The hunt for hot corinos and WCCC objects in the OMC-2/3 filament

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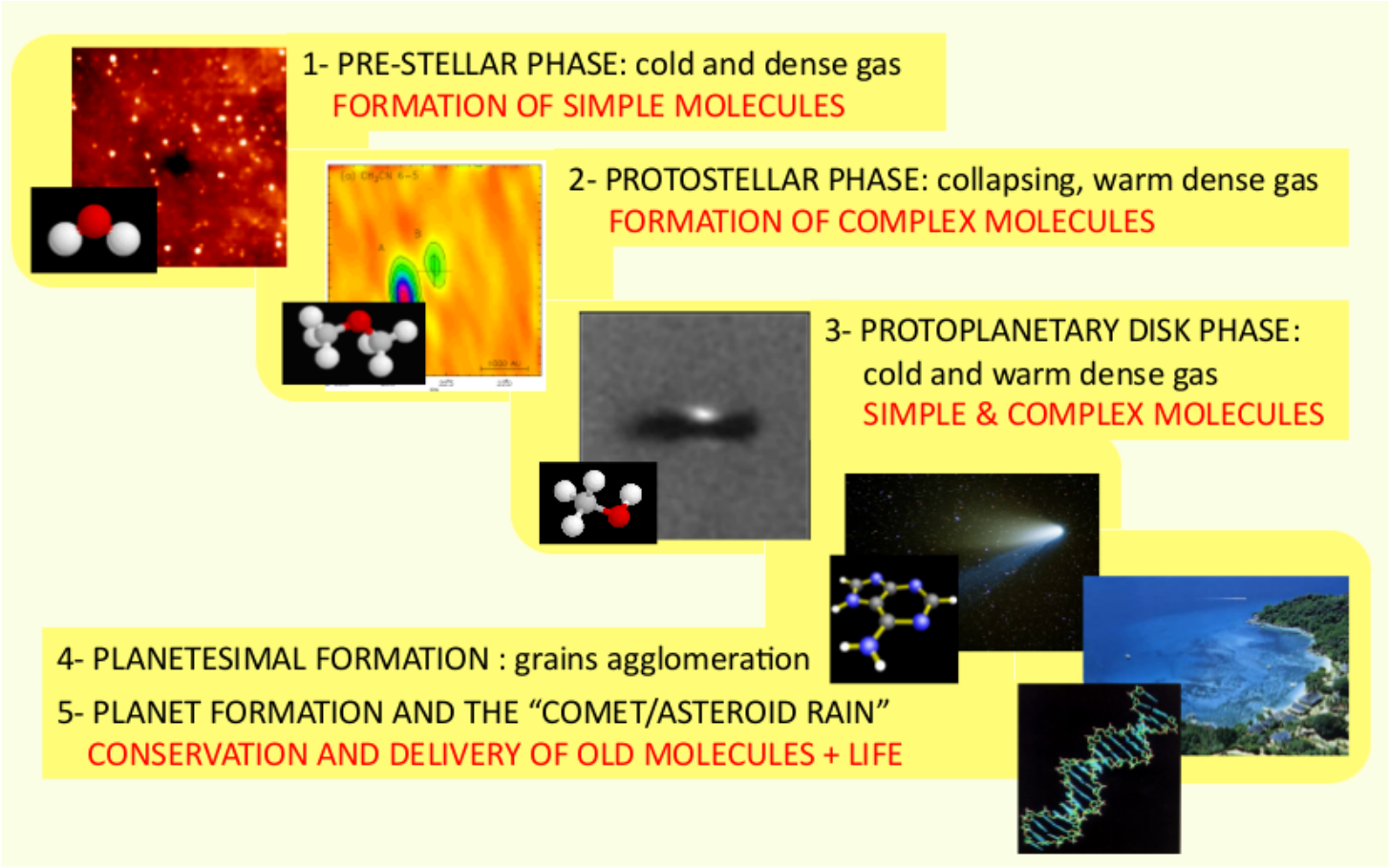
Star formation and molecular complexity



Caselli & Ceccarelli 2012

Protostellar phase: Rich molecular chemistry

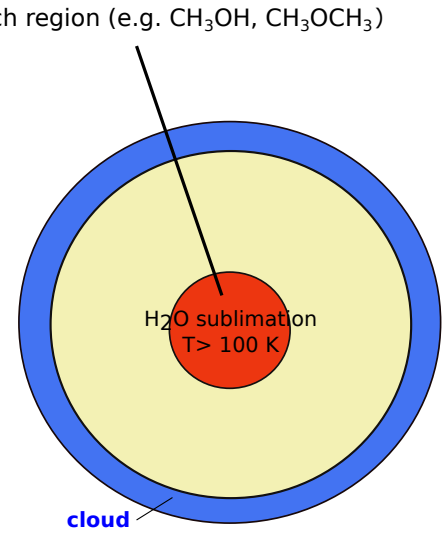
Chemical diversity among Solar-type protostars

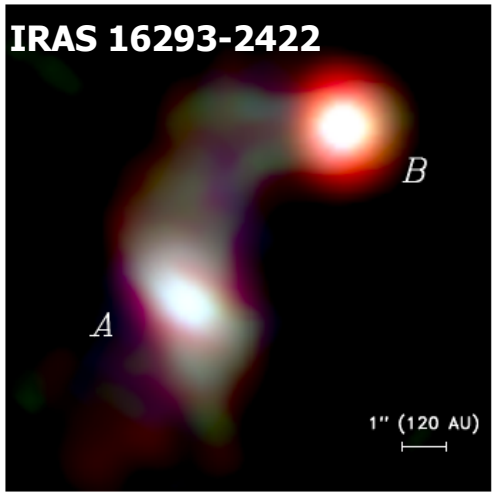
hot corinos

(Ceccarelli, …, Tielens,…2000)

# of objects ~10

See posters Bianchi, De Simone, Dehghanfar, and Ospina-Zamudio



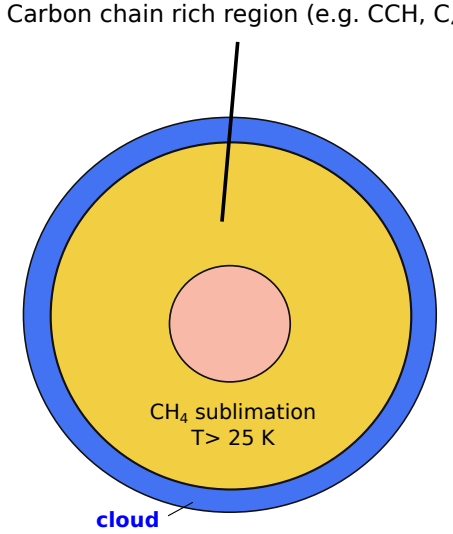


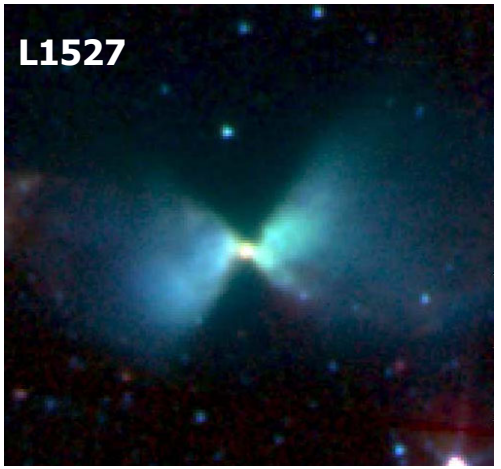
Jørgensen et al. 2016

Warm Carbon Chain Chemistry (WCCC) object

(Sakai et al. 2008)

# of objects < 5





Spitzer

iCOMs: interstellar Complex Organic Molecules

The proto-Sun: An ancient hot corino ?

- **What is at the origin of the observed protostellar chemical diversity ?**

—> Need to study large samples of Solar-type protostars

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- **Where do Solar-type protostars form ?**

- Low-mass (< $8M_{\odot}$) star forming region —> known majority of hot corinos and WCCC objects
- High- + low- mass star forming regions —> ???

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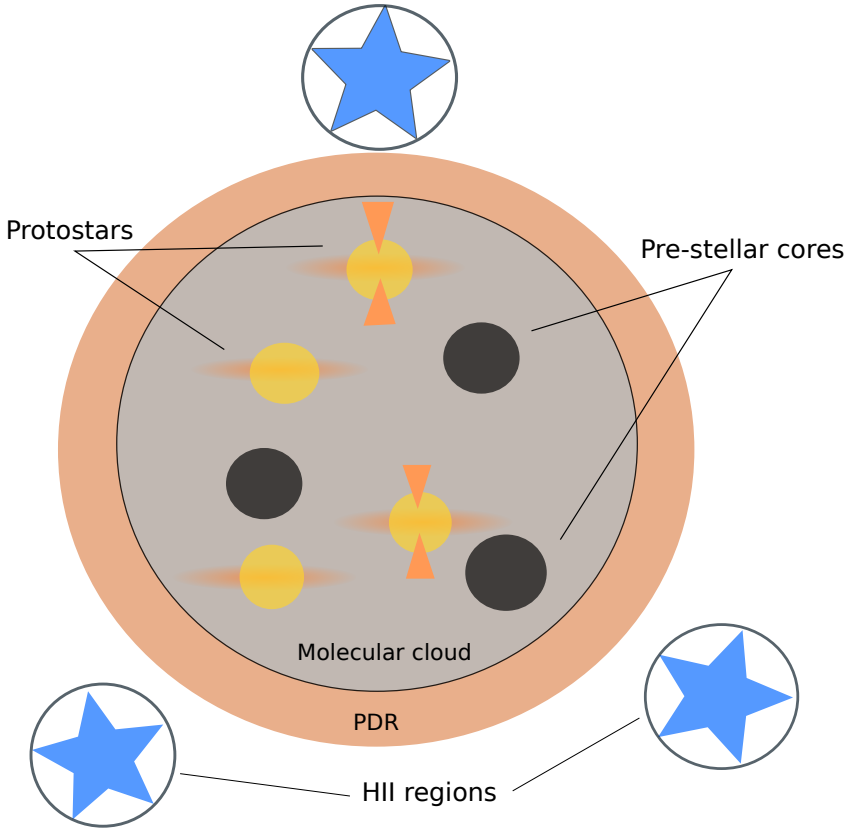
- **What is our Sun's birth environment ?**

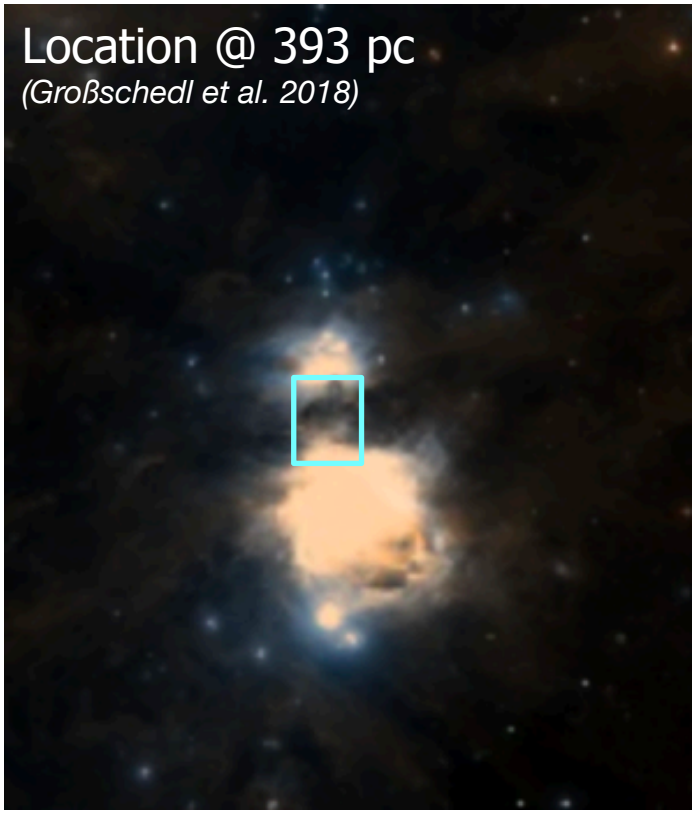
Solar Birth Environment

High- and low-mass star forming region with HII region nearby

(Adams 2010, Pfaltzner et al. 2015)



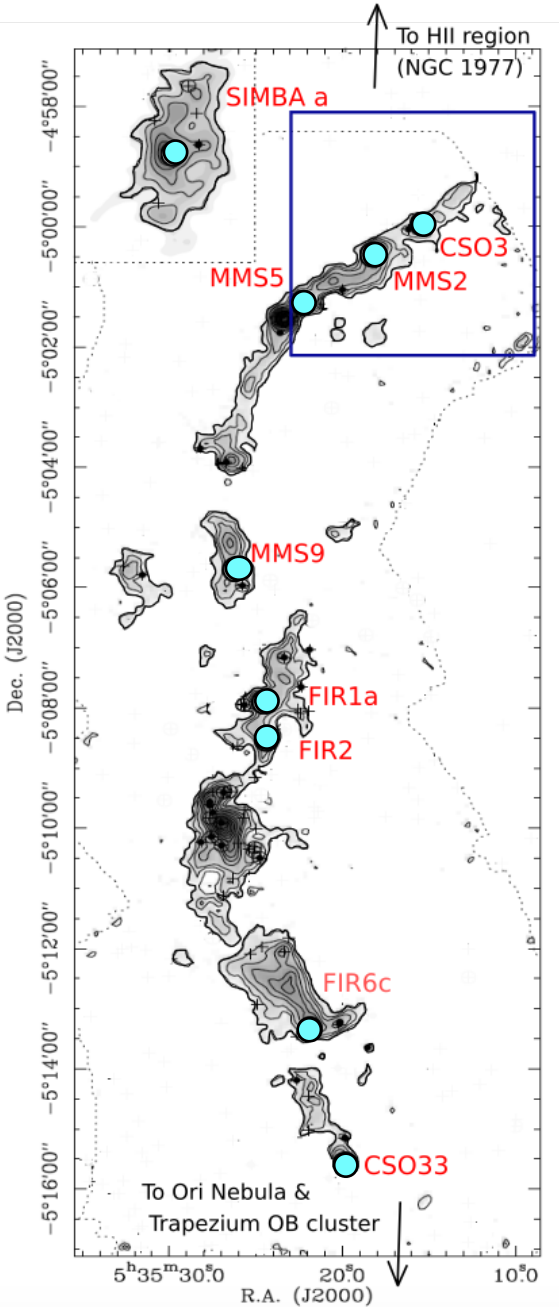
Closest analogue: OMC-2/3



http://simbad.u-strasbg.fr/

Can we find hot corinos and/or WCCC objects in OMC-2/3 ?

The OMC-2/3 filament: A pilot study



Adapted from Chini et al.1997 and Nielbock et al. 2003

Targets: 9 Solar-mass protostars

Diagnostic tool: $\frac{[CCH]}{[CH_3OH]}$

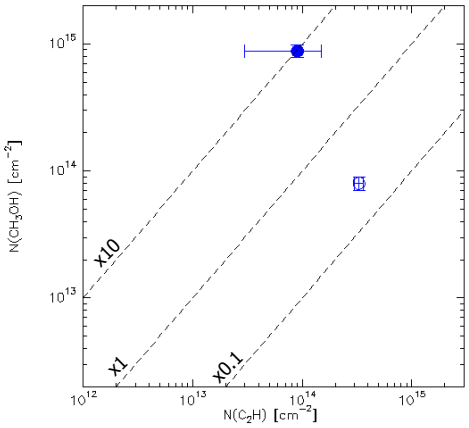
Tracer of WCCC objects

Tracer of hot corinos

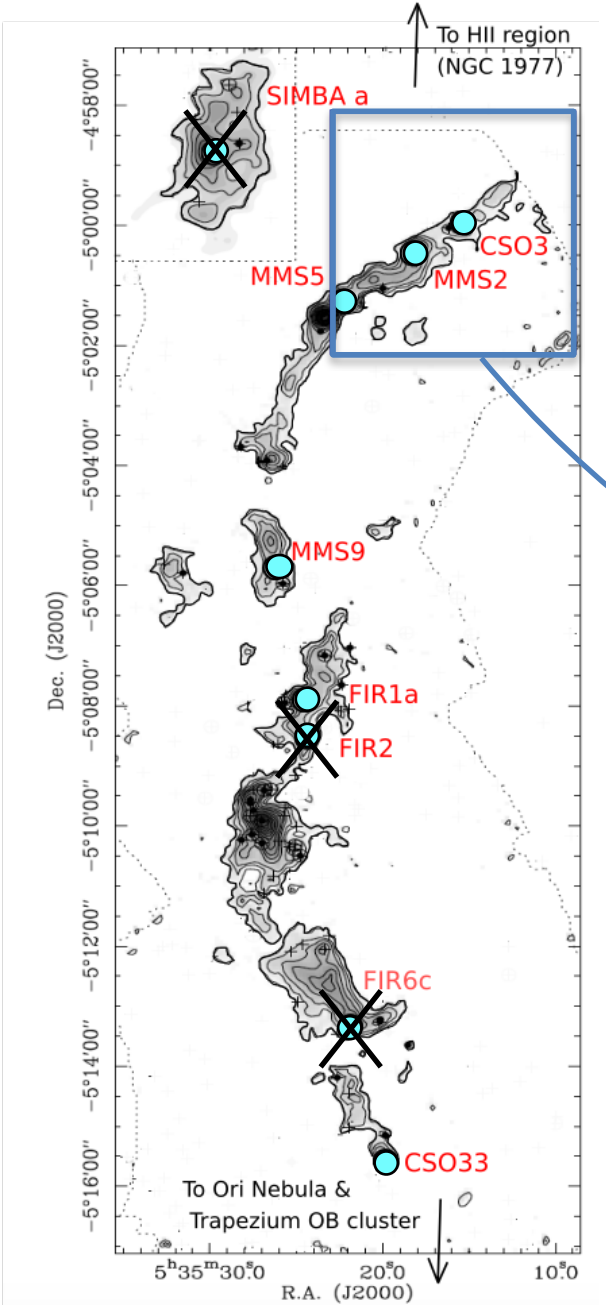
(Graninger et al. 2016, Higuchi et al. 2018)

If ratio >>1 : WCCC candidate
If ratio << 1: hot corino candidate

- ○ L1527 (WCCC)
- ● IRAS 16293-2422 (hot corino)



Van Dishoeck et al.1995
Higuchi et al. 2018



The OMC-2/3 filament: A pilot study

Targets: 9 Solar-mass protostars

3 sets of observations:
- IRAM 30m @ 1.3mm
- NRO 45m @ 3mm
- IRAM 30m @ 3mm (OTF map, blue box)

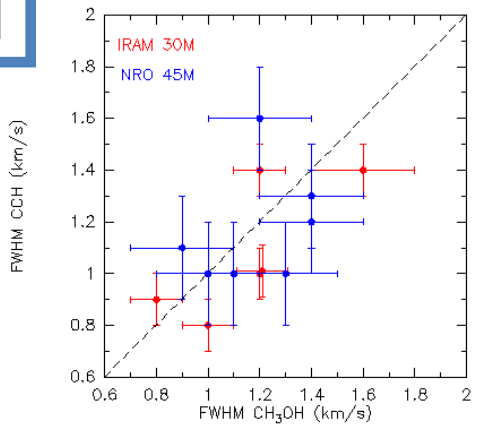
Diagnostic tool: $\frac{[CCH]}{[CH_3OH]}$

(Graninger et al. 2016, Higuchi et al. 2018)

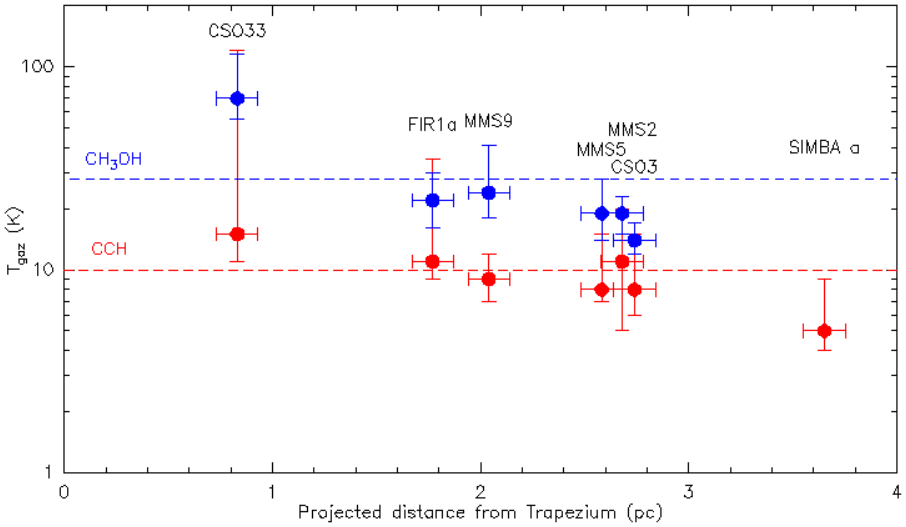
Bouvier et al. in prep

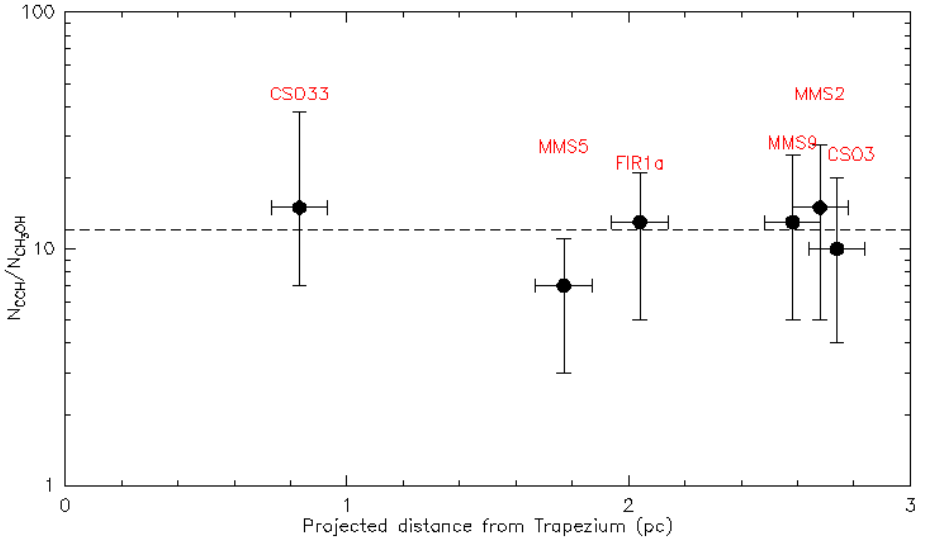
Region of emission of CCH and CH_3OH

Similar and narrow (< 2km/s) line widths
—> **CCH and CH_3OH emitted from the same region**



Results from non-LTE LVG analysis





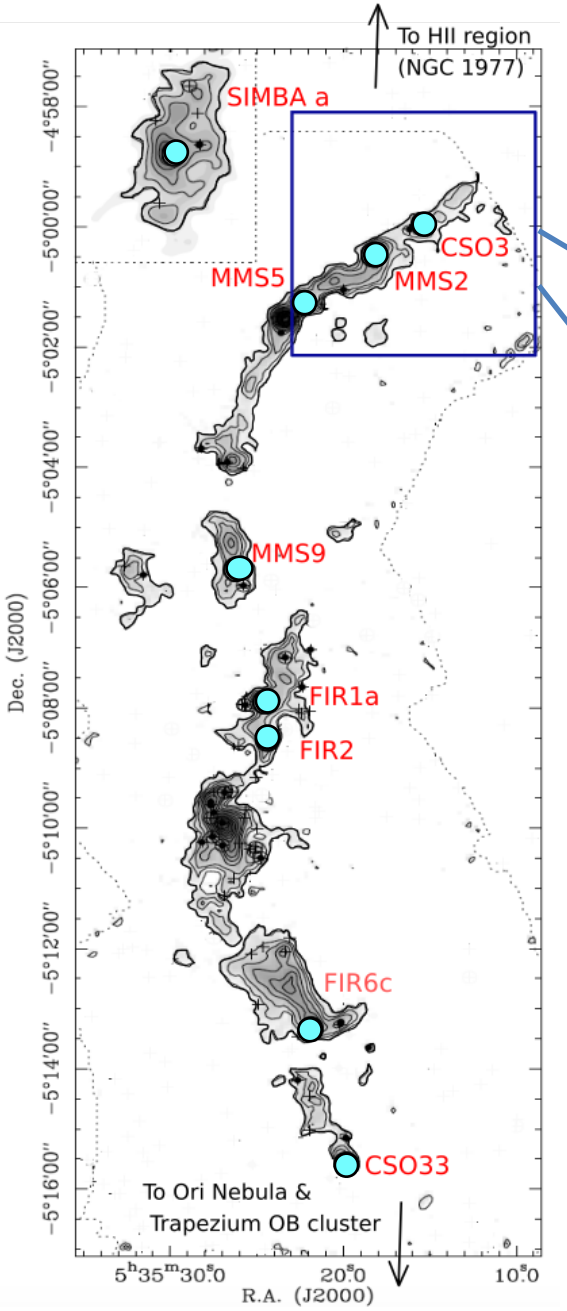
Gas Temperature:
CCH: 5 - 15 K
CH_3OH: 14 - 70 K

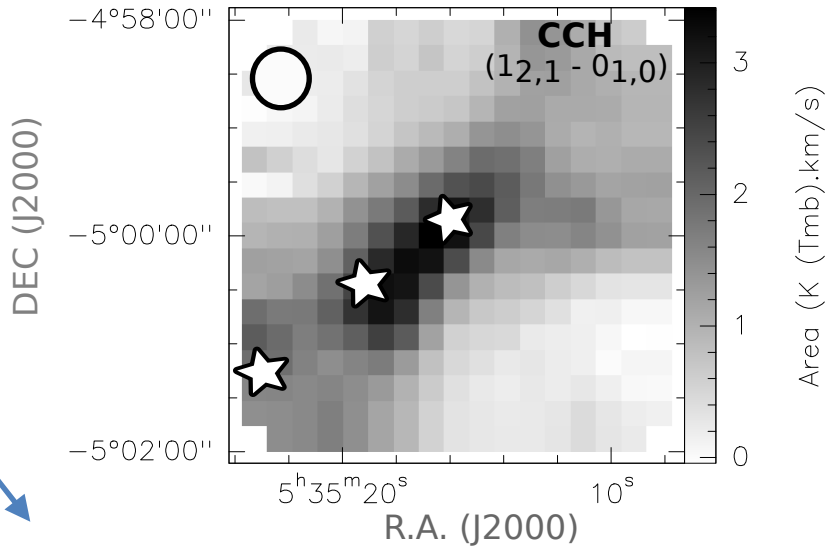
Abundance ratio constant throughout the filament

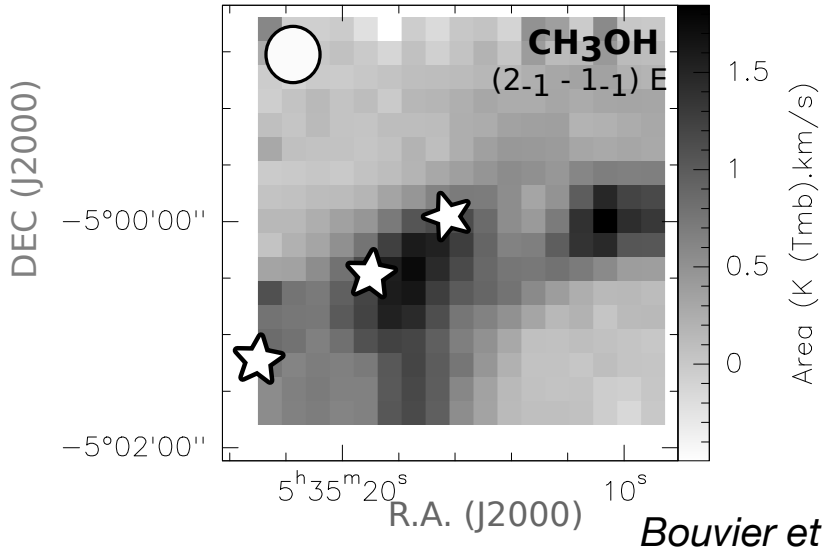
Are we tracing the parental gas where the protostars are embedded ?

Bouvier et al. in prep

OTF MAP : Evidence for extended emission



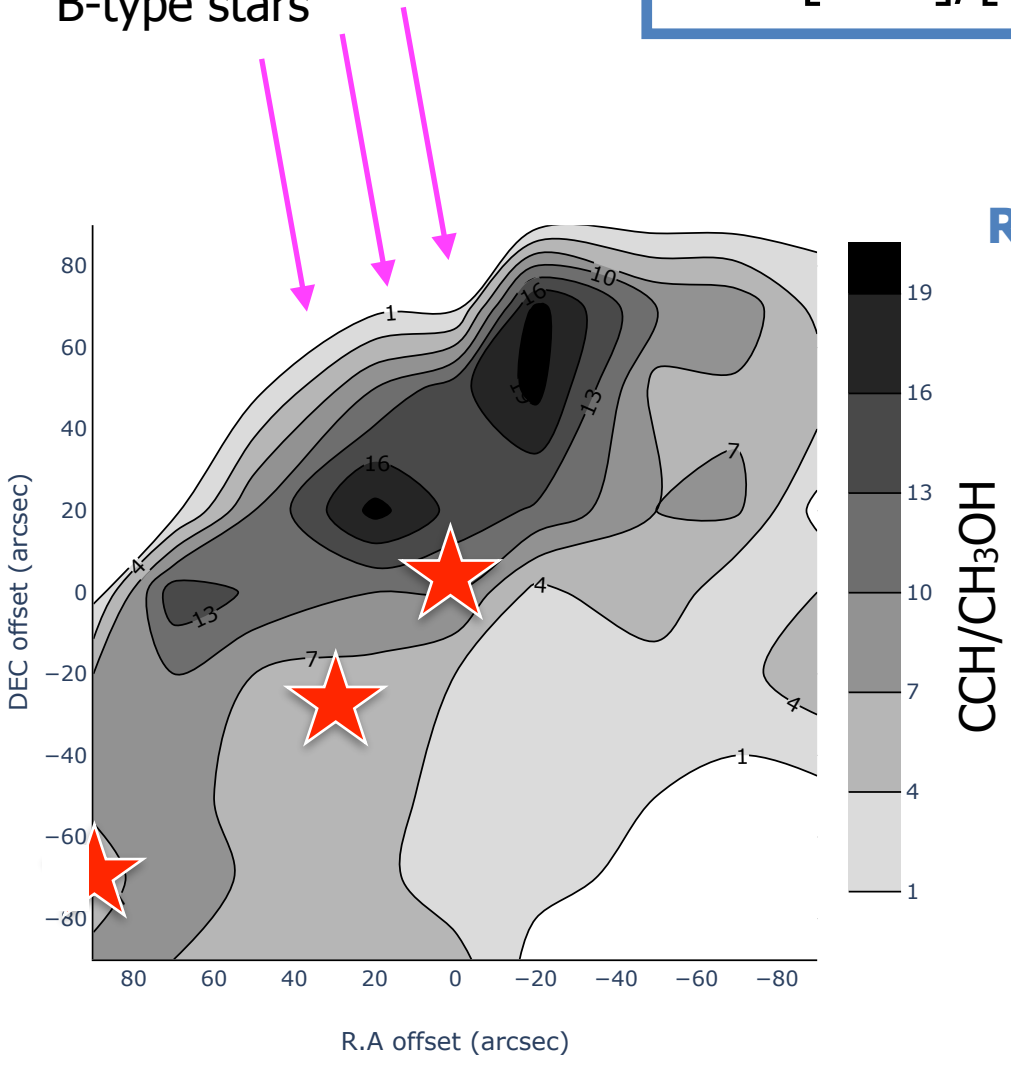




Bouvier et al. in prep

HII region NGC 1977
B-type stars

MAP [CCH]/[CH_3OH]



Results from non-LTE LVG analysis

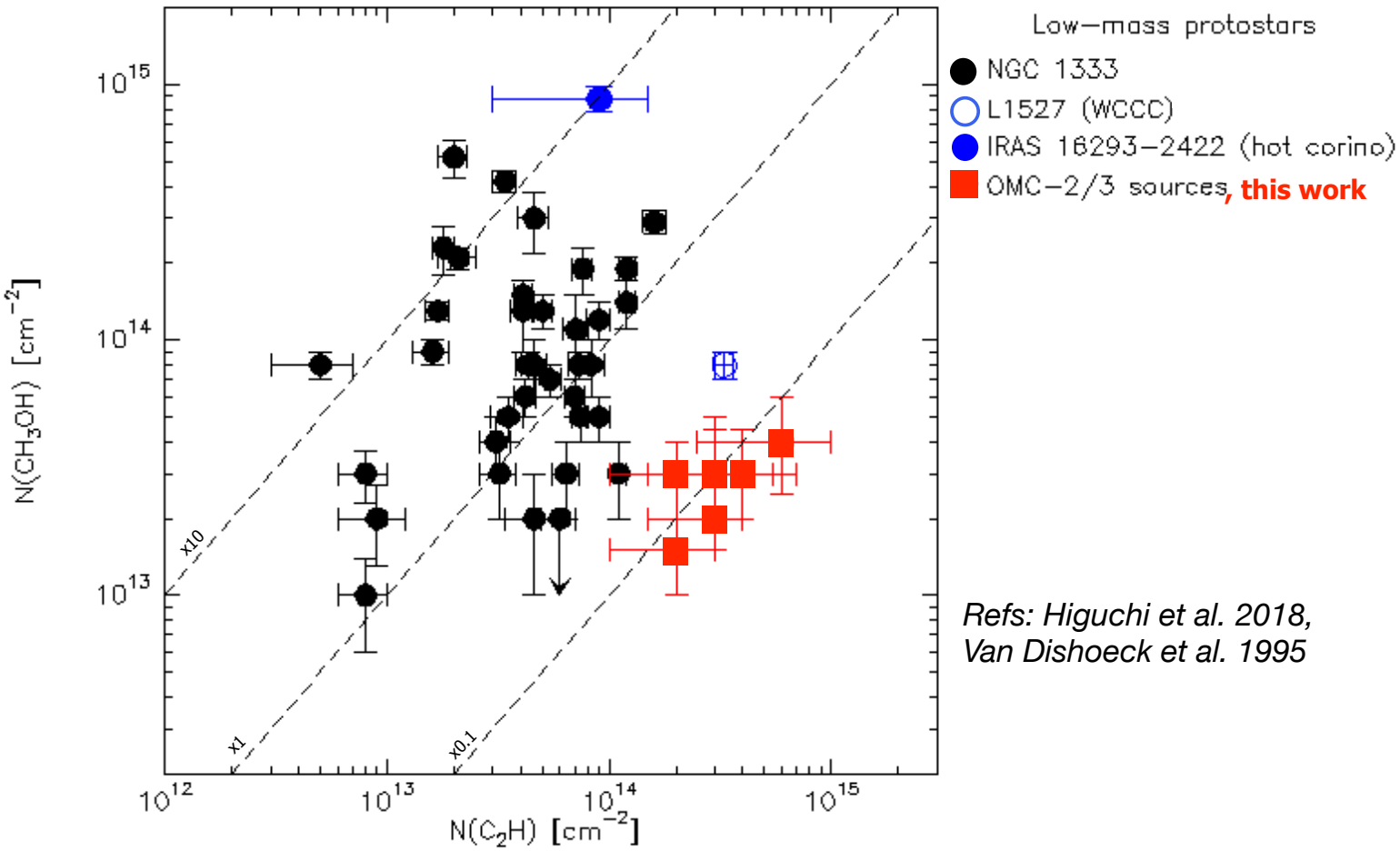
1. Abundance ratio does not vary with position of the source

2. Gradient of abundance ratio through the filament probably caused by the illumination of the nearby HII region

Are we tracing the parental gas where the protostars are embedded ? YES

Bouvier et al. in prep

Comparison with survey in Perseus (Higuchi et al. 2018)



Refs: Higuchi et al. 2018, Van Dishoeck et al. 1995

Adapted from Higuchi et al. 2018

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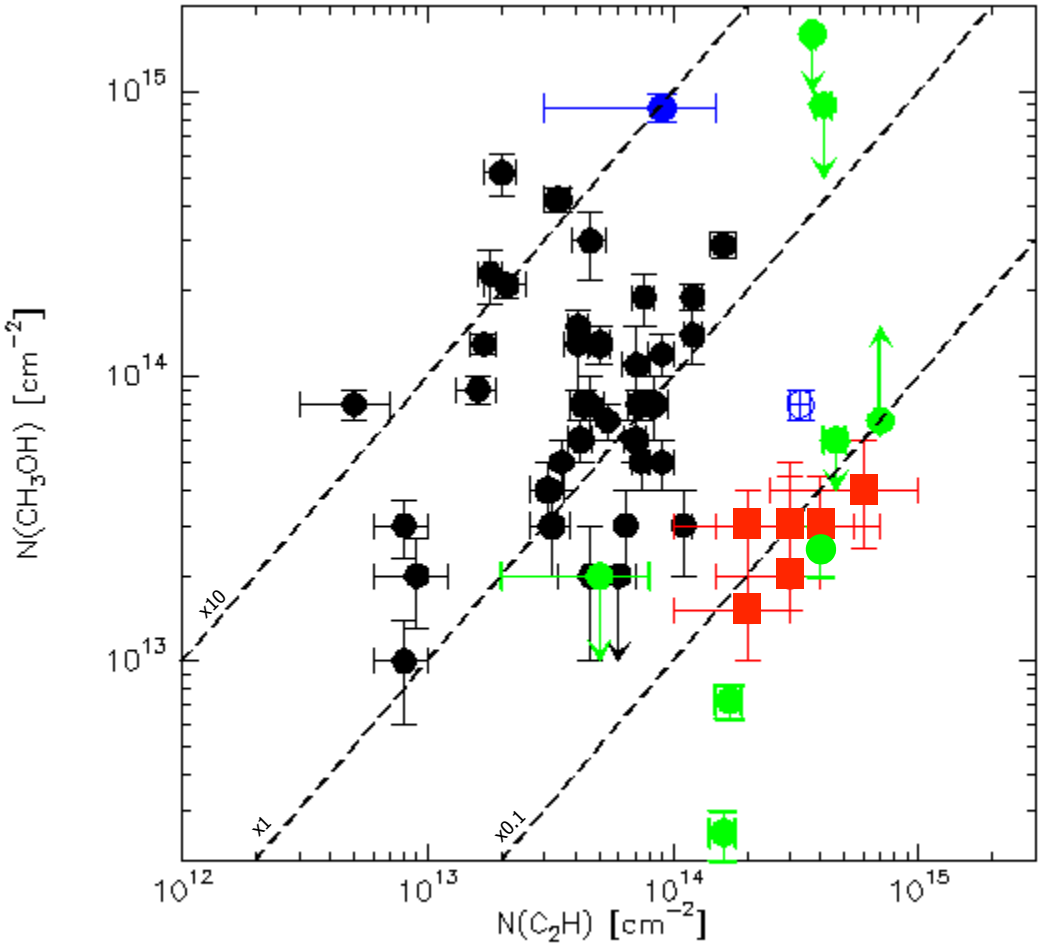

Low−mass protostars
- NGC 1333
- L1527 (WCCC)
- IRAS 16293−2422 (hot corino)
- OMC−2/3 sources, **this work**

PDRs
- Horsehead PDR/core,
- OMC−1 Ridge PDR,
- Orion Bar PDR IC63,
- MONR2 IR/MC peak

Refs: Jansen et al. 1994, Van Dishoeck et al. 1995, Ungerechts et al. 97, Teyssier et al. 2004, Higuchi et al. 2018, Cuadrado et al. 2015/2017, Ginard et al. 2012, Gúzman et al. 2014

Adapted from Higuchi et al. 2018

We are probably tracing the surrounding PDR !

[CCH]/[CH_3OH] not reliable to determine the chemical nature of Solar-type protostars

Conclusions

- Need to choose other tracers for single-dish observations (PDR contamination)
- Impossible to find hot corinos and/or WCCC candidates with [CCH]/[CH_3OH] in OMC-2/3
- We need interferometry to hopefully determine the chemical nature of protostars

(Next step !)

Acknowledgements

ERC DOC (Dawn of Organic Chemistry)

Main Collaborators: Ana López-Sepulcre, Cecilia Ceccarelli, Claudine Kahane, Muneaki Imai, Nami Sakai, Satoshi Yamamoto, Paul J. Dagdigian

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Back up slides

HH212-MM1: A hot corino in Orion but isolated

http://simbad.u-strasbg.fr/

Evidences that Sun born in stellar cluster

(Adams 2010, Pfaltzner et al. 2015)

Sun's properties

- $^{17}O/^{18}O$ anomalies -> explained by intense FUV radiation fluxes
- High metallicity / enrichment in short-lived radionuclides (SLRs) such as ^{60}Fe and ^{26}Al -> origin at scale of molecular cloud and local massive star wind scale respectively
  -> SN nearby?
- Abundance of ^{60}Fe and ^{26}Al -> large group of stars close to Sun

Constraint from Radiation field

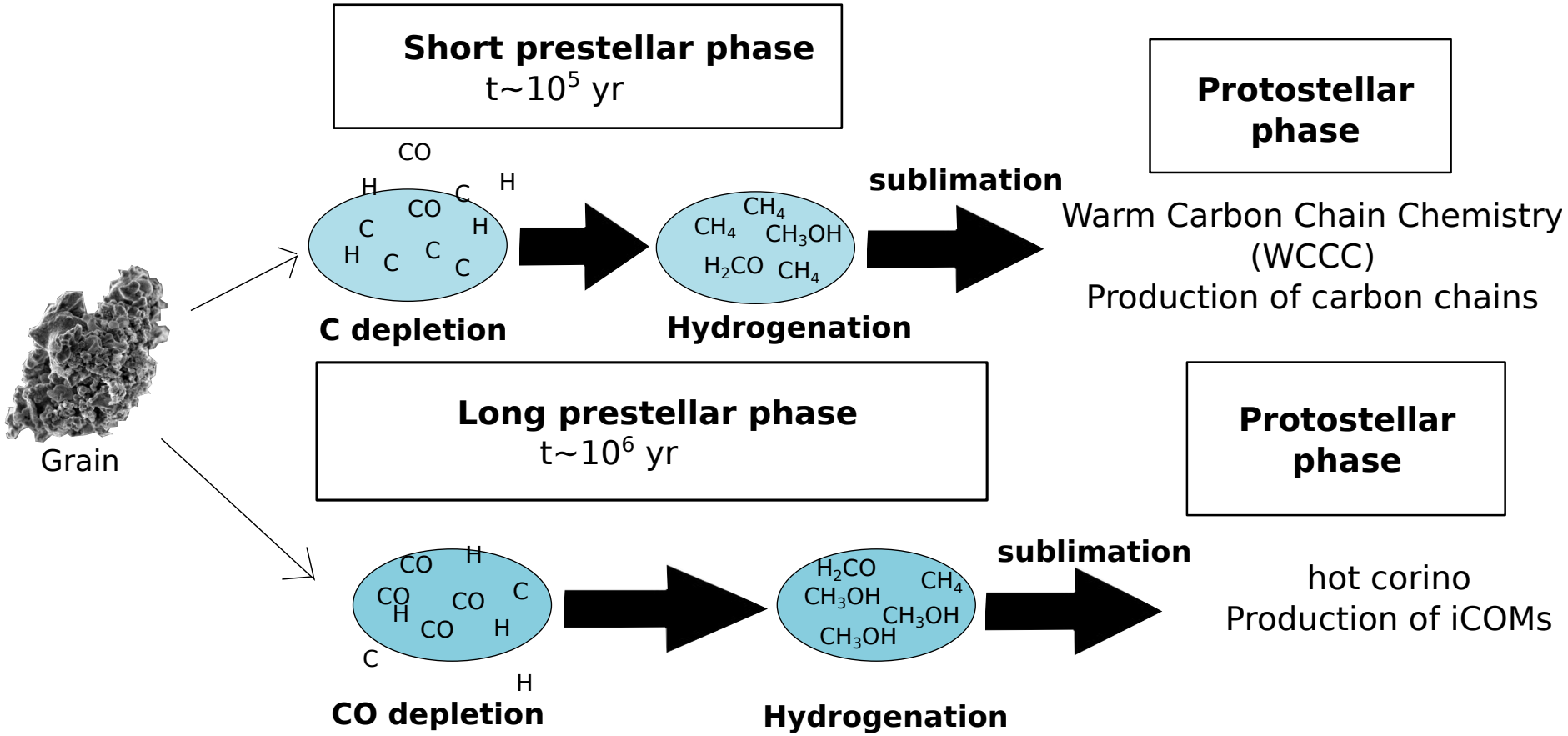
- Early solar nebula: sharp edge @ ~30au -> fly-by <10 Myr or photo-evaporation of disk ?
- Uranus and Neptune = ice giants -> photo-evaporation near 30 au require FUV flux of $G_0 \sim 10^4$

Constraint from dynamics

- Sedna has high eccentricity -> caused by close encounter ? Consistent with Sun beeing born in moderate-size cluster
- Tilt of Sun's rotation -> can be explained by star-disc interaction

Host cluster of Sun: M67 ? Same chemical composition with stars but orbits different.

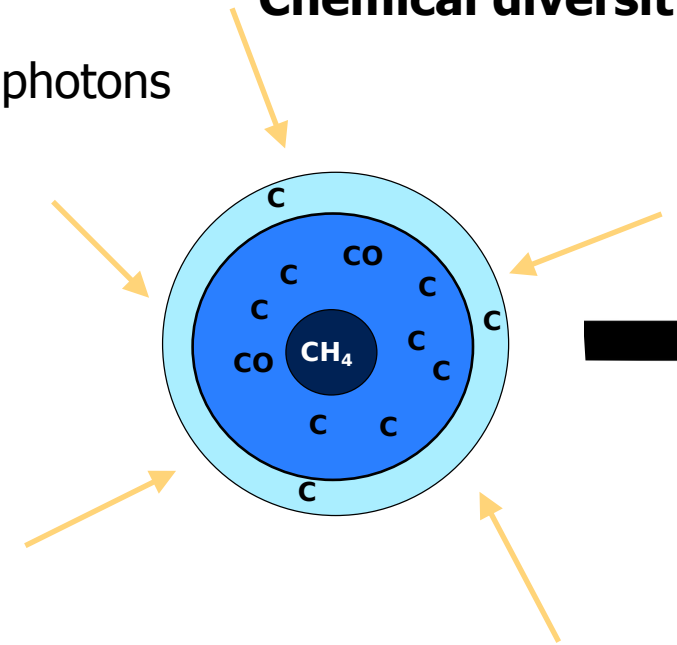
Chemical diversity among Proto-stars: Explanation 1



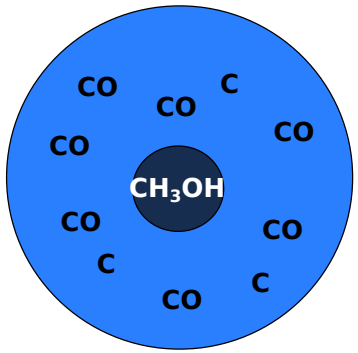
Adapted from
Sakai & Yamamoto 2013, Chem. Rev

Chemical diversity among Proto-stars: Explanation 2

FUV photons



Warm Carbon Chain Chemistry (WCCC)

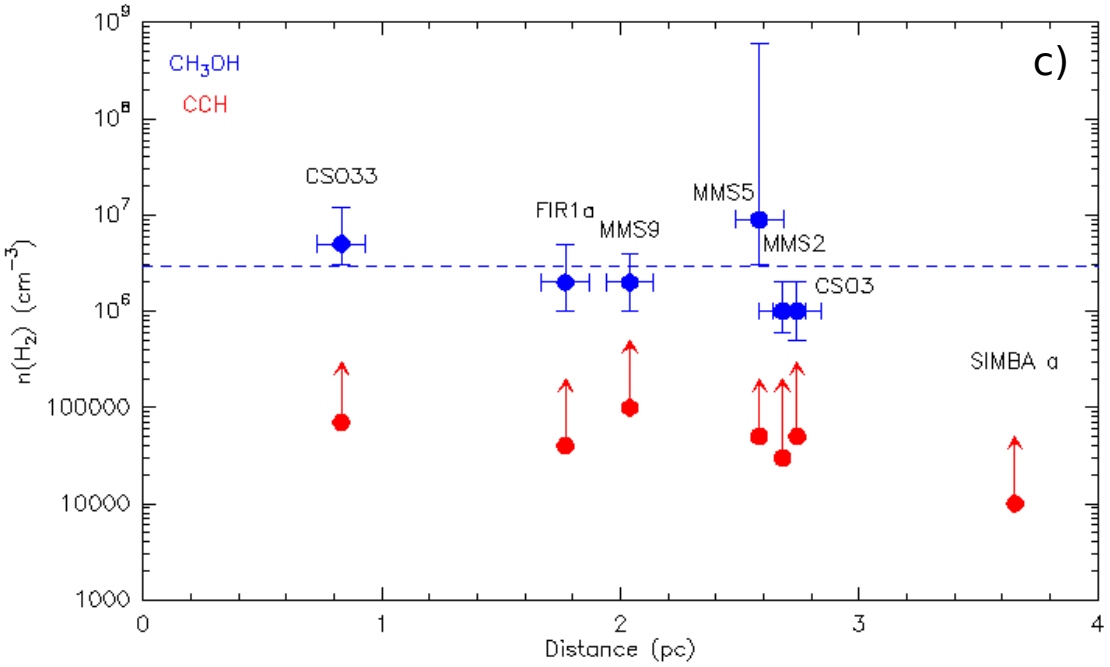


hot corino

Adapted from Spezzano et al. 2016

Only for uniform illumination

Gas density


c)
CH3OH
CCH
CSO33
FIR1a
MMS9
MMS5
MMS2
CSO3
SIMBA a
n(H2) (cm-3)
Distance (pc)
10^9
10^8
10^7
10^6
100000
10000
1000
0
1
2
3
4