Guidance for Using NEOWISE Data for NEA Observations

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Introduction

The WISE and NEOWISE missions [1,2] are a key source of thermal data of near-Earth asteroids (NEAs). The W1 (3.4 μm) and W2 (4.6μm) bands were the only ones available after the depletion of cryogenic coolant. **Careful analysis methods are crucial for working with these data. In this work we lay out some of our "lessons learned" from working with NEOWISE data [3] and provide a roadmap for others using the mission data.**

Data Selection

Ensuring only real NEA observations are used requires a detailed data vetting process.

1. Get observation tracklets for the object from the Minor Planet Center
2. Filter observations for WISE observatory code (C51)
3. Use the L1b Single Source Catalogs with Multi-Object Search. Upload the observations from the MPC, using a 0.3" search radius and the additional time constraint "abs(mjd - mjd_01) < 2./86400."
4. Check data flags on returned observations. Remove the following:
    1. cc_flags: Any observations with something other than '0' in any band
    2. ph_qual: Any observations with 'U' or 'X' in any band
    3. qual_frame: Any observations with value '0'
5. If averaging observations, require at least 3 observations with σ > 0.25 (sigmpro) in each band.
6. Check the raw images from the WISE image catalogs. Visually inspect each frame to see that an object is present and is not obscured (Fig. 1).

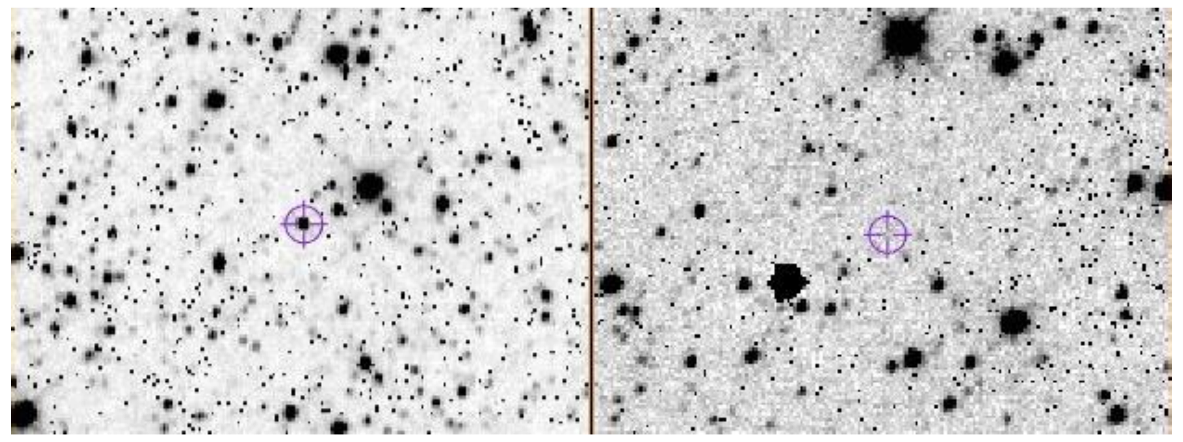


Fig 1: Raw W1 images for 1999 JM8. The reticle shows where the pipeline extracts a magnitude value. Left: A real detection with the object clearly visible. Right: A spurious detection with no object visible that has a reported magnitude of 16.2±0.3.

References

[1] Wright, E. L., Eisenhardt, P. R., Mainzer, A. K., et al. 2010, The Astronomical Journal, 140, 1868. [2] Cutri, R., Mainzer, A., Conrow, T., et al. 2015, Explanatory Supplement to the NEOWISE Data Release Products, 1 [3] Myers, S. A., Howell, E. S., Magri, C., et al 2024, The Planetary Science Journal, In Print

F_ν	$f_c(W1)$	$f_c(W2)$	$f_c(W3)$	$f_c(W4)$
$B_\nu(100)$	17.2062	3.9096	2.6588	1.0032
$B_\nu(141)$	4.0882	1.9739	1.4002	0.9852
$B_\nu(200)$	2.0577	1.3448	1.0006	0.9833
$B_\nu(283)$	1.3917	1.1124	0.8791	0.9865
$B_\nu(400)$	1.1316	1.0229	0.8622	0.9903
$B_\nu(566)$	1.0263	0.9919	0.8833	0.9935
$B_\nu(800)$	0.9884	0.9853	0.9125	0.9958

Fig 2 (above): Adapted from Table 1 in [1]. Left column is blackbody temperature in Kelvin. Remaining columns are corresponding color corrections for bands W1-W4. Fluxes are divided by this value.

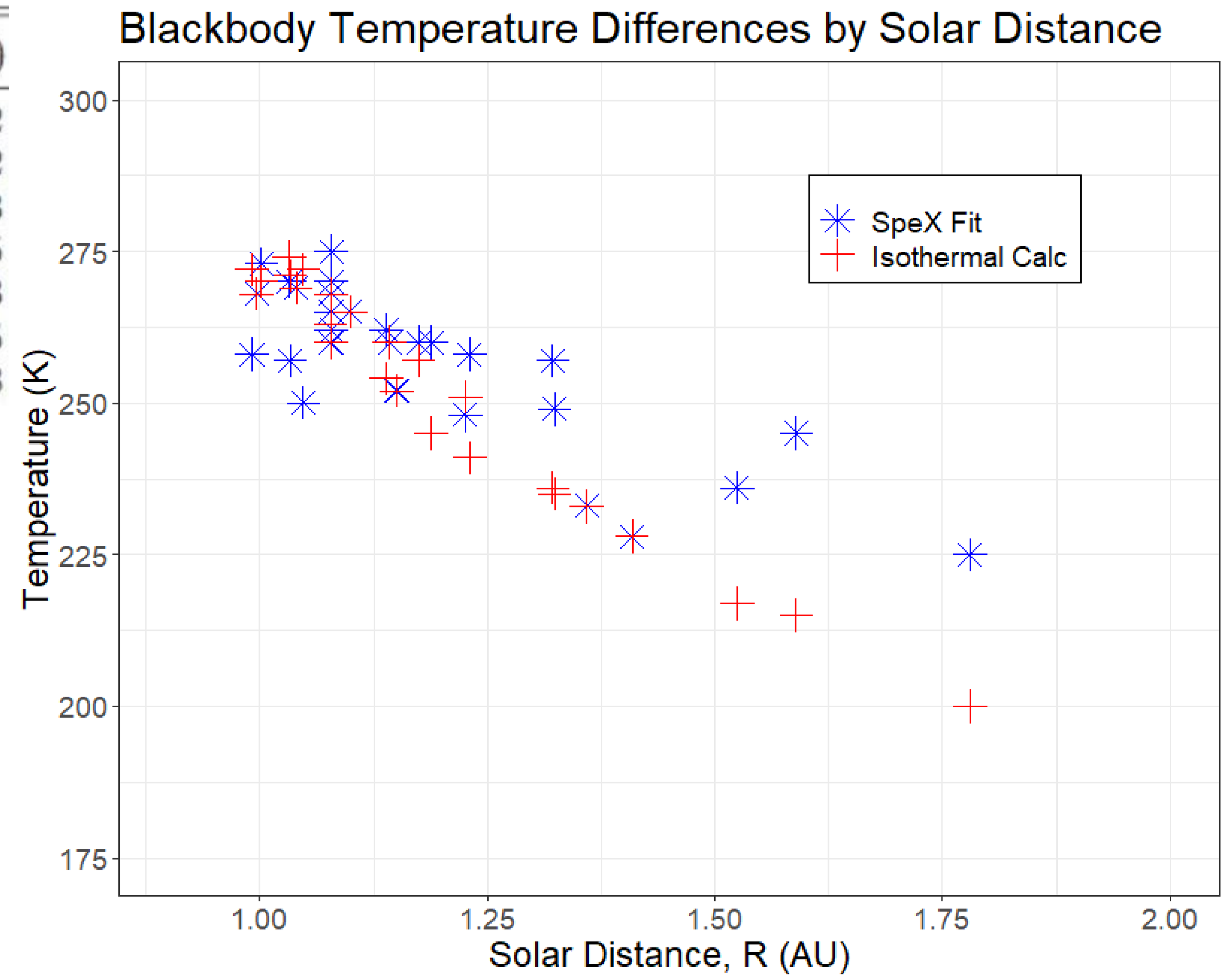
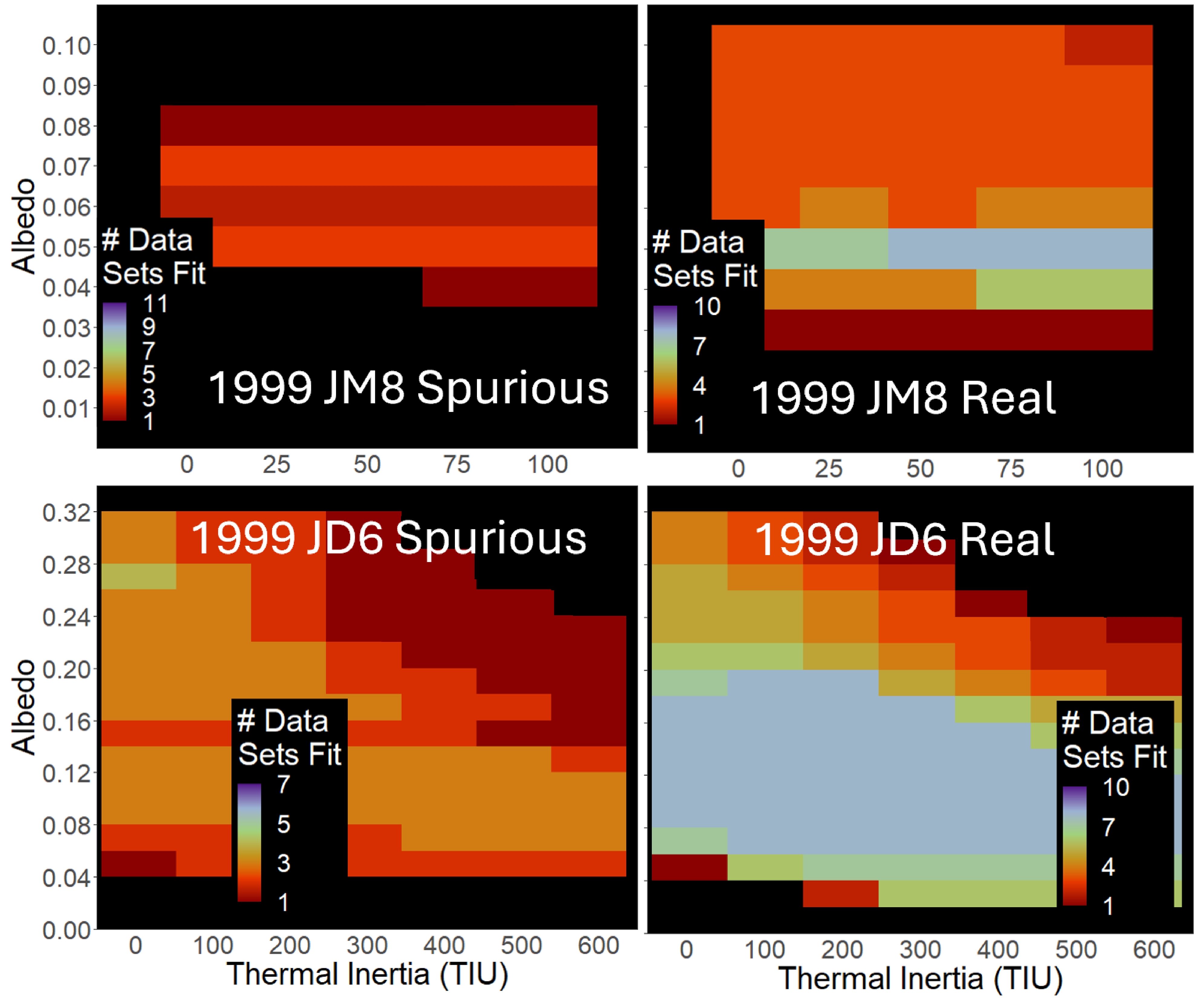


Fig 3 (right): Each vertical line of symbols is one SpeX observation, sorted by solar distance. The asterisk is the temperature found by fitting blackbody curves to the SpeX data and the cross is the isothermal calculation. The difference never exceeds 30 K. For r < 1.25 au, the direction of offset is random, for r > 1.25 au the isothermal value is less than the fitted value.

Fig 4 (right): Modeling results for 1999 JM8 and 1999 JD6. The left side shows results including spurious detections without proper color corrections. The right side shows results excluding spurious detections, with proper color corrections. Results are shown as heatmaps, where the color indicates the number of NEOWISE data sets for the given object that were fit by a simple thermal model. Note that even the best fitting models do not fit every data set. Each colored square is a different set of model parameters. The x-axis shows thermal inertia in SI units and the y-axis shows visible albedo.



Color Corrections

NEOWISE data require a color correction based on the object blackbody temperature.

- This is based on a convolution of the input spectrum and the bandpass filters.
- Example values are shown in Fig. 2. Contact us for code to calculate corrections for arbitrary temperatures.
- These values are calculated for stars, but NEAs are graybodies, with surface temperature distributions.

Exact methods for applying the color corrections to NEA data are not provided. Therefore, **we developed a technique that incorporates temperature uncertainty into the data uncertainty to avoid circularity with model results [3].** We fit blackbody curves to IRTF SpeX observations of thermal emission of NEAs at multiple viewing geometries. We use geometries with high phase angles at low solar distances and vice versa, that mimic the NEOWISE data set. We then compare the difference between these fitted temperatures to a temperature calculated using an isothermal blackbody assumption. **This gives a 30 K temperature range (Fig. 3), which we translate into a color correction range, which gives increased data uncertainties.**

Implications for Model Results

Failure to account for all the procedures here can change modeling results based on NEOWISE data (Fig. 4).

We analyzed data for six different NEAs (1999 JM8, 1999 JD6, 1998 UO1, 2003 SD220, 1996 FG3, and 1998 QE2) using a simple thermal model [3].

- Failure to compare the NEOWISE catalog against the MPC would result in the inclusion of 36 spurious detections, affecting 15 of our 46 total data sets (33%).
- Failure to adequately check the flags would result in the inclusion of 25 spurious detections, affecting an additional 7 of our 46 total data sets (15%).
- Failure to visually inspect the images would result in the inclusion of 29 spurious detections, which would have led to the inclusion of 9 additional completely spurious data sets.

Acknowledgements

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. DGE-2137419. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

If this work interests you, please reach out!

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