A Formaldehyde Deep Field with the EVLA: A Powerful New Probe of Galaxy Evolution (and Cosmology?)







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Outline

Formaldehyde (H₂CO)

A Formaldehyde Deep Field: Why?

Formaldehyde in the Local Universe

Formaldehyde versus Redshift

A Formaldehyde Deep Field: How?







Galactic H₂CO

Dark Clouds:

- "Anomalous" H₂CO absorption

(e.g. Palmer et al. 1969)

- Absorption in multiple cm lines
- No radio continuum source!



H_2CO : The DASAR

L ight (Microwave) A mplification by S timulated E mission of R adiation

Inversion: "Heating" of lines T_x >> T_{kin}

Pump required: Chemical, collisional, radiative D arkness* A mplification** by S timulated A bsorption of R adiation

Townes et al (1953)

Anti-Inversion: "Cooling" of lines T_x < T_{СМВ}

Pump required: Collisions with H₂

*Not really dark. **Not a true amplification.

H₂CO Absorption in Dark Clouds



 "Anomalous absorption" in Galactic dark clouds (Palmer et al 1969)

 \Rightarrow T_{ex} < T_{CMB}

- 2 cm lines also observed in absorption against CMB
 ⇒ "Anti-inversion" due to collisional pumping (Evans et al 1975)
 ⇒ cm line ratio proxy for n(H₂)
- 2 mm emission observed in Galact dark clouds (Evans & Kutner 1976)
 ⇒ gastrophysics

Galactic H₂CO

Dark Clouds:

- "Anomalous" H₂CO absorption
- (e.g. Palmer et al. 1969) Absorption in multiple cm lines
- No radio continuum source!

1. Can H₂CO be observed in other galaxies?

- Can "anomalous" H₂CO absorption be • observed in galaxy-scale analogs of Dark **Clouds?**
- How does H₂CO behave at high redshift? • (Ben Zeiger)



H₂CO Absorption Against the CMB



H_2CO : The DASAR

The CMB is the ultimate illumination source:

- Behind everything
- Everywhere
- Uniform on arcsec scales

H₂CO absorption against the CMB offers an unrivaled probe of dense molecular gas, independent of redshift!

A H₂CO deep field would produce immediate precise redshifts and positions of a *mass-limited* survey of star-forming galaxies, automatically omitting AGN.

Anti-Inversion Driven by Collisions

▶ Collisions are with H₂

- Anti-inversion persists over 2-3 decades in density
- Anti-inversion is significant for the first 4-5 K-doublet lines



Line Ratio Depends Weakly on Kinetic Temperature

- Line ratio is a sensitive probe of in-situ density, n(H₂)
- Line ratio is insensitive to Kinetic Temperature



Density Thresholds



Density Thresholds



The H₂CO Densitometer

What is the "density" of a galaxy?

Density regimes measured by H₂CO are *in-situ*! (not n_{crit})



Dense Gas Mass and Star Formation



Extended Illumination: PKS 1830-211



Chengalur, deBruyn, & Narasimha 1999

Patnaik et al. 1994

Nair et al. 1993

PKS 1830-211:

- Einstein ring at z = 0.89
- HI and OH absorption
- CO, HCN, HCO⁺,... absorption
- Molecular isotope absorption
- H₂CO absorption





Line Temperature vs Redshift

- How does T_{ex} depend on redshift?
- Combine local galaxies (Mangum et al 2008) with two gravitational lenses
- T_{line} grows (negatively) with redshift
- ► T_{ex} ~ 0.5 T_{CMB} at z=0 (with large scatter)

•
$$T_{ex}$$
- T_{CMB} ~ -1.4 - z



Anti-Inversion versus Redshift

- The rest-frame temperature decrement increases with redshift
- The observed temperature decrement is nearly independent of redshift!
- Absorption is redshiftindependent



Source Size versus Redshift, Beam Size

- Array resolution depends on redshift and line
- Assume a 10 kpc size scale (cf Chapman et al 2004)
- Size ~ constant for 0.8 < z < 3



Instantaneous Redshift Coverage

 Large coverage for C-band

▶ z = 0.8|-6.24

 Commensal observations



EVLA Formaldehyde Deep Field

Let's do something new!

cm lines of H_2CO absorb CMB photons

- Redshifts
- Positions
- Dense Gas SF tracer
- Multiple lines give n(H₂)

Detectability independent of redshift!

Surveys are mass-limited.

Also:

 $H_2CO + NH_3$ make density and temperature maps!