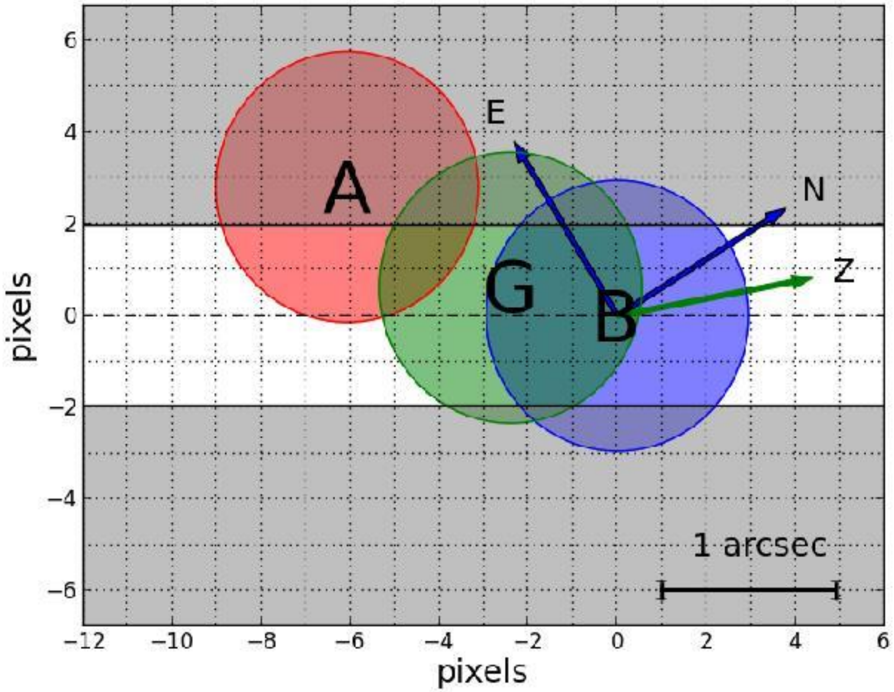
Individual task #2
(Topics 5, 6 & 7)

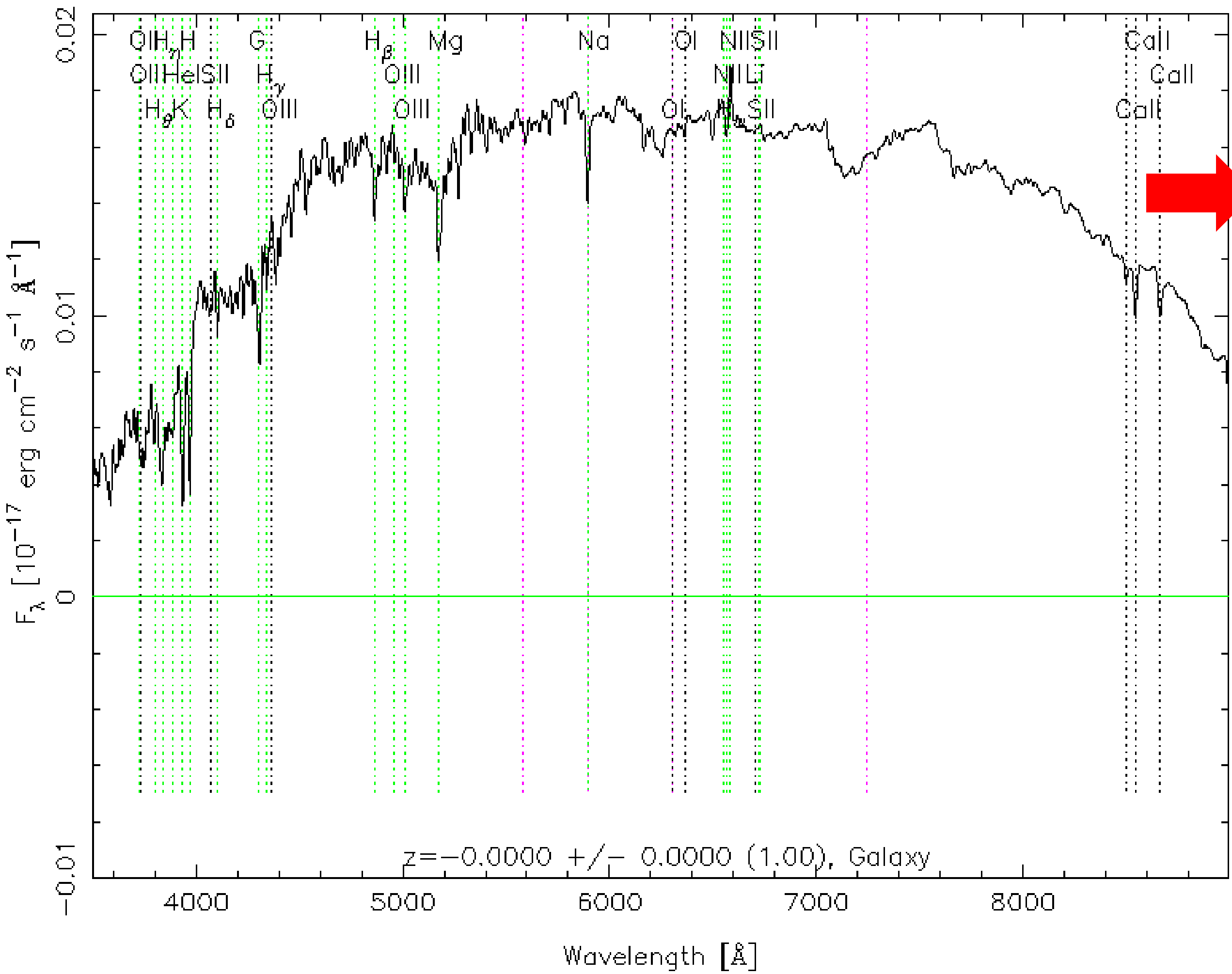
Revealing physical properties of an early-type galaxy from deep spectroscopy

A deep spectroscopic exposure of 3570 s (~1 hour) with the 10.4 m Gran Telescopio Canarias (GTC) on 27 March 2014 led to spectra for three objects A, B and G along the spectroscopic slit (see attached figure). Here, we focus on the optically-faintest source G, which was tentatively identified as an early-type galaxy

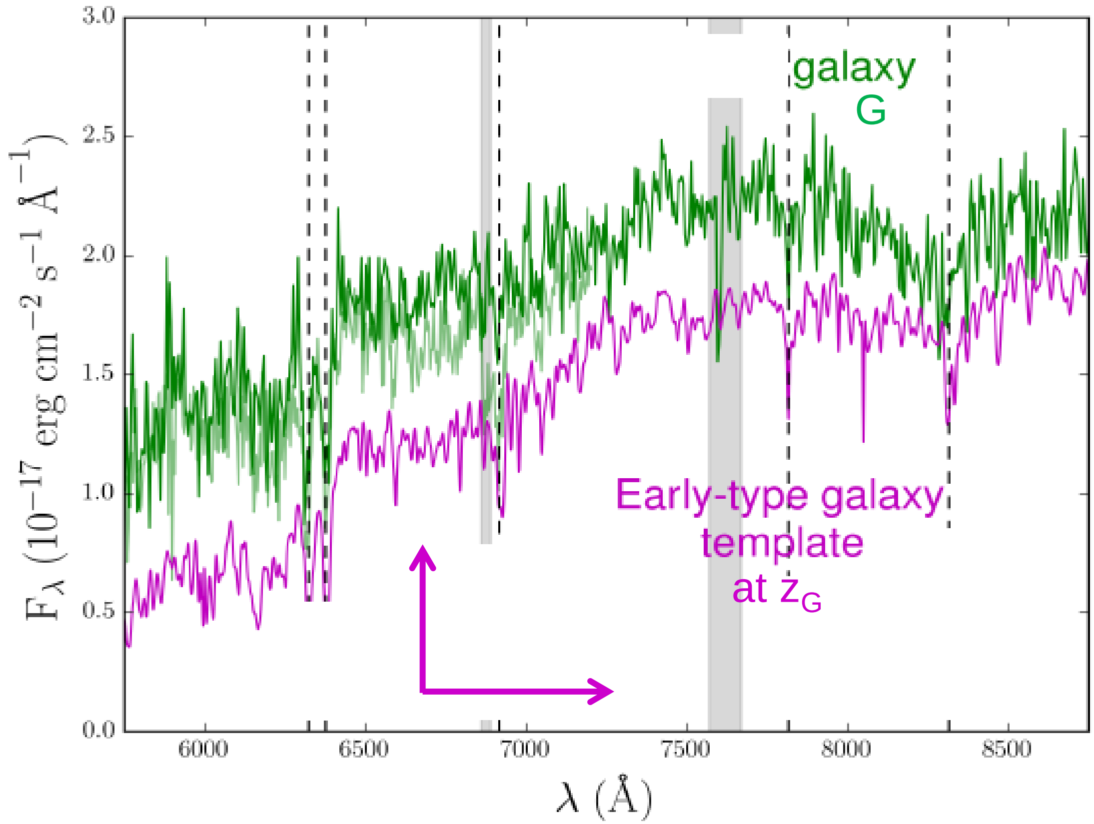
ABGspec.dat



The redshift of G can be estimated by matching its optical spectrum with a shifted version of the spectral template for early-type galaxies in the SDSS database at http://classic.sdss.org/dr5/algorithms/spectemplates/spDR2-023.gif

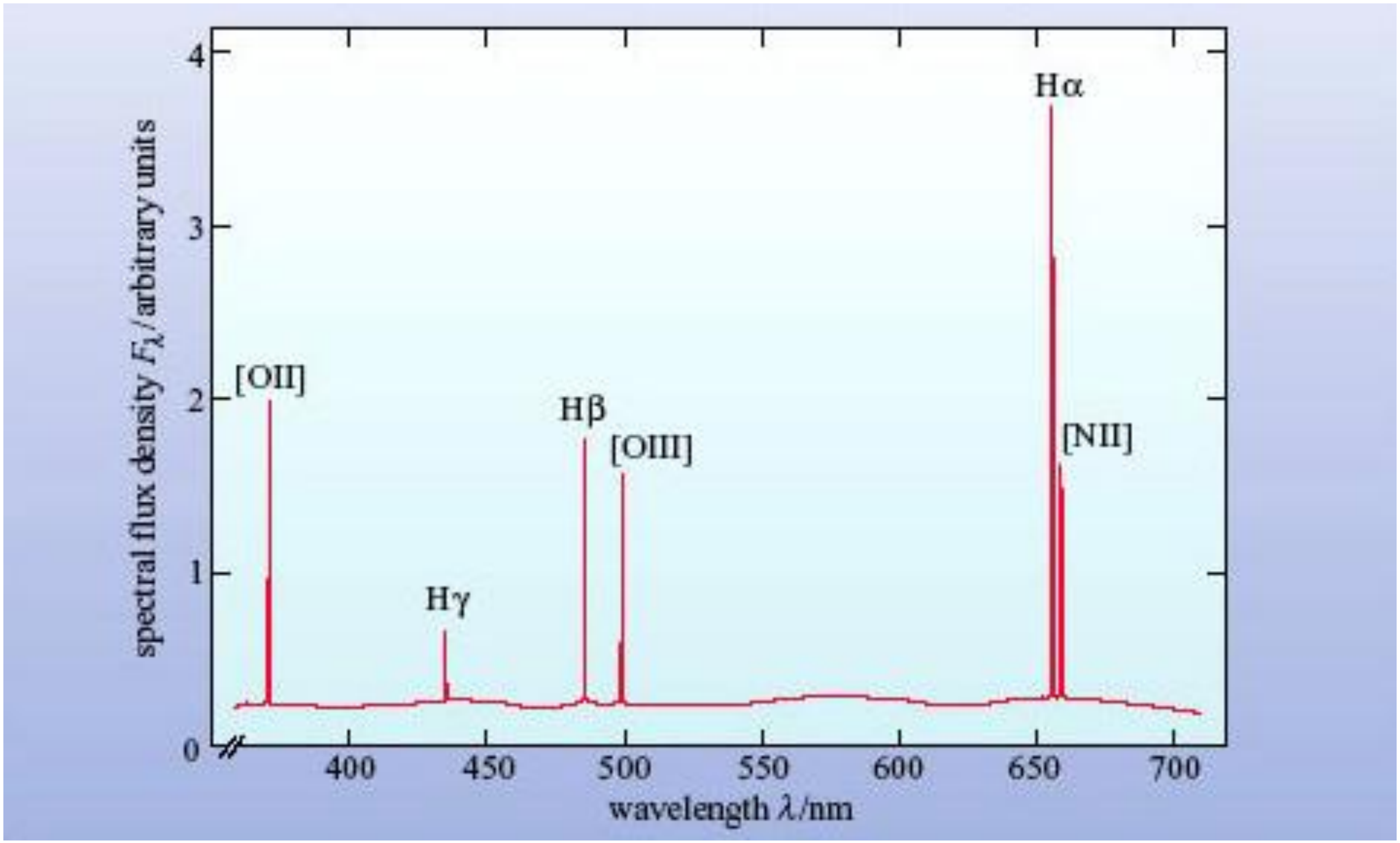


templatespec.dat



Q1: Compare the GTC data of G and the spectral template for an early-type galaxy at zero redshift. Use a cross-correlation technique to estimate the redshift of G (z_G). After doing the cross-correlation measurement of z_G, identify some main absorption features in the spectrum of G: CaII *HK* doublet, G-band, and Hβ and MgIb lines. Show the spectrum of G along with the redshifted spectral template, indicating the absorption features that you have identified (see figure above)

Q2: Analysing the spectrum of G, do you find evidence of oxygen emission [OII] at 372.7 nm? Taking the typical spectrum of an HII region into account (see figure below), is there evidence of star formation in G?

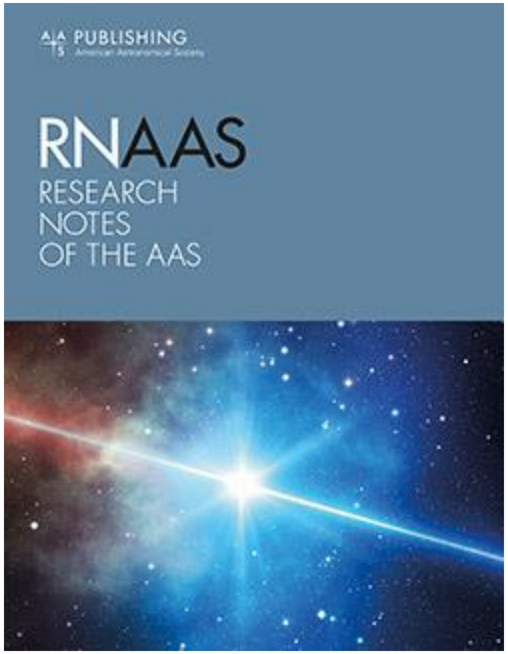


Software tool for interpreting galaxy spectra

https://github.com/HinLeung622/pipes_vis

Introducing a Real-time Interactive GUI Tool for Visualization of Galaxy Spectra
by Ho-Hin Leung, Vivienne Wild, Adam Carnall, and Michail Papathomas

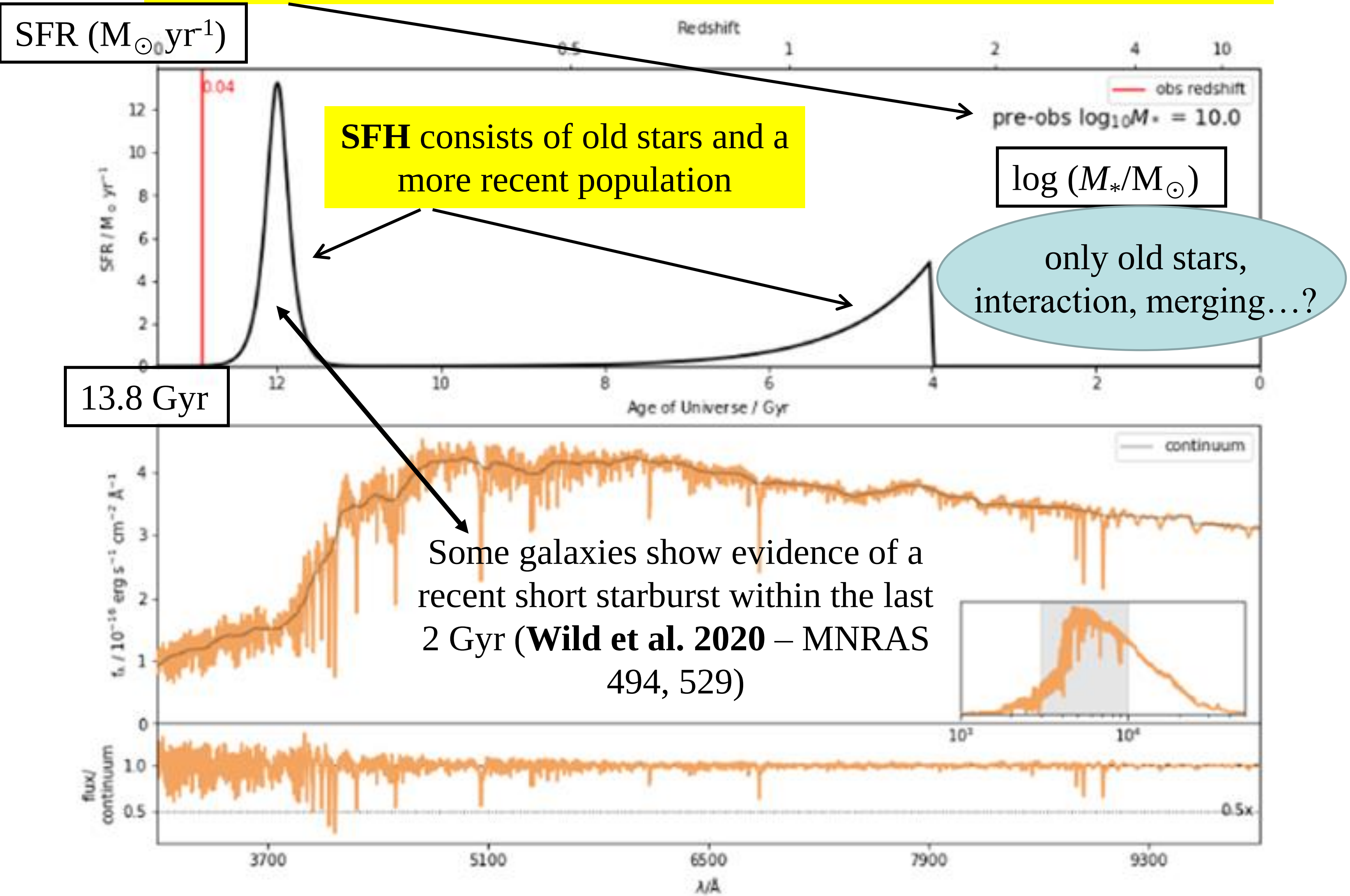
***Res. Notes AAS* 5 171** (July 2021)



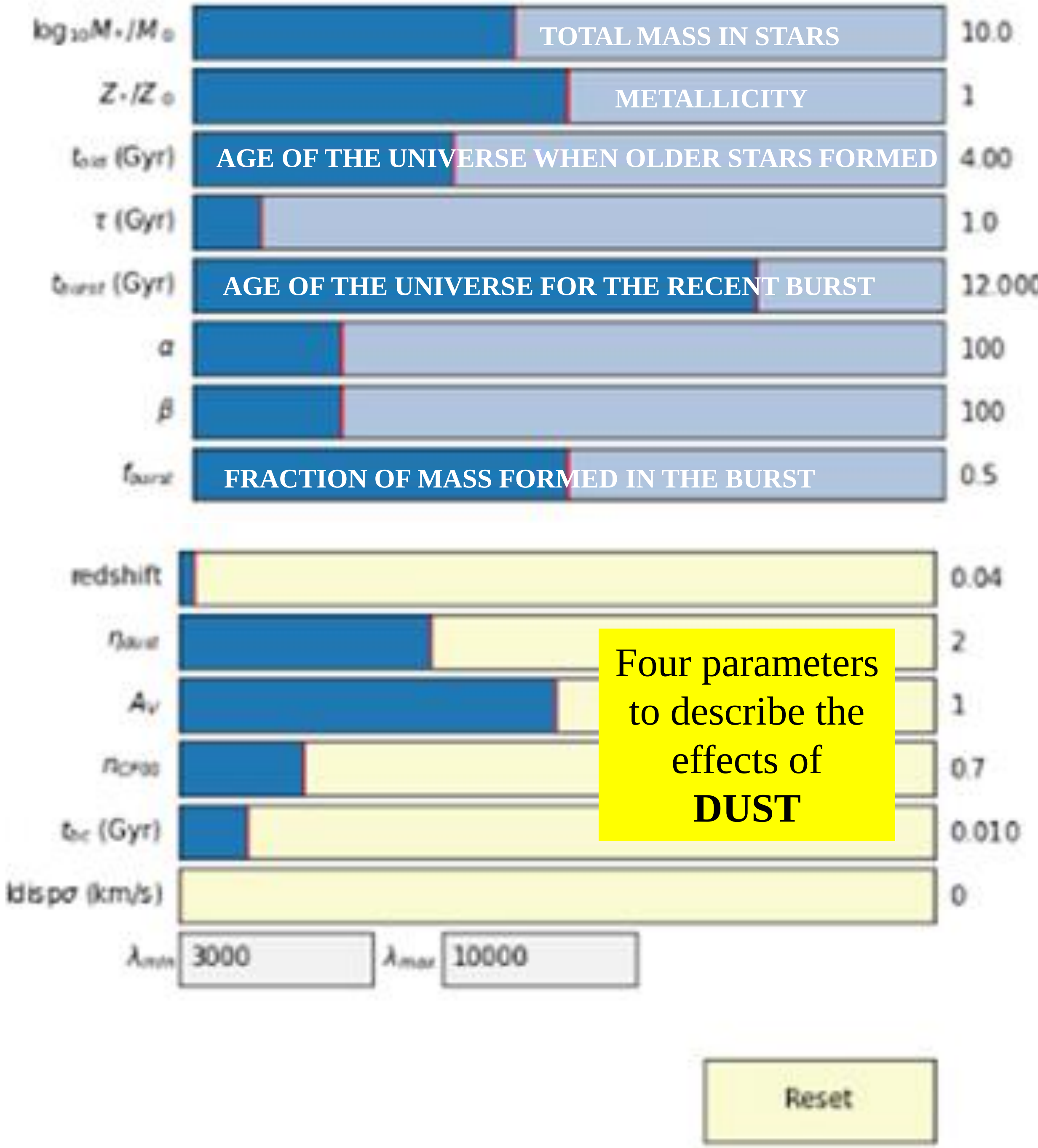
Very recently, Leung et al. (2021) have introduced a python tool to model the observed spectrum of a galaxy considering its star formation history (SFH) from the beginning of the Universe to $z = z_G$. The tool provides predictions (realistic spectra) from complex SFHs, accounting for dust extinction/emission and emission lines generated in HII regions. The code relies on a ΛCDM cosmology with $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$ and $h = 0.7$

For generating model galaxy spectra, read:
https://bagpipes.readthedocs.io/en/latest/index.html

total stellar mass formed prior to the time of observation (red vertical line)



See the Jupyter notebook: pipes_vis_example.ipynb



Four parameters to describe the effects of **DUST**

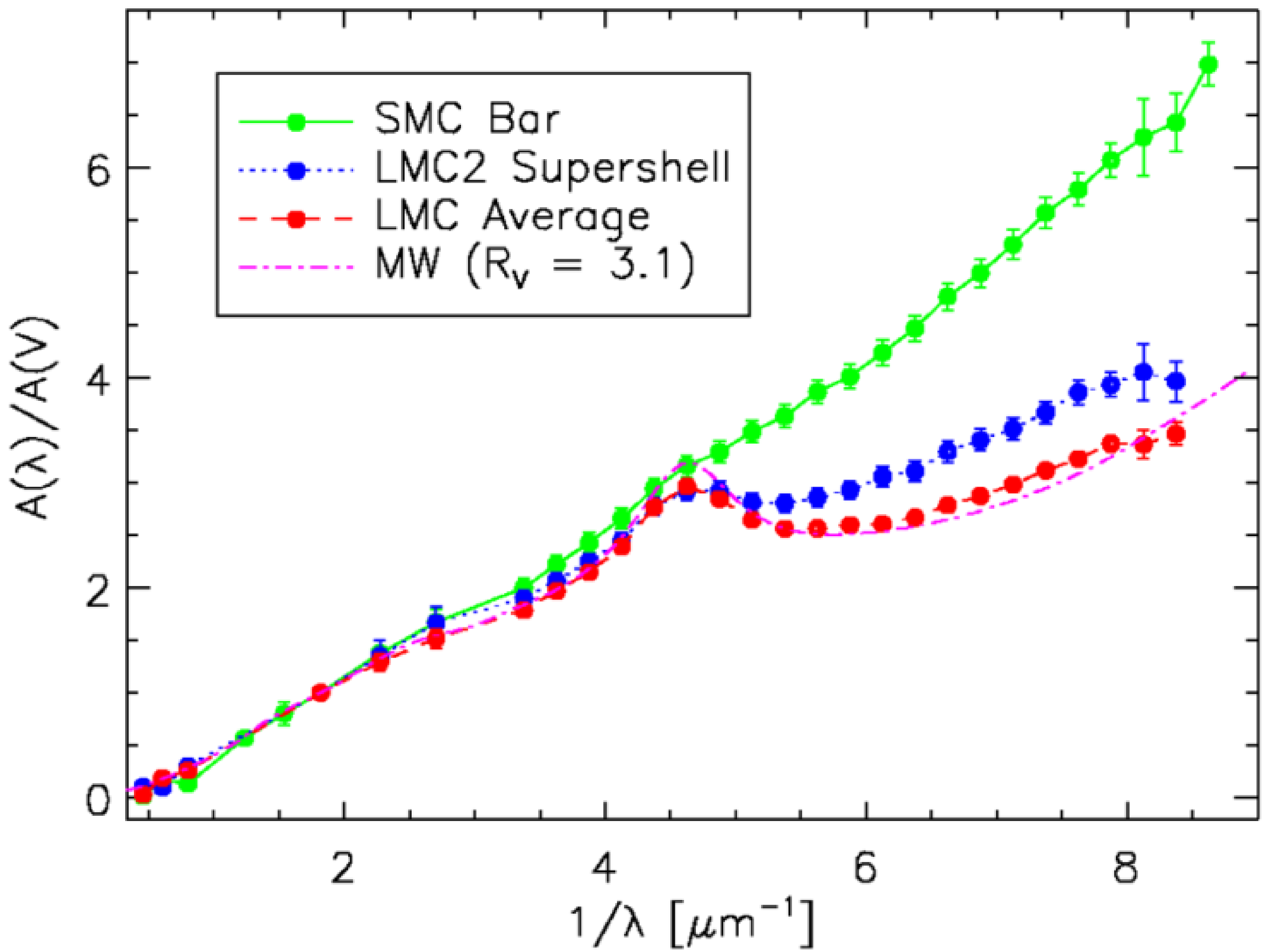
SFH characterized by 8 parameters

OLD STARS: SFR WITH EXPONENTIAL DECAY (τ)

RECENT BURST: DOUBLE POWER-LAW WITH INDICES α AND β

Charlot & Fall 2000 (ApJ 539, 718): η (dust in star-birth clouds), t_{bc} (duration of star-birth clouds), A_V (extinction in the *V* band), and *n* (slope of the atenuation law) $\propto \lambda^{-0.7}$

Cardelli et al. 1989 (ApJ 345, 245):
MW-like dust-extinction with only a free parameter A_V



Q3: Assuming a metallicity $Z_* = Z_\odot$, use the pipes_vis software to discuss physical scenarios that are consistent with the observed spectrum of G in the wavelength range [570, 870] nm, i.e., if $F = F_\lambda$ (10^{-17} erg cm^{-2} s^{-1} A^{-1}), then there are three main observational constraints: (i) presence of CaII *HK* doublet, G-band, and Hβ and MgIb lines at $z = z_G$, (ii) $F_{min} \approx 1.1$, and (iii) $F_{max}/F_{min} \approx 2.3$.

(a) As a starting point, take log ($M_*/M_\odot$) = 10 (low-mass elliptical), a single starburst with exponential decay (τ = 0.1 Gyr) when the Universe was very young (t_{form} = 1 Gyr), and a Cardelli et al.'s dust-extinction law with A_V = 0.1 mag. Are you able to reproduce the observational behaviour (i) + (ii) + (iii)? how will modify the model spectrum the presence of a second starburst within the last 2 Gyr?

(b) Compare the results with those from similar single bursts at t_{form} = 4 Gyr and t_{form} = 6 Gyr. How does the maximum-to-minimum flux ratio change?

(c) Take a single burst at t_{form} = 6 Gyr (τ = 0.1 Gyr), and then discuss the role that M_* plays. For example, consider a typical and a massive elliptical galaxy, having log ($M_*/M_\odot$) = 11.3 and log ($M_*/M_\odot$) = 12, respectively, and compare the new results and those for the low-mass elliptical. Can you account for the observations using the three masses and A_V = 0.1 mag?

(d) If you think an accurate dust extinction plays a role, decide about the total mass in stars and the A_V value that are required to account for the observed spectrum [*Hint*: in addition to A_V = 0.1, consider the three dust scenarios A_V = 0 (no dust; zero extinction), A_V = 0.25, and A_V = 1.2 (high extinction)]