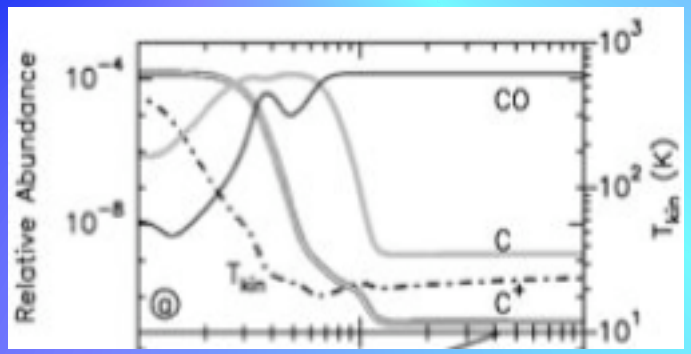
CO - H_2 abundancies: theoretical models and observations

(Federman et al., 1980)

- H_2 is the most abundant molecule
- In cold clouds almost all H is molecular



A_V

(Keene et al., 1998)

- CO is the most abundant heavy molecule in ISM
- In thick clouds contains almost all C
- Used as a tracer of structure and kinematics of molecular clouds

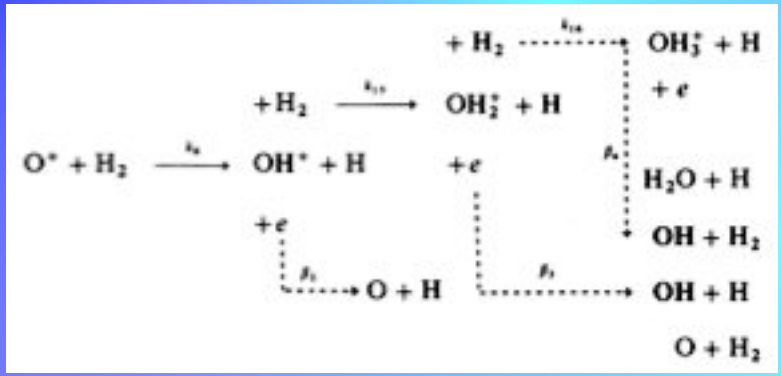
CO - H_2 relations

Most important method for CO synthesis:

oxygen charge exchange chemistry

Progenitor reacton: $H^+ + O \rightarrow H + O^+$

Production of OH:



Synthesis of CO:

$$C^+ + OH \xrightarrow{k_{17}} CO^+ + H,$$
$$CO^+ + H \longrightarrow CO + H^+,$$
$$CO^+ + H_2 \longrightarrow HCO^+ + H,$$
$$HCO^+ + e \longrightarrow CO + H,$$

(Federman et al., 1980)

From this sheme N(CO) is expected to be
a quadratic function of N(H_2)

Other pathways for CO synthesis:

radiative association chemistry (high densities)

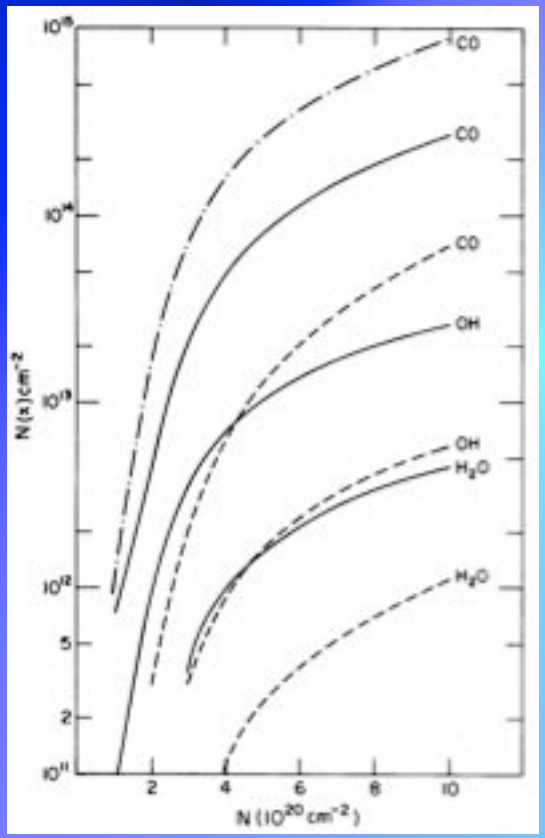
Starting from: $C^+ + H_2 \rightarrow CH^+ + H$

CH is produced (as previous scheme), then a neutral reaction of O and CH
(Black & Dalgarno, 1973)

non-equilibrium processes of CH^+ synthesis (low densities)
CH is produced from reaction of O and CH
no relation with H_2
(Zsargò & Federman, 2004)

And other minor reactions
All the processes depend on temperature and density
The result expected is a dependence of N(CO) from N(H_2) softer than a power 2 (intermediate between 1 and 2)

Theoretical models



(Glassgold & Langer, 1976)

CO, OH and H_2O (HCO and ions involved)

warm (40 - 80 K) regions

diffuse and moderately thick clouds

Reactions

- Ion-molecule

$$C^+ + OH \rightarrow CO + H^+$$

- Charge exchange

$$CO^+ + H \rightarrow CO + H^+$$

- Dissociative charge exchange

$$He^+ + CO \rightarrow C^+ + O + He$$

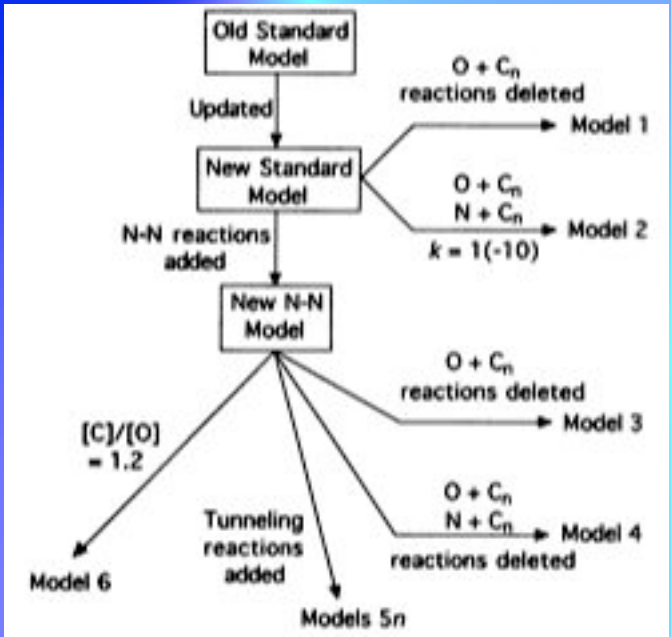
- Dissociative recombination

$$e + CO^+ \rightarrow O + C$$

- Photodestruction

$$h\nu + CO \rightarrow C + O$$

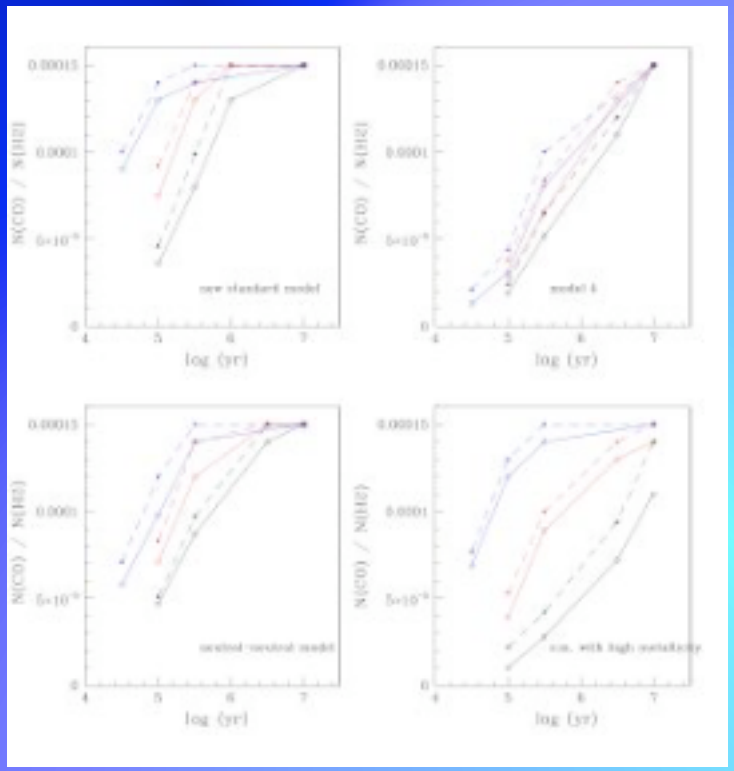
Recent models



(Bettens et al., 1995)

- Many chemical species and reactions
- Include neutral-neutral reactions
- Focused on complex molecules

New standard model



(data from Lee et al., 1996)

solid lines: 10 K, dashed lines: 50 K
black: n = 10^3 cm^{-3}
red: n = 10^4 cm^{-3}
green: n = 10^5 cm^{-3}
Last point refers to steady state

- **3785 reactions, 409 species**
- **N-N reactions added**

- NSM gives a dependence of N(CO) with density as a power low intermediate between 1 and 2
- Maybe model 4 is inadeguate
- N-N reactons give only second order variations in N(CO)

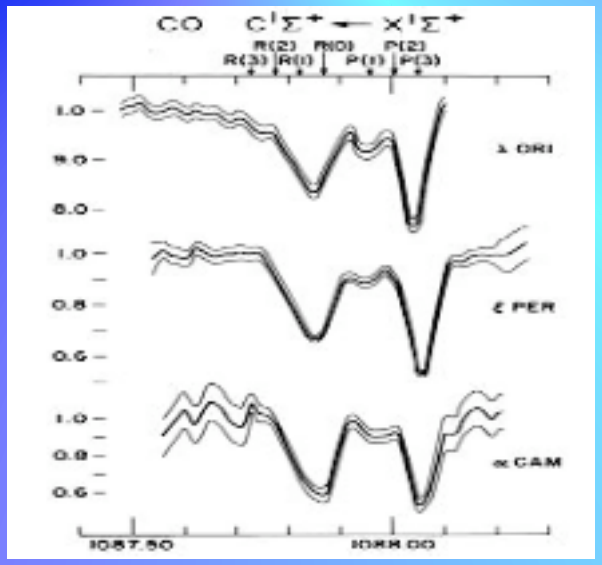
Observations

Both CO and H_2 absorption lines can be observed in UV

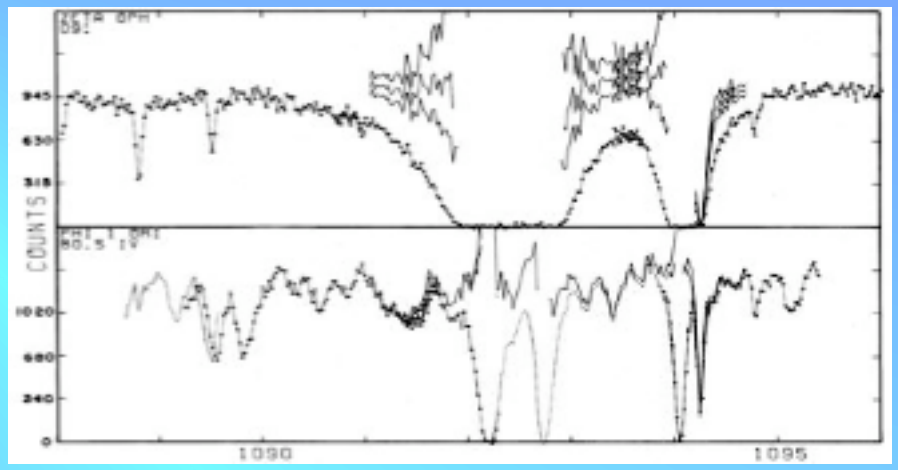
The lines are often saturated or not easly detected

UV satellite Copernicus observations toward bright stars

CO **H_2**



(Jenkins et al., 1973)



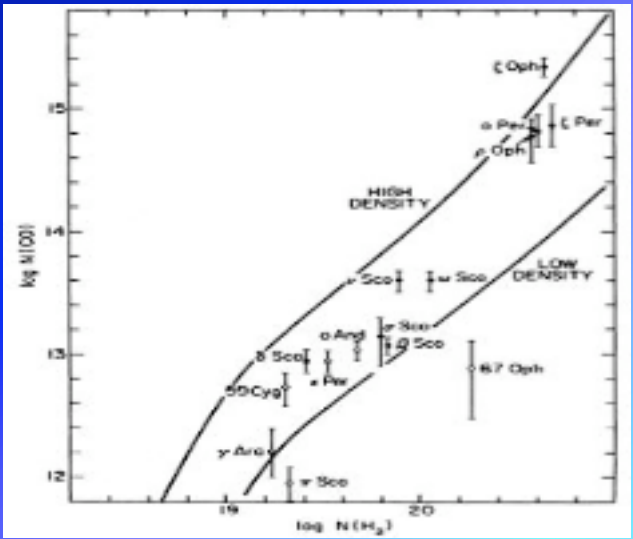
(Savage et al., 1977)

Strongest UV transitions:

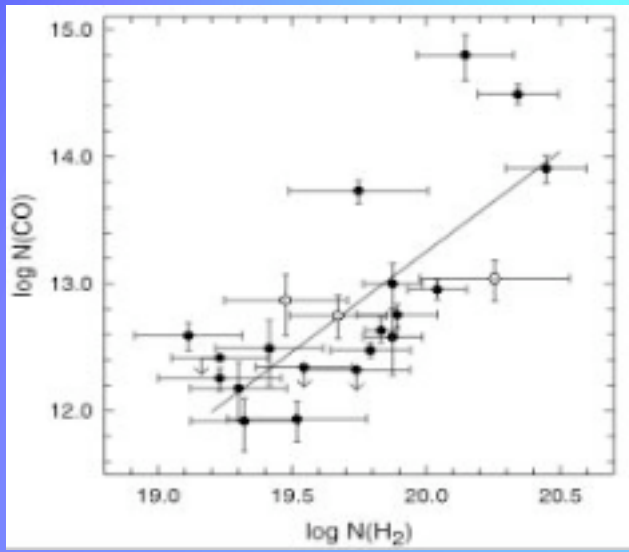
0-0 $(C^1\Sigma^+ - X^1\Sigma^+)$ at 1088 A

0-0 $(E^1\Pi - X^1\Sigma^+)$ at 1076 A

R(0) R(1) and P(1) of ground vibrational state at 1092.19 1092.73 and 1094.05 A



(Federman et al., 1980)



(Crenny & Federman, 2004)

- **Observations: Copernicus surveys**
- **Models: Glassgold & Langer 1976 (revised)**

Low density: T=30-75 K, density 70-300 cm^{-3}
High density: T=25-35 K, density 2000-3000 cm^{-3}

- Models are in general agreement with data
- Slope intermediate between 1 and 2

- **Reanalysis of Copernicus measures**
  - Slope: 1.58 ± 0.34

The relation between N(CO) and $N(H_2)$ is confirmed, but the exact relation is still theorically and observationally uncertain, as many chemical and physical parameters are involved

References

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