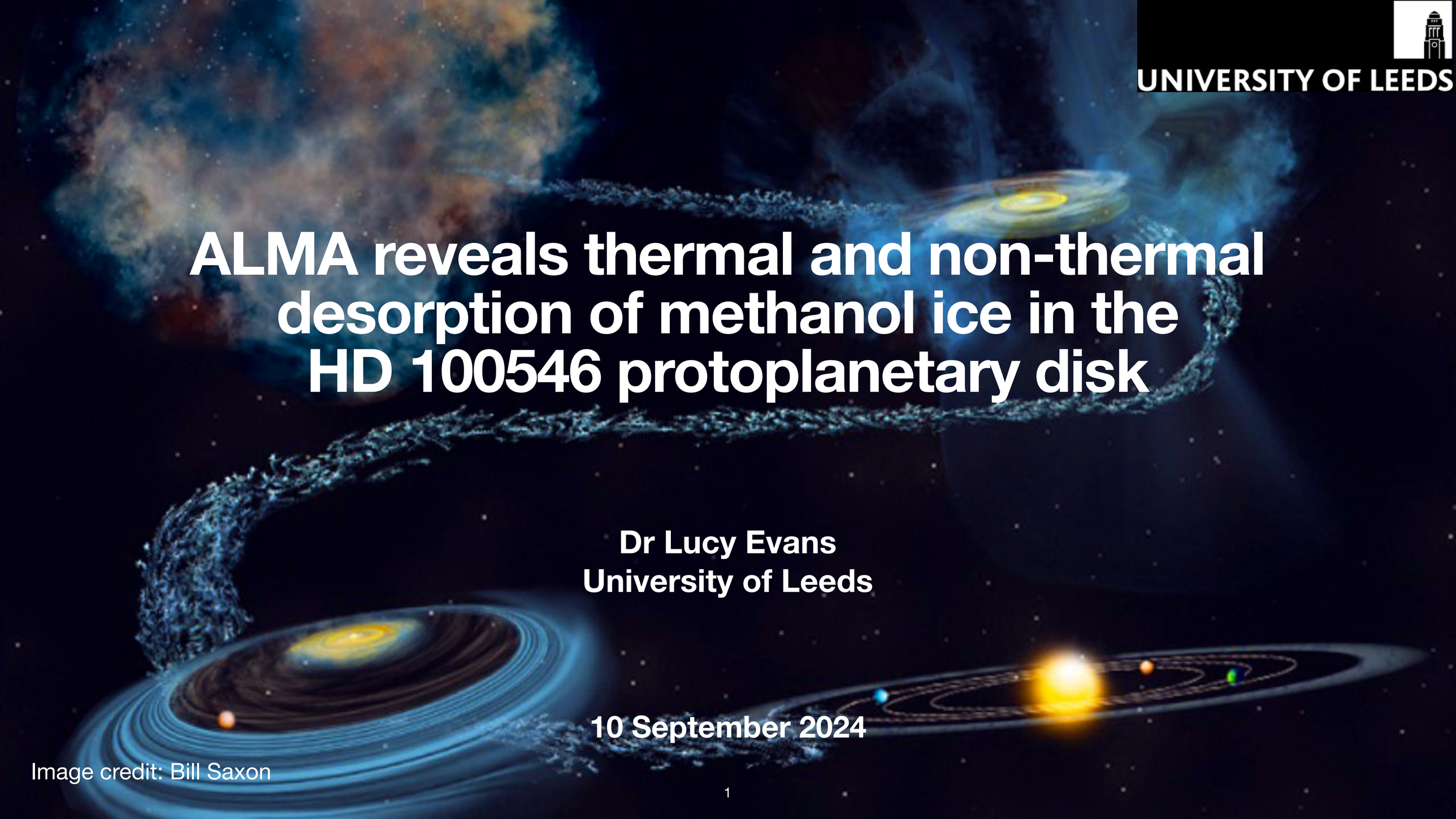

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ALMA reveals thermal and non-thermal desorption of methanol ice in the HD 100546 protoplanetary disk

Dr Lucy Evans
University of Leeds

10 September 2024

Image credit: Bill Saxon

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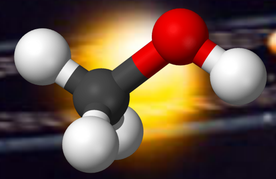
How much chemical complexity is retained at these early stages?



Why methanol?

- Simplest COM (Complex Organic Molecule)
- Prebiotic molecule - acts as a bridge towards more complex organics
- Large number of optically thin transitions (unlike CO)
- Formaldehyde is linked in formation
- Large E_{up} range - can empirically determine T_{gas}

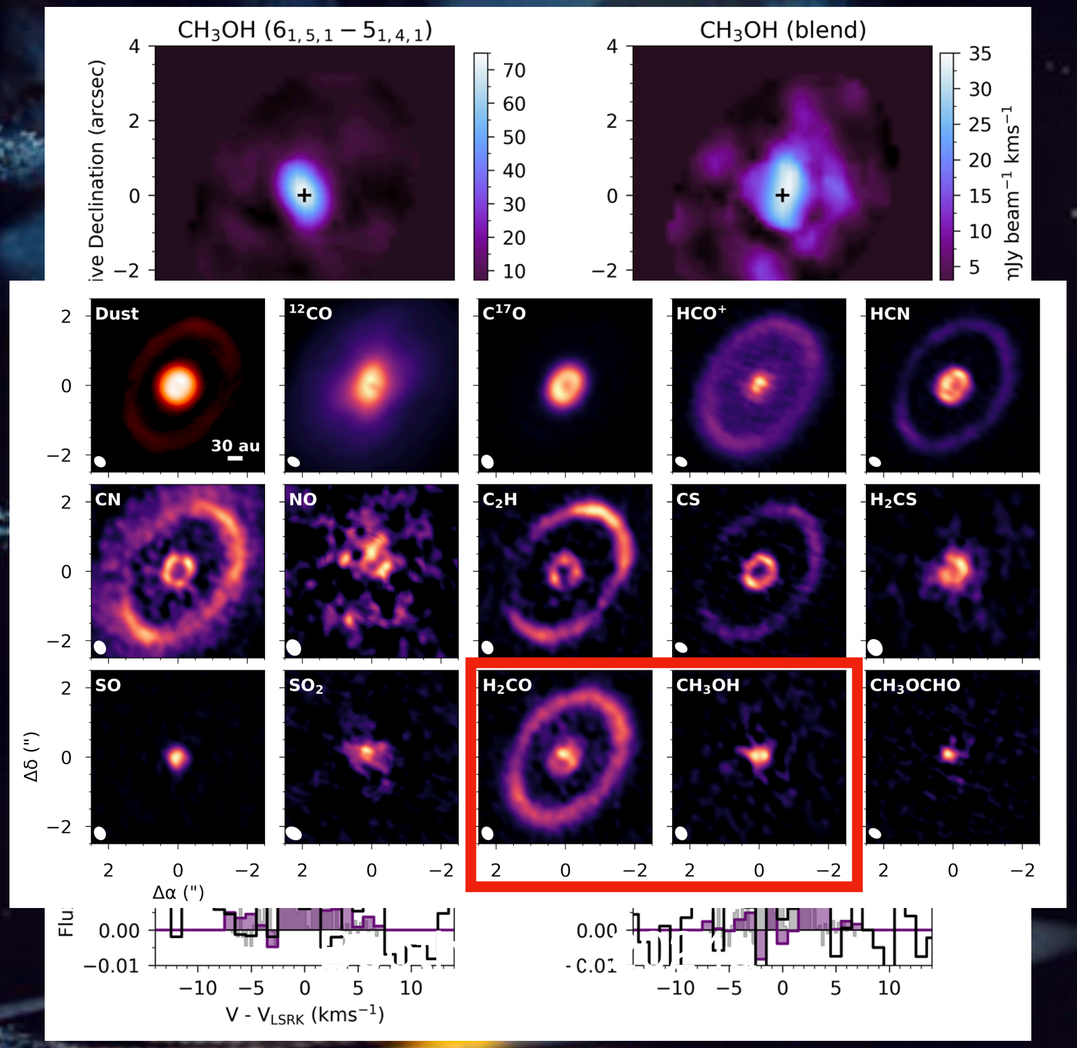
$$\mathrm{CO} \xrightarrow{\mathrm{H}} \mathrm{HCO} \xrightarrow{\mathrm{H}} \mathrm{H_2CO}$$

$$\mathrm{H_2CO} \xrightarrow{\mathrm{H}} \mathrm{CH_3O/CH_2OH} \xrightarrow{\mathrm{H}} \mathrm{CH_3OH}$$

Hiraoka+94, Watanabe+Kouchi02, Fuchs+09

Context

- Booth et al. 2021:
  - Methanol **serendipitously** detected in **disk surrounding HD 100546**
  - Gas-grain modelling —> **INHERITED!**
- Booth et al. 2024a, b:
  - Cycle 8 ALMA observations of HD 100546 - **chemical inventory**
- My focus: **methanol** and **formaldehyde**

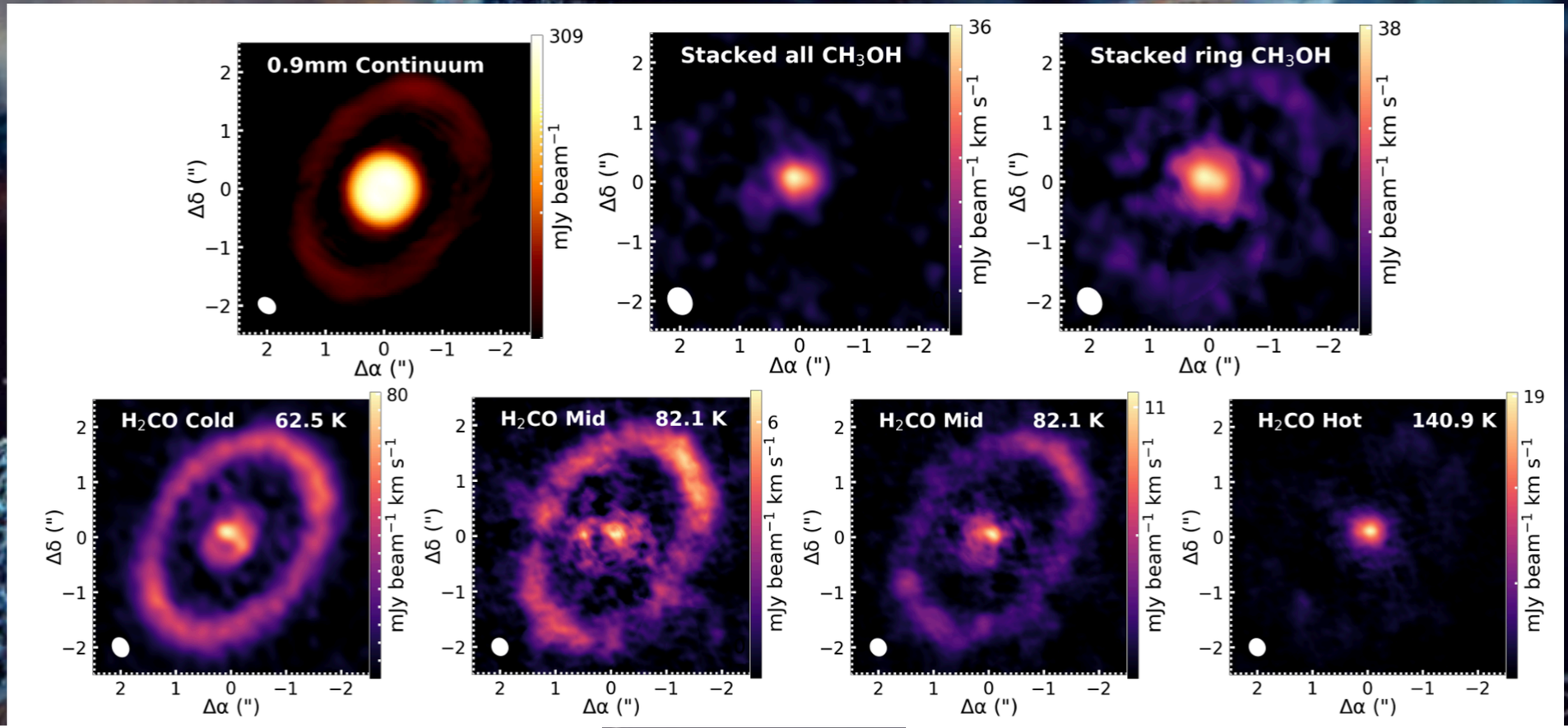


Booth et al. 2021

Our Transitions

Evans et al. in prep.

Multiple emission components!



We have **10** CH_3OH transitions

E_{up} range: 16-260 K

We have **5** H_2CO transitions

E_{up} range: 62-141 K

Rotational Diagrams

Evans et al. in prep.

Evidence for distinct desorption mechanisms!

Inner:

T_{rot}:

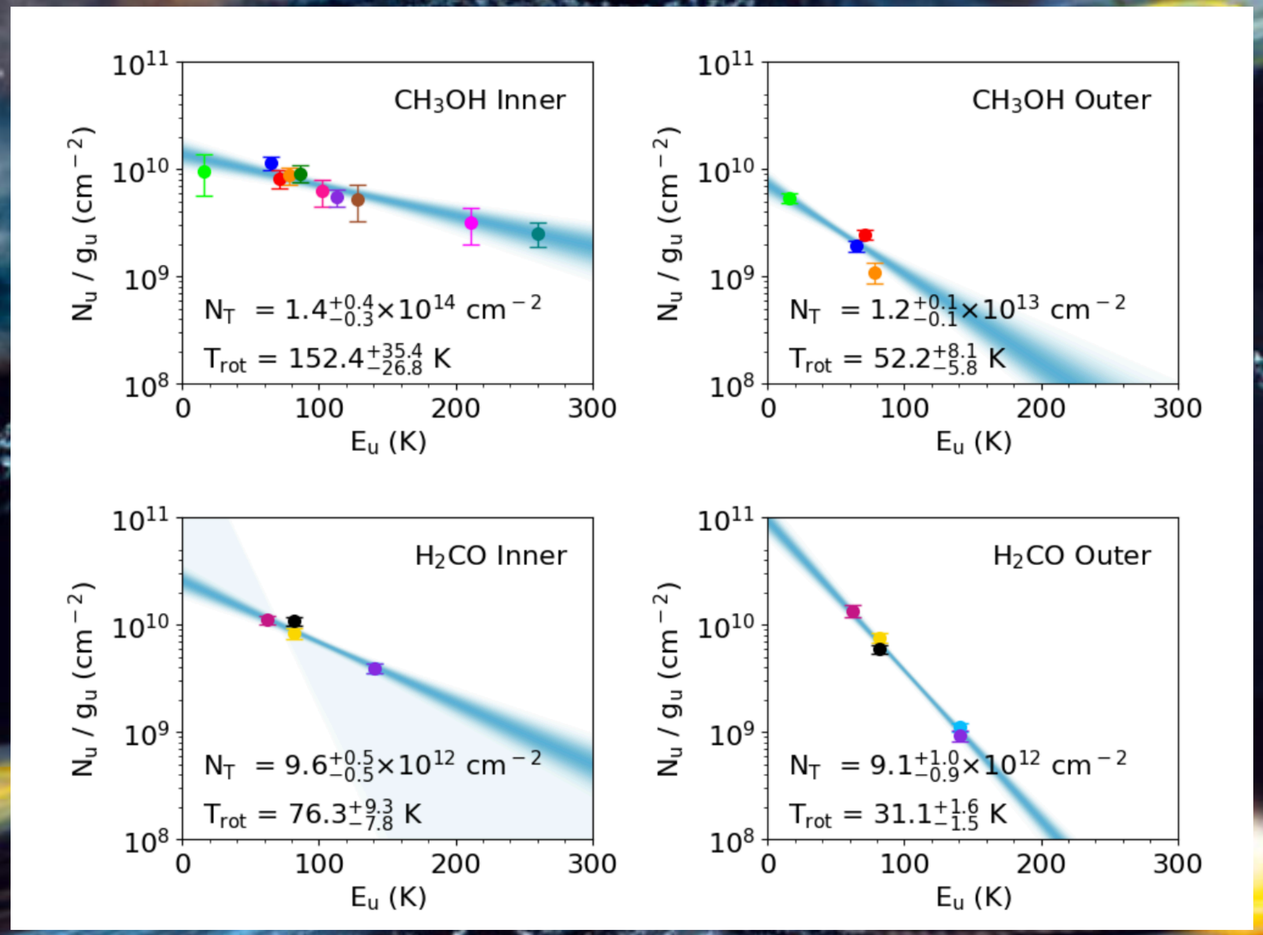
CH_3OH/H_2CO:

152^{+35}_{-27} K

$14.6^{+5.8}_{-4.6}$

H_2CO:

76^{+9}_{-8} K



Outer:

T_{rot}:

CH_3OH/H_2CO:

52^{+8}_{-6} K

$1.3^{+0.3}_{-0.2}$

H_2CO:

31±1 K

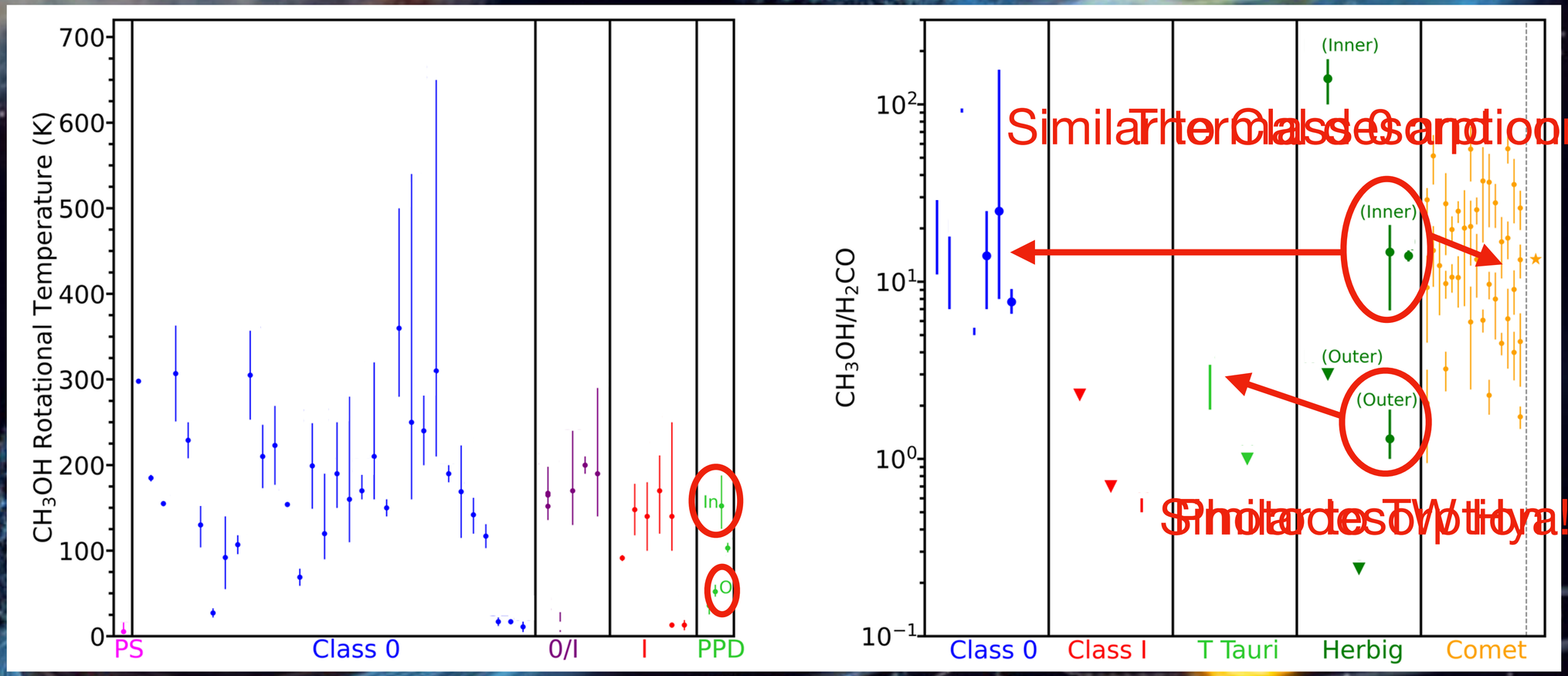
Order of magnitude decrease from inner to outer region!

Decreases from inner to outer region!

Comparison: Observations

Evans et al. in prep.

Evidence for inheritance!



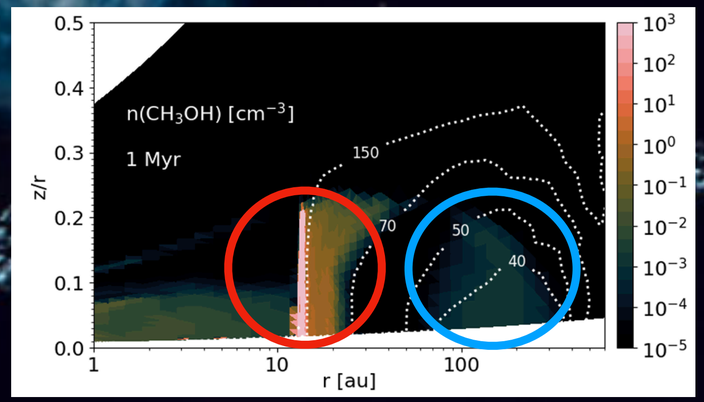
CH_3OH T_{rot}

CH_3OH/H_2CO

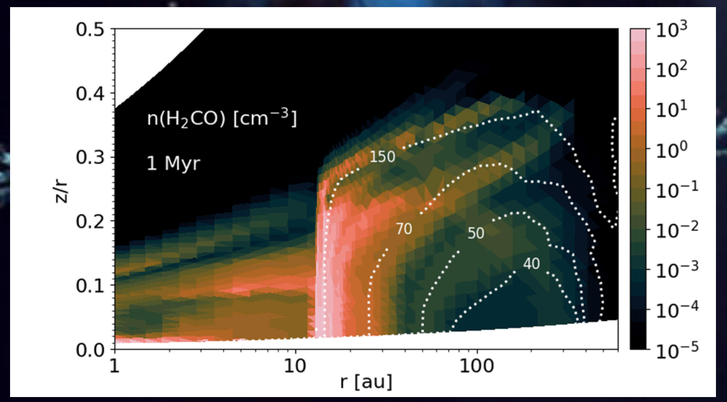
Comparison: Modelling

Evans et al. in prep.

Inner (thermally desorbed) component



Methanol



Formaldehyde

Outer (non-thermally desorbed) component

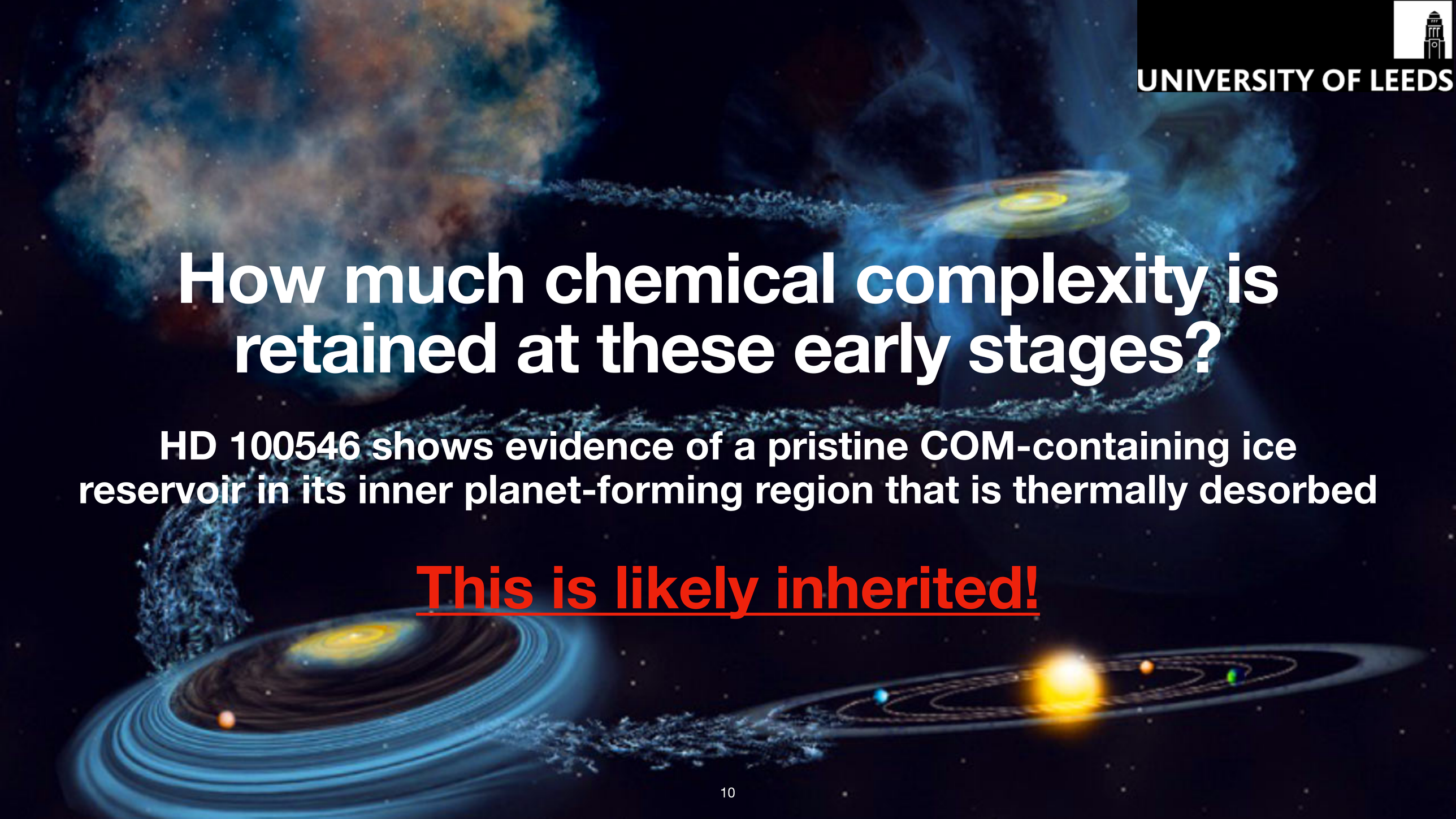
Observations **validating** disk models!

First time for **two distinct** emission components

Conclusions

Evans et al. in prep.

- We have **empirically** measured the gas temperature of a planet-forming region
- CH_3OH in **inner region** of HD 100546 shows **similar** T_{rot} to younger objects - similar chemical origin —> **thermal desorption**
- **Outer region** shows similar T_{rot} to TW Hya —> **photodesorption**
- **Decrease** in CH_3OH/H_2CO ratio going from **inner to outer regions** - similar to other similar disks —> H_2CO forming efficiently **in gas phase**
- Observed column densities **in line with** gas-grain chemical modelling predictions
- We have observationally validated modelling predictions of two distinct reservoirs **FOR THE FIRST TIME**



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How much chemical complexity is retained at these early stages?

HD 100546 shows evidence of a pristine COM-containing ice reservoir in its inner planet-forming region that is thermally desorbed

This is likely inherited!


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Thank you!