星・惑星形成領域におけるダスト表面上での水素分子のオルソ・パラ変換
Modeling of the H_2 ortho-para spin conversion on grain surfaces in star- and planet-forming regions

*古家 健次[1]、Sameera W. M. C.[2]、羽馬 哲也[2]、渡部 直樹[2]、相川 祐理[3]
*Kenji Furuya[1], W. M. C. Sameera[2], Tetsuya Hama[2], Naoki Watanabe[2], Yuri Aikawa[3]

1. 筑波大学　計算科学研究センター、2. 北海道大学　低温科学研究所、3. 東京大学
1. Center for Computer Sciences, University of Tsukuba, 2. Institute of Low Temperature Science, Hokkaido University,, 3. The University of Tokyo

Hydrogen is the most abundant element in the universe. In star- and planet-forming regions, hydrogen is primary present in H_2, which has two nuclear spin configurations, ortho and para. As the internal energy difference between ortho-H_2 and para-H_2 (170 K) is much higher than the typical temperature of star-forming regions (around 10 K), the H_2 ortho-to-para ratio (OPR) can affect the chemical evolution, including deuterium fractionation, significantly.

H_2 molecules form on grain surfaces with the statistical OPR of three. The ortho-para spin conversion proceeds through proton exchange reactions with H^+ and/or with H_3^+ in the gas phase. Laboratory experiments have found that the H_2 spin conversion can also occur on bare grains and on amorphous water ice in laboratory timescales (around a few hours). Given this very short timescale, it has been thought that the spin conversion on surfaces affects the H_2 OPR evolution in star- and planet-forming regions. However, its efficiency in the astronomical conditions remains unclear; almost all H_2 is present in the gas phase rather than on grain surfaces, and thus the spin conversion timescale of overall H_2 (i.e., gas + solid) via the spin conversion on surfaces depends on how efficiently gaseous and solid H_2 interact.

We investigate the efficiency of the H_2 spin conversion on grain surfaces under physical conditions that are relevant to star- and planet forming regions. We utilize the rate equation model that considers adsorption of gaseous H_2 on grain surfaces which have a variety of binding sites with different potential energy depth, thermal hopping and desorption of adsorbed H_2, and the spin conversion. We find that the conversion efficiency depends on H_2 gas density and surface temperature. As a general trend, increased H_2 gas density reduces the conversion efficiency, while the temperature dependence is not monotonic; there is a critical temperature at which the efficiency is maximum. We will discuss whether the spin conversion on surfaces can dominates over that in the gas-phase in star- and planet-forming regions.

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