Chemical tracers of episodic accretion in embedded protostars

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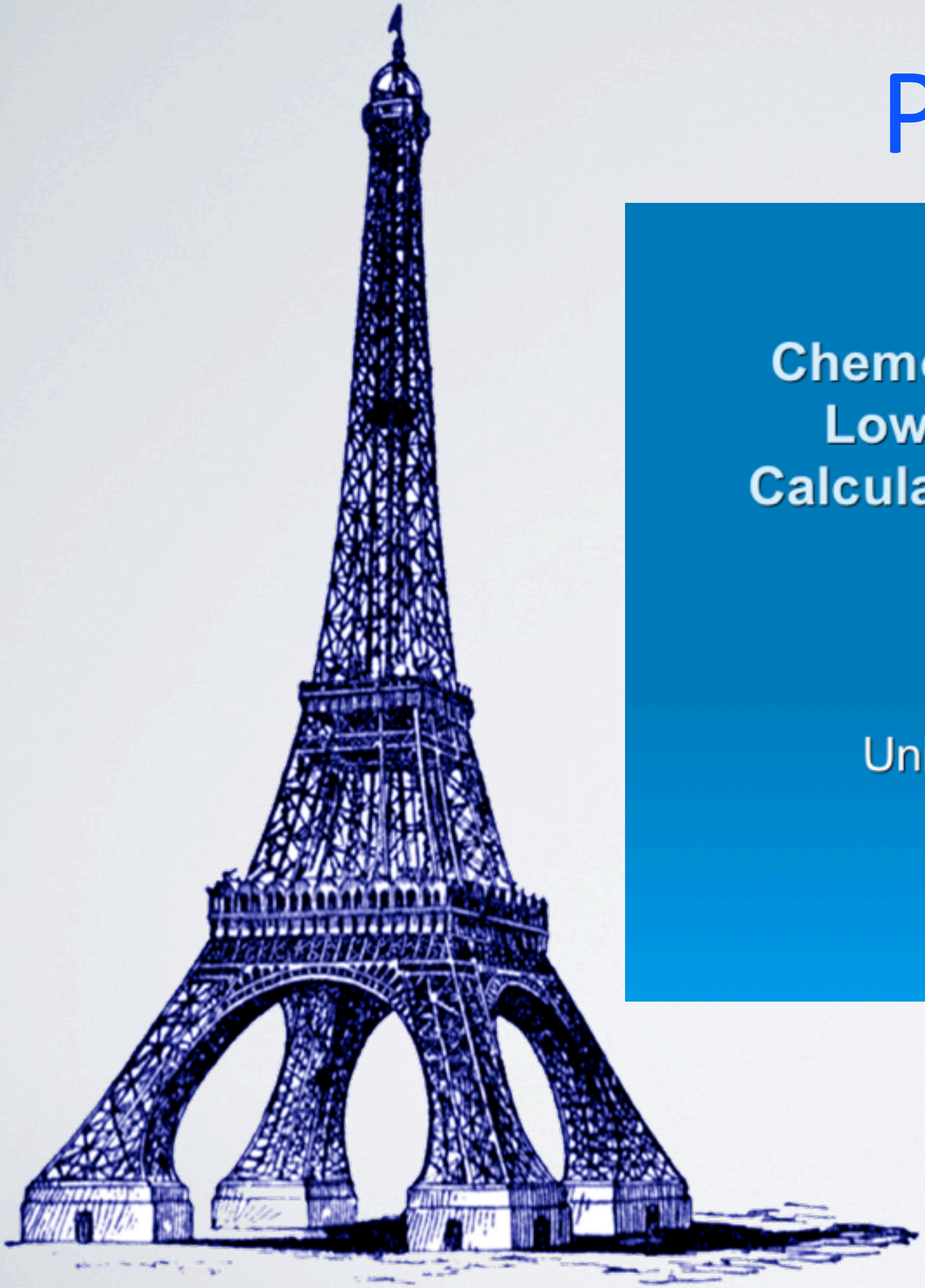
PARIS, 2007



Chemo-dynamical Modeling of Low Mass Star Formation: Calculations and Comparison to Observations

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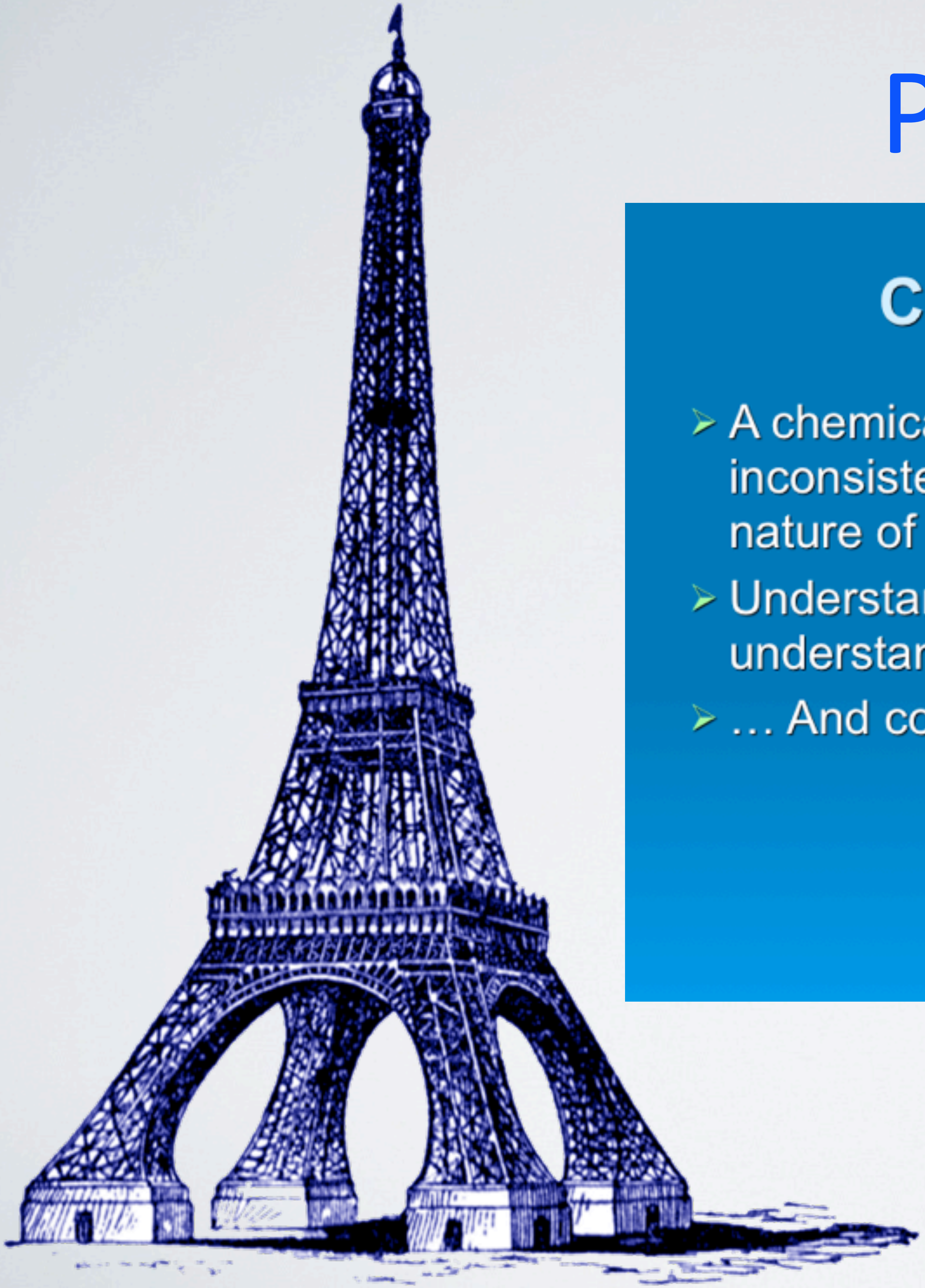


Paris, 2007

Chemical Memory

- A chemical abundance pattern inconsistent with current L is a clue to nature of episodic accretion
- Understanding astrochemistry is crucial for understanding how stars are built
- … And conditions in planet forming disks

WHAT DOES L_{BOL} REALLY MEASURE?

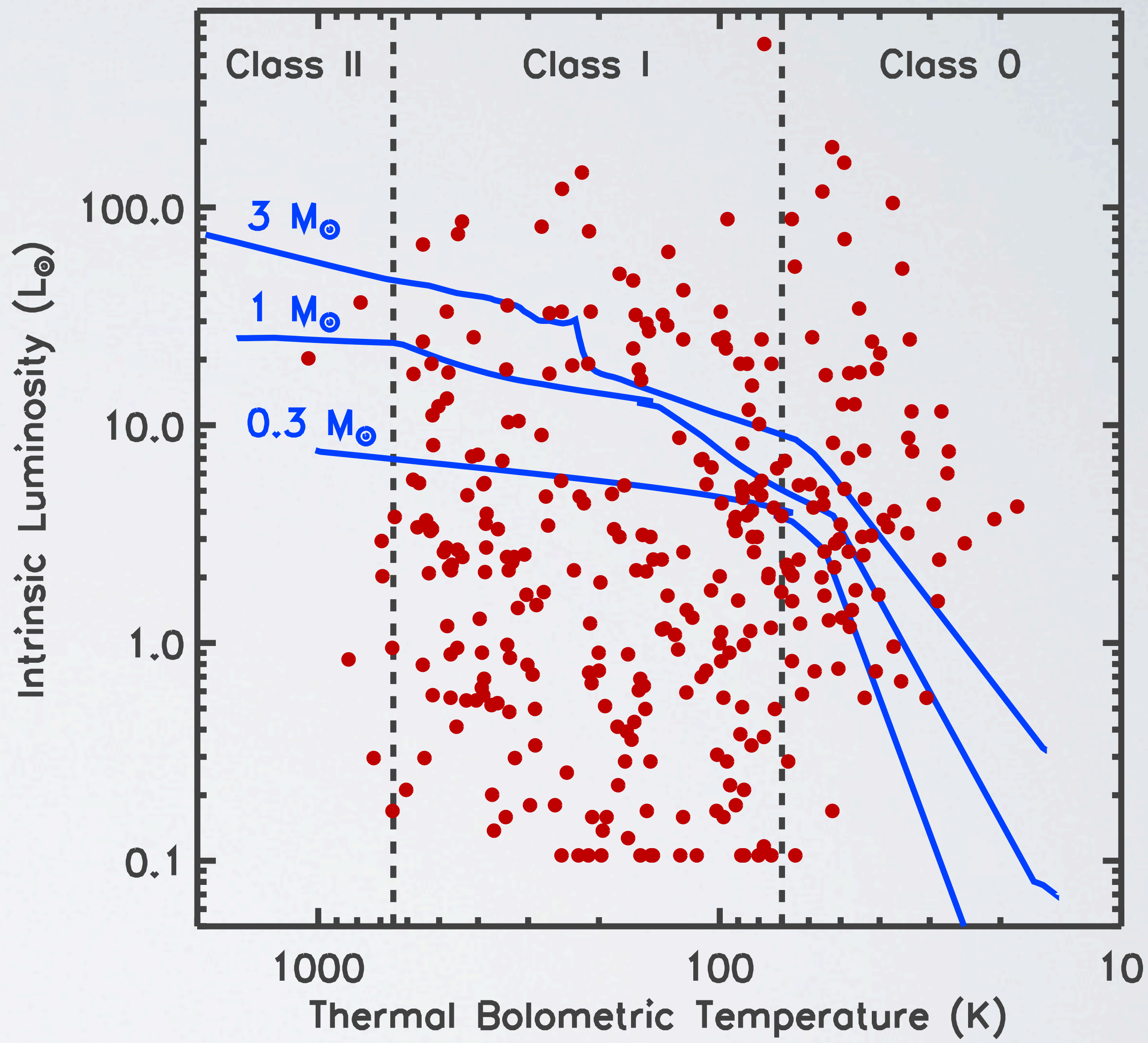
Stellar mass

Gravitational constant

$$L_{\rm bol} \approx L_* \approx \frac{GM_*\dot{M}}{R_*}$$

Stellar radius

Accretion rate

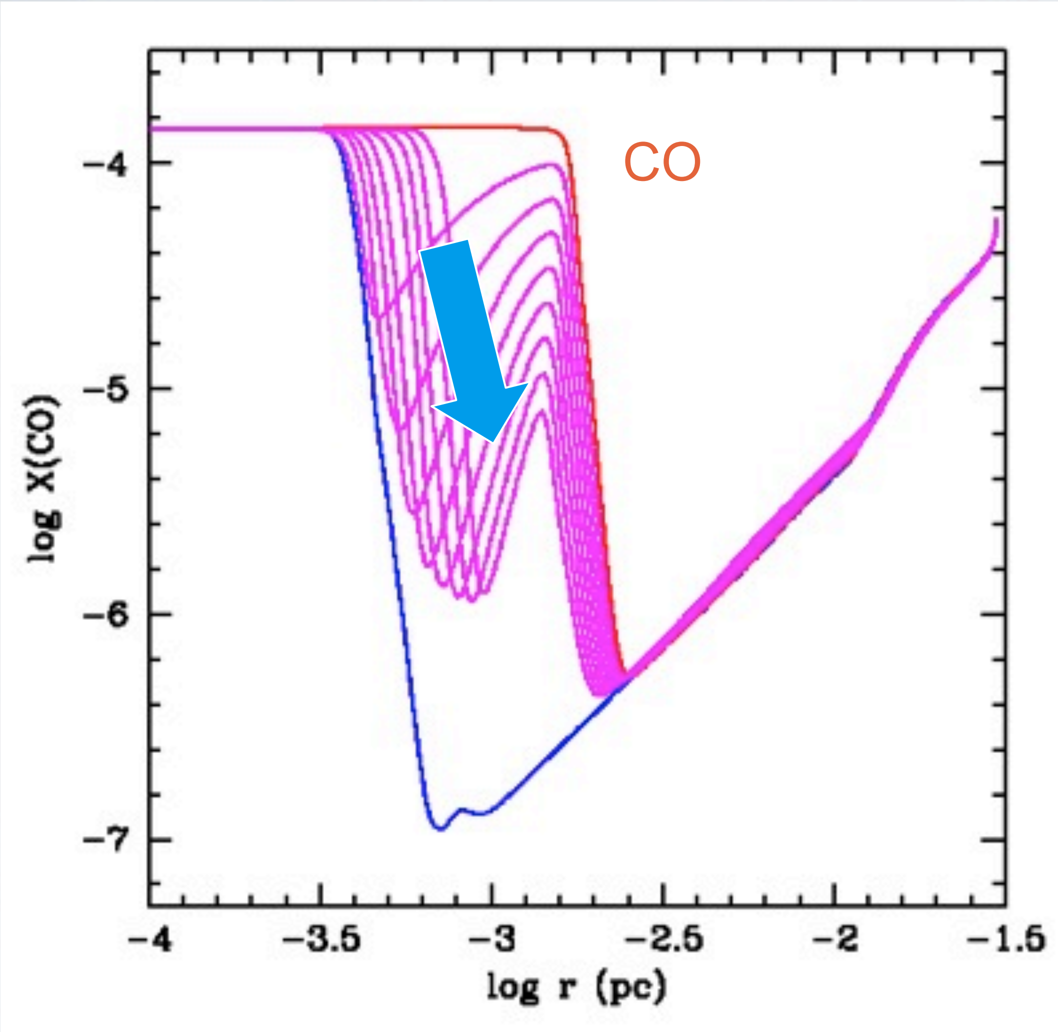


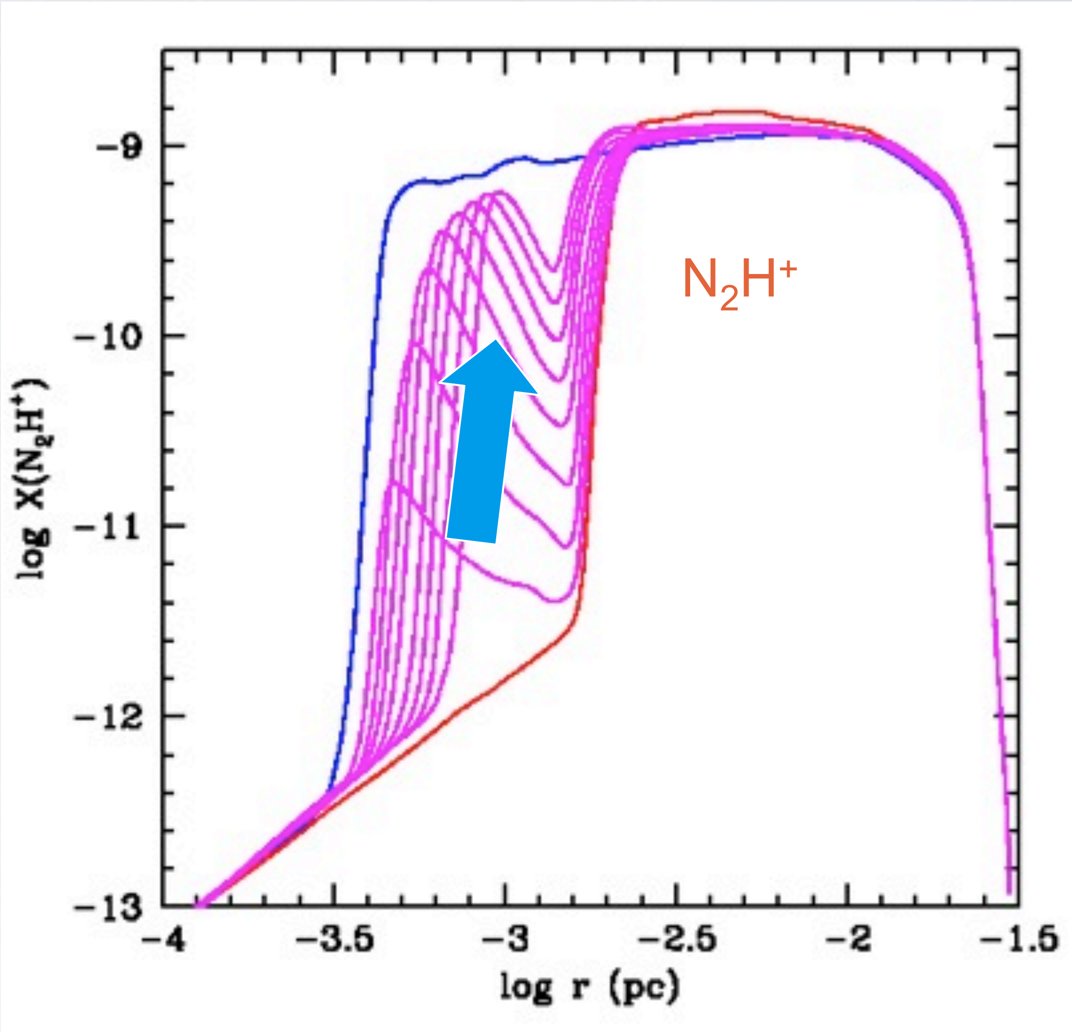
Evans et al. (2009)

"High" $L_{\rm bol}$ could mean:

- low-mass protostar undergoing accretion burst
- intermediate-mass protostar in quiescent phase

CO AND N_2H^+

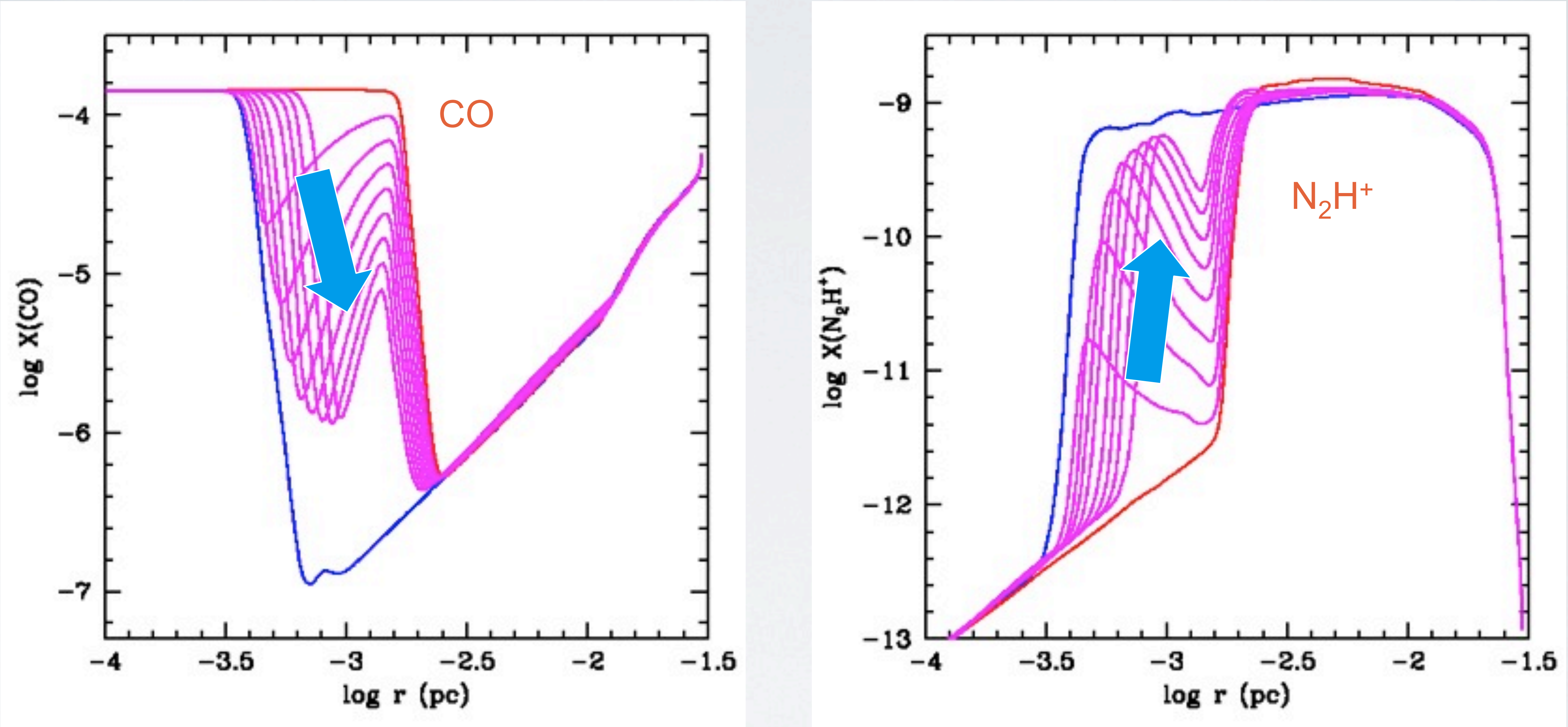




- After a burst: CO increases, N_2H^+ decreases
- Possible probes: $C^{18}O$ $J=5\text{–}4$ and N_2H^+ $J=5\text{–}4$
- *Problem: intrinsic variation in line intensities*

Lee (2007)

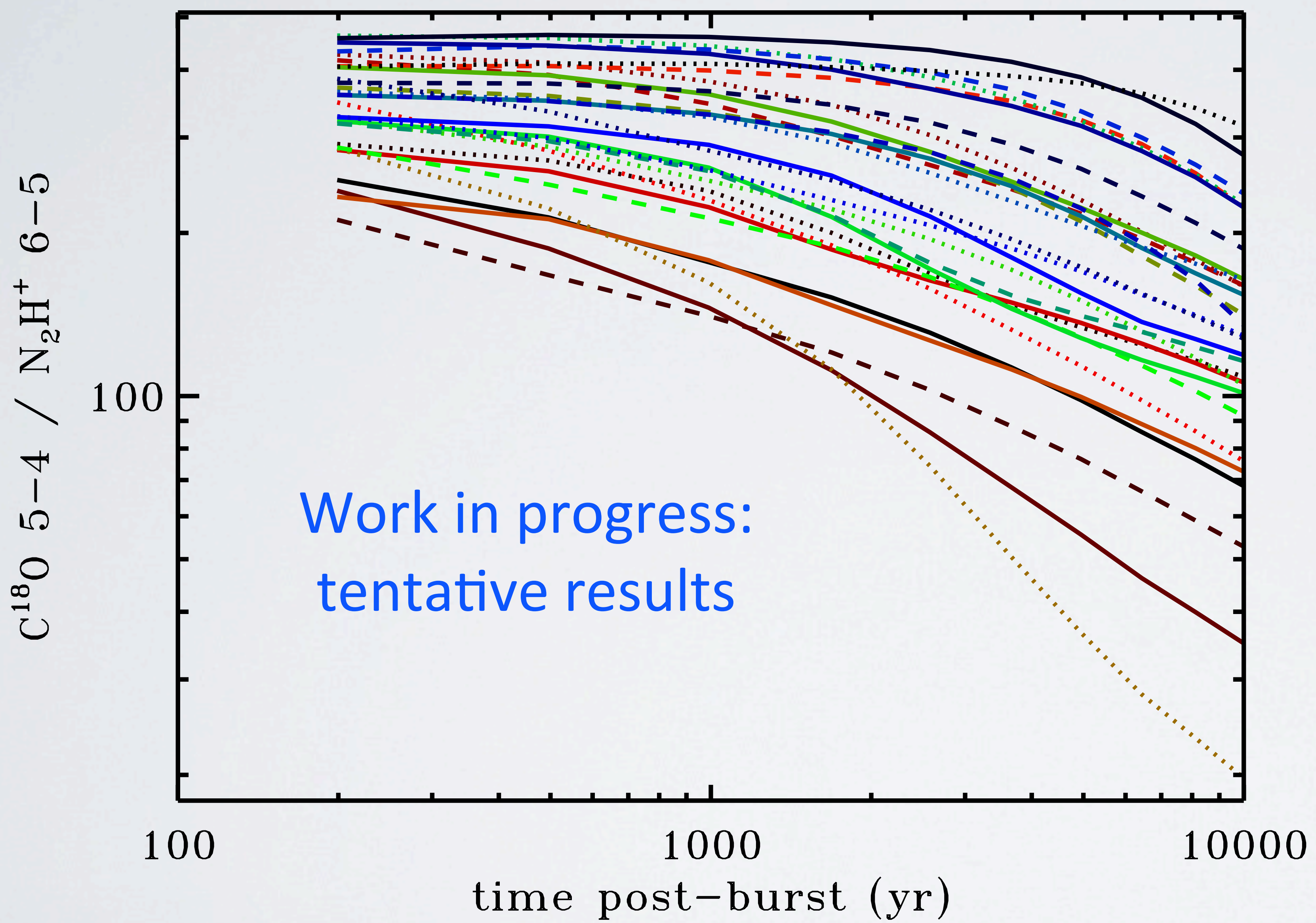
CO and N_2H^+



If we have a protostar in a quiescent phase, can we measure the time since the last burst?

Lee (2007)

RECIPE FOR SPAGHETTI?



- WISH sample of 29 low-mass protostars
- $L_{bol} = 0.8–37\ L_\odot$
- Assumption: all are in quiescent phase
- Good news: general downward trend
- Bad news: I don't like spaghetti

Visser & Bergin (in prep.)

ENTER: THE FREEZE-OUT TIME

$$t_{\mathrm{freeze}} = 10^4\,\mathrm{yr}\sqrt{\frac{10\,\mathrm{K}}{T}\,\frac{10^6\,\mathrm{cm}^{-3}}{n(\mathrm{H}_2)}}$$

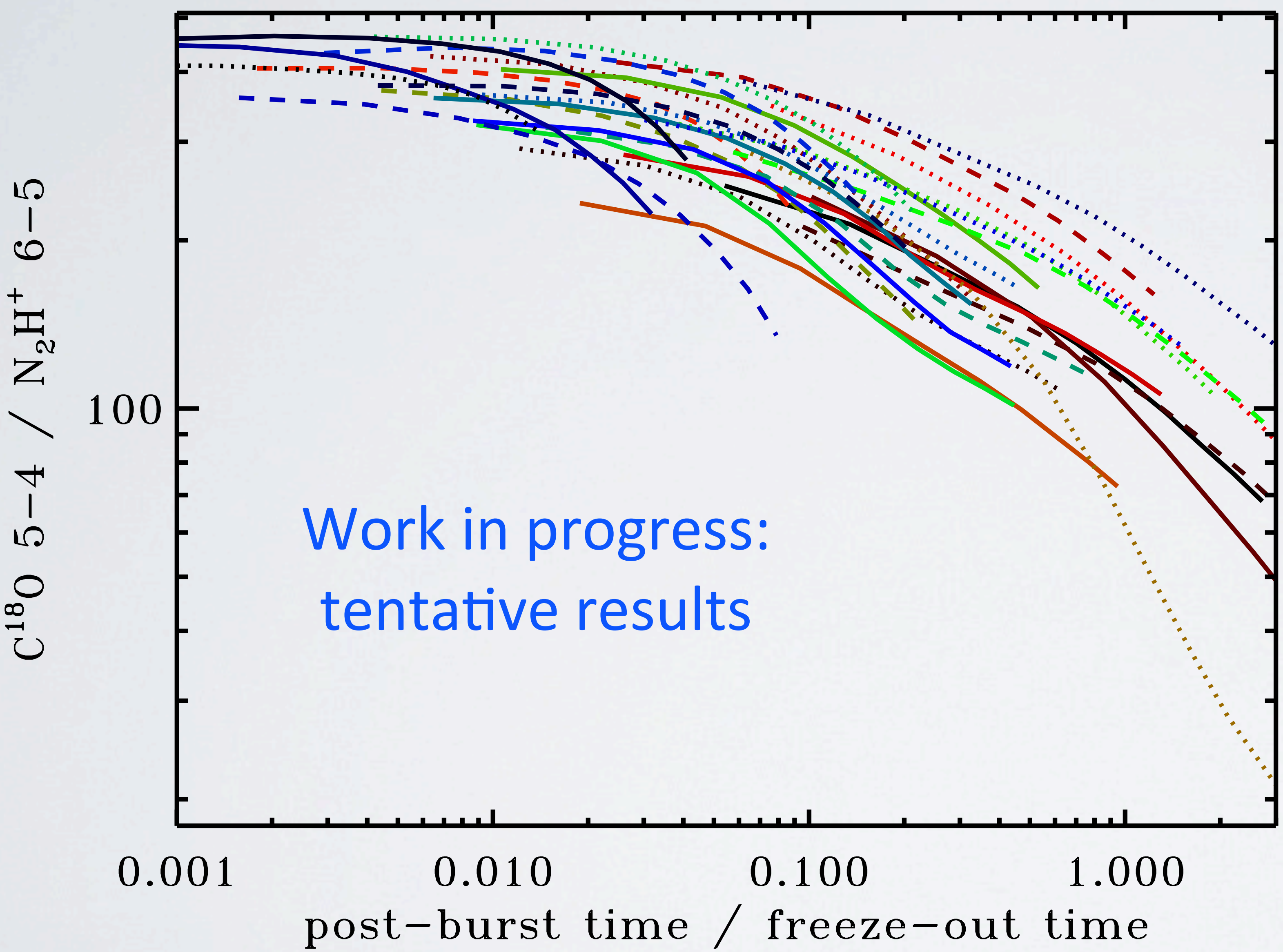
Temperature

Gas density

- Chemical timescale dominated by freeze-out
- Freeze-out rate set by collisions with dust
- *Depends on density-temperature profile for each source*

Visser & Bergin (2012)

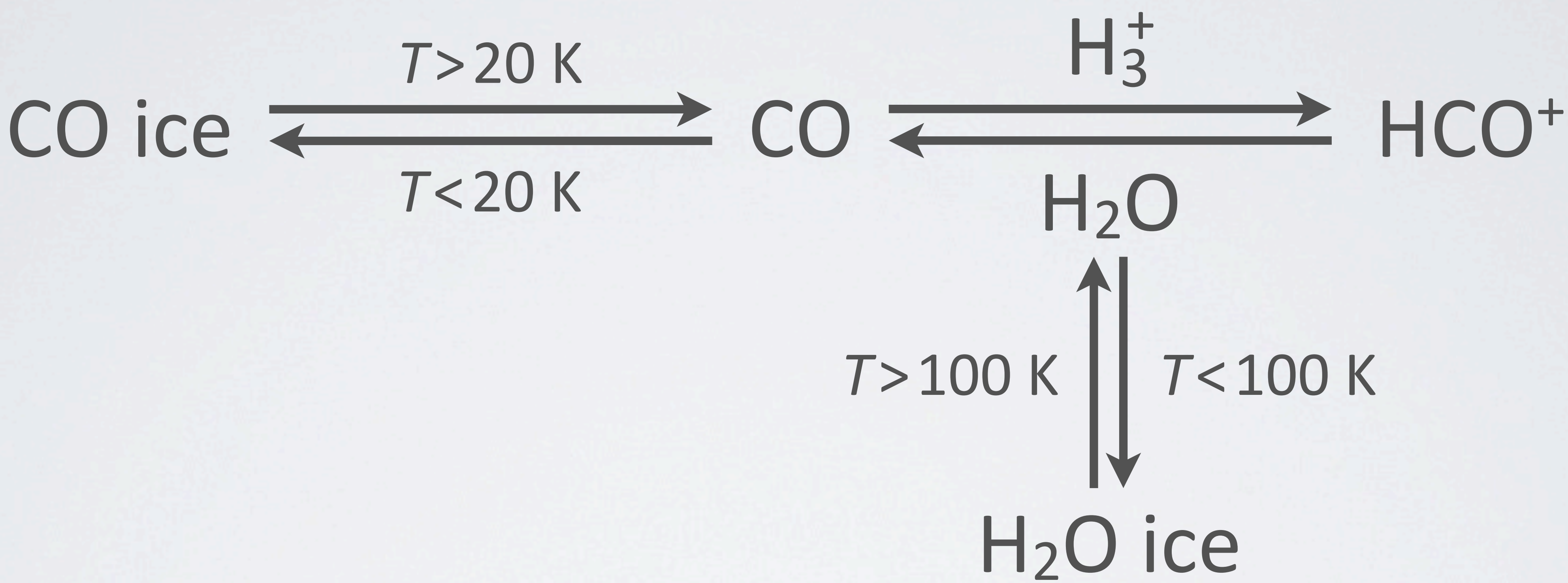
NORMALIZE BY FREEZE-OUT TIME



- Reduced scatter
- Observed ratio in eight sources: 0.8 – >16
- *Are these sources really quiescent?*

Visser & Bergin (in prep.)

ALTERNATIVE TRACER: HCO^+

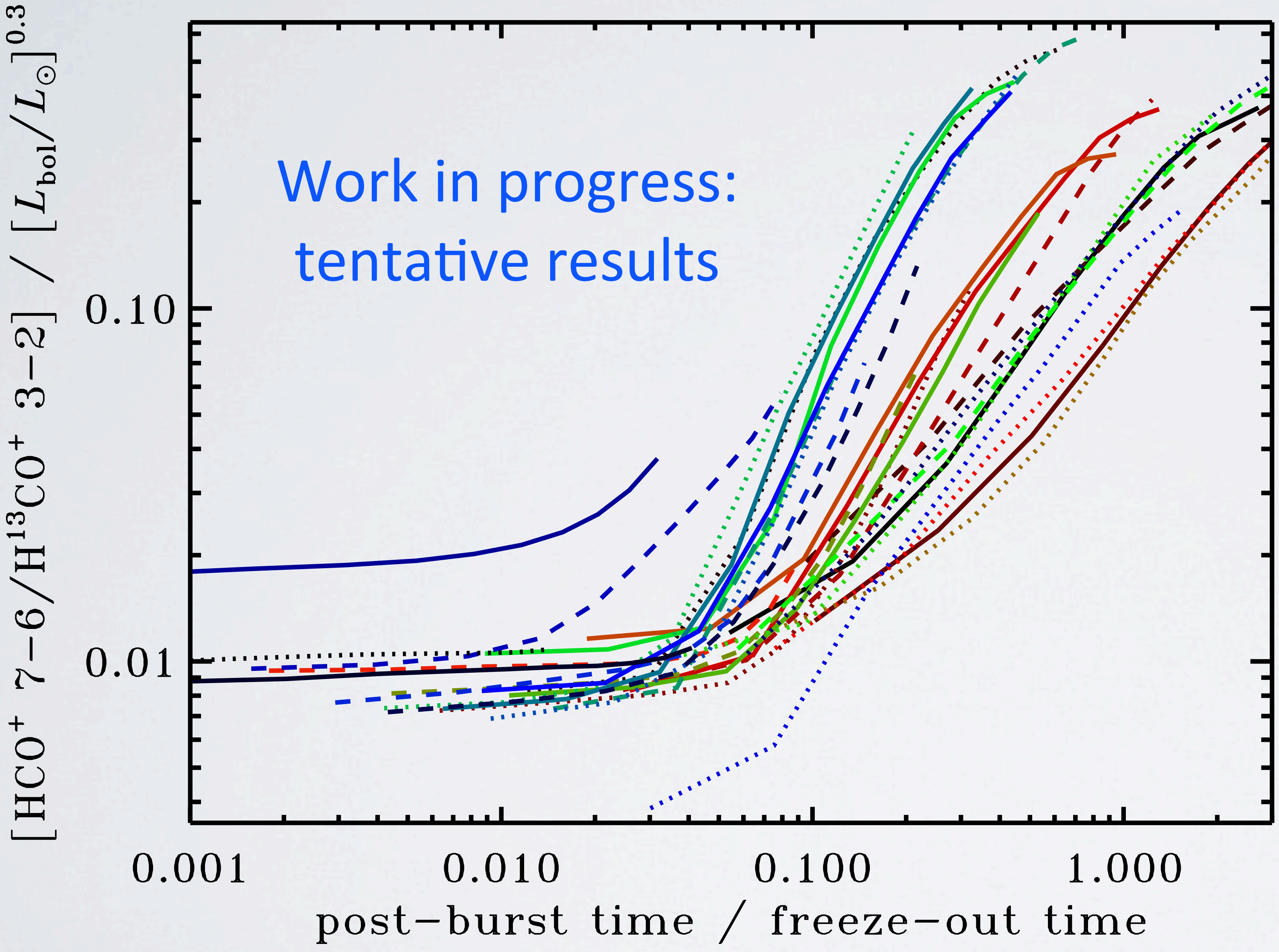


$T < 20$ K: freeze-out of CO reduces HCO+

20 K $< T <$ 100 K: evaporation of CO enhances HCO+

$T > 100$ K: evaporation of H_2O reduces HCO+

HCO^+ 7–6 / $H^{13}CO^+$ 3–2



- Vertical axis normalized by $L_{bol}^{0.3}$
- Larger dynamic range than $C^{18}O/N_2H^+$
- Same caveat: *Are these sources really quiescent?*

Visser & Bergin (in prep.)

Closing thoughts

A chemical abundance pattern inconsistent with current *L* is a clue to nature of episodic accretion

Challenge 1:
how can we filter out chemical variations due to e.g. $M_{\rm env}$ or intrinsic $L_{\rm bol}$?

Challenge 2:
how many protostars with strong molecular lines are actually in a quiescent phase?

Visser & Bergin (2012), Visser & Bergin (in prep.)