Ken Tatematsu

1992-1994: postdoc working with Dan Jaffe and Neal

STRUCTURE OF DENSE CORES IN M17 SW. I. A MULTITRANSITION CS AND $C^{34}S$ STUDY

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ATOMIC CARBON IS A TEMPERATURE PROBE IN DARK CLOUDS

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Chemical variation in the molecular cloud cores in the Orion A GMC

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Background:

dark clouds Tk ~ 10 K, M~10^3 Mo, isolated low-mass SF

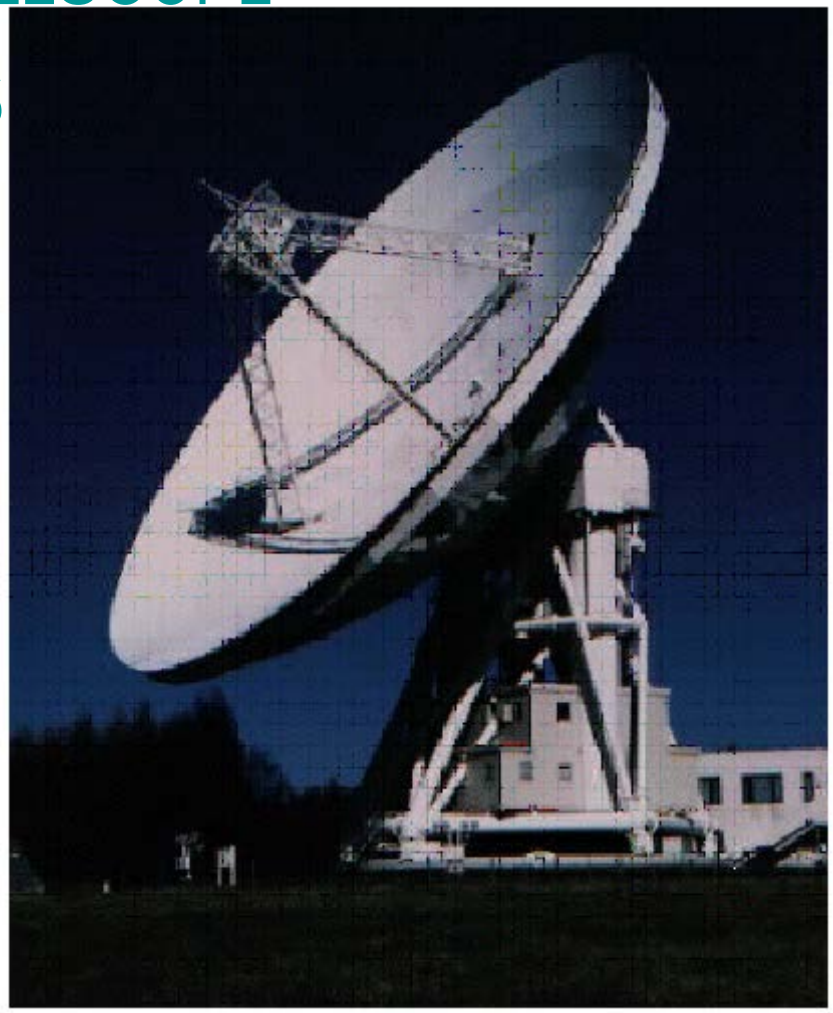
GMCs Tk ~ 10-100 K, M~10^5 Mo, cluster SF, massive SF

1. INTRODUCTION

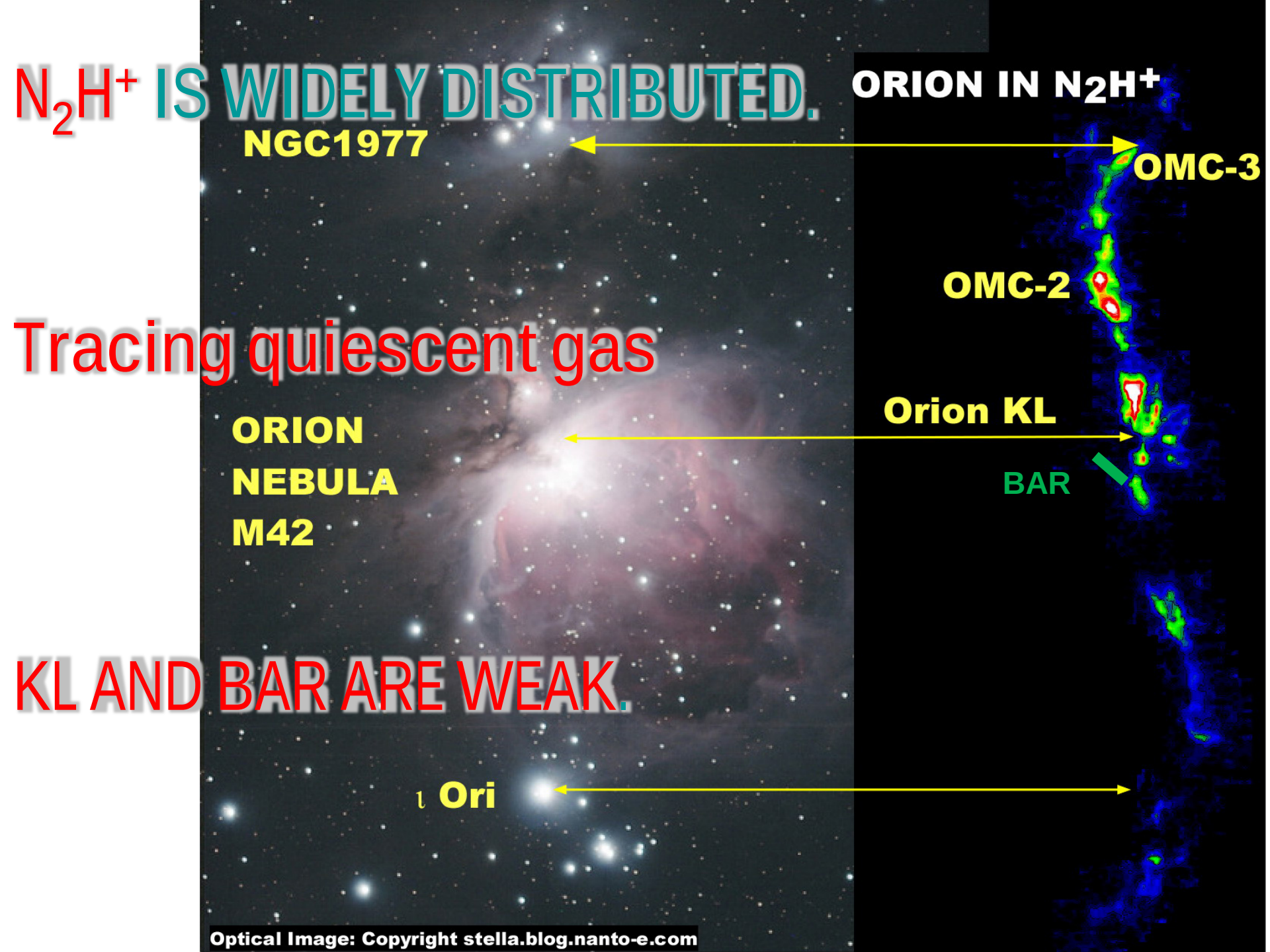
- In dark clouds, chemical evolution of Carbon Chain (CCS, HC_3N) → N-Bearing (NH_3, N_2H^+) is well established (e.g., Hirahara et al. 1992; Suzuki et al. 1992; Benson et al. 1998).
- Most stars form in GMCs rather than in dark cloud
- What about chemical evolution in GMC? Our target is Orion A GMCs
- CCS had not been detected in GMCs

2. OBSERVATIONS

- NOBEYAMA 45-m RADIO TELESCOPE
- RECEIVERS S40, T1Z, BEARS
- CCS at 45.4 and 81.5 GHz, N_2H^+ at 93 GHz
- 38" BEAM at 45GHz
- 19" BEAM FOR 80-100GHz



- Trot (NH_3) data is taken from Wilson+99


N_2H^+ IS WIDELY DISTRIBUTED.
ORION IN N_2H^+
NGC1977
OMC-3
OMC-2
Tracing quiescent gas
Orion KL
ORION
NEBULA
M42
BAR
KL AND BAR ARE WEAK.
ι Ori
Optical Image: Copyright stella.blog.nanto-e.com

Summary(1)

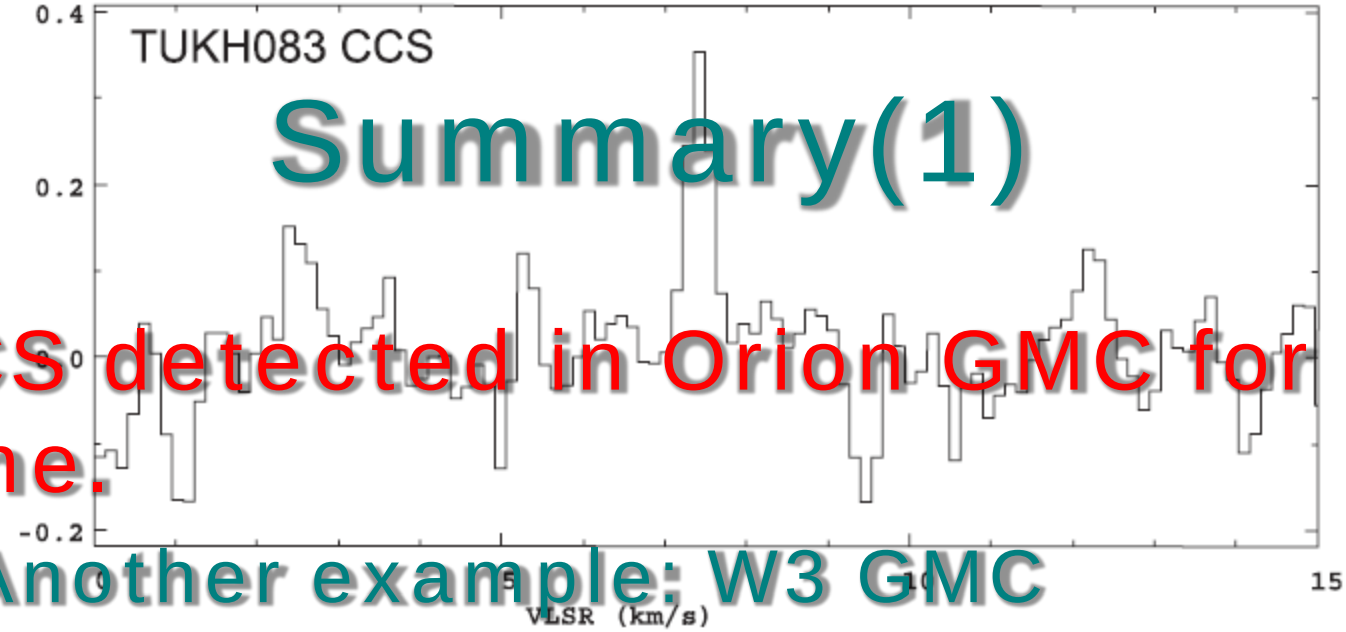


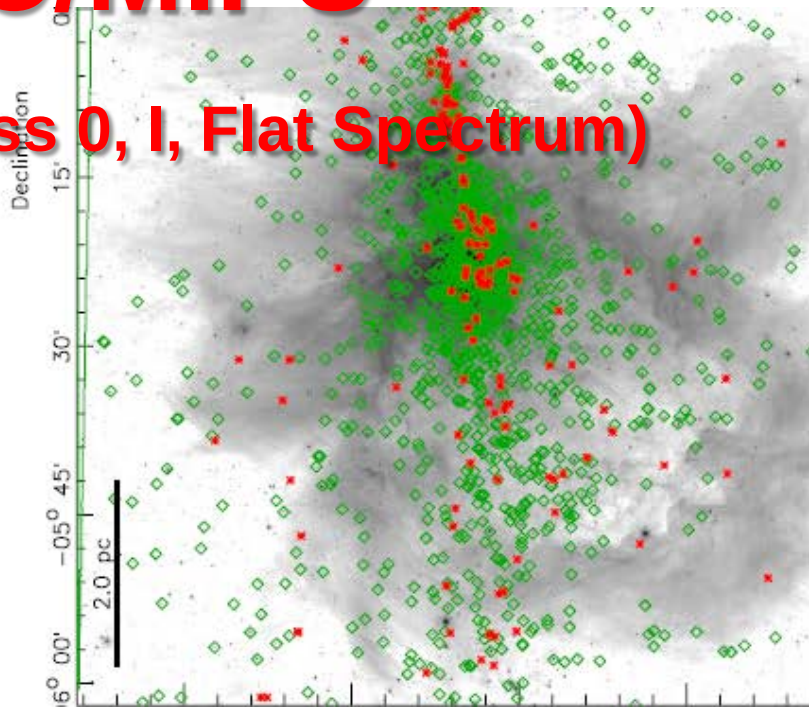
Fig. 1. CCS $J_N = 4_3$–3_2 spectrum observed toward TUKH083.

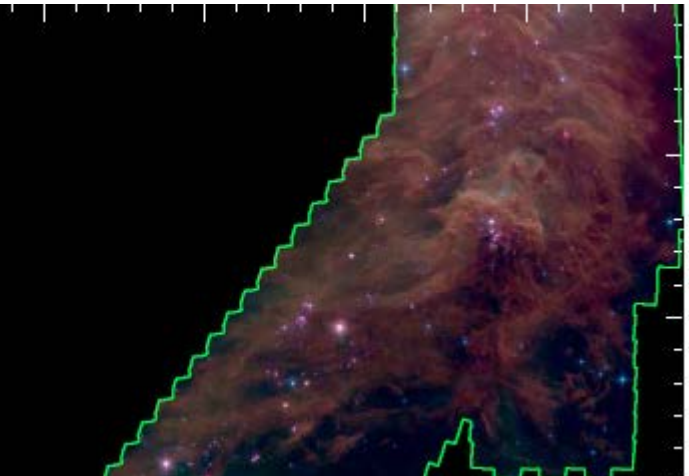
- CCS detected in Orion GMC for 1st time.
  - Another example: W3 GMC (Sakai+06).
  - Note that no CCS in IRDC (Sakai+08)
- No or weak CCS/ N_2H^+ in Bar (PDR) and KL
- CCS-N_2H^+ evolution was seen at least in cold (T_{rot}<20K) GMC cores

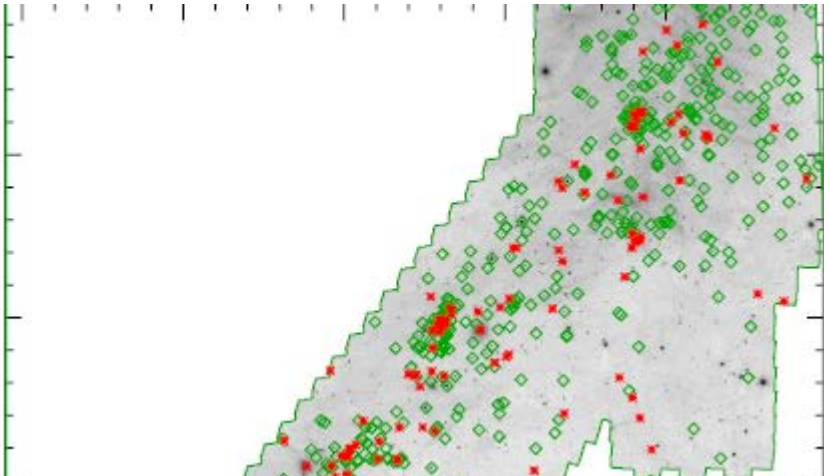
- Tatematsu et al. 2008, PASJ, 60, 407; Tatematsuet al. 2010, PASJ, 62, 1473; Tatematsu et al. 2013, in prep

YSO identification: Megeath+12 Spitzer IRAC/MIPS

red=protostar (class 0, I, Flat Spectrum)

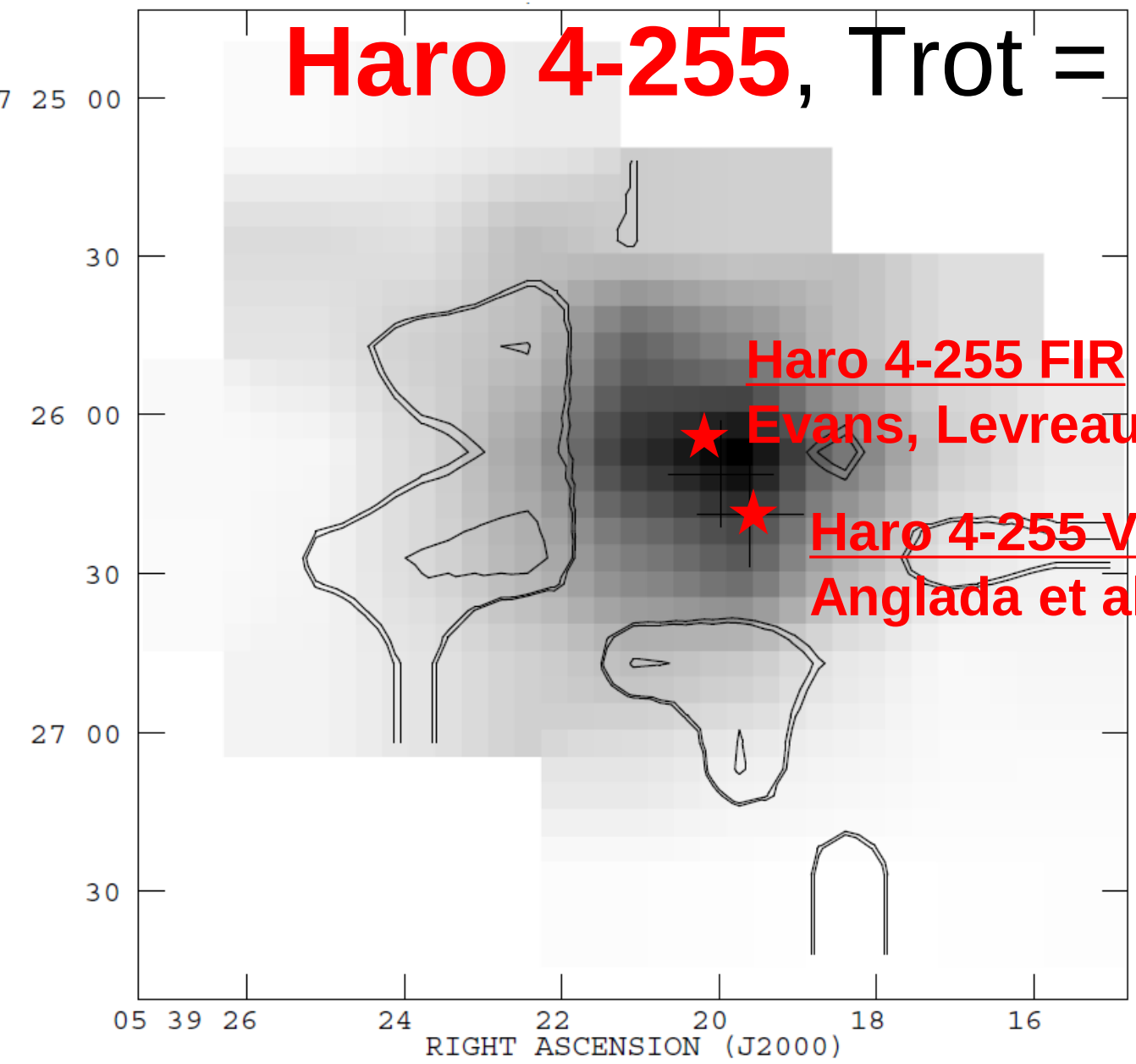






Contour=CCS, Grey=N_2H^+

Haro 4-255, Trot = 10 K

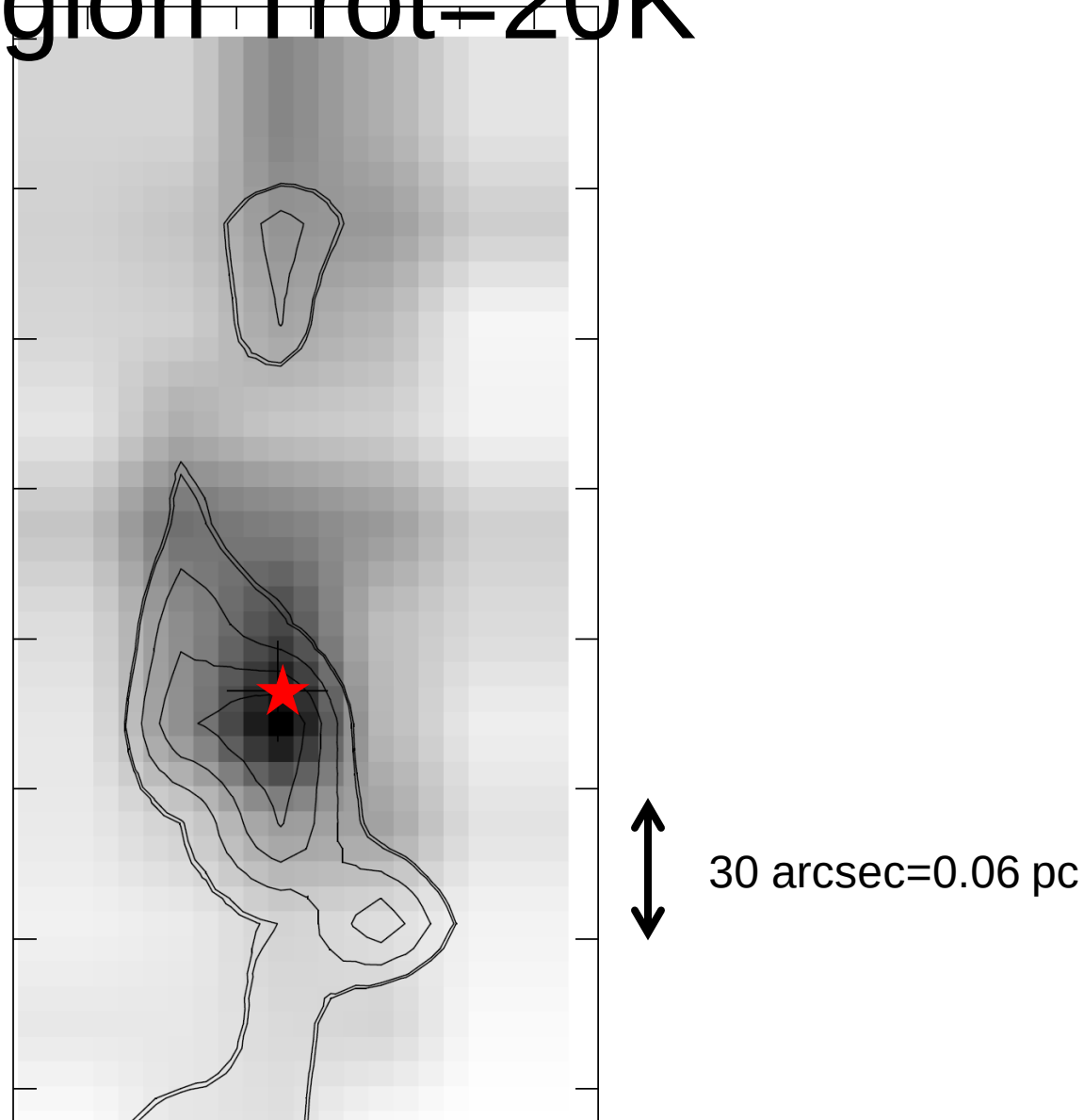


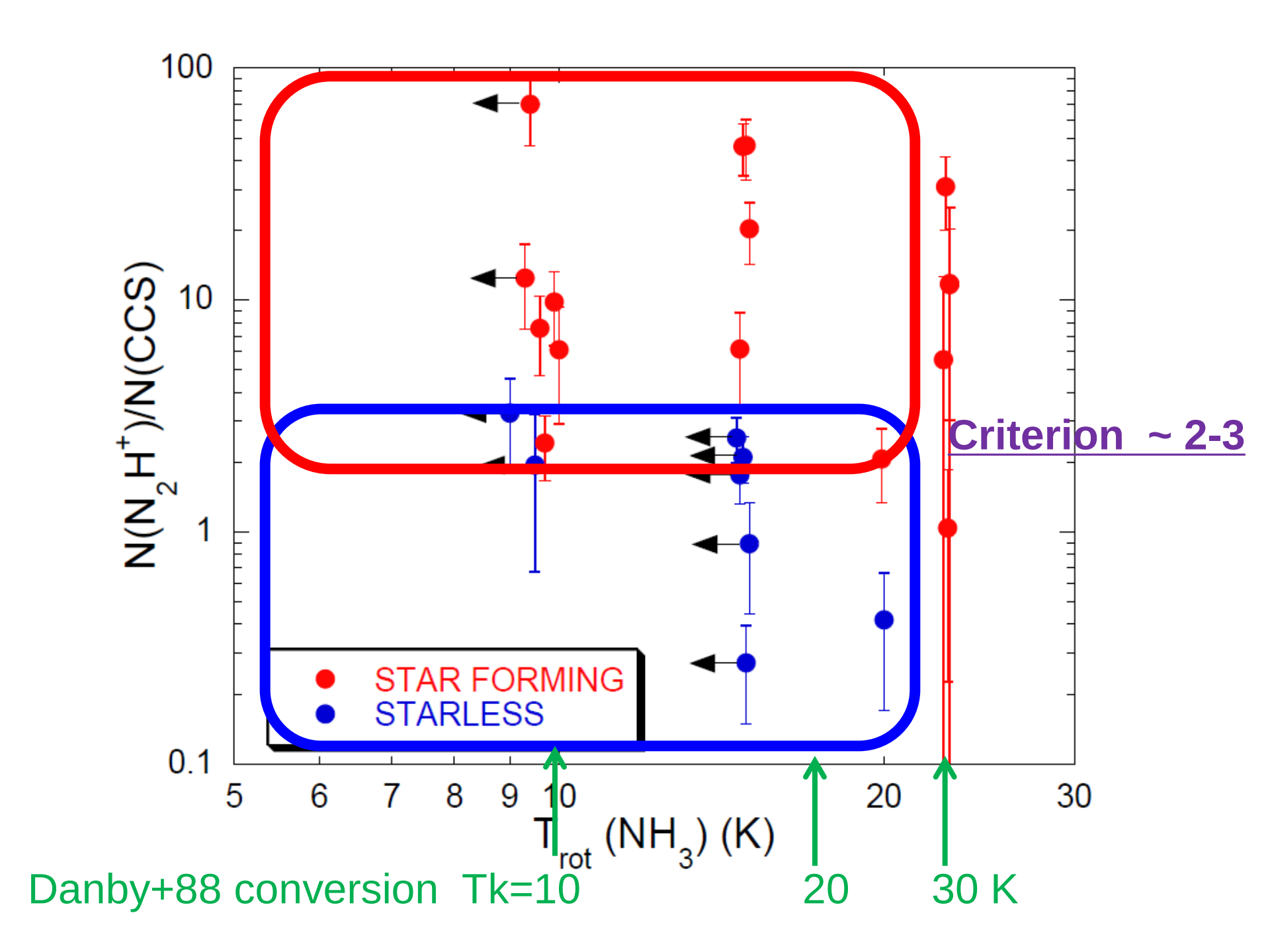
Haro 4-255 FIR
Evans, Levreault, Harvey 1986

Haro 4-255 VLA1
Anglada et al. 1992

30 arcsec=0.06 pc
(~max travel distance
for Class I: 3E5 yr)

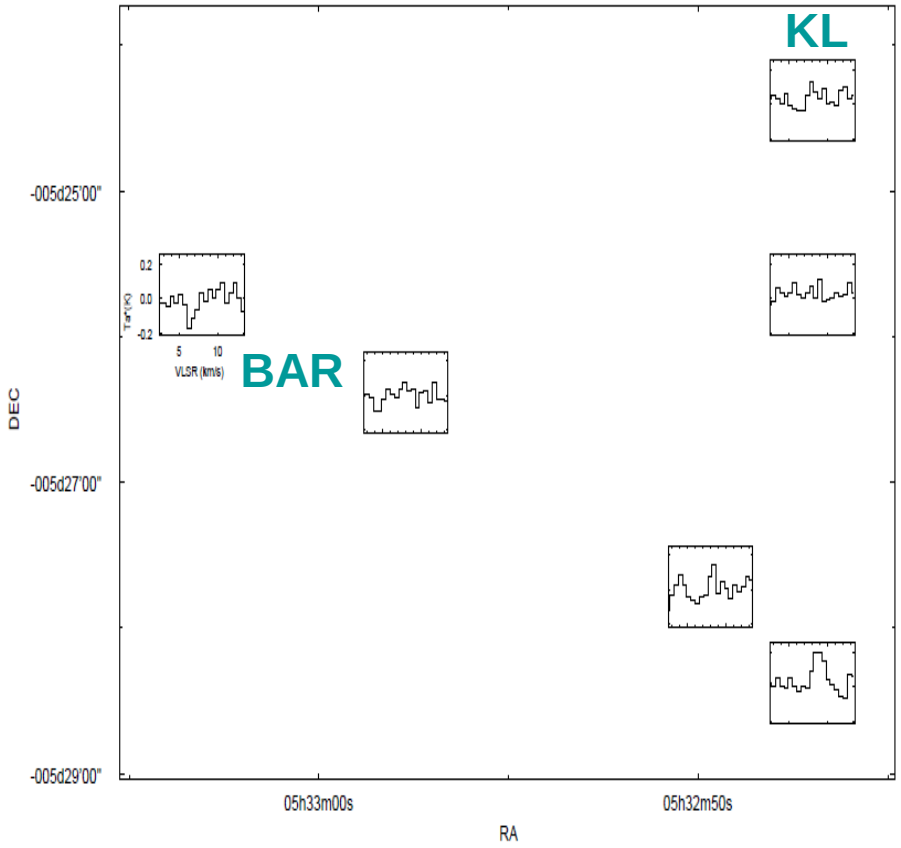
Contour=CCS, Grey=N_2H^+
Region Trot=20K

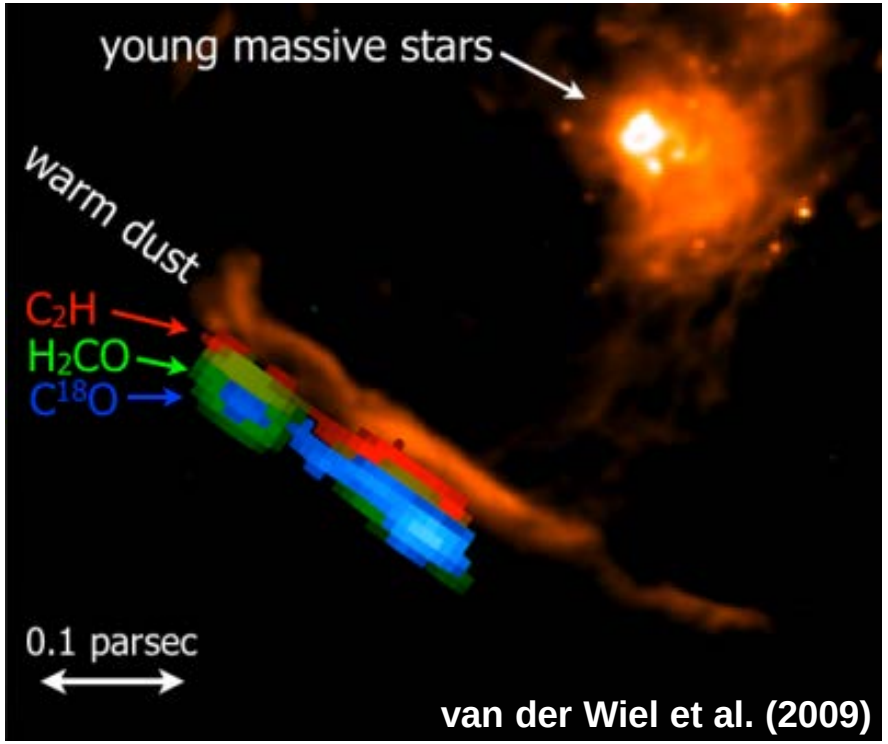



100
10
1
0.1
N(N2H+)/N(CCS)
5
6
7
8
9
10
20
30
Trot (NH3) (K)
STAR FORMING
STARLESS
Criterion ~ 2-3
Danby+88 conversion Tk=10
20
30 K

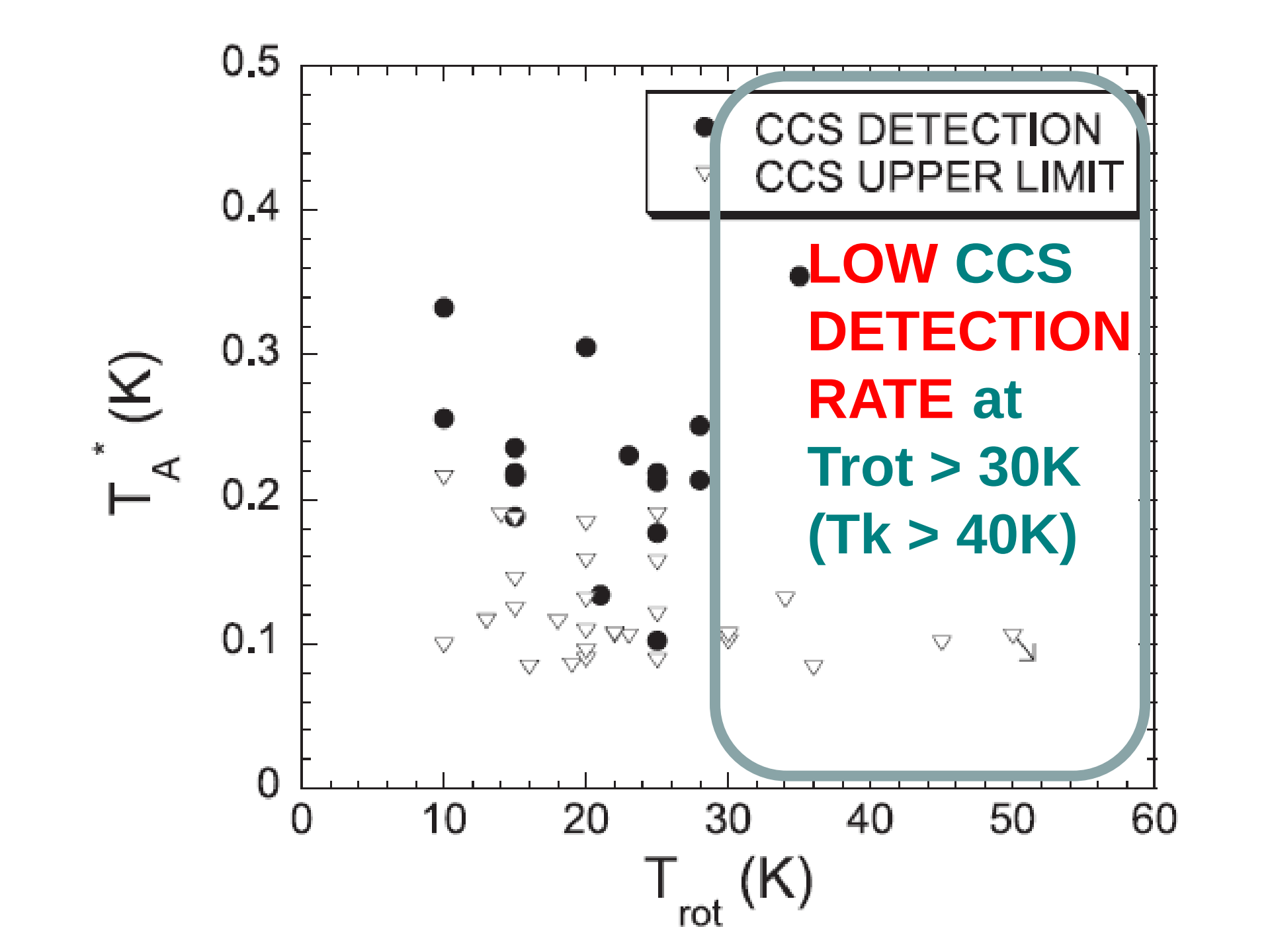
Orion Bar- the PDR

- **No detection of CCS at the Orion Bar or KL**





JCMT


CCS DETECTION
CCS UPPER LIMIT
LOW CCS DETECTION RATE at Trot > 30K (Tk > 40K)
T_A^* (K)
T_{rot} (K)
0
0.1
0.2
0.3
0.4
0.5
0
10
20
30
40
50
60

Summary(2)

- CCS-N_2H^+ evolution also in GMCs
  - Starless cores: CCS
  - Star-forming cores: N_2H^+ (and CCS)
- In evolved region like KL and Bar, no or weak CCS/N_2H^+ (N_2H^+ only trace quiescent gas. CCS core is rare in warm >30 K gas)

- **Thank you for your attention! Thank you, Neal!**