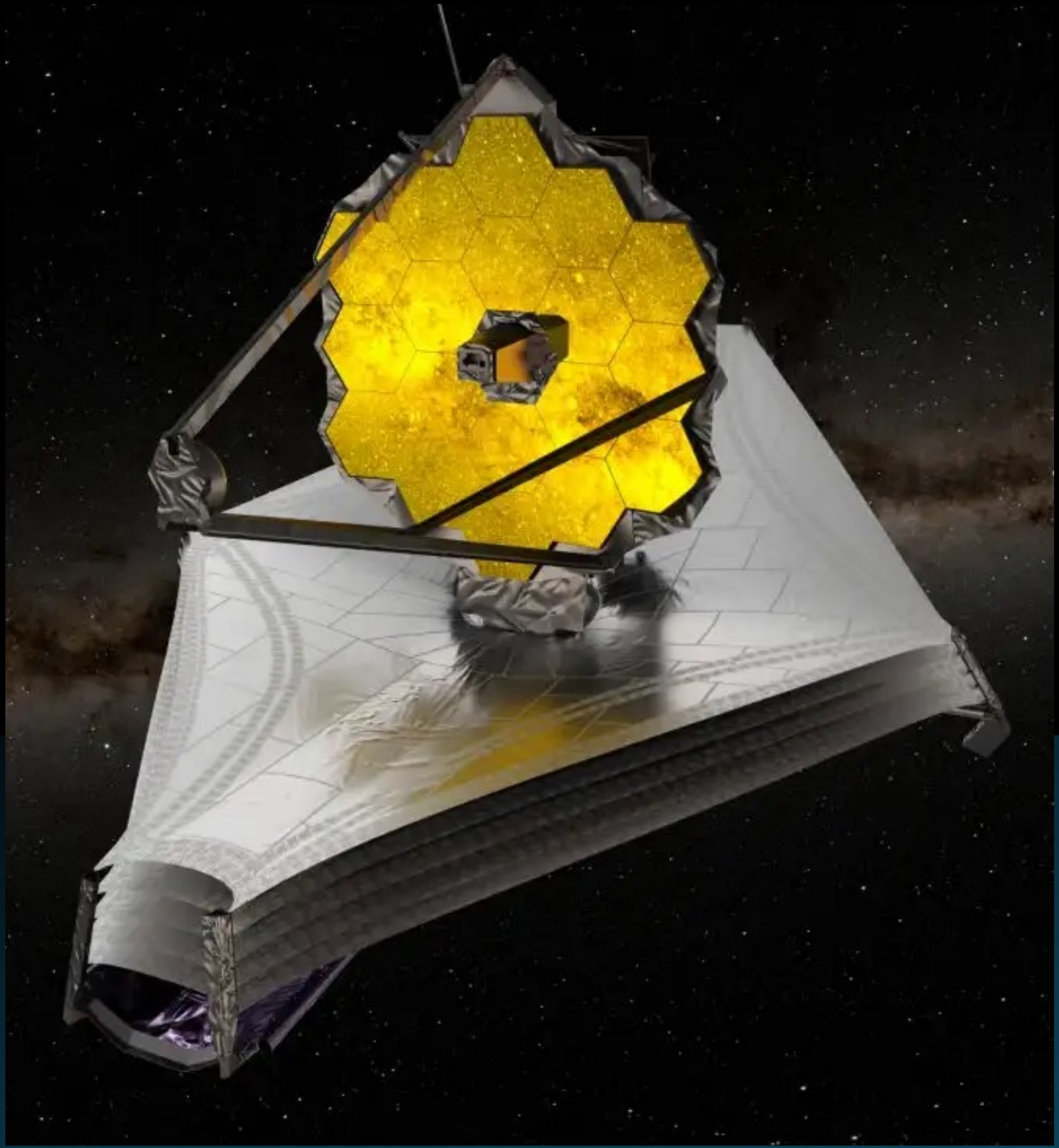
The CIA Mystery: Collision-Induced Absorption in Cool White Dwarfs



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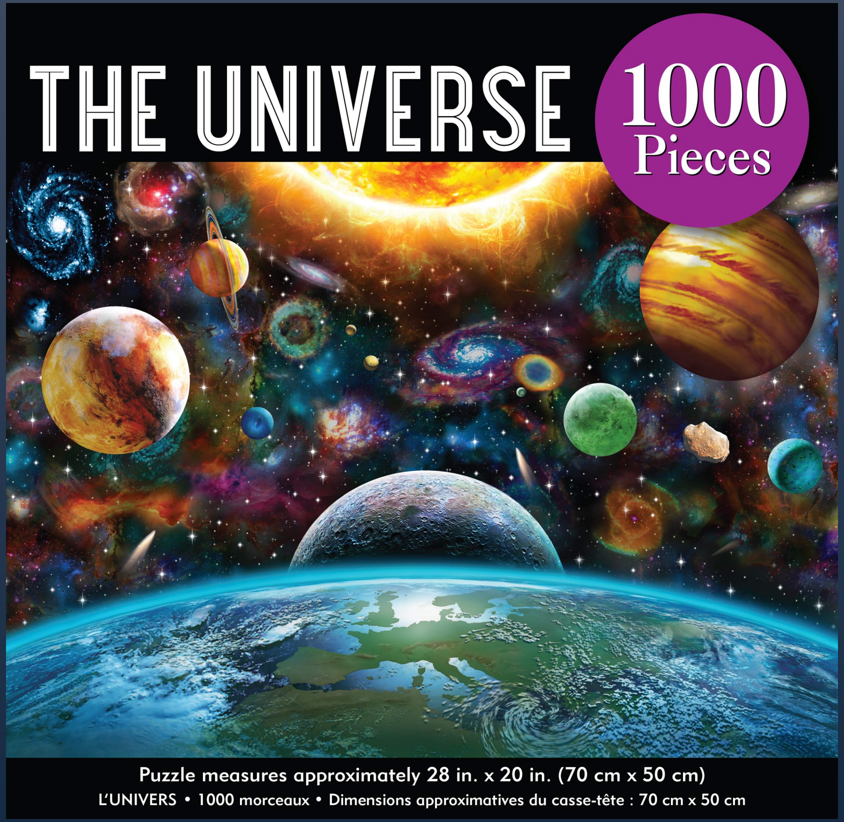
White Dwarf Age Dating

- Many applications require accurate WD model atmospheres to reliably infer WD ages:
  - Determining the ages of individual stellar populations[6, 7]
  - Reconstituting the formation history of our Galaxy[4]
  - Calibrating models for M, L, and T dwarf companions[11]
  - Tracing back the chemical evolution of our Galaxy[10]



Current Issues

- 10% (400 K) uncertainty on T_{eff} implies 1 Gyr error on cooling age
- Recent analyses differ by more than 1000 K[1, 3]
- Poor agreement between models and observations
- Atmospheric compositions can only be inferred from a detailed fit to their SEDs
- Difference in cooling time between He-dominated and H-dominated atmosphere is of the order 2 Gyr

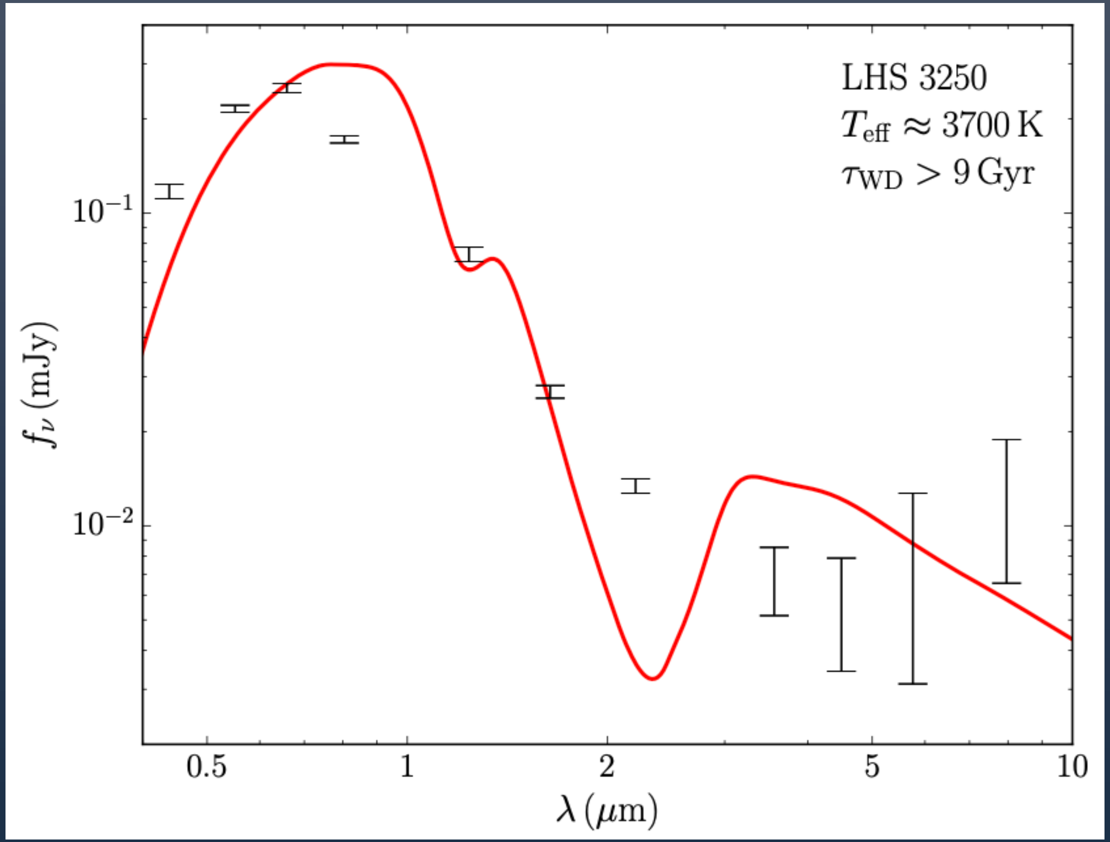


Figure 1: Best fit (in red) to the SED of LHS 3250, a typical ultracool WD and one of the three targets. The error bars show the BVRIJHK and Spitzer 3.6 – 8 μm photometry.

Not so cool after all...

- Ultracool WDs might be in the T_{eff} = 4000 – 5000 K range[1] instead of T_{eff} = 3000 – 4000 K range[5]
  - Updated physics of models[2]
  - Explored effect of changing collision-induced absorption (CIA) opacities
- Found much better fits using older CIA calculations[9]
- Predictions of the locations of the H_2 absorption features differ greatly

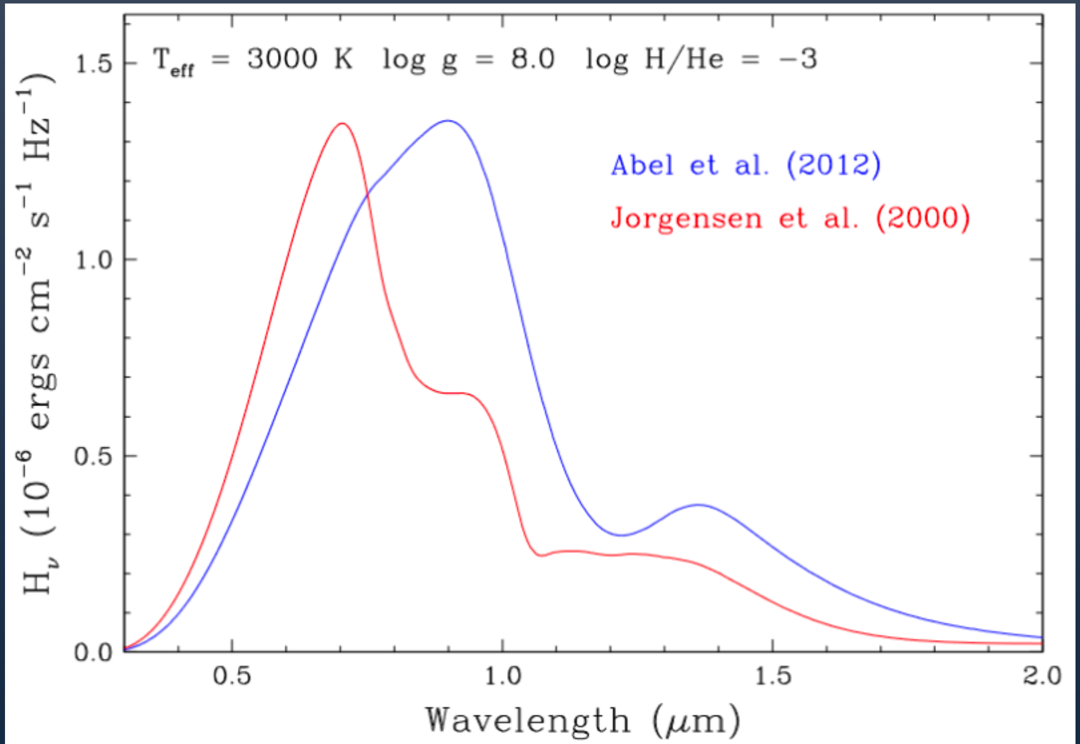


Figure 2: Model SEDs of ultracool WDs for two different choices of CIA opacities. (Bergeron et al. 2022)

Goals

Obtain first IR spectra of ultracool WDs using NIRSpec and MIRI

Utilize IR spectra to unveil & resolve CIA features

Settle the debate on the very nature of ultracool WDs

NIRSpec and MIRI Capabilities

- NIRSpec:
  - 0.6 – 5 μm wavelength range (low-resolution spectroscopy)
  - 1 – 5 μm wavelength range (medium-resolution spectroscopy)
  - Multi-object observation capability
- MIRI:
  - 5 – 28 μm wavelength range
  - Astrophotography
  - Medium-resolution spectroscopy

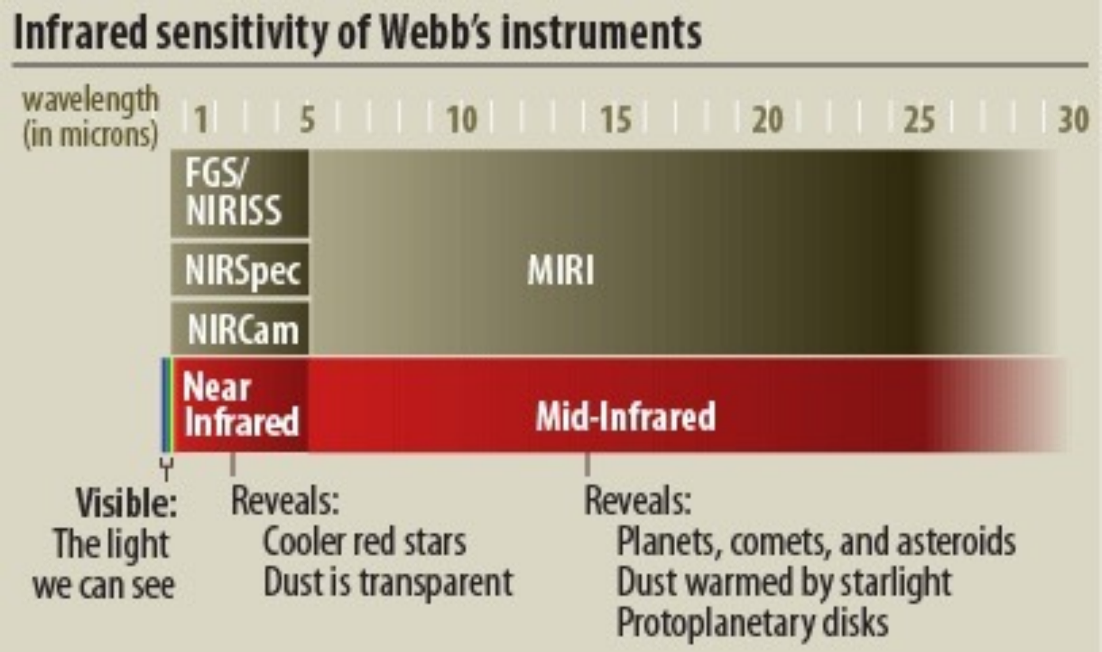


Figure 3: Infrared sensitivity of Webb's instruments, taken from webb.nasa.gov.

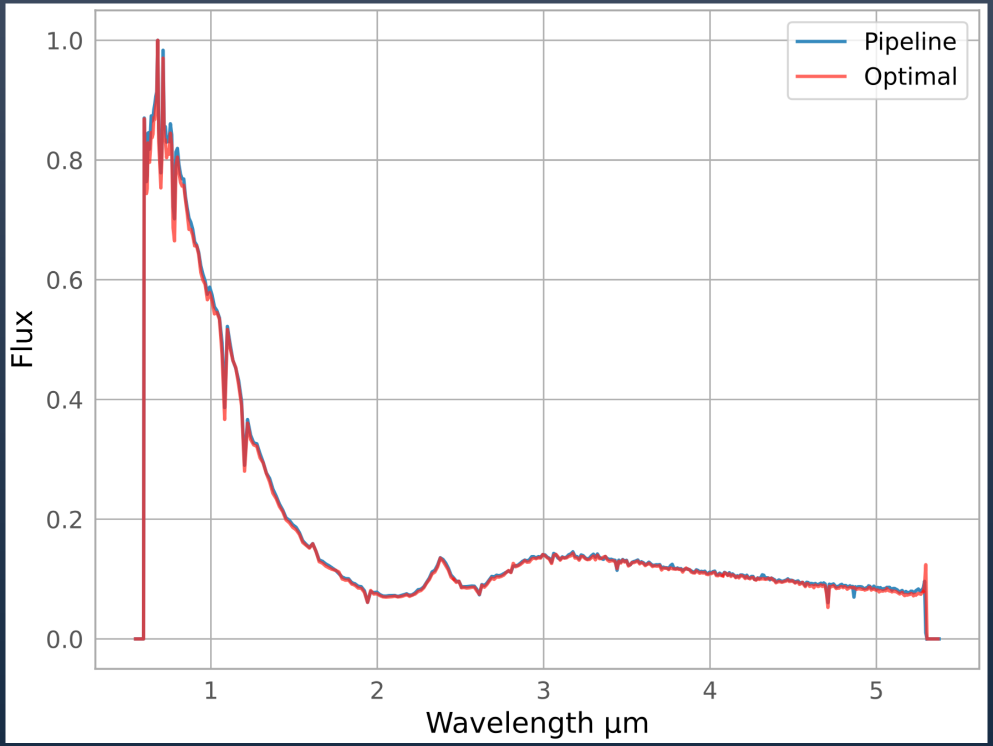
Our Targets

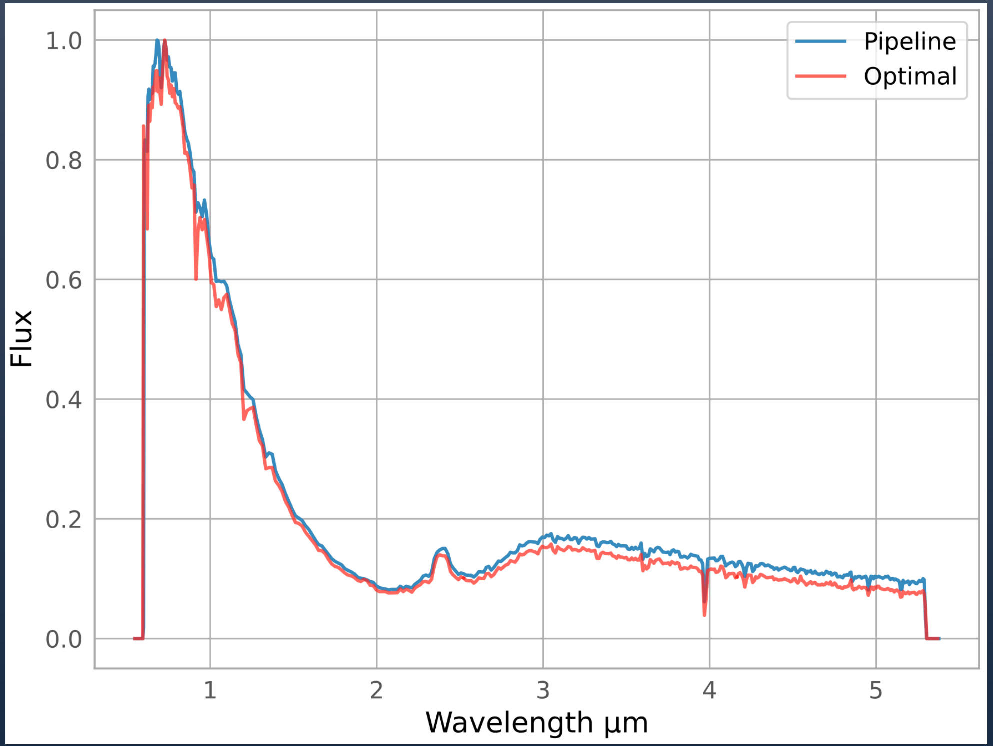
- LHS 3250: The first "ultracool" white dwarf discovered[8]. Little progress made in constraining its temperature, mass, and age. Resolving the location of its absorption band at 4 – 7 μm will allow differentiation between competing CIA models.

- J1922: Shows an atomic absorption line in its visible spectrum[12]. Na doublet can be used to pinpoint its atmospheric density and mitigate a source of uncertainty for the model atmospheres. Vastly different T_{eff} for this star[1, 3]

- GD 362: Shows potential emission features near 6 μm that could be due to water vapor. Unique WD with heavily polluted atmosphere and an infrared excess, indicating a surrounding dusty disk likely formed from disrupted planetary material.

What has been done so far?





Figures 4 (left) and 5 (right): Optimally extracted spectrum of the two dithers for the J1922 target (red) compared with the x1d pipeline product (blue). Note the emission feature near 2.4 µm.

- JWST uses the Pipeline to calibrate and process data to produce third stage final products.
- Optimal extraction uses stage 2 data products from the pipeline, but gives control over third stage output.

Optimally Extracted Spectrum: LHS 3250

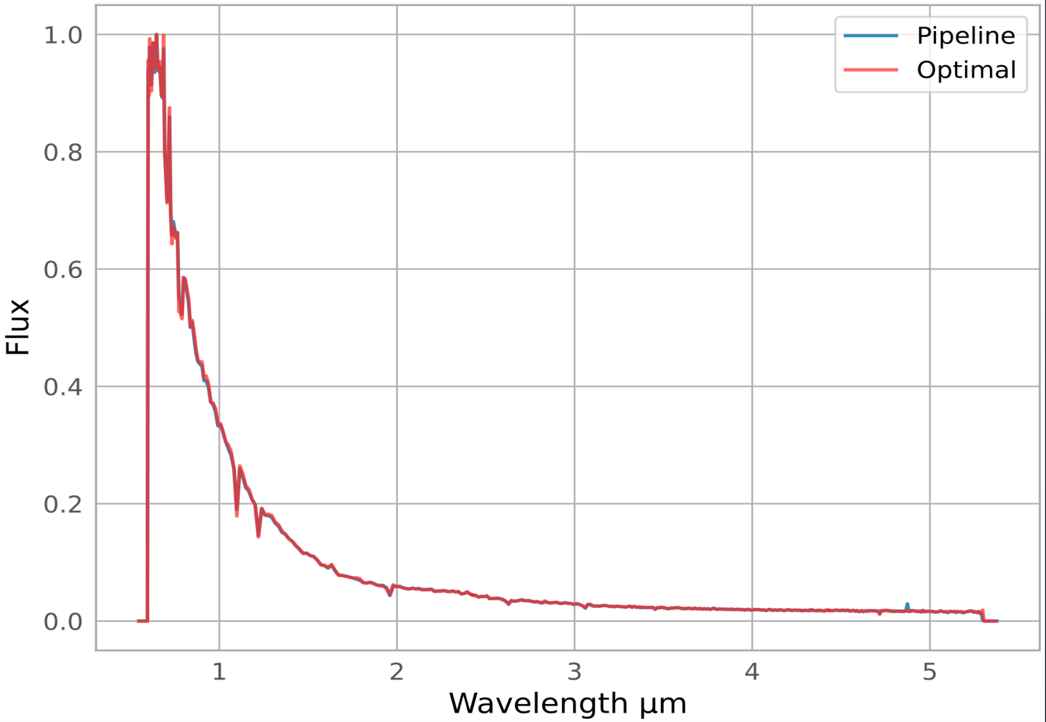


Figure 6: Optimally extracted spectrum of the first dither for GD 362.

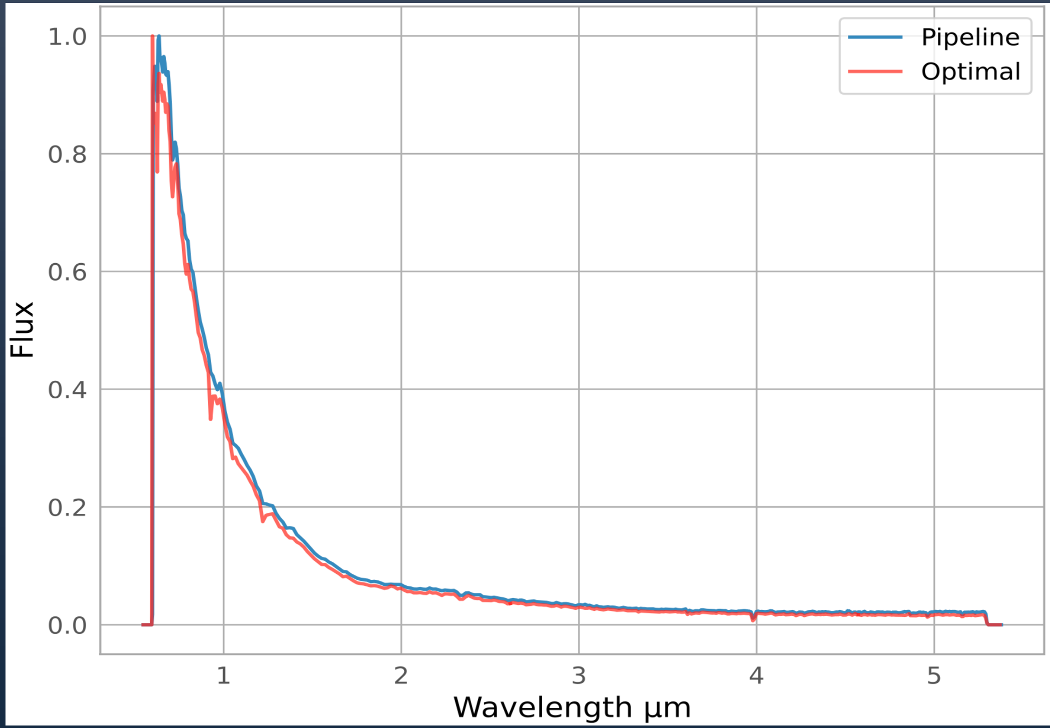


Figure 7: Optimally extracted spectrum of the second dither for GD 362.

Optimally Extracted Spectrum: GD 362

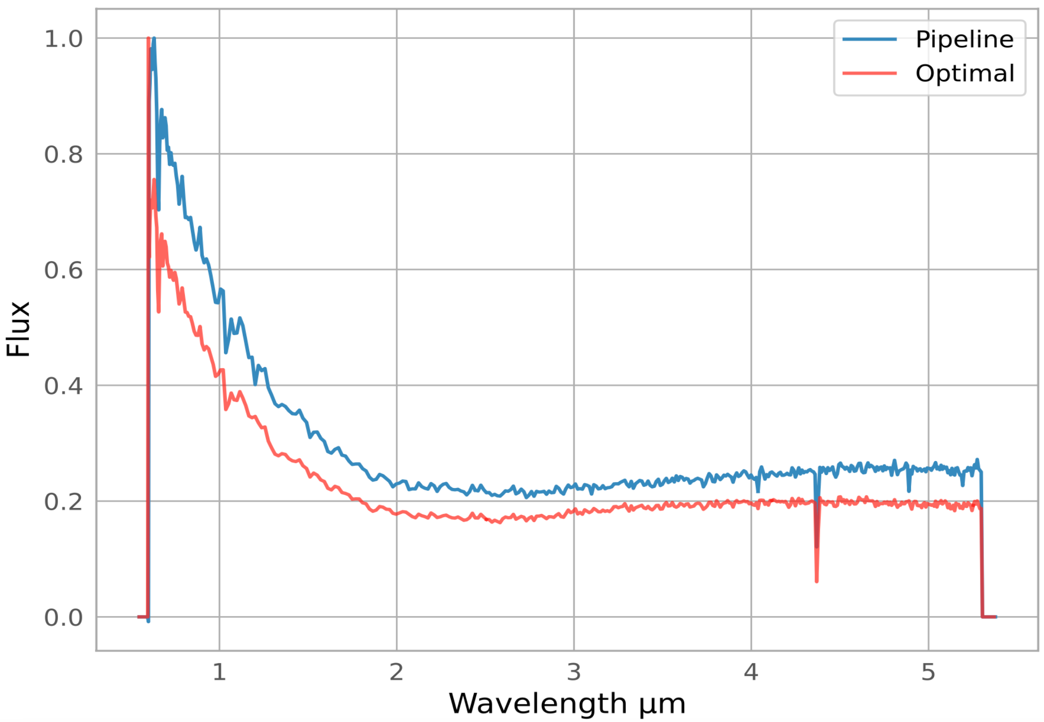


Figure 8: Optimally extracted spectrum of the first dither for GD 362 (before normalization).

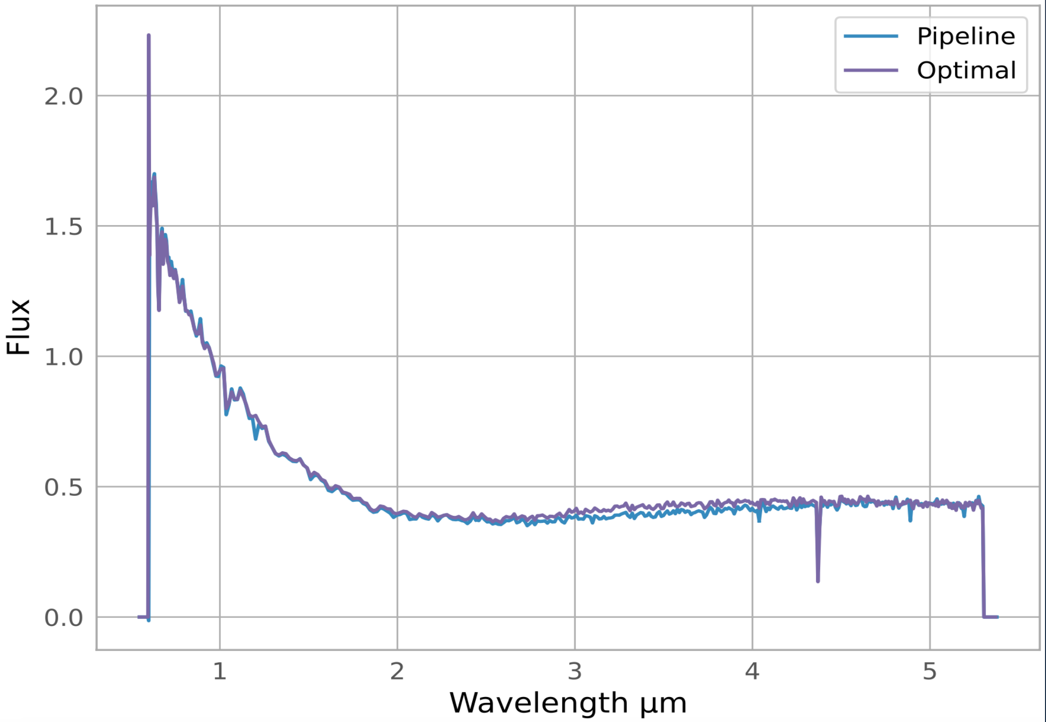
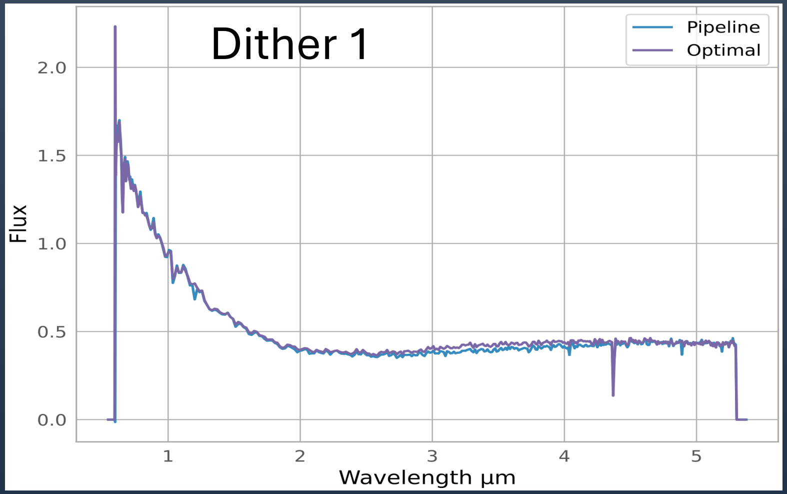
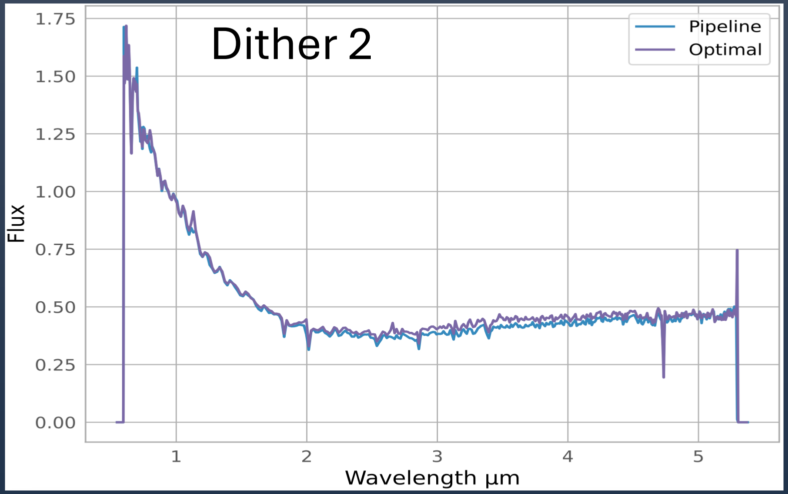
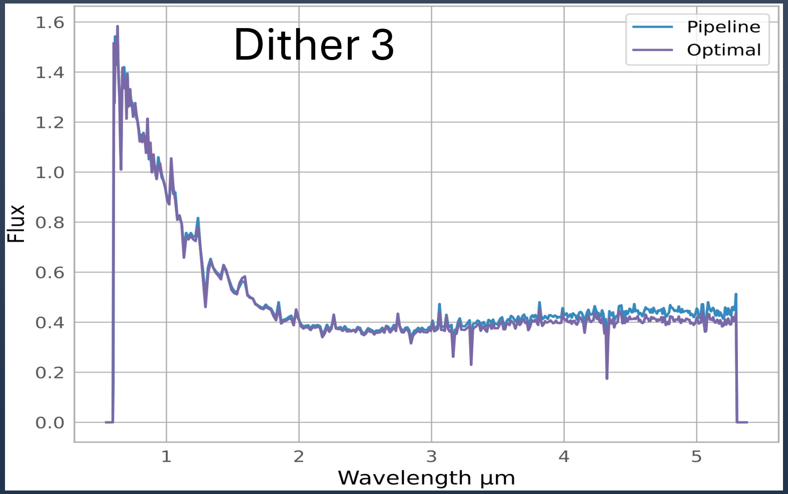


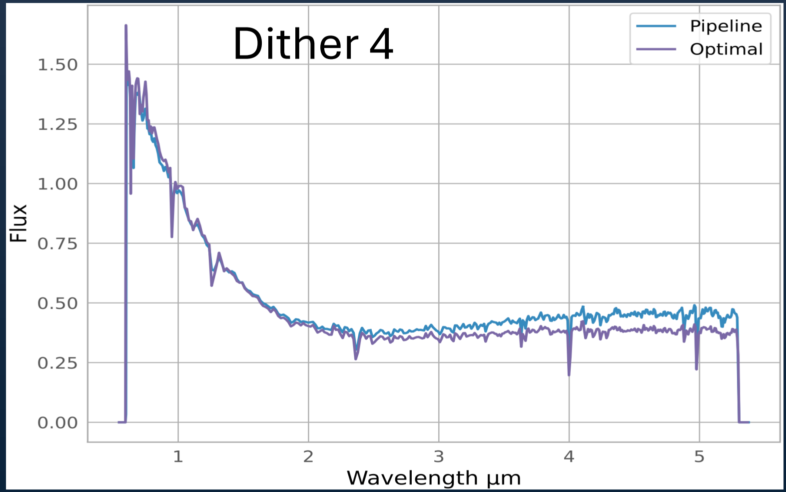
Figure 9: Optimally extracted spectrum of the first dither for GD 362 (after normalization).

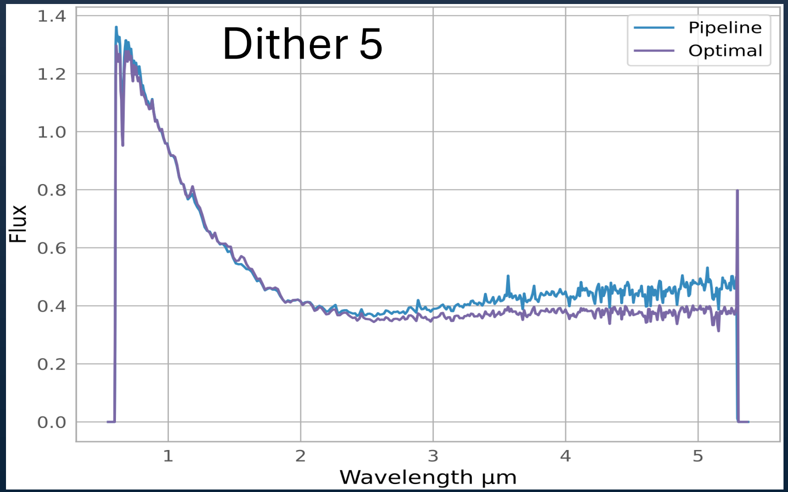
Optimally Extracted Spectrum: GD 362



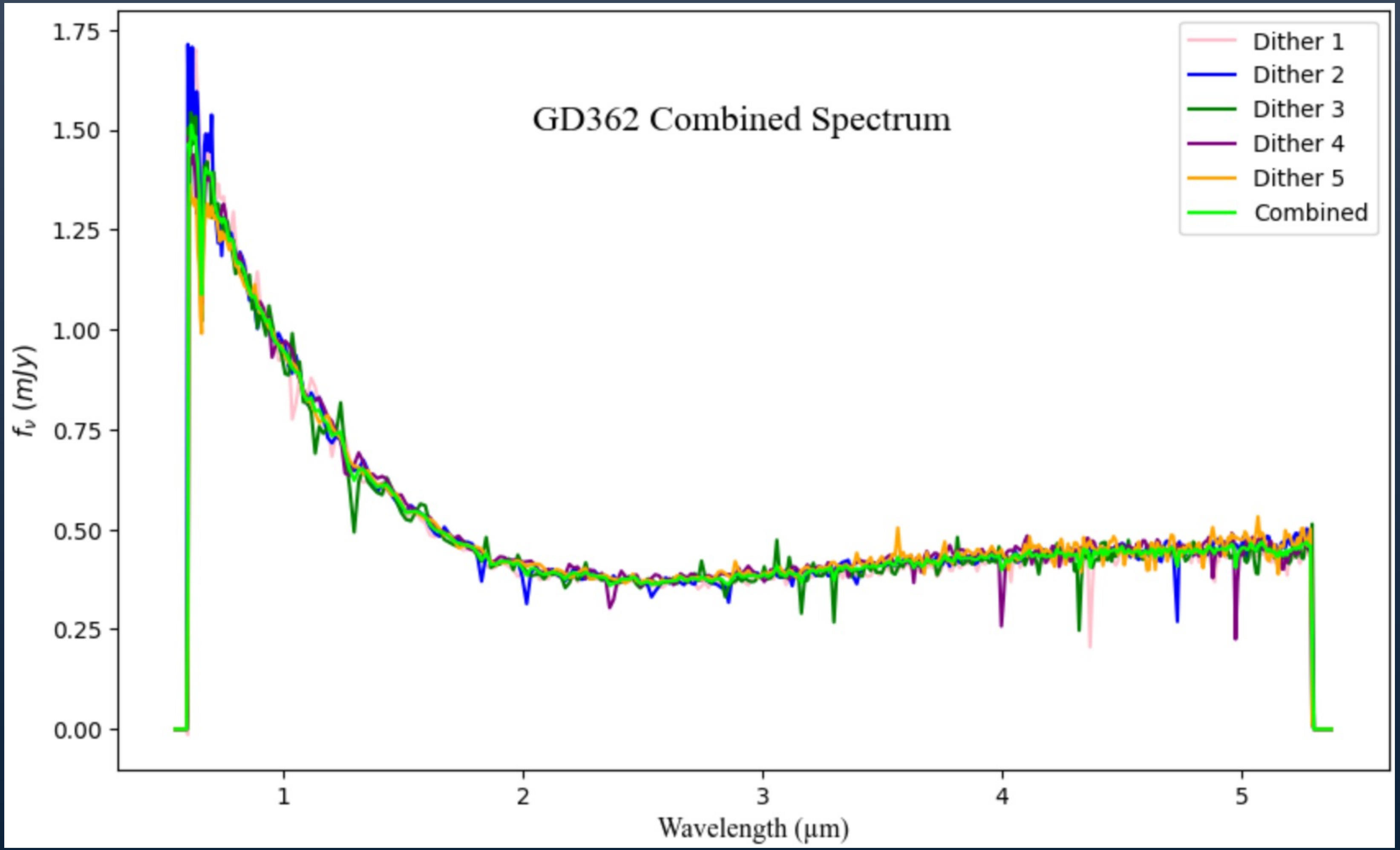




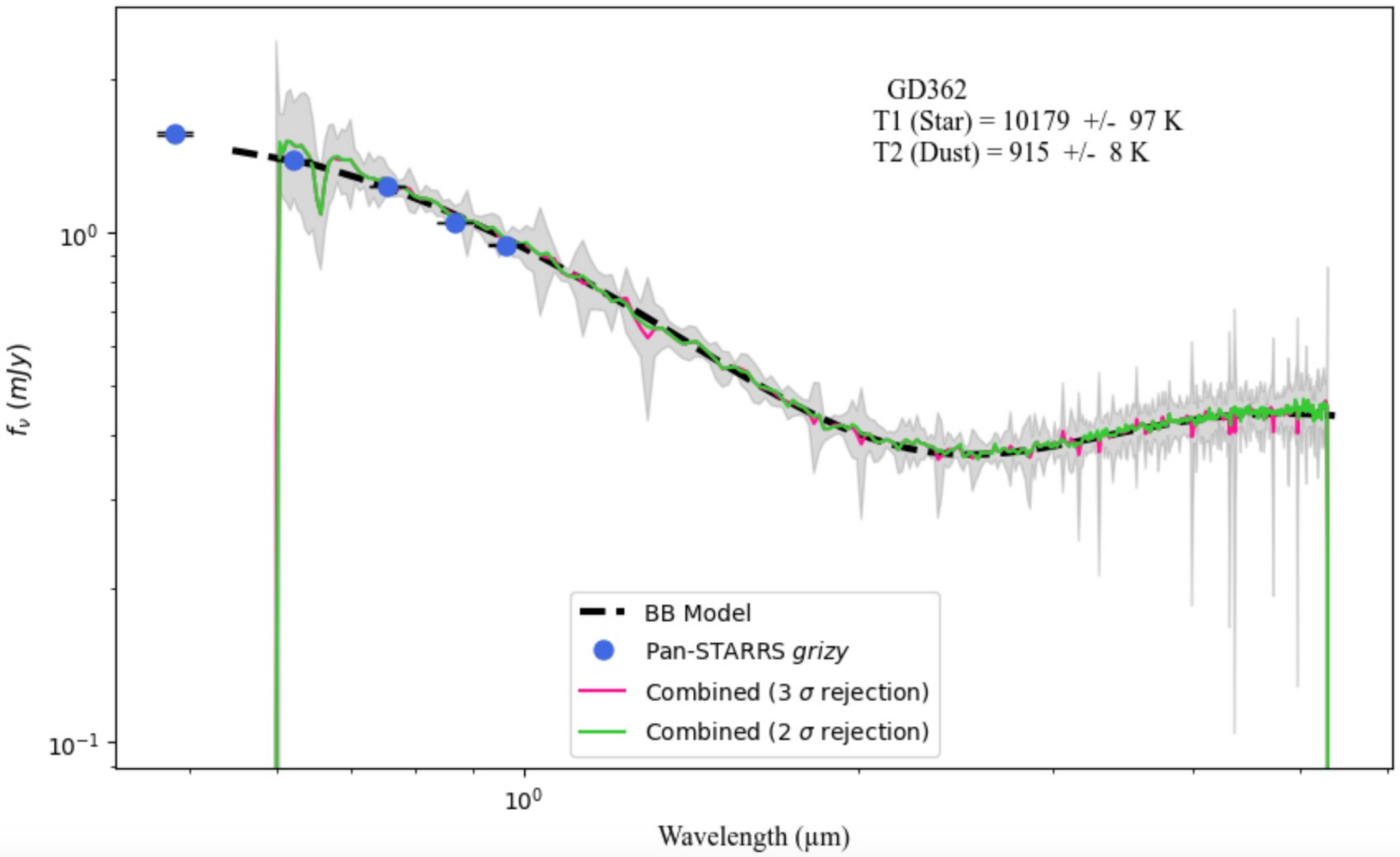




Combined Spectrum: GD 362



Blackbody Curve Fitting: GD 362



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[11] Meisner et al. 2020, ApJ, 889, 123

[12] Tremblay et al. 2020, MNRAS, 497, 130