The JCMT users meeting

Studying the thermal state of molecular gas with JCMT

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outline

- Why kinetic temperature?
- how to derive kinetic temperature?
- examples
- summary

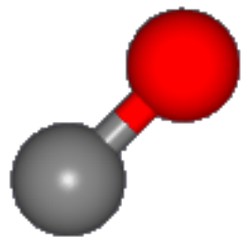
How important is the kinetic temperature of molecular gas?

- a fundamental parameter in all physical and chemical processes:
  - balance result between cooling and heating processes
  - directly affect chemical reaction rates
  - sound speed $\sqrt{\frac{\gamma k T_{\rm kin}}{\mu m_{\rm H}}}$
    - Mach number: shocks
    - Jean Mass: $\simeq (2\ {\rm M}_\odot) \left(\frac{c_s}{0.2\ {\rm km\ s^{-1}}}\right)^3 \left(\frac{n}{10^3\ {\rm cm^{-3}}}\right)^{-1/2}$

and so on ……..

How can we measure the kinetic temperature?

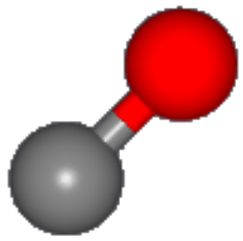
CO LTE



the most abundant molecule after H_2

- method
  - CO optically thick
  - Tex from RT equation
  - populations fully thermalised : Tex = Tkin
- shortcoming:
  - not LTE, populations not fully thermalised

CO LTE



the most abundant molecule after H_2

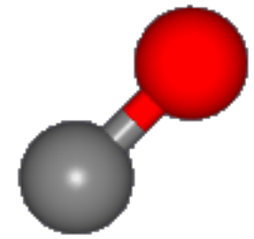
- method
  - CO optically thick

Any other more accurate method?

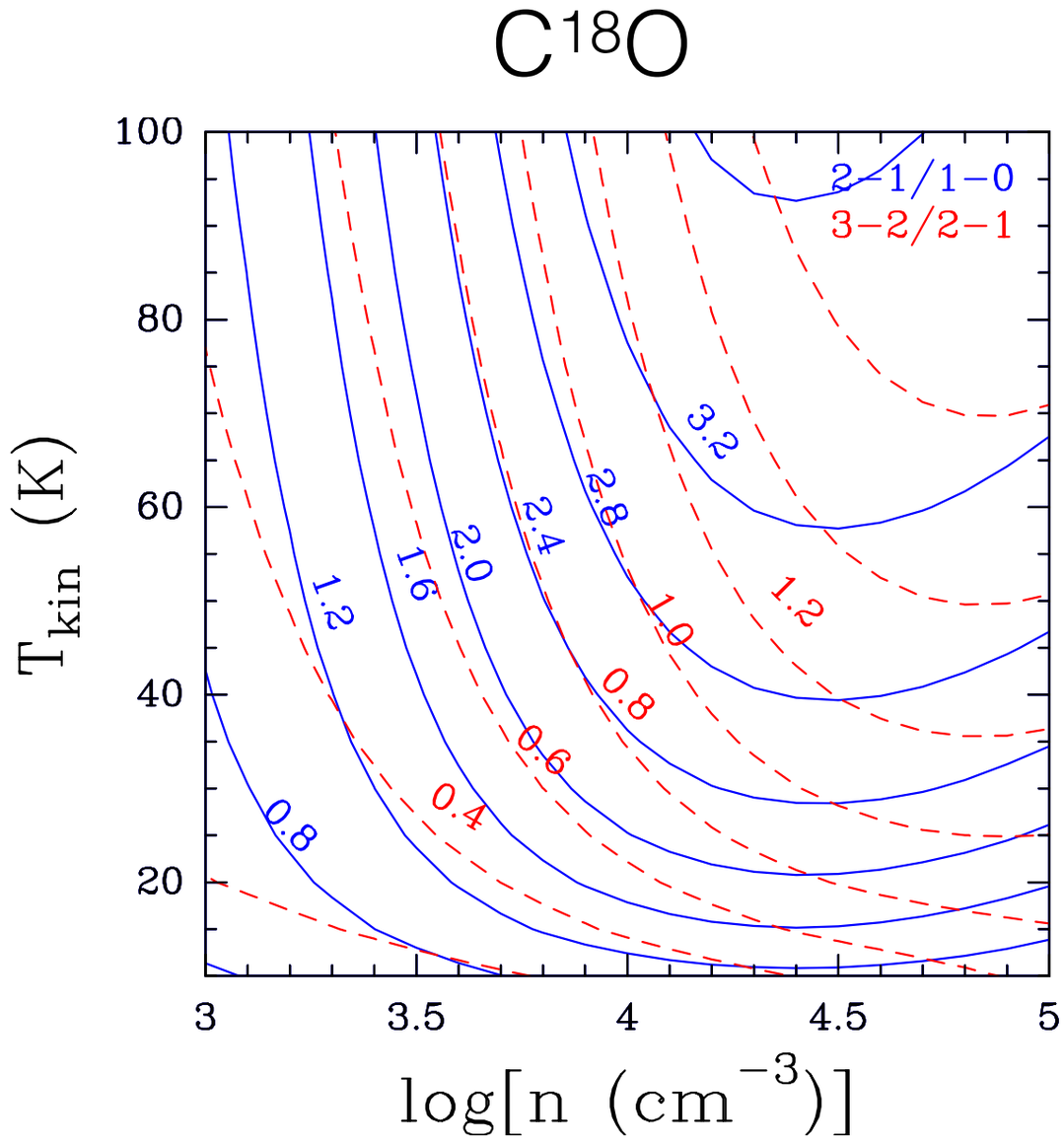
Yes, non-LTE radiative transfer

- shortcoming:
  - not LTE, populations not fully thermalised

CO non-LTE



- method
  - multiple-J CO lines J=1-0, 2-1, 3-2
  - solve the statistical equilibrium equation (non-LTE RT): gives us kinetic temperature and density
  - possible: JCMT (2-1, 3-2) data in combination with the MWISP (1-0) data can be used to do the method



- MWISP: the **M**ilky **W**ay **I**maging **S**croll **P**ainting project

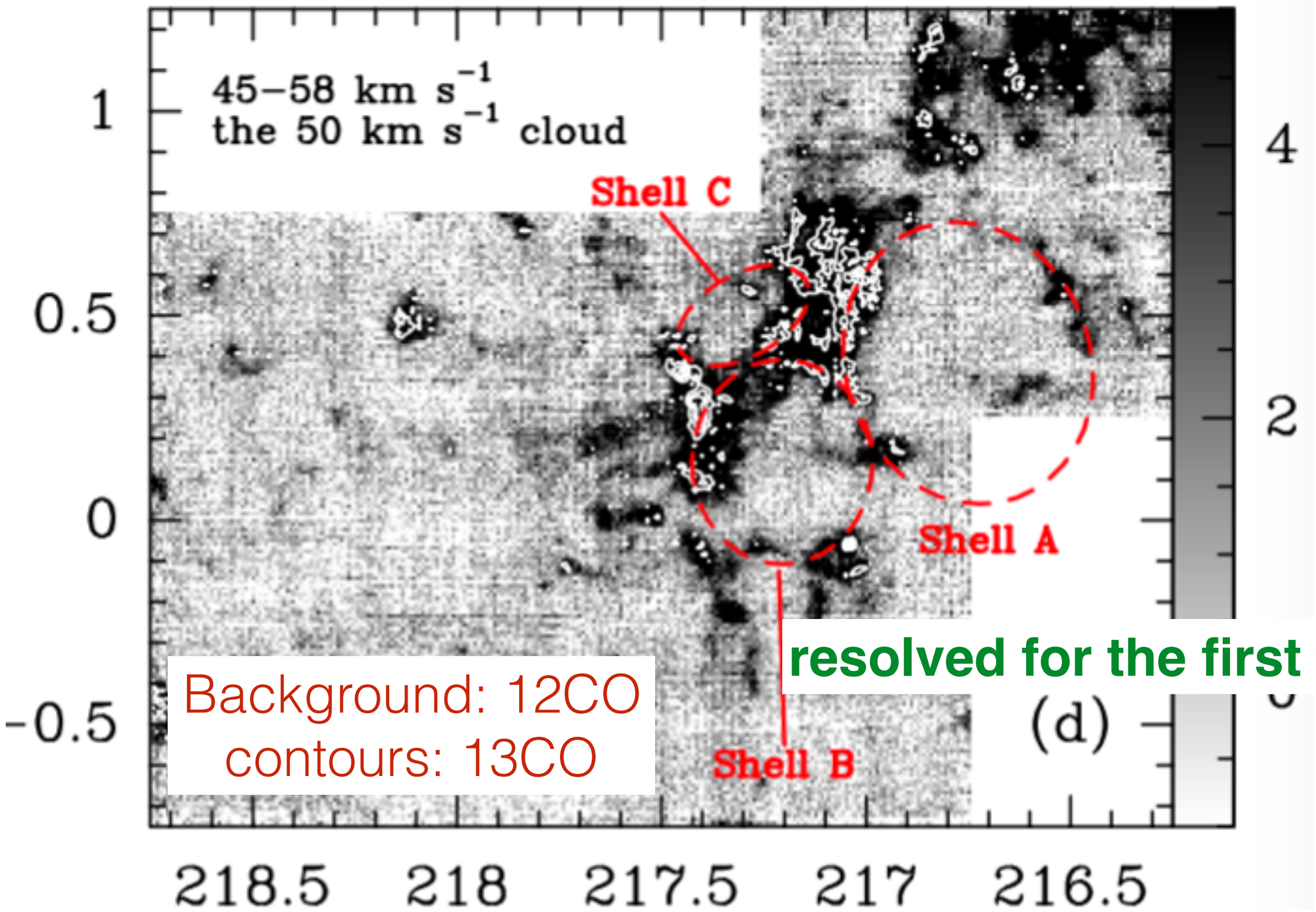
- simultaneous observations of ^{12}CO ^{13}CO $C^{18}O$ (1-0) with the PMO-13.7 m telescope

- large-scale: targets the northern Galactic plane and several other regions of interests

- information website: http://www.radioast.nsdc.cn/mwisp.php

A MWISP example

This is a large area mapping toward MC in outer arms



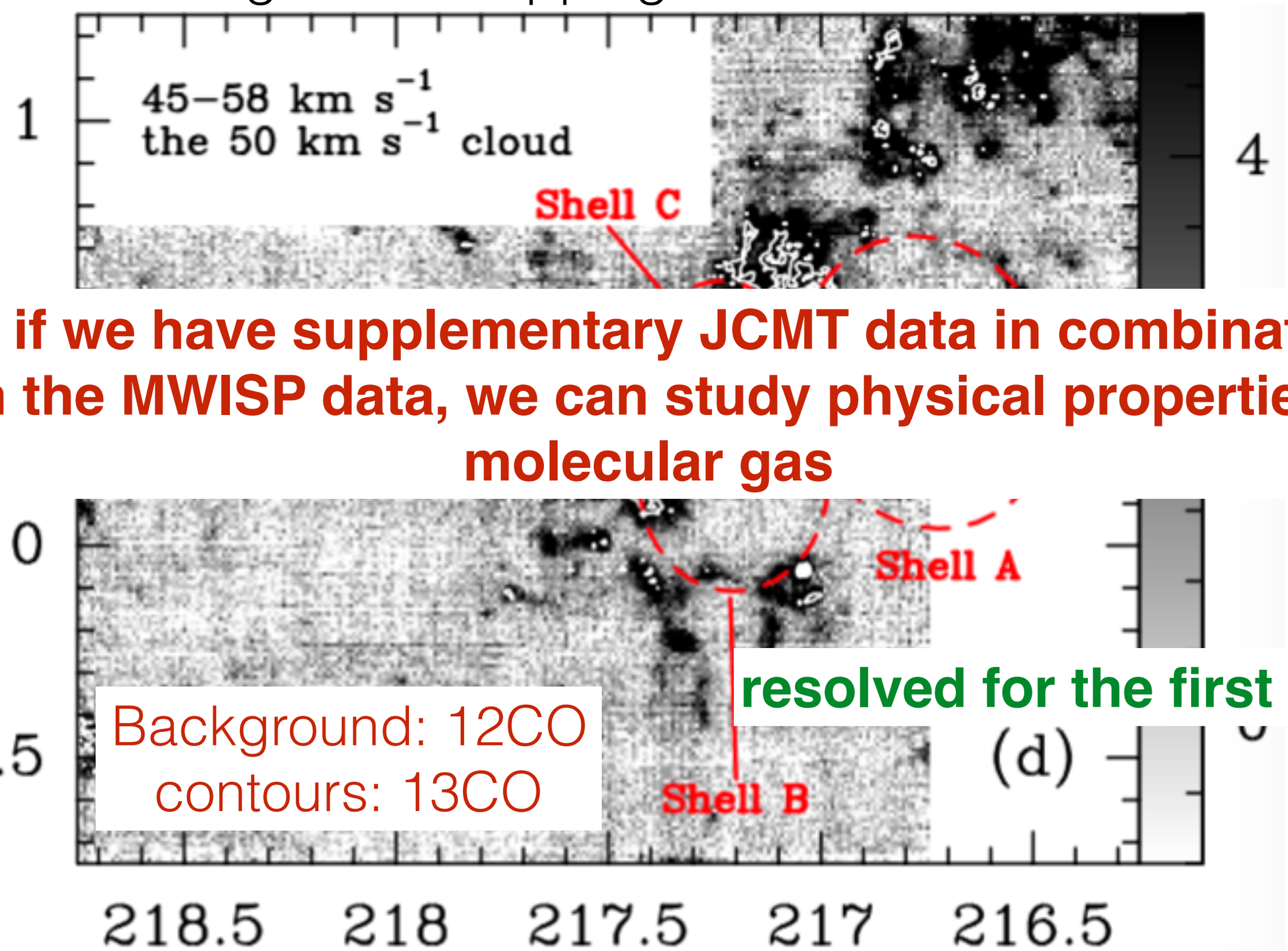
Background: 12CO
contours: 13CO

resolved for the first time

Gong et al. (2016), A&A, 588, 104

A MWISP example

This is a large area mapping toward MC in outer arms



So, if we have supplementary JCMT data in combination with the MWISP data, we can study physical properties of molecular gas

Gong et al. (2016), A&A, 588, 104

However

- shortcomings of multi-J CO lines
  - different beam sizes
  - usually cannot be obtained with only one telescope
  - different calibrations, different pointing accuracy

However

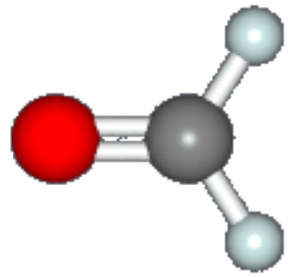
Any other method to overcome these shortcomings?

- usually cannot be obtained with only one telescope

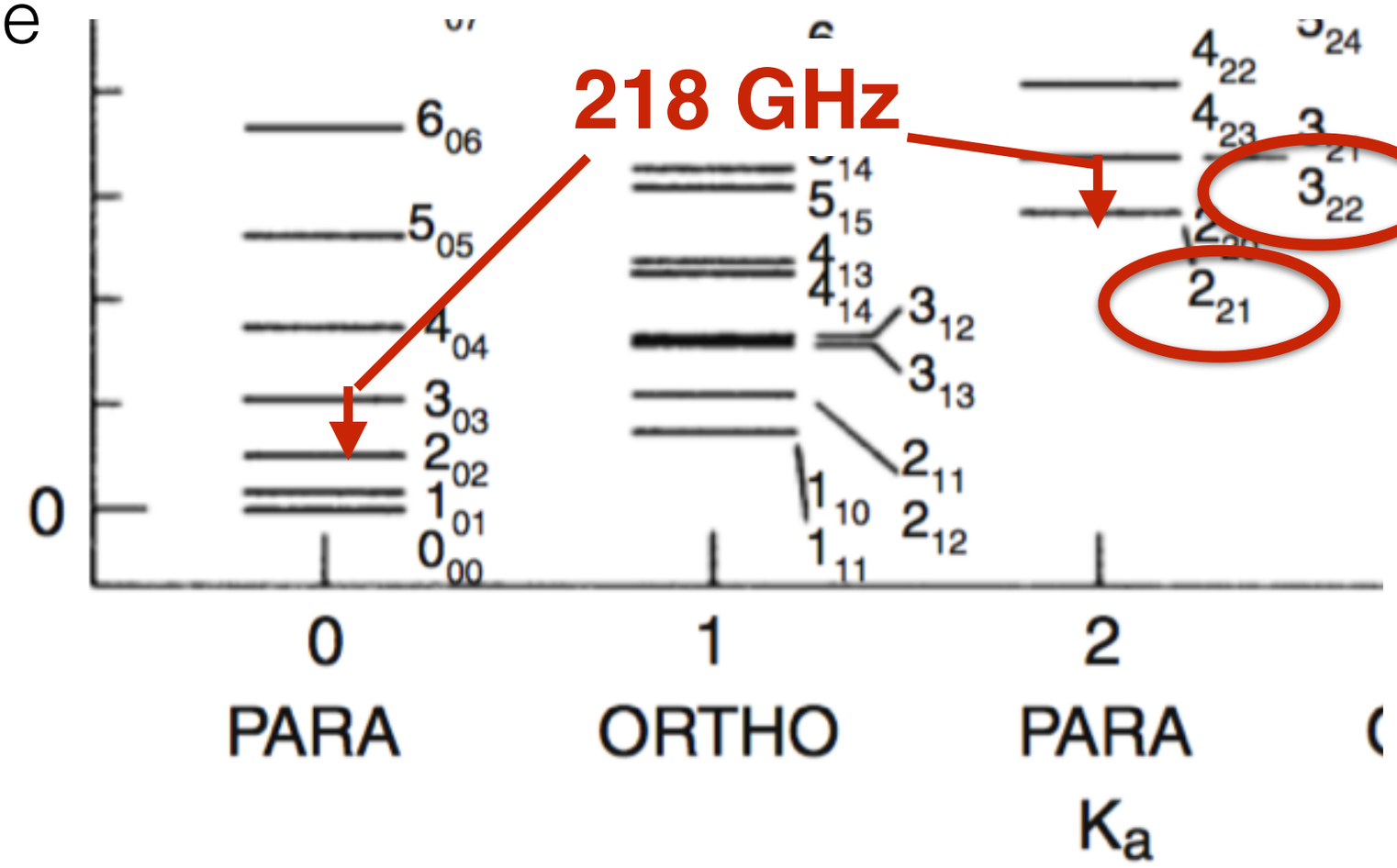
  Yes, use H_2CO

- different calibrations, different pointing accuracy

H_2CO

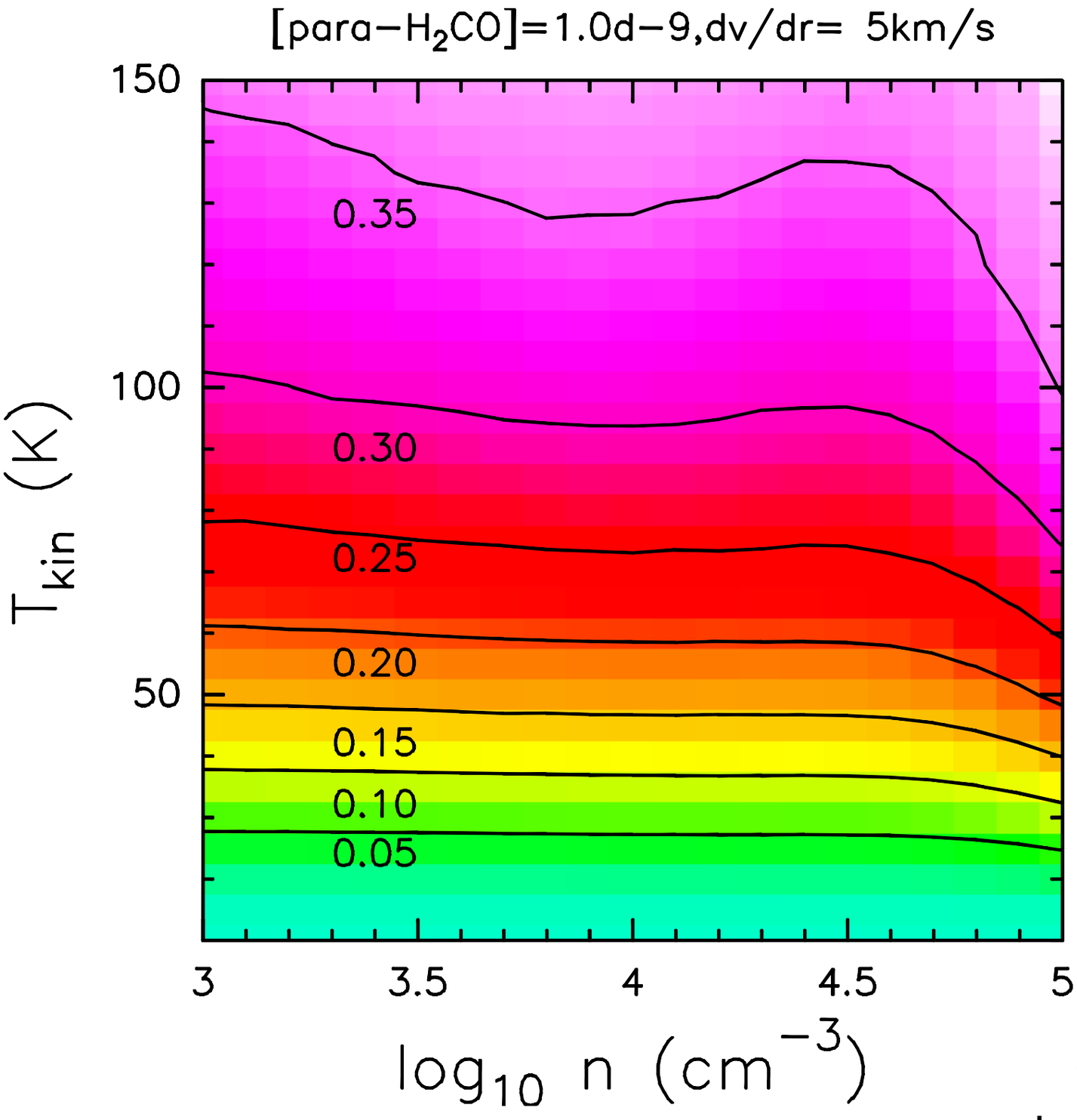


- p-H_2CO 218 GHz lines, close in frequency, ΔKa = 2
- fall in JCMT RxA band
- can be obtained simultaneously
- the ratios free of pointing accuracy, calibration errors, different beam sizes
- abundance changes little (10^{-10} ~ 10^{-9})



Wilson et al. (2009)

RADEX: H_2CO

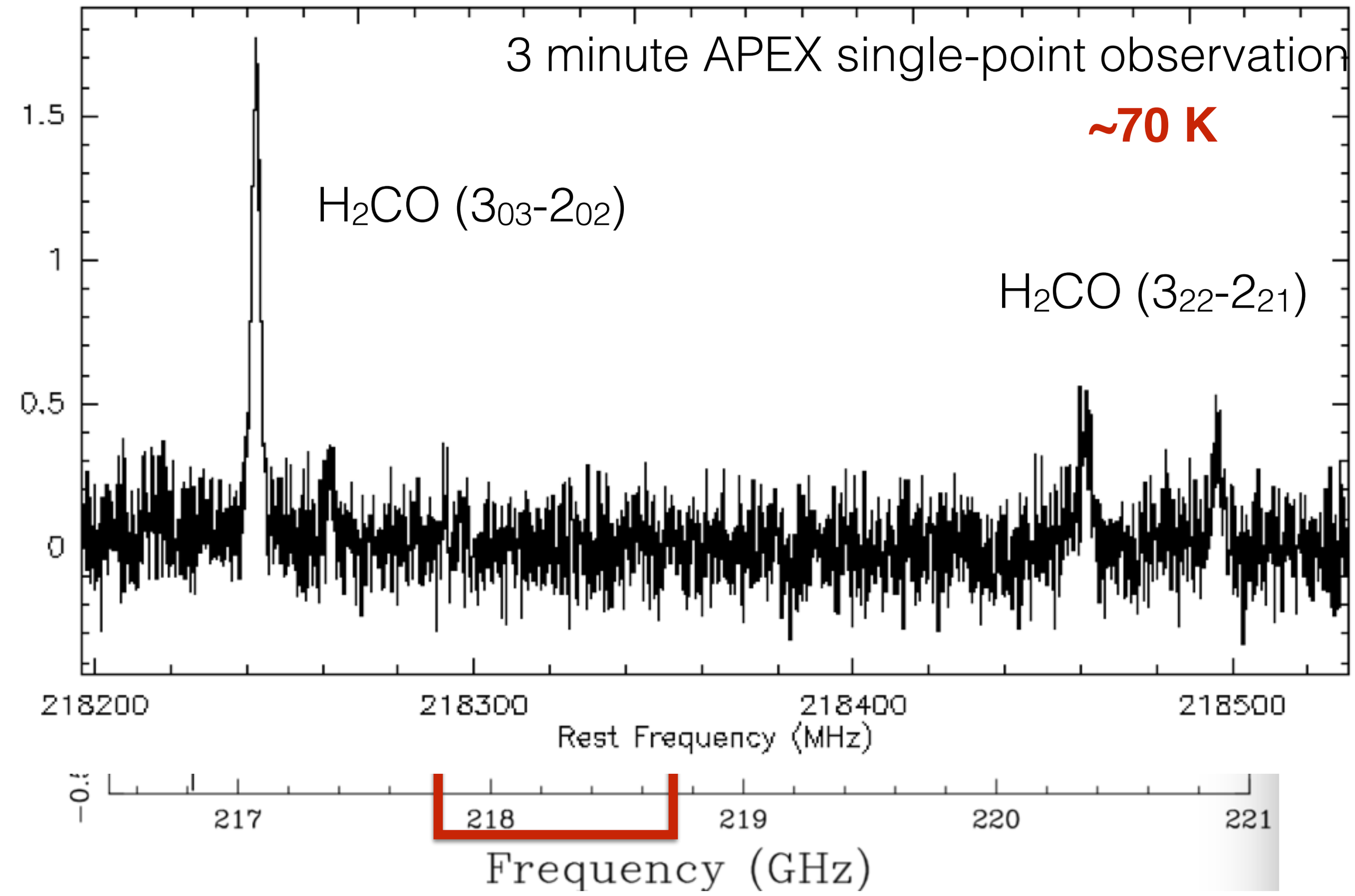


See also Ao et al. (2013)

the ratio
p-H_2CO (3_{22}-2_{21})/(3_{03}-2_{02})

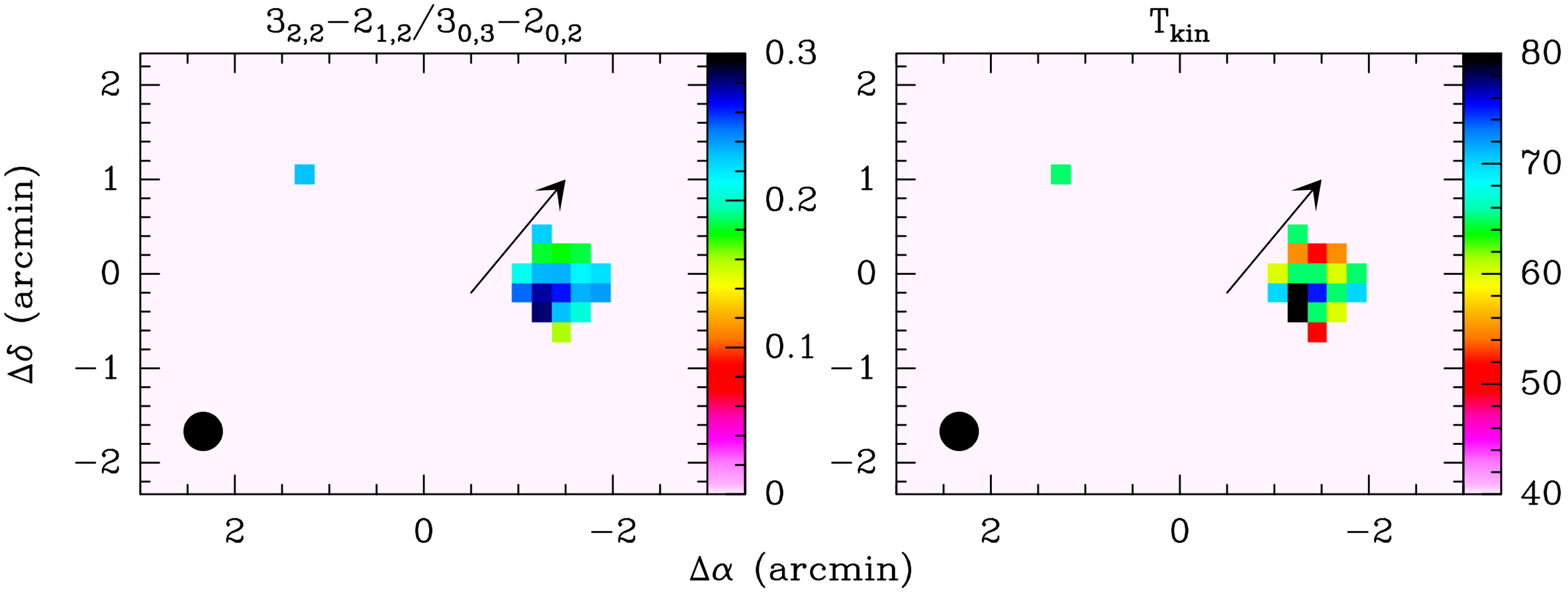
sensitive to temperature
independent of density
So the ratios can be used
to derive kinetic temperature

examples of 218 GHz H_2CO line observations



Another example

IRAM 30m mapping observations of a dust clump

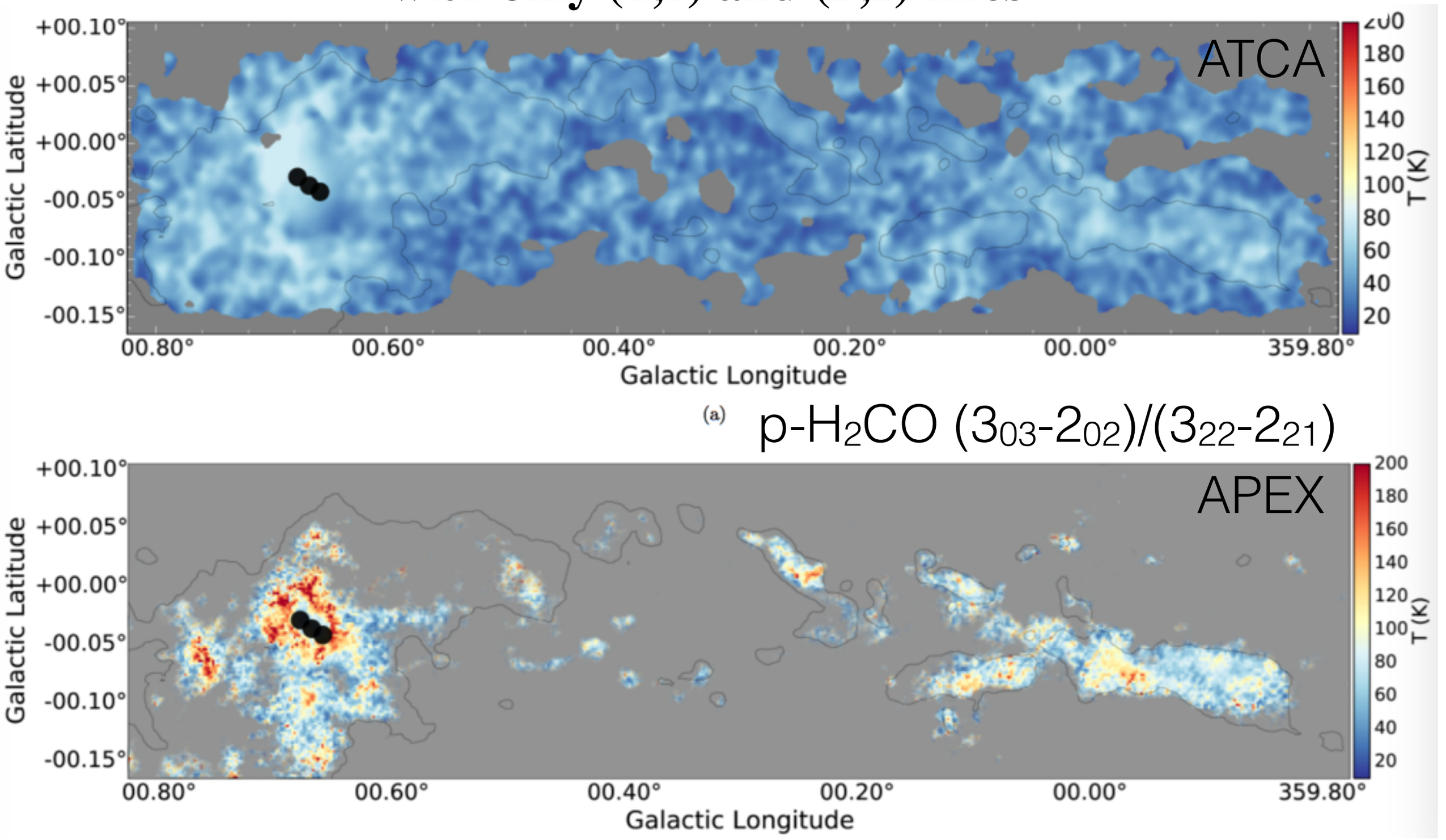


higher than the kinetic temperature (~30 K) derived from NH_3

a temperature gradient across the clump
not radial profile ($r \sim T^{-a}$)

Heating mechanisms? outflows?

The NH_3 thermometer has a more limited temperature range with only (1,1) and (2,2) lines



(a) p-H_2CO (3_{03}-2_{02})/(3_{22}-2_{21})

Ginsburg et al. (2015): warm gas by turbulent heating

summary

- JCMT data + the MWISP data： multiple-J rotational transitions of CO lines can be used to study the properties of molecular gas

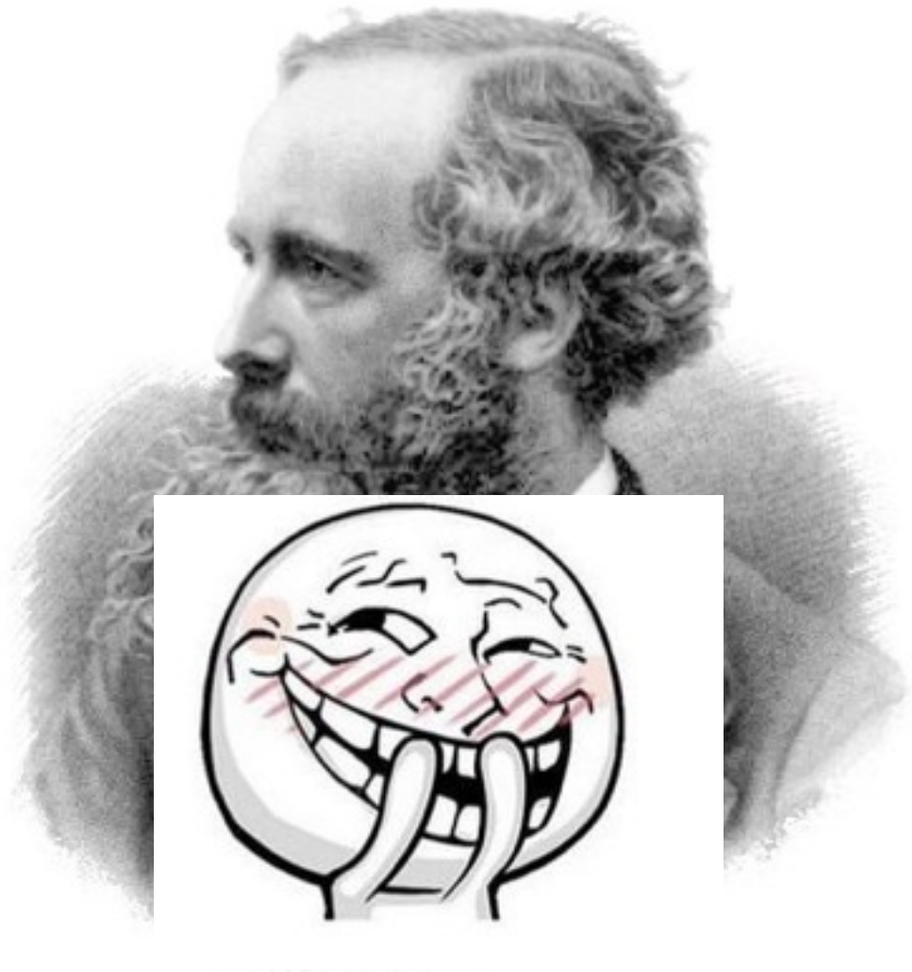
- JCMT observations of 218 GHz H_2CO lines can be used to study the temperature of dense clumps

Hope that I can obtain the JCMT data in the future

Thanks for your attention!

Herschel

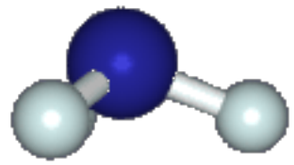
Maxwell



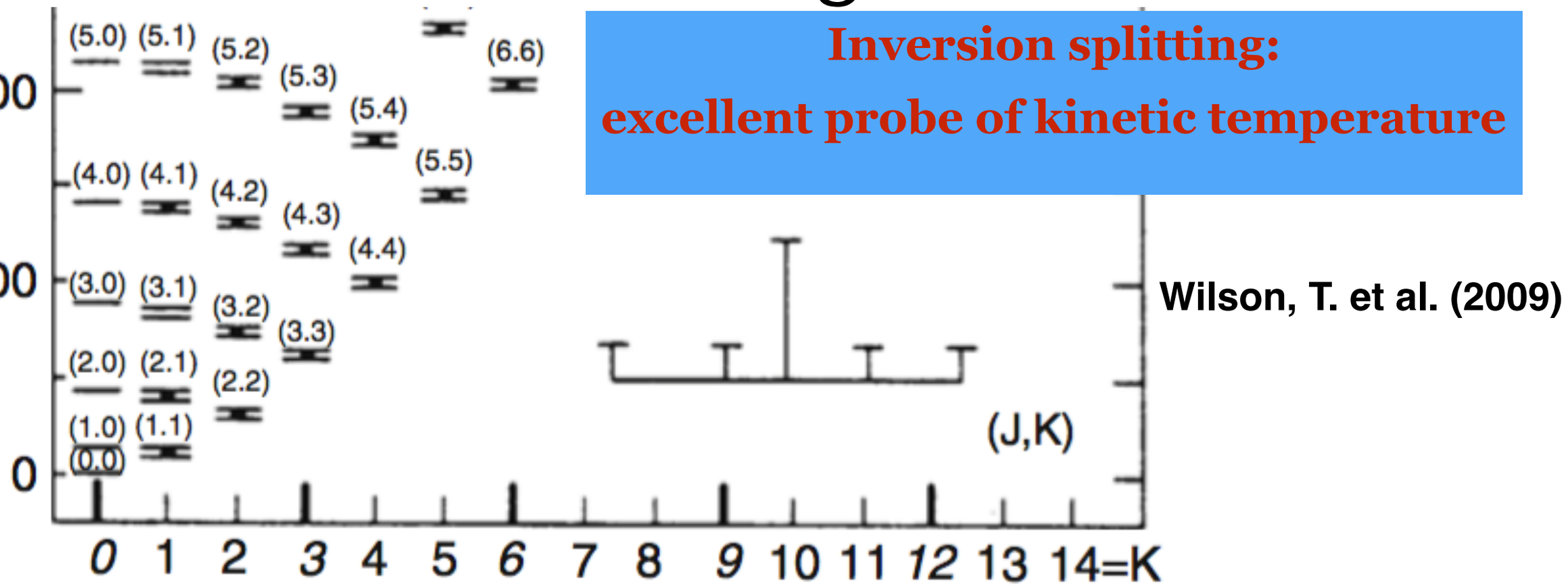
Sorry man, your telescope is already dead,

but my telescope still survives

NH_3



Inversion splitting:
excellent probe of kinetic temperature



Wilson, T. et al. (2009)

- a symmetry top molecule
- A widely used thermometer

abundances change a lot
not accessible with JCMT

- inversion lines: (1,1), (2,2) close in frequency (23.7 GHz)