The Spitzer Atlas of Stellar Spectra

Data Delivery 2.0

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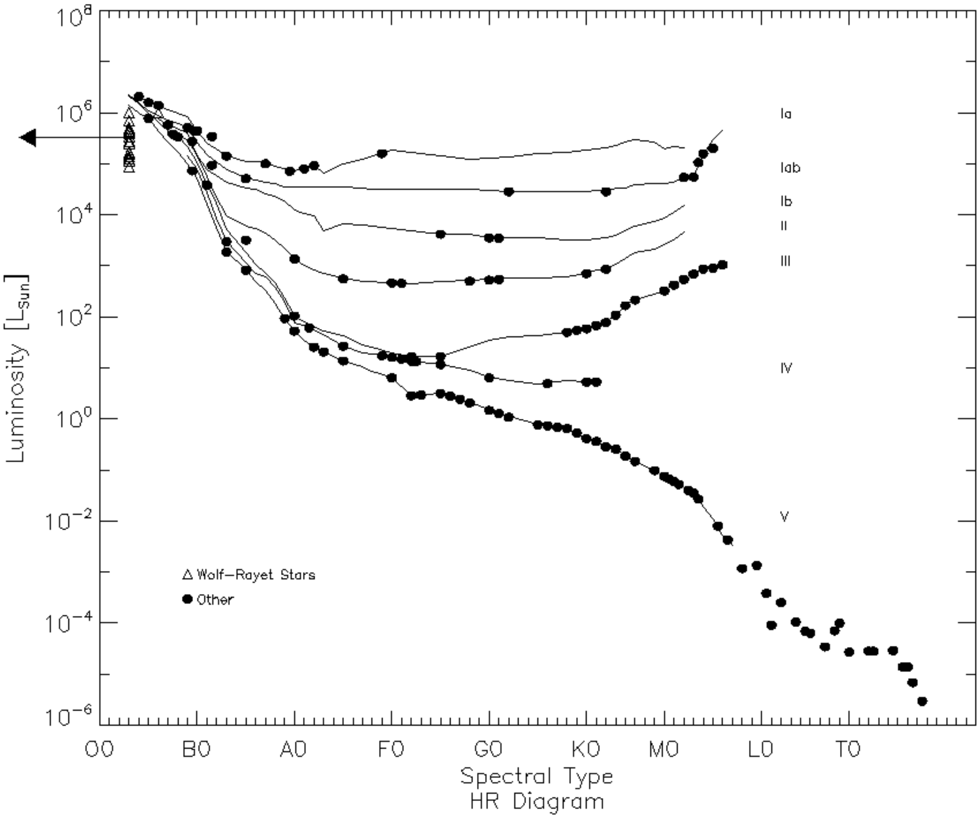

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[1] This delivery corrects coordinate errors in the spectral headers and minor typos in this document.

Introduction

The *Spitzer* Atlas of Stellar Spectra contains spectroscopic observations of 159 stars, performed during the cryogenic mission of the Spitzer Space Telescope (2003 - 2009). The main reference for this Atlas is Ardila et al. 2010, ApJS, 191, 301.

The goal of the project is to obtain a complete sampling of the HR diagram with the Infrared Spectrograph (IRS) low-resolution modules (R~64 to 128, 5 to 35 μm).

Sample Selection

From the 14,927 different IRS Staring observations that had been scheduled up to November 2008, we selected those stellar AORs and/or targets that had archival observations in all the IRS modules. We focused on targets that were public or whose observations would become public by 31 May 2009.

The focus on IRS Staring observations allowed us to make use of the sky-subtracted products provided in the IRS pipeline (those with the suffix bksub.tbl) and these products formed the backbone of the Atlas.

For each target, we searched the literature to find its spectral type. In general, the spectral types were taken from (in order of priority): NStED[2], NStars[3], the Tycho-2 Spectral Type Catalog (Wright et al. 2003), and SIMBAD. We assigned luminosity classes in the same priority. NStED bases its spectral types primarily on the Michigan Spectral Type Catalog, as does NStars. The spectral types on the Tycho-2 catalog are determined by cross-referencing the catalog with primary and secondary spectral type references, including the Catalogue of Stellar Spectra Classified in the Morgan-Keenan System (Jaschek et al.1964), the Fifth Fundamental Catalogue (Fricke et al. 1988, 1991), etc. SIMBAD uses all these and complements them by current literature observations. For certain types of objects, specialized catalogs in the literature served as the source of the spectral types. For example, the spectral types from WR stars were taken from the 7th Catalog of Galactic Wolf-Rayet stars (van der Hucht 2001).

Because the spectra should serve as templates to understand the spectral classes they belong to, we did not include young stars with circumstellar material, stars with debris disks, RS CVn's, Be stars, or eclipsing binaries: for these objects there is no characteristic spectrum.

In the case of bright giants (luminosity class II), giants (class III), subgiants (class

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[2] http://nsted.ipac.caltech.edu/

[3] http://nstars.nau.edu/nau nstars/about.htm

IV), and dwarfs (class V), we generally rejected targets presenting IR excesses. Beyond ~10μm, the photospheric IR continuum is relatively flat for spectral types earlier than mid-M. For each candidate star, we compared its spectrum with (depending on the effective temperature) a blackbody function, available stellar templates (Cohen et al. 2003; Decin et al. 2004), or an Engelke function (Engelke 1992). Our determination of excess is qualitative, and low-level excess may still be present in the spectra.

The no-excess restriction was lifted for certain classes. For example, for Wolf-Rayet (WR) stars all members of the class are surrounded by circumstellar material. In addition, we also included L and T dwarfs that had spectral coverage only to 14 μm. These objects are unique enough to include them in the Atlas.

During the exploration of the Spitzer archive it became clear that some classes did not have observations performed with the low-resolution modules. In addition certain unique objects like RR Lyrae, examples of Cepheids, and blue stragglers had never been observed with the IRS. We gained approval of a proposal for Director's Discretionary Time in order to complete missing or incomplete classes of stars (DDT 485, PI Ardila).

For each class, we selected the highest signal-to-noise representative for inclusion in the Atlas.

Reduction

We trimmed the orders in the ranges indicated in Table 1. While we kept data up to 35 μm in LL1, fluxes beyond 32 μm fall on a significantly damaged region of the detector and present very high levels of rogue pixels. In addition we found that LL3 presents less rogue pixels than LL2 and replaced the long wavelength region of LL2, from 19.35 μm to 20.5895 μm, by LL3.

In the calibration provided by SSC, the low-resolution modules of the IRS are calibrated using the MARCS models (see Decin et al. 2004) for a single standard star, the K1 giant HR 7341 (see the IRS Data Handbook). All bksub.tbl observations of this star are averaged and the ratio between the observations and the model is fit with a polynomial. This polynomial is the multiplicative factor by which all spectra are corrected

To the bksub.tbl products provided by SSC pipeline 18.7.0 we applied additional corrections as follows:

- Teardrop correction (http://ssc.spitzer.caltech.edu/IRS/calib/teardrop/): We used the archival calibration observations of HR 7341 to derive a multiplicative correction for this effect.

- Slit position correction: To make use of the better knowledge of the in-orbit performance of the spectrograph, SSC changed the slit position tables, which determine the orientation of the slit on the focal plane, starting on 19 June 2006. The current calibration provided by the pipeline is an average calibration, applied equally to data before and after this date. We used the observations of HR 7341 to derive multiplicative polynomial corrections to the spectra depending on their date.

- Residual model corrections: Even after these corrections, order curvature was present in the spectra of flat sources, like A0 stars. The source of this curvature is unknown, although its presence points to errors in the model of HR 7346. We used archival observations of the A0 star α Lac and compared them with a template model for this star (Cohen et al. 1999) to determine residual corrections to the spectra.

- The 24 mic flux deficit: Observations of faint sources present a flux deficit at 24 mic, as well as anomalous slopes in LL2 (http://ssc.spitzer.caltech.edu/irs/features.html#3_LL1_24u_Deficit). For these sources, we determined an additional multiplicative correction, based on 120 sec ramps observations of α Lac and the Cohen template.

For each target, we calculated the offset distance between its predicted coordinates and those of the slit, and rejected those observations with offsets larger than 2.5". After applying these corrections, all the spectra for a given source were averaged. Residual order mismatches were present in the data. We assumed that these mismatches were due to pointing uncertainties and matched the spectra to the highest order. The error in the overall flux level is that of the standard IRS calibration (~5%).

The spectra have not been corrected for interstellar extinction. In this Atlas, most stars from bright luminosity classes show silicate absorption at 10 μm as well as reddened spectral slopes. However, the reddening correction is negligible for nearby (intrinsically faint) stars, as one magnitude of extinction in the Johnson V band corresponds to 0.05 mag at 8 μm. See the galactic dust reddening and extinction maps (Schlegel, Finkbeiner & Davis 1998) available from IRSA.

Acknowledging

Works using these data should cite "Ardila et al. 2010, ApJS, 191, 301" Questions should be directed to David R. Ardila (ardila@ipac.caltech.edu).

Acknowledgments

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References

Ardila, D.R. et al. 2010, ApJS, 191, 301.
Cohen, M. et al. 1999, AJ, 117, 1864.
Decin, L. 2004, AJ, 154, 408.
Engelke C.W. 1992, AJ, 104, 1248.
Fricke, W. et al. 1988, Veroeffentlichungen des Astronomischen Rechen-Instituts Heidelberg, 32
Fricke, W. et al. 1991, Veroeffentlichungen des Astronomischen Rechen-Instituts Heidelberg, 33
Jaschek, C., Conde, H., & de Sierra, A. C. 1964, Observatory Astronomical La Plata Series Astronomies, 28, 1.
Nordstrom B. et al. 2004, A&A, 419, 989.
Schlegel, D.J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525.
van der Hucht K.A., 2001, NewAR, 45, 135.
Wright C.O. et al. 2003, AJ, 125, 359.

Table 1: Ranges used for each order

Order	Range (microns)
SL2	5.2 – 7.54588
SL1	7.57612 – 14.2898
LL2	14.2387 – 20.5895 (LL3 from 19.35 to 20.5895)
LL1	20.5895-35

Table 2: Polynomial multiplicative corrections applied to the data, as follows: $p=a_0+a_1(\lambda-\lambda_0)+a^2(\lambda-\lambda_0)^2+\ldots$, where a_0, a_1, a_2, etc, are given above.

Correction	Order	Pivot λ_0	Polynomial coefficients
Teardrop	SL1 (> 13 mic)	0	1.73716, -0.132743, 0.00584572
Nod 0, old	SL2	6	0.990966, -0.00669176, -0.000115076

Nod 0, new	SL2	6	1.00474, -0.00658626, -0.00244433
Nod 1, old	SL2	6	0.992103, 0.0144322, -0.00376203
Nod 1, new	SL2	6	1.00370, 0.00993892, -0.00270484
Nod 0, old	SL1	10	0.984629, 0.00165273, -0.00102893,0.000355763
Nod 0, new	SL1	10	1.00018, -0.00244389, -0.000367869, 0.000233202
Nod 1, old	SL1	10	0.998734, 0.00903313, -0.00118942, -0.00137535, 0.000198369
Nod 1, new	SL1	10	1.00611, 0.00543378, -0.000617655, -0.00149233, 0.000244382
Nod 0, old	LL2	18	0.987009, 0.000834591, -0.000564992
Nod 0, new	LL2	18	1.00121, 0.00117174, -0.000130143
Nod 1, old	LL2	18	0.997453, -0.000512385, 0.000749858
Nod 1, new	LL2	18	1.00857, -0.00104855, 0.000283562
Nod 0, old	LL1	26	1.00047, -0.00172408
Nod 0, new	LL1	26	1.00800, 0.000159851
Nod 1, old	LL1	26	0.990219, 0.00229134
Nod 1, new	LL1	26	1.0, 0.000368189
α Lac, old	SL2	6	0.993109, -0.000274152, 0.00304373
α Lac, new	SL2	6	0.99988661, -0.0031066054, 0.0019065623
α Lac, old	SL1	10	1.00100, -0.00186966, 0.000672951
α Lac, new	SL1	10	1.0019434, -0.0012843547, 0.00030117893
α Lac, old	LL2	18	0.989320, -0.000477111
α Lac	LL1	26	0.996167, -0.000998179, -0.000334123
Faint source deficit	LL2	18	1.0, -0.00056316124
Faint source deficit	LL1	26	1.0, 0.0026269022, 0.00084026423