Probing the Formation Mechanisms of Brown Dwarfs and Planetary-Mass Objects using Keck/LRIS

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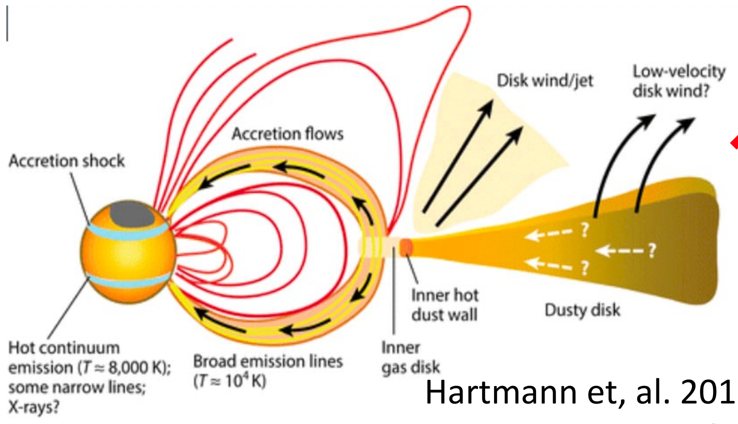
FOLLETTE LAB

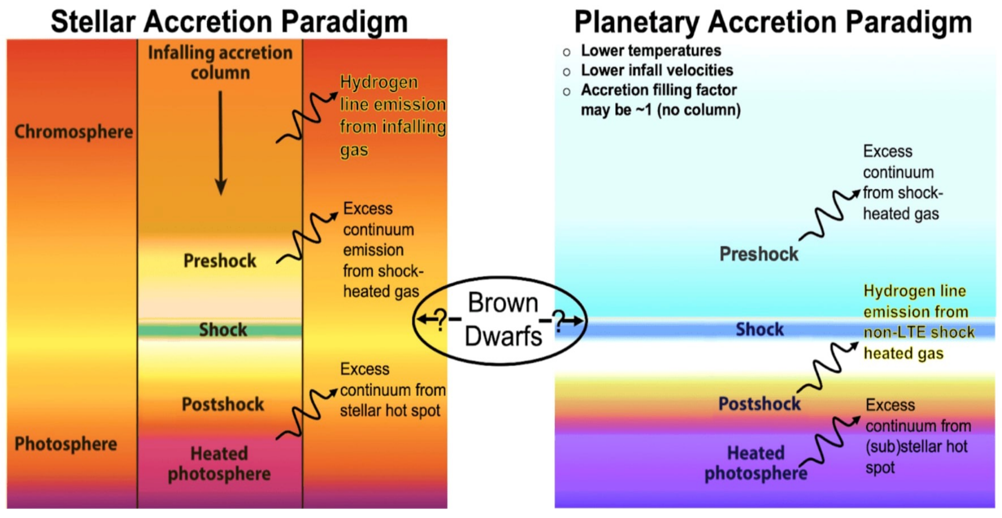
The Importance of Mass Accretion Measurements

Why Mass Accretion?

- Studying the mass accretion rate measurements of young brown dwarfs enhances our ability to understand the **formation and accretion** mechanisms of substellar objects.
- Brown dwarfs can form in molecular clouds, similar to solar-mass stars, however they can be **isolated** or **bound** to a star (also known as planetary mass companions).
- **Mechanisms of substellar accretion remain unclear** with various theories proposed such as accretion shock and magnetospheric accretion.



Hartmann et, al. 2016



(modified from Hartmann+ 2016) (based on Aoyama+ 2018)

Schematic representation of the stellar paradigm and a proposed planetary accretion paradigm depicts how material accretes onto its surface and causes an accretion shock in its stellar photosphere.

Stellar and Planetary accretion paradigms differ in their shock processes because of where hydrogen line emission comes from. For the stellar accretion case, it possibly comes from the infalling accretion column. For the planetary case, it possibly comes from the post-shock region where, unlike stars, the temperatures are still low enough to have bound hydrogen.

Our Goal(s):

We performed long-slit spectroscopy, using Keck/LRIS, for ten substellar objects ranging in spectral type M5 to M9 and ~8-60 M_{Jup}.

1. **Expanding excess continuum measurements** of **accreting substellar objects** into the lower-mass regime and increase the number of UV excess measurements for accreting brown dwarfs by 30%.
2. **Characterize accretion from both UV continuum excess** and line emission to understand **formation mechanisms** of pre-main sequence accretion. These multiwavelength measurements can also be used to estimate accretion rates and test scaling relations.

Data Reduction Pipeline

Using a data reduction pipeline called PypeIt, we were able to extract reduced 1D and 2D spectra for our desired object(s), as well as perform flux calibrations.

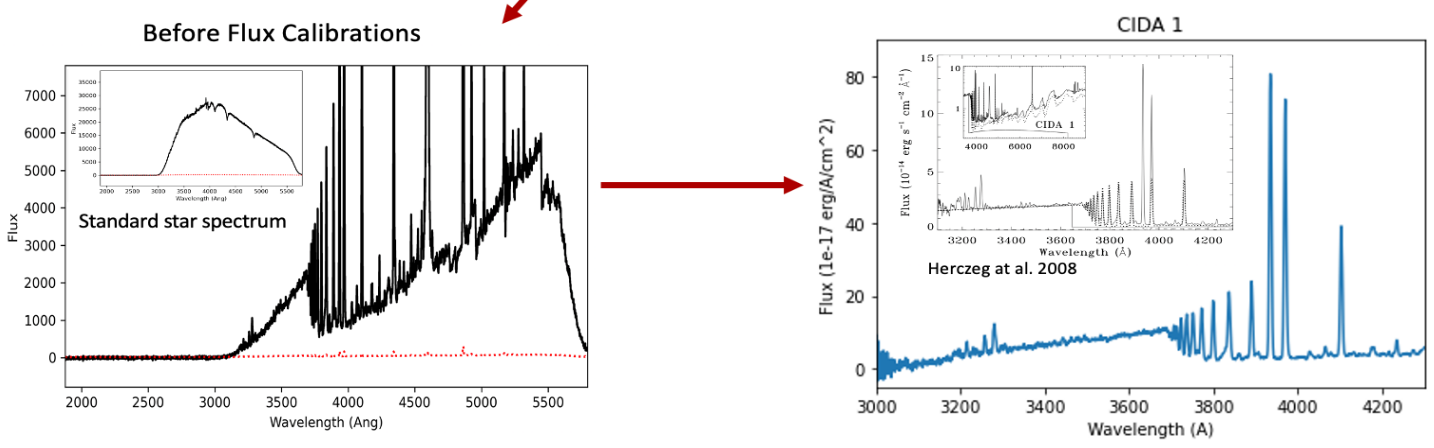


Fig 1: Published 1D Spectrum of CIDA 1 (young, low-mass star) being compared with our PypeIt 1D and 2D spectra.

Flux Calibrations

Our flux calibrations were performed using our standard star (PG0939+262) that is available within Pypeit and matched within their library to create a sensitivity function.

If our standard star is not recognizable, we are working on alternative methods that will allow for accurate calibrations.

Keck/LRIS Sample

Instrumental Setup

- Keck/LRIS is the only ground-based facility with the sensitivity to measure accretion rates as low as 10^{-13} $M_{\odot}$/yr.
- We utilized the 400/3400 A (R ~ 700) blue side grism and the 400/8500 A red channel grating (R ~ 1000).

We collected a sample of **bound** (blue) and **isolated** (green) substellar objects with varying parameters such as mass, age, and magnitude, as well as **photospheric templates**/weak accretors (yellow).

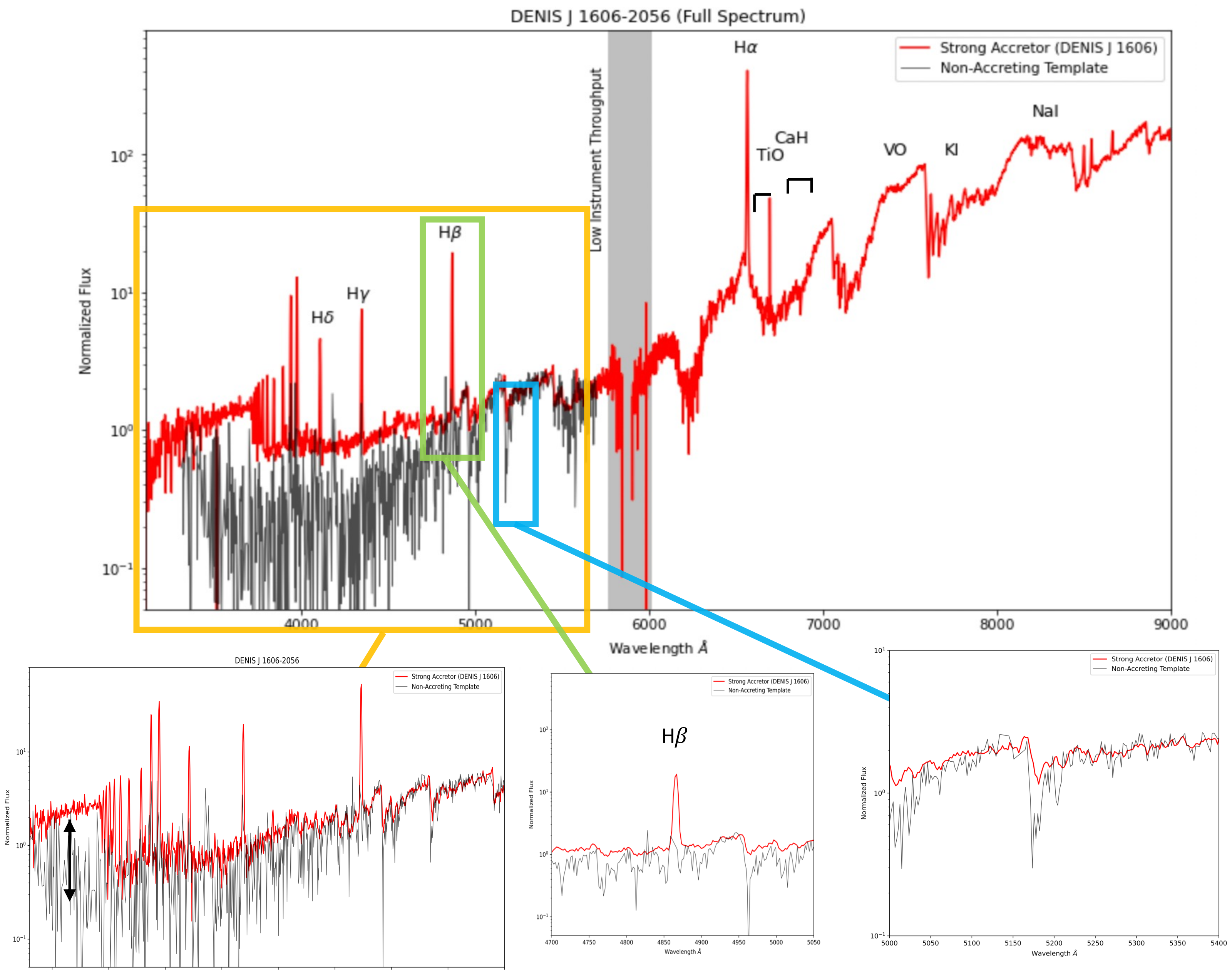
Source	Star Forming region	Age (Myr)	A_V	SpT	U (mag)	R (mag)	M (M_{Jup})	Log $\dot{M}$ ($M_{\odot}$/yr)
2M J1541-3345	Upper Centaurus Lupus	16 ± 2	0	M6.5	22	19	46	-11.3
DENIS J 1606-2056	Upper Scorpius	10 ± 3	0	M7.5	19	16	34	< -10.8
2M J1608-2315	Upper Scorpius	10 ± 3	0.13	M8.5	24	22	23	-12.1
GSC 06214-00210 b	Upper Scorpius	10 ± 3	0.2	M9.5	22	18	14	-10.8
KPNO Tau 12	Taurus	2 ± 1	0.02	M9.0	24.7	21.9	19	-10.5
KPNO Tau 6	Taurus	2 ± 1	0.68	M8.5	22	10.6	22	-10.8
KPNO Tau 7	Taurus	2 ± 1	0.93	M8.25	24.2	10.4	24	-11
MHO 5	Taurus	2 ± 1	0.3	M6.5	20.5	16.7	60	-10.8
CFHT 3	Taurus	2 ± 1	0.81	M7.75	n/a	20.9	30	< -12
2M J0455+3028	Taurus	2 ± 1	1.0	M5.5	21	16.7	61	< -12

Fig 3: Table of our Keck/LRIS 2021 and 2022 objects.

A Preliminary Result

DENIS J 1606-2056

Fig 4: A preliminary flux calibrated spectrum of DENIS J1606-2056, an actively accreting substellar object.



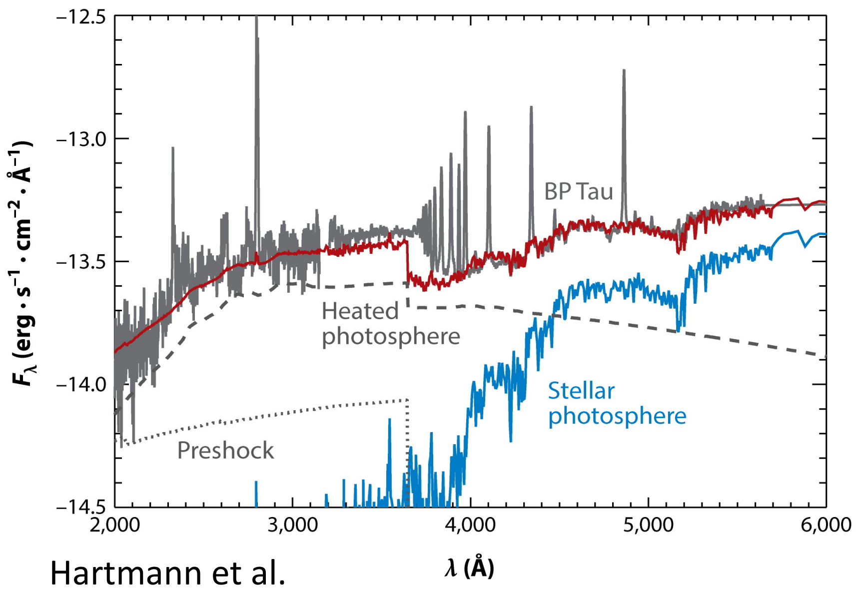
Balmer Jump – measures accretion continuum.

Emission Line Flux – measures accretion line contribution.

Veiling – measures the accretion continuum at longer wavelengths.

Takeaways/Future Work:

- Our preliminary results show that **we can detect excess line and continuum emission for a range of substellar object masses**.
- We plan continue our data reduction with our observed Keck/LRIS data from 2021-2022 of our **six substellar targets from 3000-9000+ A**.
- Once we have flux-calibrated spectra of accreting brown dwarfs, we will use accretion models and scaling relations to **determine accretion rates, test empirical scaling relations, and compare bound and isolated brown dwarfs**.



Hartmann et al.

Fig 5: Model of BP Tau's standard spectrum and stellar photosphere with slab models.

For the NIR side check out Sarah Betti's poster (ES-07-0012)!

References

Hartmann et al. 2016
Herczeg et al. 2008
Prochaska et al. (2020, JOSS)

Contact

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