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Mapping the Distribution of Solid Icy Material in Star-Forming Regions

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On behalf of ***"IDATSE - Ice Distribution Across Time & Space Epochs"***
a team of' prospective' JWST observers from the ice community including
(Whittet, Pontoppidan, Boogert, Oberg, Shimonishi, Olivera, Gerrakines)
and the many Astrochemistry Group Members who contributed including
(Aleksi Suutarinnen / Jennifer Noble / Alison Craigon / Anita Dawes)

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Why ice?

IMPACT of “cold” solid–state “stuff” on astrophysics

- Pre-stellar clouds
- Proto-planetary disks
- Comets & ‘ice-teroids’
- (Exo)planets & moons
- Extra-galactic SF

“Ethanol” (or other alcohols i.e methanol)

- COMS
- Life?
- 1st COMS z= ?

ICE = largest molecular reservoir in Universe (excluding (H_2))

In SFR SOLID H_2O = more abundant than gas-phase CO!!!!!!!

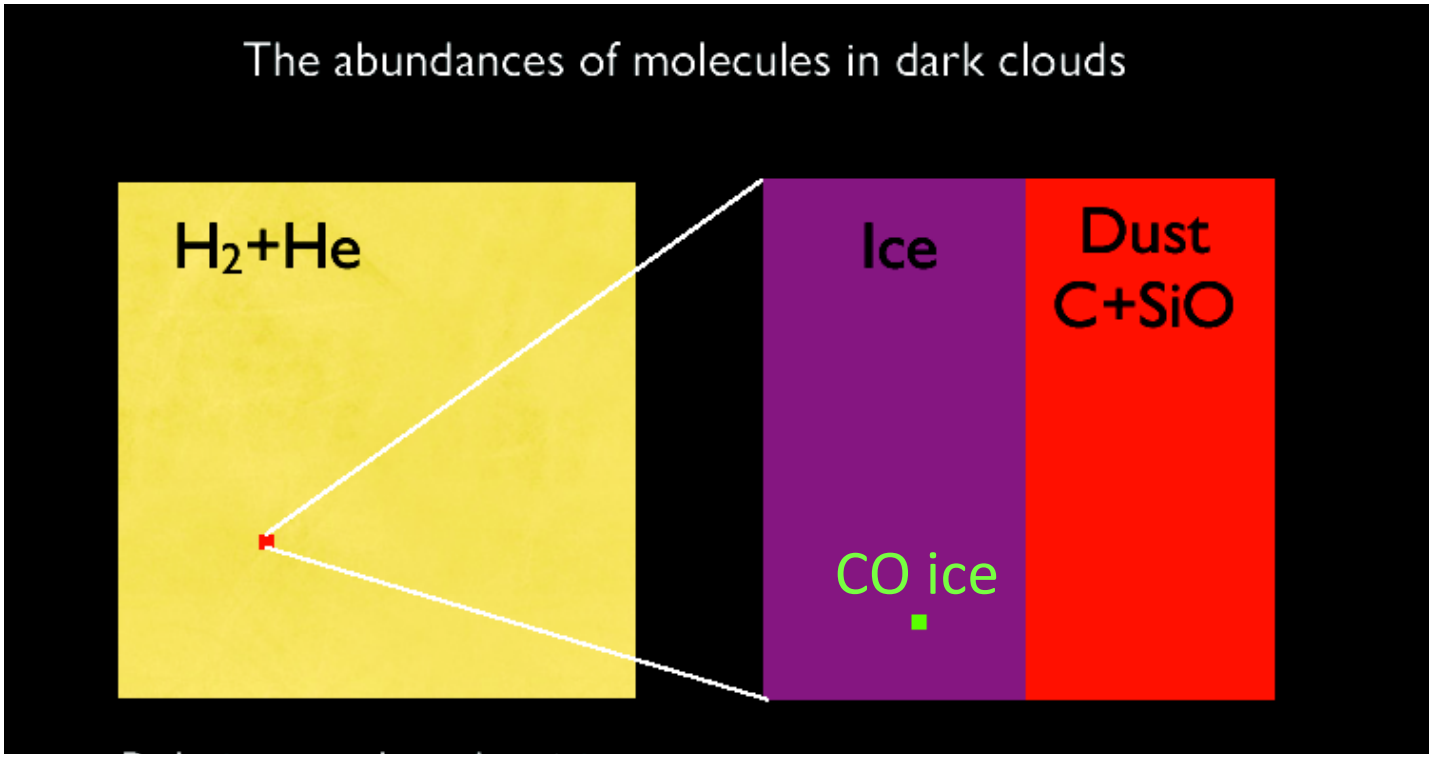

Image courtesy of K Pontoppidan

Affects gas-solid synergy (molecular reservoir (trapping))

→ Affects grain sticking (ice porosity = "glue")

Affects reactivity (binding sites and surface area) / H_2 formation

Affects mobility (deuteration exchange & outgassing)

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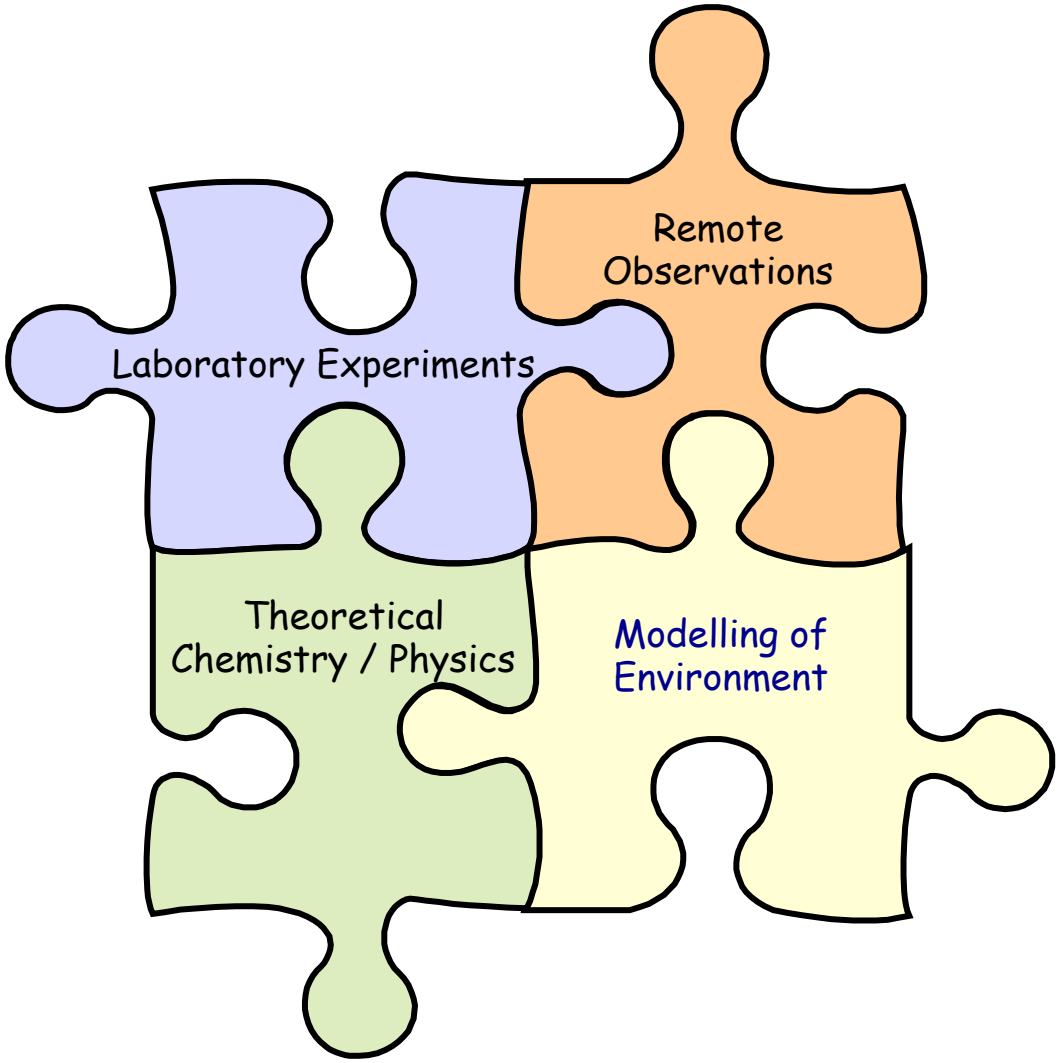
Bottom Line

From observations we want to know

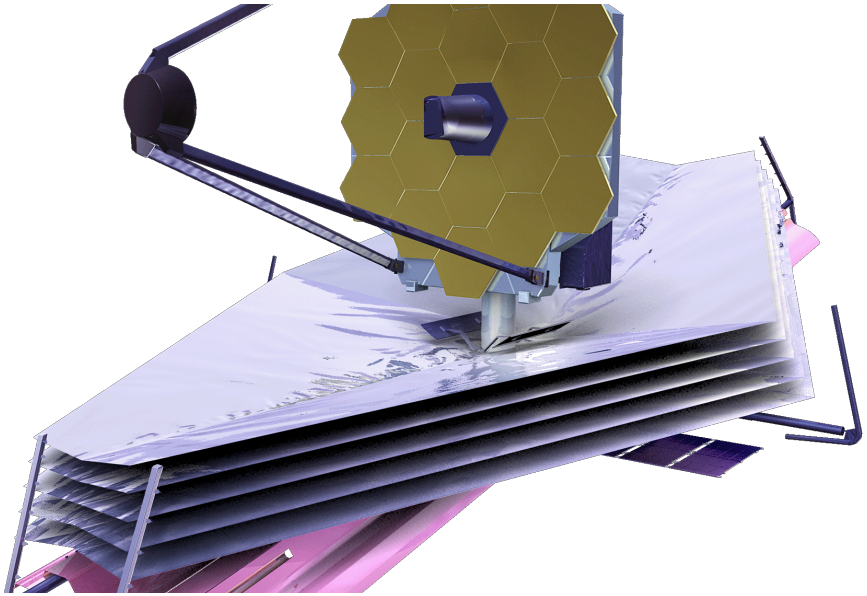
How much ice?
What type of ice?
Where is it?

How do we build understanding?



It's still a
HUGE
issue where support data comes from and how it is accessed

JWST - advantages



Parallel observing

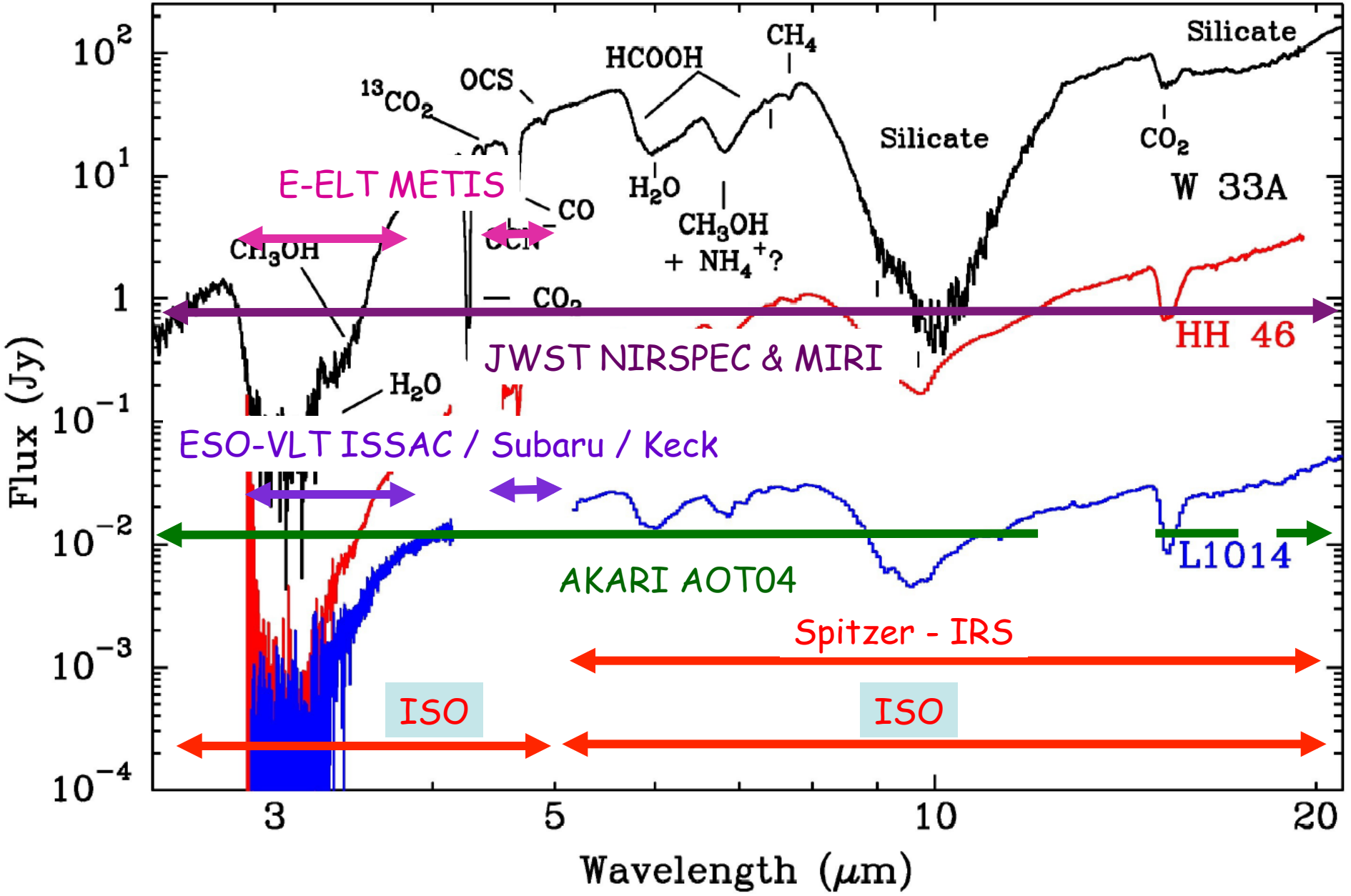
Spectral Coverage

Resolution

Sensitivity

NIRSpec: (masked) spectroscopy 1-5 μm at R=100-3000 **PLUS**
MIRI: imaging (+ coronagraphy) and spectroscopy 5-28 μm at R=100-3000
NIRCam: 1-5 μm narrow and broad band imaging (including coronagraph) (slitless spectroscopy)

Spatial resolution 3-28 μm: 0.12-1.1 arcsec (21-190 AU for cloud at 150 pc distance)



van Dishoeck et al., Pacific-Chem Proceedings (2006)

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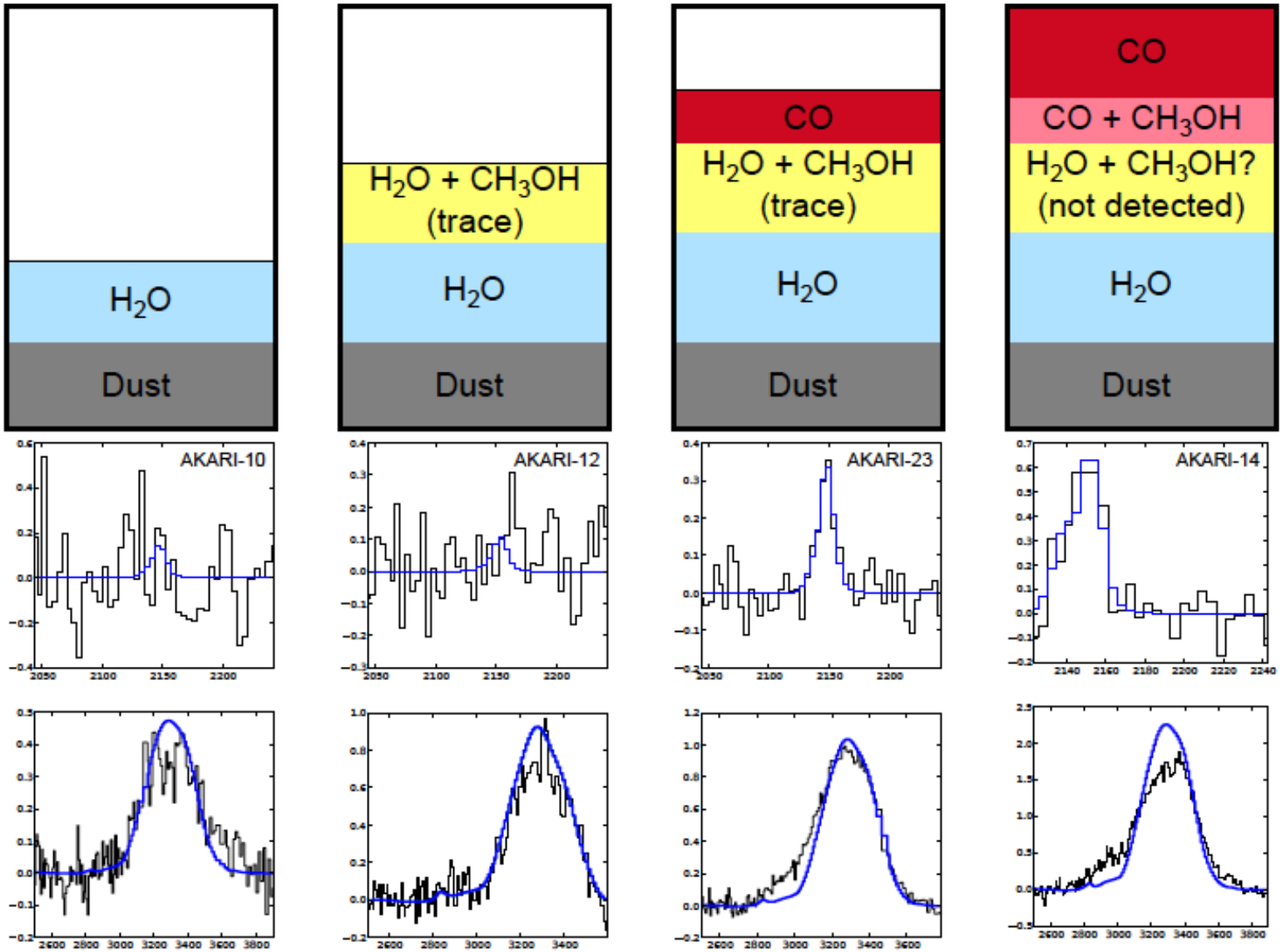
Methanol-
The case for NIR + MIR Spectroscopy

Requires CO freeze-out to form

Needed to form COMS

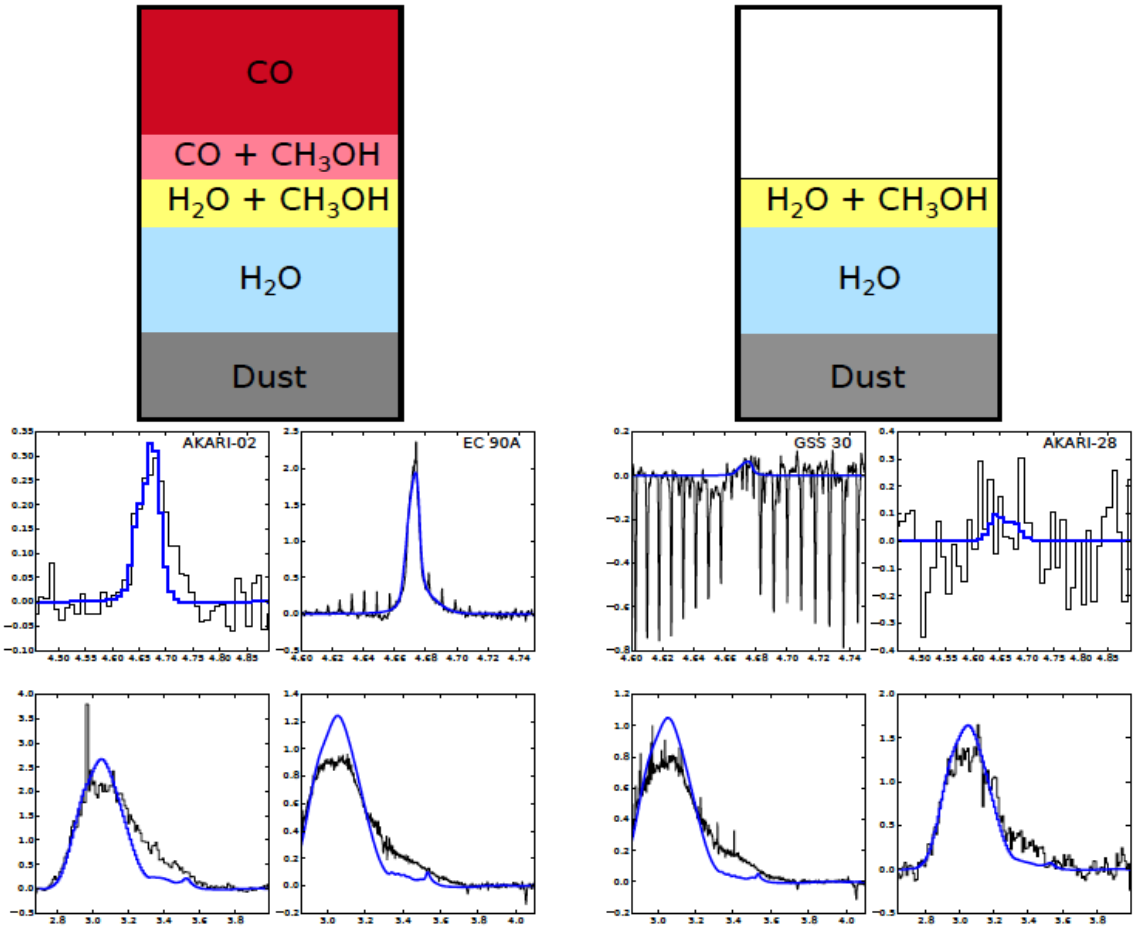
Evolution and Chemistry from multi-wavelength data: Pre-stellar

Suutarinen et al MNRAS (2015) submitted



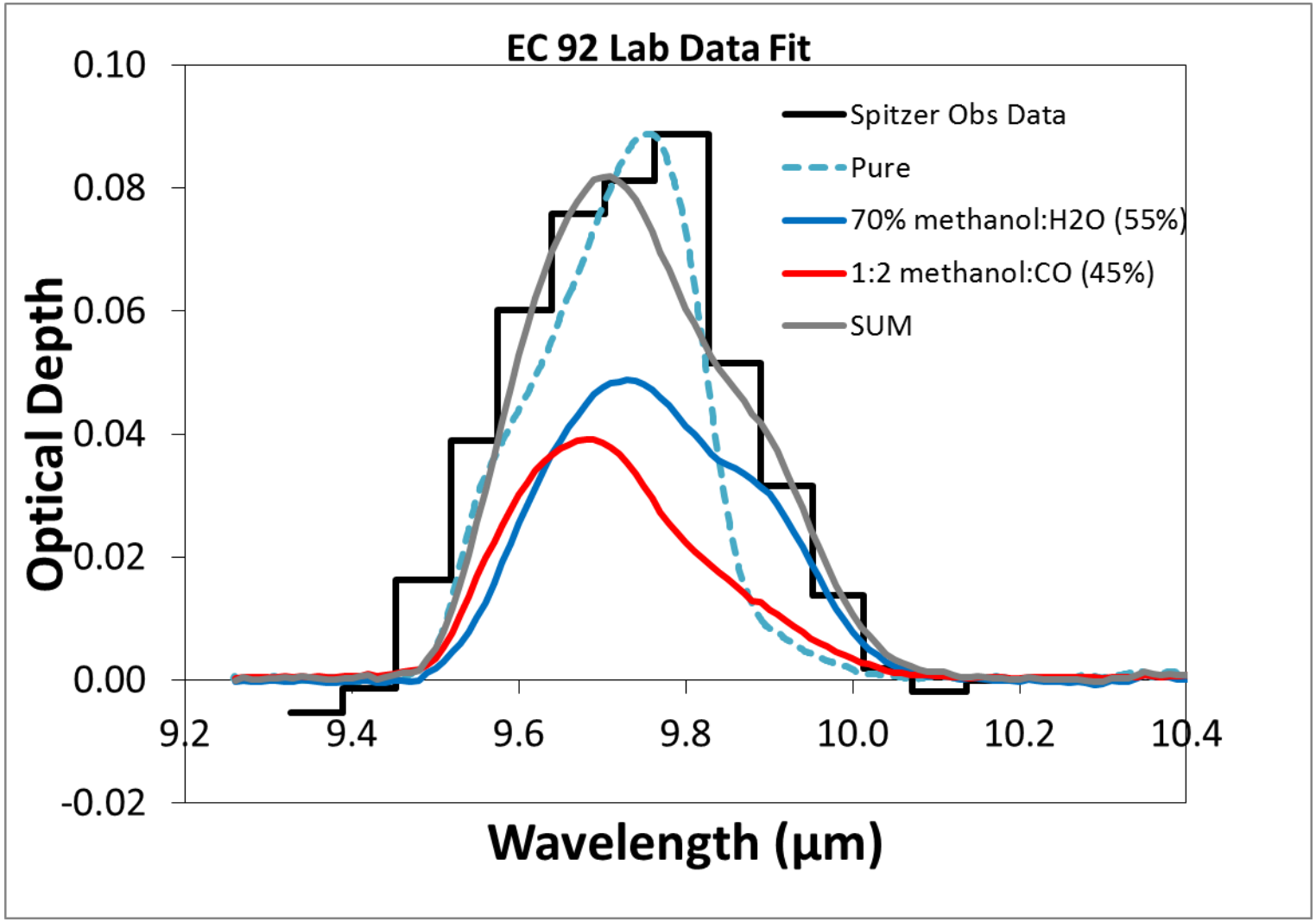
Linking Spectroscopy to Modeling: Proto-stellar

Suutarinen et al MNRAS (2015) submitted

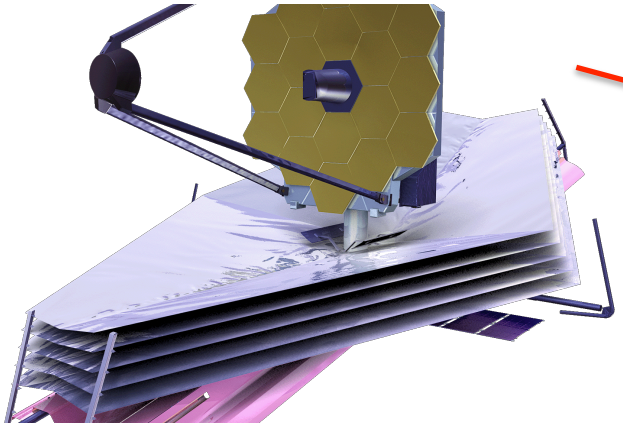


From NIRSpec to MIRI …

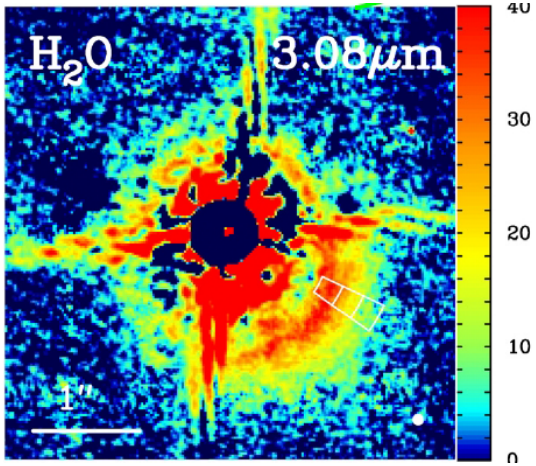
Dawes et al MNRAS (2015) in prep



JWST – “Ice Cool”….



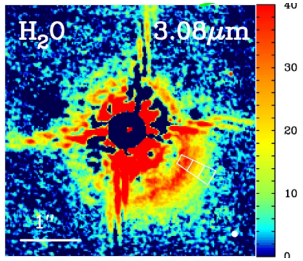
Coronagraphic spectrophotometry (+adaptive optics)
Herbig Ae star HD 142527
3 μm ‘image of disk ice band in scattered light.
(Honda et al (2009)

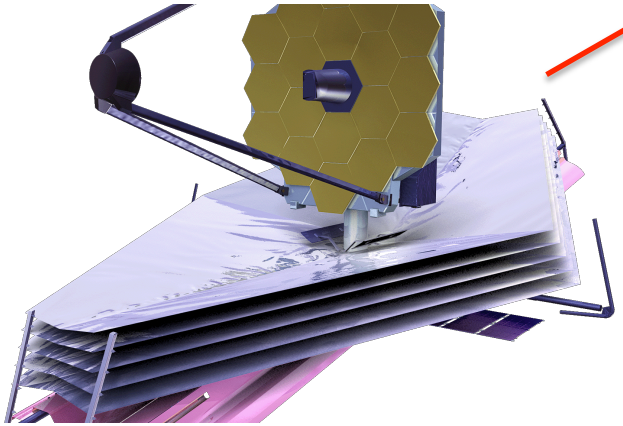


NIRCam / JWST with coronograph
Scattered light probes older more tenuous disks cf absorption = larger evolutionary range

JWST – “Ice Cool”….

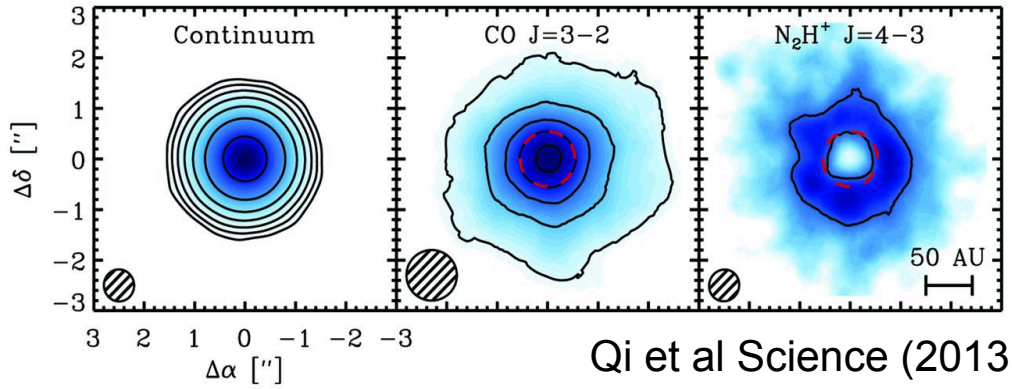
NIRCam / JWST with coronograph



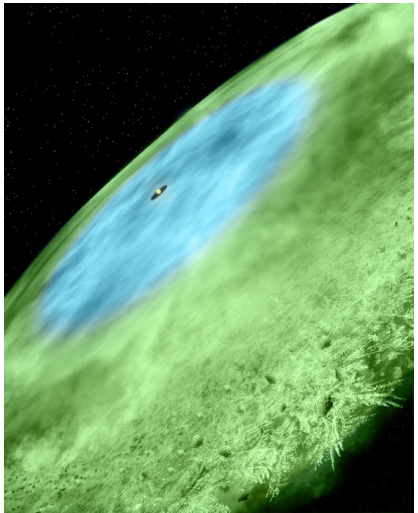


NIRSPEC + MIRI / JWST
“routine” observations

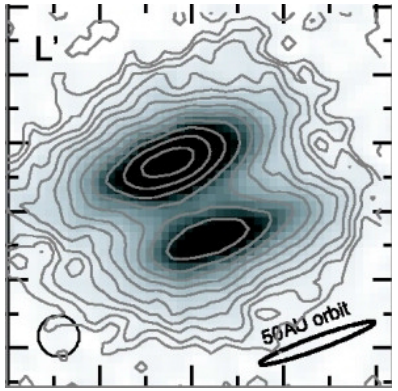
ALMA / JWST “snow-line” imaging



Qi et al Science (2013)

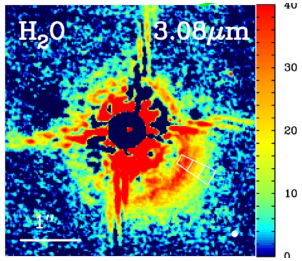


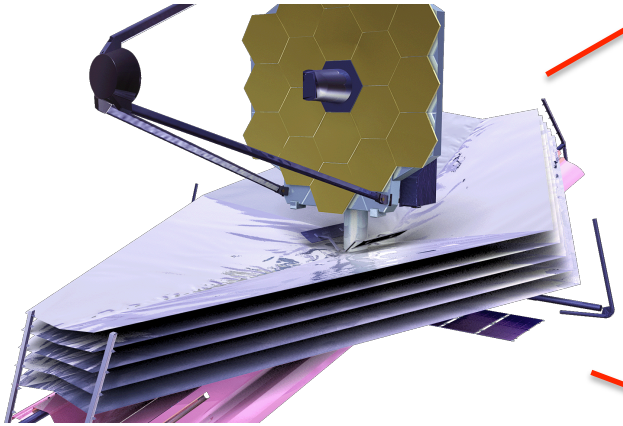
HV Tau C
Terada et al. (2007, 2012)
1X1'' FOV@0.12” FWHM

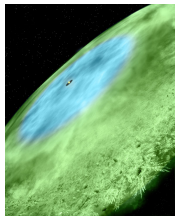


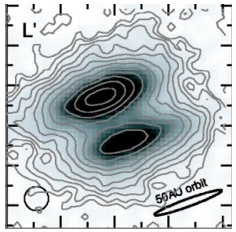
JWST – “Ice Cool”….

NIRCam / JWST with coronograph





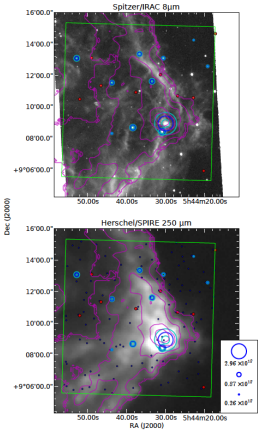




NIRSPEC + MIRI / JWST

Ice Mapping

NIRSPEC + NIRCam + MIRI / JWST



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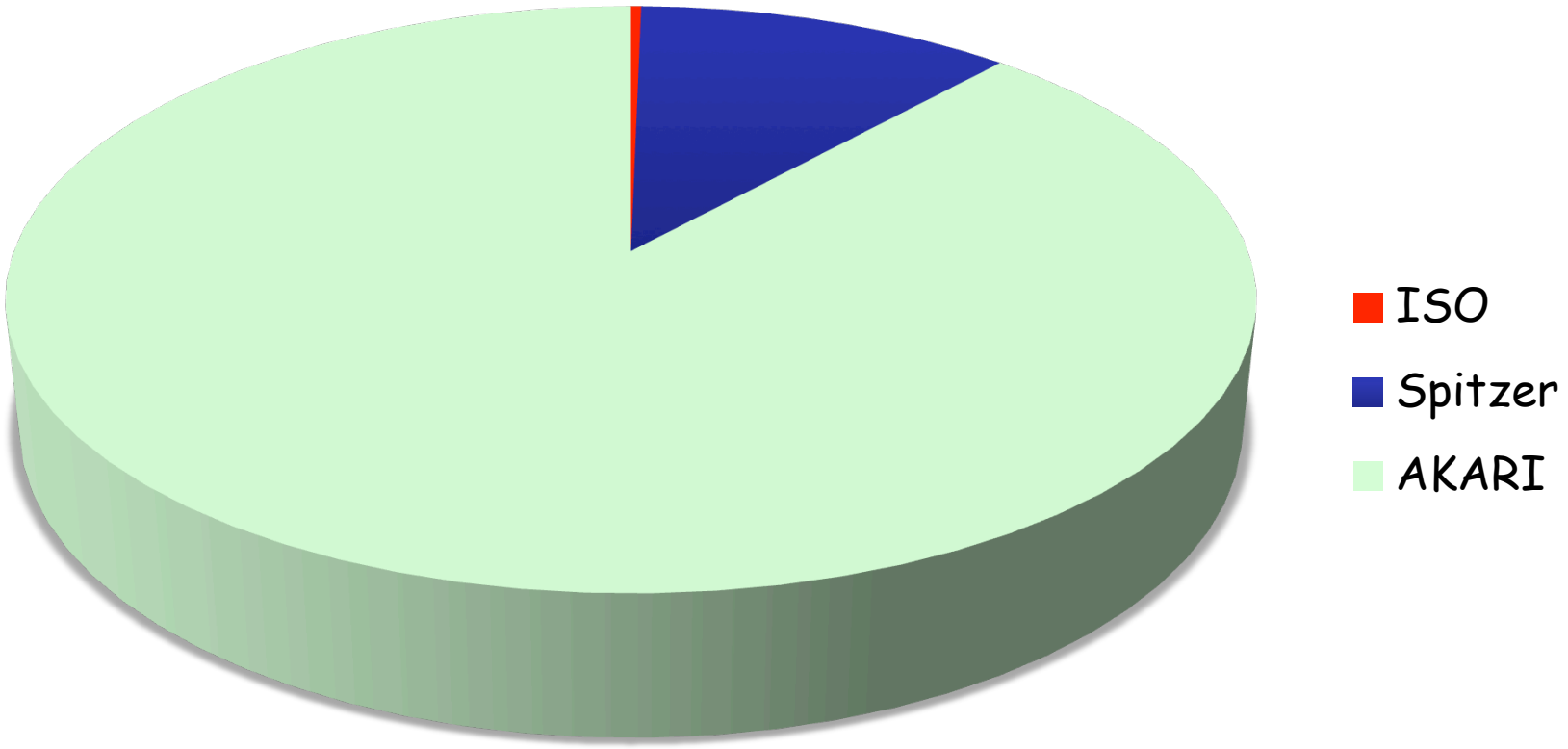
Pre-stellar Cores (Interstellar Ice)


MATTHEW McCONAUGHEY
ANNE HATHAWAY
JESSICA CHASTAIN
MICHAEL AND CAINE
THE END OF EARTH WILL NOT BE THE END OF US.
FROM THE DIRECTOR OF THE DARK KNIGHT TRILOGY AND INCEPTION
INTERSTELLAR
COMING SOON


A FILM BY CHRISTOPHER NOLAN
INTERSTELLAR
IN CINEMAS NOVEMBER 7

No. of Observed Background Stars with Ice



CAVEAT:- Current background star ice observations trace ices well before collapse.

AKARI Slitless Spectroscopy Legacy

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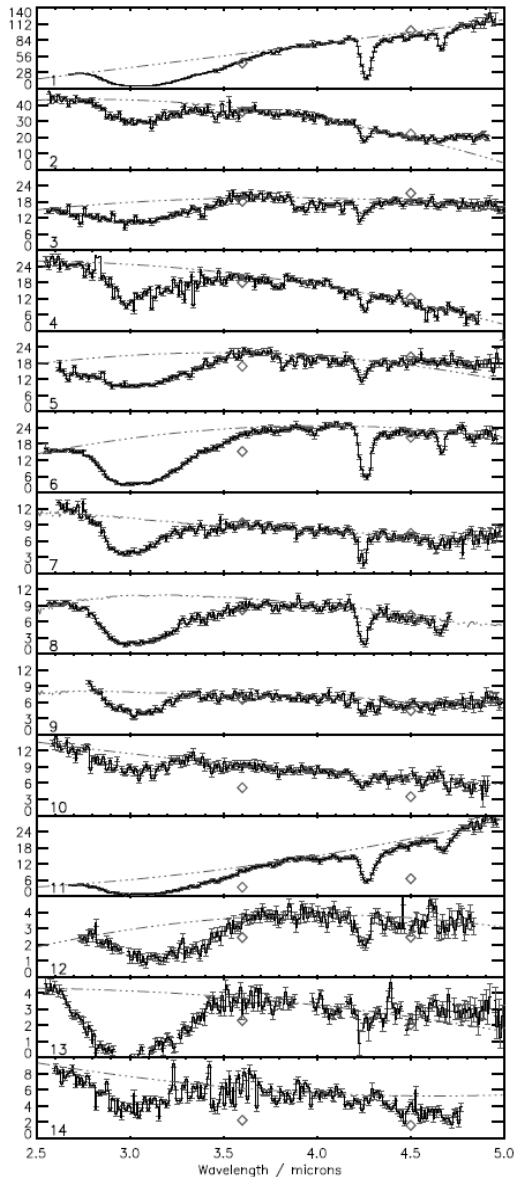
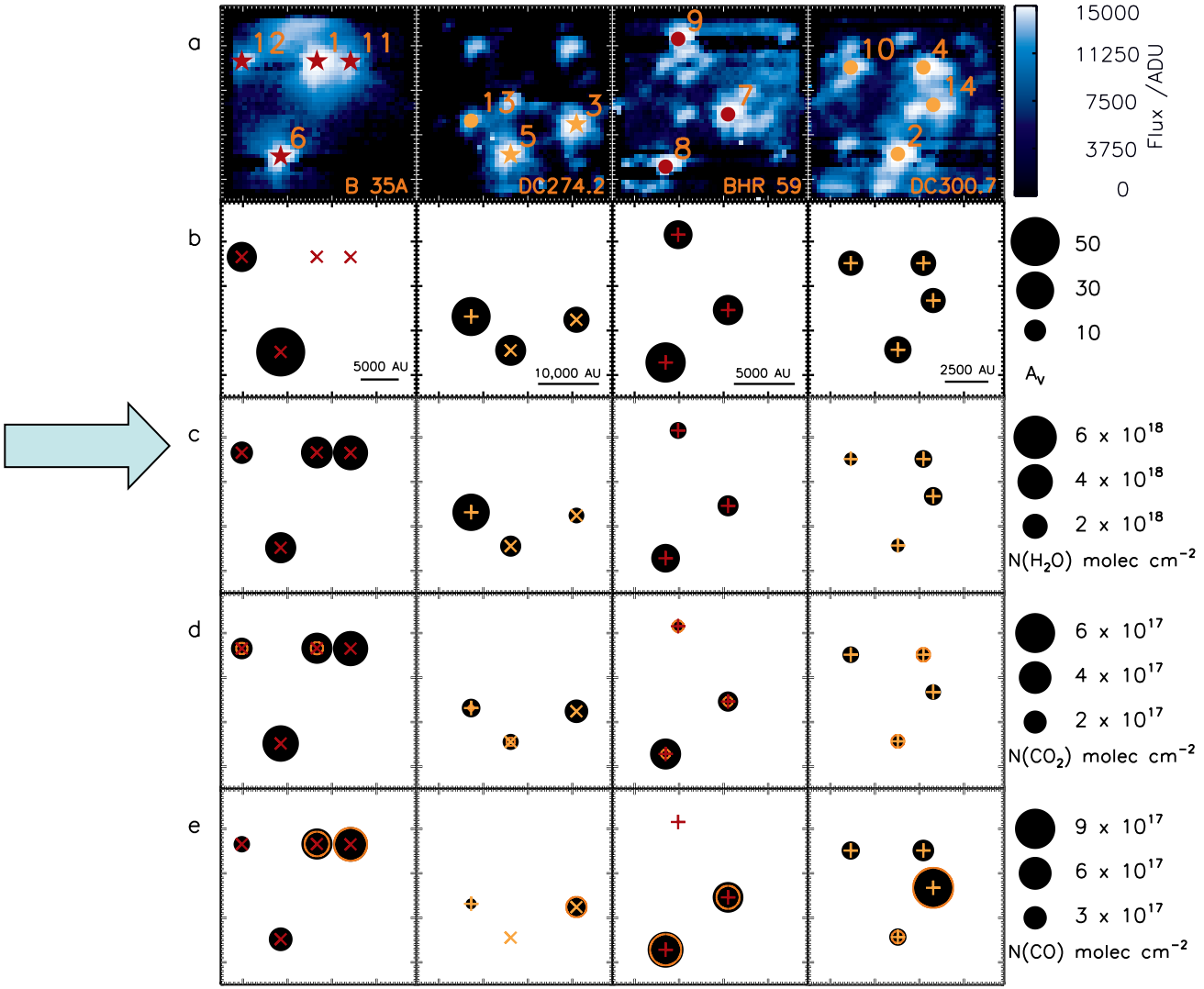
SPIZER STATE OF THE ART…

- Most obscured background stars ever observed in ices (A_V~40 mag), with deepest 3 μm H_2O ice bands (Boogert et al. 2011)

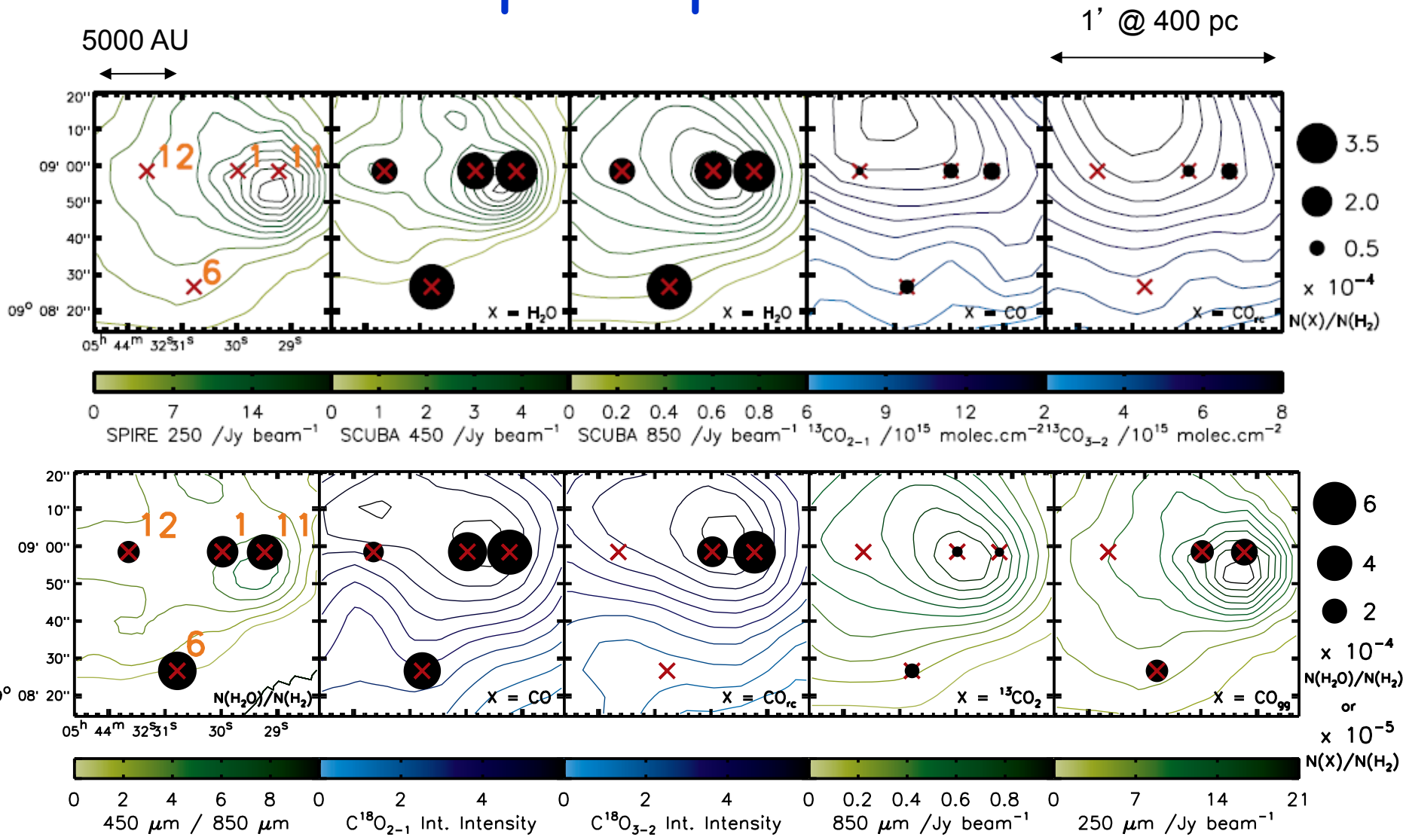
Ice Mapping





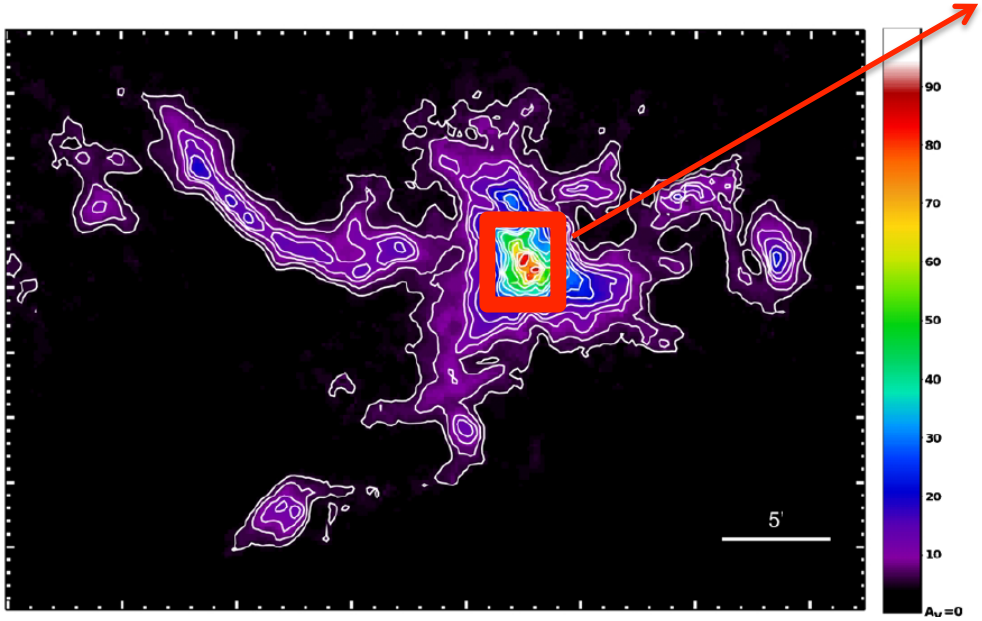
Noble et al (2013)
Noble et al MNRAS (2015) submitted

Ice "controls" chemistry and desorption processes.



Fraser et al (2015) in prep
Noble et al MNRAS (2015) submitted

What could JWST do?



B 59 star-forming core. A_V contours 5-90 mag
derived from background stars [Roman-Zuniga et al. 2010]

JWST/NIRSpec Micro Shutter Array (MSA):
- 1-5 μm, R~3000
- >100 targets simultaneously
- 3'x3'field of view > AKARI (no confusion)

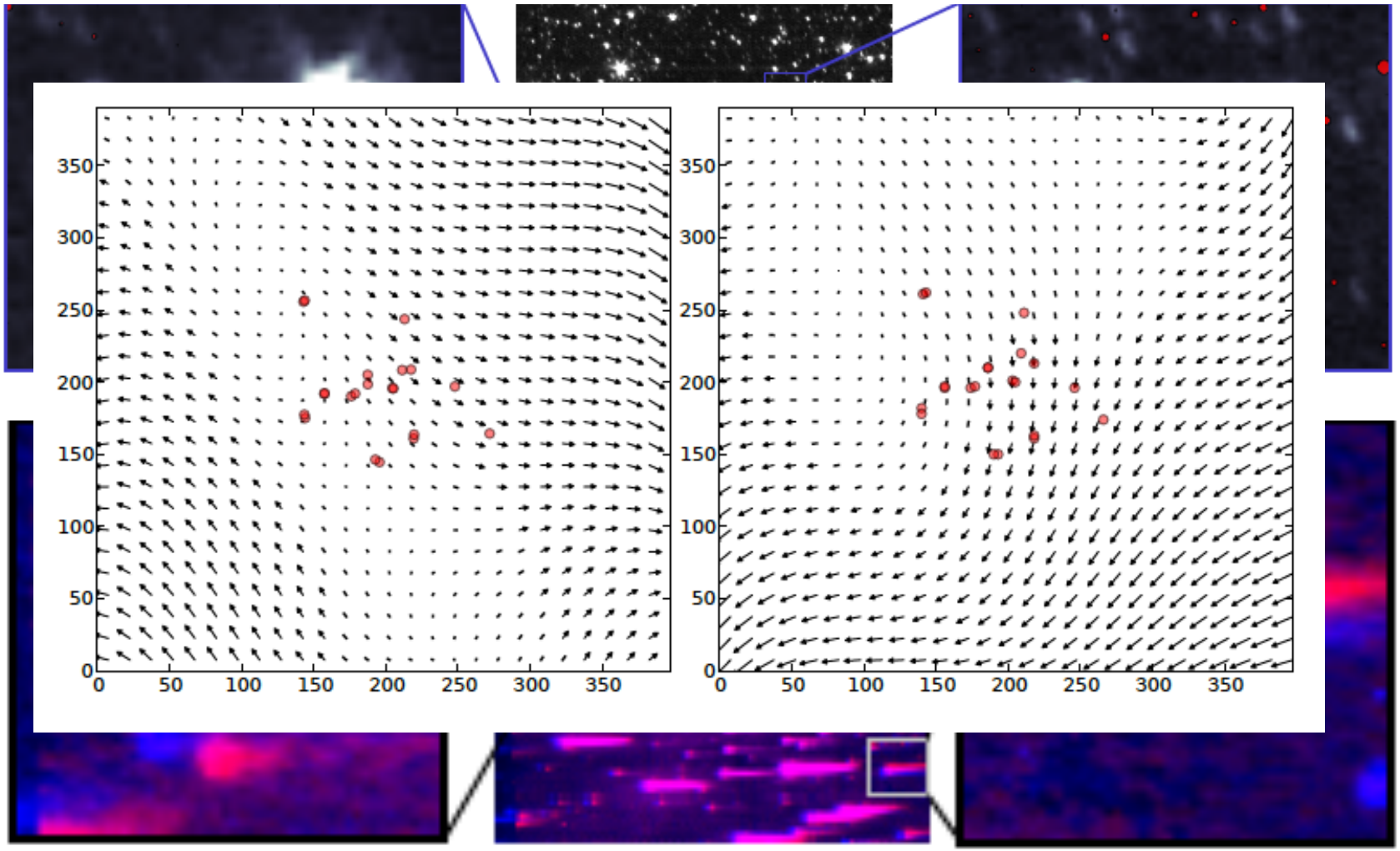
JWST/NIR CAM Slitless Spectroscopy mode:
- 2-5 μm, R <<< (100 is enough)
- all targets at once
- 0. 2 mJy sources

(2 oom > Spitzer 1 oom > AKARI)

CHALLEGE = DATA REDUCTION

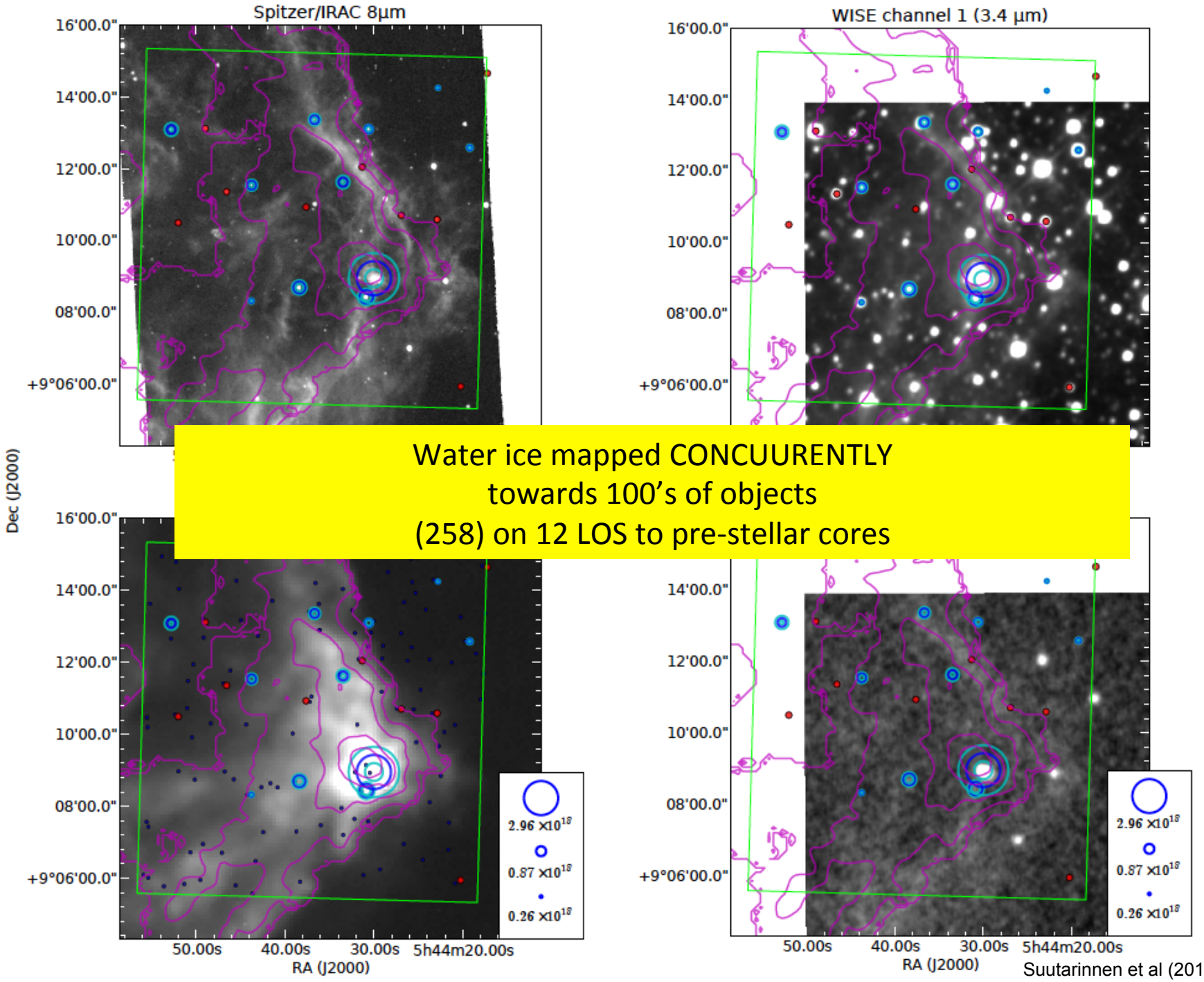
JWST/MIRI cluster mode:
- 5-28.3 um, R~3000
- 1 target at a time
- 0. 2 mJy sources (2 oom > Spitzer 1 oom > AKARI)

FOV Imaging (& Prism / Grism Distortion)



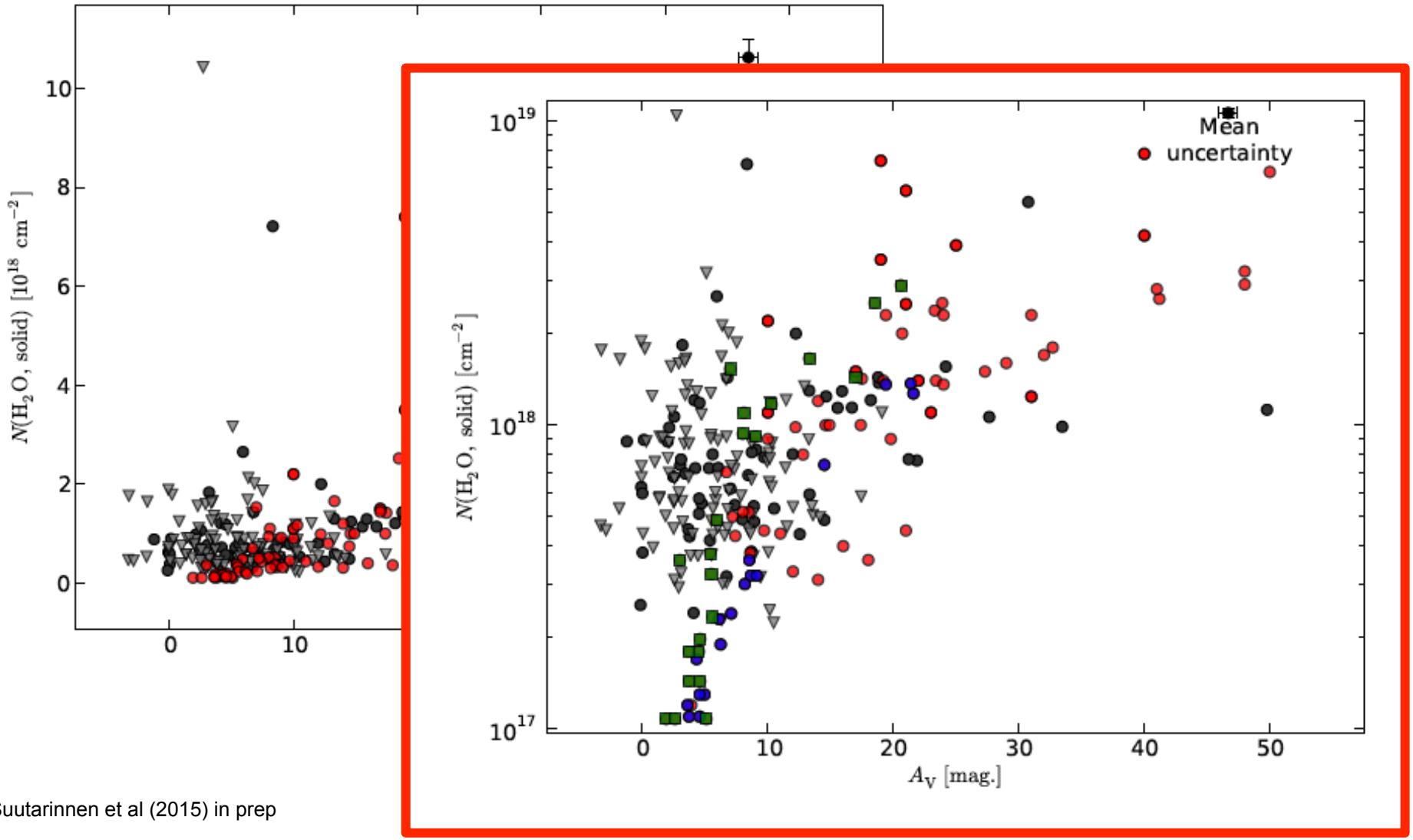
B35a AKARI 10’ x 10’ FoV

Suutarinen et al (2015) in prep



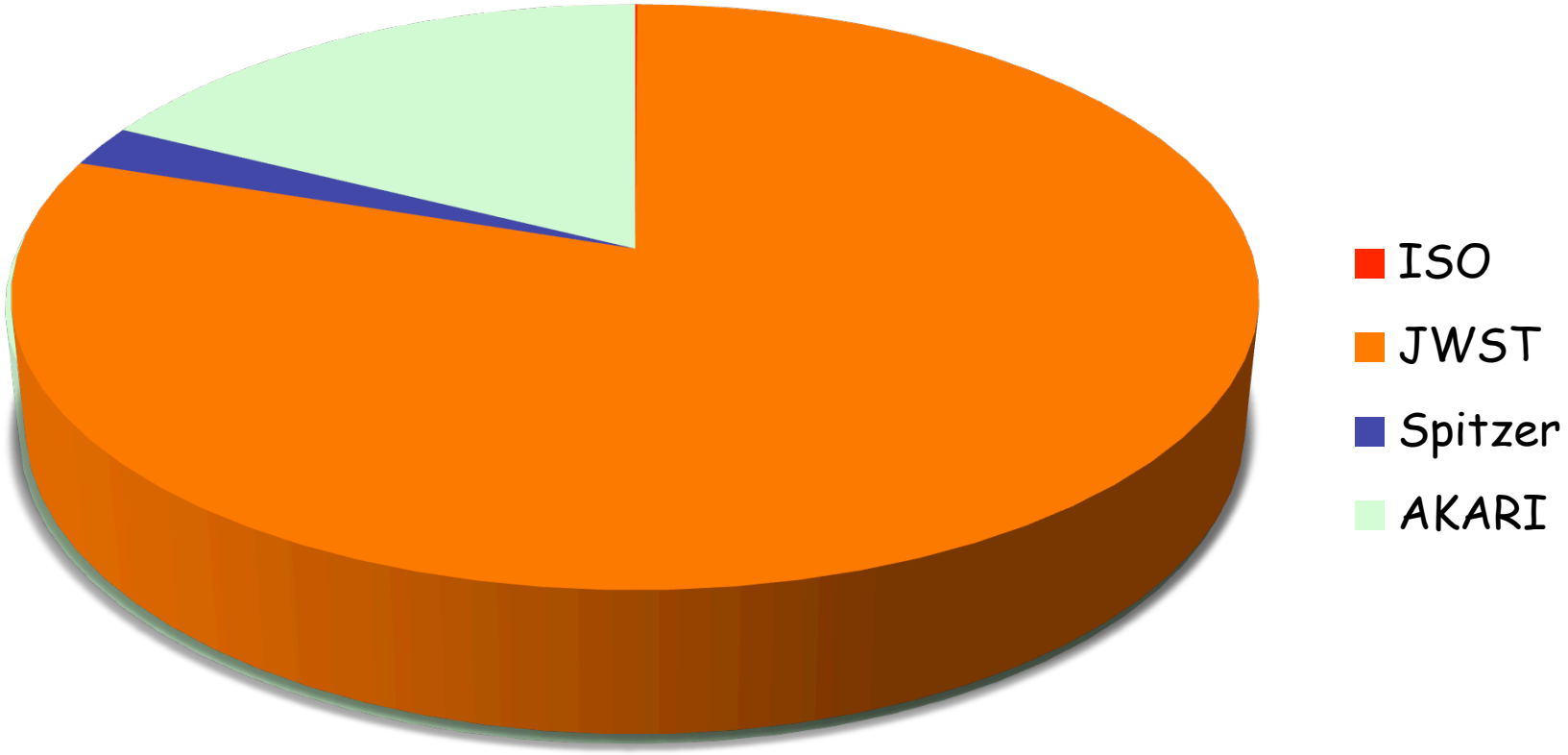
Suutarinnen et al (2015) in prep

Is there a critical A_v onset to ice formation?



Suutarinnen et al (2015) in prep

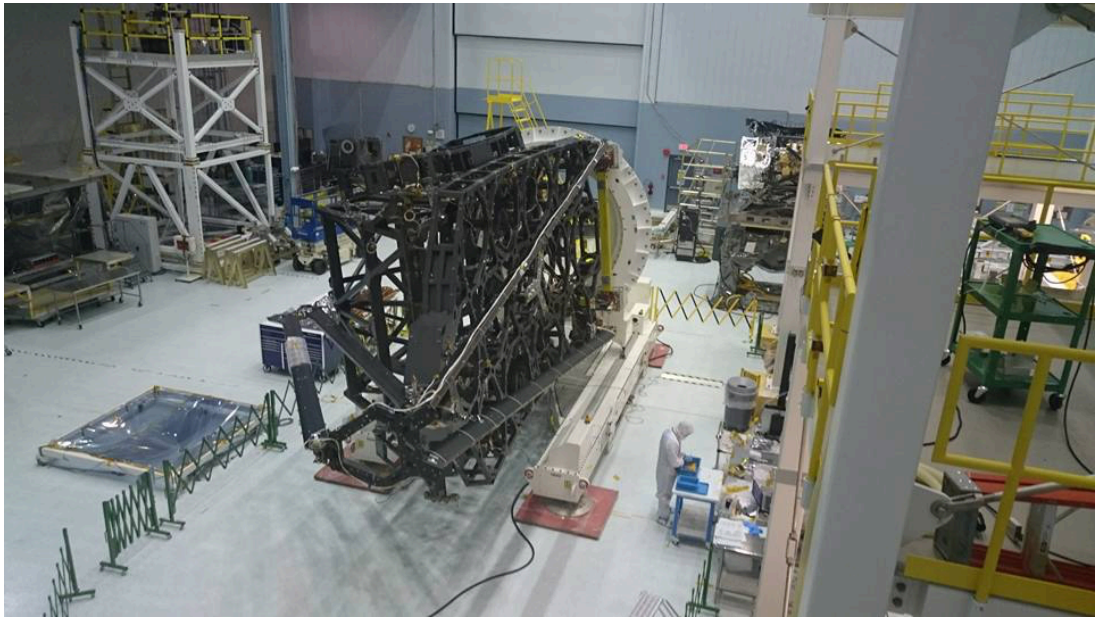
No. of Observed Background Stars with Ice

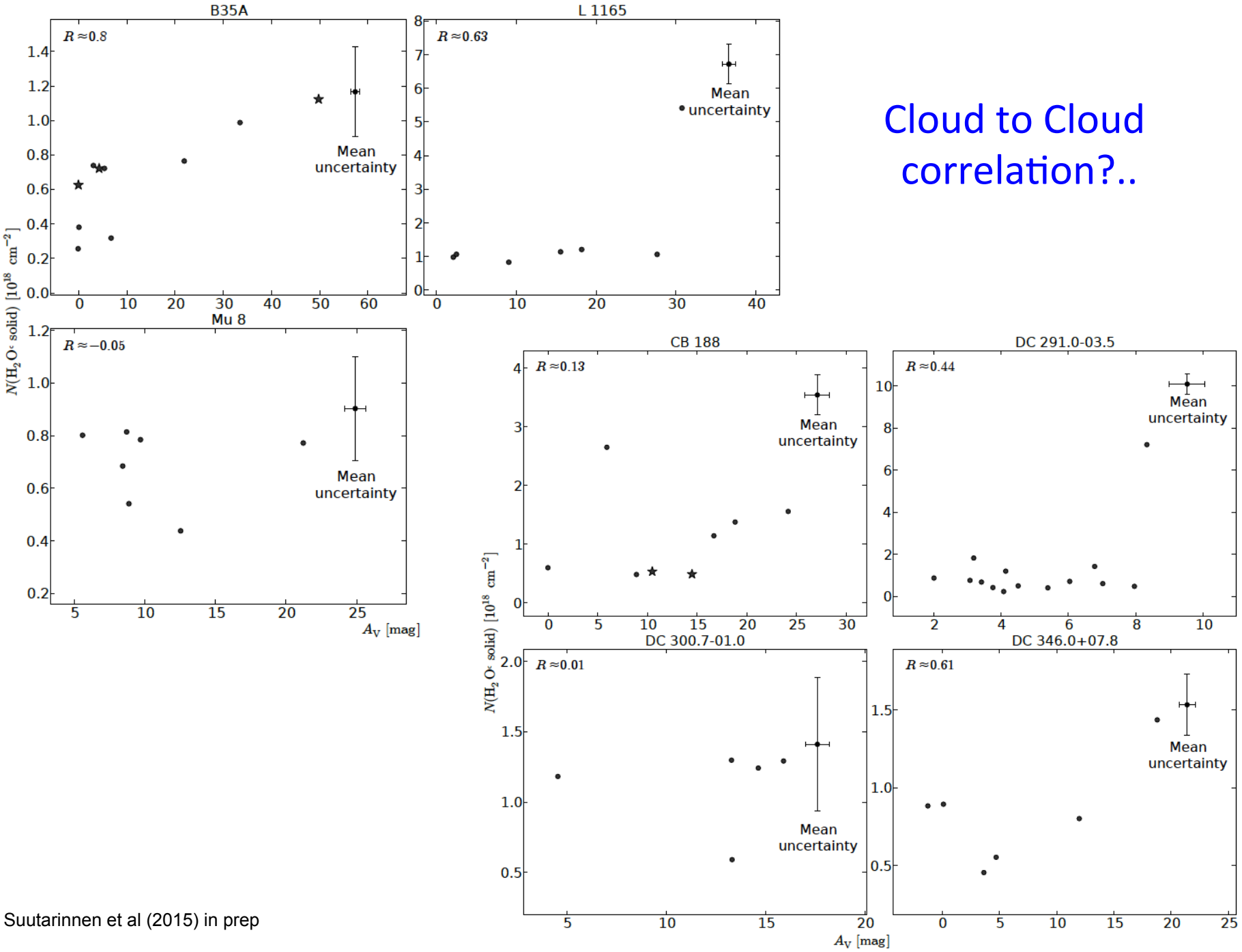


CAVEAT:- Current background star ice observations trace ices well before collapse.

JWST will ALSO have the sensitivity to study HIGHLY EXTINCTED LoS CLOSE to collapse cf. A_V~90 background stars requires S/N=100 for ~1 mJy continuum at 3-5 μm

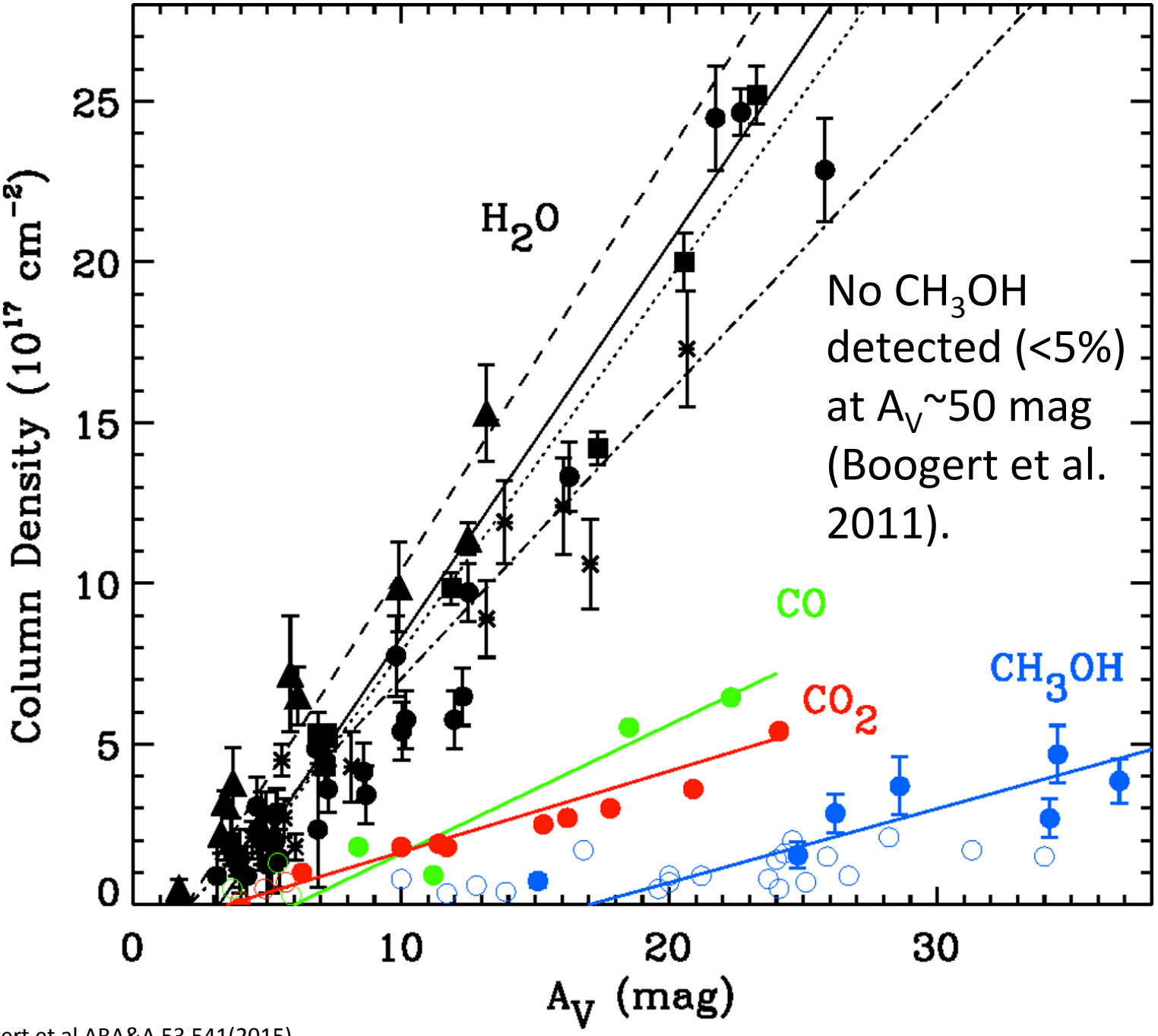
Can't wait…





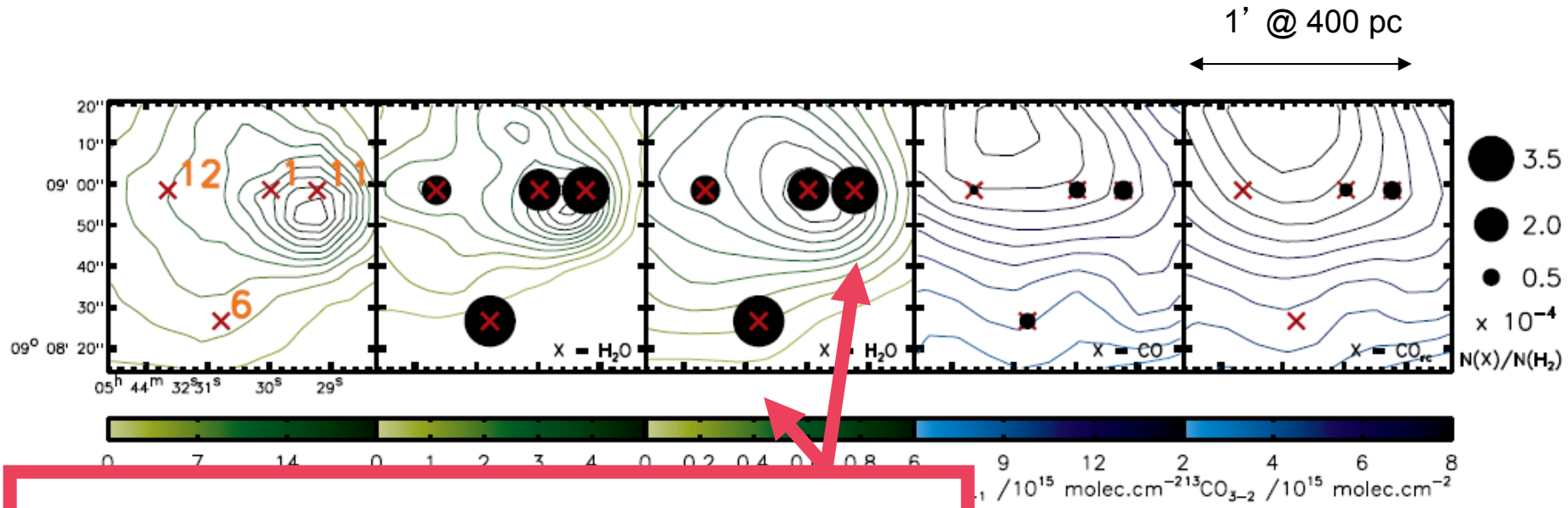
Cloud to Cloud correlation?..

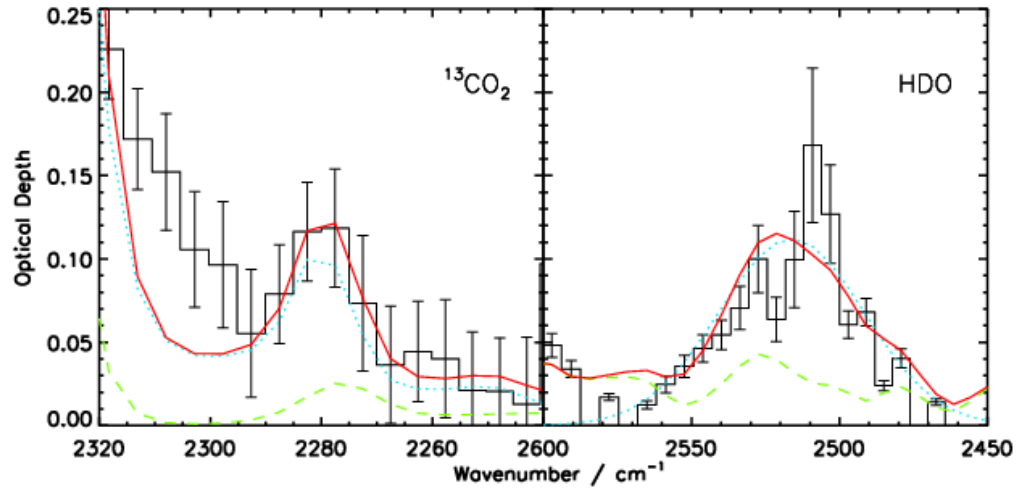
Suutarinnen et al (2015) in prep



Boogert et al ARA&A 53 541(2015)

Isotope Abundances.



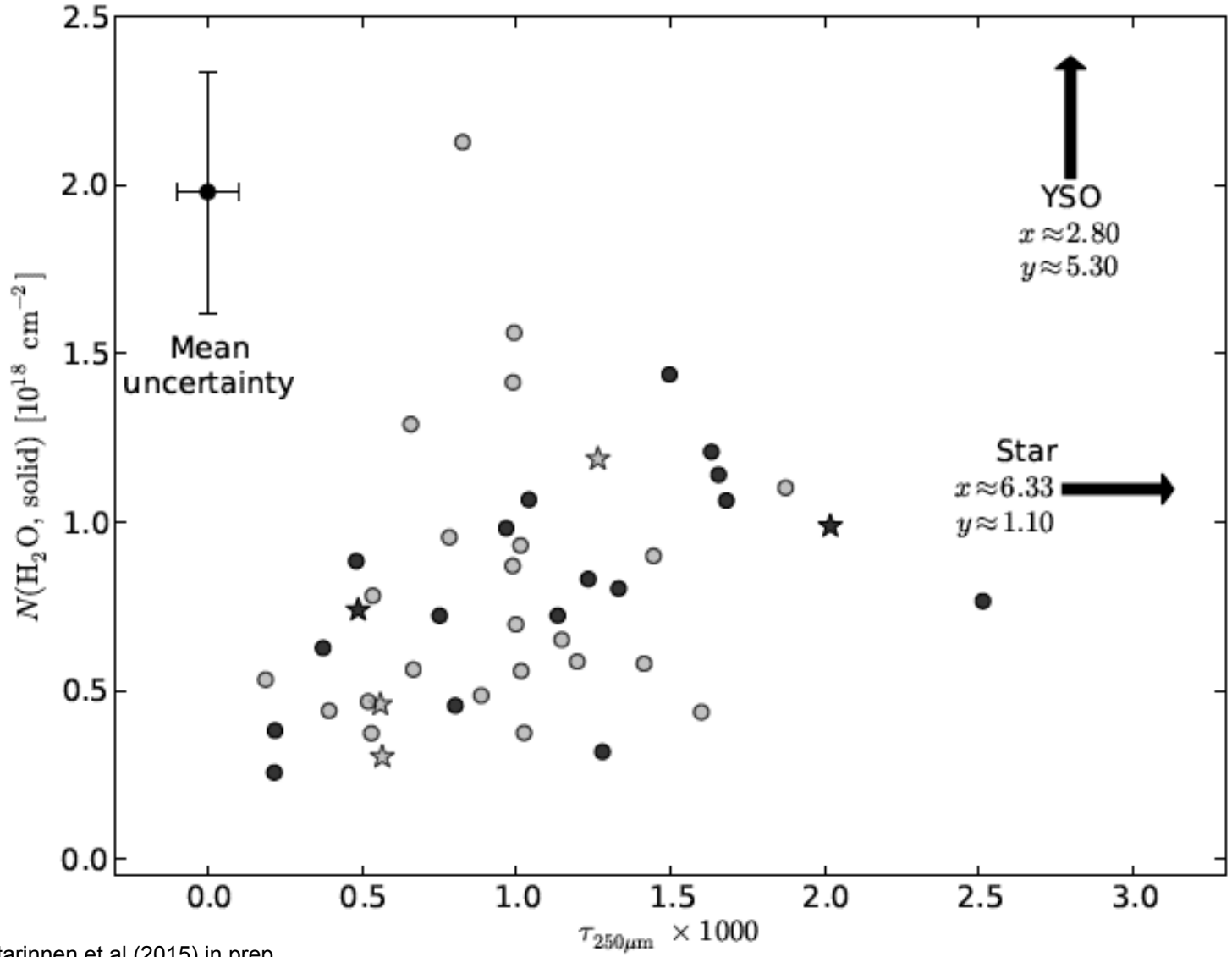


$HDO / H_2O = 2 - 4\ \%$

$[HDO] = 8.6\times10^{17} - 1.7\times10^{17}$

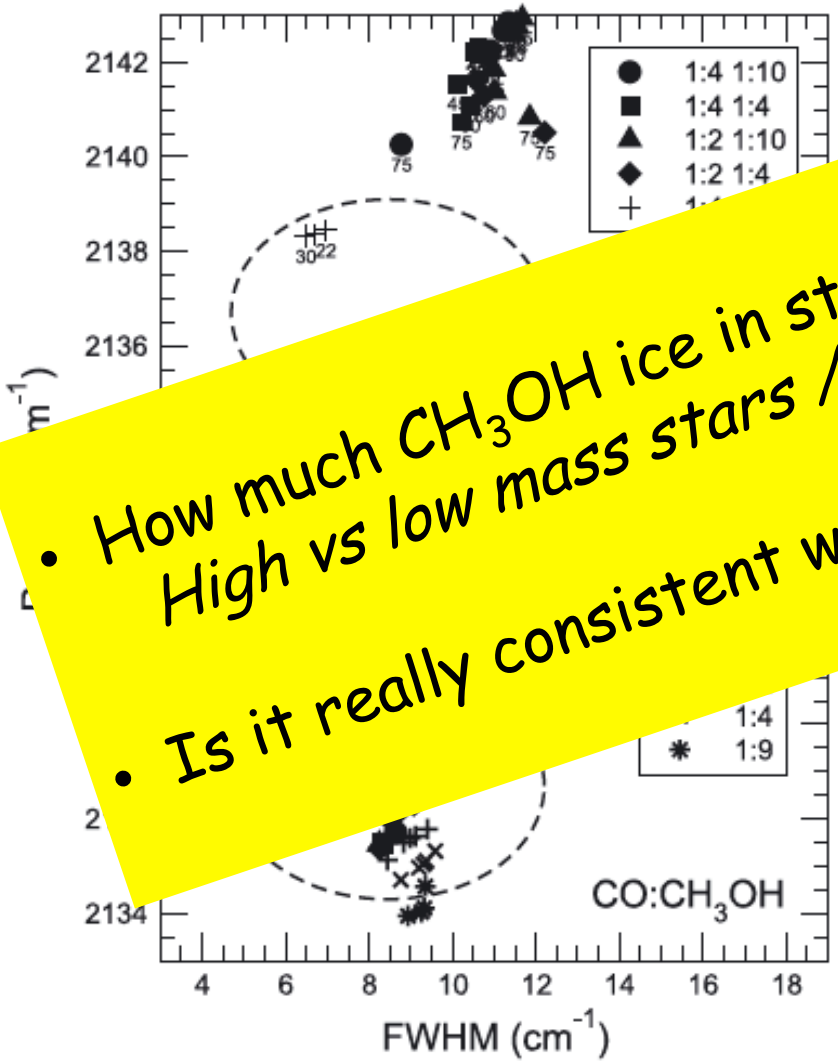
Fraser et al (2015) in prep
Noble et al MNRAS (2015) submitted

What else is related to ice? DUST!!

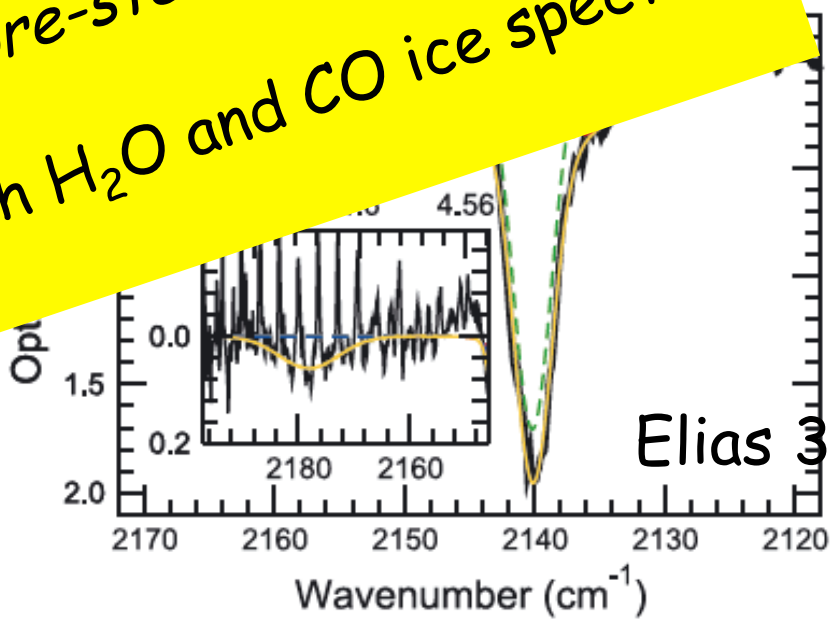


Suutarinnen et al (2015) in prep

CO “red wing”



- How much CH_3OH ice in star-forming regions? High vs low mass stars / pre-stellar regions
- Is it really consistent with H_2O and CO ice spectra?



Cuppen et al MNRA

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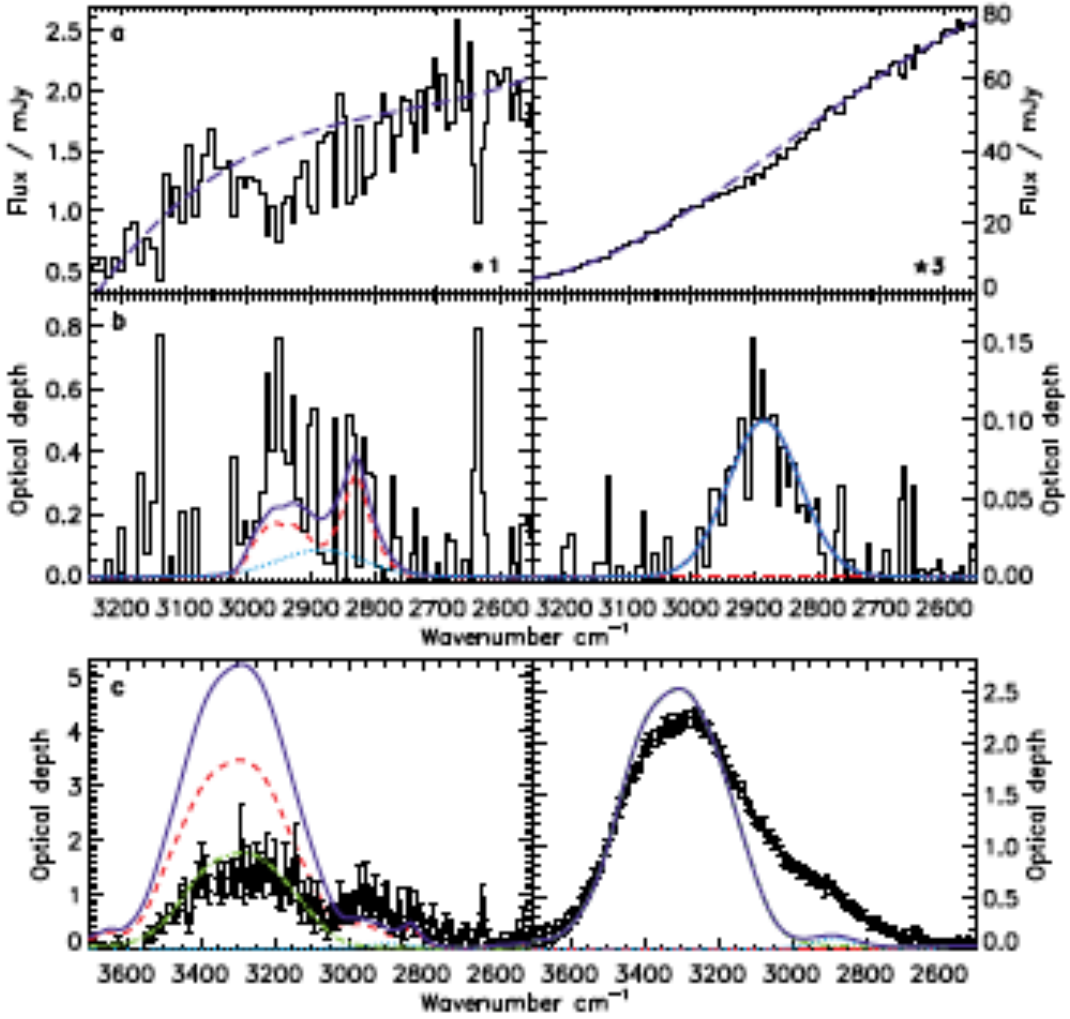
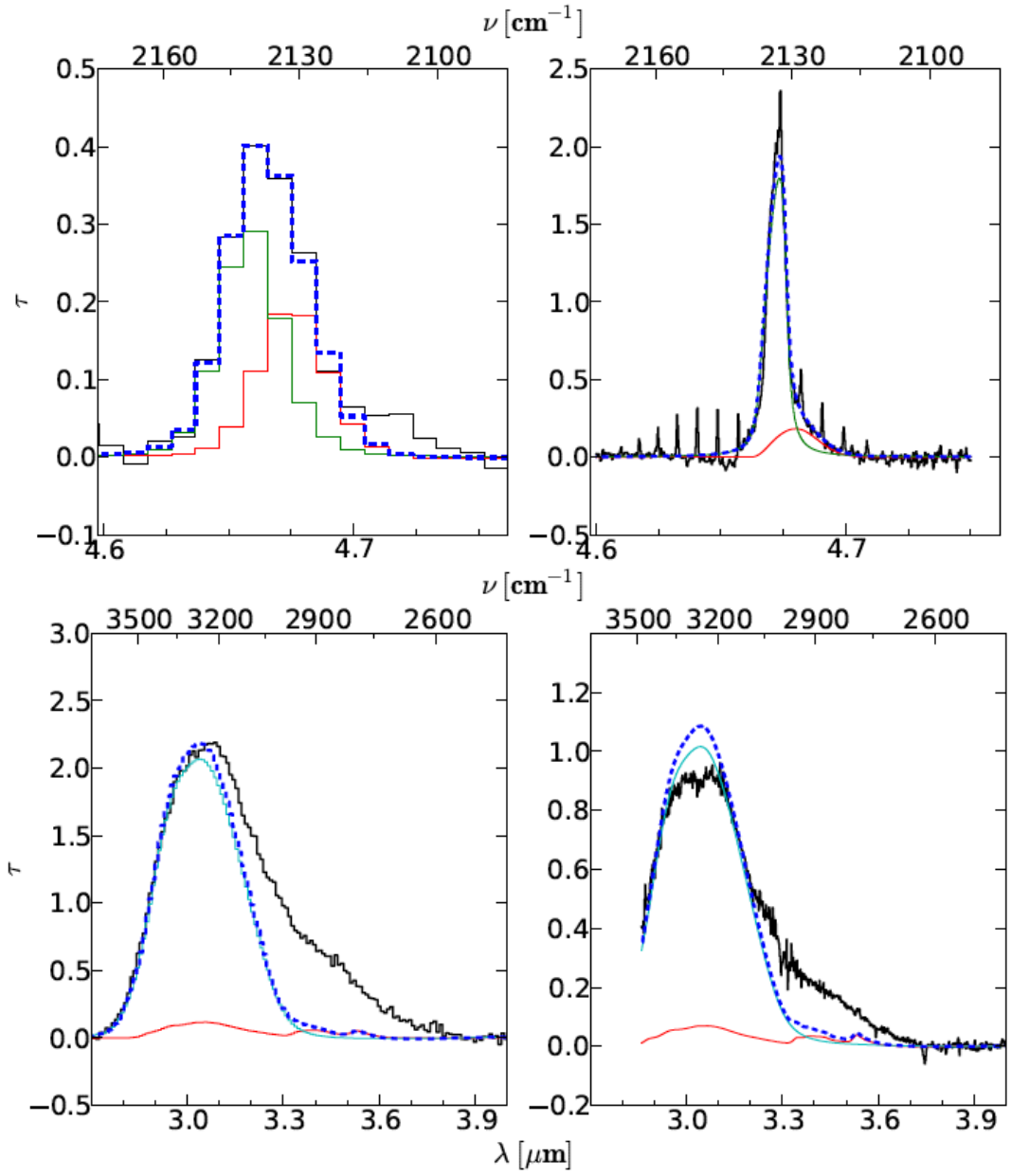
How to back out CH_3OH?



Noble et al (2015) in prep
Suutarinnen et al (2015) MNRAS submitted

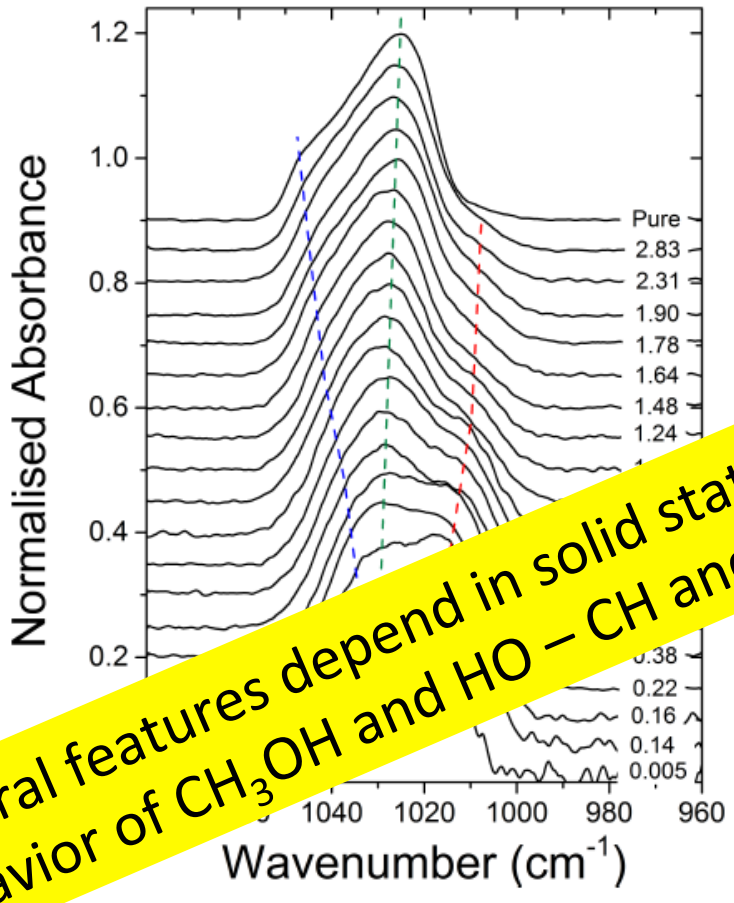


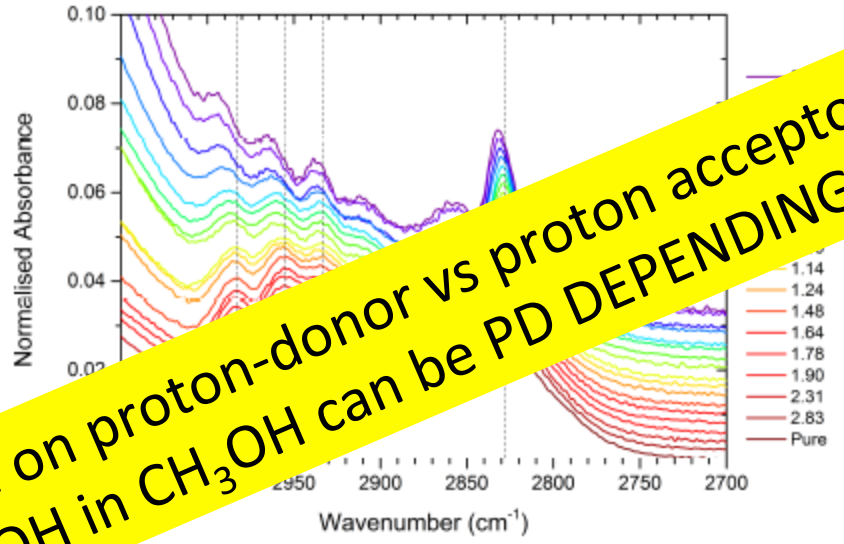
Concurrent Band Fitting AKARI (26) & VLT (28)

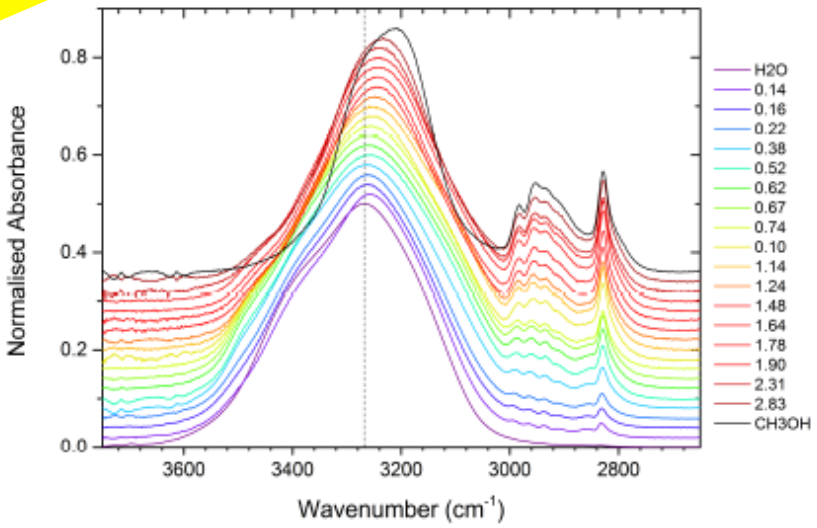
Suutarinnen et al (2015) MNRAS submitted

“Sods Law”

The data you need won’t be in the literature or a database ☹





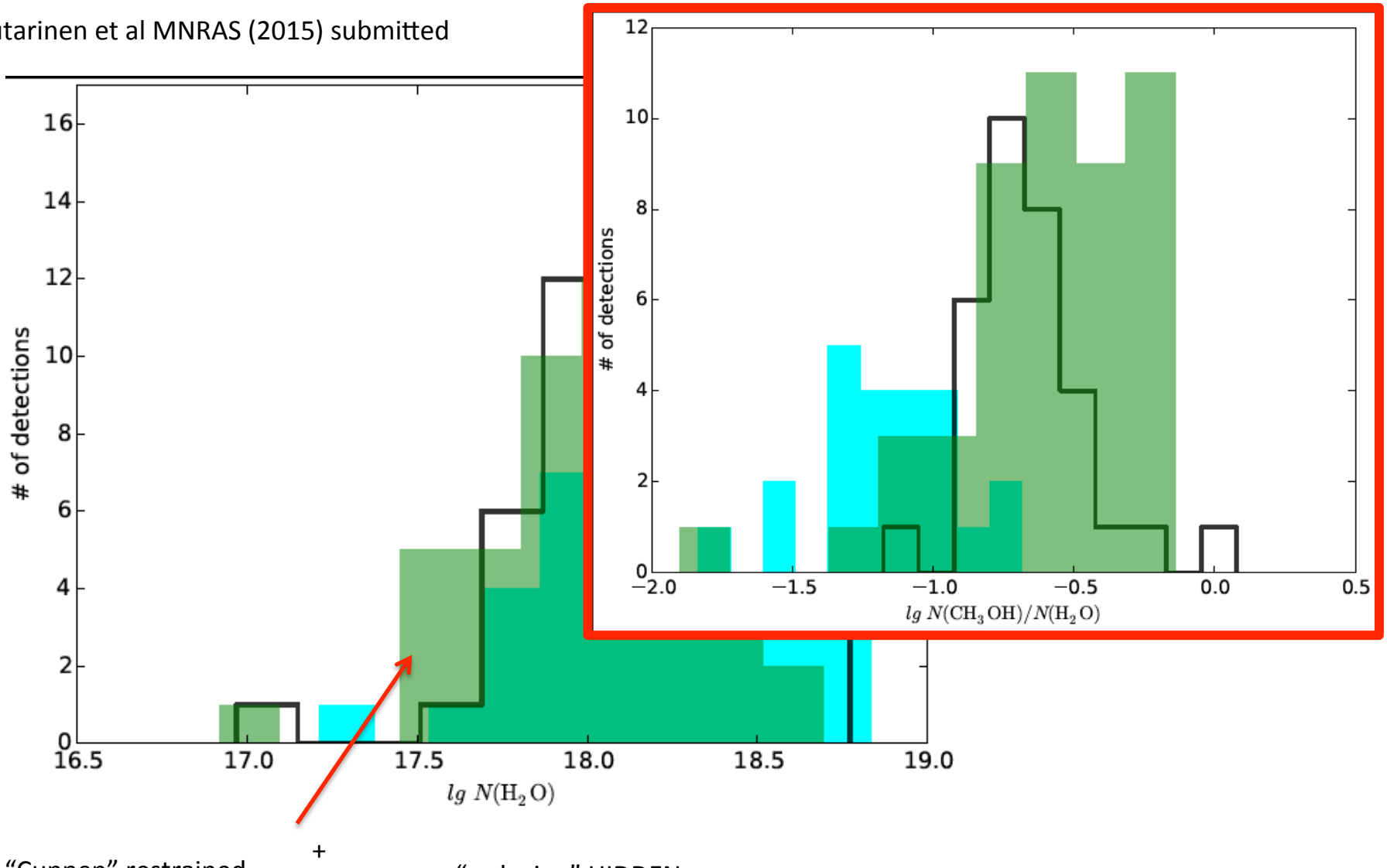


Spectral features depend in solid state on proton-donor vs proton acceptor behavior of CH_3OH and HO – CH and OH in CH_3OH can be PD DEPENDING on []

Dawes et al (2015) PCCP submitted

How does it affect water ice?

Suutarinen et al MNRAS (2015) submitted

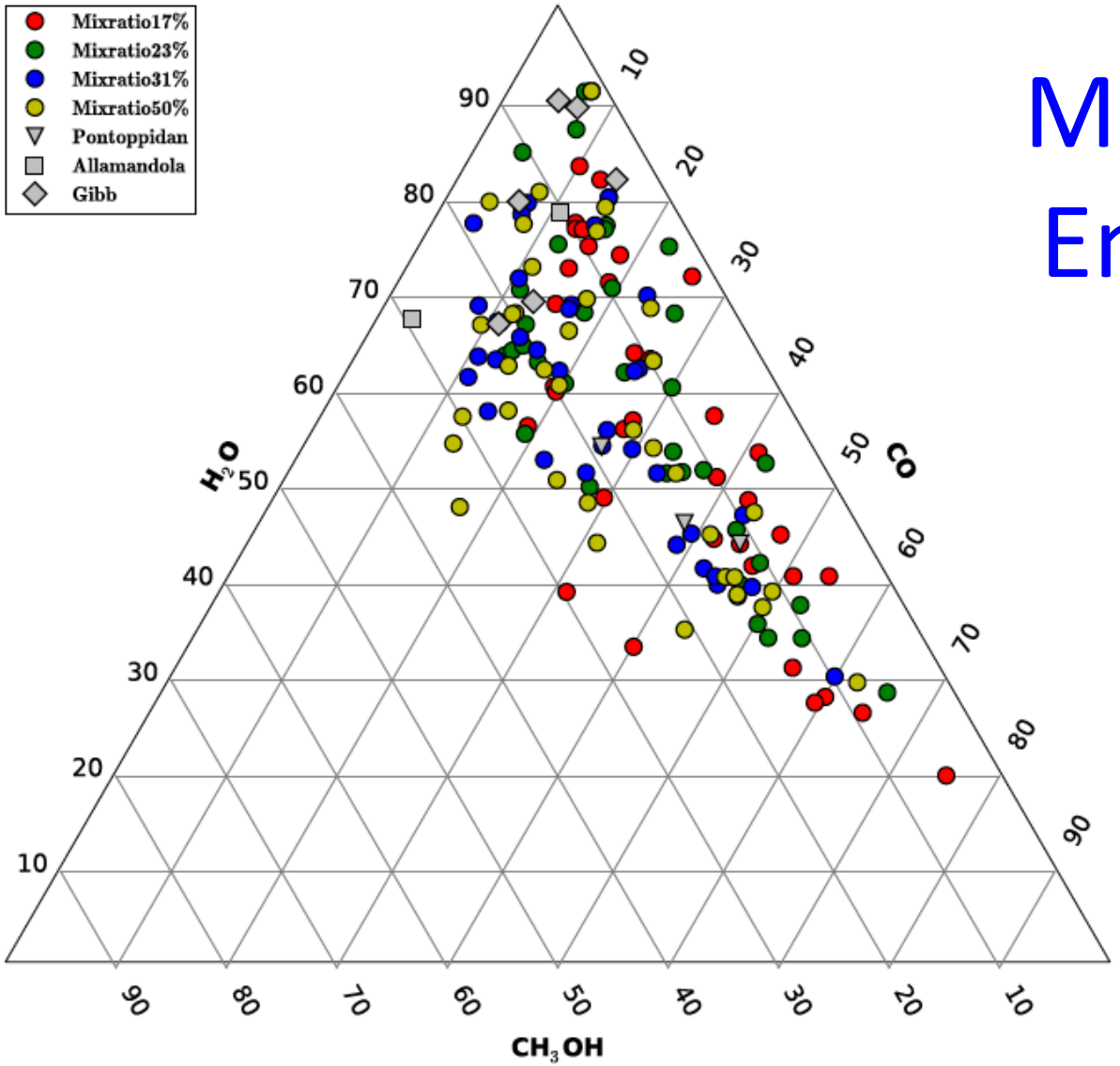


"Cuppen" restrained
CH_3OH (from CO band)

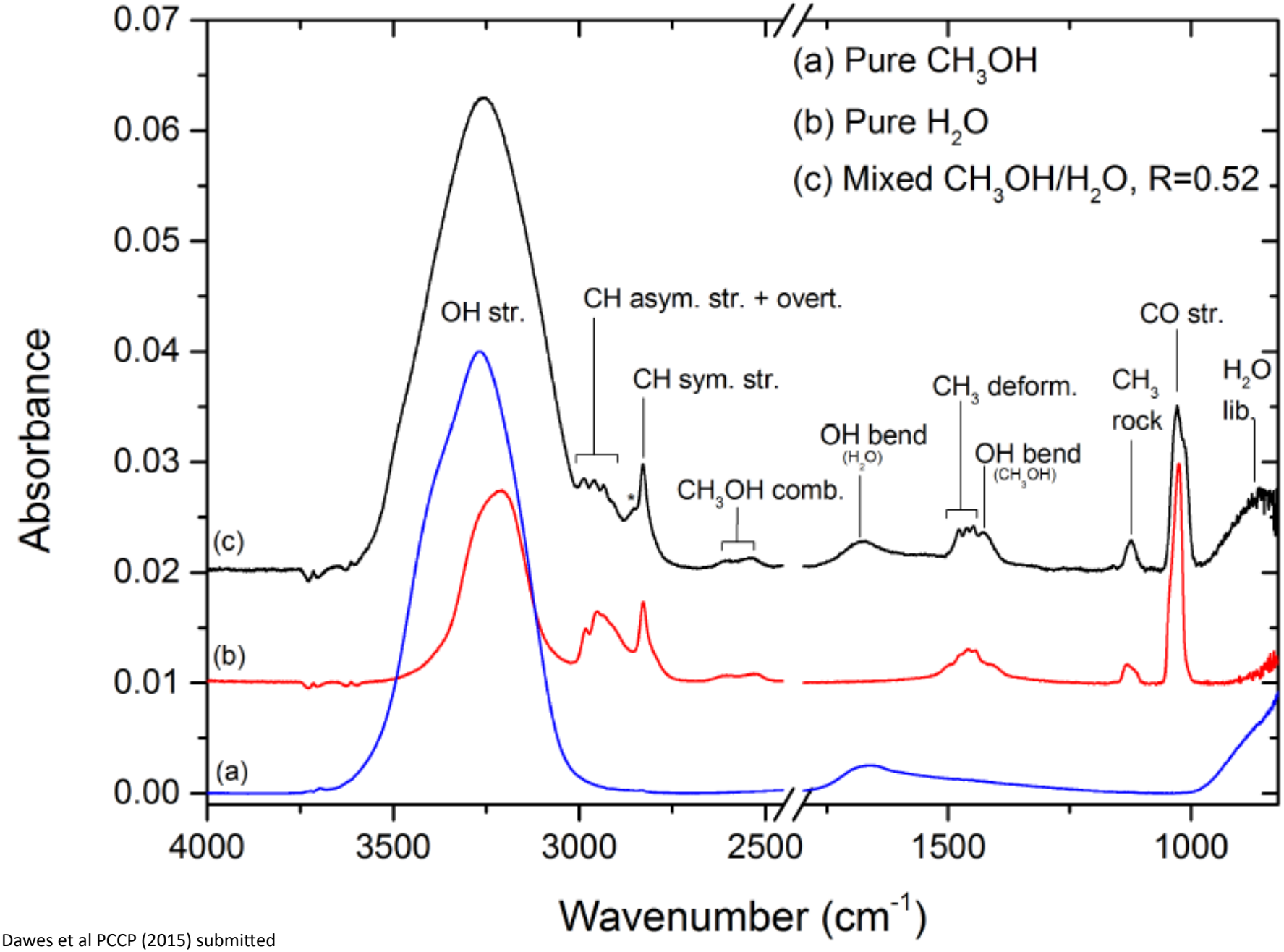
+

"red wing" HIDDEN
CH_3OH (from H_2O band)

Methanol Ice Environment

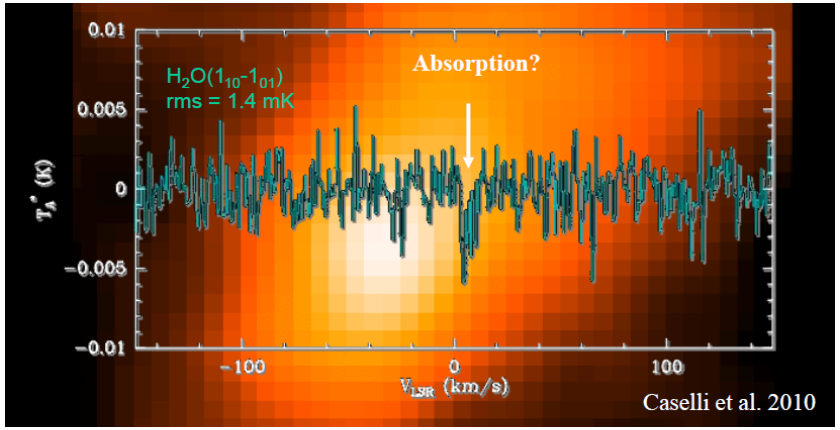


Noble et al (2015) in prep
Suutarinnen et al (2015) MNRAS submitted



Dawes et al PCCP (2015) submitted

Herschel & Non-Thermal Desorption



PRESTELLAR ISM:

Hershel HIFI data – shows gas Ø water lines x100 weaker than predicted = All water (essentially) in pre-stellar cores frozen out as ice

BUT ….

Integrate even longer…

H_2O (g) in a COLD PRE-STELLAR CORE

Caselli et al ApJ (2012)

MODELLED by H_2O (ice) photo-desorbtion via CR induced UV photons (CR+ H_2)