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Deuterium Chemistry in star forming regions.

Martin Emprechtinger[1], **Martina C. Wiedner**[1]

[1] 1. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany

Abstract. We present a simple model, which calculates the abundance and the ortho/para ratio of H_2D^+ and some observations of the deuterated molecule N_2D^+ in cold, dense environments.

Keywords. Astrochemistry, deuterium, stars: formation

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1. Introduction

In their early stages star forming regions consists of dense ($\approx 10^6$ cm^{-3}), cold (≈ 10 K) and highly shielded ($A_v \approx 100$ mag) cloud cores. In such environments the chemistry is very different form other locations in the universe. Due to the low temperatures many endothermic reactions and most neutral neutral reactions are suppressed. Depletion of molecules like CO and in the end N_2 change the abundances completely. Since almost all metals freeze out onto dust grains only molecules consisting of hydrogen and deuterium are present in the centre of dark cloud cores. The lack of a permanent dipole momentum in H_2, H_3^+ and D_3^+ makes H_2D^+ (next to D_2H^+) the only appropriate tracer to study the kinematics and chemistry of the very inner part of the early stages of star forming regions. This is particularly true since theoretical studies and observational evidences show an enhancement of deuterated molecules towards these sources (e.g. Millar et al. 2000). However H_2D^+ is difficult to observe due to the low atmospheric transparency at its line frequencies. Because N_2 is the last molecule that freezes out onto dust its daughter molecule N_2D^+ is the next best tracer of cold gas and a probe for H_2D^+.

2. Chemical model

Since their activation energy is relatively high neutral-neutral reactions, in contrast to ion-neutral reactions, don't play an important role in the cold gas chemistry. Because H_3^+ and its isotopic variants are the most abundant ions they have a major impact on the whole chemical network. Due to the high fractionation of deuterated molecules in cold environments H_2D^+, D_2H^+ and D_3^+ have to be taken into account. The fractionation of deuterated molecules occurs because of the endothermicy of reactions like H_3^+ (HD, H_2) H_2D^+ $(\Delta E = 220\ K)$.

The actual ratio of H_2D^+/H_2 depends on a variety of factors such as temperature, density and depletion of CO. Our model is a pure gas phase model including 40 reactions with rate coefficients taken form Walmsley et al. (2004). In the simplest model total depletion of molecules containing atoms heavier than He is assumed. In consequent models reactions with CO were included and CO depletion was treated following Hasegawa & Herbst (1993) assuming a desorption energy of 1210 K (Hasegawa & Herbst 1993) and 960 K (CO on CO ice (Willacy & Millar 1998)) respectively. The ortho/para ratio of H_2 was adopted to be thermal, but not below $6 \cdot 10^{-5}$.

The results show that the H_2D^+/H_2 ratio decreases slightly below 15 K (see Fig. 1) due to temperature dependency of the rate coefficient of H_2D^+ recombining with electrons. On the contrary, the ortho/para ratio of H_2D^+ increases again towards lower tempera-

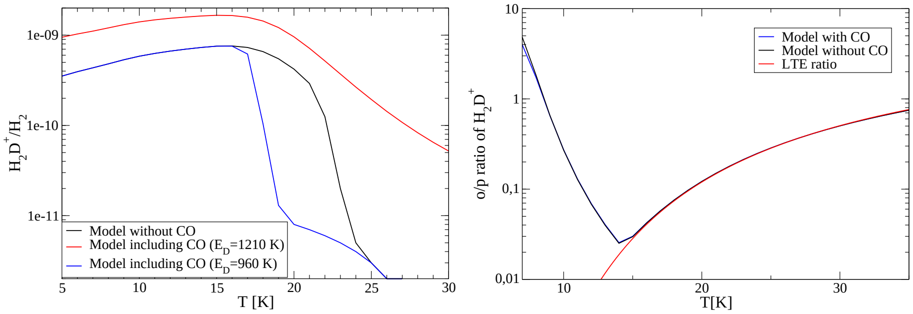

Figure 1. Left: H_2D^+/H_2 ratio as function of temperature **Right:** Ortho/para ratio of H_2D^+. The density in both cases is 10^6 cm^{-3}.

tures, because para to ortho conversion of H_2D^+ becomes relevant at low temperatures. The ortho/para ratios is not sensitive to the abundance of CO, but the absolute abundance of H_2D^+ shows a cut off at temperatures, at which CO desorbs form dust ($\approx$ 23 K and $\approx$ 18 K, respectively). The ortho/para ratio of H_2D^+ is important because up to now only ortho H_2D^+ (at 372 GHz) has been observed in a few sources (e.g. Caselli et al. 2003) and thus the total H_2D^+ abundance is based on such models. We have to admit that our model is very crude since only the most important reaction are included. In particular, spin statistical restrictions and a state specific consideration will improve the models a lot (Schlemmer priv. comm.). In the near future para H_2D^+ observation at 1.37 THz using the CONDOR receiver (Wiedner et al. 2003, Schmidt et al. 2004) will allow a verification of these models.

3. Preliminary N_2D^+ observation of sources in star forming regions

In order to find sources, which are worth to be studied in H_2D^+, we observed several sources in both high mass and low mass star forming regions in N_2D^+ J=3-2 (231 GHz) with the KOSMA 3m Telescope. Because of the large beam size (2 arcmin) the emission lines are very faint. However, we have been able to detect N_2D^+ in the 2 low mass protostars NGC1333-IRAS 2 and IRAS 03282+3035 and for the first time towards high mass star forming regions, namely S106 and the molecular ridge to the north of DR21 in Cygnus X.

Towards the source near DR21 we observed N_2H^+ (3-2). Assuming an excitation temperature of 10 K we derived a N_2D^+/N_2H^+ ratio of 0.13 leading to an estimation of the H_2D^+/H_3^+ ratio of 0.297 following the calculation of Crapsi et al. (2003). Because of the large beam size and the uncertainty of T_{ex}, this ratio has to be treated with caution. Further observations with larger telescopes and of several other emission lines are intended.

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