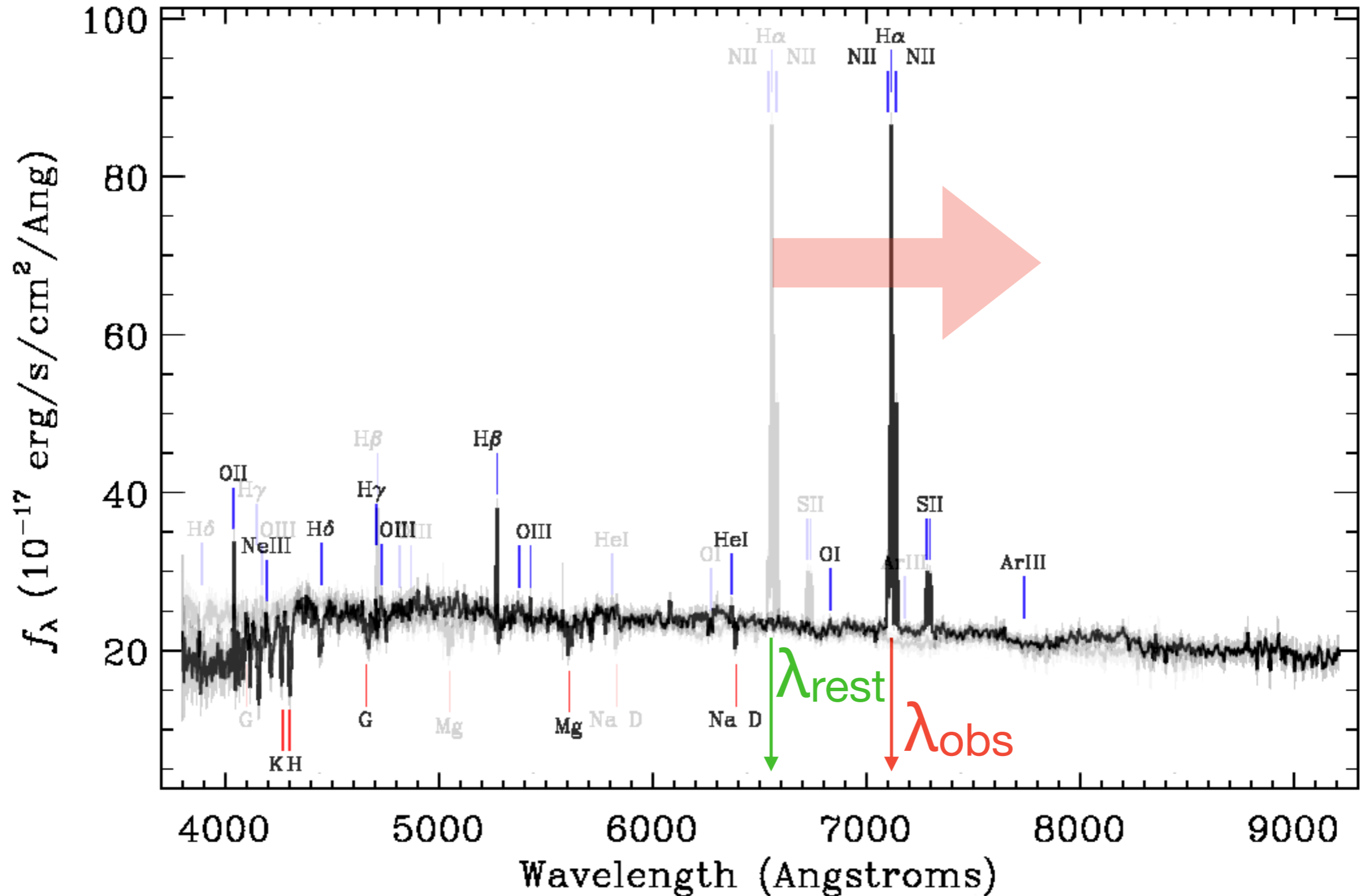


The Art and Agony of Photometric Redshift Estimation

(maybe I should just call this “EAZY does it?”)

Kevin, measuring redshifts is so straightforward!



$$z = \left(\frac{\lambda_{\text{obs}} - \lambda_{\text{rest}}}{\lambda_{\text{rest}}} \right) = \lambda_{\text{obs}} / \lambda_{\text{rest}} - 1$$

A vast field of galaxies, including spirals, ellipticals, and irregular shapes, scattered across a dark cosmic background. The galaxies are rendered in various colors like yellow, blue, and purple, with some appearing as bright points of light. The overall scene is a rich, multi-colored galaxy field.

**but what if we wanted to
measure redshifts for a
bunch of galaxies at once**

“Lyman Break” Galaxies

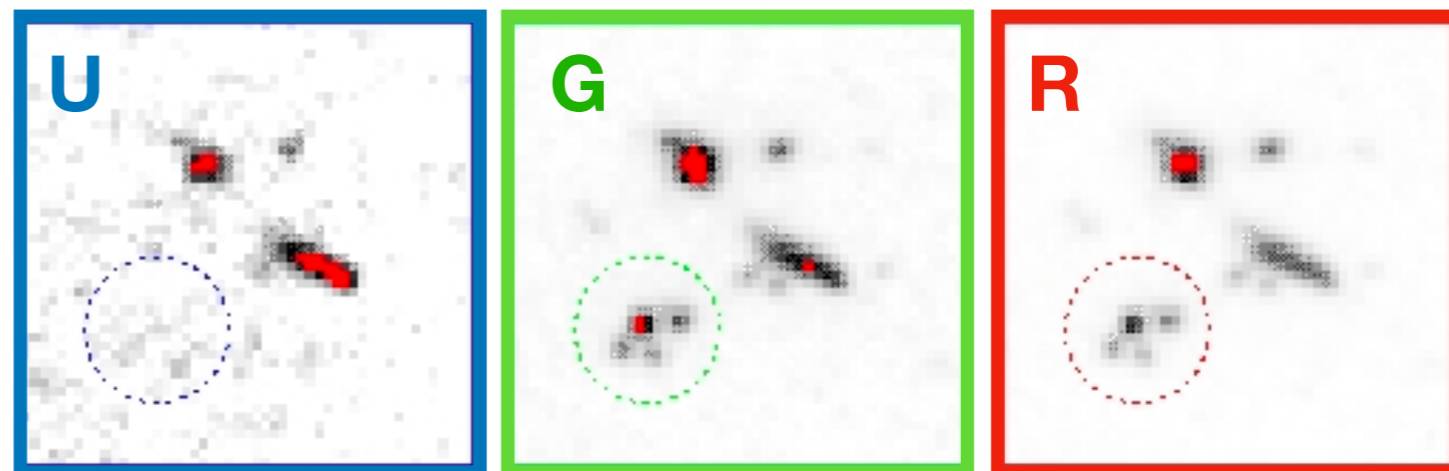
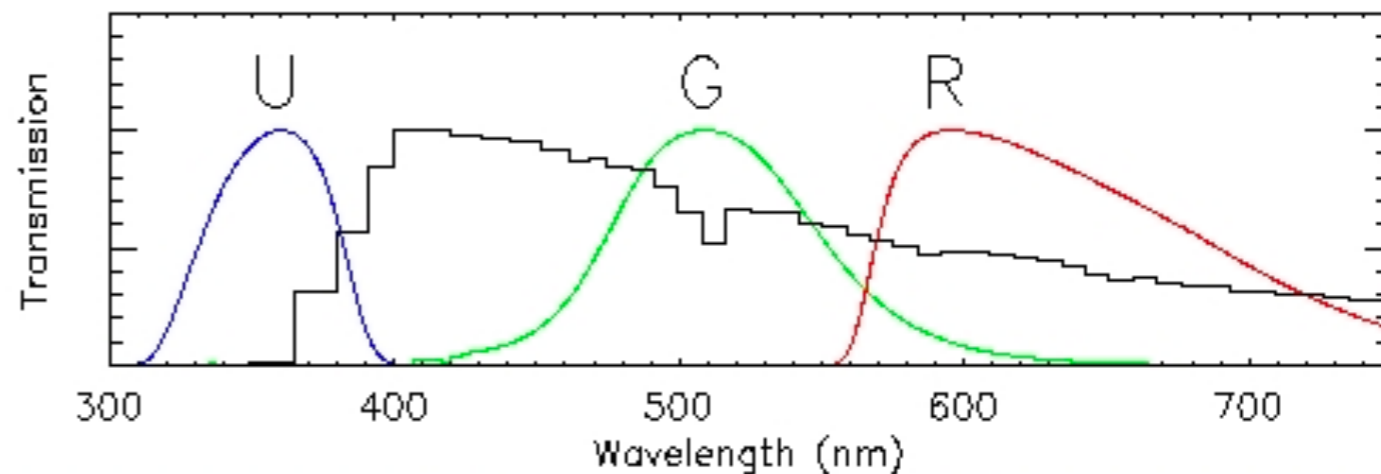
Lyman break observed wavelength: 4000 Å

Lyman break rest wavelength: 1216 Å

$$z = (\Delta\lambda / \lambda_{\text{rest}})$$

$$= (4000 \text{ \AA} - 1216 \text{ \AA}) / (1216 \text{ \AA})$$

$$= \mathbf{2.28}$$



<https://www.nbi.dk/~jfyngo/LBG.html>

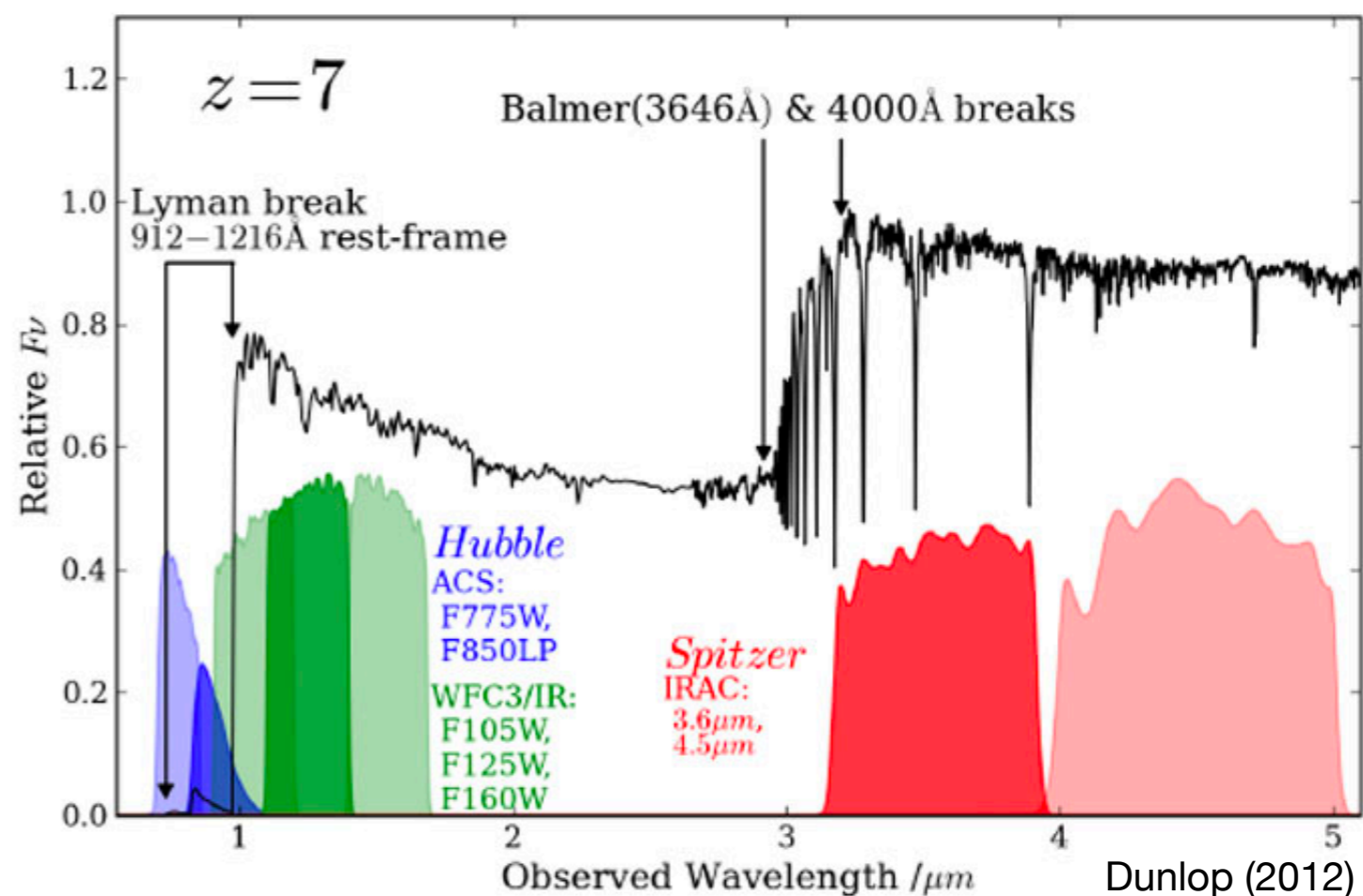
Lyman break observed wavelength: 10000 Å

Lyman break rest wavelength: 1216 Å

$$z = (\Delta\lambda / \lambda_{\text{rest}})$$

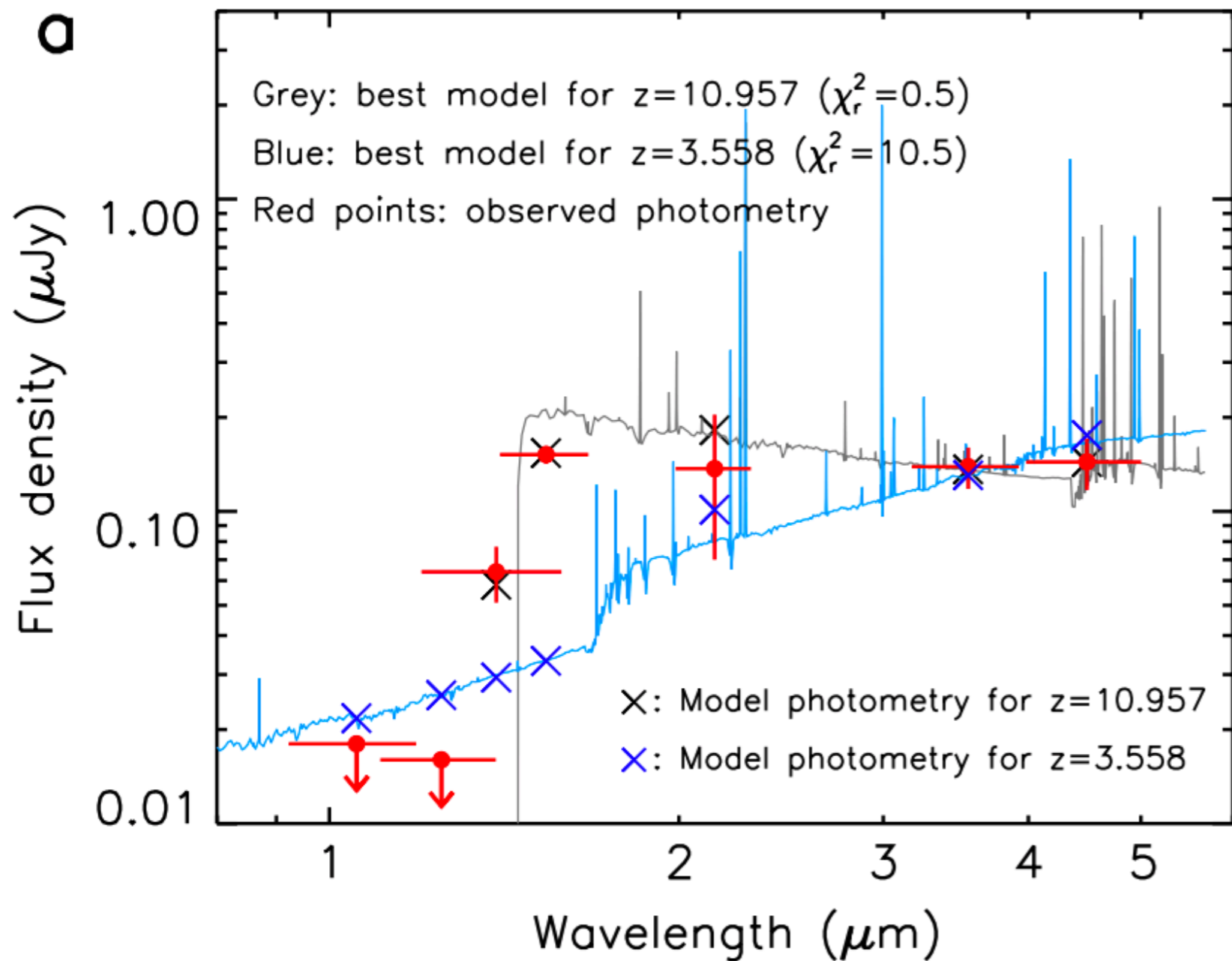
$$= (10000 \text{ \AA} - 1216 \text{ \AA}) / (1216 \text{ \AA})$$

$$= \mathbf{7.22}$$



Dunlop (2012)

you can do this in a slightly more robust way by fitting models to the photometry



Jiang et al. 2021

“Photometric Redshifts” are derived by fitting the observed galaxy SED, largely by focusing on the colors introduced by the Lyman and Balmer breaks, as well as any nebular continuum or line emission/absorption.

Some photometric redshift techniques use stellar population synthesis models, often using MCMC. Some techniques compare the SED to a set of simulated or observed galaxy templates, which is significantly faster.

Photometric redshifts should be considered “guesses,” as there are degeneracies between dust, redshift, age, and galaxy colors which can fool redshift codes.

Enter Gabe Brammer's *EAZY*

Easy and **A**ccurate *z*_{phot} from **Y**ale

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EAZY is a photometric redshift code designed to produce high-quality redshifts over $0 < z < 4$ for situations where complete spectroscopic calibration samples are not available. Details of the algorithm and tests of the code on public multi-wavelength photometric datasets are presented by Brammer, van Dokkum & Coppi (2008)[\[ADS\]](#)[\[PDF\]](#).

EAZY is freely distributed to the astronomical community. Instructions on how to download and install the code are available on the [Download](#) page, and a user's manual describing how to set up the code for your own dataset is available on the [Documentation](#) page.

If you find this code useful, please include a citation to "Brammer, van Dokkum & Coppi, 2008, *ApJ*, 686, 1503" in the bibliography of any published work that makes use of EAZY.

- Gabriel Brammer, Pieter van Dokkum, Paolo Coppi (New Haven, July 2008)

<< UPDATE (September 2012) >>

The most up-to-date version of the code is now hosted in an SVN repository available here: <http://code.google.com/p/eazy-photoz/>. Along with numerous bug fixes, the latest version of the code provides estimates of rest-frame color indices, such as those used by [Brammer et al. \(2011\)](#) and other papers from the [NMBS](#) project. A new template set with improved treatment of emission lines and a filter file with many additional (e.g. HST) filters is also provided.

Brammer, van Dokkum, & Coppi 2008

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EAZY: A FAST, PUBLIC PHOTOMETRIC REDSHIFT CODE

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ABSTRACT

We describe a new program for determining photometric redshifts, dubbed EAZY. The program is optimized for cases where spectroscopic redshifts are not available, or are only available for a biased subset of the galaxies. The code combines features from various existing codes: it can fit linear combinations of templates, it includes optional flux- and redshift-based priors, and its user interface is modeled on the popular HYPERZ code. A novel feature is that the default template set, as well as the default functional forms of the priors, are not based on (usually highly biased) spectroscopic samples, but on semianalytical models. Furthermore, template mismatch is addressed by a novel rest-frame template error function. This function gives different wavelength regions different weights, and ensures that the formal redshift uncertainties are realistic. We introduce a redshift quality parameter, Q_z , which provides a robust estimate of the reliability of the photometric redshift estimate. Despite the fact that EAZY is not "trained" on spectroscopic samples, the code (with default parameters) performs very well on existing public data sets. For K -selected samples in CDF-South and other deep fields, we find a 1σ scatter in $\Delta z/(1+z)$ of 0.034, and we provide updated photometric redshift catalogs for the FIRES, MUSYC, and FIREWORKS surveys.

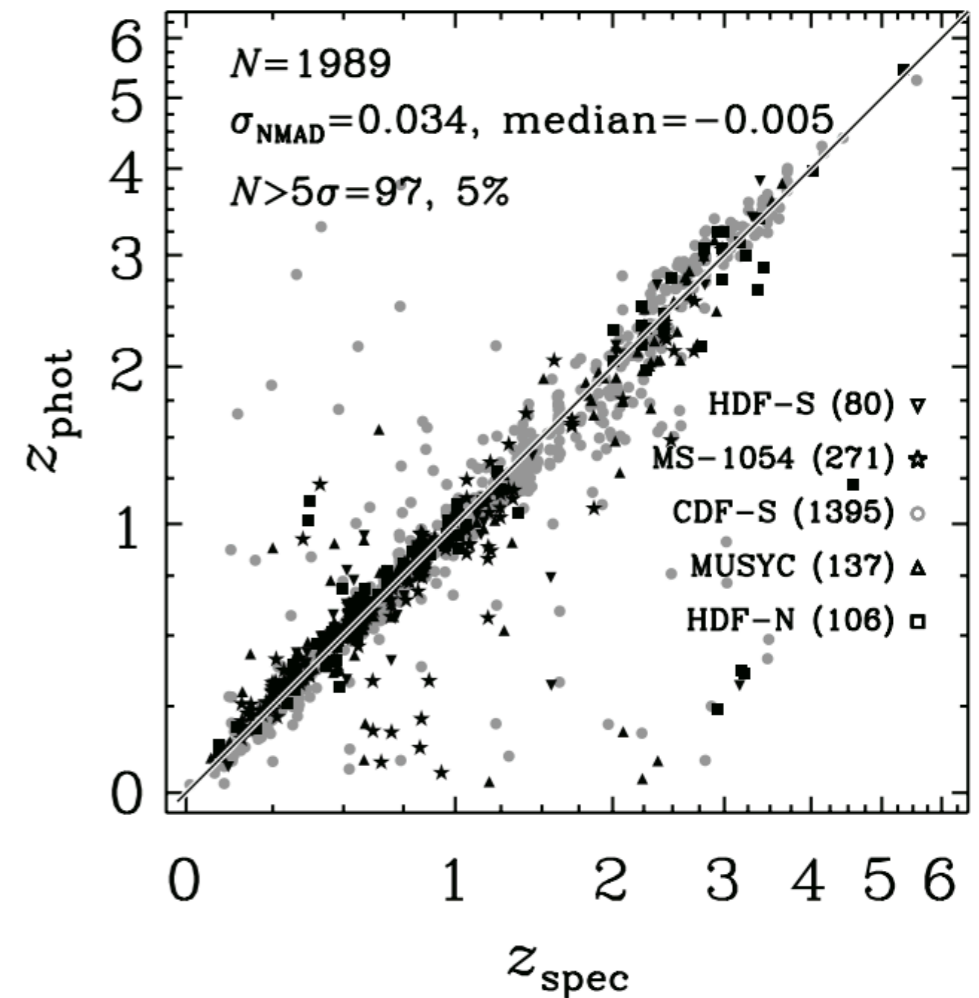
Subject headings: cosmology: observations — galaxies: evolution — galaxies: formation

1. INTRODUCTION

Accurate redshifts of distant galaxies are crucial for nearly all of observational cosmology. Whereas extensive spectroscopy with multiobject spectrographs on 8–10 m class telescopes has yielded redshifts for thousands, and in some cases tens of thousands, of galaxies (e.g., Steidel et al. 2003; Davis et al. 2003; Le Fèvre et al. 2005), these galaxies tend to be relatively bright at optical wavelengths. For galaxies fainter than $R \sim 25$ we rely almost exclusively on photometric redshifts, derived from fitting template spectra to broad- or medium-band photometry (e.g., Lanzetta et al. 1996; Wolf et al. 2003; Franx et al. 2003; Mobasher et al. 2004; Drory et al. 2005). This situation is not likely to change, even with the advent of efficient spectrographs with very wide fields (such as WFMOS; Bassett et al. 2005), multiobject capabilities in the near-infrared (e.g., MOIRCS; Ichikawa et al. 2006), or larger telescopes. The signal-to-noise ratio (S/N) per resolution element in the continuum decreases with spectral resolution as $S/N \propto R^{-0.5}$ for a given exposure time. Therefore, the required integration time to maintain a given S/N per resolution element increases linearly with the spectral resolution, quite independent of the

Ilbert), which do a straightforward χ^2 minimization; GREGZ³ (Rudnick et al. 2001, 2003), which allows linear combinations of templates and uses Monte Carlo methods to determine the redshift uncertainties; BPZ (Benítez 2000), which uses Bayesian statistics allowing the use of priors; and ZEBRA (Feldmann et al. 2006) and kcorrect (Blanton & Roweis 2007; hereafter BR07), which include (distinct) iterative template-optimization routines that make use of the extensive spectroscopic databases of the zCOSMOS (Lilly et al. 2007) and Sloan Digital Sky Survey (SDSS; York et al. 2000) projects, respectively.

For obvious reasons, photometric redshifts benefit from having high-quality photometry in many bandpasses and from sampling strong continuum features in the observed wavelength region (such as a Lyman or Balmer break), irrespective of the methodology. However, given a set of objects with good-quality photometry, the aspect that is of paramount importance for obtaining reliable photometric redshifts is the selection of the template set (see Feldmann et al. 2006, § 2.2). Feldmann et al. (2006) obtain very good results by iteratively adapting the templates, minimizing the systematic differences between the best fitting templates and



EAZY, while not the most complex codes, is still one of the more commonly used photometric redshift methods because of how straightforward it is to use.

Currently you'll probably want to use the python version of *EAZY*:

<https://github.com/gbrammer/eazy-py>

eazy-py: Pythonic photometric redshift tools based on EAZY

Under heavy construction...

Documentation will be here: <https://eazy-py.readthedocs.io/>, though it's essentially just the module API for now.

Templates and filter files still here: <https://github.com/gbrammer/eazy-photoz/>.

Note

Please submit any questions/comments/problems you have through the [Issues](#) interface.

Installation instructions

```
pip install eazy
```

```
# Forked dependencies that are not yet released on PyPI  
pip install git+https://github.com/gbrammer/dust_attenuation.git
```



...which still largely points to the non-python version of *EAZY* for the templates and filter files:

<https://github.com/gbrammer/eazy-photoz/>

***EAZY* is a code that combines a set of galaxy templates and calculates the χ^2 values for these templates at a variety of redshifts.**

The output is, most importantly, the χ^2 surface and a variety of values estimated from this surface, like photometric redshifts and confidence intervals on these photometric redshifts.

(eazy-py also spits out stellar population synthesis parameters providing you use specific template files)

observed fluxes and
uncertainties in each filter

throughputs for
each filter used

simple file helping *EAZY* know
which filters are being used

INPUT

**Photometric Catalog, Filter File, Translate File,
Templates and Templates File, Parameter File or
Python Parameters.**

simulated or observed
galaxy templates, and a
file that organizes them

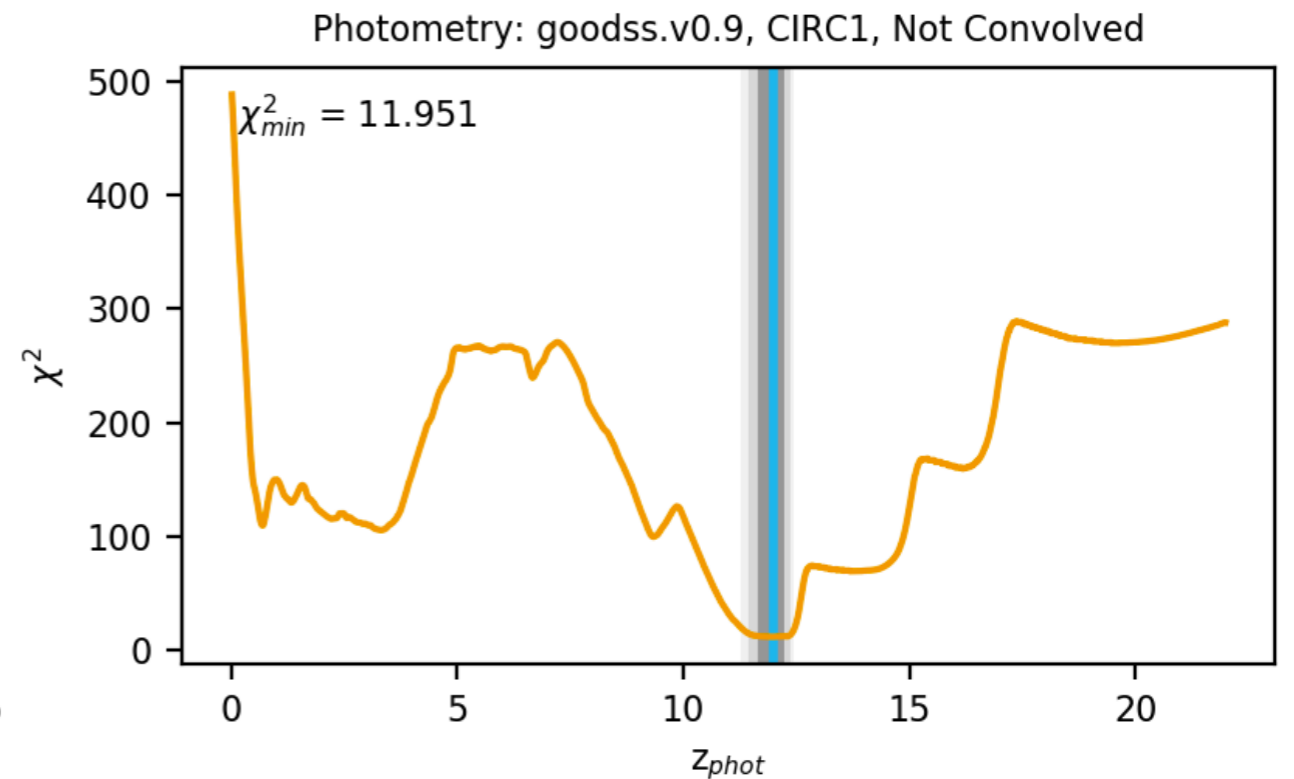
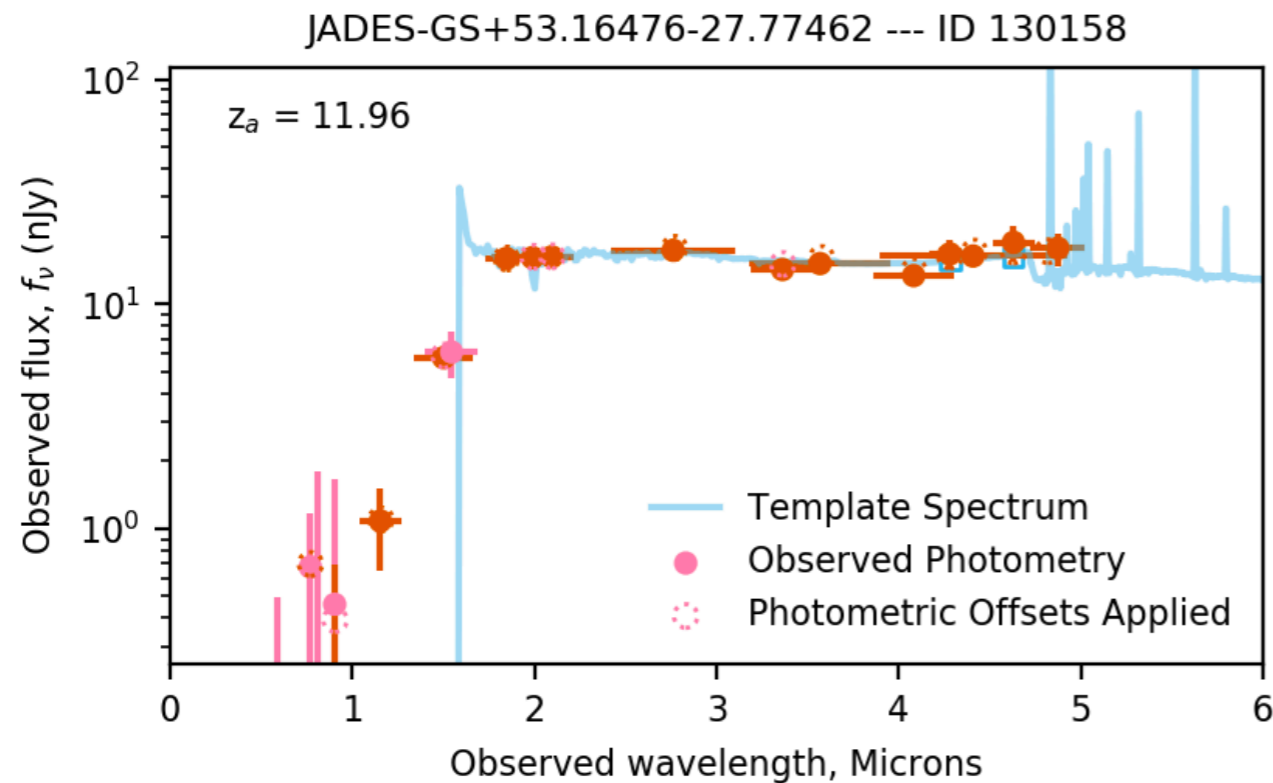
Stuff like the minimum and
maximum redshift to explore,
the usage of a prior, the usage
of photometric zero points, etc

OUTPUT “zout” file, “self” object

input and derived parameters: ID,
RA/DEC, z_spec from input file,
number of filters used in the fit, a
series of redshifts and chi-square
values, rest-frame UVBJ fluxes,
and galaxy parameters

The output chi-square
surface, the input
parameters, the best-
fit coefficients at each
redshift tested.

Plots that can be generated from EAZY output:



***EAZY*-py produces the coefficients on the individual templates that result in the best-fit SED, allowing you to plot this SED, and the photometry associated with this SED, at any redshift explored.**

This chi-square surface is the primary important output from EAZY, as there are multiple ways in which you can interpret these results. You can convert this to $P(z)$, or just take the redshift corresponding to the minimum chi-square.

Pros of Using *EAZY*

- very quick to run on enormous datasets.
- *EAZY* photometric redshifts have been shown to agree quite well with spectroscopic redshifts for many samples, modulo the filter choice and depth.
- very straightforward to use multiple template sets, or change the filters used, or the redshift range probed.
- python-based, so fairly straightforward to automate its use and output. *EAZY-py* allows you to very easily grab the best-fit SED for any of the redshifts probed.
- built-in iterative tool for estimating photometric offsets.
- multiple template sets exist for use with *EAZY*.
- there are many tools for you to explore the results, including creating Plotly/Dash websites for looking at the whole sample
- open source.

Cons of Using *EAZY*

- has (almost) no documentation whatsoever. It's currently difficult to explore the code directly to find exactly how to get what you want from the output.
- the python code has numerous weird things built-in that are never explained which makes modifying things to use your own filters file or templates a little less straightforward.
- chi-square minimization can return local minima.
- the templates can be combined in unphysical combinations.
- produces different results on the same photometric dataset and with the same parameters and template file as the non-python version of *EAZY*.
- bug reporting on the GitHub page rarely results in a response.