

# Atmospheric Properties of L Dwarfs as Evidenced by Spectral Features in the Infrared (5-14.5 $\mu\text{m}$ )

Mollie Van Gordon (American Museum of Natural History, Barnard College), Kelle Cruz (American Museum of Natural History)

## Introduction

- We present Spitzer IRS low-resolution spectra of two M dwarfs and sixteen L dwarfs (5-14.5  $\mu\text{m}$ ).
- Our spectra confirm the silicate feature in the 9 to 11 micron range of early-to-mid L dwarfs proposed by Cushing et al. 2006 that indicates the presence of small-grained silicate clouds (enstatite, forsterite).
- Our spectra demonstrate the variability of the presence of the silicate feature and the variable strength of water features in L dwarfs.
- Eventual comparison with theoretical models will offer insight into the role of gravity, metallicity, and cloud properties of the atmospheres of brown dwarfs in their resultant spectra.
- We show the influence of Spice version and pipeline on our final spectra.

## Targets

2MASS designation	RA	dec	K	J-K	distance (pc)	SPType
2M0429-31	04 29 18.4	-31 23 56	9.80	1.086	11.4 +/- 2.2	M7.5, comb
2M2351-25	23 51 50.4	-25 37 36	11.29	1.170	18.2 +/- 1.5	L0, comb
2M1707-07	17 07 23.43	-05 58 24.9	10.71	1.341	13.8 +/- 1.7	L0, comb
2M1731+27	17 31 29.74	+27 21 23.3	10.91	1.180	11.8 +/- 0.7	L0
2M1045-01	10 45 24.0	-01 49 57	11.81	1.319	16.8 +/- 1.1	L1
2M1048+01	10 48 42.81	+01 11 58.0	11.62	1.301	15.3 +/- 1.0	L1.5
2M1807+50	18 07 15.9	+50 15 31	11.61	1.356	14.6 +/- 1.1	L1.5
2M2057-02	20 57 54.0	-02 52 30	11.75	1.375	15.7 +/- 1.1	L1.5
2M0445-30	04 45 53.8	-30 48 20	11.98	1.425	16.6 +/- 1.3	L2
2M0921-21	09 21 14.10	-21 04 44.6	11.69	1.089	12.4 +/- 1.0	L2
2M1051+56	10 51 19.00	+56 13 08.6	11.91	1.339	15.4 +/- 1.2	L2
2M0523-14	05 23 38.2	-14 03 02	11.63	1.486	13.4 +/- 1.1	L2.5
2M0251-03	02 51 14.8	-03 52 45	11.65	1.429	12.1 +/- 1.1	L3
2M1425-36	14 25 27.98	-36 50 22.9	11.81	1.942	16.4 +/- 3.0	L3, comb
2M0700+31	07 00 36.6	+31 57 26	11.31	1.614	12.2 +/- 0.3	L3.5, comb
2M1448+10	14 48 25.63	+10 31 59.0	12.68	1.873	19.6 +/- 4.0	L4, comb
2M0144-07	01 44 35.3	-07 16 14	12.28	1.904	13.4 +/- 1.5	L5
2M0624-45	06 24 45.95	-45 21 54.8	12.60	1.895	15.3 +/- 3.3	L5, comb

Table 1 -- Objects for which infrared data is presented here. The 2MASS designation and photometry are listed along with our derived distance with uncertainty and measured optical spectral type.

## Infrared Data

- Spectra obtained with the Infrared Spectrograph (Houck et al. 2004, IRS) on Spitzer during Cycle 1 GO program (PID 3136).
- The Short Low module was used to obtain low-resolution ( $R \sim 100$ ) spectra covering 5-14.5  $\mu\text{m}$ .
- IDL was used for sky subtraction.
- SPICE was used to extract each observation with a wavelength-dependent extraction width set to 4 pixels at 7  $\mu\text{m}$ .
- IDL scripts were used to coadd the individual observations, merge the orders (SL2 and SL1), and refine the flux calibration.
- Because a non-standard extraction width was used, the spectra were further calibrated using a correction factor between the standard and non-standard extraction widths obtained from reduction of  $\eta$ 1 Dor.

## Acknowledgements

This work is based on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. Support for this work was provided by NASA through an award issued by JPL/Caltech and in part by the New York NASA Space Grant Program.

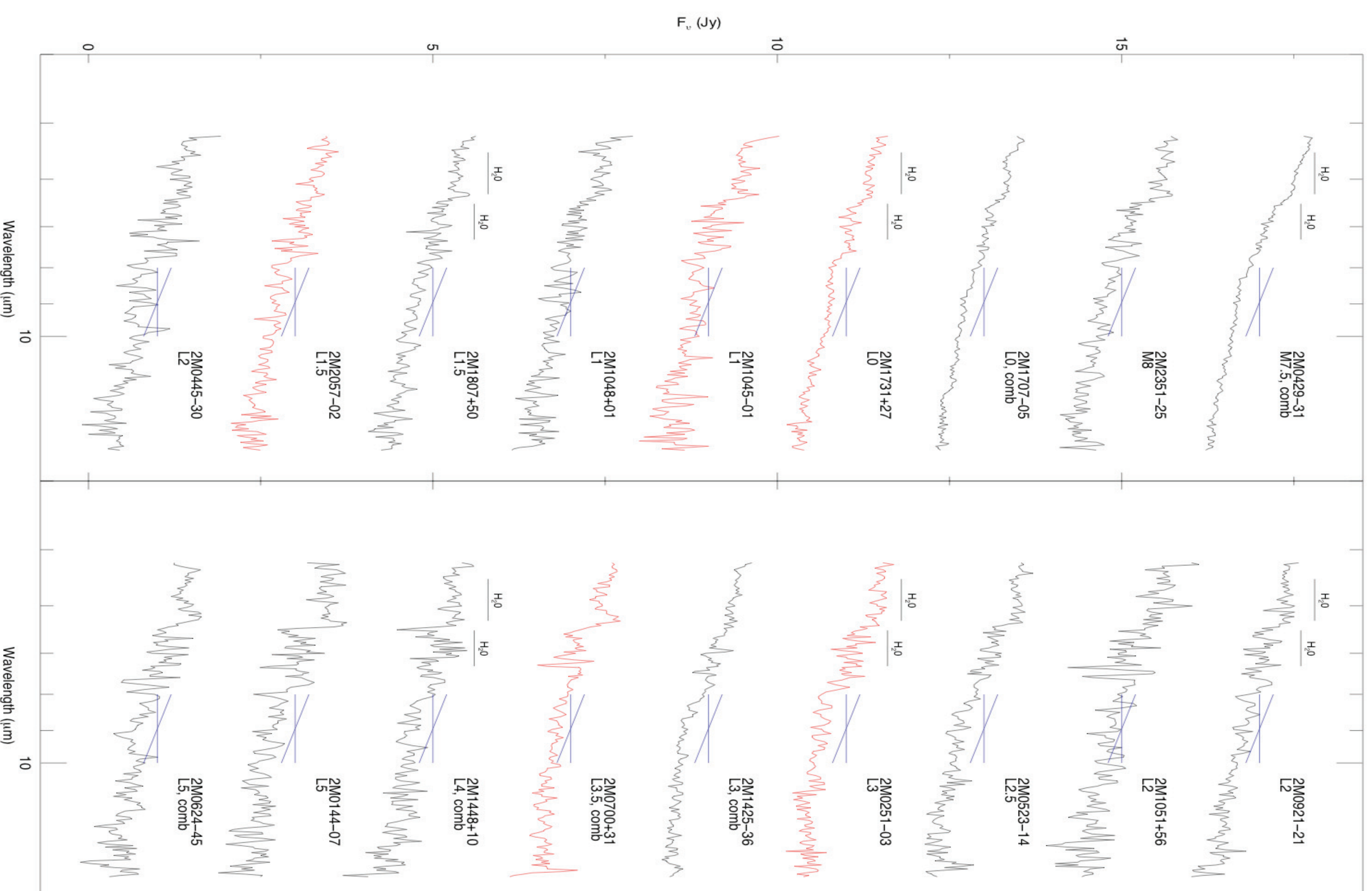


Figure 1 -- Infrared (5-14.5  $\mu\text{m}$ ) spectra of the eighteen objects listed in Table 1. Locations of water absorption bands are marked. Log scale is used to emphasize the silicate feature and reference lines are included to aid in identification of the feature. Spectra in which we detect the silicate feature appear in red.

## Summary/Conclusions

- The flux calibration will be tied to our IRAC observations in the future.
- We have observed evidence supporting variable cloud properties among L dwarfs.
- We obtained spectra on a further number of objects, but those data are not of sufficient quality (S/N) to analyze.
- Clearly, higher S/N data is needed to further investigate the variable features.

## Spectral Features

- Our spectra confirm the 9-11 micron silicate feature proposed by Cushing et al. 2006 in the spectra of early-to-mid L dwarfs.
- The silicate feature indicates the presence of small-grained silicate clouds in the atmospheres of these L dwarfs composed of enstatite as well as forsterite that are not predicted by current models.
- Our spectra demonstrate the variability of the presence of the silicate feature and the variable strength of the water feature.
- Variability of the silicate feature occurs within spectral type.
- If due to atmospheric cloud properties, the variable silicate feature indicates variable cloud properties among L dwarfs of the same optical spectral type.

## Significant Reduction Factors

- Different versions of SPICE make a difference.
- The newer SPICE version used includes IRS tune v.3.2 and Params v.1.8.
- The older SPICE version used includes IRS tune v.3.0a and Params v.1.5.
- The differences in SPICE version may also be in Ridge.
- Different pipelines make a less significant difference.

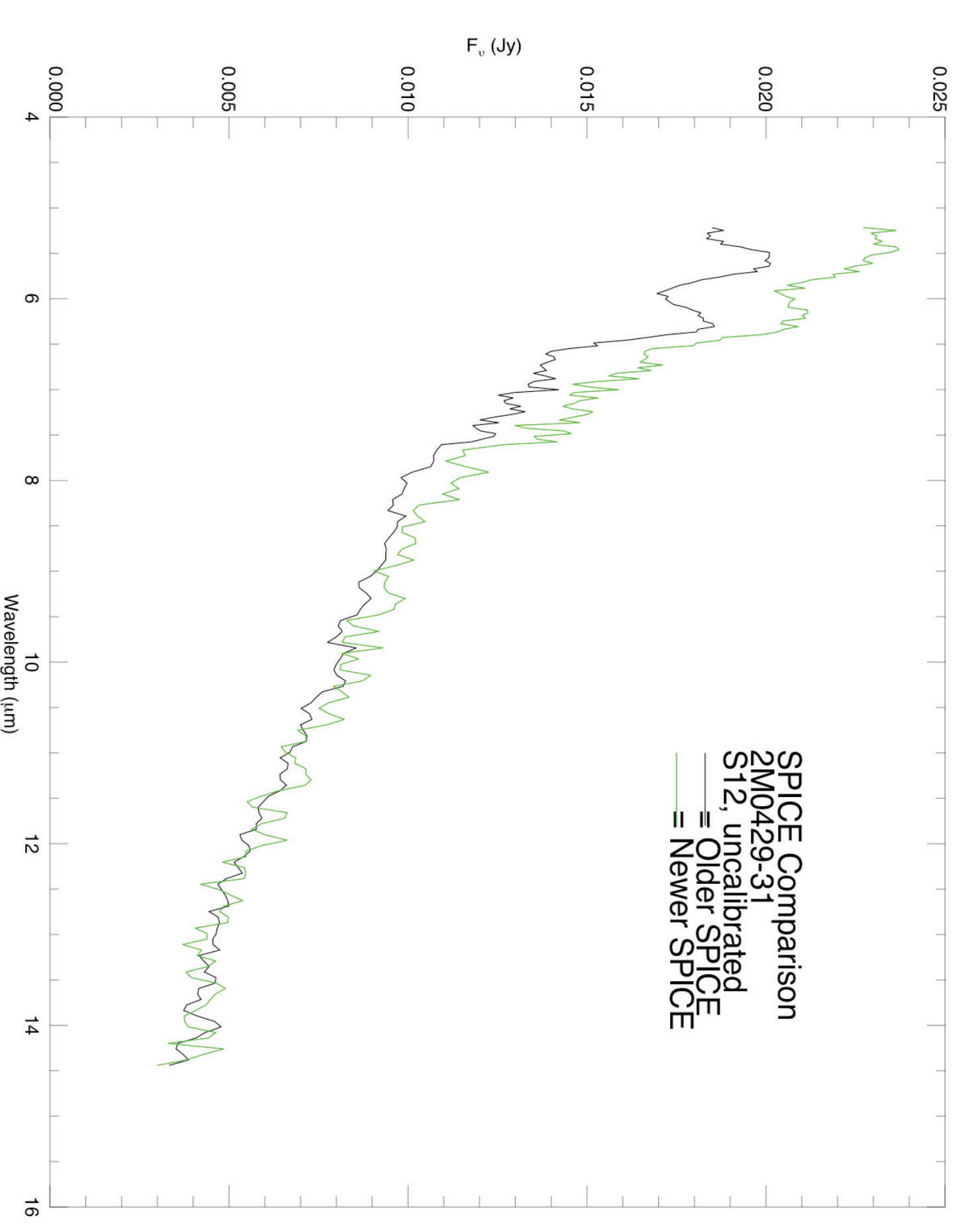


Figure 2 -- SPICE version comparison of S12 data for 2M0429-31, one spectrum reduced with an older version of SPICE (black), one spectrum reduced with a newer version of SPICE (green). Both spectra are not flux calibrated.

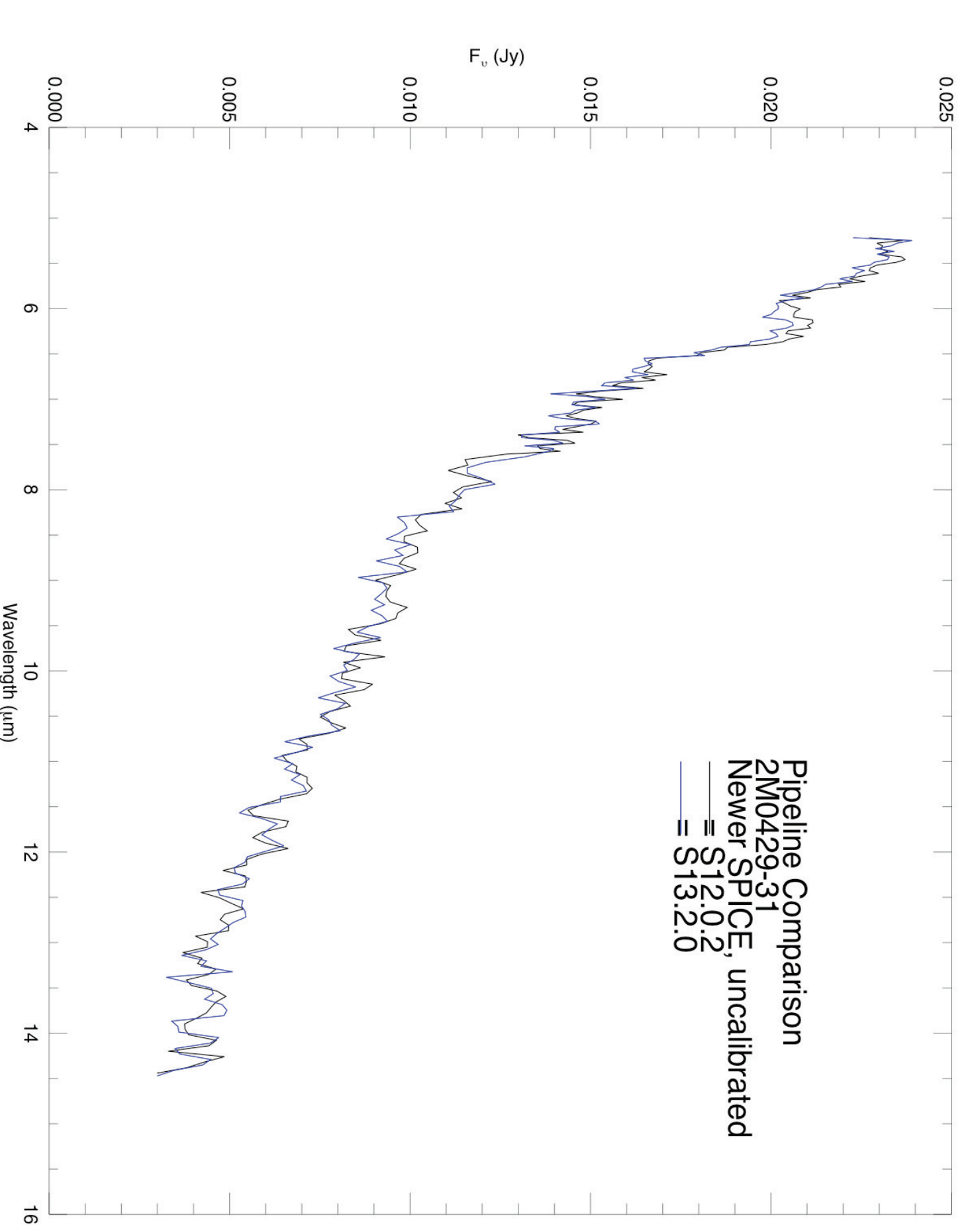


Figure 3 -- Pipeline comparison of S12 (black) and S13.2 (blue) for 2M0429-31. The spectra are reduced using an identical newer version of SPICE. Both spectra are not flux calibrated.