Unveiling Ultracool Dwarfs with Euclid and ATMO

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PhD at IAC

Under the supervision of:
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Collaborators:
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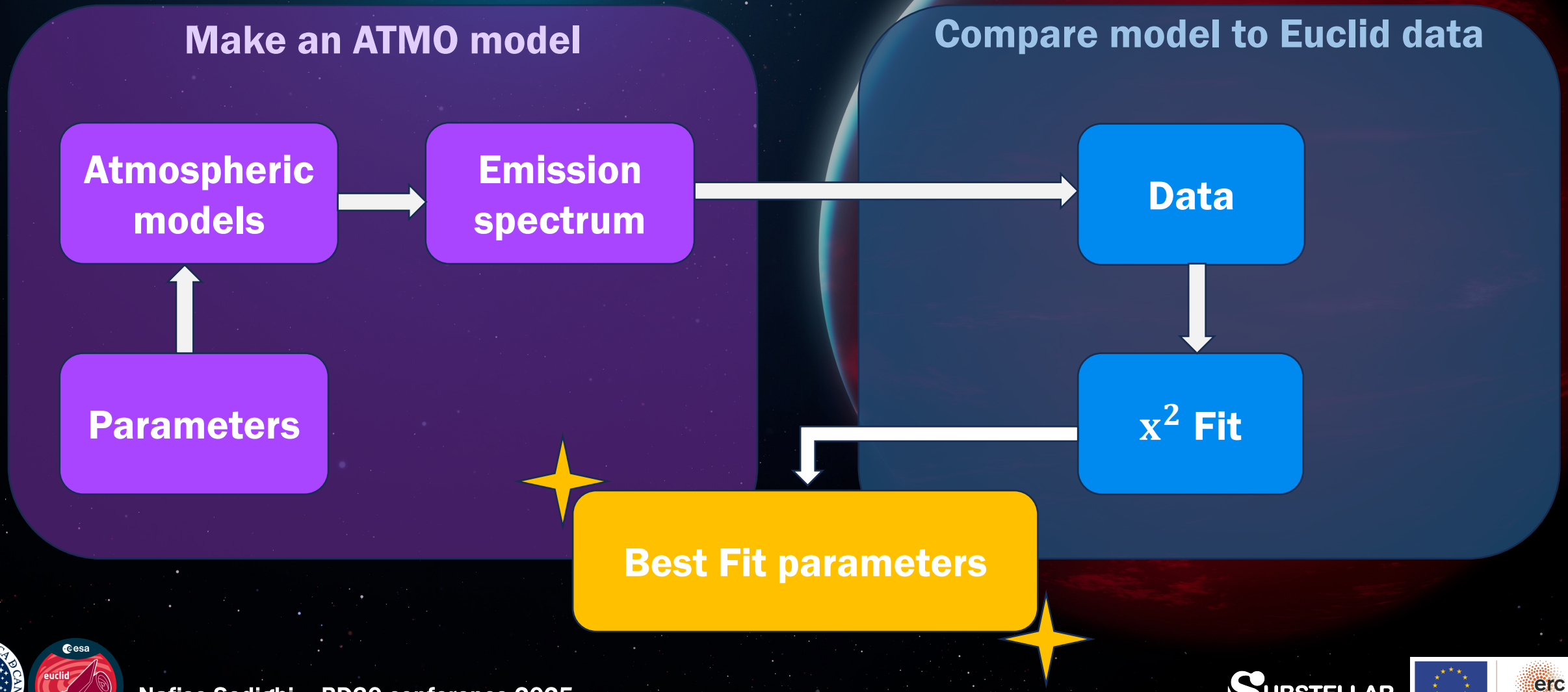
Overview of the Workflow



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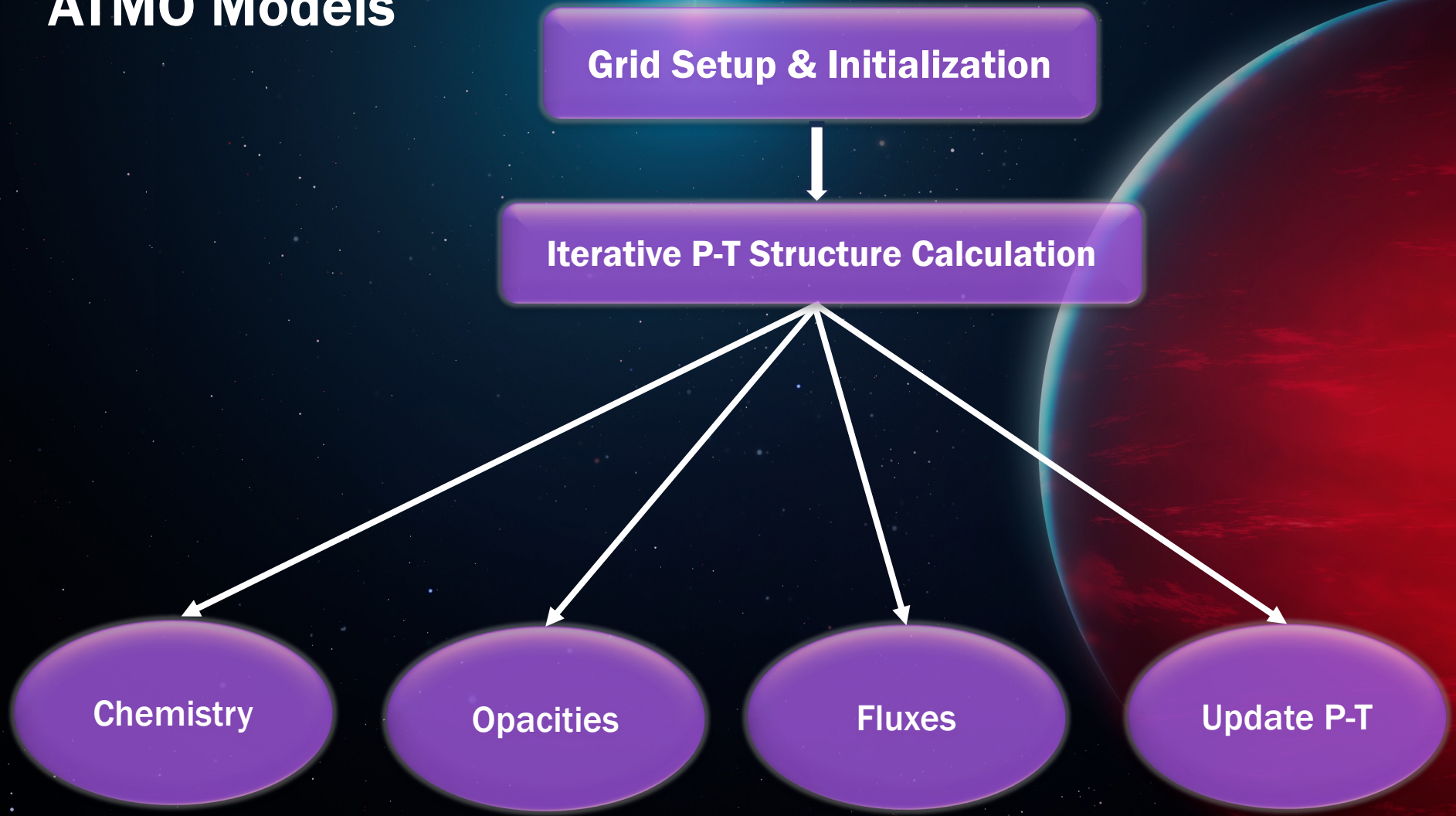
ATMO Models



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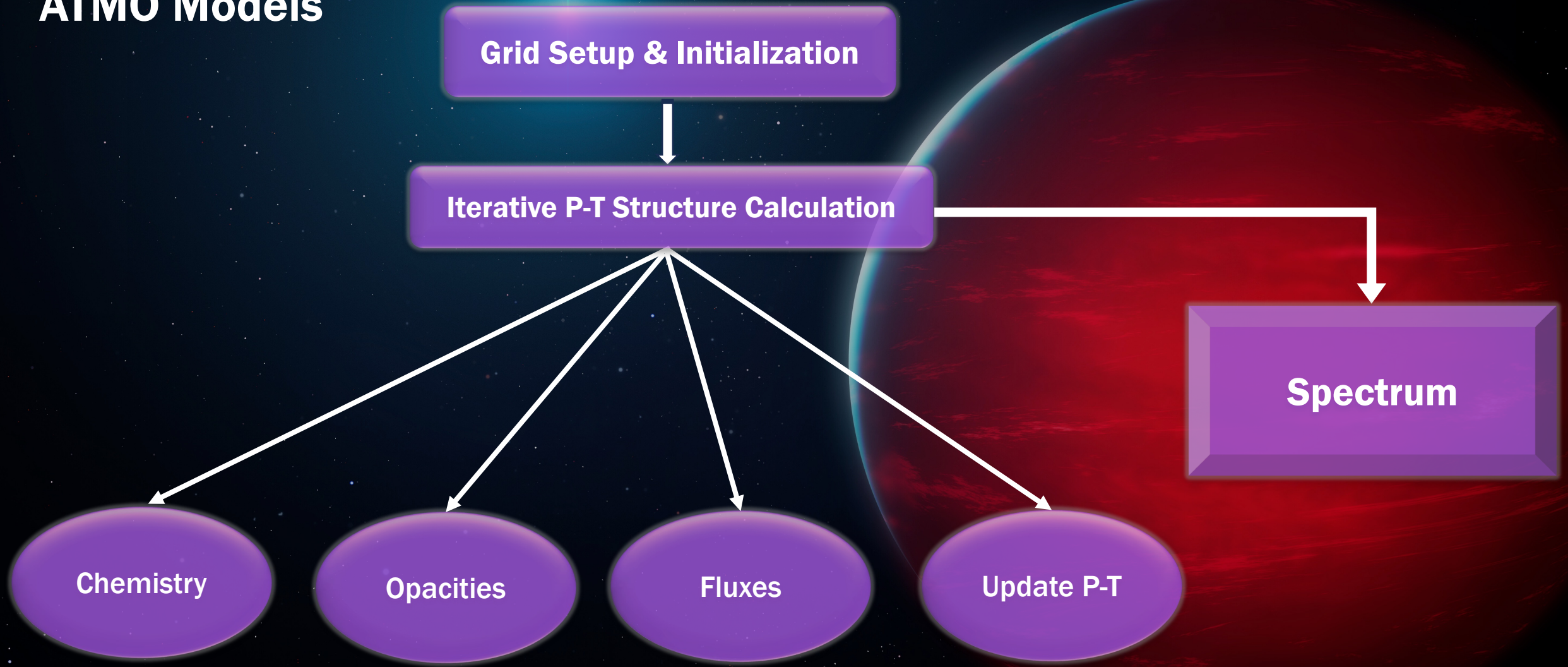

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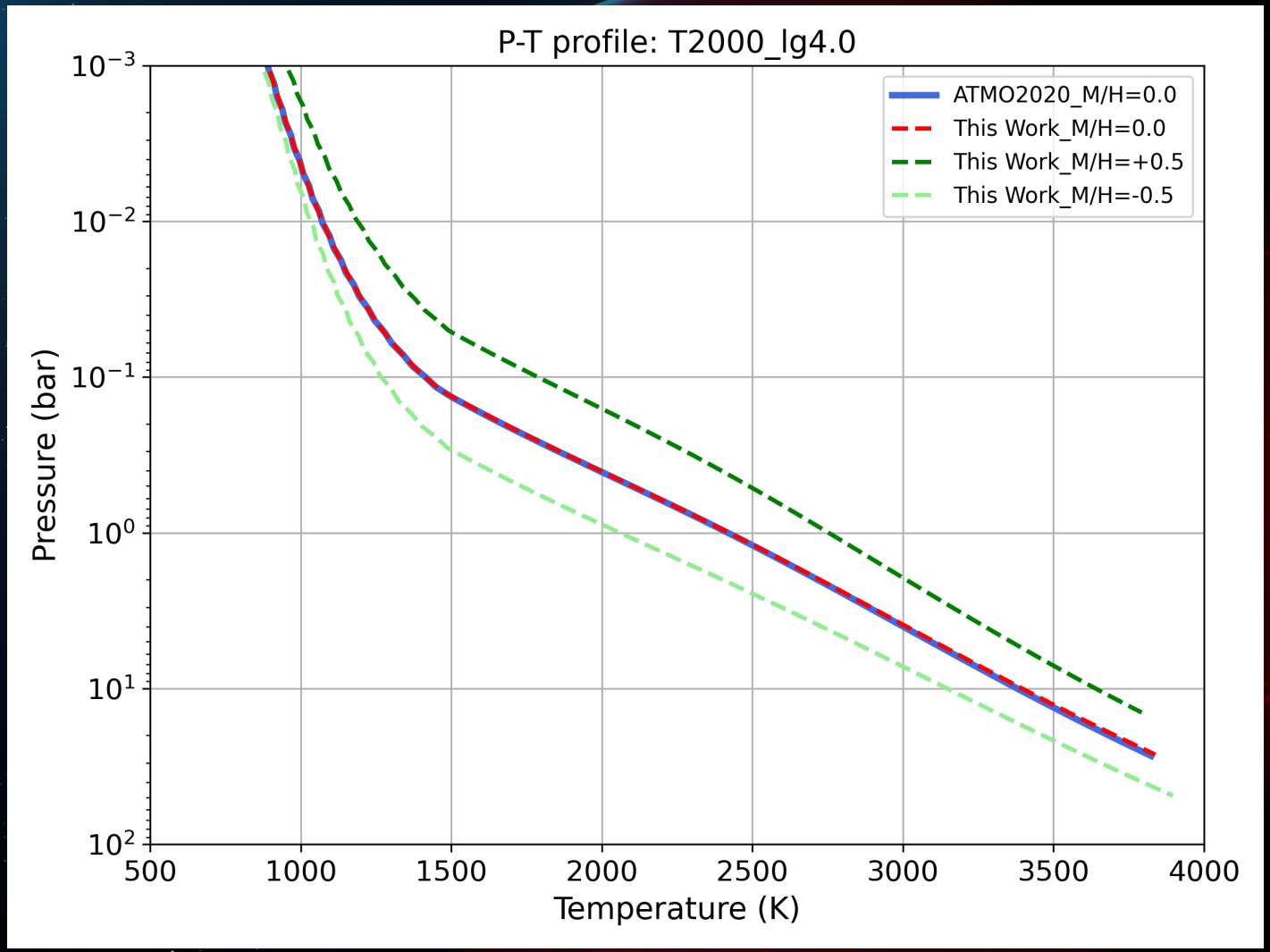
Modelling

ATMO 2020 models:

- Equilibrium & non-equilibrium chemistry
- Teff: 200–3000 K, log(g): 2.5–5.5
- Solar metallicity

Introduced new ATMO models:

- Non-solar metallicities
- Adding new opacities: MgO, SiO



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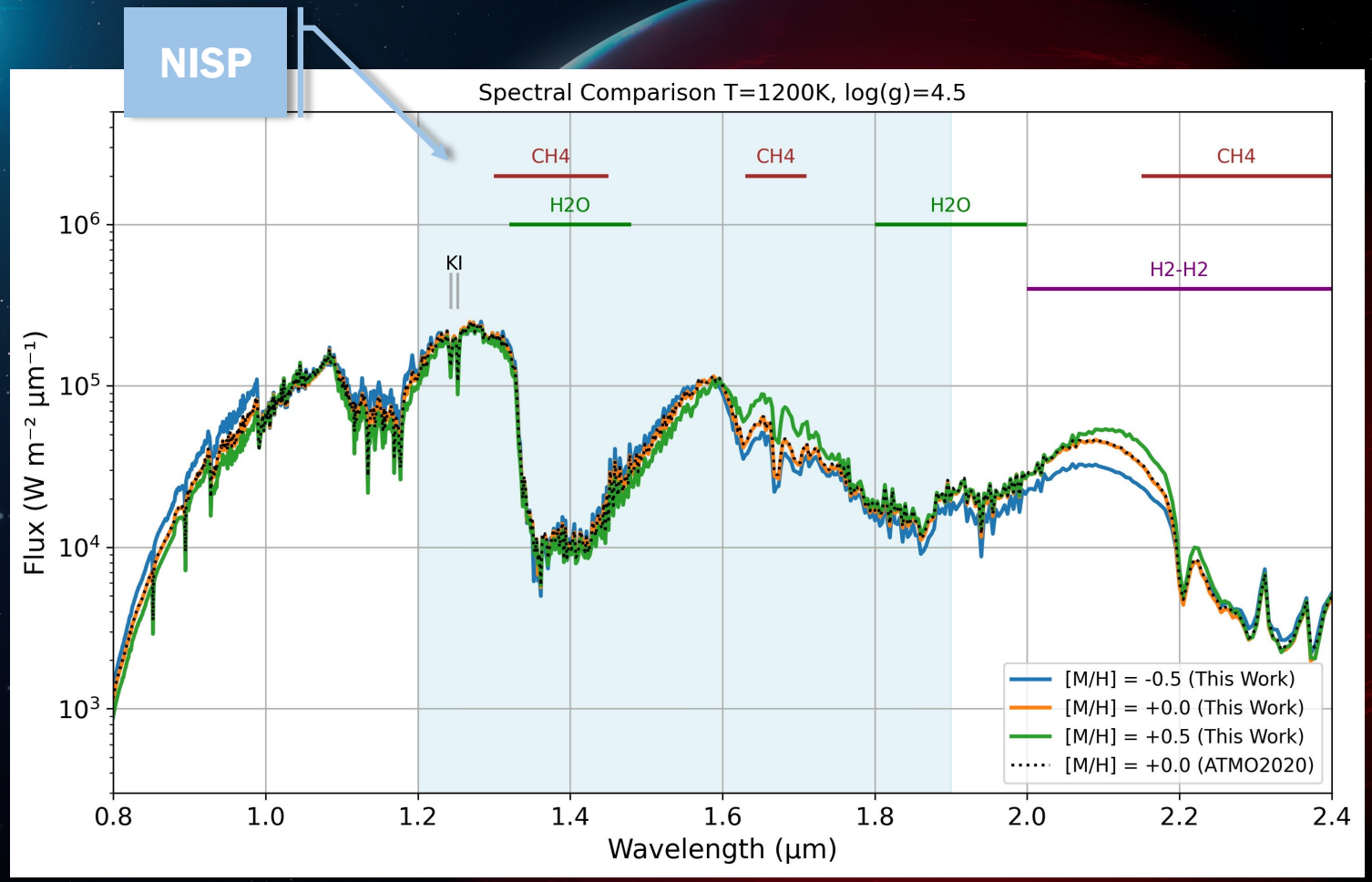
Spectra:

- Effective temperature
- Surface gravity
- Metallicity



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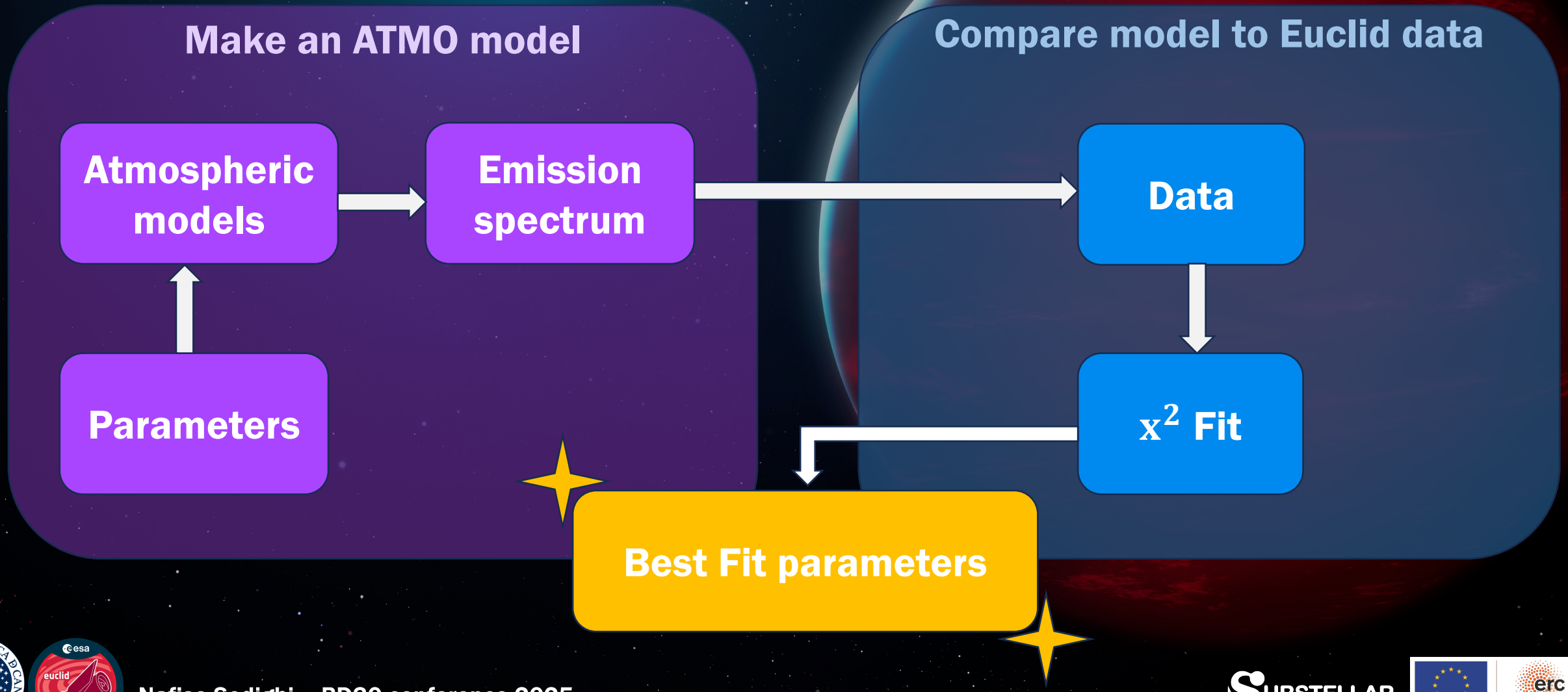

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A New Era with ESA's Euclid Mission

- Wide-field near-infrared space telescope
- Key features for UCD science:
  - Spectroscopy: R ≈ 450 (1.2–1.9 μm)
  - Imaging: High-resolution, deep coverage

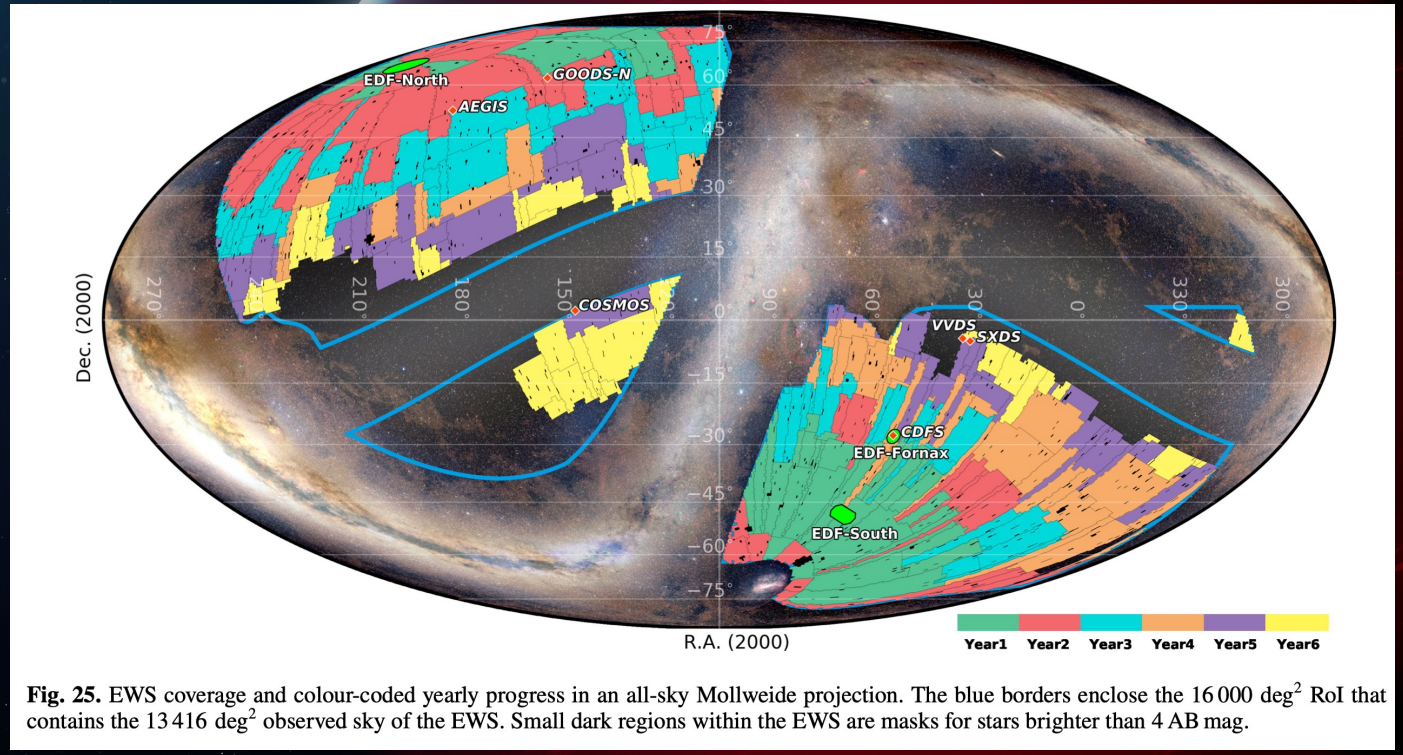

Fig. 25. EWS coverage and colour-coded yearly progress in an all-sky Mollweide projection. The blue borders enclose the 16 000 deg^2 RoI that contains the 13 416 deg^2 observed sky of the EWS. Small dark regions within the EWS are masks for stars brighter than 4 AB mag.

Mellier, Y., et al. (2024)

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Euclid's UCD Dataset: A Game-Changer

- Sky-wide discovery of ultra-cool dwarfs
- Atmospheric characterization in large-scale
- Unlocks population-level studies and rare object discovery

What do we expect?

Builds on Q1 results (15 T dwarfs)

- Identifying hundreds of cool brown dwarfs

Table 7. Late-L and T dwarfs found by the spectral index search

Alias (Ref.)	SpT	*Euclid* ID	RA(J2000)	Dec(J2000)	I_E (mag)	Y_E (mag)	J_E (mag)	H_E (mag)
E511520	T1:	-511520903274482292	03:24:36.5	-27:26:53.6	22.9	19.6	19.1	18.7
E517518[4]	L9	-517518361295768184	03:27:00.4	-29:34:36.5	23.3	19.9	19.3	18.8
E523574	T4	-523574860290315045	03:29:25.8	-29:01:53.4	26.7	21.4	20.9	21.1
E528241	T5	-528241075263163744	03:31:17.8	-26:18:58.9	27.6	23.6	23.2	23.6
E536416	T2:	-536416224285940430	03:34:34.0	-28:35:38.6	25.4	21.5	21.2	20.9
E581332[1]	T7	-581332495491830038	03:52:32.0	-49:10:58.8	24.3	20.0	19.5	20.1
E597913[1]	T7	-597913643476826162	03:59:09.9	-47:40:57.4	24.8	20.2	19.8	20.2
E644720[4]	T1:	-644720877461587627	04:17:53.3	-46:09:31.5	22.9	19.5	19.2	18.9
E265716[4]	T4p	2657163304658383990	17:42:51.9	+65:50:18.2	24.4	20.5	20.1	19.8
E266485[2]	T6:	2664850113649936423	17:45:56.4	+64:59:37.1	24.7	20.4	20.0	20.5
E267056[4]	L9:	2670569747654000953	17:48:13.7	+65:24:00.3	24.0	20.7	20.0	19.4
E271006[3]	T2	2710066793674540980	18:04:01.6	+67:27:14.8	24.6	20.3	19.9	19.5
E271934[4, 5]	L9p	2719340730667146696	18:07:44.2	+66:42:52.8	23.8	20.4	19.9	19.5
E273015[4]	T1:	2730150213677979458	18:12:03.6	+67:47:52.6	23.2	20.2	19.8	19.7
E273062	T3p	2730620775659672177	18:12:14.9	+65:58:02.0	24.0	20.9	20.6	20.5
E274809[3]	T0	2748094058670347269	18:19:14.3	+67:02:05.0	23.3	19.4	19.0	18.7

NOTE— The object alias with no notes are discoveries by the spectral index search, the rest are: (1) two already cited in Zhang's compilation (and references therein); (2) one cited in G. N. Mace et al. (2013); (3) two already found by Žerjal et al. (in prep.); (4) six discovered by the spectral index search that were later found in the process of creating Žerjal's catalog; (5) one also included in Mohandasan et al. (in prep.). Uncertainties in the spectral classification > 1 subtype are noted by a colon; peculiar objects are indicated by "p". The magnitudes are from Žerjal et al. (in prep.).

Dominguez-Tagle et al. 2025

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- Atmospheric characterization in large-scale
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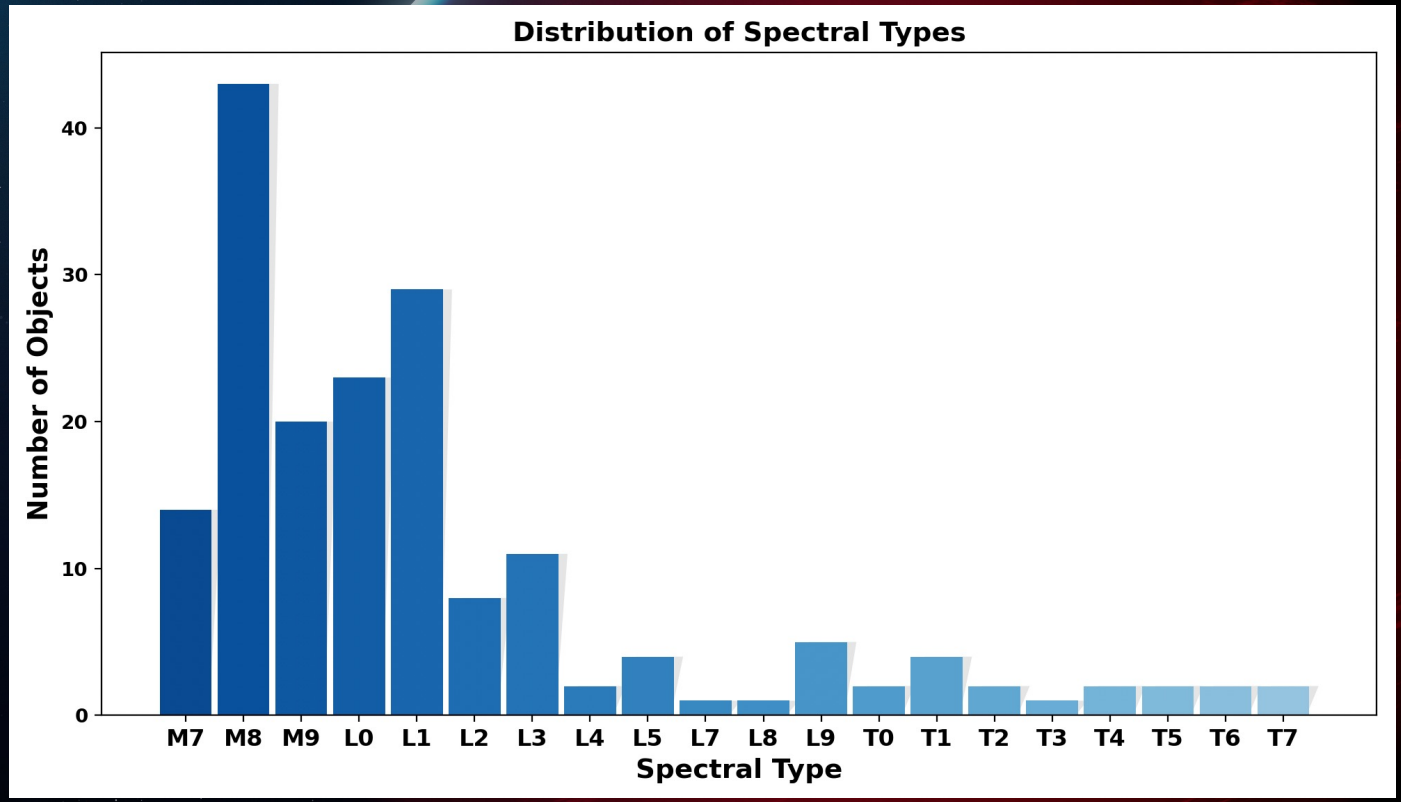
What do we expect?

Builds on Q1 results (15 T dwarfs)

- Identifying hundreds of cool brown dwarfs
- Potential detection of Y dwarfs



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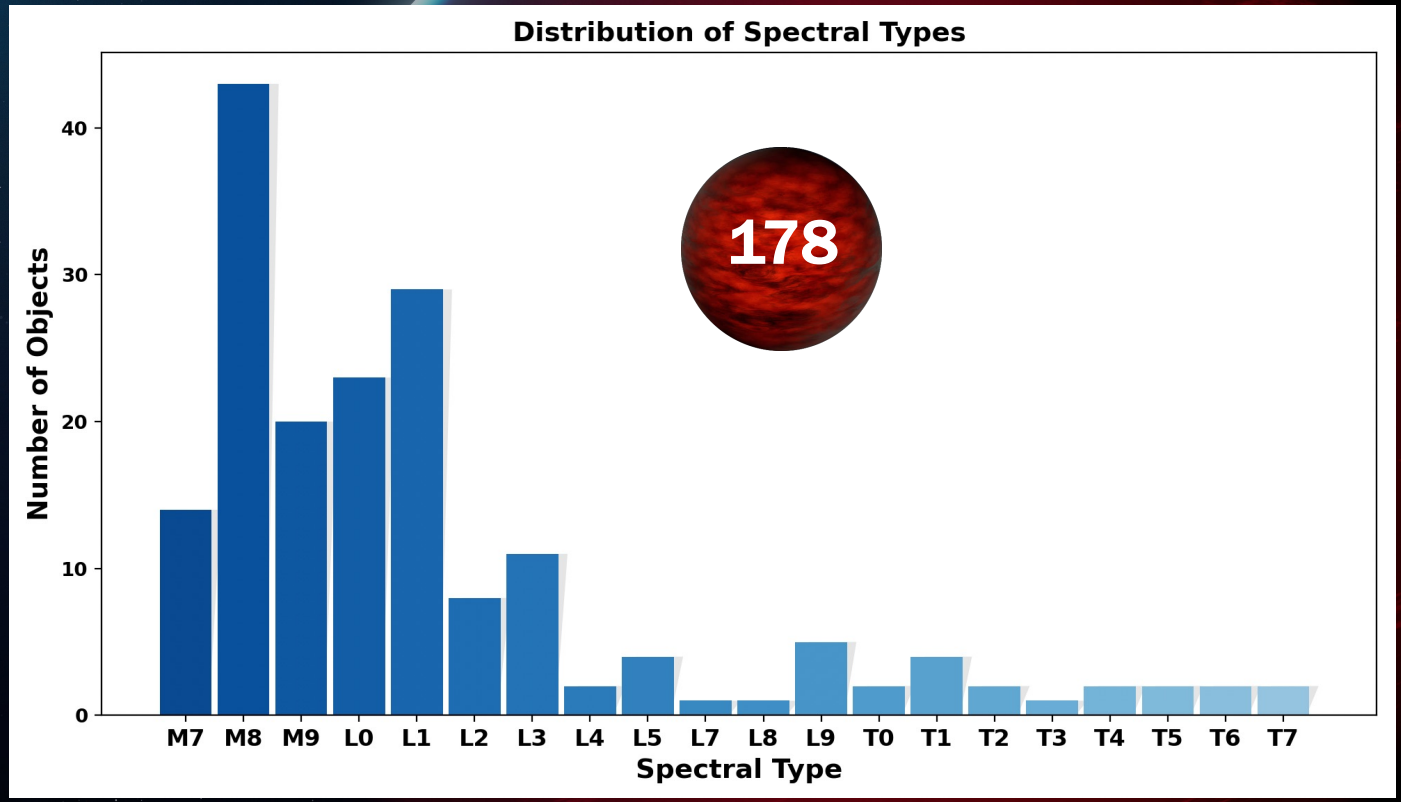

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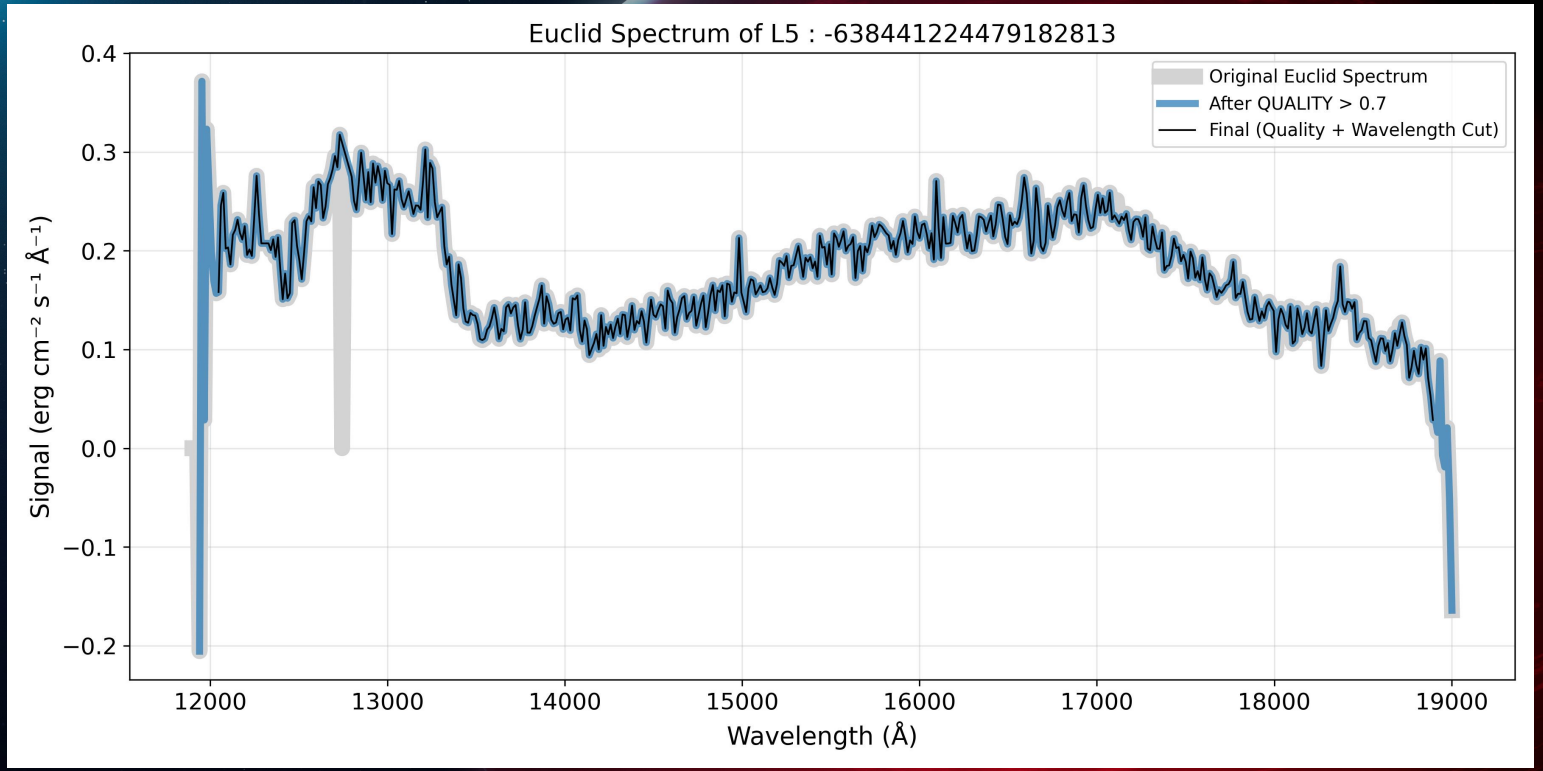
Spectral Fitting Methodology

1. Preprocessing of Euclid spectra:
- Apply QUALITY filtering



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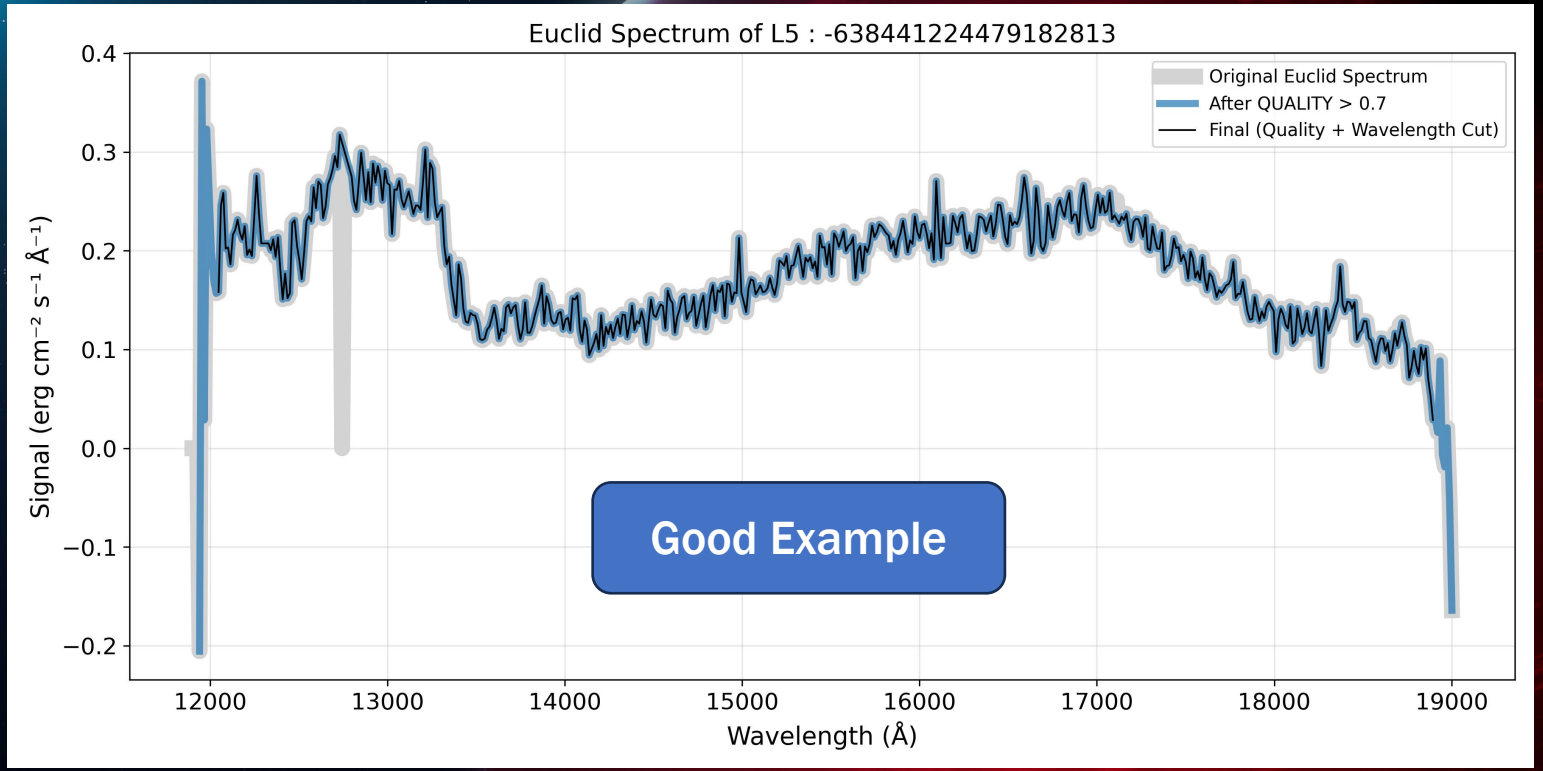

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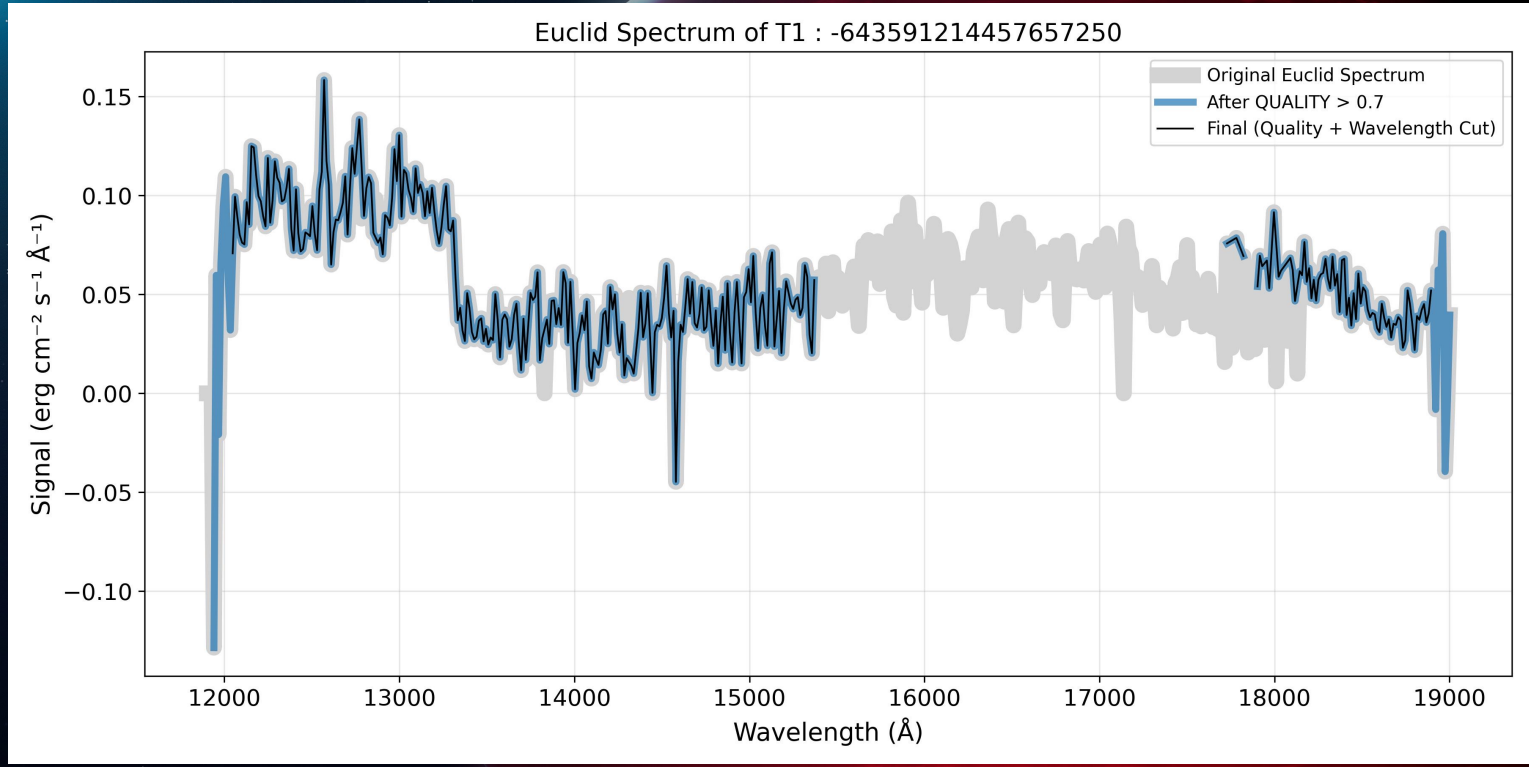

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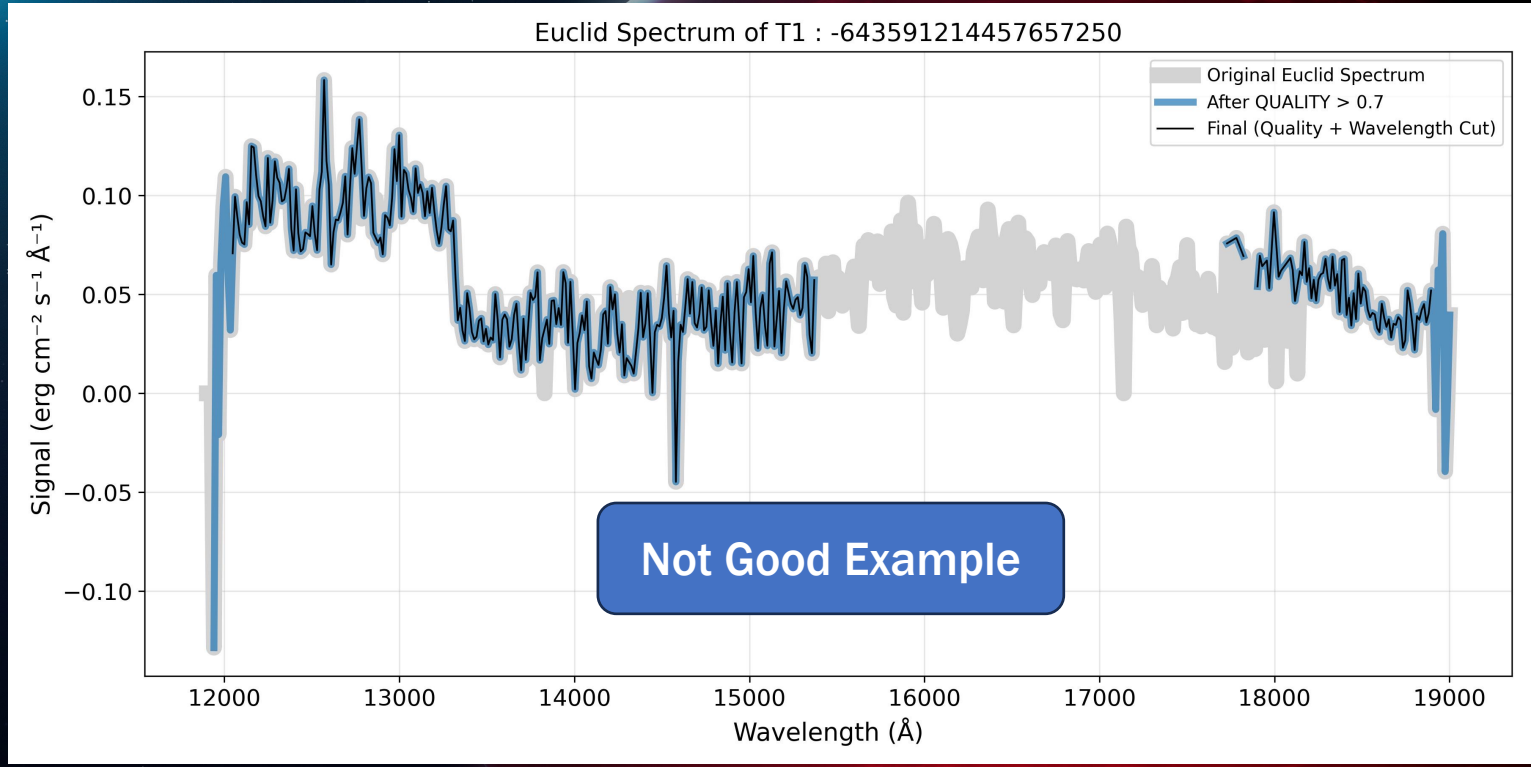

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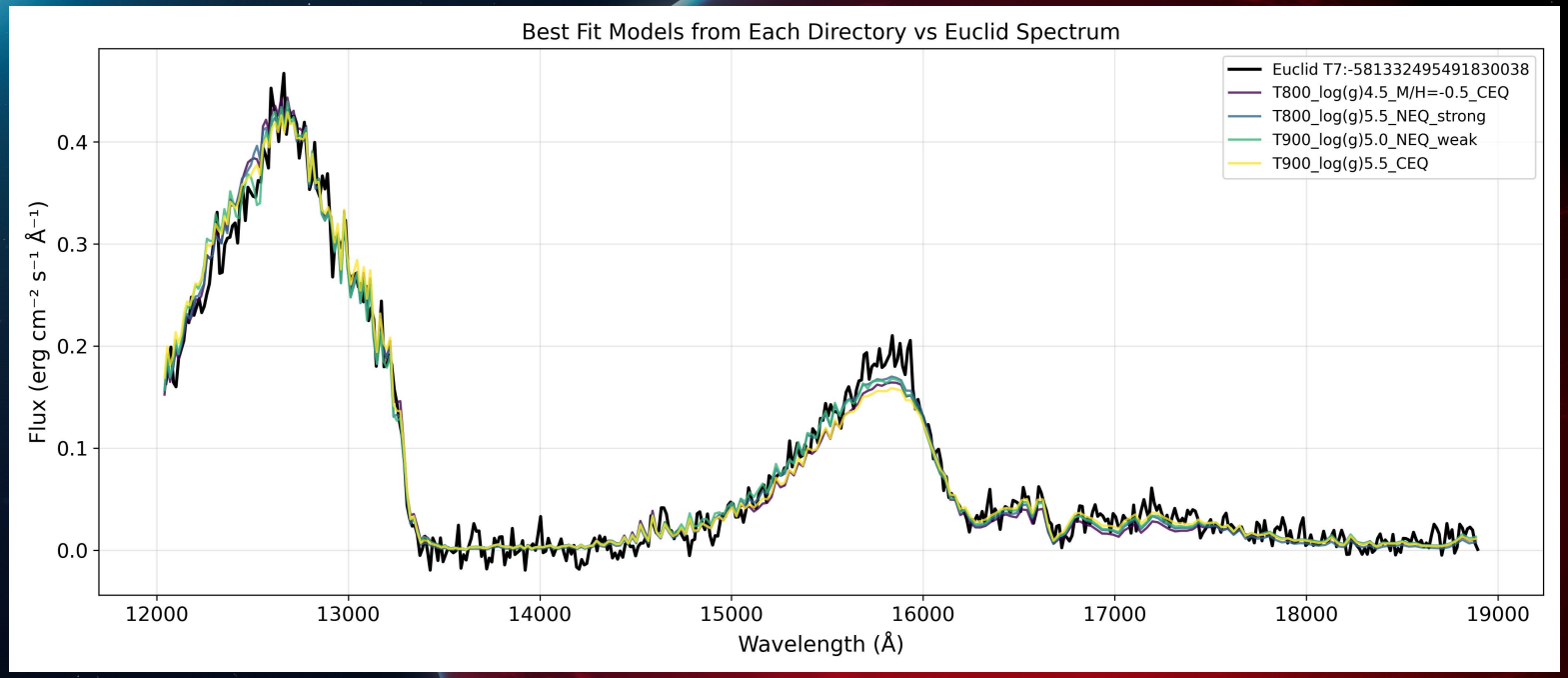
Spectral Fitting Methodology

1. Preprocessing of Euclid spectra:
   - Apply QUALITY filtering

2. The χ^2-based fitting across full spectrum



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Spectral Fitting Methodology

1. Preprocessing of Euclid spectra:
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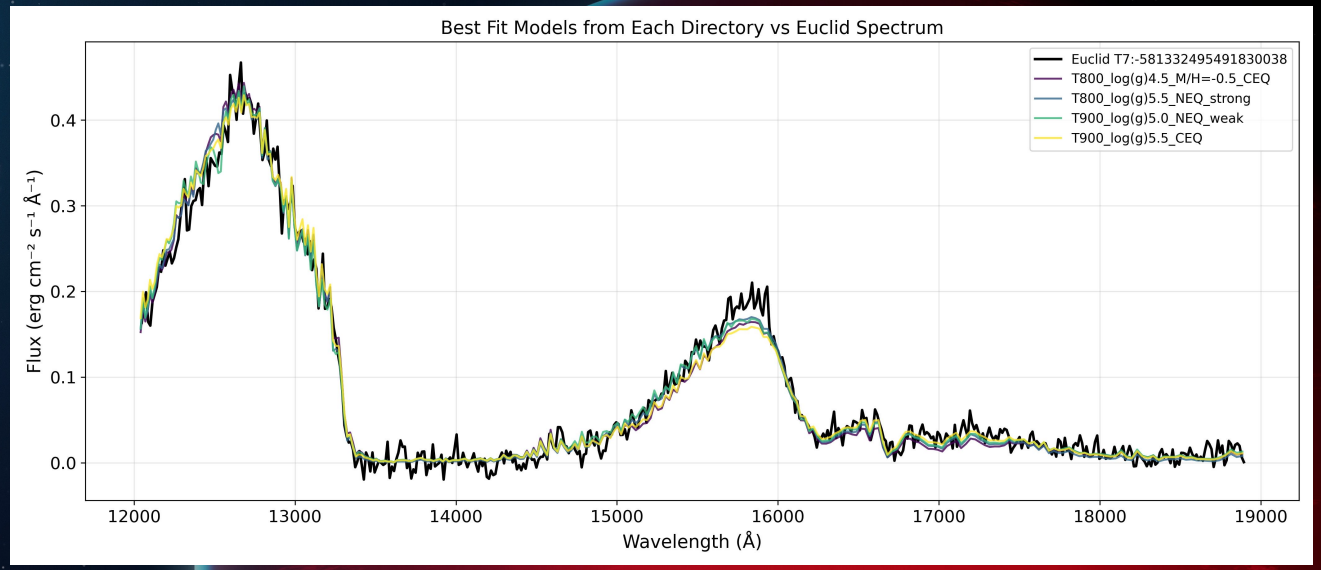
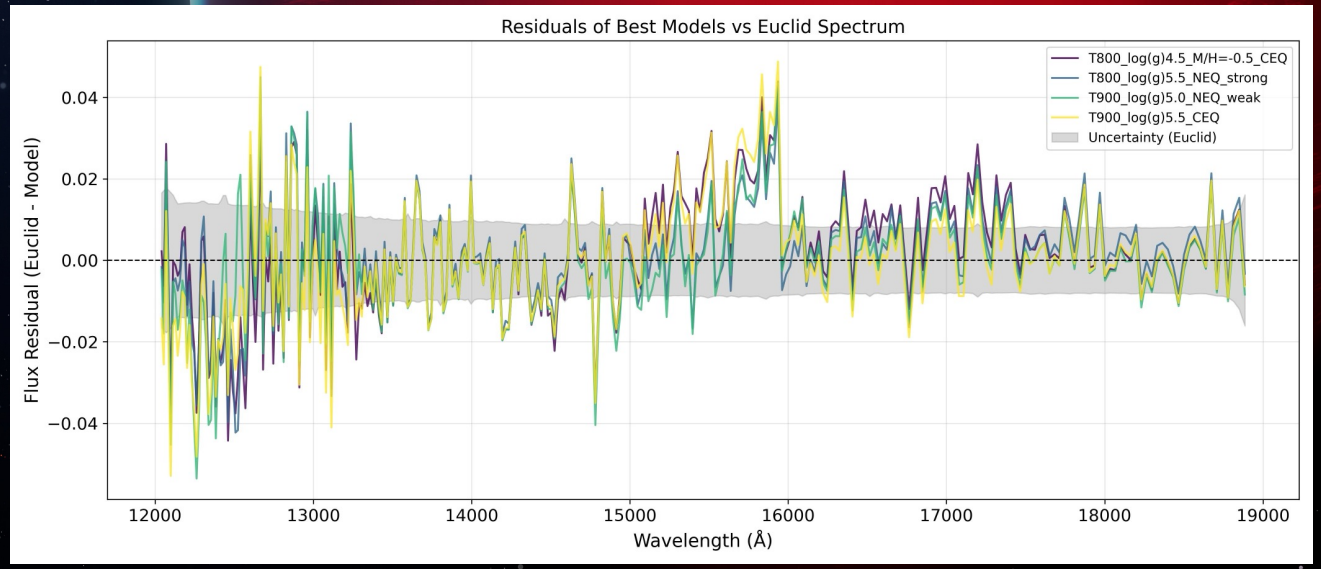
3. Residuals and uncertainties





Model with Lowest X^2:
Teff=800, log(g)=5.5, NEQ_strong
Sum of Squared Residuals (SSR = 0.05)

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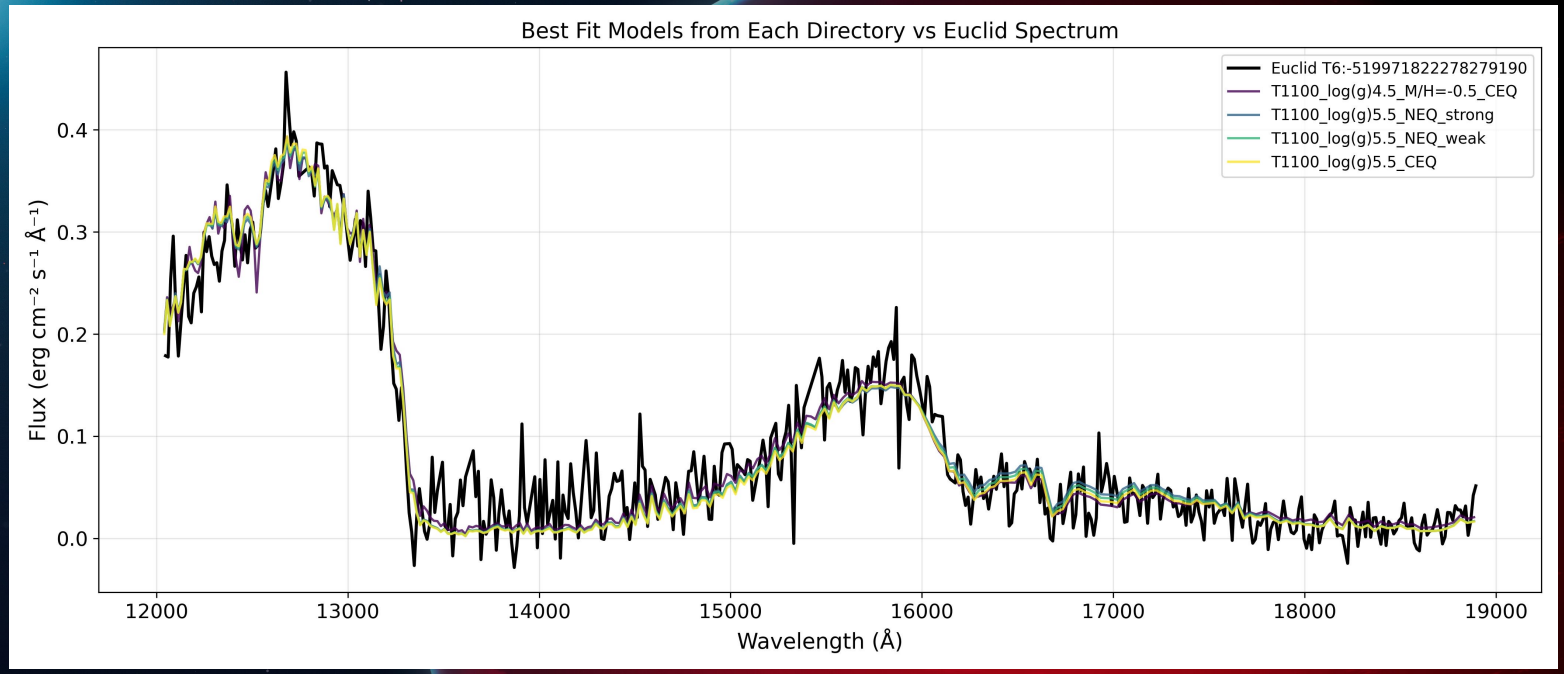

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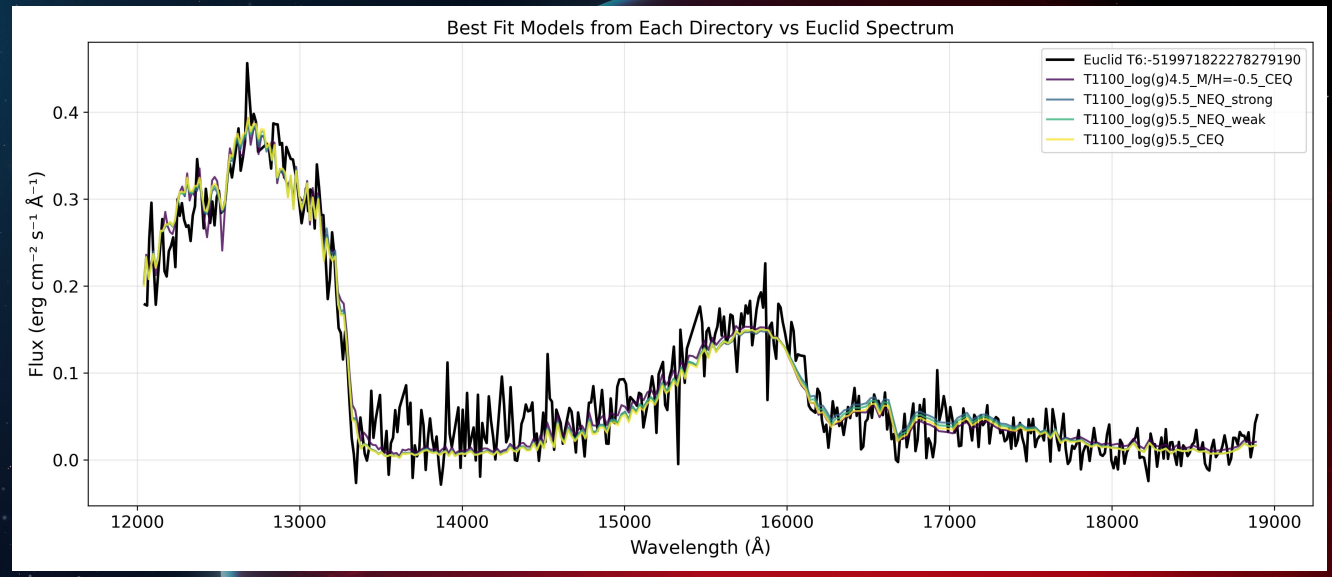

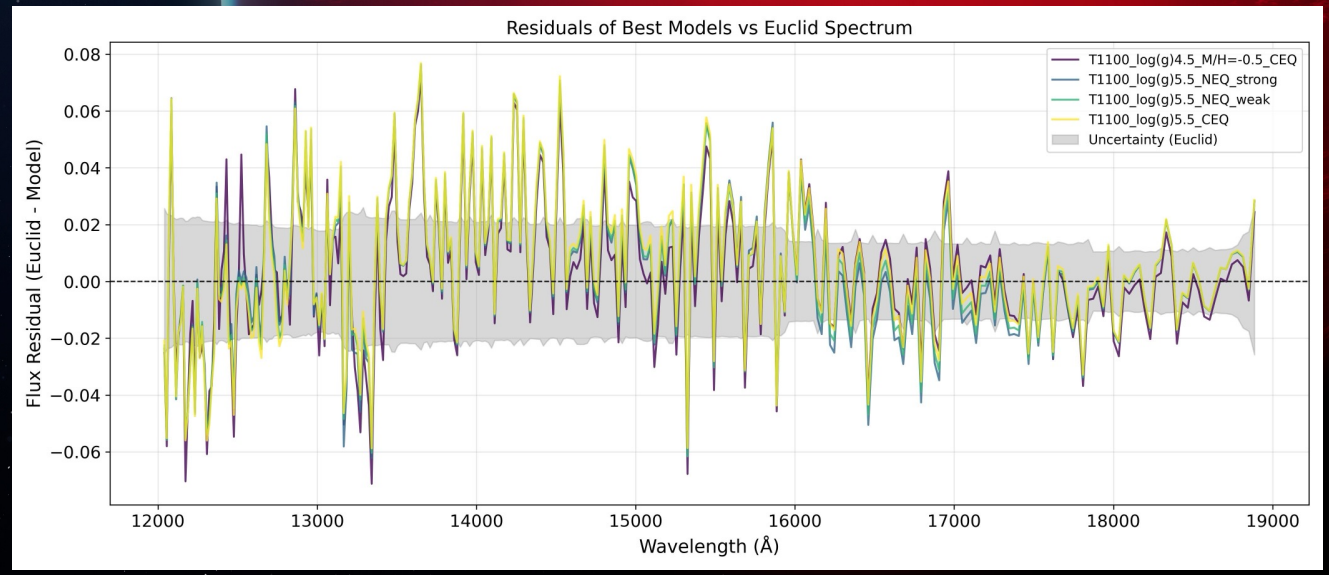

📉 Model with Lowest X^2 :
Teff=1100, log(g)=4.5, Z= -0.5, CEQ
(SSR = 0.09)

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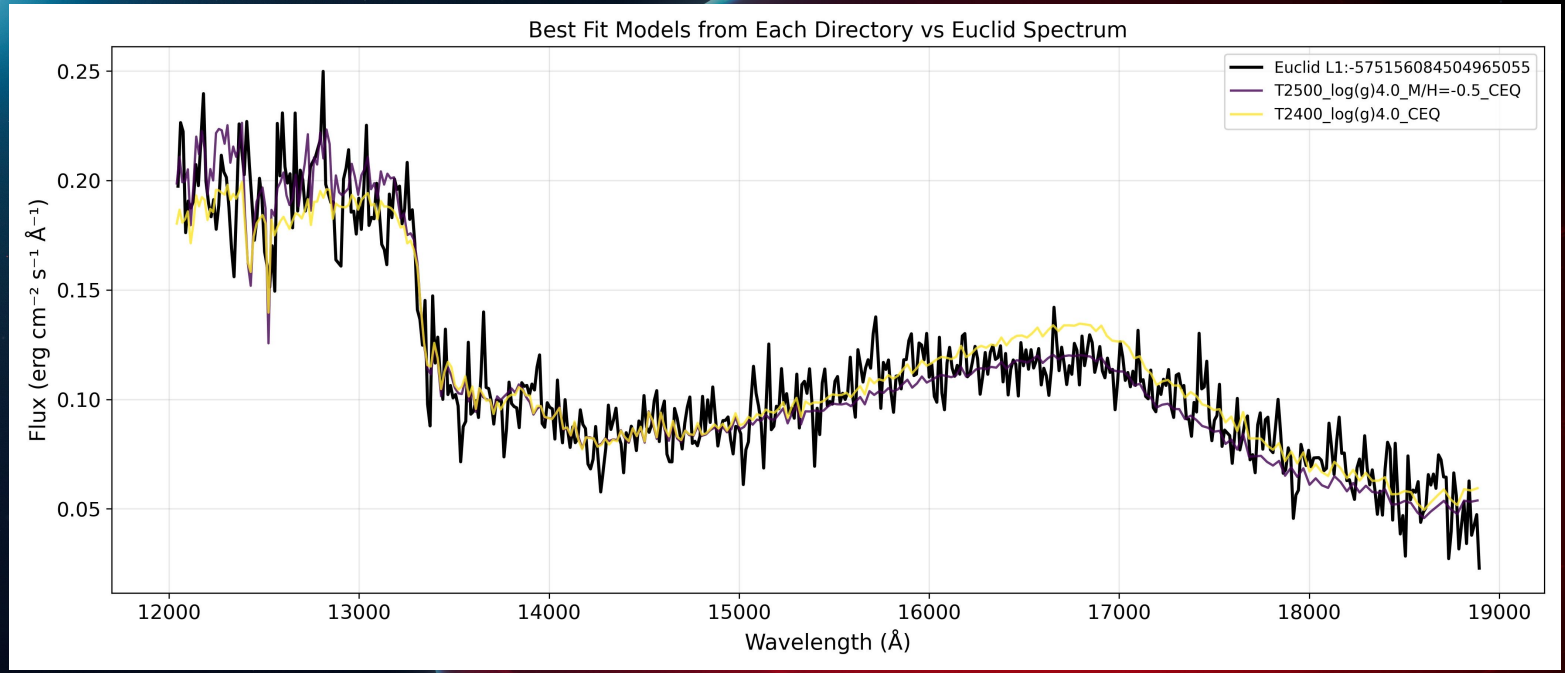

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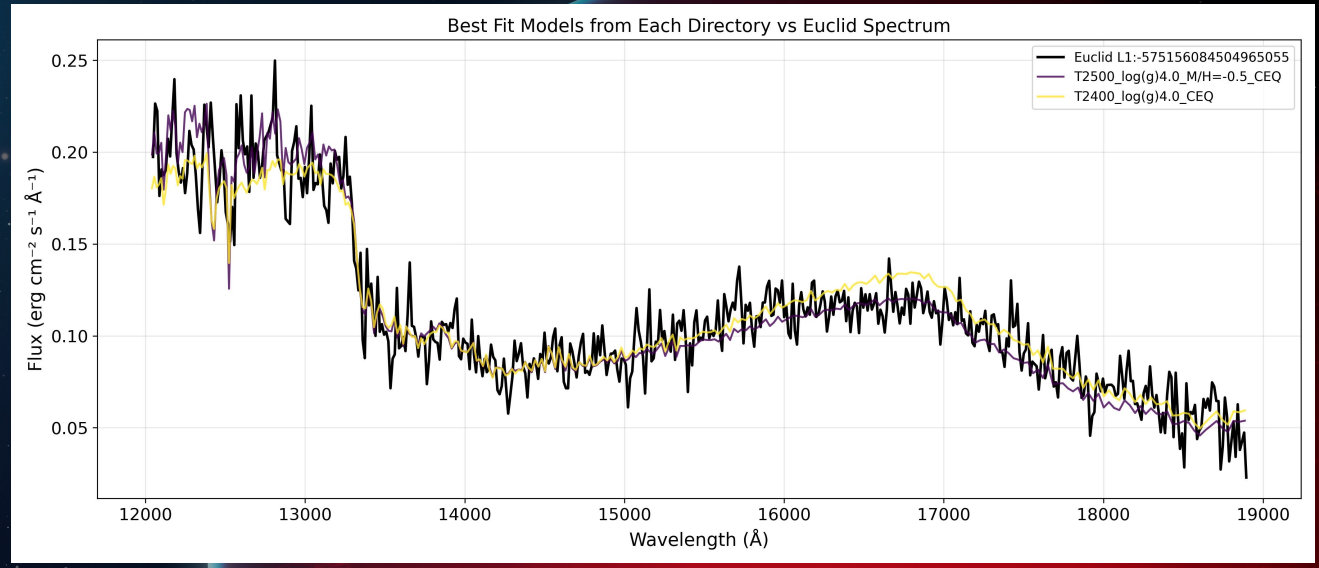

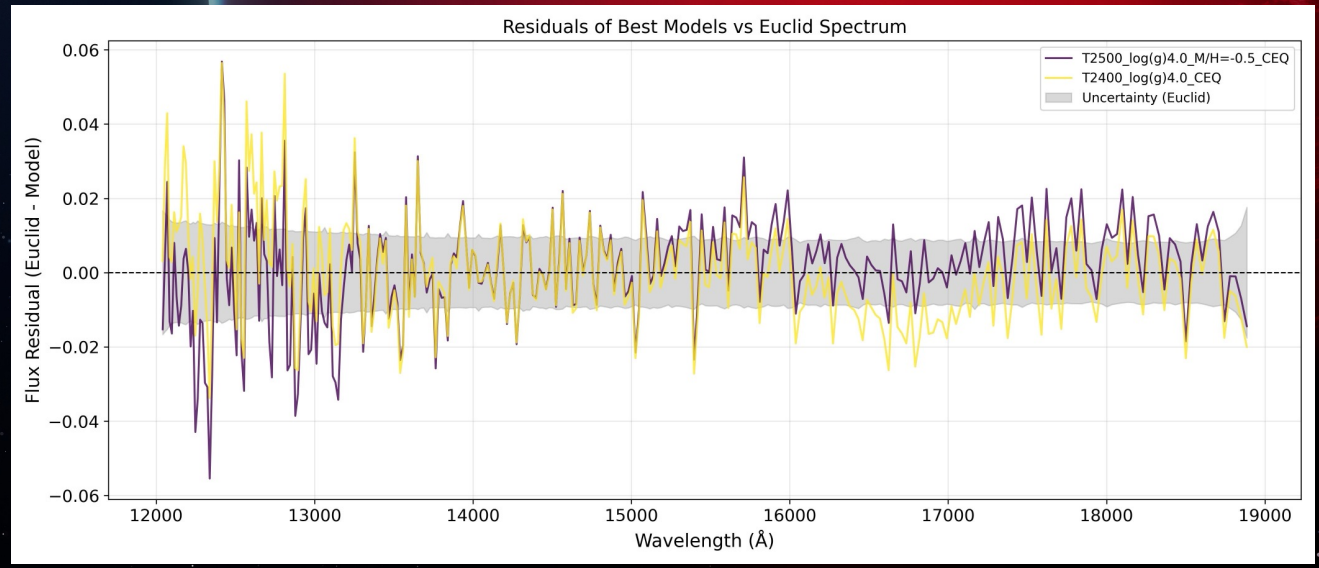

📉 Model with Lowest X^2 :
Teff=2500, log(g)=4.0, Z= -0.5, CEQ
(SSR = 0.06)

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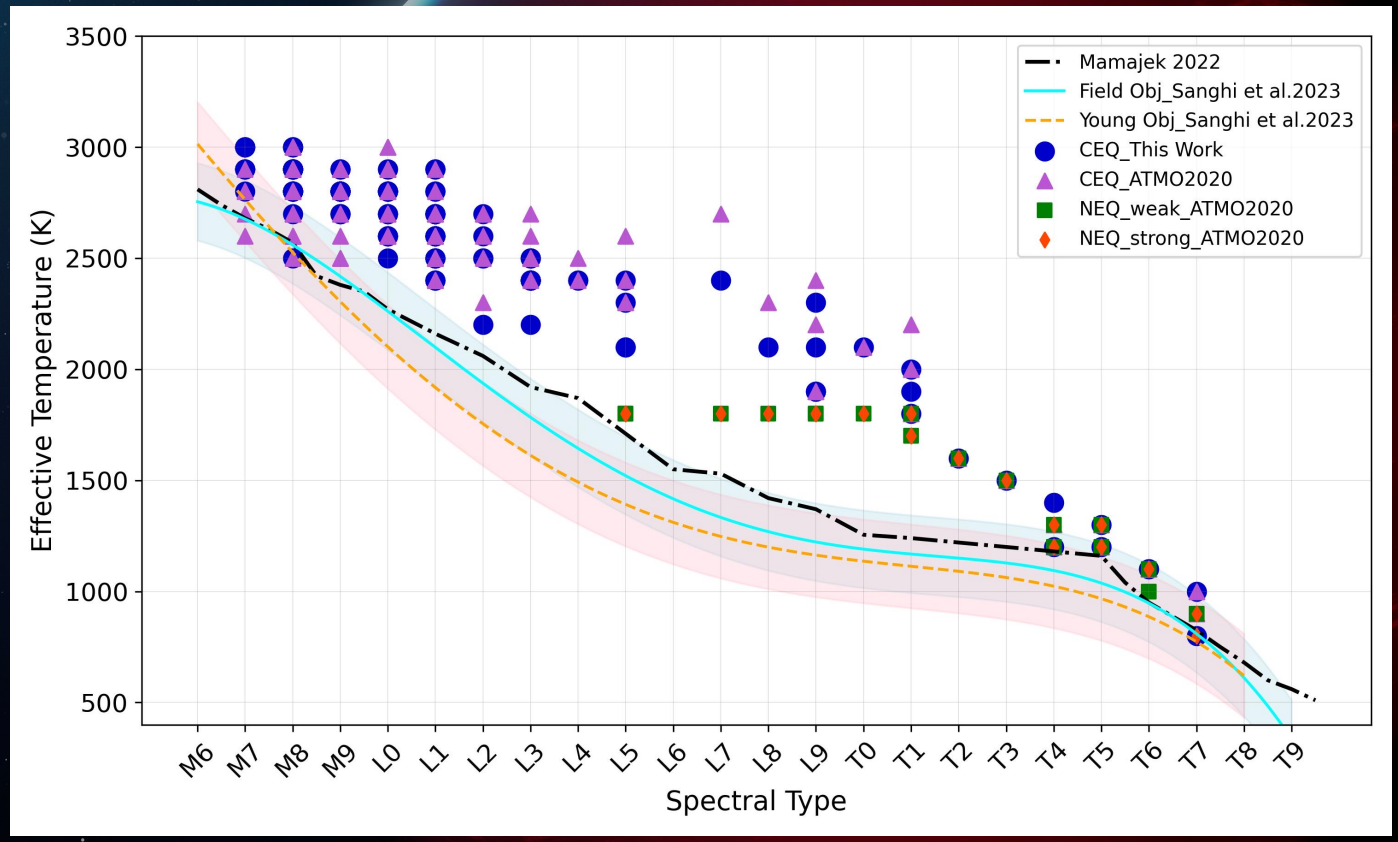
Effective Temperature vs. Spectral Type

- Temperature trend:

Effective temperature decreases steadily from late-M to T dwarfs.



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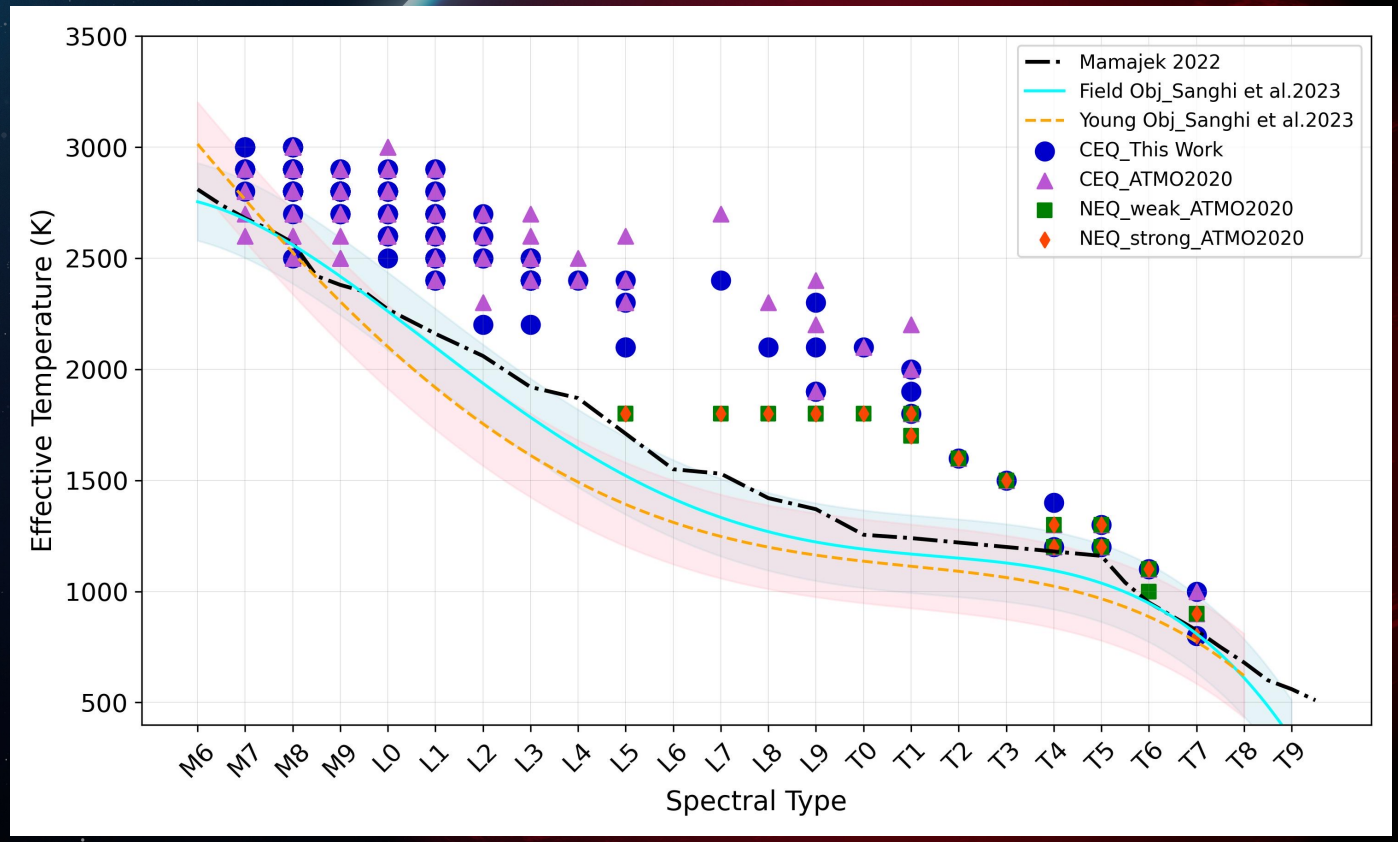
Effective Temperature vs. Spectral Type

- Temperature trend:

Effective temperature decreases steadily from late-M to T dwarfs.

This work (blue circles):

- Predict effective temperatures of T dwarfs with high precision.
- Show offsets for L and M type.



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Future Steps

- Presenting the new grids of atmosphere models for different metallicities with new included opacities
- Generating the models with non-equilibrium with extended metallicity range
- Fitting other models which include clouds and dust such as Sonora, BT-SETTL
- Comparing the models with a larger sample of spectroscopic data including Euclid DR1
- Generating models with different C/O ratio
- Evolutionary models

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Take-Home Message

• Euclid provides spectra of large UCD samples, enabling statistical studies of metallicity.

• ATMO models predict effective temperatures of T dwarfs with high precision, including equilibrium and non-equilibrium chemistry.

• The solar metallicity is the most common result as expected and its evenly distributed across all spectral types.

• Together: Euclid + ATMO deliver new insights into the formation pathways, evolutionary tracks, and atmospheric physics of brown dwarfs.

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Thank You

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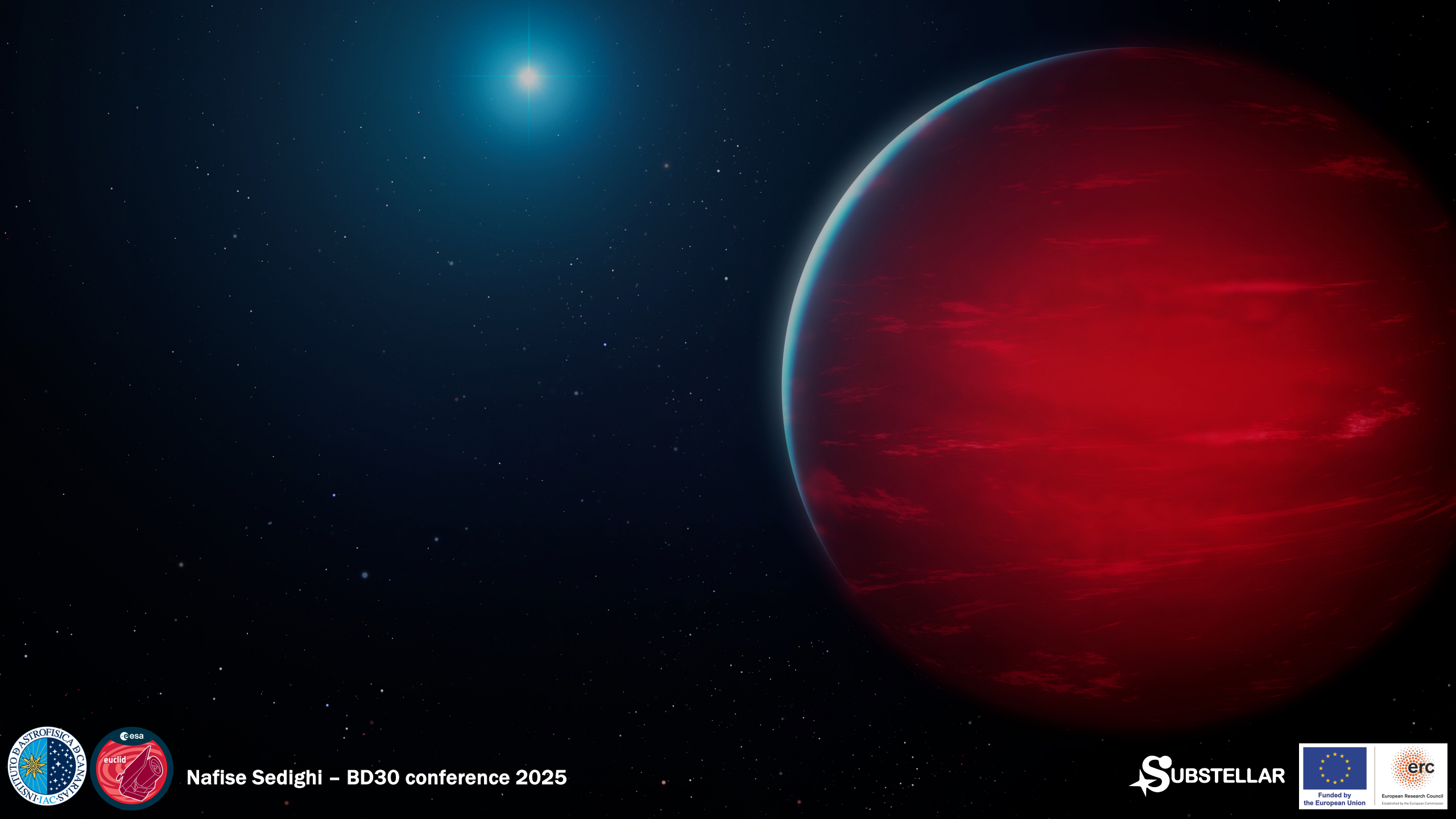

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