole (active galactic nuclei or AGN).
- All three processes associated with a lot of gas.

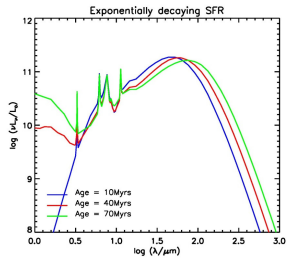
  Gas is associated with a small amount of material (~1%) in solid form (dust) which is much more opaque than gas.
- **Dust** absorbs the optical and ultraviolet radiation and re-emits in the infrared (1-1000μm)
- We therefore need observations of galaxies from 0.1-1000μm and radiative transfer models for their emission in order to interpret the observations.

Andromeda: the nearest spiral galaxy.

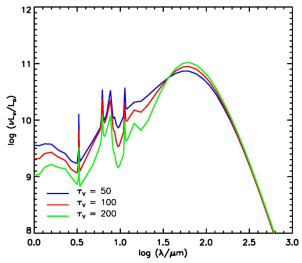
Starburst Models

Starburst models (e.g. Efstathiou et al. 2000) predict the emission spectrum of young stars embedded in optically thick clouds of dust and gas.

Spectra of starbursts of different ages

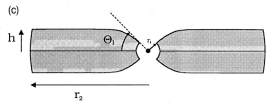


Spectra of starbursts with different optical thickness

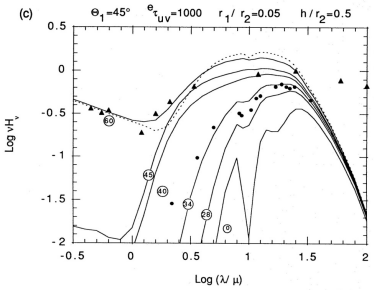


AGN Torus Models

AGN torus models (e.g. Efstathiou & Rowan-Robinson 1995) model the emission of the toroidal structure that partly obscures the accreting supermassive black hole in AGN and quasars.



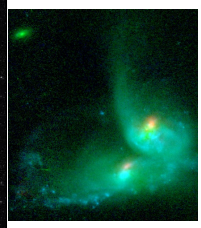
The figure below shows the emission spectrum for different inclinations.



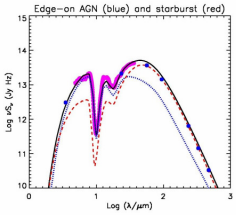
The Most Luminous Infrared Galaxy in the local Universe

IRAS 08572+3915: A candidate for the most luminous infrared galaxy in the local (z < 0.2) Universe (Efstathiou et al. 2013)

Hubble ST image



A model of the 1-1000micron spectrum



Models for the Panchromatic Emission of a Large Sample of Infrared Galaxies

- We plan to model a sample of ~200 galaxies with Spitzer 5-35μm spectra using a combination of starburst, AGN torus and quiescent disk galaxy models. The spectra are publicly available from the CASSIS database (http://cassis.astro.cornell.edu/atlas).
- The Spitzer data will be supplemented by Herschel and IRAS data.
- We are exploring a number of different model-fitting techniques (χ^2 minimization, Markov Chain Monte Carlo) and we implement them using parallel computing techniques on HPC facilities.

References

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