Impact of Axion Decay on the Cosmic Background

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The Cosmic Background (CB) is defined as the isotropic diffuse radiation field with extragalactic origin. Different astrophysical sources dominate the CB emission at different energies, such as stars in the optical or active galactic nuclei in X-rays. Assuming that dark matter consists of axions with masses on the order of electron volts or higher, we expect an additional contribution to the CB due to their decay into two photons. Here, we model the CB between the optical and X-rays regimes, and include the contribution of decaying axions. Through a comparison with the most recent direct and indirect CB measurements, we attempt to constrain the photon-axion coupling parameter space. We also show for which coupling values it is possible to explain the excess in the optical background observed with the LORRI instrument on the New Horizons Probe that does not contradict limits from other optical instruments.

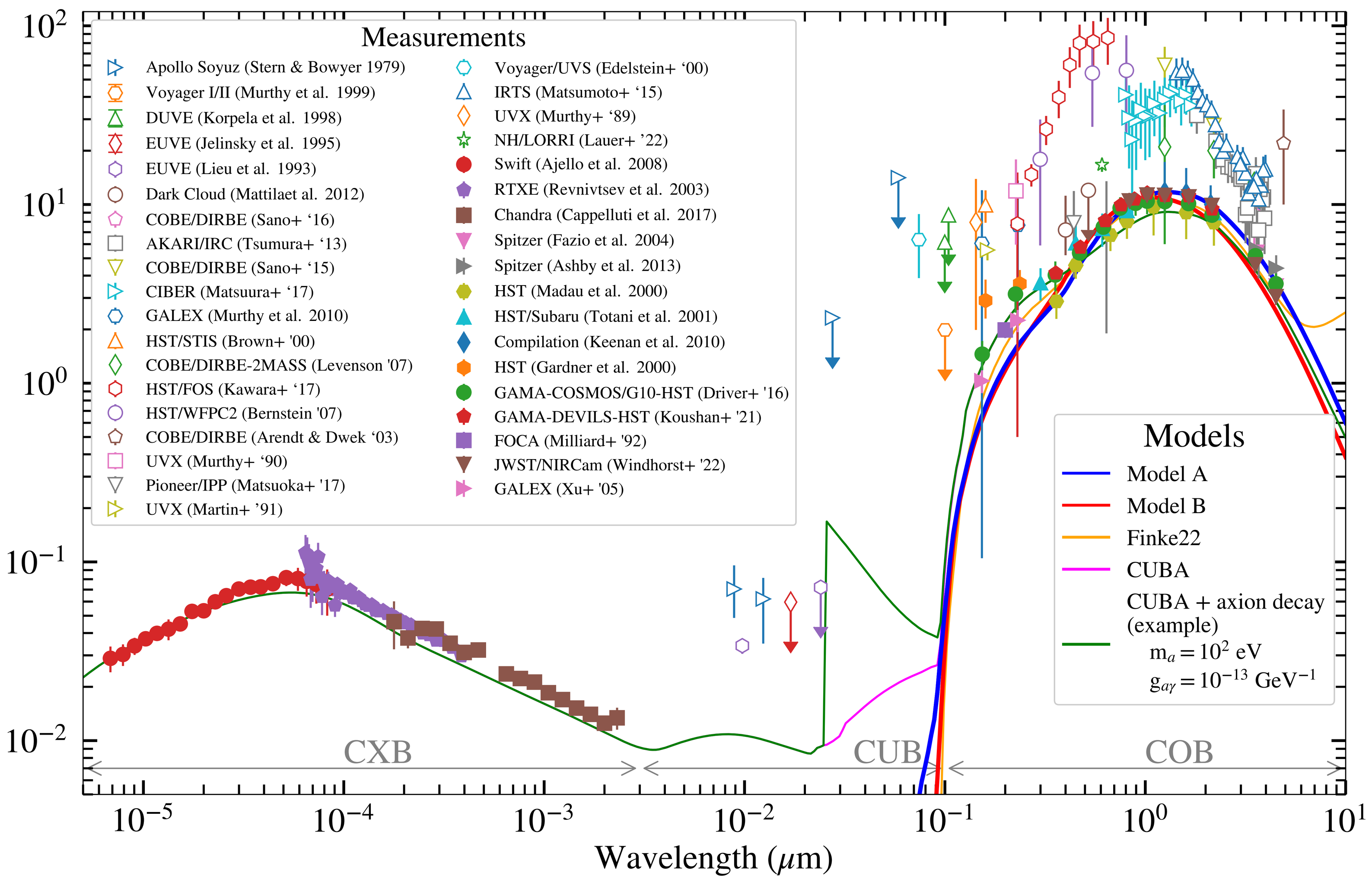


Figure 1: CB measurements and models. Data from Hill et al. [1] and Biteau et al. (in prep).

The Cosmic Background (CB)

- Homogeneous and isotropic diffuse radiation background, extragalactic origin [1].
- Covers the entire electromagnetic spectrum.
- Focus on the range 10^{-6} – 10 µm or 10^{13} – 10^{20} Hz.
- Different models to describe parts of the CB, e.g. the CUBA [2] and the Finke22 [3] models in Fig. 1.

Cosmic Optical Background (COB)

- Dominated by stellar emission, and absorption by interstellar dust.
- Other known sources account for up to 10% of the stellar emission.
- Direct measurements are difficult because of foreground emissions. Usually treated as upper limits (open symbols).
- Lower limits are calculated from galaxy counts (filled symbols).
- The New Horizons probe (NH) took a measurement at a distance of 51 AU [4]. Foreground emissions should be completely removed, however NH datapoint significantly above lower limits (represented with a green star).

Cosmic Ultraviolet Background (CUB)

- Main components are young stars and interstellar nebulae, scattering by gas and hot intercluster gas.
- Very low intensity due to neutral hydrogen's absorption.

Cosmic X-ray Background (CXB)

- Created mainly by accretion disks around active galactic nuclei.

Axions and Axion-Like Particles

- Pseudo-Nambu–Goldstone boson
- Arises from the Peccei–Quinn solution to the strong CP problem [5].
- One of the preferred dark matter (DM) candidates.

- Relaxing m_a - $g_{a\gamma}$ relation, we have Axion-Like Particles (ALPs).
- $m_a \geq$ O(eV) so they decay into two photons, Fig. 2.
- Minimum mean life $\tau_{a,\,min} \approx 10^{17}$ s (age of the Universe).

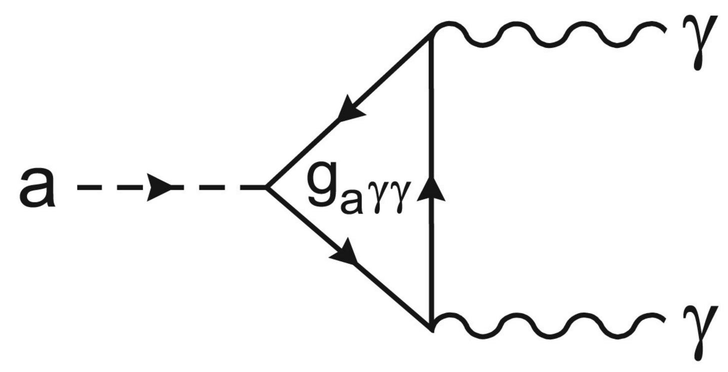


Figure 2: Feynman diagram of axion decay into two photons.

So, Axions or ALPs Anywhere?

We add the axion decay to the astrophysical CB as seen in Fig. 1, and probe the m_a - $g_{a\gamma}$ parameter space as presented in Fig. 3.

We use the NH datapoint (green star in Fig. 1):

- As a measurement, so the decay contribution has to strictly fit to it. This means that ALP decay could explain the NH excess over lower limits. Black strip in Fig. 3 at $g_{a\gamma} \sim 10^{-10}$ – 10^{-11} GeV $^{-1}$, with 69% and 95% acceptance percentiles in red and blue lines.
- As an upper limit, so it produces stronger constraints. We use it alongside the other upper limits from Fig. 1.

Different COB models are shown in the inset in Fig. 3 as brown lines, but their differences are very small.

Only a small region of axion parameter space explains the NH point as well as being accepted by the upper limits, located at m_a ~ 4-5 eV. This parameter space is ruled out by other experiments.

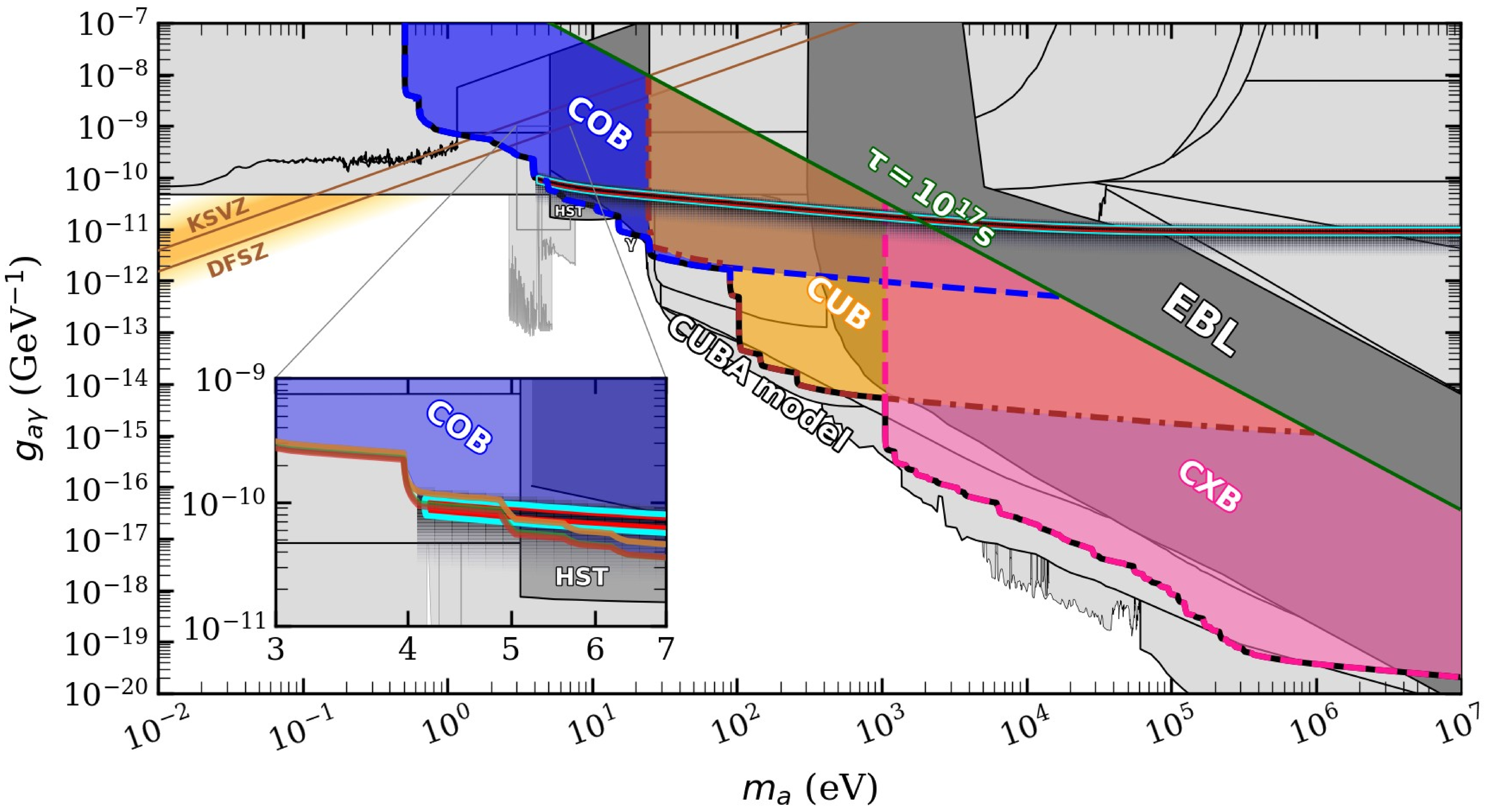
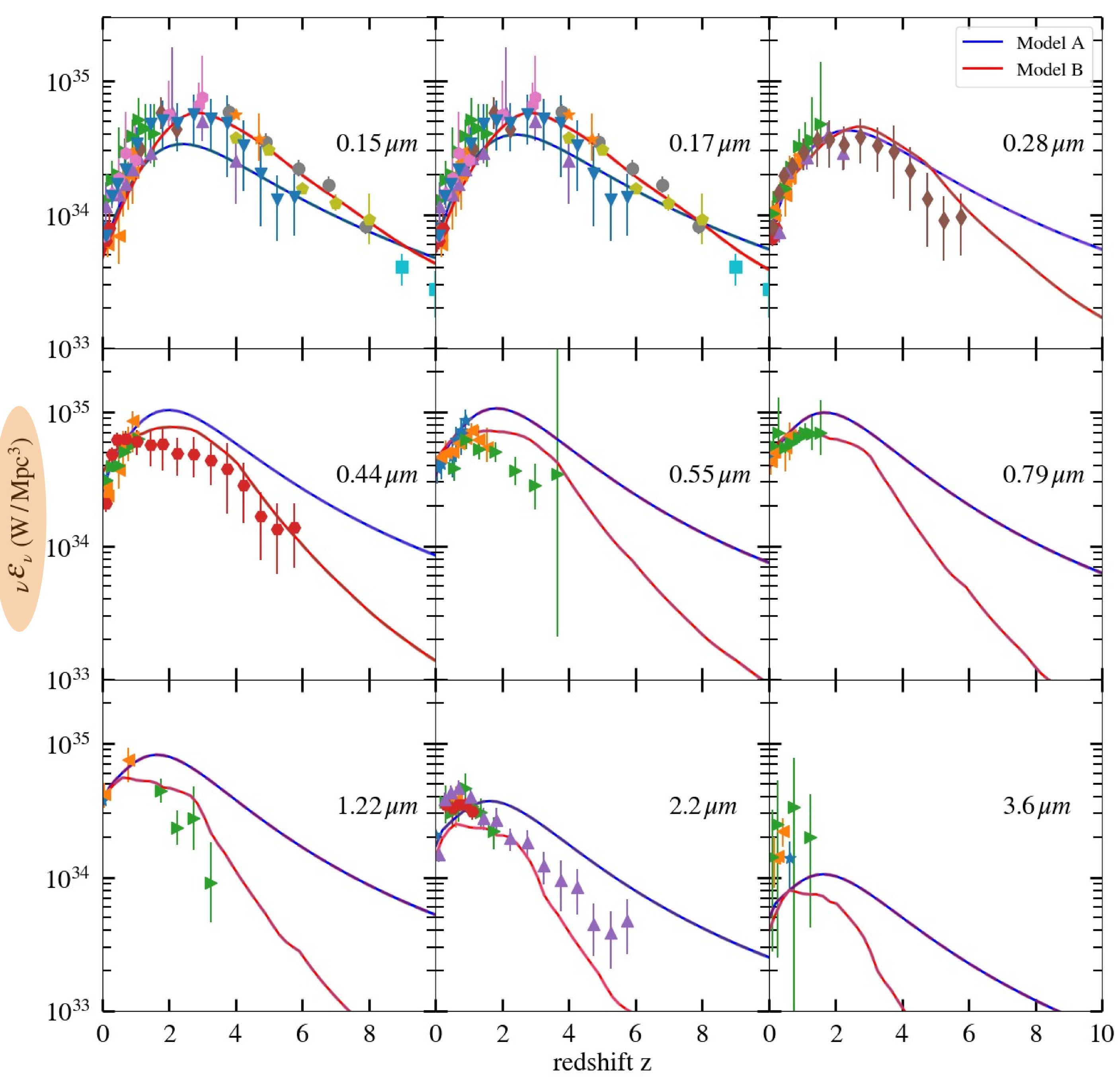


Figure 3: Axion and ALP parameter space. Our new set of constraints using the CUBA model and the axion decay are listed around the different regions of the CB. Software and literature limits from C. O'Hare [6].

How to Model the COB

- We use synthetic stellar spectra to simulate the luminosities of stellar populations [7, 8].
- We propose two cases to study, model A (calibrated to starburst galaxies) [9] and model B (general stellar evolution) [3]. They differ in stellar spectra, metallicity and dust treatment.
- Freeing the stellar formation rate (sfr) parameters, combined fit of CB, emissivities and sfr to observational data. Fits in Figs. 1 and 4.
  - Our models do not incorporate dust reemission, so from ~ 3 µm they start failing.
  - Our models have fixed stellar metallicity. We compare our results with Finke22, who do incorporate this evolution in Fig. 1.



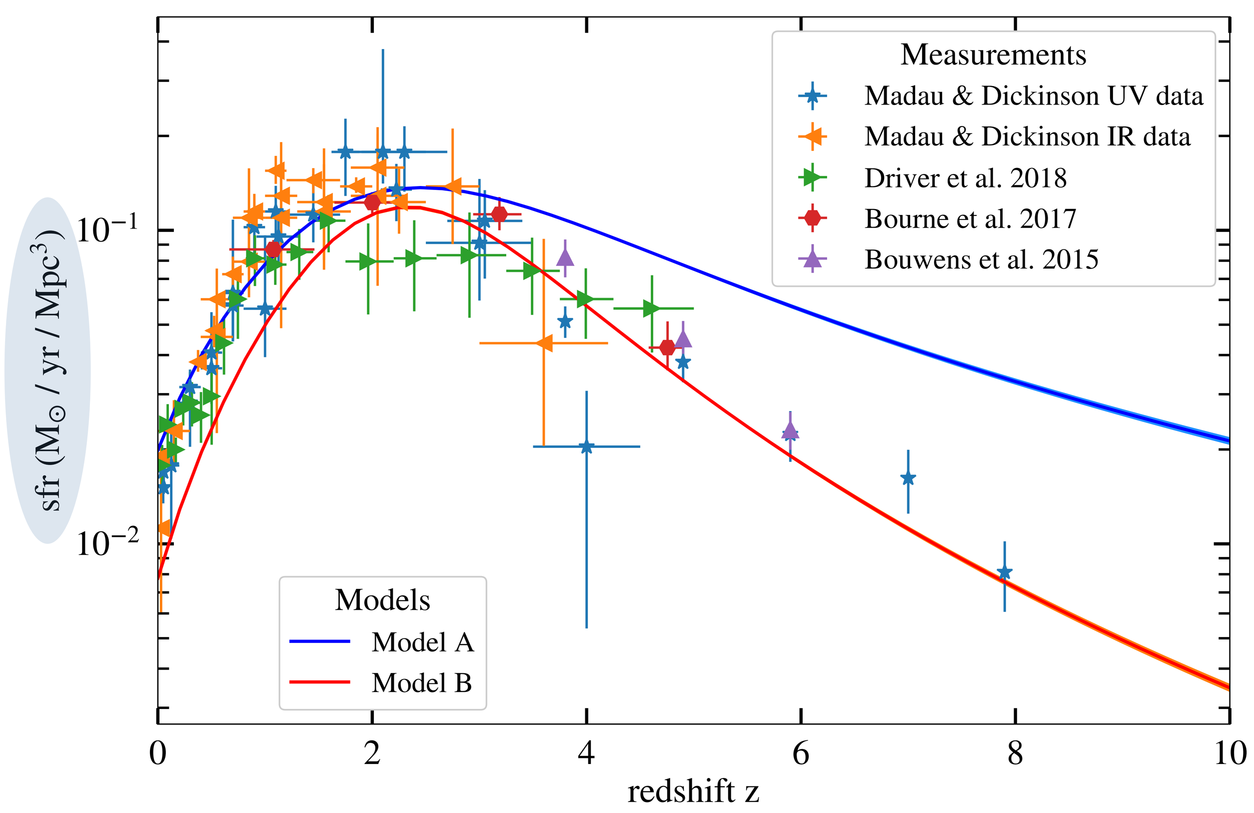


Figure 4: stellar emissivity over a range of redshifts, for a list of individual wavelengths. Data taken from [3]. Best fits for our models represented as blue and red lines (left). Sfr data compilation, also with our fitted models (right).

Acknowledgements

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