Star and planet formation

What an amazing journey over the past 30+ years!

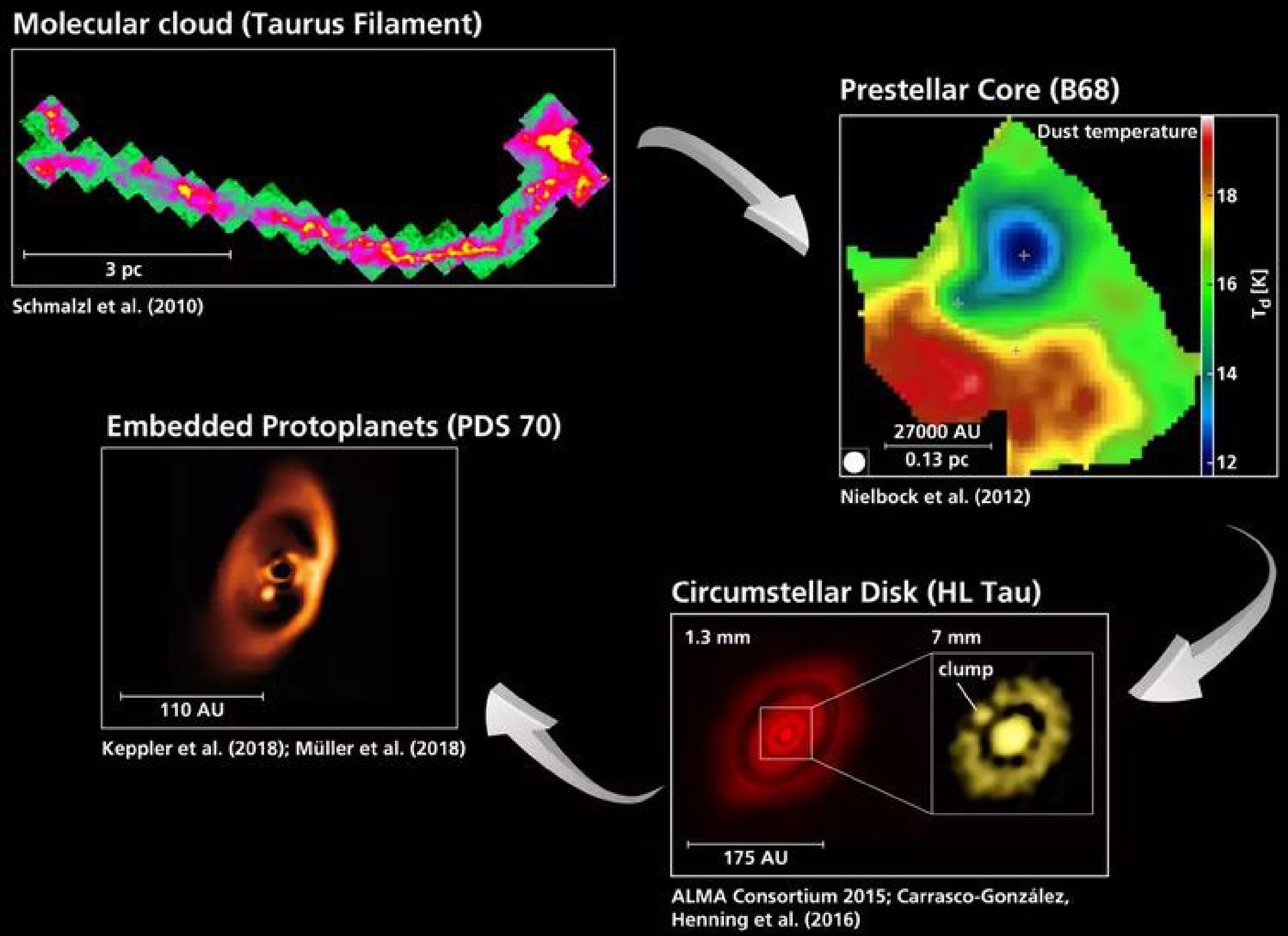
Ewine F. van Dishoeck

Leiden Observatory/MPE

Perspectives in star and planet formation
Heidelberg, June 22, 2026

This talk
- Intro Thomas' career
- Protostars with JWST

Thomas’ career: a one slide summary?



Th. Henning, March 5, 2024
Villa Vigoni

Much more: *“Bringing observations, theory, instrumentation and lab astrophysics together”*

Early years in Jena

“Staub in Sternentstehungsgebieten”
MPG Arbeitsgruppe 1991-1996

Wissenschaftliche Mitarbeiter:

Dr. B. Begemann, Dr. J. Blum, Dr. J. Dorschner, Dipl.-Phys. R. Launhardt (DARA), Dr. B. Michel (DFG), Dr. H. Mutschke, Dr. W. Schmitt, Dr. B. Stecklum, Dr. J. Steinacker, Dr. R. Stognienko.

Doktoranden:

Dipl.-Phys. A. Burkert, Dipl.-Phys. M. Feldt, Dipl.-Phys. A. Heines, Dipl.-Chem. C. Jäger, Dipl.-Phys. S. Kempf (DARA, DFG), Dipl.-Phys. H. Klahr, Dipl.-Phys. M. Löwe, Dipl.-Phys. V. Manske, Dipl.-Phys. R. Mucha (Adenauer-Stiftung), Dipl.-Phys. T. Poppe (DFG), Dipl.-Phys. R. Sablotny, Dipl.-Phys. M. Schnaiter (DFG), Dipl.-Phys. K. Schreyer (Studienstiftung), Dipl.-Phys. E. Thamm, Dipl.-Phys. G. Wurm (DARA).

6 Tagungen, Projekte am Institut und Beobachtungszeiten

6.1 Tagungen und Veranstaltungen

Die Arbeitsgruppe richtete eine internationale Tagung unter dem Titel „Galactic Star Formation and Early Stellar Evolution“ aus, die vom 29. Mai bis 2. Juni 1995 auf Schloß Ringberg/Bayern abgehalten wurde.

PhD Jena: 1984
Professor in Jena: 1992-now
MPIA Director: 2001-2024

The importance of “staub”

Astron. Astrophys. 291, 943–959 (1994)
ASTRONOMY AND ASTROPHYSICS

>2000 cit

Dust opacities for protostellar cores

V. Ossenkopf and Th. Henning
Max-Planck-Gesellschaft, Arbeitsgruppe “Staub in Sternentstehungsgebieten”, Schillergäßchen 2-3, D-07745 Jena, Germany

Received 16 April 1994 / Accepted 25 June 1994

Ossenkopf & Henning 1994

Astron. Astrophys. 276, 129–141 (1993)
ASTRONOMY AND ASTROPHYSICS

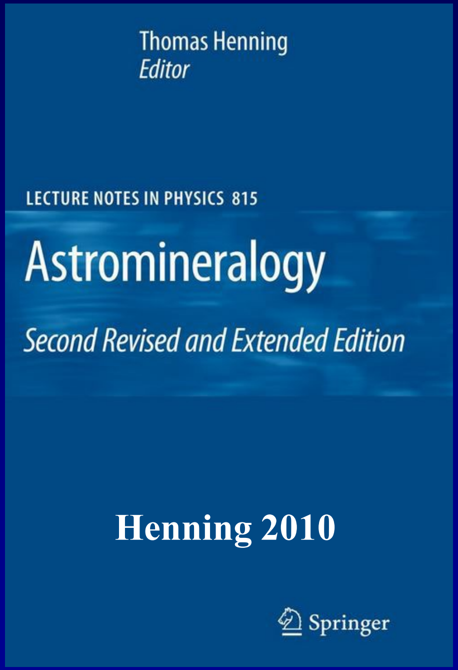
A 1.3 mm survey for circumstellar dust around young Chamaeleon objects*

Th. Henning[1], W. Pfau[2], H. Zinnecker[3], and T. Prusti[4]
[1] Max-Planck-Gesellschaft, AG “Staub in Sternentstehungsgebieten”, Schillergäßchen 2-3, D-07745 Jena, Germany
[2] Universitäts-Sternwarte, Schillergäßchen 2, D-07745 Jena, Germany
[3] Institut für Astronomie und Astrophysik, Am Hubland, D-97074 Würzburg, Germany
[4] Space Science Department, ESTEC, Postbus 299, NL-2200 AG Noordwijk, The Netherlands

Received March 10, accepted May 23, 1993

Henning et al. 1993

Crystalline silicate revolution
ISO



Henning 2010

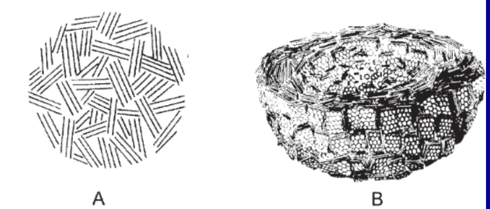
SCIENCE'S COMPASS • REVIEW

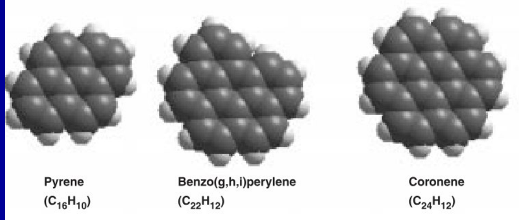
REVIEW: CARBON

Carbon in the Universe

Th. Henning and F. Salama

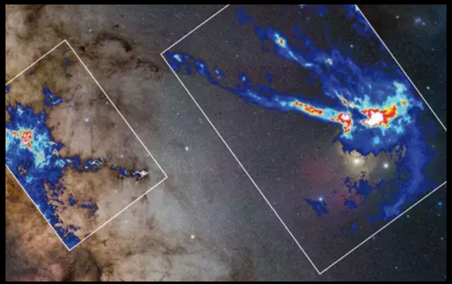
1998

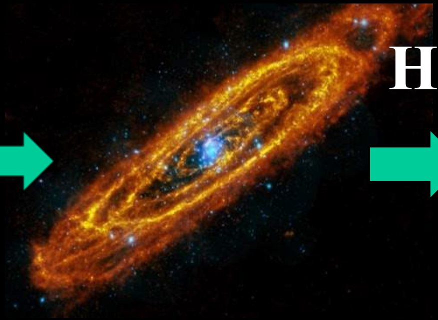




Henning 2010, ARAA
Cosmic Silicates

Clouds: From the biggest to the smallest scales





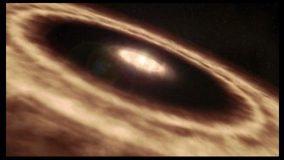
High z

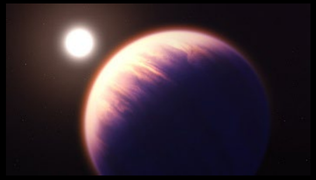
Cloud

Protostars:
Hydro, RT

Disk

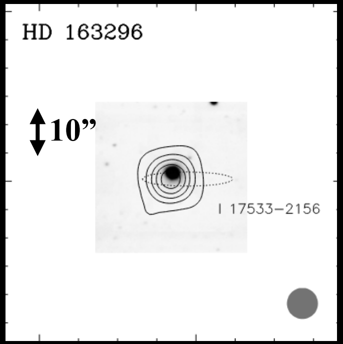
Inner disk



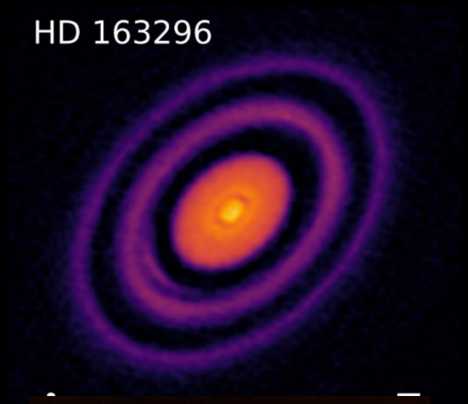


ExoPlanets, Origins of Life

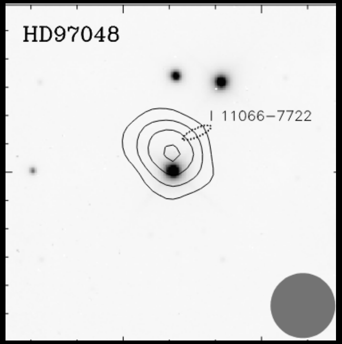
From "blobs" to planet-forming disks

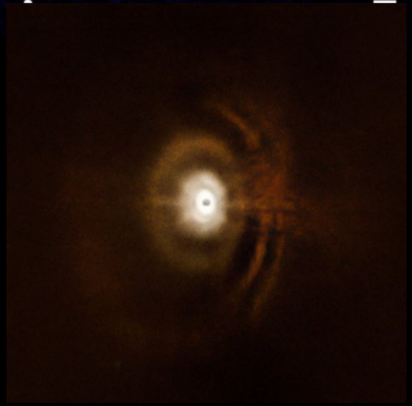


Henning et al. 1998

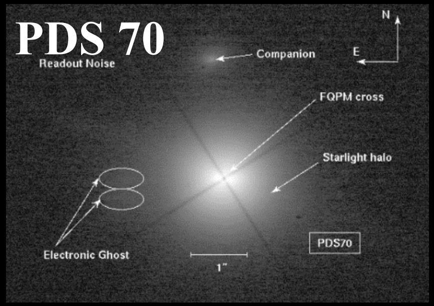


ALMA, Andrews et al. 2018

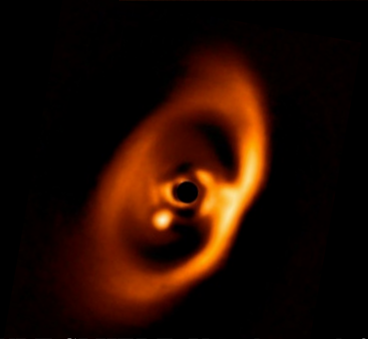




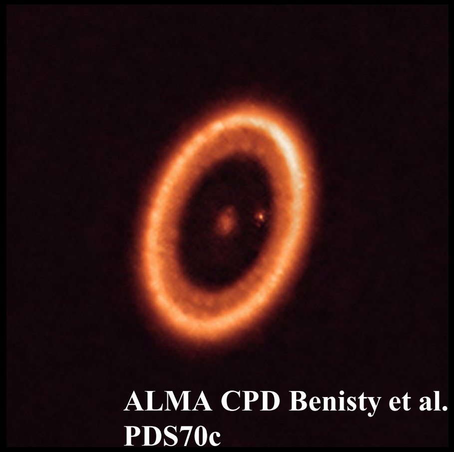
VLT-SPHERE, Ginski et al. 2016



Riaud et al. 2006 NAOS-CONICA

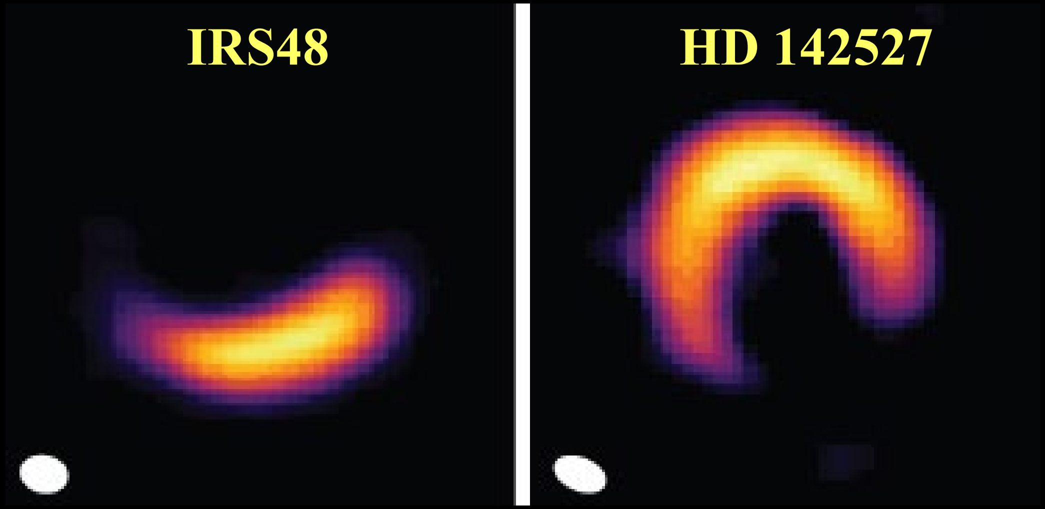


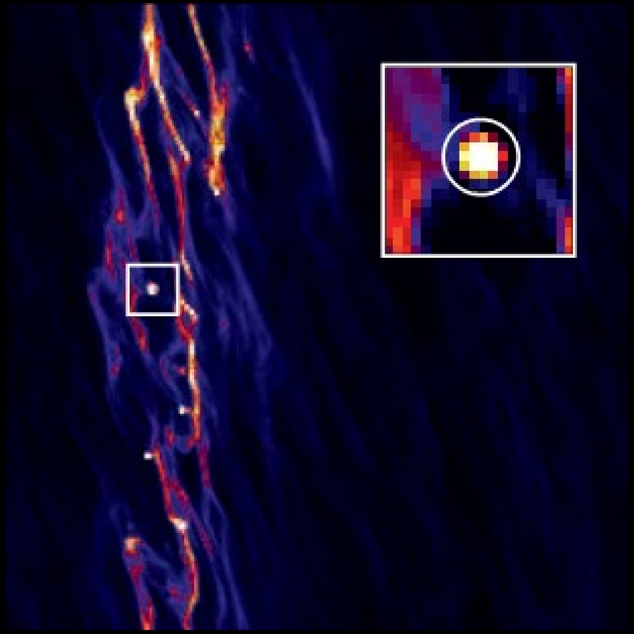
VLT-SPHERE, Keppler et al. 2018
PDS70b



ALMA CPD Benisty et al. 2021
PDS70c

Dust trapping, planetesimal formation





Regular Article

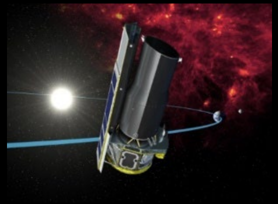
Particle-Trapping Eddies in Protoplanetary Accretion Disks

H.Hubertus Klahr [a], Thomas Henning [a] **1997**

Johansen et al. 2007

Progress in astronomy driven by new instrumentation…

ISO
1995-1998

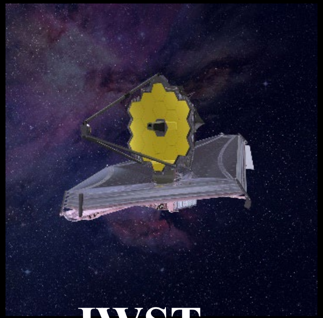


Spitzer
2003-2011

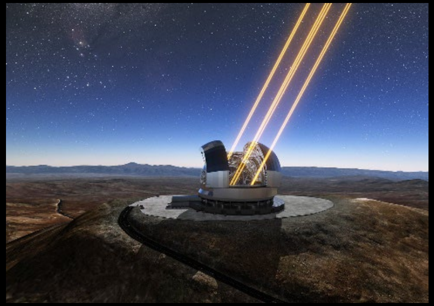
VLT/VLTI
2002-

Herschel
2009-2013

ALMA
2012-



JWST
2022-



ELTs >2030

PRIMA

…and by scientists with a vision!

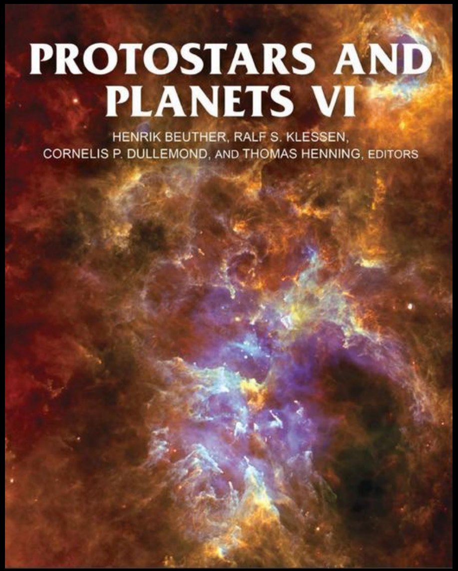
Co-PI: JWST-MIRI, VLTI-MATISSE-GRAVITY
Co-I: MIDI, SPHERE, Carmenes, PACS, METIS, ….

And by steering European and worldwide astronomy

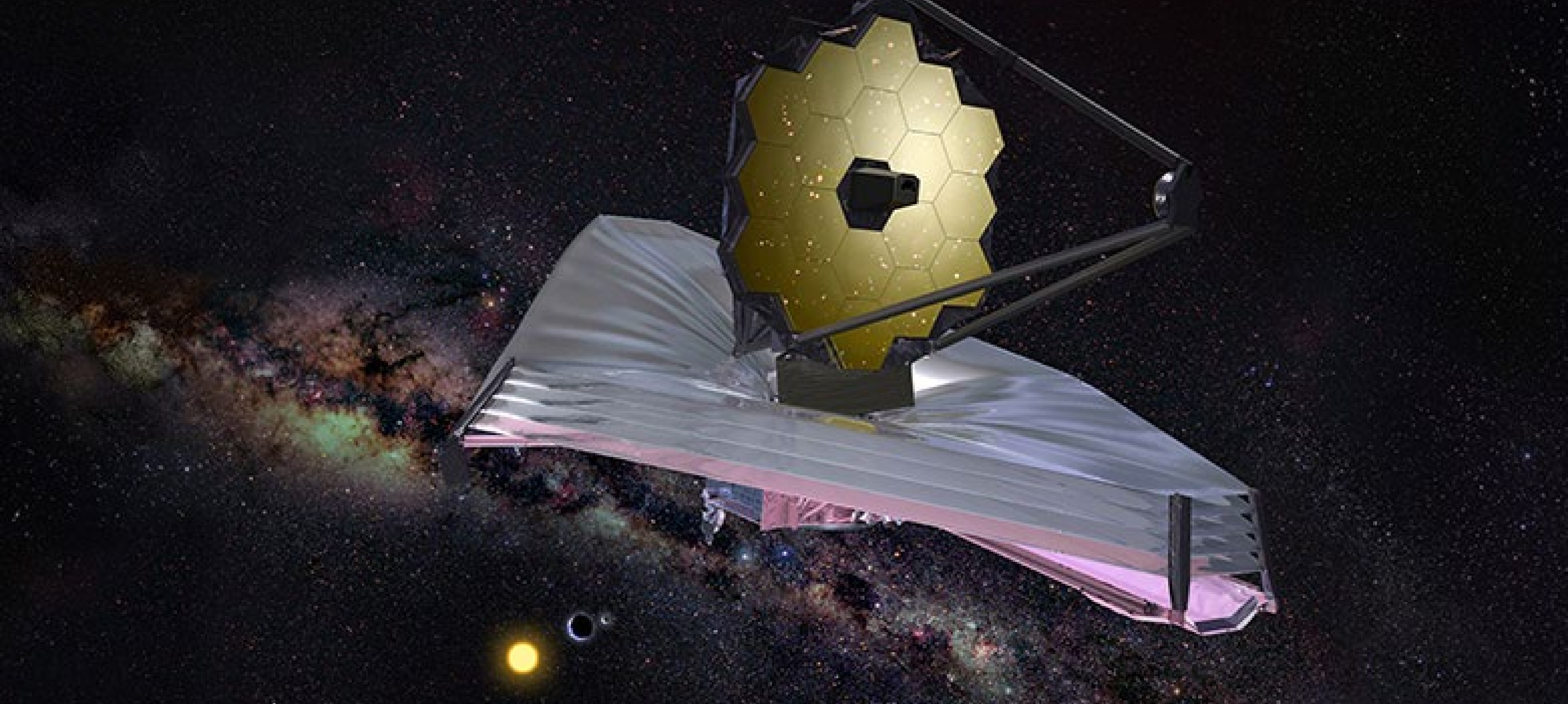
ESO Council 2014

Discussing ESO Council 2024

ALMA
Inauguration 2013



Enter JWST



MIRI European Consortium

WEBB SPACE TELESCOPE

NASA

esa

CSA ASC

Many memorable MIRI EC meetings
25+ years

Dublin 2007

Edinburgh May 2026

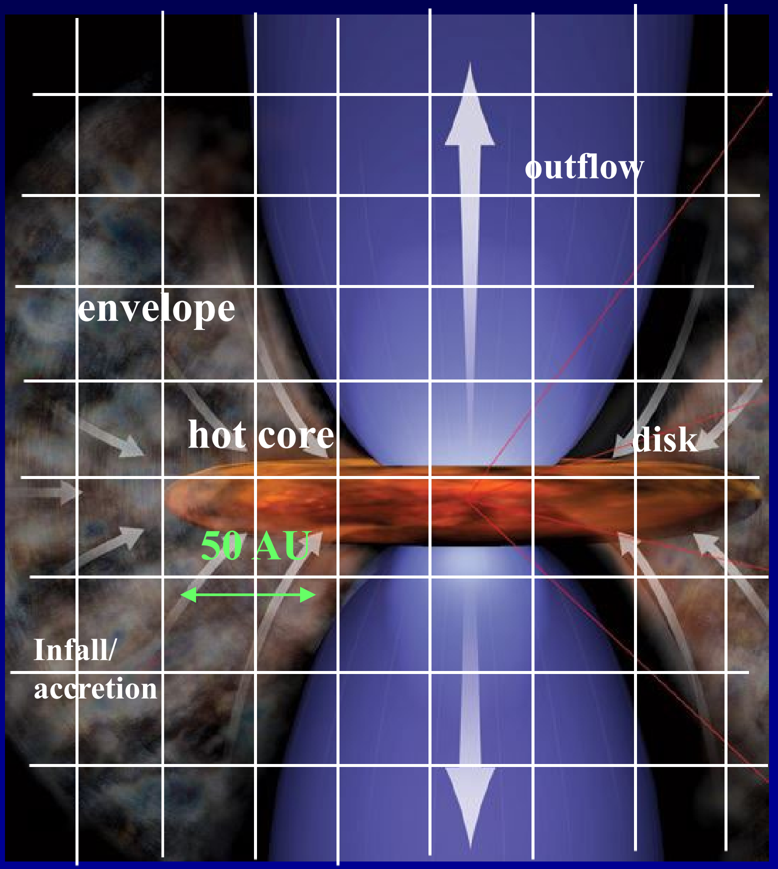
Biosphere, Tucson 2024

Thanks to Thomas and MPIA for bringing community together, many times!

“The dawn of MINDS and JOYS”

MIRI team 2010: GTO program

Embedded protostars with JWST: main questions



B. Saxton NRAO

- Jets, disk winds, outflows
- Protostellar accretion rates
- Ice composition envelope
- Hot cores
- Composition young disks
- Low to high-mass protostars

~30 sources in JOYS+

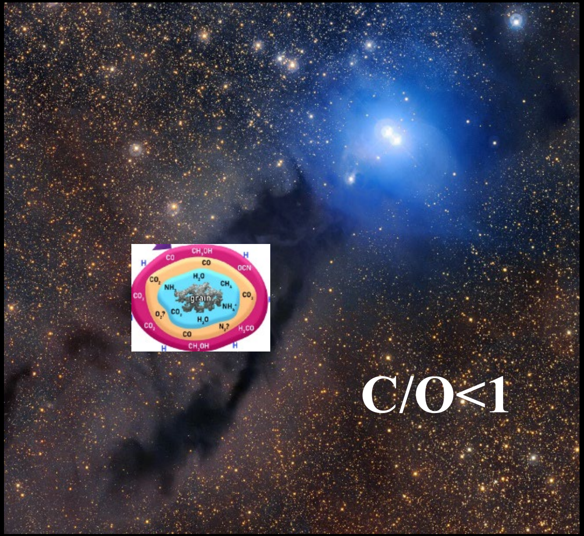
Spatial resolution JWST IFUs well matched to sizes of physical components

0.2”-0.9”, 30-150 au at 150 pc

miri.strw.leidenuniv.nl
21 papers

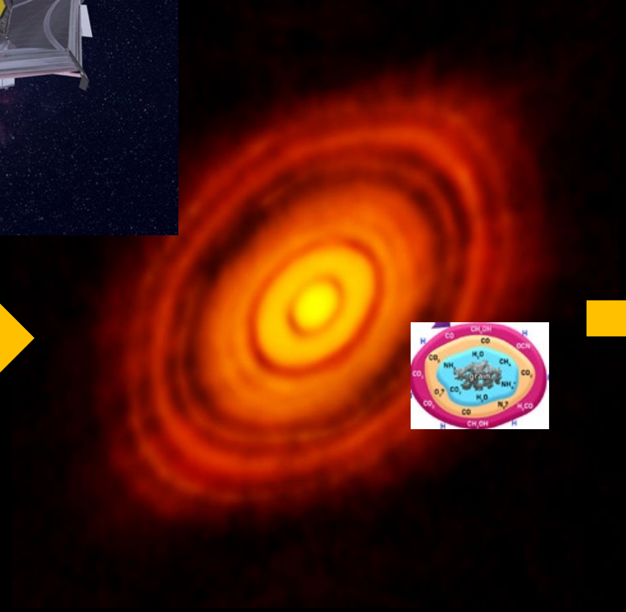
Overview in vD et al. 2025

Trail from clouds to disks and planets



Dark cloud

Protostar



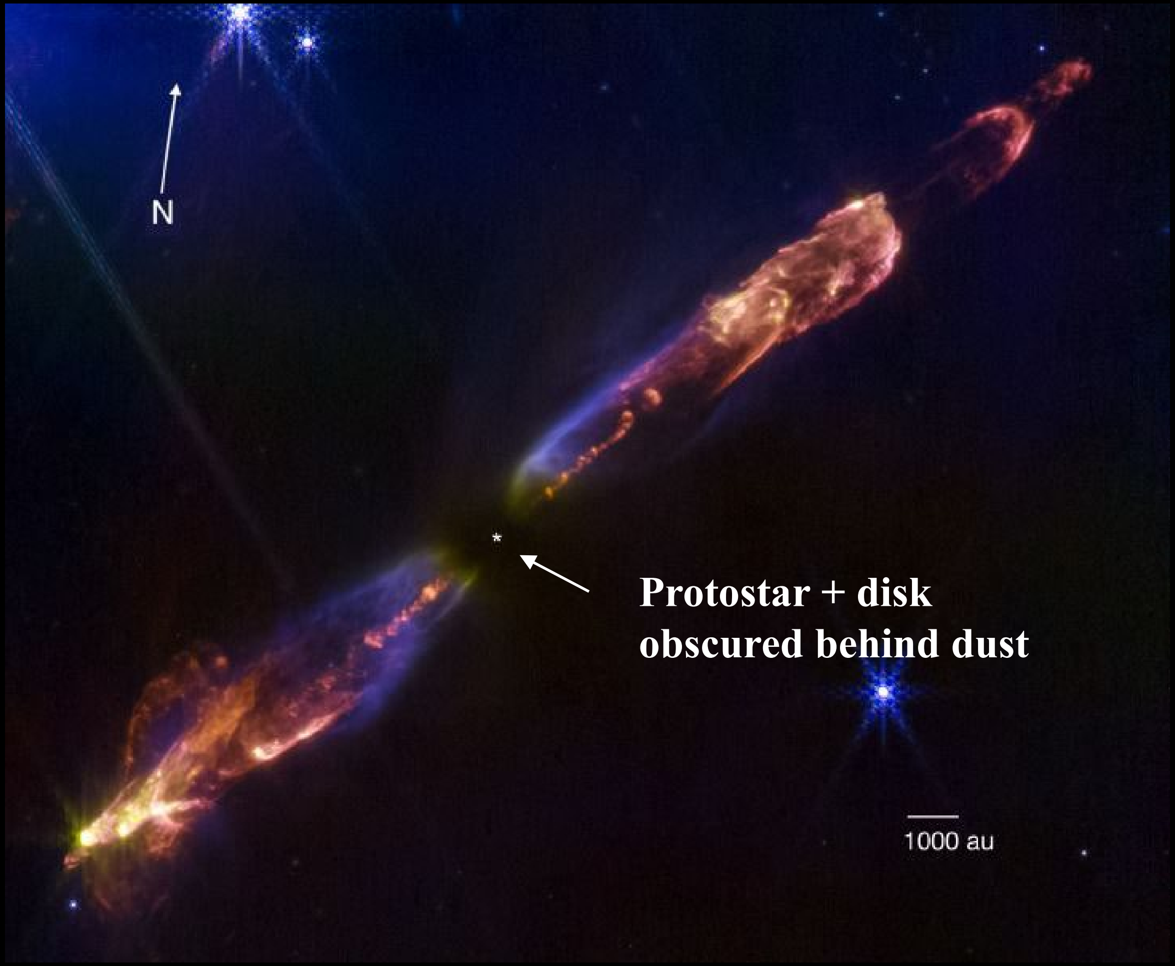
Disk

Planets

Comets

- What is chemical composition at each of stages? Inherited or reset?
- What sets the composition of exoplanets? Role of disk structure?

Protostars with JWST: jets, outflows



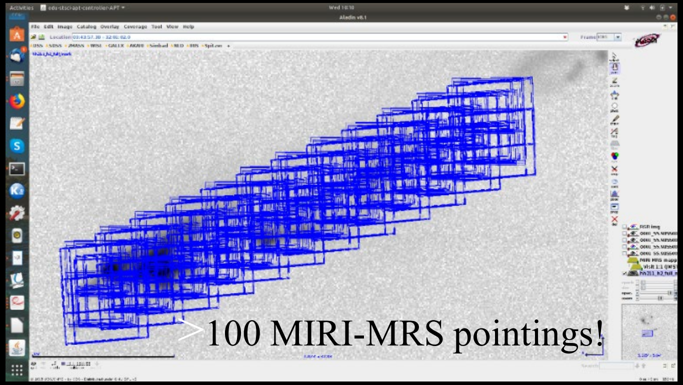
HH 211
Class 0

Ray et al. 2023
Cover Nature Oct. 5

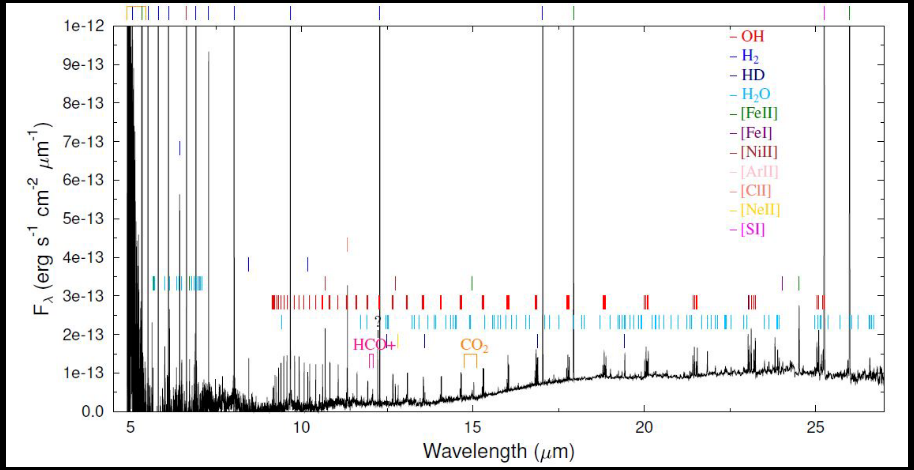
Blue: 2.10+3.23
Green: 4.60 M
Orange: 4.66 N **(CO)**
Red: 4.70N (H_2)

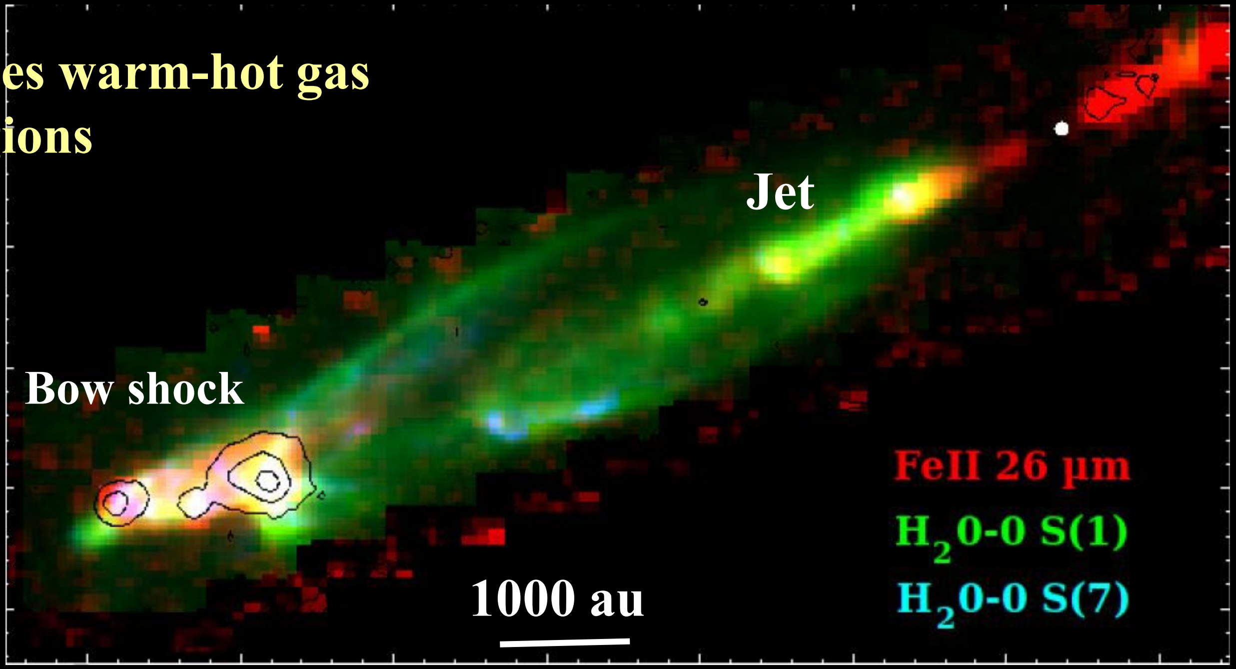
Jet is mostly molecular, with an atomic/ionized inner core

MIRI-MRS map of HH 211 blue lobe



Mid-IR uniquely probes warm-hot gas in highly extincted regions



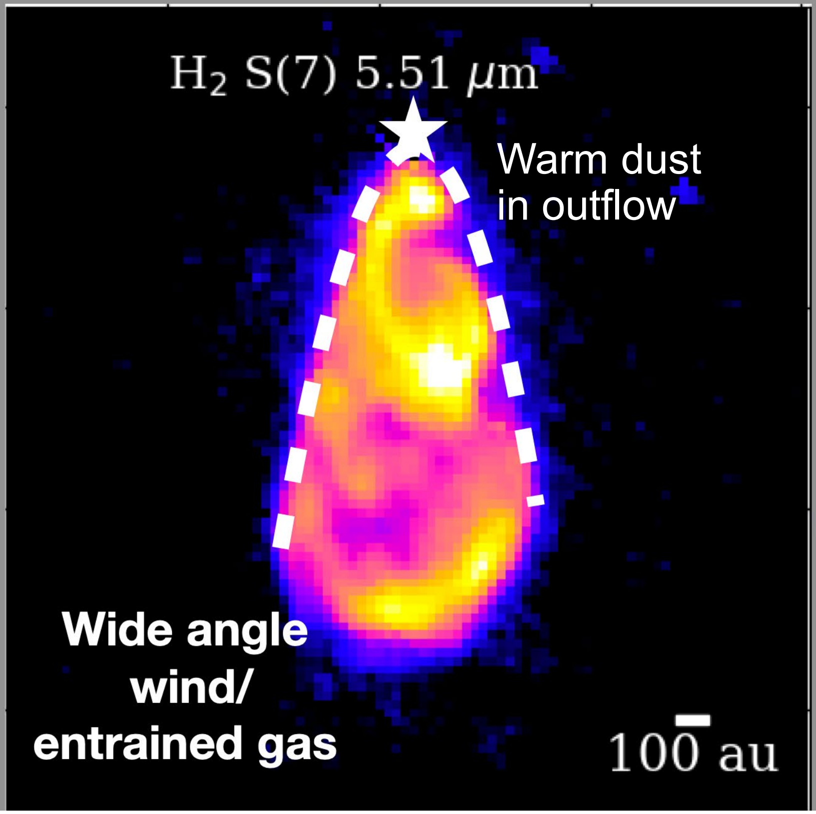


- Warm H_2 is primary mover of outflow in Class 0 phase, in contrast with Class II
- Dust lifted from disk mostly survives jet

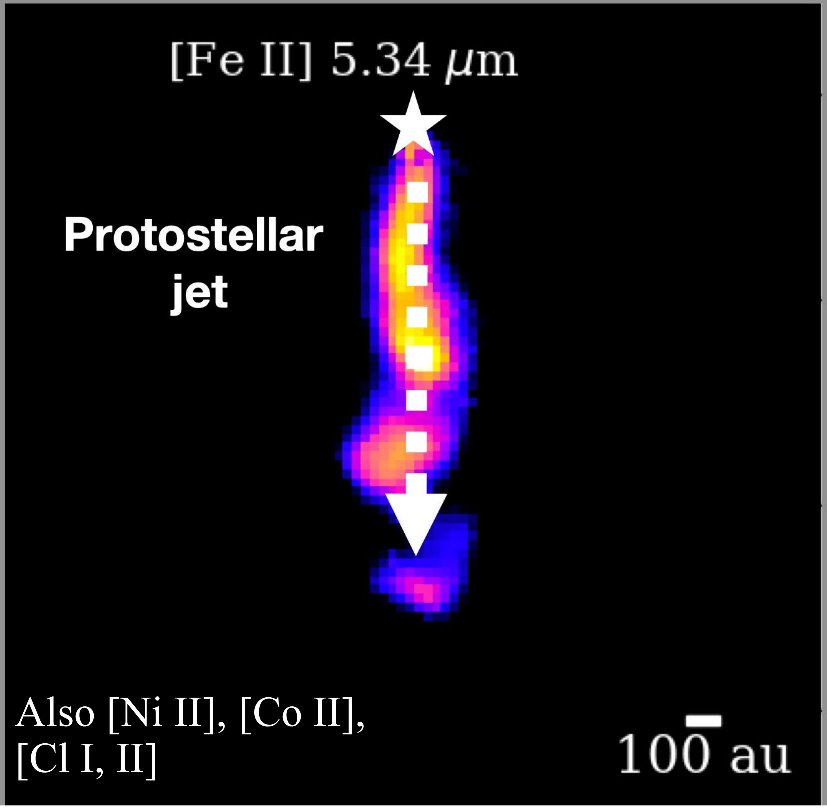
Caratti o Garatti+2024

BHR71 - a young protostellar outflow

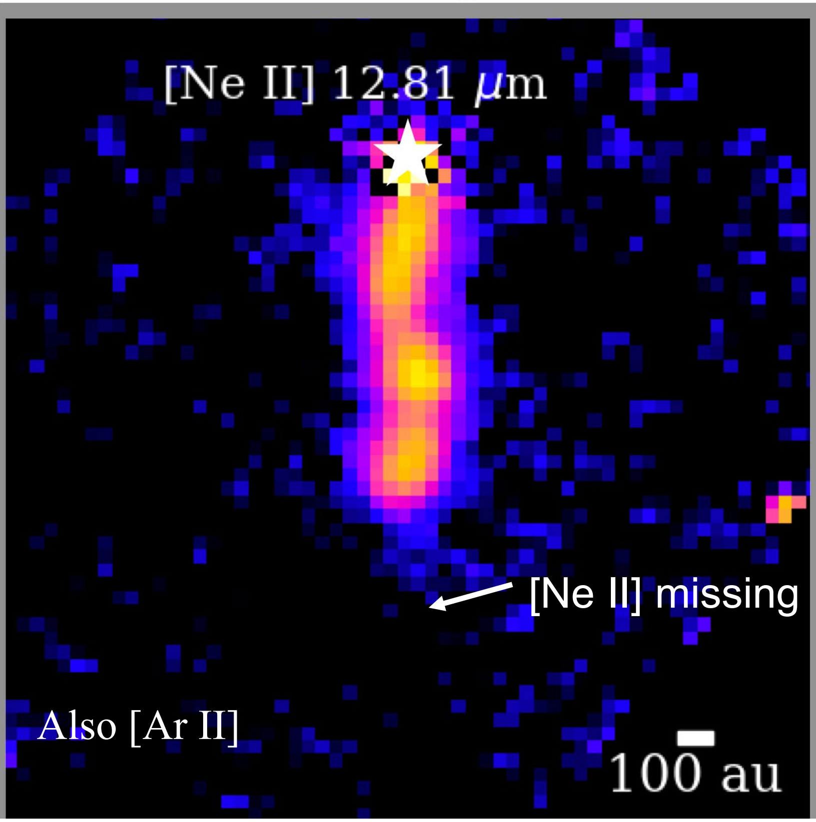
Molecular hydrogen



Refractory



Noble gas

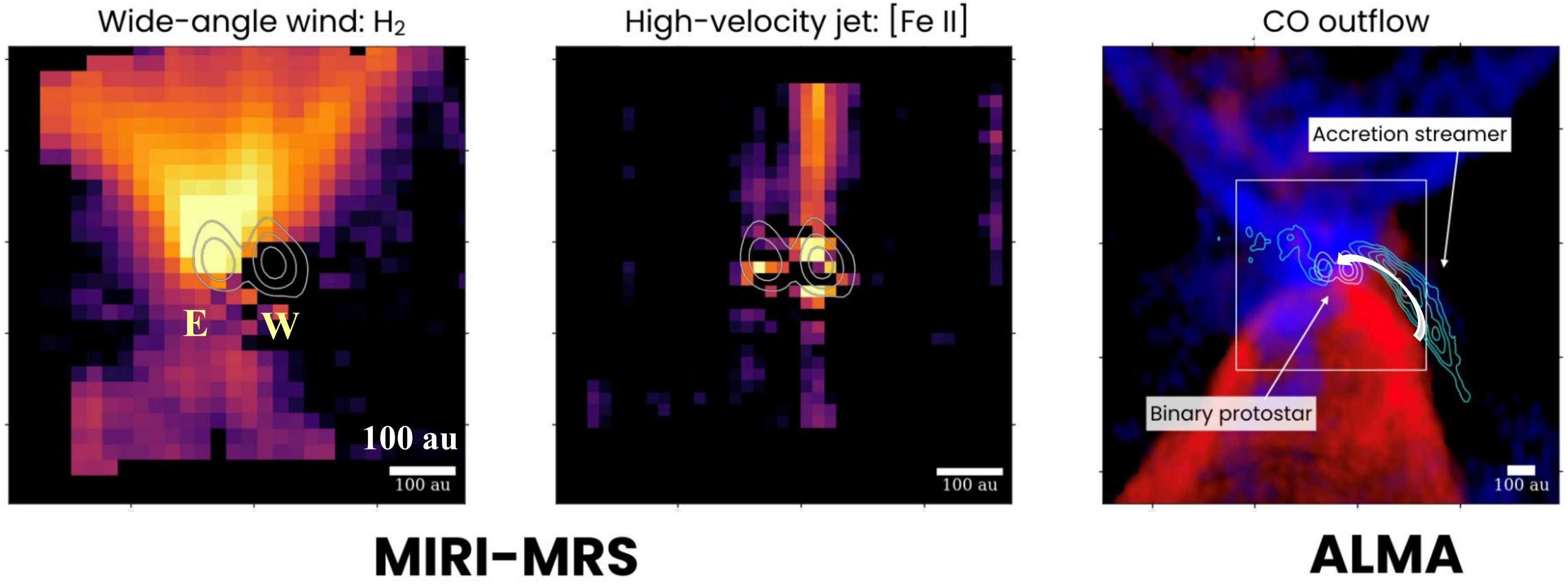


Dust is destroyed in jets → Fe, Ni, Co, … returned to gas but some fraction of dust survives (abundances < solar)

Tychoniec+ 2026

Also L1448-mm: Vorster et al., subm

Imaging disk wind and jet in TMC1 binary

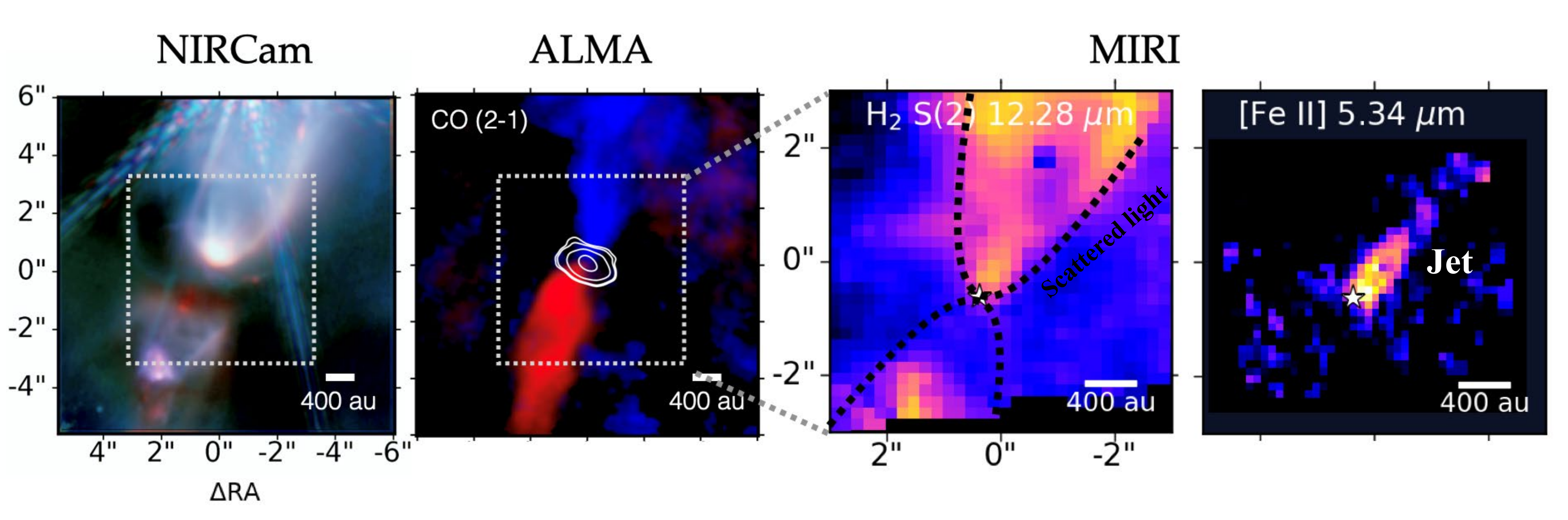


TMC-1
Class I source

- **W source: atomic jet**
- **E source: wide angle molecular wind, triggered by streamer**

Tychoniec et al. 2024

Nested structure: Class 0 Serpens SMM3

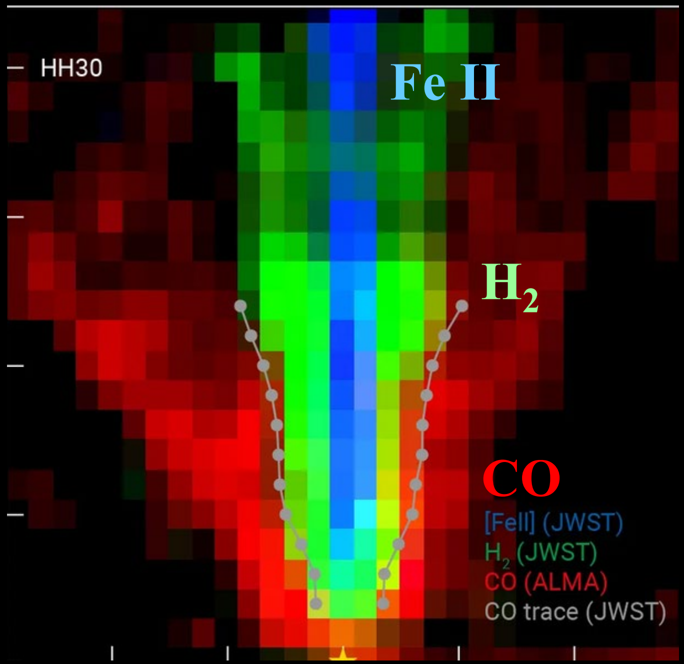


Nested structure is common: ionized core of jet traced by [Fe II]
molecular layer traced by high-*J* H_2
wide angle wind traced by low-*J* H_2

van Dishoeck , Tychoniec et al. 2025
Le Gouellec et al. 2026, to be subm.

Class I nested structures winds and jets

© NAOJ

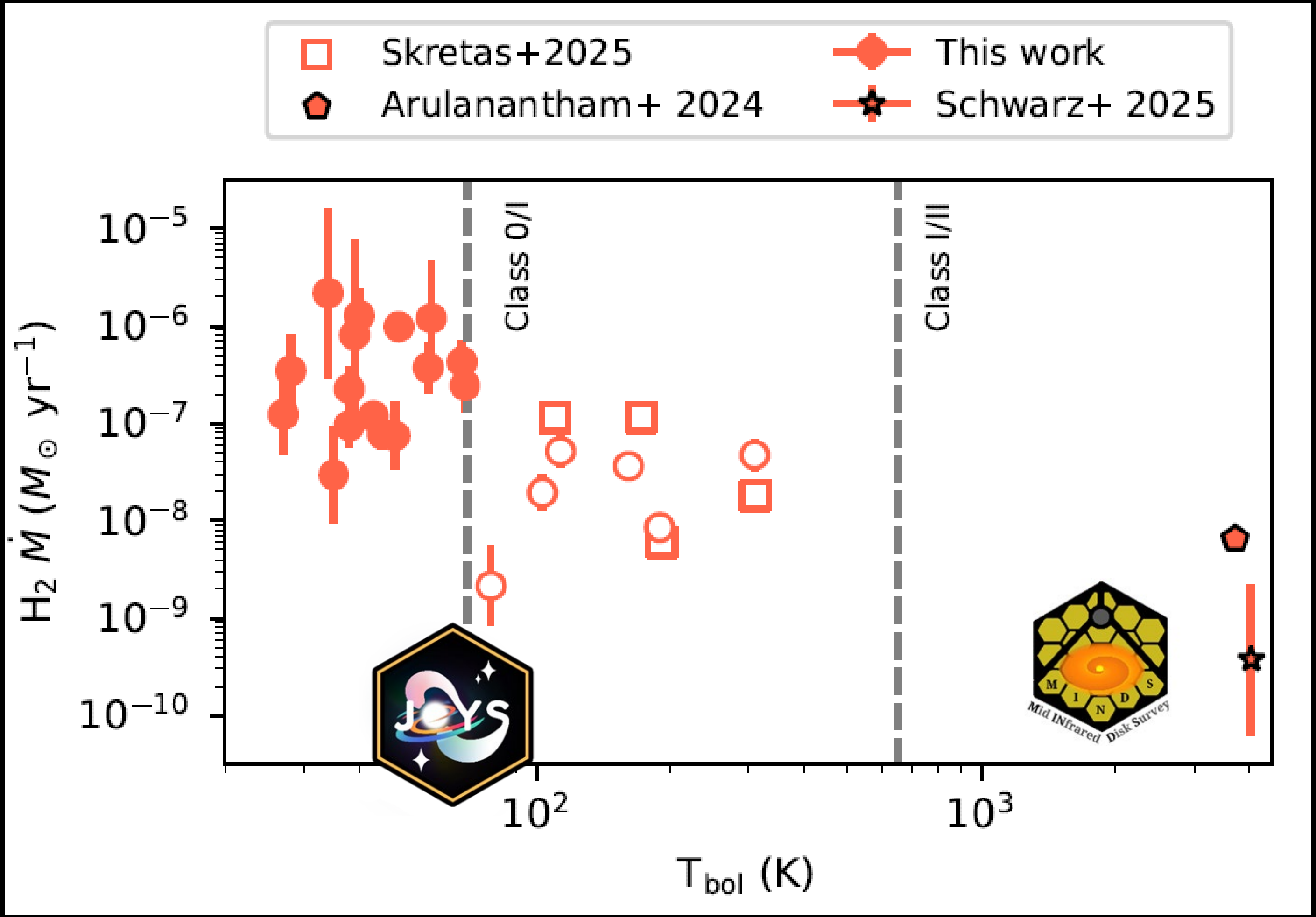


Pascucci et al. incl. TH 2024, NIRSpec

Also: Sturm et al. 2023, Delabrosse et al. 2024, Tychoniec et al. 2024, Federman et al. 2025, Tyagi et al. 2026, Francis et al. 2026

Origin disk wind: MHD wind
Photoevaporative wind

Evolution mass loss rate

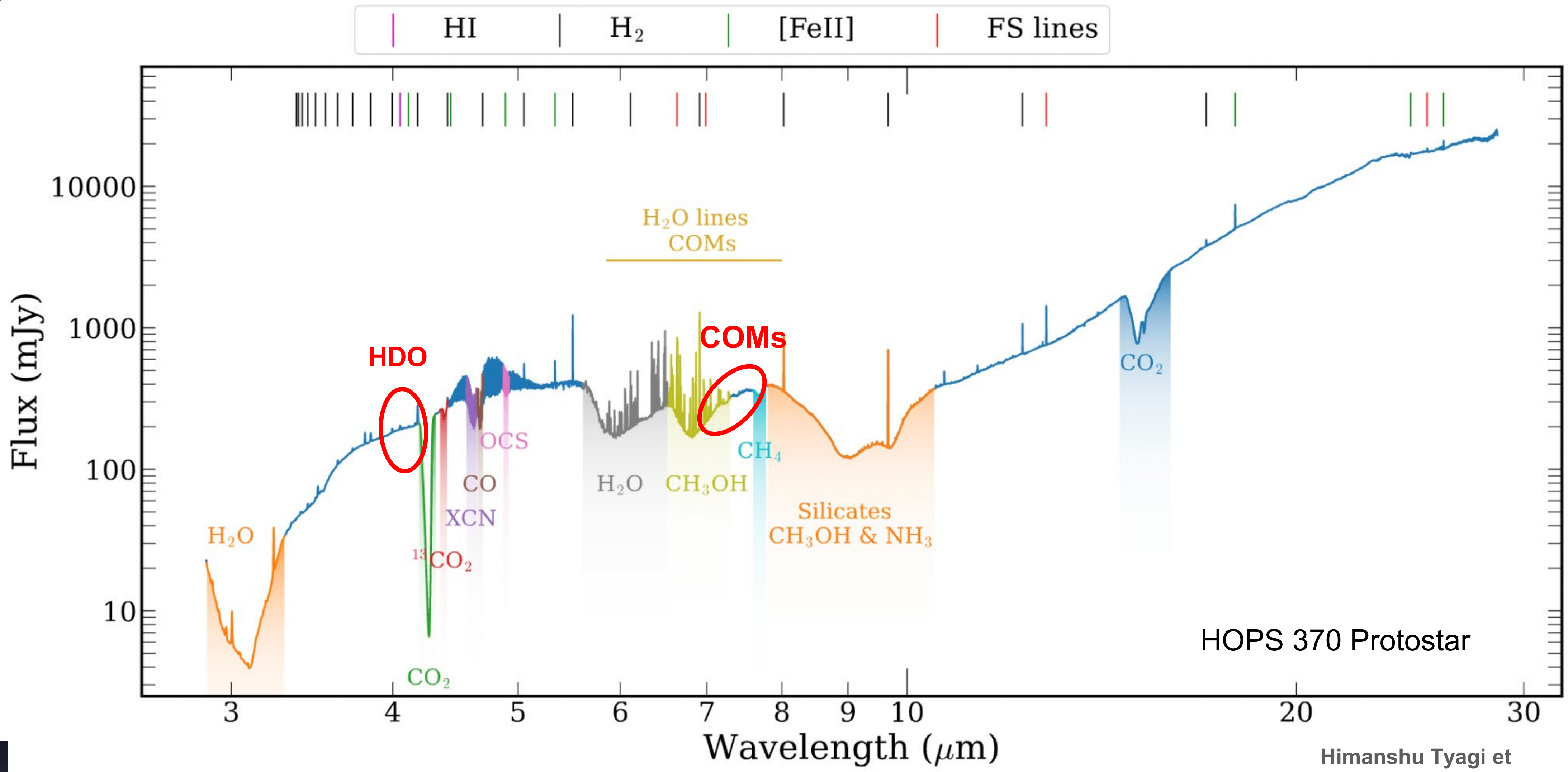


Francis+2026

- H_2 mass loss rate ~10% of accretion rate
- Factor 10-100 less than entrained mass loss rate from CO mm data

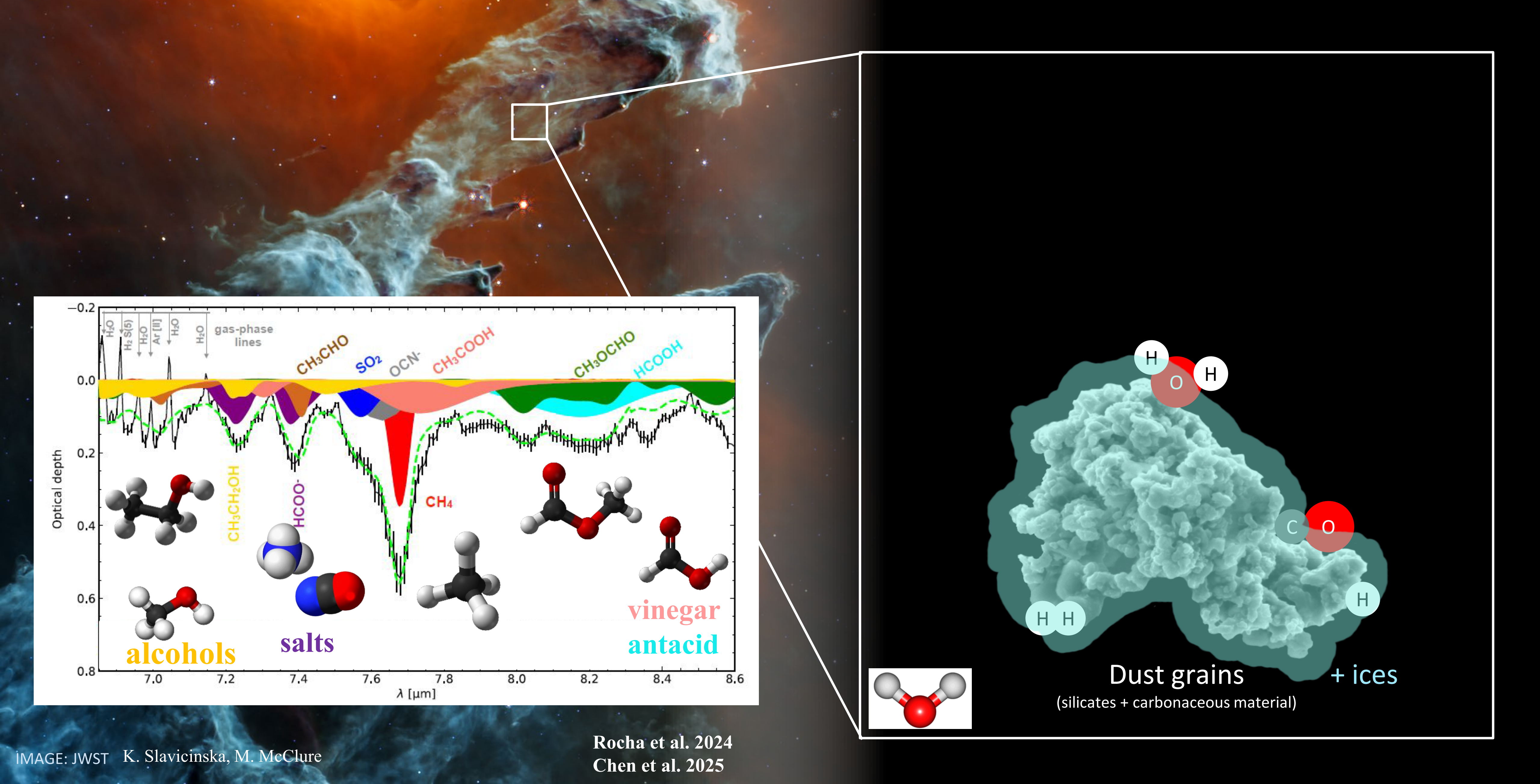
Ices: from outer envelope to disk

Full 3-27 μm spectra are rich in gas and ice features

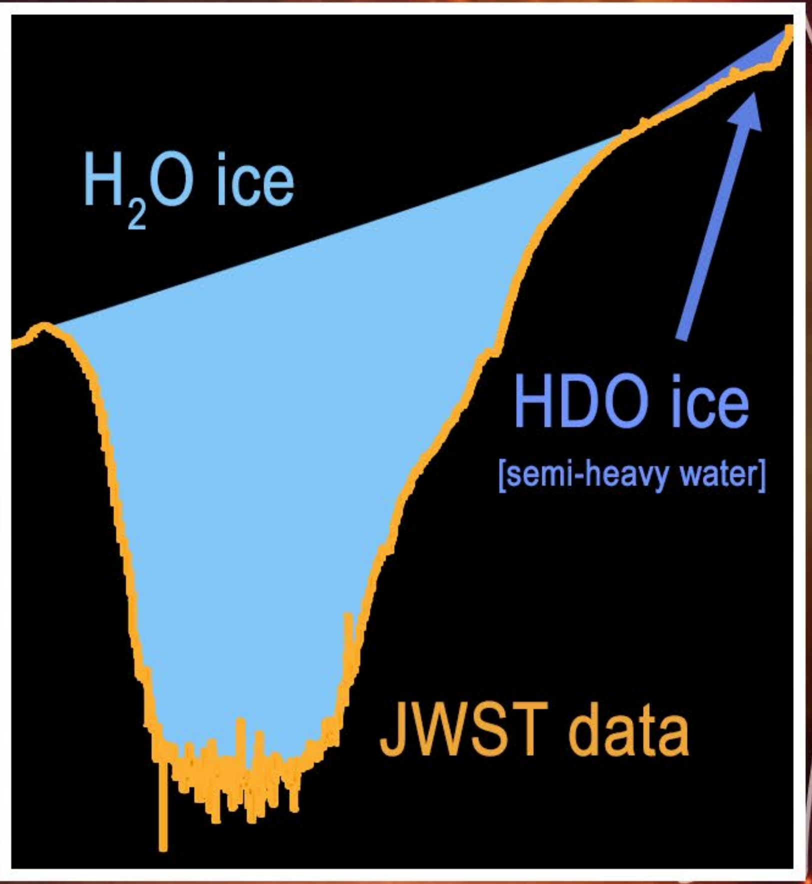


Himanshu Tyagi et al. 2024
IPA program
T. Megeath

Detection of complex molecules and salts in ices



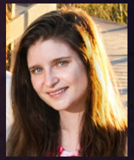
Tracing water's journey from disks to comets



planet-forming disk

HDO/H_2O~0.4%

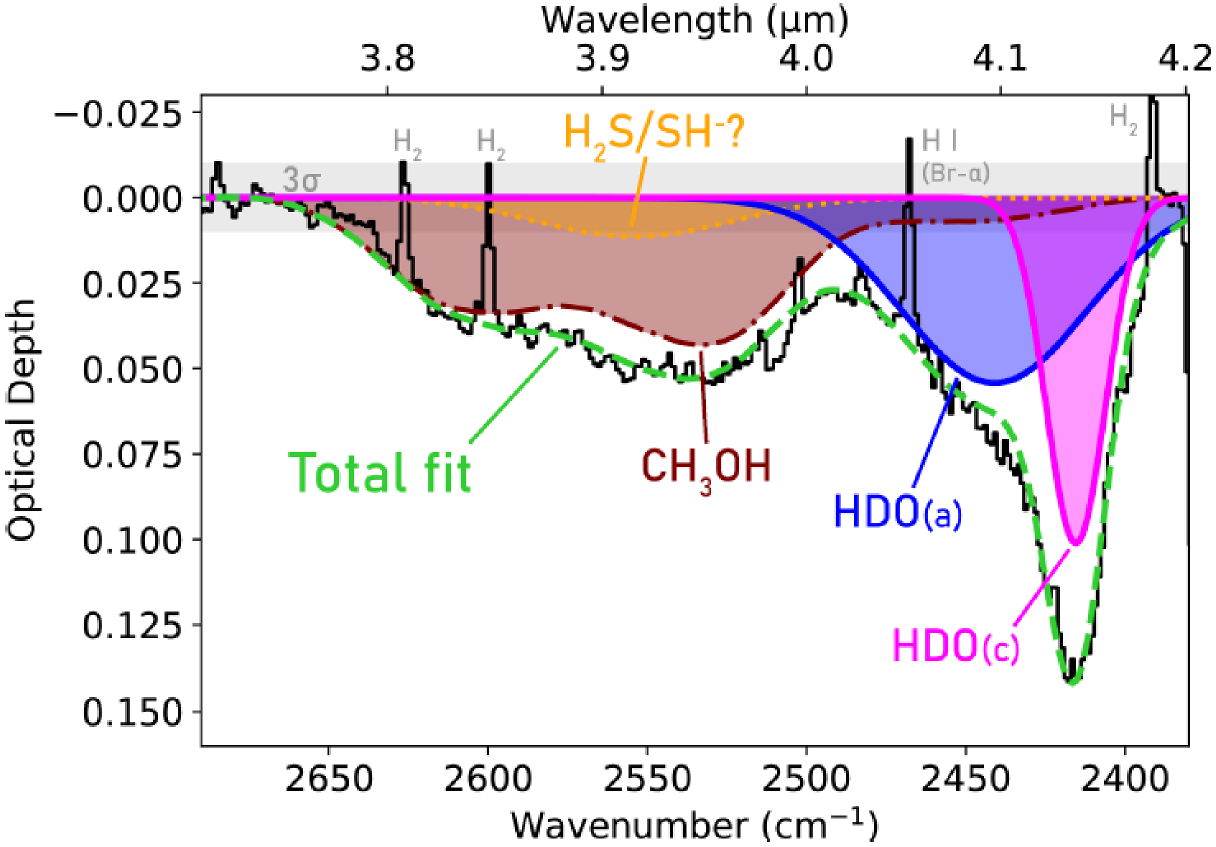
similar to disks, higher than comets



NASA, ESA, CSA, STScI; Image Processing: Joseph DePasquale (STScI), Alyssa Pagan

Slavicinska et al. 2025

HDO ice in solar mass protostar!



Low-mass YSO
L1527

Slavicinska et al. 2025b
NOVA press release June 17 2025

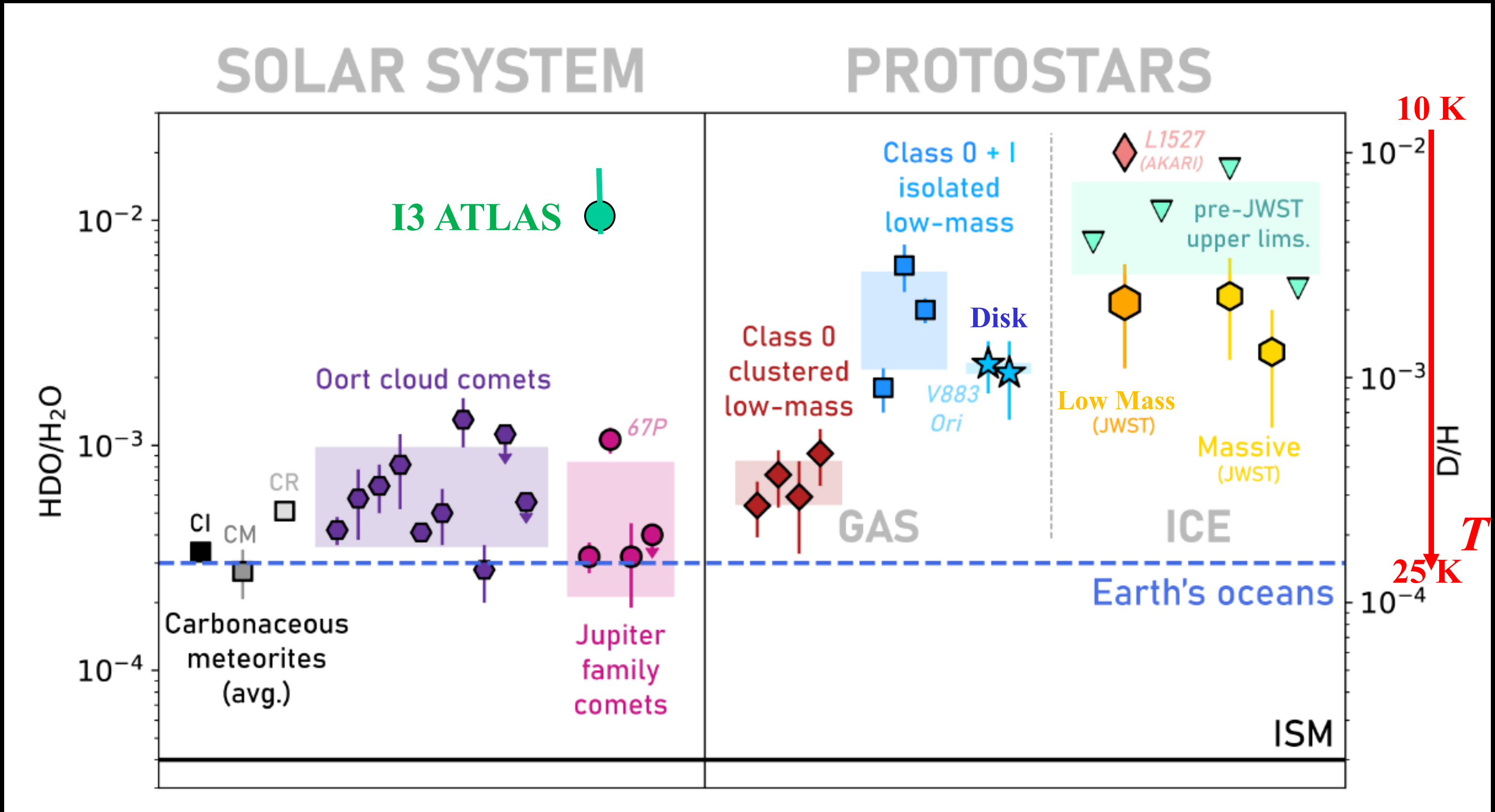
D/H in ices vs comets

IPA sources: high mass
JOYS+ sources, low mass B1-c

H_2O ice column
from 13 μm libration mode

Possible detection Aikawa et al. 2012, Akari

Inheritance HDO/H_2O from cloud to disk, higher than solar system comets



Ice data and figure by Slavicinska

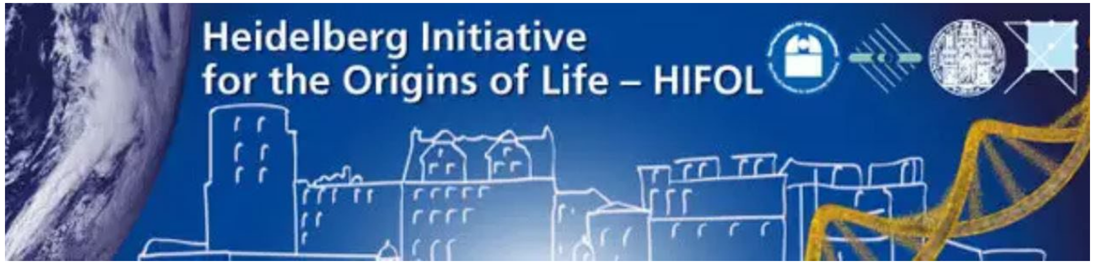
Gas phase HDO/H_2O similar to ice ratios and disk

Slavisinska et al. 2025b, 2026, vD et al. 2025
Altwegg et al. 2019, Jensen et al. 2019, Tobin et al. 2023

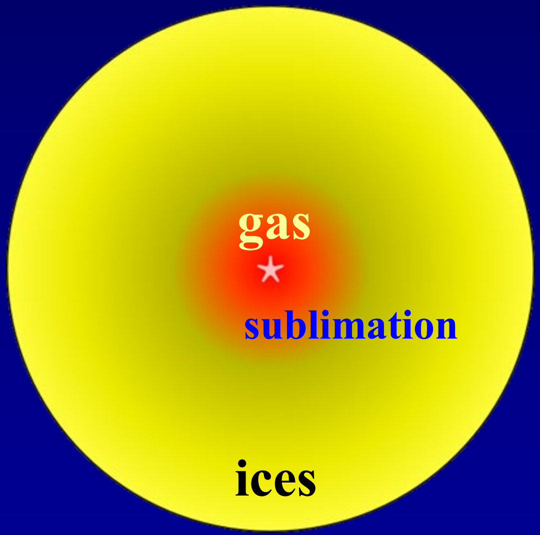
Points to icy planetesimals formed at a range of temperatures

Summary ices

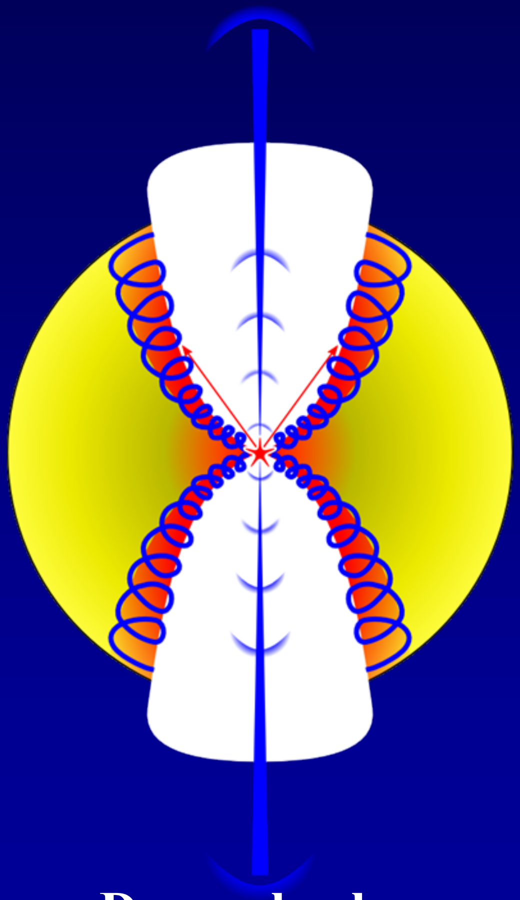
- Ice inventories at the earliest pre- and protostellar stages: ices form early
- Ice features as diagnostics of heating, $^{12}C/^{13}C$
- COMs formed and detected in ices
  - subsequent chemistry upon sublimation
- HDO/H_2O ice points to inheritance cloud to disk
- Sulfur budget: ~20% of S in salts: NH_4SH



Gas: molecules



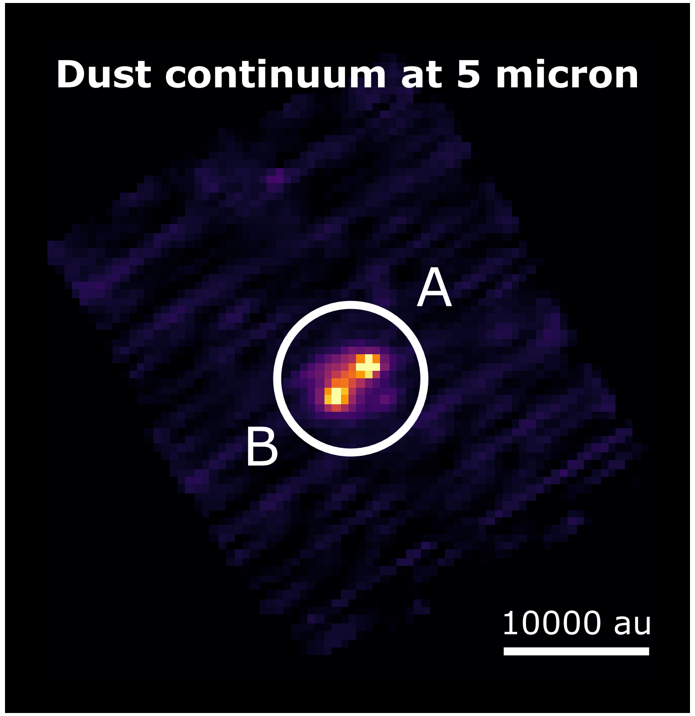
Hot core:
Sublimation of ices

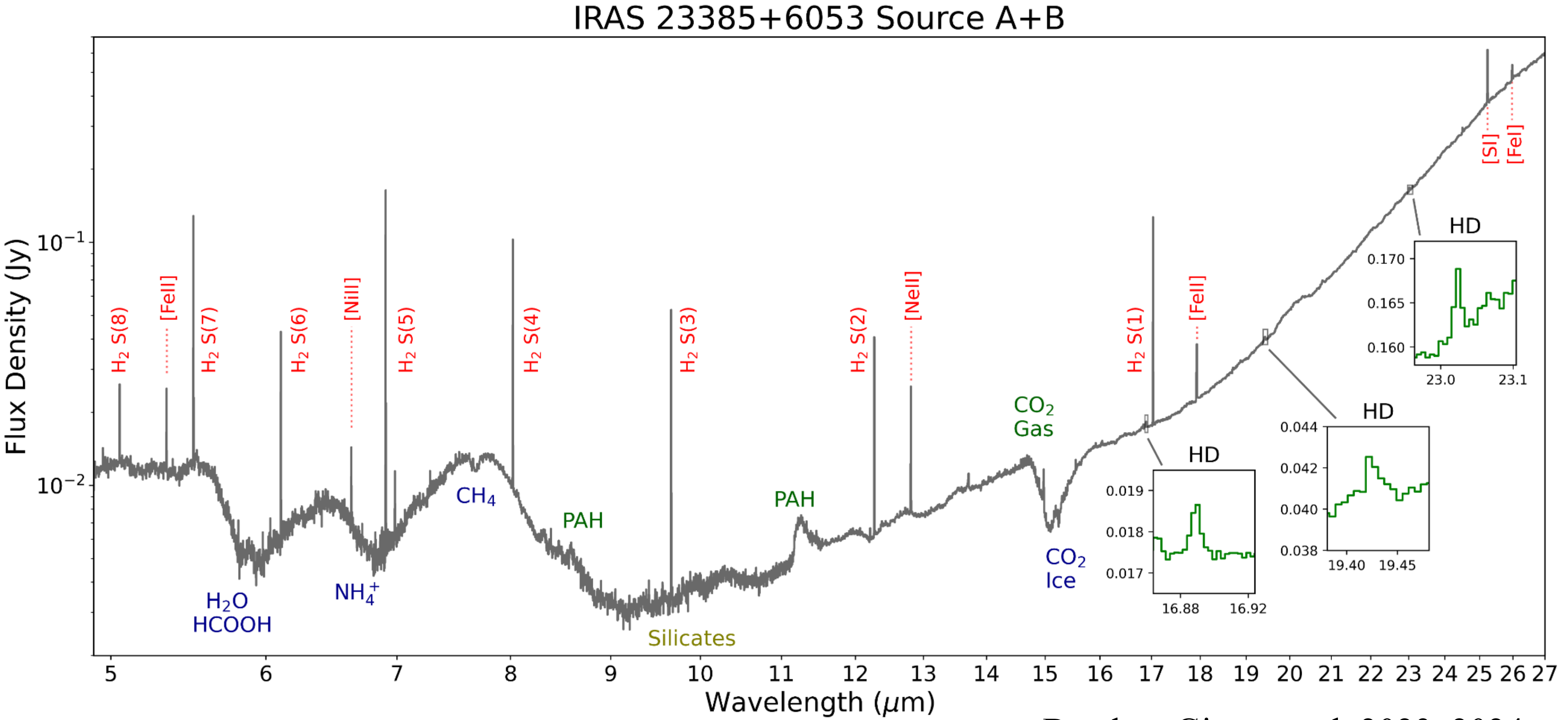


Dense shocks

JOYS: high-mass protostar

- High-mass protostar at 4.9 kpc in outer Galaxy with $L = 3000\ L_{\odot}$
- Resolved into a binary at MIR

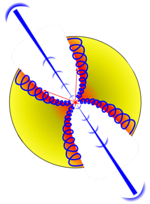


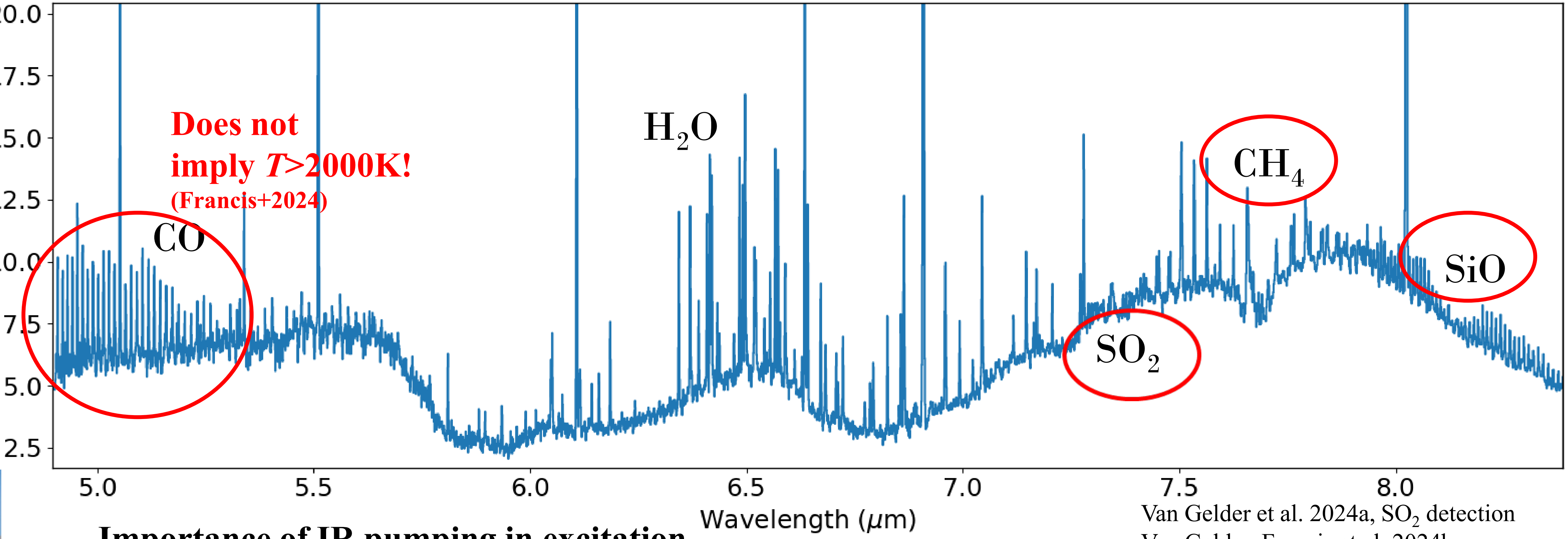


Beuther, Gieser et al. 2023, 2024

Very rich molecular spectra

L1448-mm: Class 0 low-mass YSO: **hot core vs dense shocks**

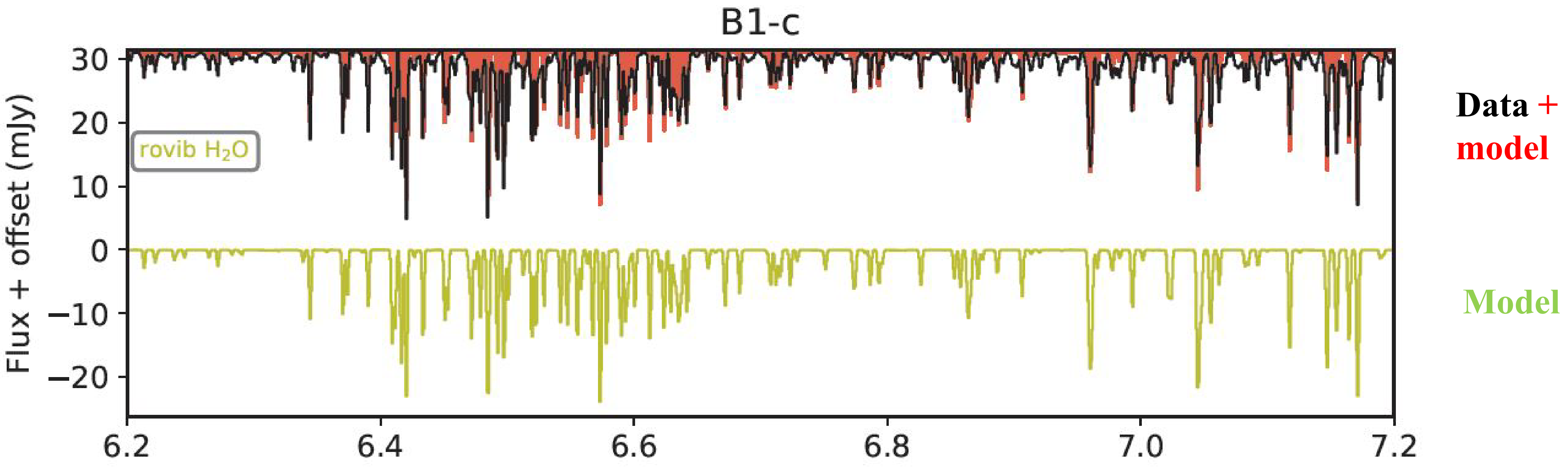




Importance of IR pumping in excitation

Van Gelder et al. 2024a, SO_2 detection
Van Gelder, Francis et al. 2024b

Low-mass hot core B1c: absorption!



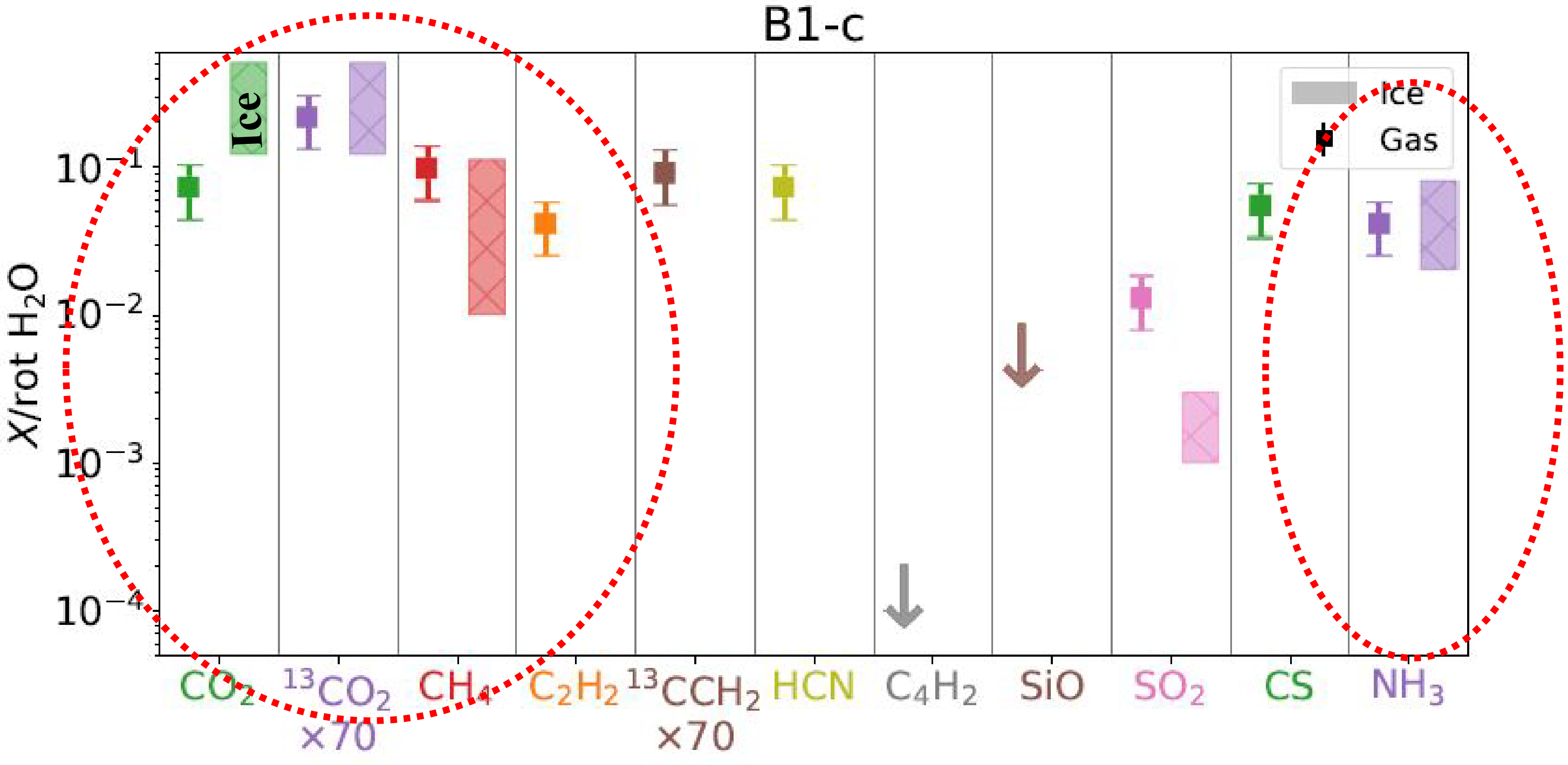
Low-mass protostar with hot core seen in complex molecules with ALMA

Van Gelder et al. 2024b

Sublimating ices: cinematic edition

B1-c low-mass hot core

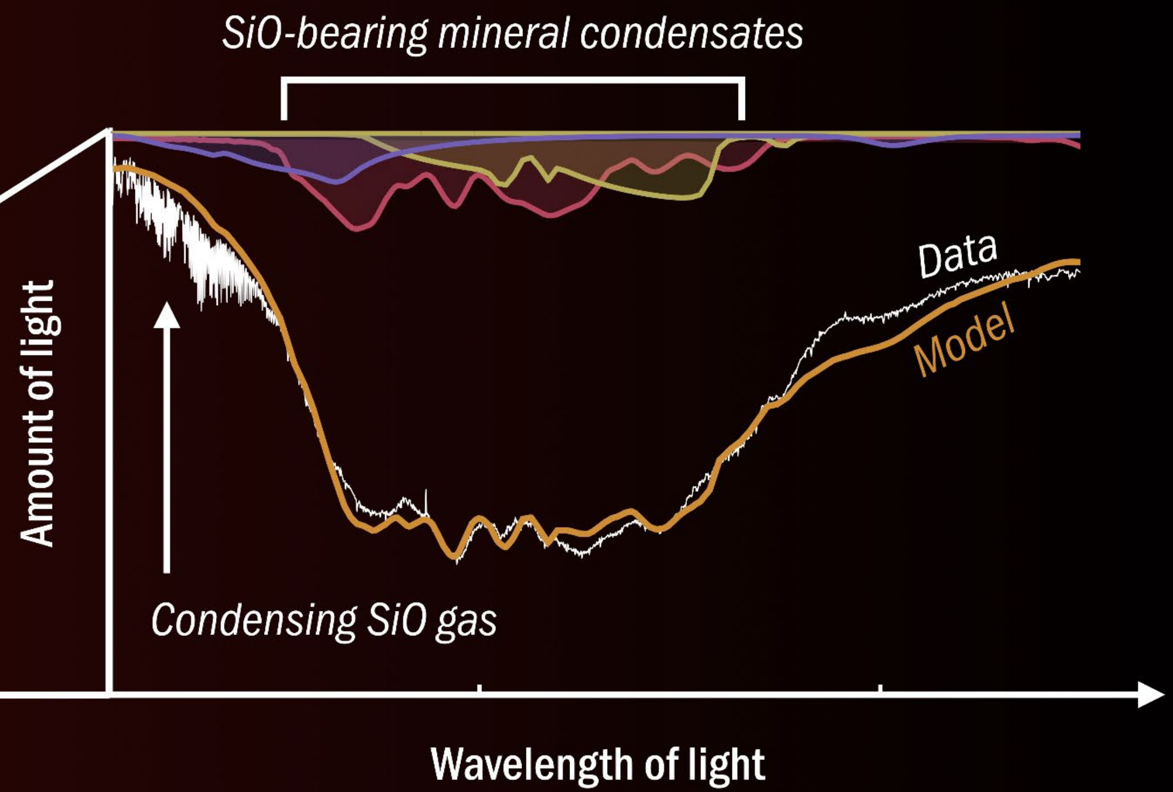
Directly comparing gas and ice abundances: consistent with ice sublimation → Hot core

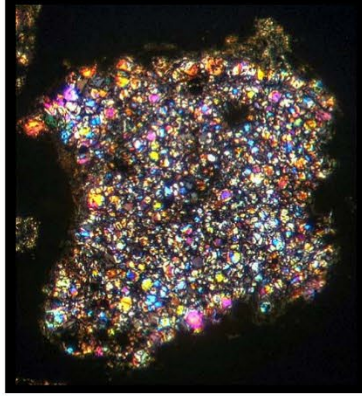


Ice sublimation (B1c) vs shock chemistry (L1448)

Van Gelder et al. 2024b

Young disks: dust condensation

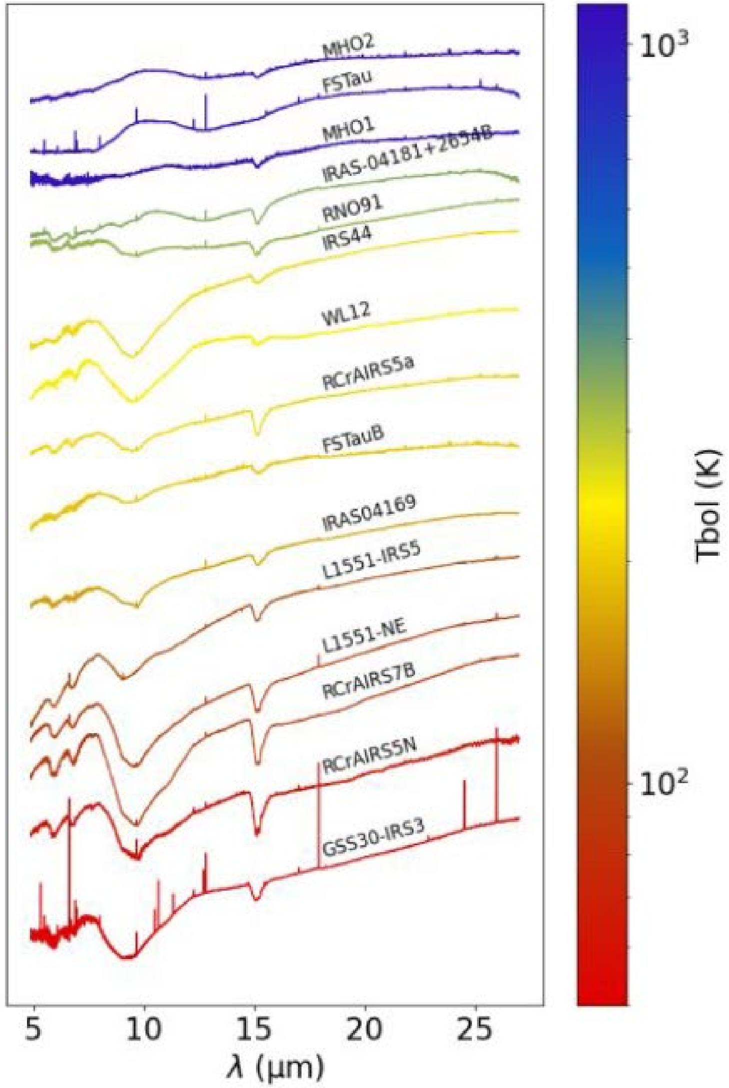


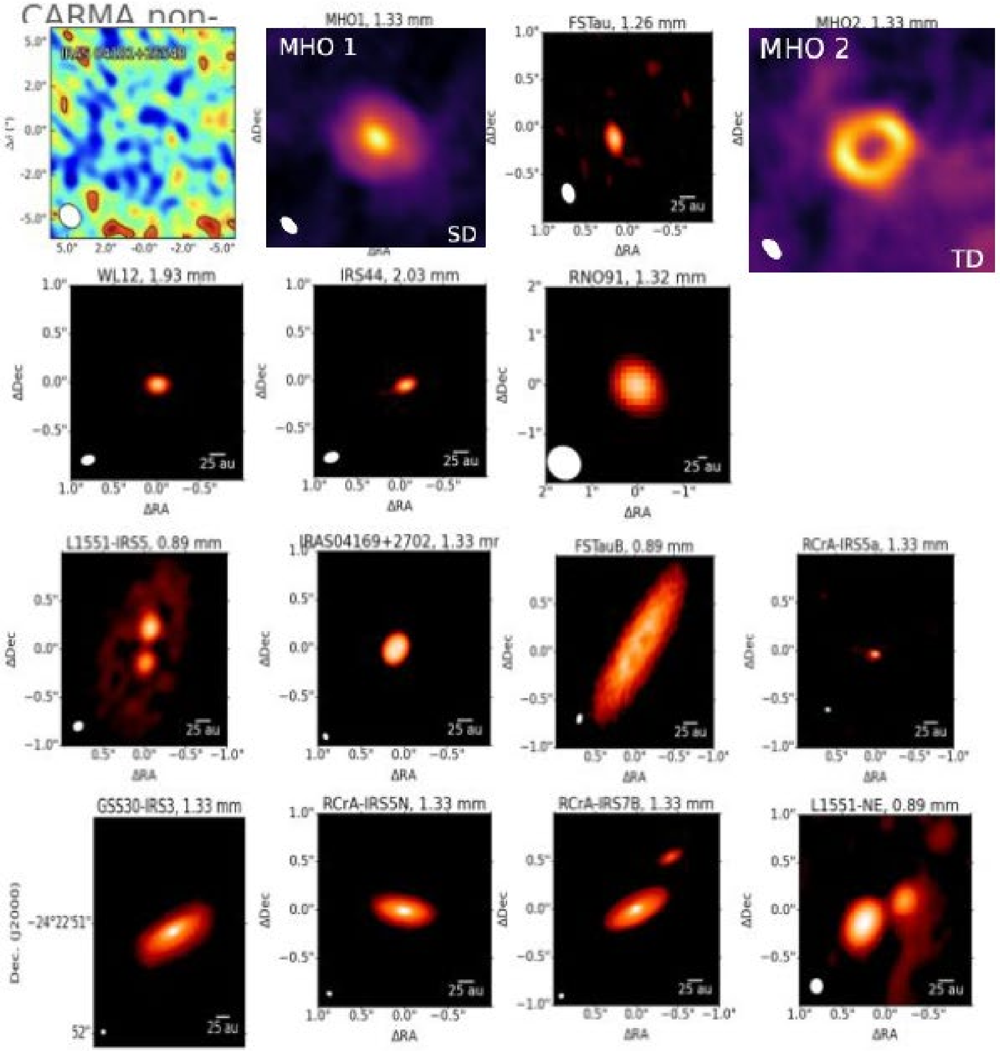


Meteoritic mineral condensates are oldest solid relicts of young Solar System.

M. K. McClure et al. (2025), Nature

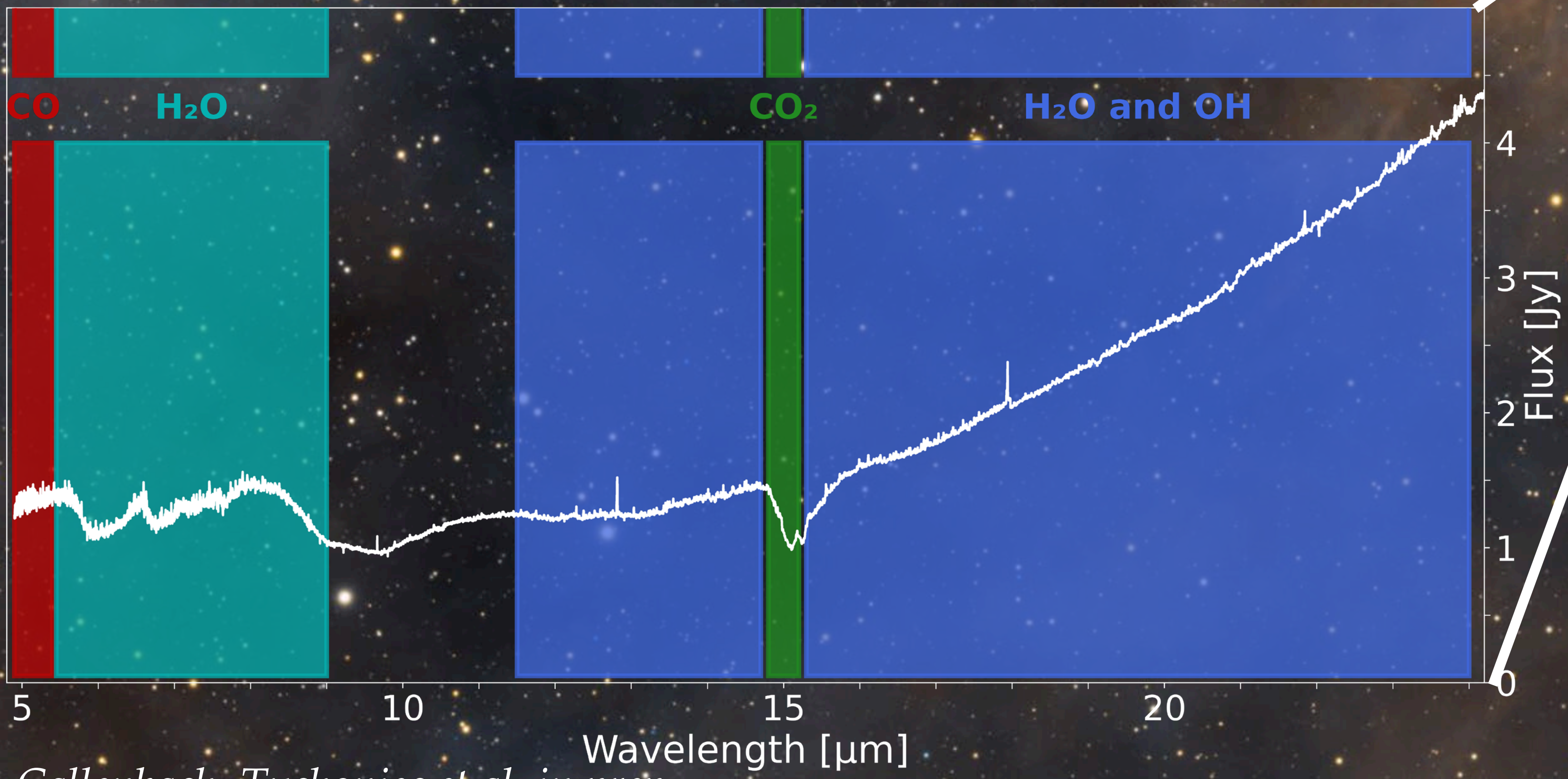
Next step: Young Disks linking JOYS and MINDS





Courtesy of Ł. Tychoniec

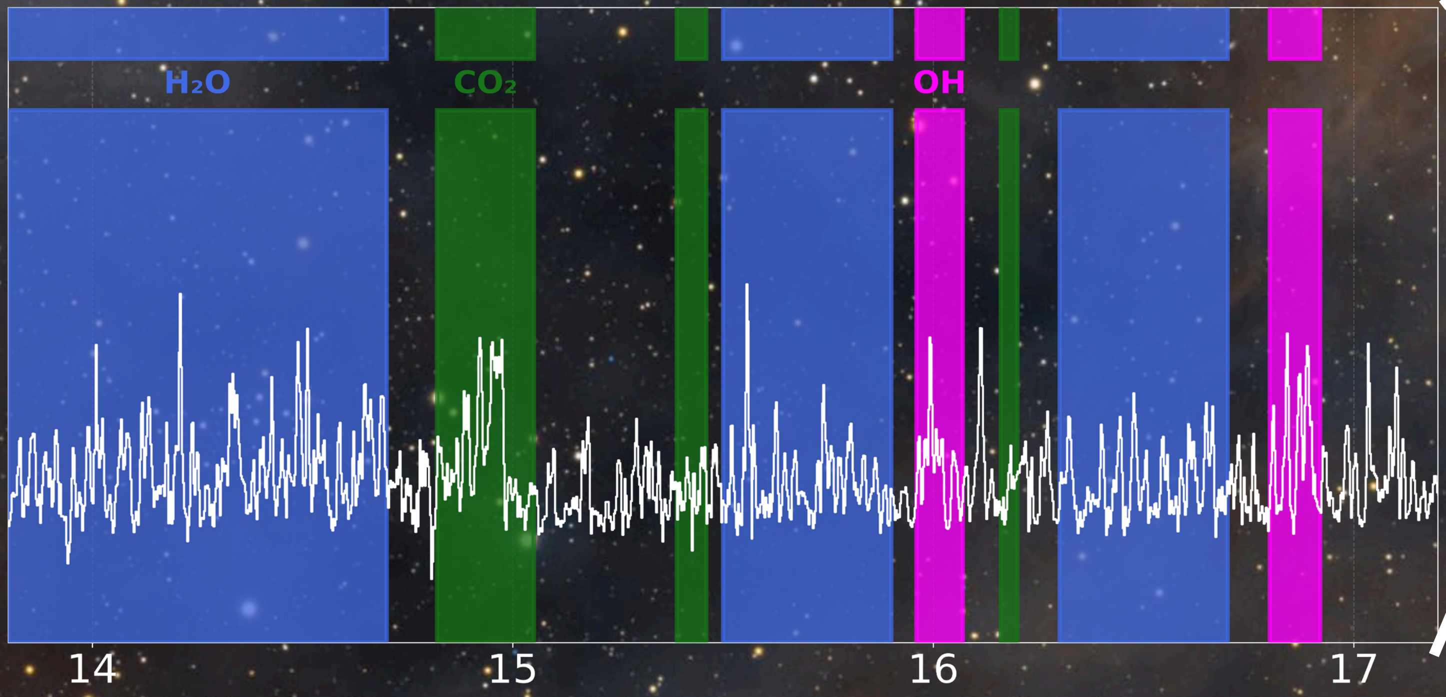
H_2O-rich gas in the planet-forming regions of a young embedded disk



Callenbach, Tychoniec et al. in prep.

Photo credit: instagram.com/bolahdan

H_2O-rich gas in the planet-forming regions of a young embedded disk



Callenbach, Tychoniec et al. in prep.

Photo credit: instagram.com/bolahdan

Thanks for making MPIA such a welcoming place!

…and for training the next generation: 90+ PhD students, ~80+ postdocs

A toast to Thomas!