Automatic analysis of optical AGN spectra

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in collaboration with:
Luciano Nicastro[2], Gabriele Ghisellini[3], Massimo Dotti[4],
Tullia Sbarrato[4], Francesco Shankar[5], Monica Colpi[4]

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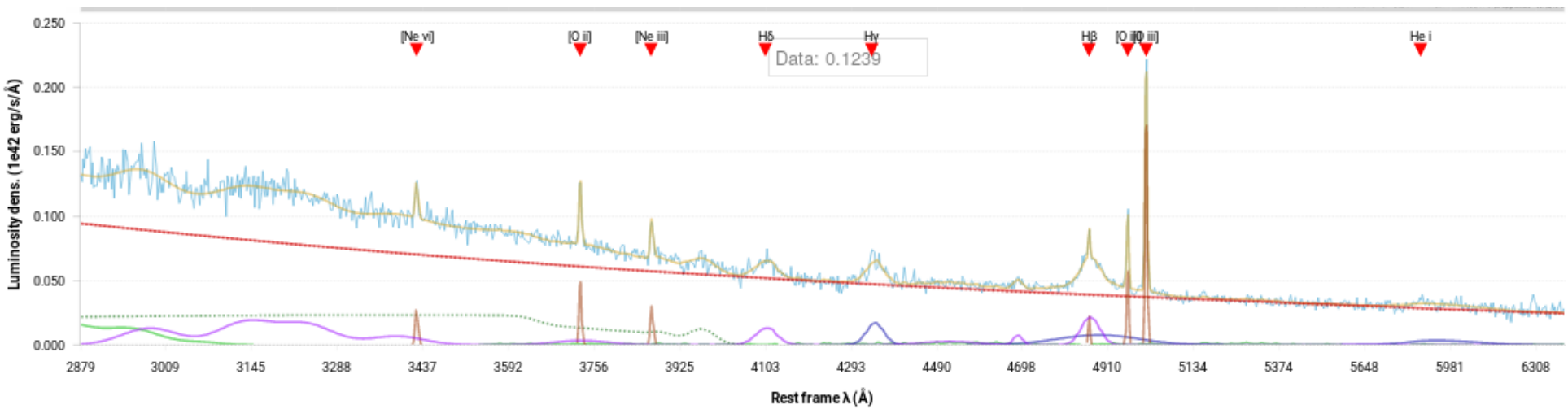
[3] *INAF – Osservatorio Astronomico di Brera,* [4] *Università degli studi di Milano–Bicocca,* [5] *University of Southampton (UK)*



Quasar spectral catalogs in literature

Shen et al. 2011 (S11) catalog

- Sample of 105,783 Type 1 AGNs:
  - M_i brighter than -22;
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- Spectra from SDSS/DR7 ($\sim$ 3800–9000Å)
- Catalog of spectroscopic properties, e.g.
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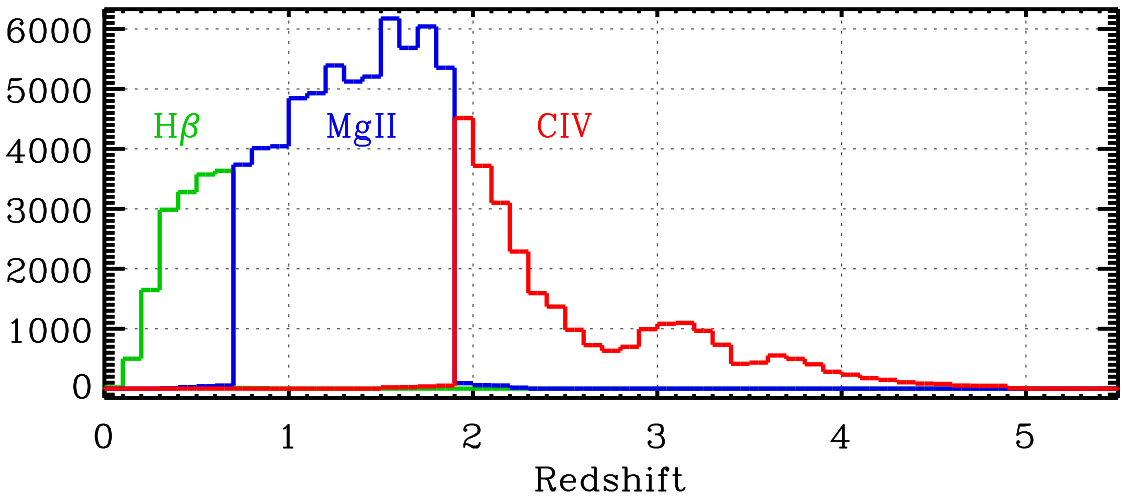
  - FWHM of Hβ, Mg II and C IV (and other) lines



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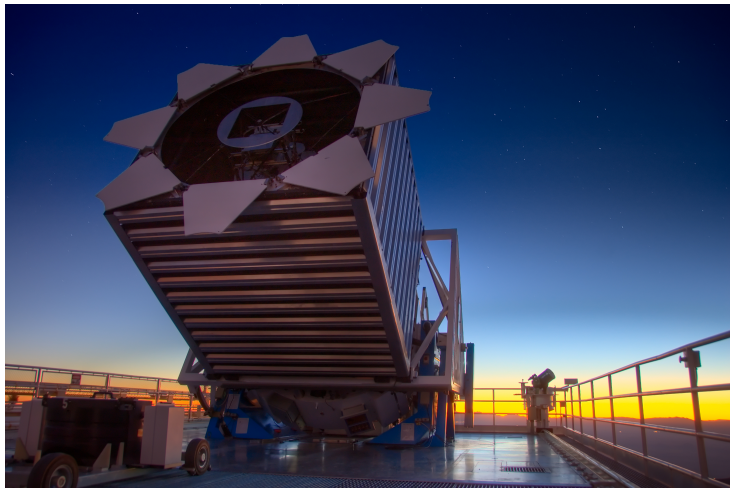

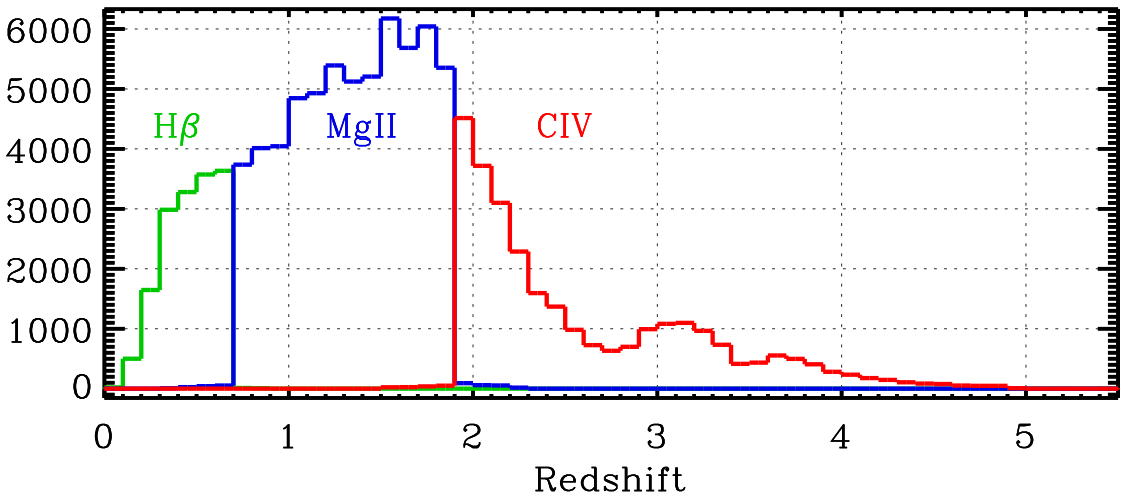

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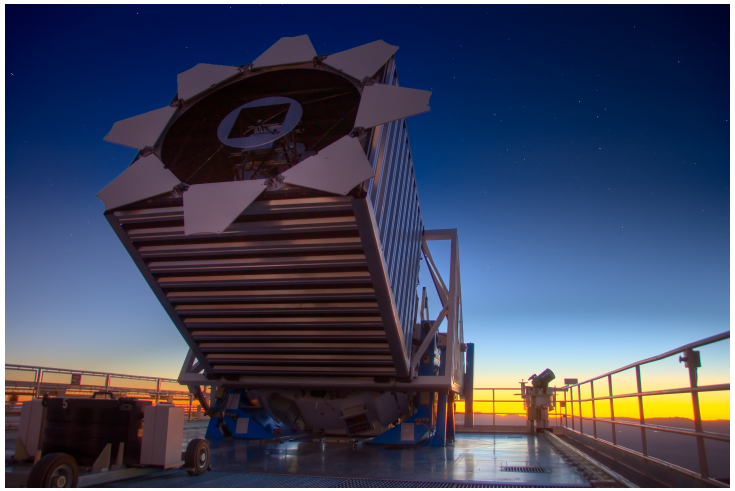

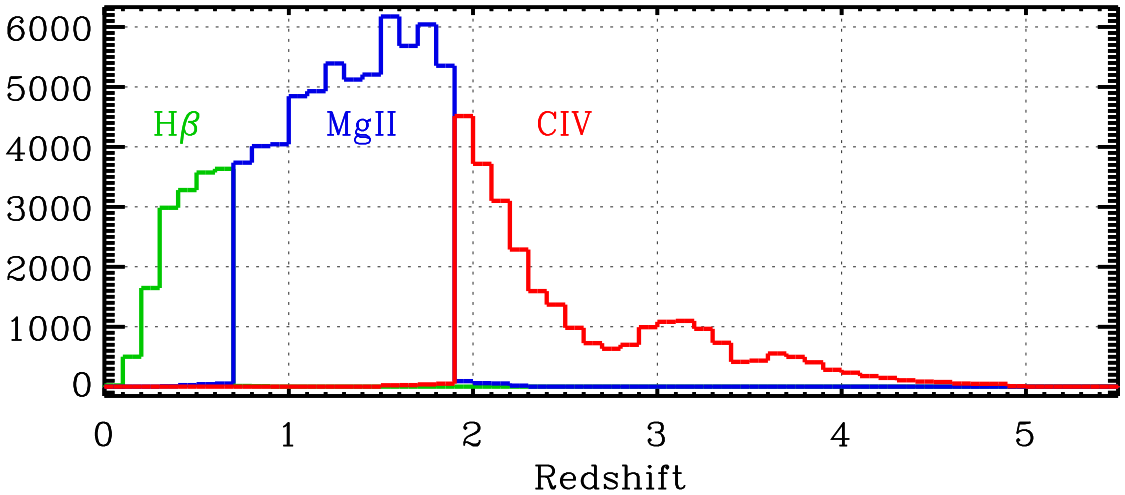

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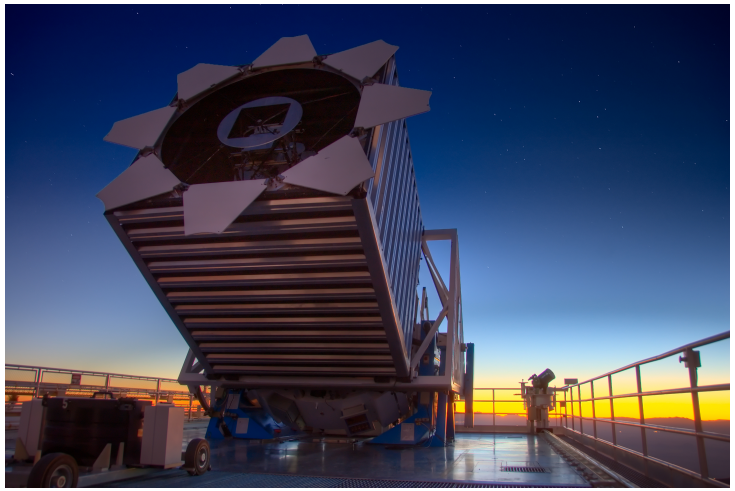

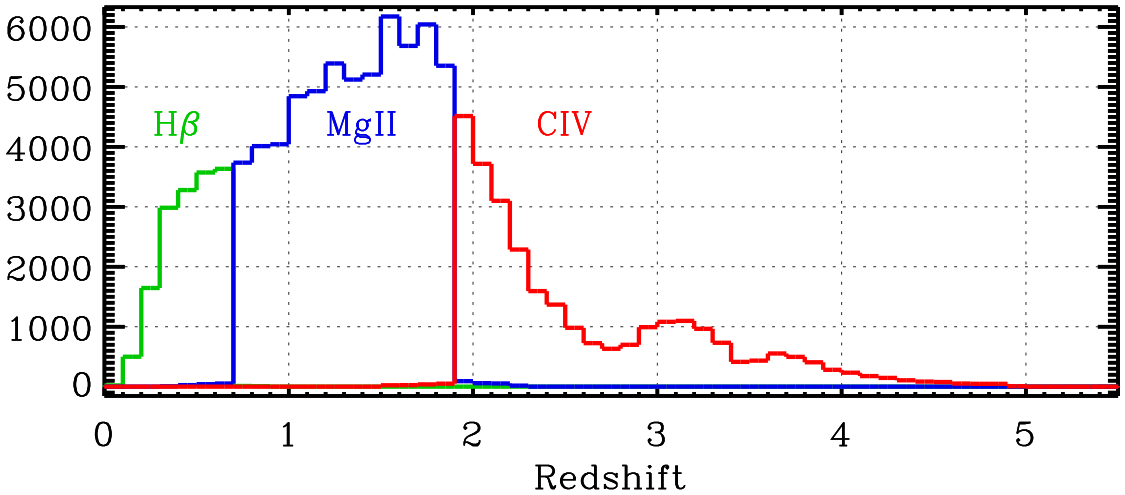

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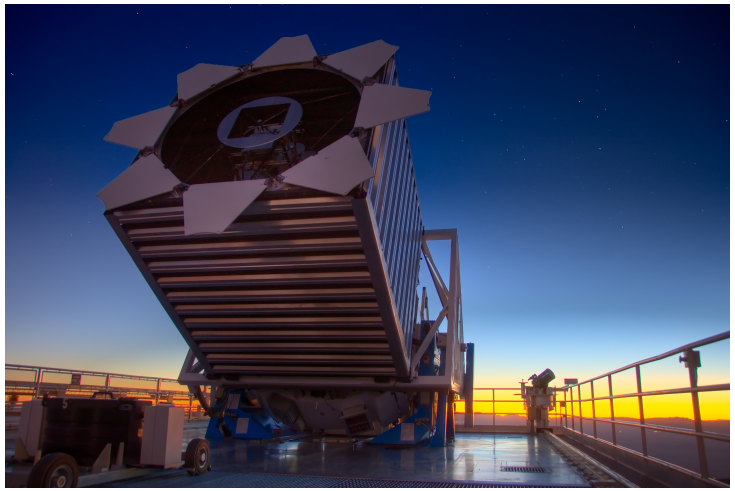

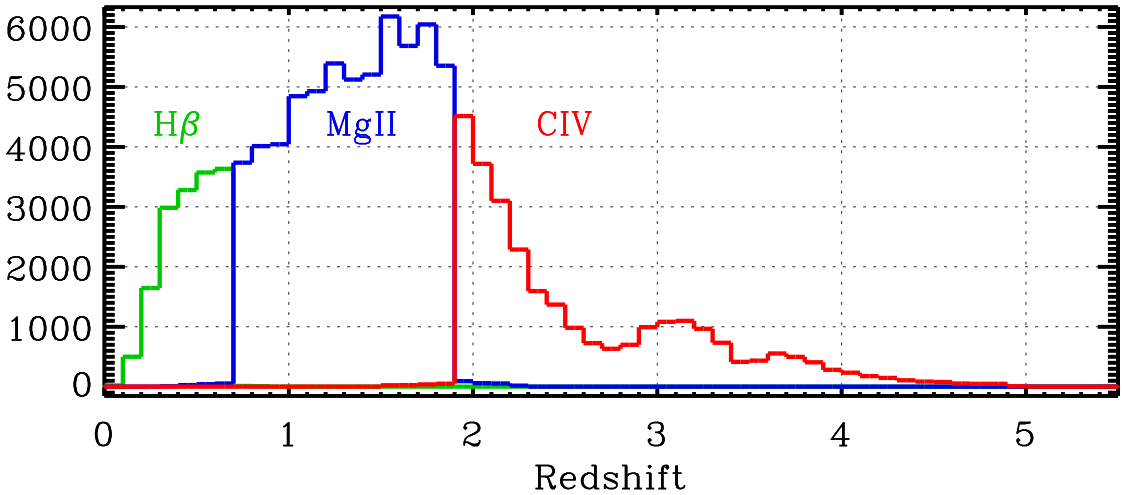

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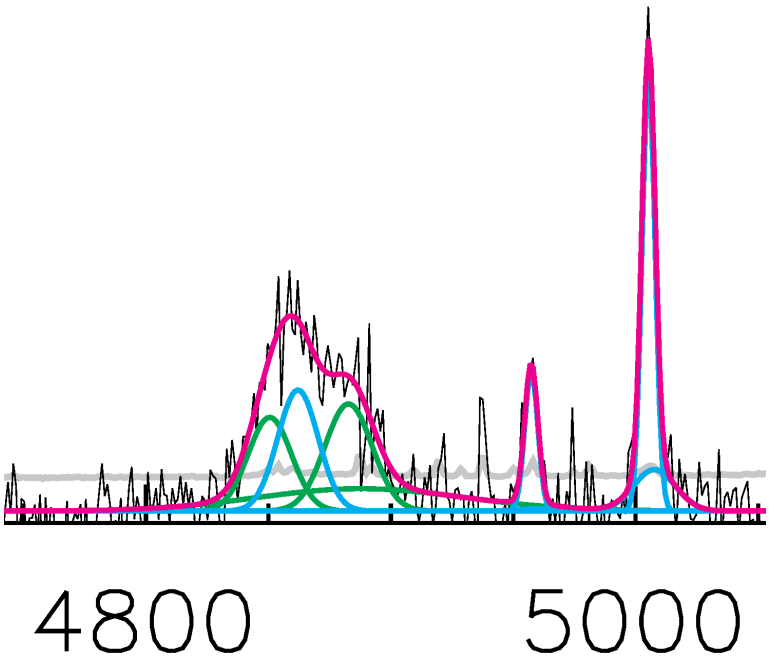

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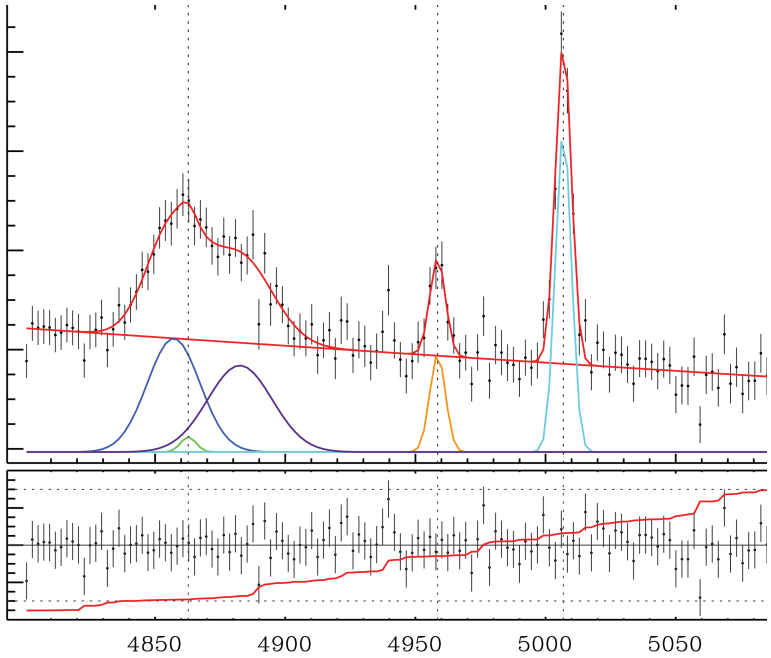

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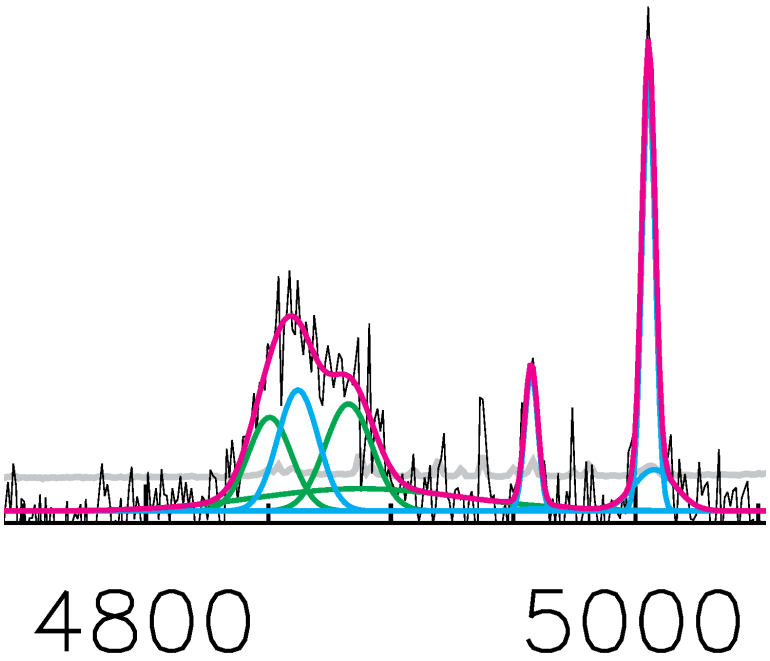

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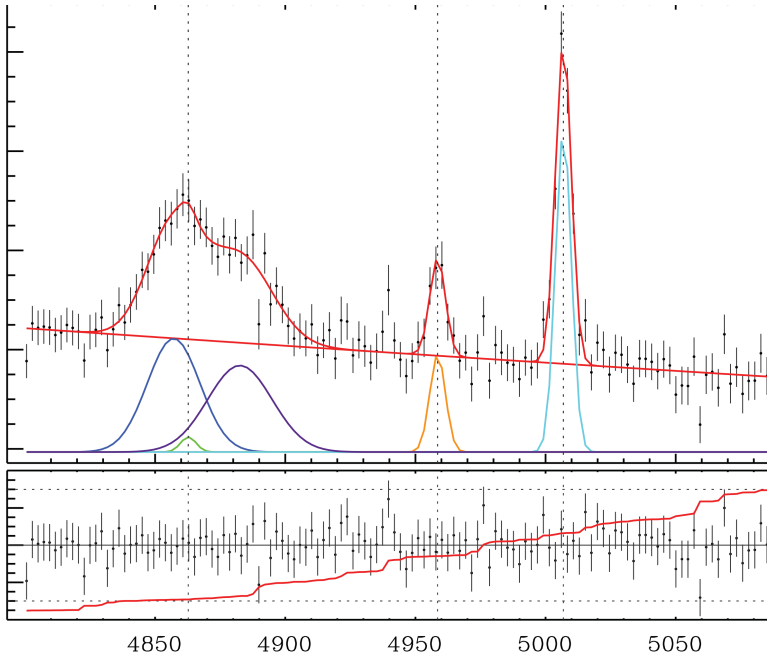

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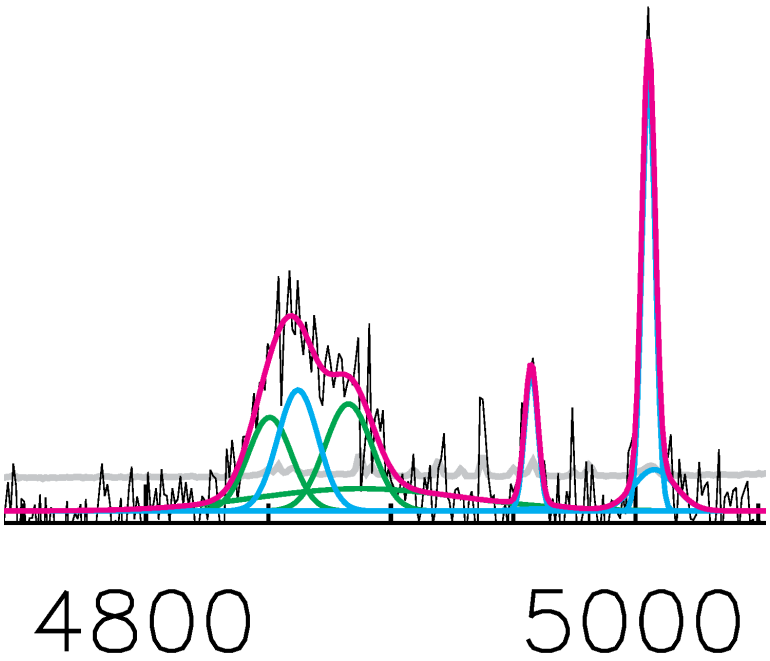

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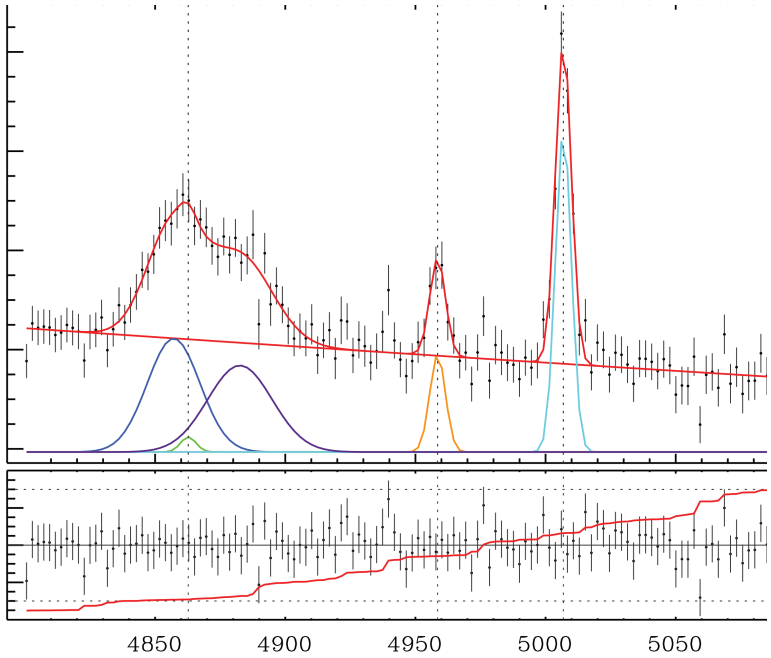

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- Analysis of new spectra ?
- Need a custom analysis (e.g. add a prior, add a specific em. line ? etc...)
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QSFit: Automatic analysis of AGN optical spectra

Motivations:

- estimate AGN spectral quantities (luminosities, slopes, emission line properties, etc...);
- do it **quickly** and **automatically** on large samples;
- Goal: generate a catalog of spectral quantities.

- analyze AGN spectra in a **simple, replicable and shareable way** using standardized recipes;
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- automatic spectral analysis of $\sim 10^5$ sources (SDSS-DR7 Quasar catalog);

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1. Several model “components”:
   - non–thermal continuum
   - emission line profile
   - host galaxy
   - Iron and Balmer templates
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   - arbitrary combination;
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2. Subtract continuum offset: negative residuals: 50% $\rightarrow$ 10%;
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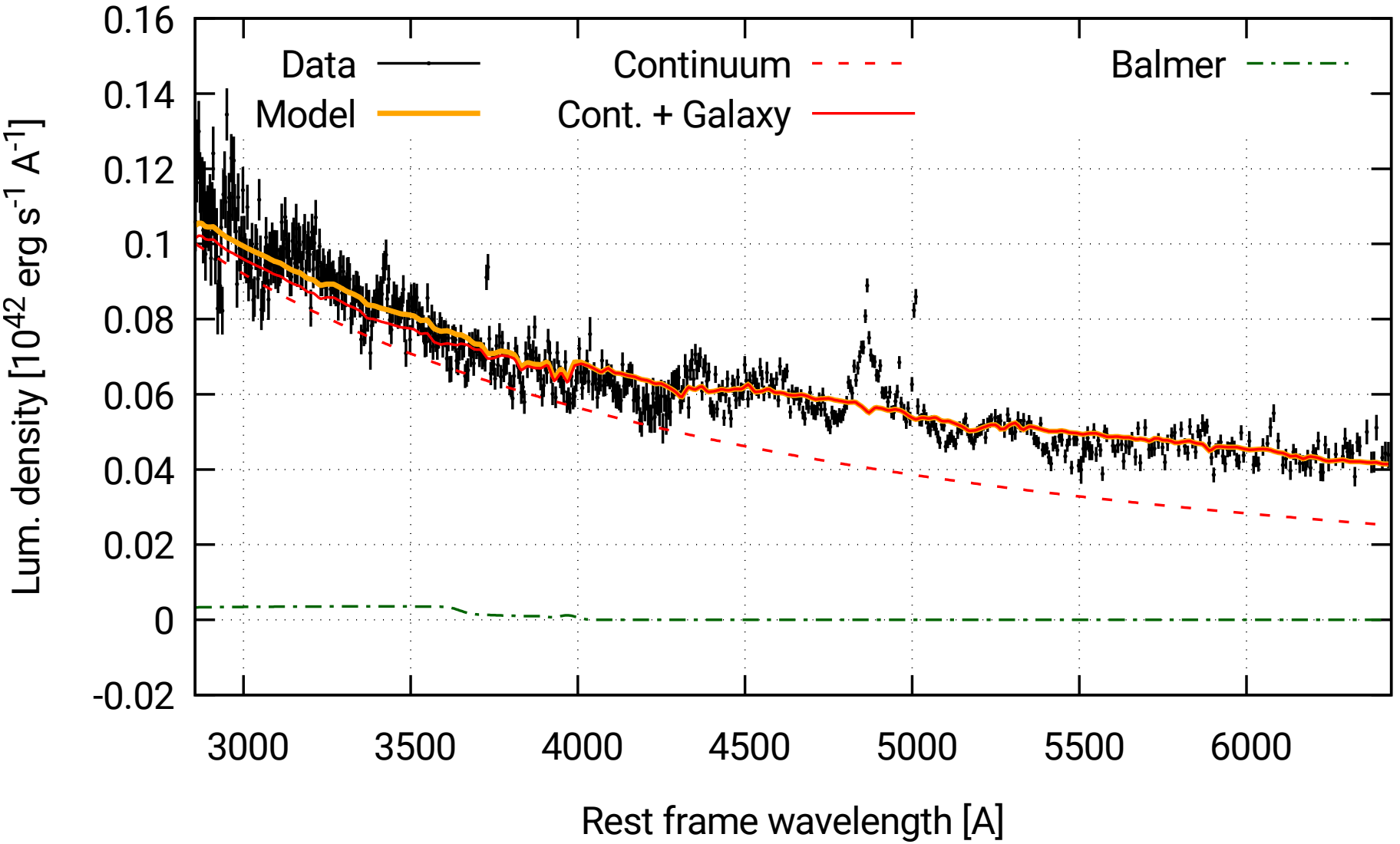

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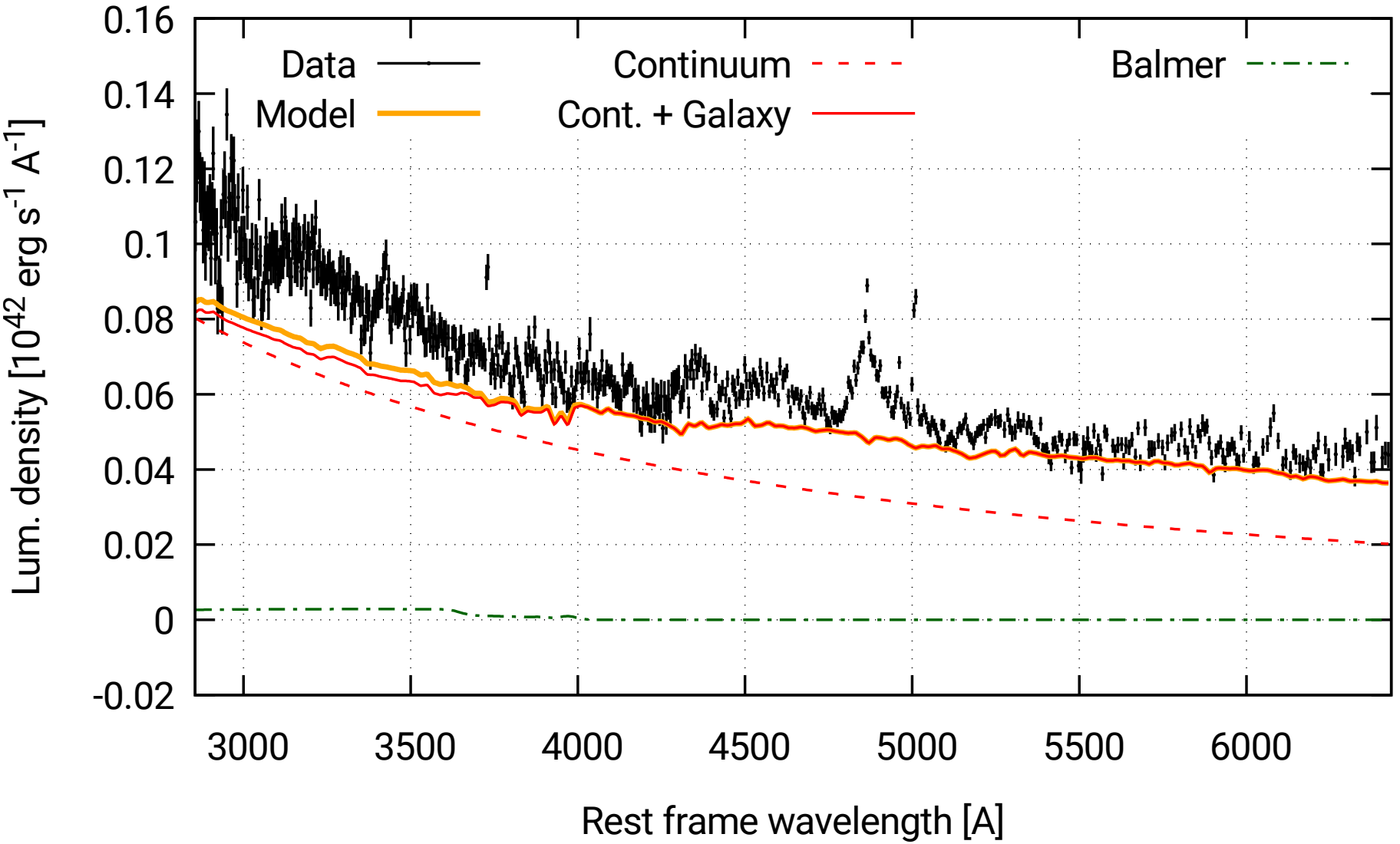

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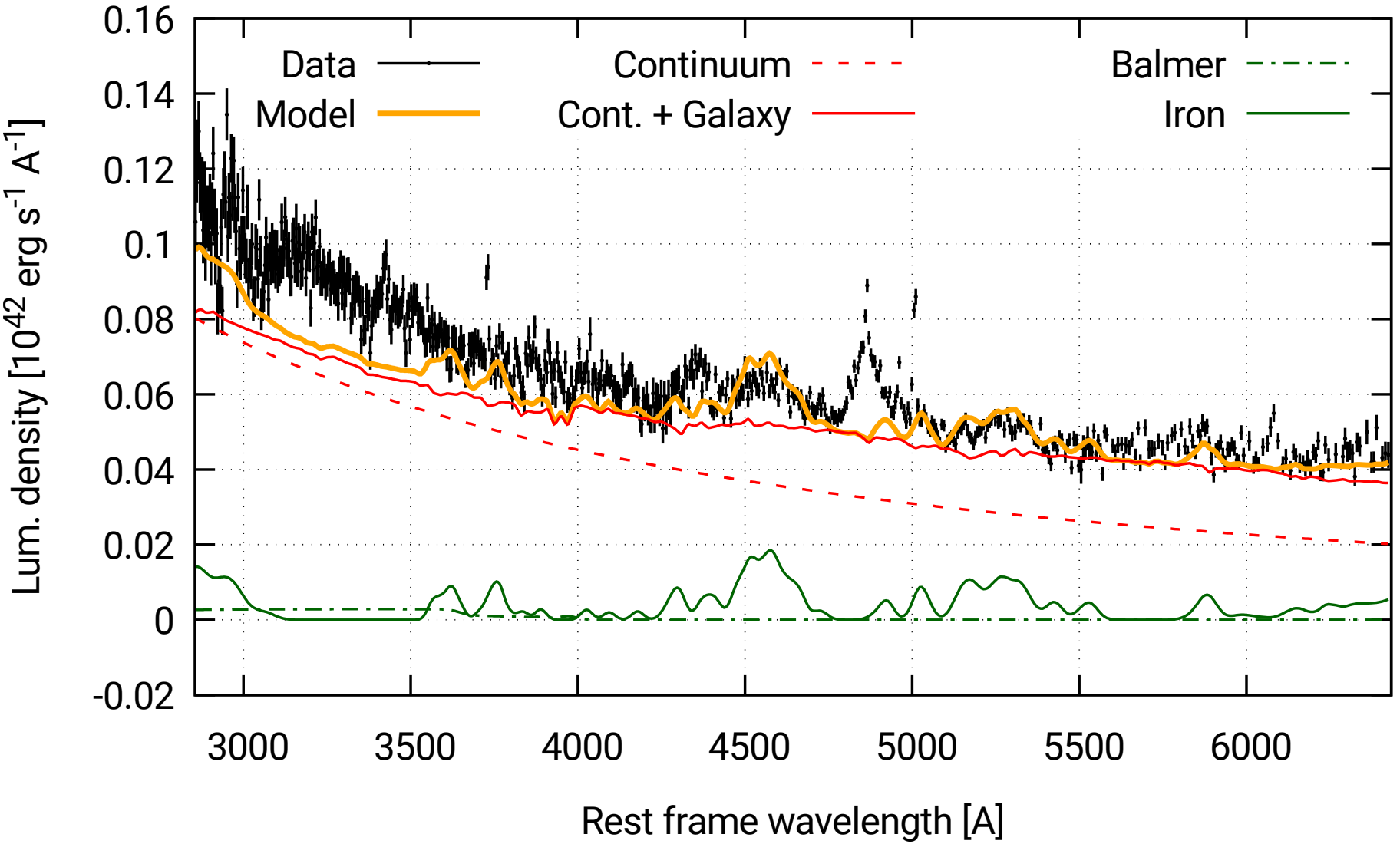

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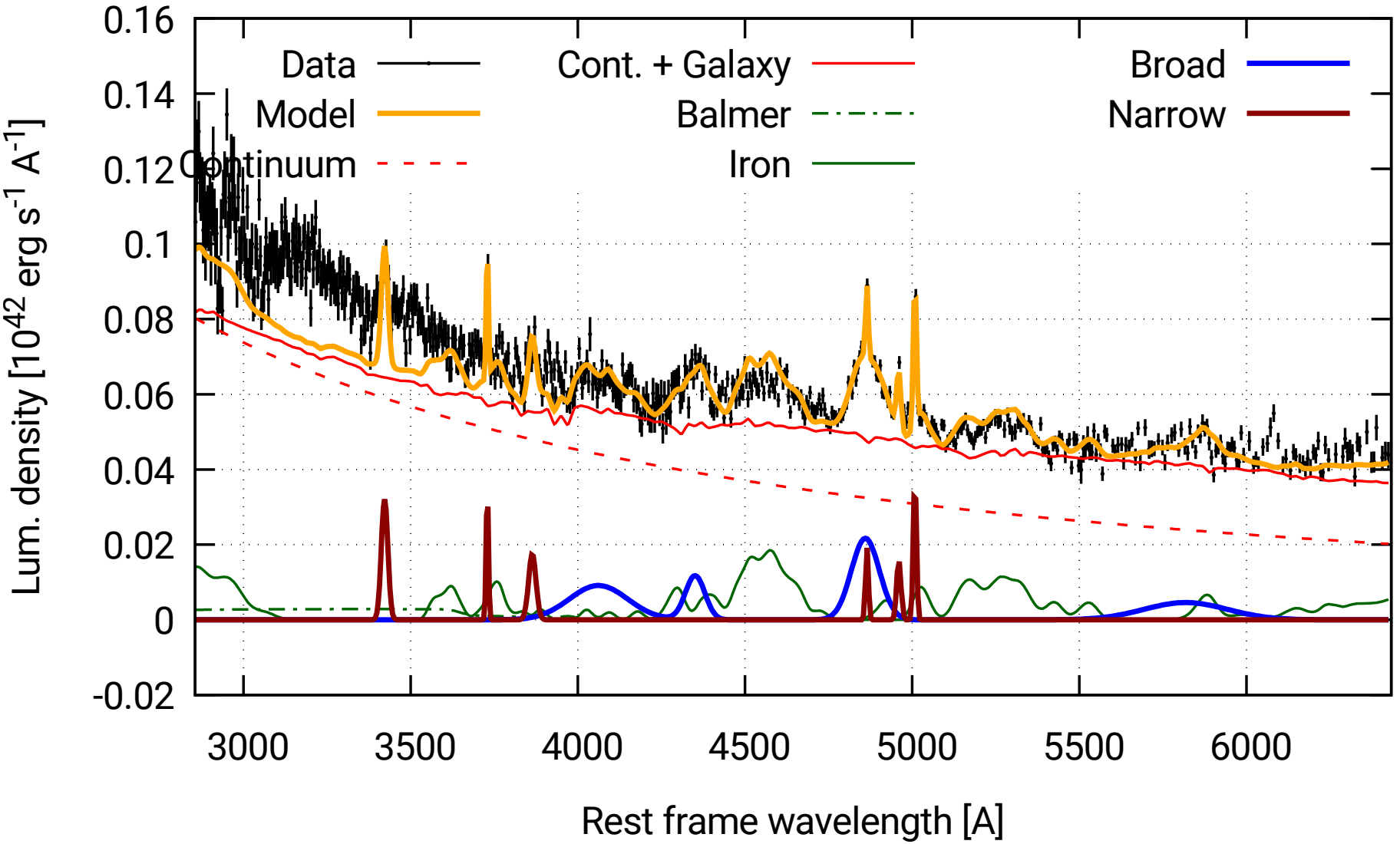

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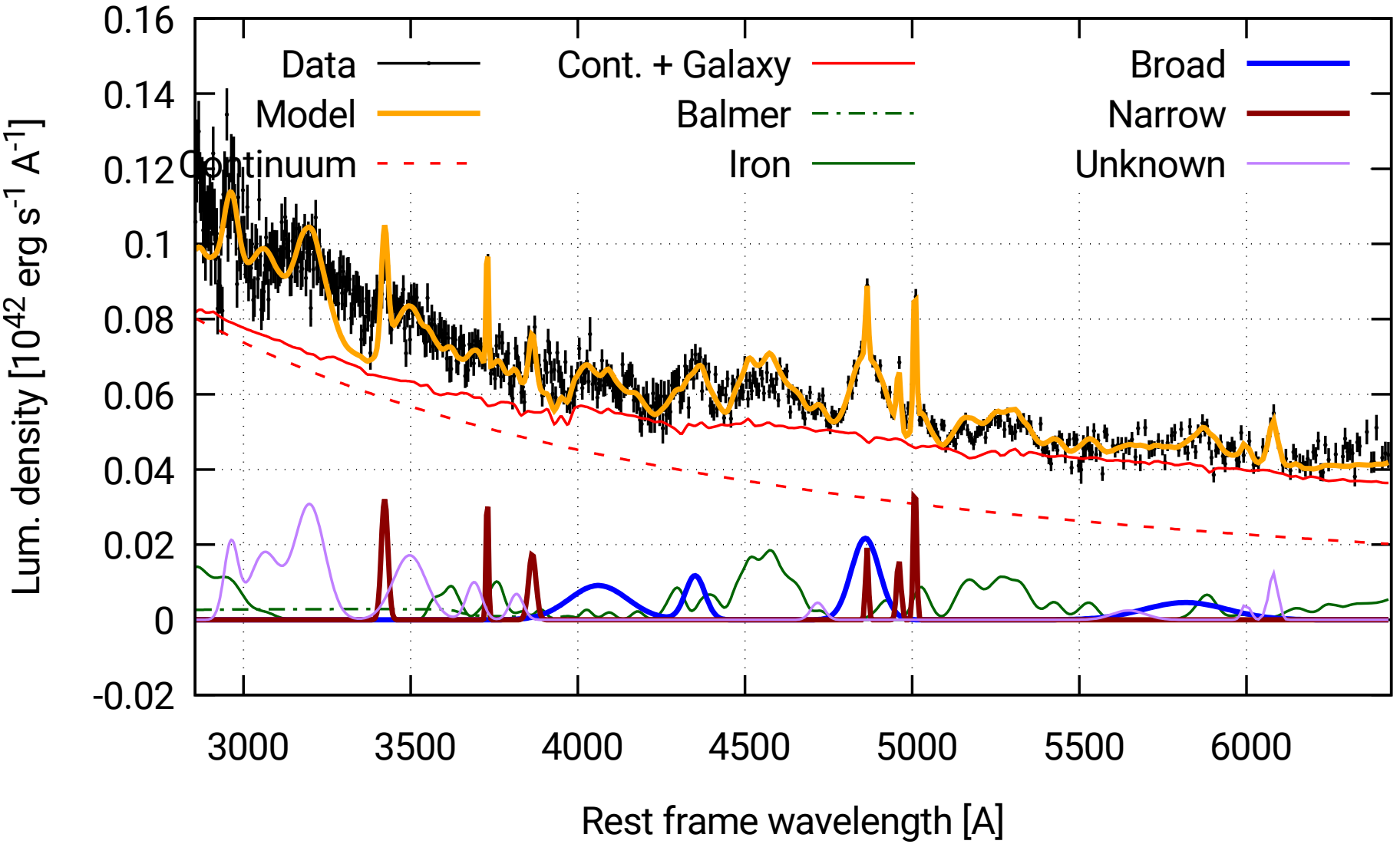

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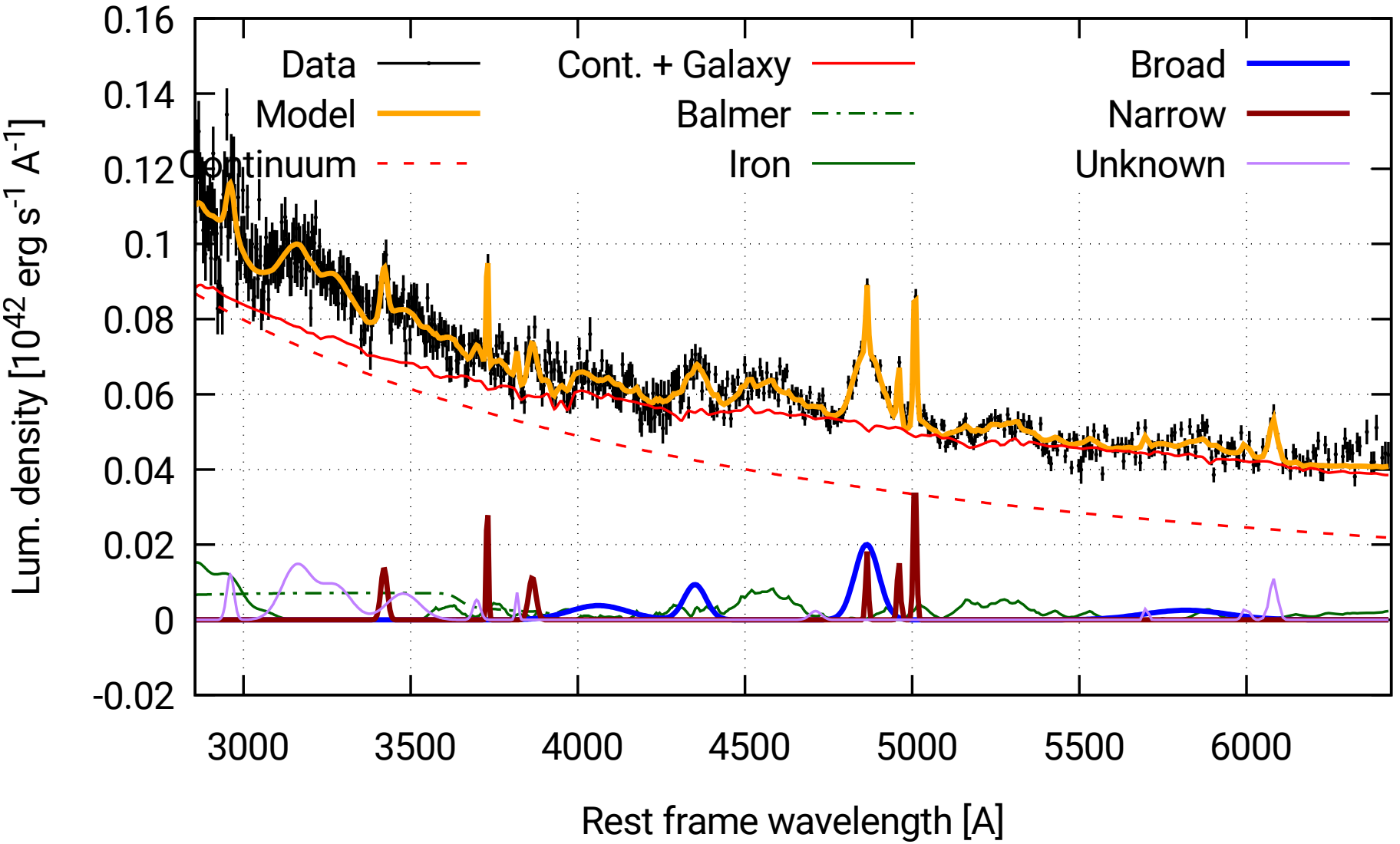

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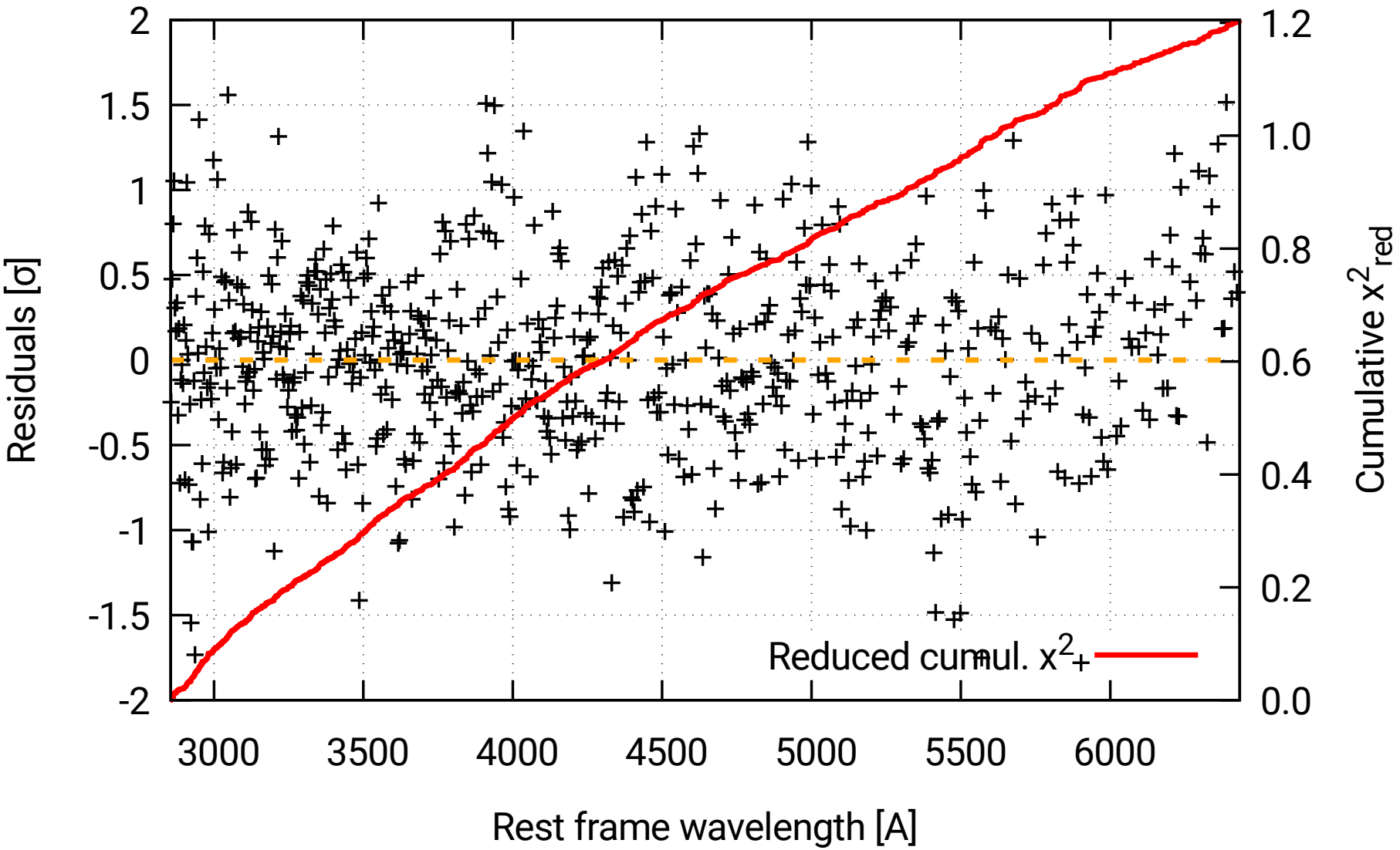

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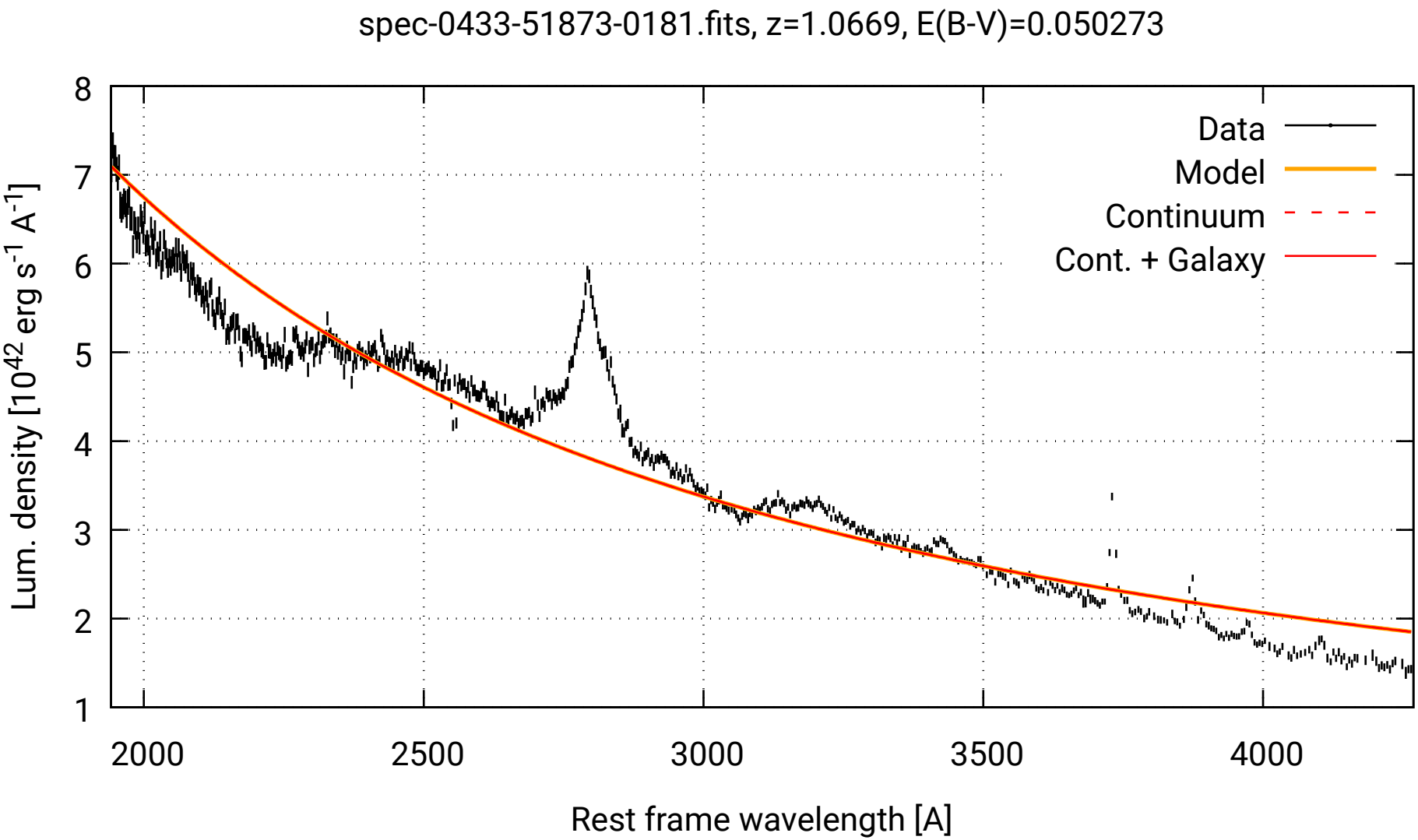

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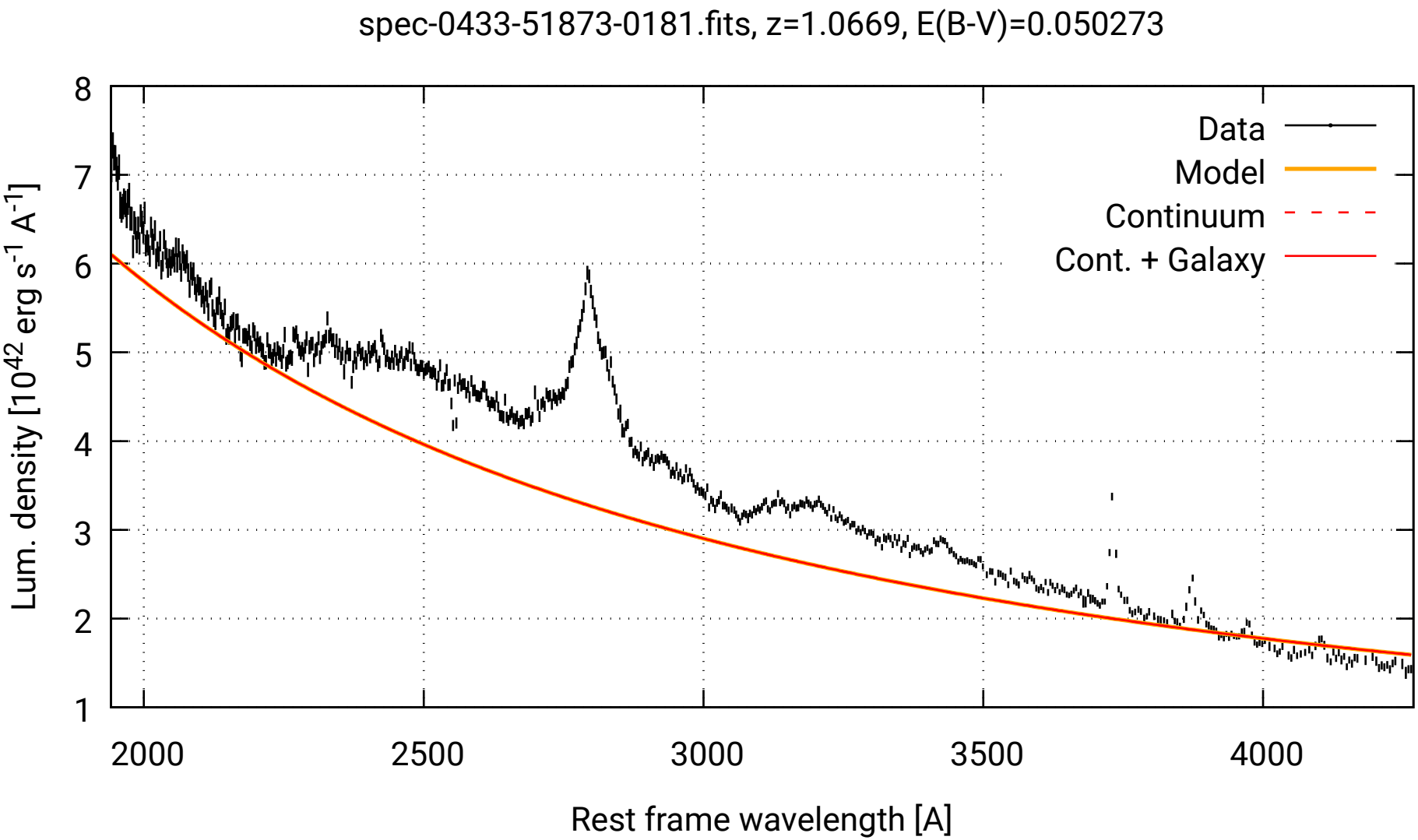

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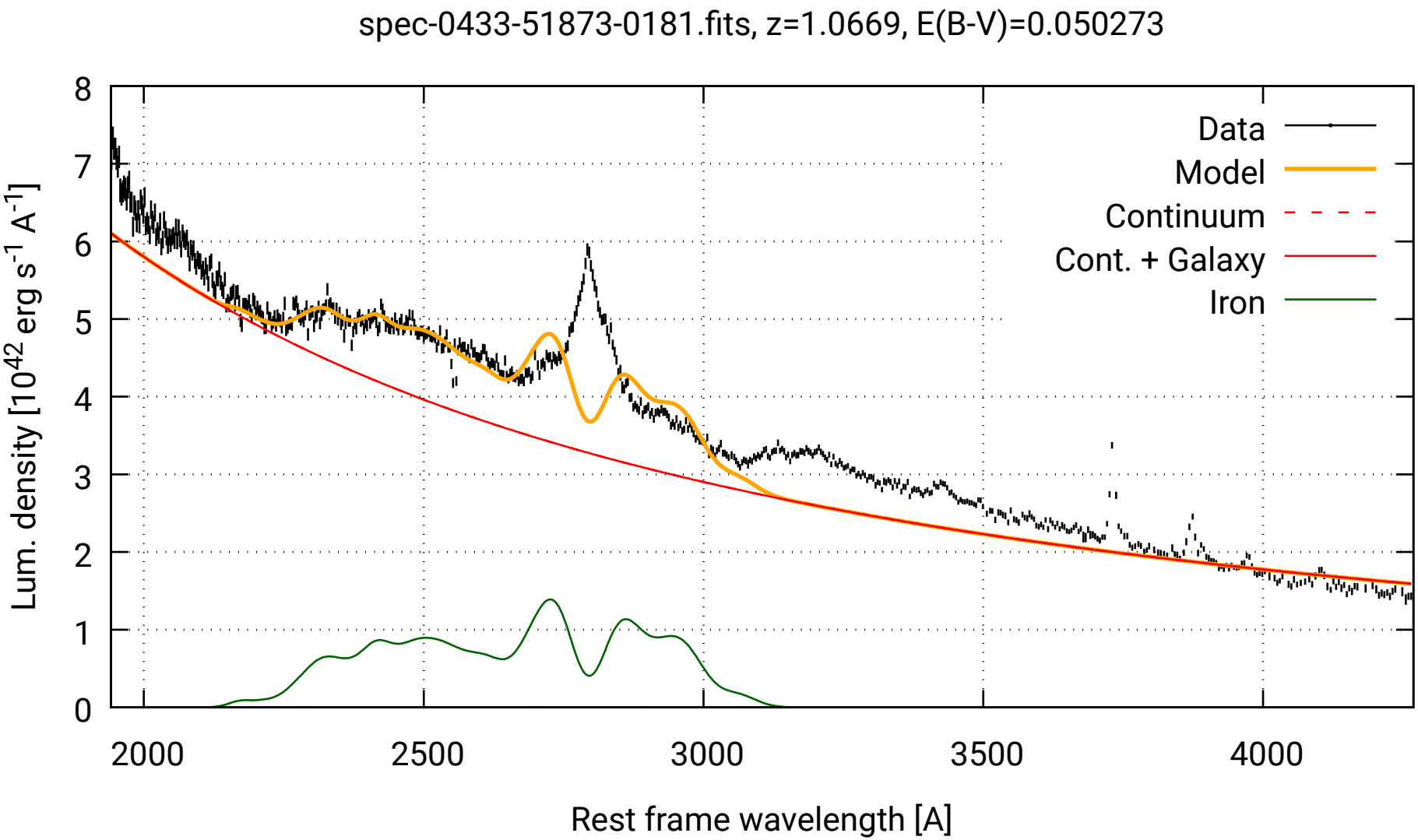

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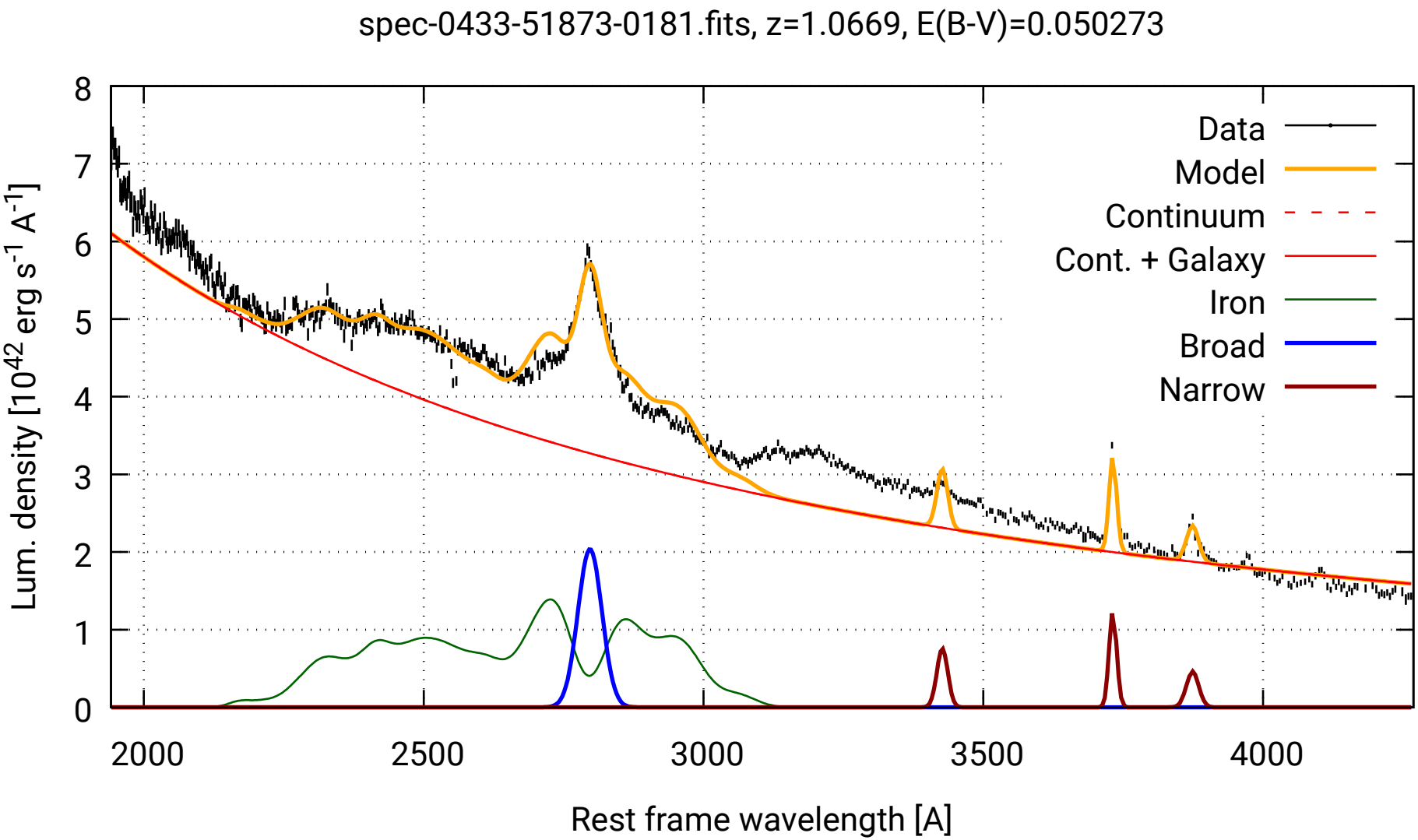

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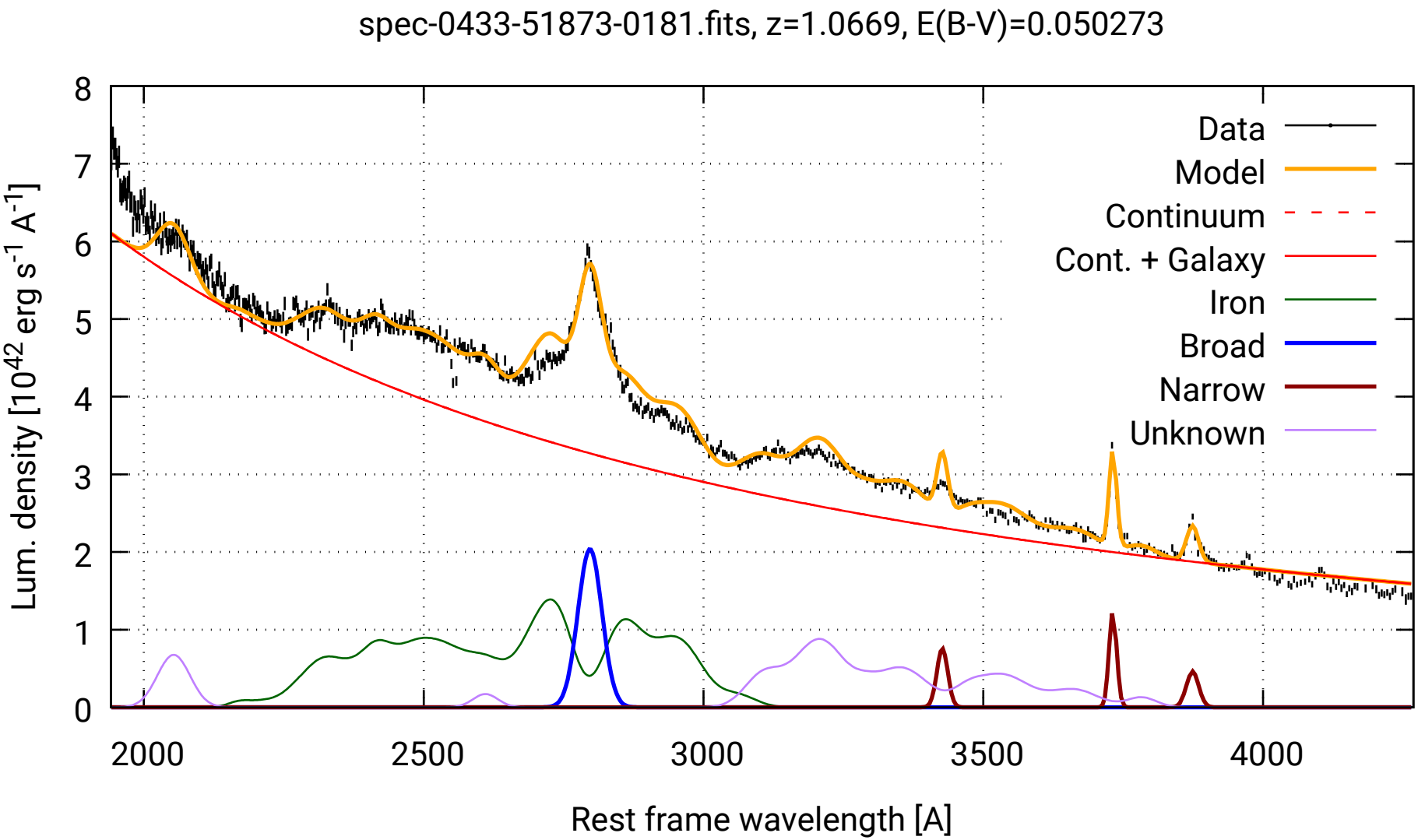

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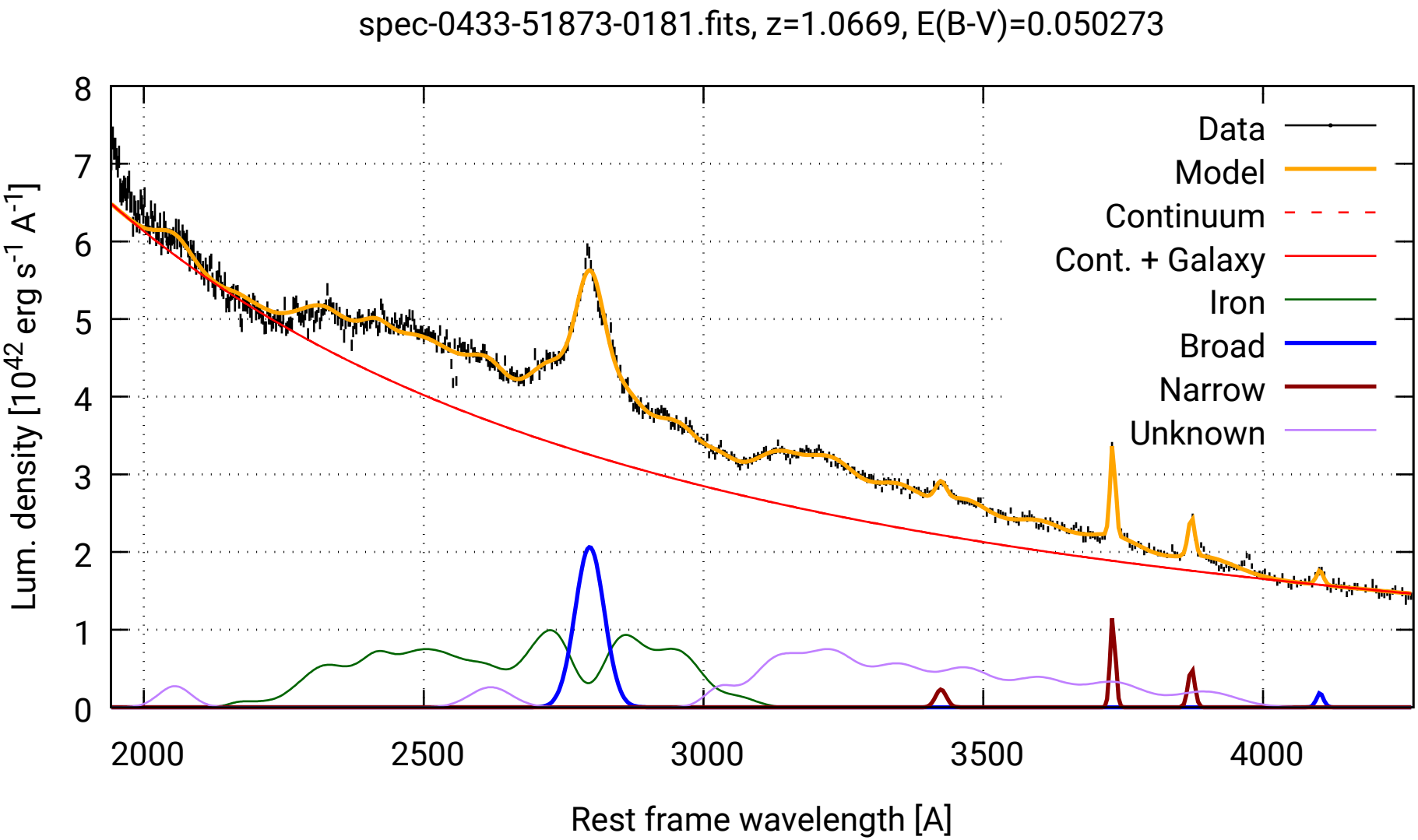

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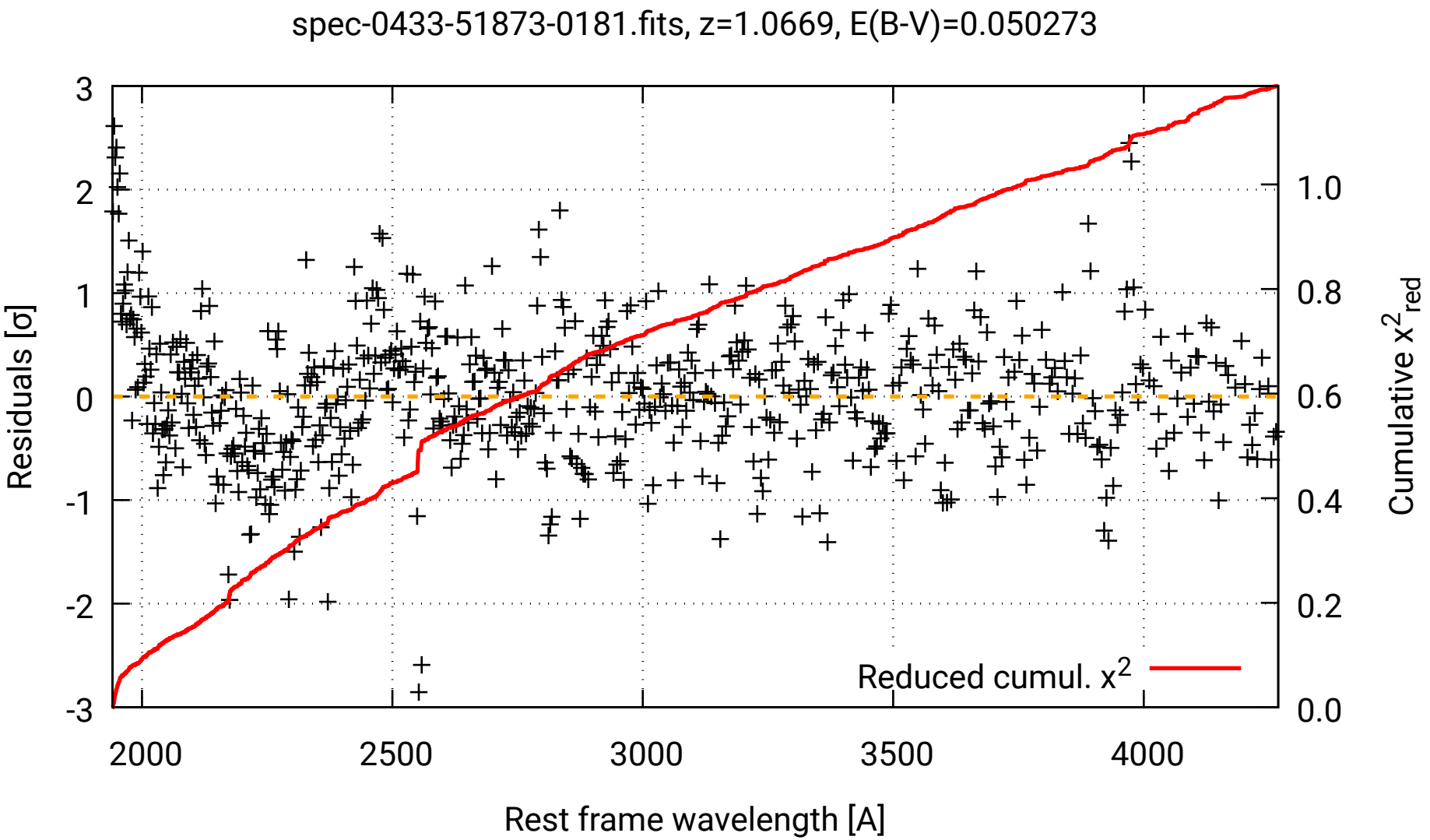

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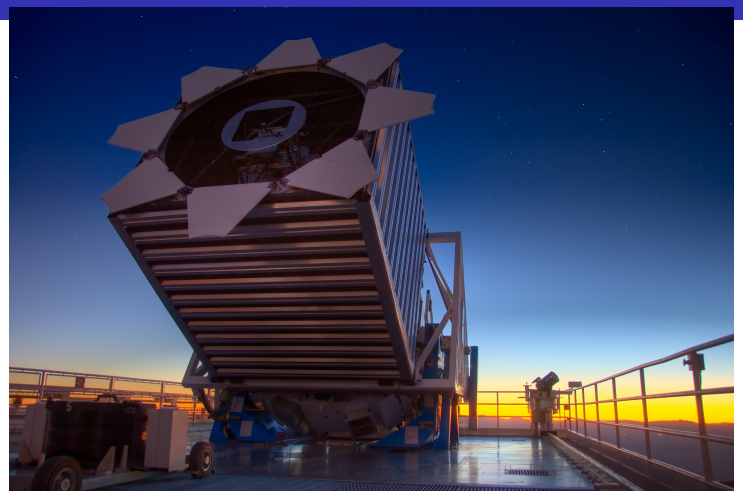

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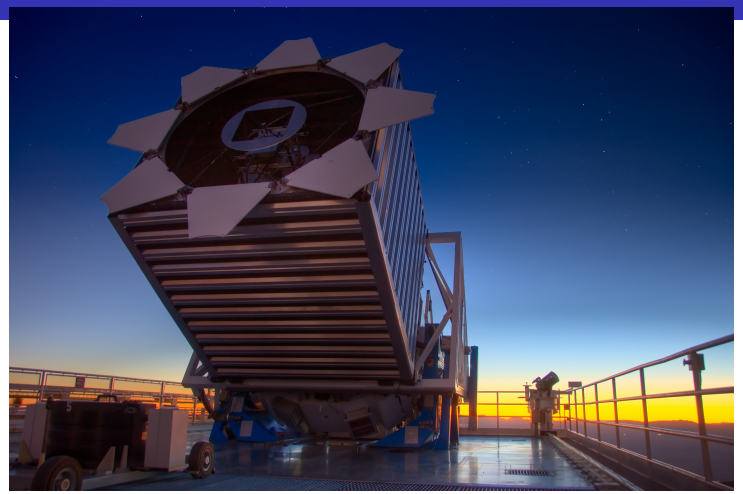

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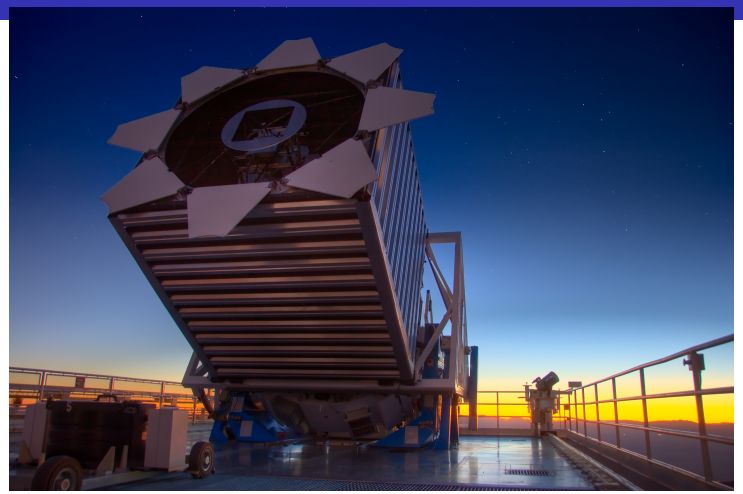

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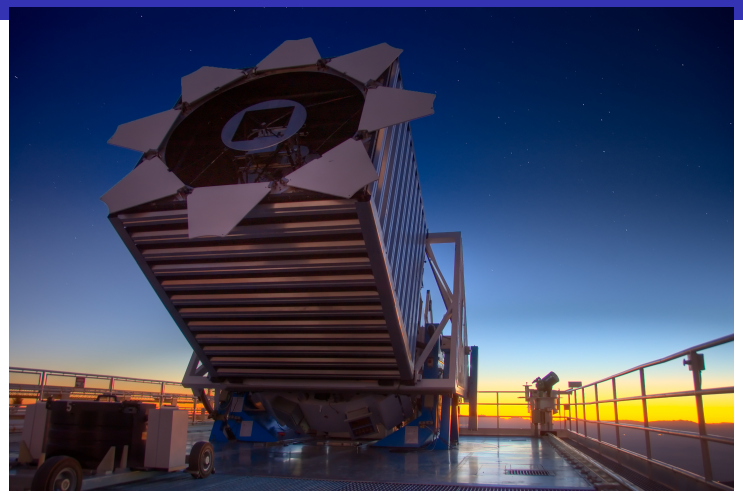

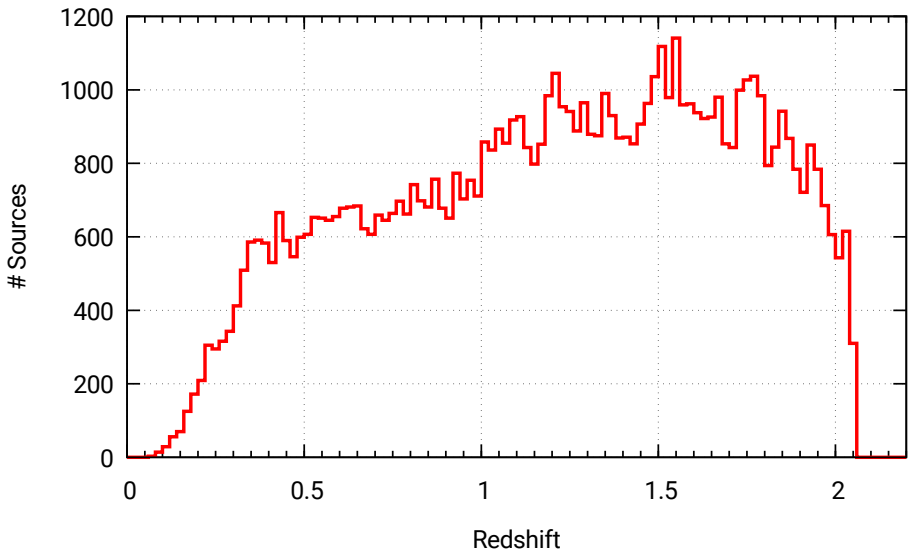

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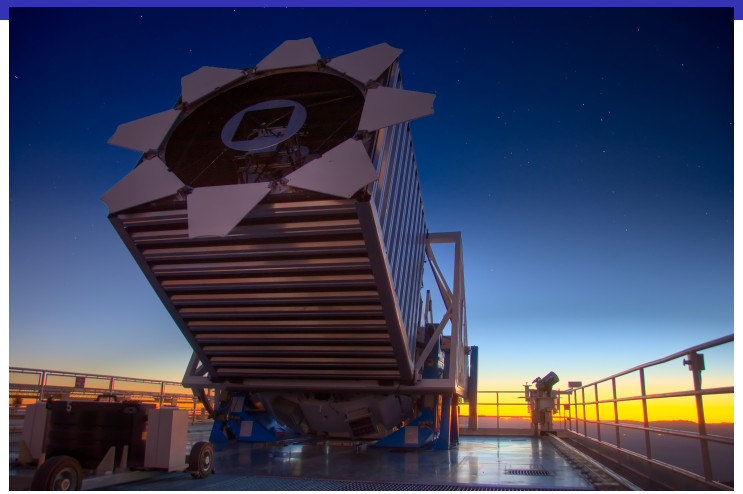

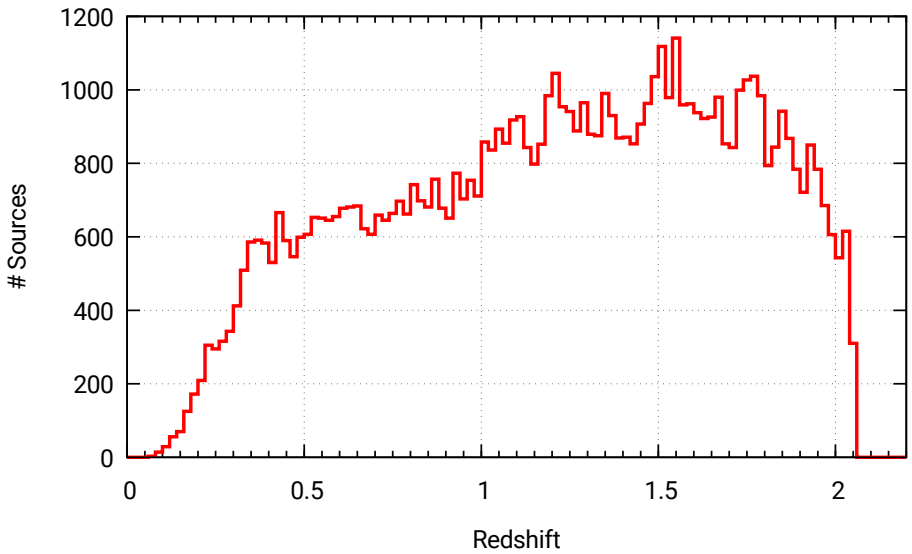

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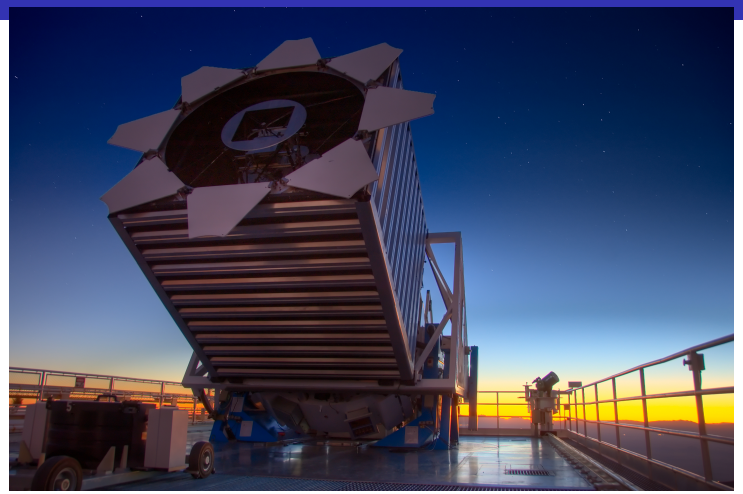

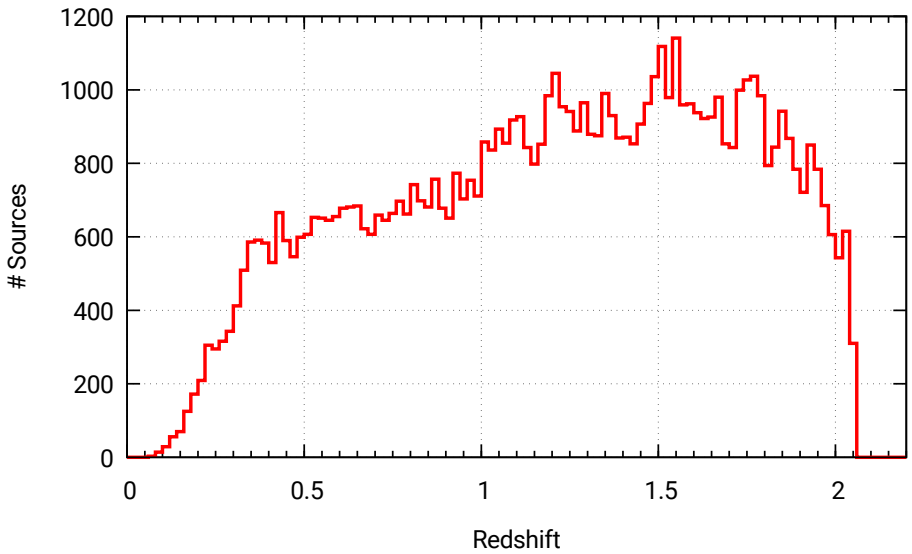

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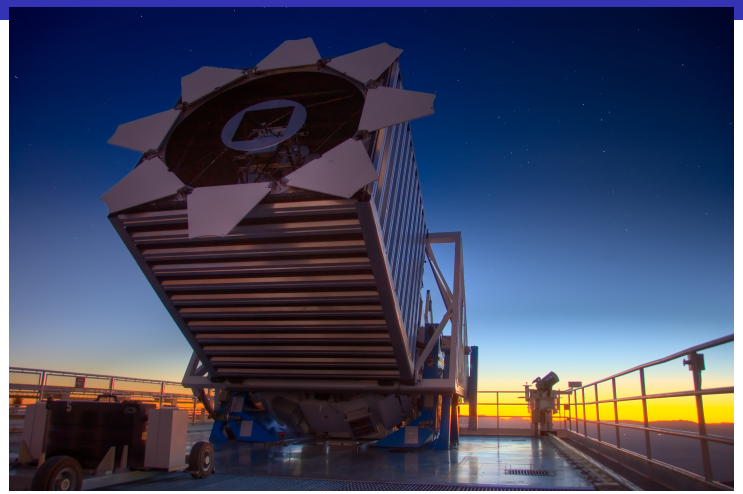

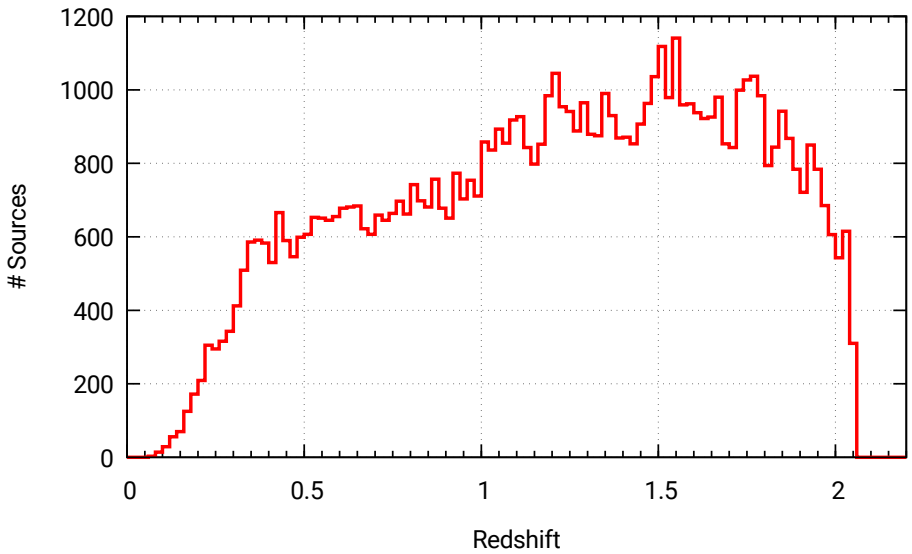

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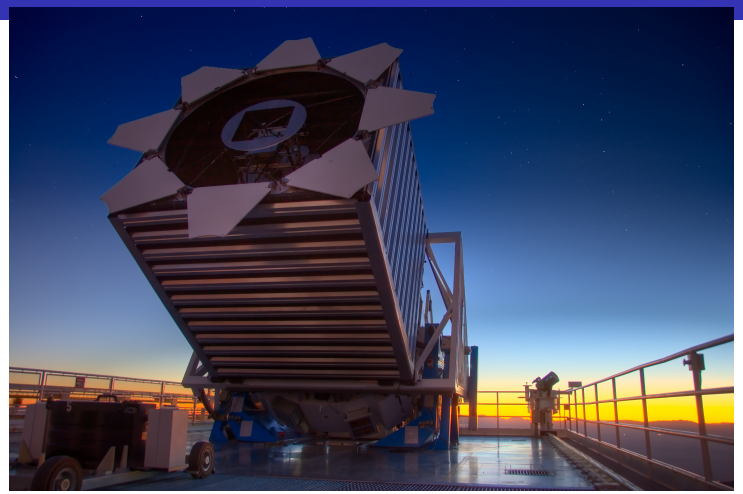

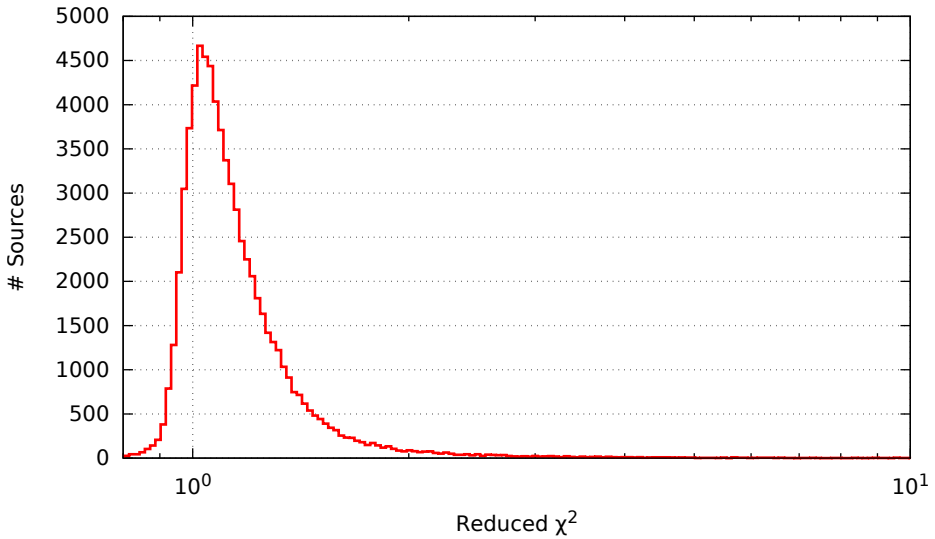

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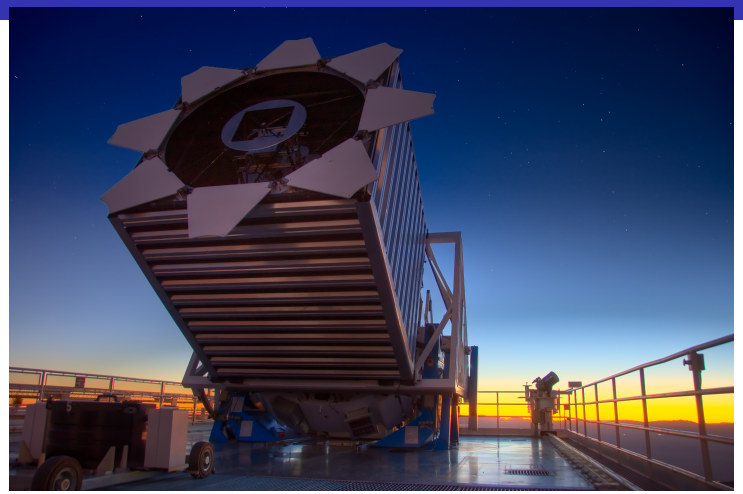

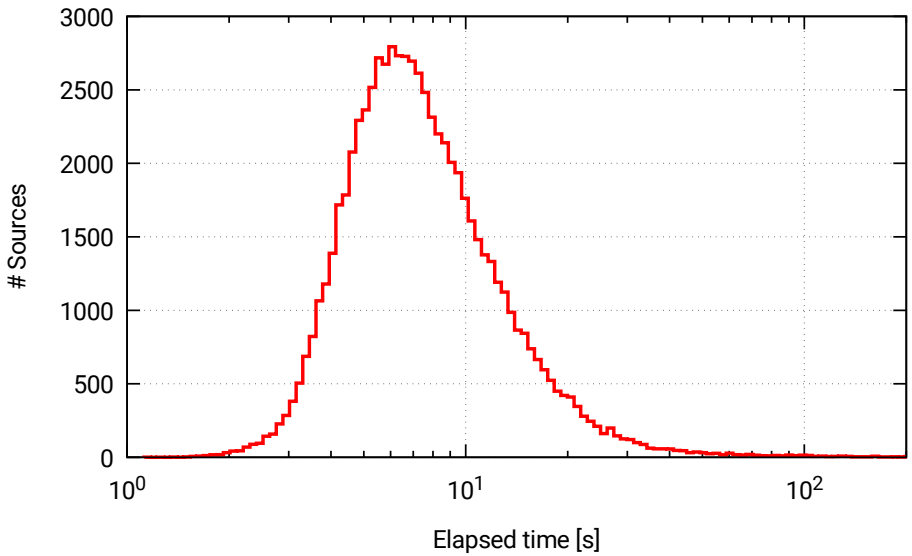

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Quasar Spectral FITting package

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- AGN continuum luminosities and slopes at several rest frame wavelengths;
- host galaxy luminosities (for sources with $z < 0.8$);
- luminosities, widths and velocity offsets of 20 individual emission lines (Hα, Hβ, MgII, [OIII], CIV, etc.), and luminosity of the blended Balmer lines ($n \geq 7$);
- luminosities of iron blended lines at optical and UV wavelengths;
- luminosity of the Balmer continuum;
- several "quality flags" to assess the reliability of the results.

The main purpose of QSFit is to allow anyone to perform AGN spectral analysis in a simple, replicable and shareable way. The code is available on Github and can be easily customized for specific purposes.

Reference Paper

The paper was published on **MNRAS, 472, 4051-4080 (2017)**. Preprint available from **arXiv**.

If you make use of the catalog or the code, please unknowledge as: **Calderone et al., MNRAS, 72, 4 (2017)**

New version released (v1.3.0)

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Also, a new online calculator is available **here**.

Catalog of spectral properties (ver. 1.2.4)

NEWS
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- the freezing/thawing of the iron template component at optical wavelengths (this bug affected only the spectral estimates for the sources with $z < 0.4$);
- the calculation of the spectral coverage of the emission lines (this bug affected only those source with many spectral channels whose quality mask is not zero, as marked by the SDSS reduction pipeline);
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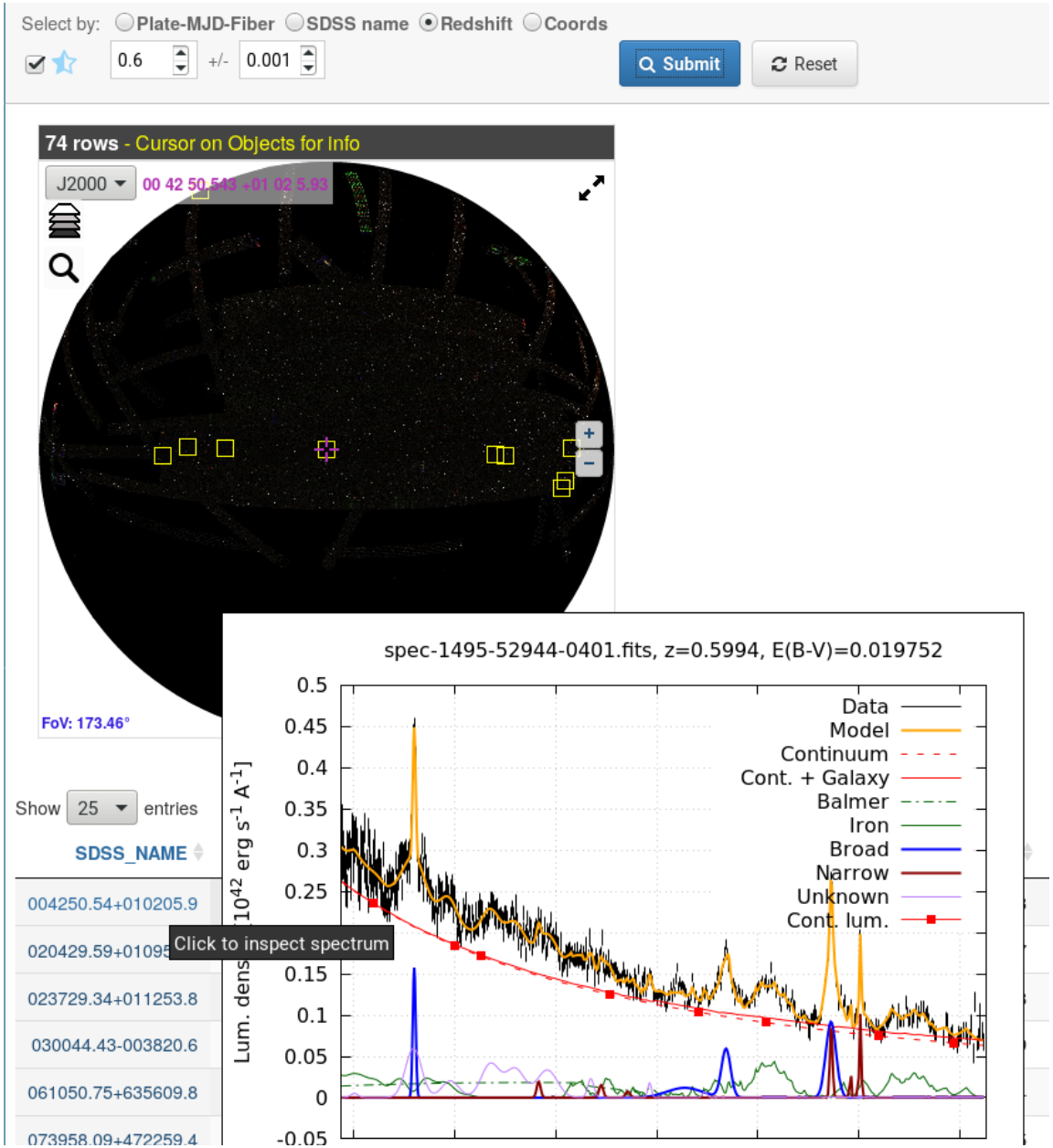
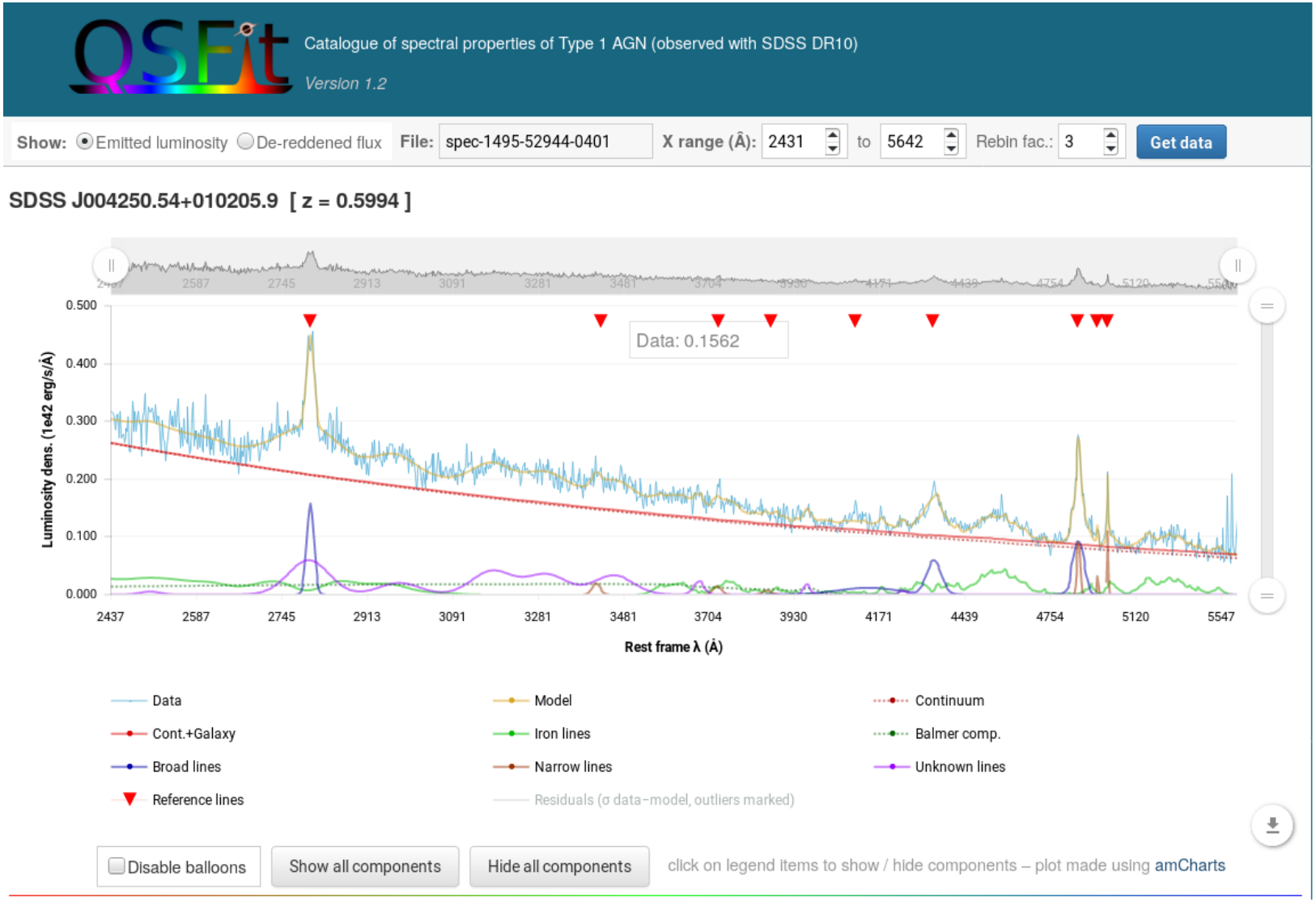


The QSFit catalog: browse the spectrum



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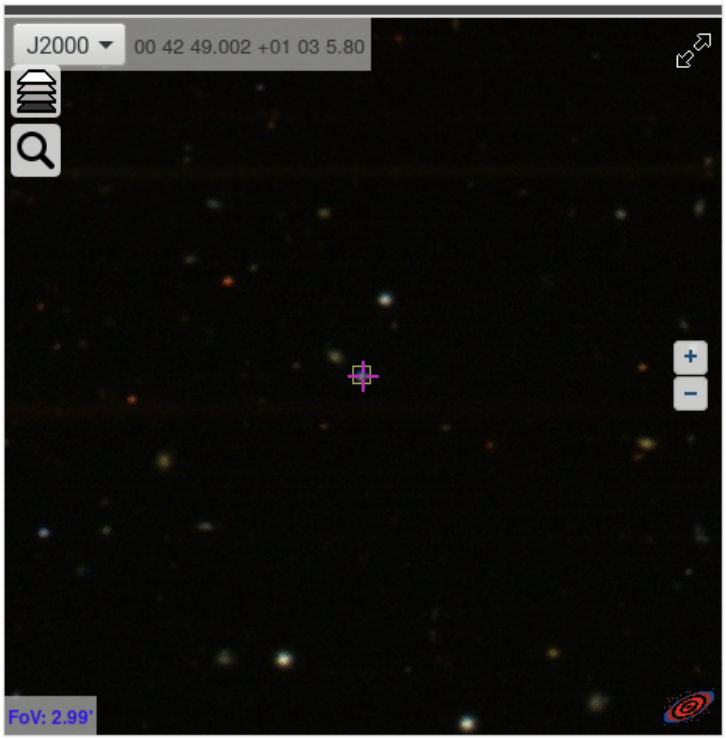
Sky view & Catalogue selected fields



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DEC	1.03498	GALAXY__LUM	34.2103
PLATE	1495	BR_CIV_1549__LUM	null
MJD	52944	BR_CIV_1549__FWHM	null
FIBER	401	BR_MGII_2798__LUM	8.78398
SPEC	spec-1495-52944-0401	BR_MGII_2798__FWHM	2312.27
E_BV	0.019752	BR_HB__LUM	5.78621
Flux to Lum. fac.	1.5218e-2	BR_HB__FWHM	3633.69
CONT1450__LUM	null	BR_HA__LUM	null
CONT3000__LUM	552.43	BR_HA__FWHM	null

Re-center on source | View all fields

Associated files

View fit log file | Preview PNG | Download: [Log file | Gnuplot data | Gnuplot residuals | IDL data | SDSS DR10 FITS]

Query: SELECT * FROM `spec-1495-52944-0401` WHERE x >= 1000 AND x <= 10000 ORDER BY x

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS — L. Nicastro & G. Calderone 2016, 2017

Applications:

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  - slopes of BAL vs. nonBAL sources ($\Rightarrow$ C. Campbell, master thesis @ Univ. Southampton);
- Estimate importance of Balmer continuum in SEV mass estimates ($\Rightarrow$ Varisco+18, master thesis @ Univ. Milano–Bicocca);
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- Added [OIII]5007 blue wing model component;
- Supports Lorentzian profiles;
- Supports absorption lines (guess wavelengths manually provided);
- Online calculator: `http://qsfit.inaf.it/cat_1.30/onlinefit.php`
- **Last version in IDL**;

The *near* future: Calderone 2019 (...or 2020 ?)

- Analyze the DR14Q (up to $z \sim 3$) catalog (Pâris et al. 2018);
- Extend the analysis to $z \sim 3$ (consider absorptions up to Lyman edge);
- **Abandon IDL!** $\Rightarrow$ complete open source implementation in **Julia**:

QSFit catalog creation guidelines

Easy reproducibility of results is a must!

- Released as free software (`https://www.gnu.org/philosophy/free-sw.en.html`)
- Resist the temptation to design an all–encompassing, or too general package;
- Identify a clear goal:
  - focus on "low" resolution ($R \lesssim 5,000$) of "low" redshift ($z \lesssim 2$) Type I AGN spectral analysis, customization and performances;

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- Avoid relying too much on individual software/language/library/standard: sooner or later it'll become a jail;
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The *cooking* paradigm:

- **Ingredients:** small, well-defined functionalities which can be documented in less than$\sim$ 1 page, and implemented in a black box (i.e. a library);
- **Recipes:** brief solutions to a problem (even an ill–posed one) based on ingredients.
  - No need to be perfect: **if you can do science with it, it is worth to be relased!**

Conclusions

- QSFit allows **simple, replicable and shareable** standardized recipes for AGN spectral fitting;
- It is the only open source package currently available, allowing customized recipes;
- We applied the **QSFit** recipe to a sample of 71,251 sources with $z < 2 \Rightarrow$ QSFit catalog:
  - all results, plots and logs, are publicly released in a dedicated website;
- Upcoming **QSFit** applications:
  - Automatic analysis of the DR14Q (up to $z \sim 3$) catalog (Pâris et al. 2018);
  - Automatic analysis of J–PAS low resolution spectra;

References:

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- QSFit website: `http://qsfit.inaf.it/`
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Is it relevant to the INAF spectroscopy laboratory?

- many functionalities have been implemented many times from scratch;
- attempt to identify SW development habits ensuring **reproducibility** and **long term use**;
- Basic take home messages:
  - **Think (plan) before you code!**
  - **Keep It Simple and Short (KISS)**
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