Spin Temperature of H_2O in Comets — A Cosmogonic Indicator? B. P. Bonev[1,2], M. J. Mumma[2], Y. L. Radeva[2,3], M. A. DiSanti[2], & G. L. Villanueva[2] [1]Dept. of Physics, Catholic U. of America, Washington, DC 20064 (bonev@cua.edu), [2] NASA's GSFC, MS 690.3, Greenbelt, MD, 20771. [3]Dept. of Astronomy, U. of Maryland, College Park, MD 20742.

H_2O spin temperatures in comets: Molecules containing identical nuclei display isomers grouped according to their total nuclear spin. The probability for conversion between different isomers is under many circumstances low, but nonzero. However the conditions that assist this process are often not well defined, and an improved understanding could elevate spin conversion to an important tool in science [1,2].

The H_2O molecule is organized into two isomers depending on whether the nuclear spins of its H atoms are parallel (ortho "ladder") or antiparallel (para "ladder"). Radiative and collisional transitions between ortho and para states are strongly forbidden. Recent studies suggest that the radiative nuclear spin conversion times of H_2O are more analogous to the extremely long conversion times of H_2 than those of species like CH_4 for which faster conversion can occur [3].

Water ortho-para abundance rations (OPRs) have been measured in about a dozen comets, and corresponding spin temperatures (T_{spin}) are inferred by placing the measured OPRs on the theoretical curve on Fig. 1. The OPR error limits then define the uncertainties in T_{spin}. For example, $T_{spin} = 21 \pm 2$ K for point 7b (Fig. 3), while $T_{spin} > 34$ K (1σ lower bound) for point 9. Note that in the asymptotic limit of OPR = 3.0 (statistical equilibrium), T_{spin} (or its upper bound) cannot be defined (e.g., points 2, 5, 6, 9, 10, 11, 12).

The meaning of these spin temperatures has interested astronomers since H_2O was first detected in the atmosphere of a comet in the mid-1980s. Crovisier [4] and Mumma et al. [5,6] introduced the idea that T_{spin} is a faithful measure of the chemical formation temperature of cometary H_2O. To date, there is no definitive evidence that H_2O molecules undergo nuclear spin conversion during their long residence in the interior of a comet or after sublimation in the coma. However, the meaning of spin temperatures in comets is "enigmatic", considering the "gaps" in our understanding of the conditions permitting nuclear spin conversion. Improved understanding would benefit from development of reliable laboratory techniques for separation and enrichment of a particular isomer, and also from the realization of IR spectrometers with adequate sensitivity for testing the extremely weak ortho-para radiative transitions predicted by Miani & Tennyson [3].

Recent Progress: We review recent progress in water OPR measurements. Fig. 1 is an updated summary from Bonev et al. [7], including new measurements on comets C/2004 K4 (LINEAR) [8] and 73P/Schwassmann-Wachmann 3 [9, 10]. The presented database of OPRs in "incoherent" since it includes measurements obtained via various techniques which (very likely) have included different sources of systematic uncertainties. To date, all observed spin temperatures have exceeded ~20 K. The current data do not support a unique spin temperature, that can be attributed to the whole comet population.

Spatially-resolved measurements of H_2O rotational temperature and ortho-para ratio were reported for comets C/2004 Q2 (Machholz) [7], 73P-B/Schwassmann-Wachmann 3 [10], and C/2004 K4 [8]. Here, we present similar measurements for C/2000 WM_1 (LINEAR). We discuss the significance of such measurements for investigating OPR invariance in cometary comae.

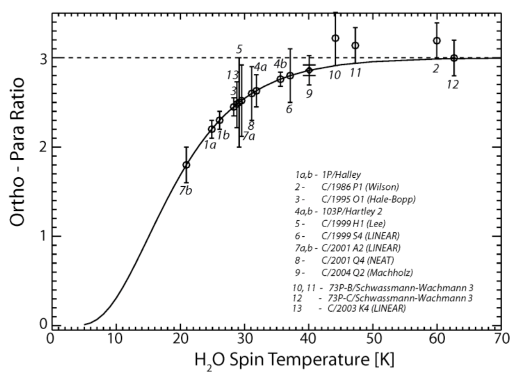

Fig. 1 Ortho-para ratios for H_2O in comets. Updated from Bonev et al. [7] which provides the original references except for 73P/Schwassmann-Wachmann 3 [9,10] and C/2004 K4 [8]. The OPR measurements are placed on the theoretical curve to identify the corresponding spin temperature. OPR measurements 2, 10, and 11 are larger than 3.0. However, the error bars are consistent with statistical equilibrium, implying $T_{spin} > 50$ K, 42 K and 45 K for 2, 10, and 11 respectively.

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