21cm Quantum Amplifier

John P. Wallace

Casting Analysis Corp.,
8379 Ursa Lane, Weyers Cave,
Virginia 24486 USA

Michael J. Wallace

Freeport-McMoRan, Phoenix,
Az 85050

Neutral atomic hydrogen is normally difficult to detect even in objects as large as the local Virgo cluster of galaxies because its magnetic dipole transition is glacial in generating the 1420.4 MHz emission. Detecting intense signals from the earth's atmosphere near the 1420.4 MHz of the neutral hydrogen emission line provides an opportunities to explore the chemistry of the upper atmosphere, a novel chemical bond, location of the ozone hole, monitor the motion of hydrogen in the upper atmosphere, and a chance to do radio astronomy on the cheap.

CONTENTS

I. BACKGROUND

Magnetic fields unlike electric fields because of their dipole source can form long range structures. These fields winding through low density matter can support longitudinal oscillations with long wavelengths. Longitudinal magnetic excitons on these fields even though very low energy have mass (Wallace, 2009) (Wallace and Wallace, 2014). In trying to learn something about the fields the earth sweeps up on it travels a survey was started in the low frequency range, ~ 1 milli Hertz. Normally it is assumed that the atmosphere is not a particularly active magnetic medium, however, in this study of weak fields that assumption cannot be made. So in conjunction with the magnetic measurements a second survey of the high frequency field behavior in the low background noise regions of the UHF band that is not strongly attenuated by the earth's atmosphere was also started to check if there were any correlated effects.

It was noticed that there was a slight drop in the magnetic signal amplitudes when high density bands of states

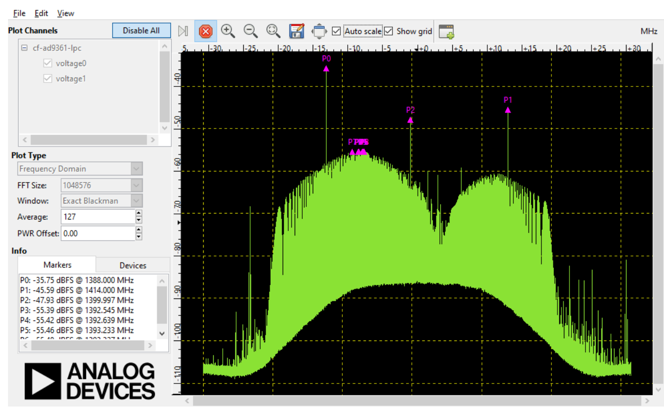


Figure 1 **Pair of bands spanning 1380-1420 MHz with the spectrum taken with an EW polarization with a 1 meter parabolic antenna pointed towards the zenith. The signal level at the peak is 30 db above the noise floor. The weather was a strong rain and a thick fog with a temperature of 5^oC. Center frequency of the spectrum was set at 1401 MHz with a band pass set at 20 MHz. 127 FFTs of 1,048,576 samples were averaged and taken at a rate of 60 Mega samples per second.**

with very narrow line widths less than 60Hz appeared at frequencies below the 1420.4 MHz of the 1S hydrogen triplet to singlet transition. This region of the UHF spectra is thought to be barren of molecular emissions. Two types of spectra were found: individual lines that were always present unless overwhelmed by the intense bands of line. The second type were bands of lines when in the off state were sometimes partially visible just a couple of db above noise and when on as much as 30 db above the noise floor. These bands are not always present as strong signals but turn on and off abruptly a few times a day.

Because of the narrow line widths the origin of these signals would have to come from a cold low density region of our atmosphere where the principal interaction between molecules would be via their magnetic fields and not scattering since the transition at 1420.4 MHz is a magnetic dipole transition. Weak energy collecting activities are not uncommon in quantum systems. The implications of these active processes is that a form of atomic hydrogen to both absorb and emit below the 1420.4 MHz hydrogen line where there is a broad but weak band of energy from the red-shifted neutral hydrogen emissions from space.

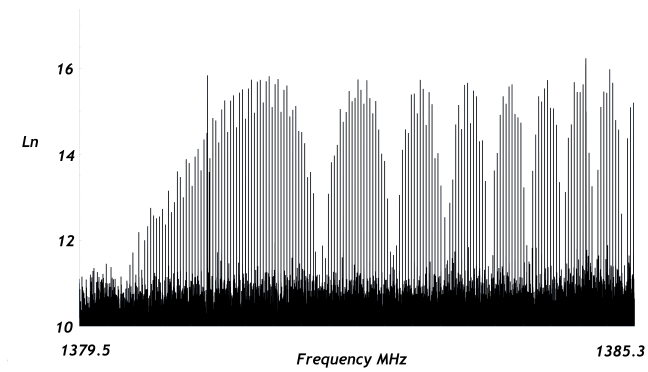


Figure 2 **The entire 40 Mhz signal band from 1380 to 1420 MHz is made up of approximately 2600 narrow emissions with a half-width of less than 50 Hz. An expanded version of the bottom edge is shown where the spacing between emission is $\sim$ 31.6 kHz. The stray line is an artifact from the SDR down conversion.**

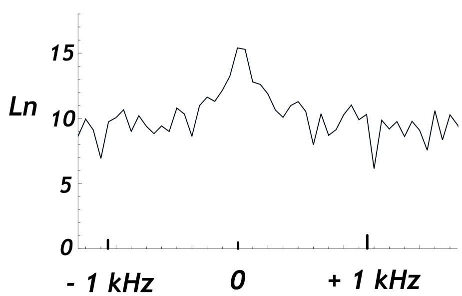


Figure 3 **Single emission line expanded from the dense band of lines.**

Normally inexpensive receivers that are used as teaching tools for implementing software defined radio are not ideally suited for radio astronomy when using the most primitive 3" long broad band dipole antenna. Even with this simple tool, strong signals were detected in the regions of the 1420 MHz emission of neutral hydrogen, see figure 1 through 4. This work was following earlier work by Swartz who found detectable emissions from from atomic deuterium by an even more primitive re-

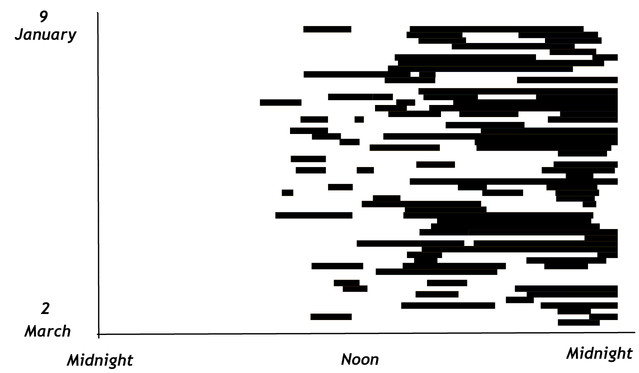


Figure 4 **Plot of when the strong 1380-1420 MHz emission were active in black. They typically shut down by midnight or a few minutes afterwards. The data was taken with a vertical dipole antenna. The pattern conforms to two possible sources of radiation to pump these emission. First is the solar heating of the earth's upper atmosphere by the sun. Secondly is the pattern corresponds to the time of day when the zenith at our location has the disk of the Milky Way and even M31 in position to supply a band of radiation that encompasses the highest frequency that belong to these emission at 1420.010 MHz. The red shifted radiation from outside the solar system seem to be a key component in driving these processes.**

ceiver (Swartz, 2020). To investigate these RF signal a 1 meter parabolic antenna was constructed that could be pointed to the zenith where the polarization of any emitter due to the earths magnetic field could also be detected.

A. Apparatus

Observations were done using a software defined radio receiver that is part of the Analog Devices ADALM-PLUTO device that operates from .325 to 3.5 GHz. The maximum down converted detection bandwidth is 20 MHz. Surveys for a few months were performed with the antenna supplied with the unit that could marginally detect the on state of the bands from 1380-1420 MHz. The receiver antenna was replaced with Southwest Antennas half wave dipole 1.34-2.5 GHz 2.4 dbi. Software used was the I/O oscilloscope supplied by Analog Devices. The receiver was operated as a spectrum analyzer with a sample rate of 60 million samples a second with a sample length of either 16,384 or 1,048,576 which were fast Fourier transformed (FFT) and 127 are averaged. Averaging spectra does two things it helps identify made made sources by detecting baseline elevation and detects infrequent molecular emissions that would normally be lost in the noise that only occur at very specific frequen-

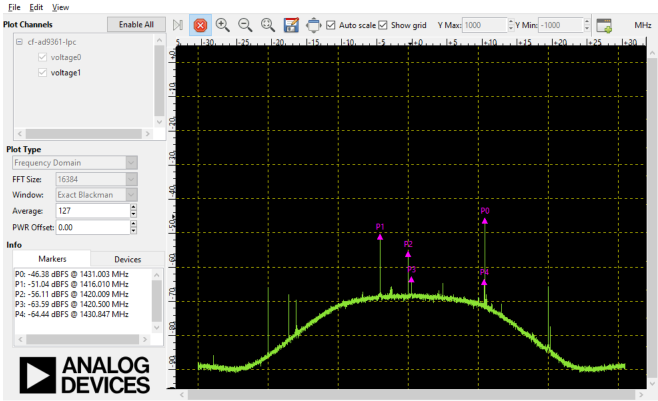


Figure 5 **Center frequency 1420.5 MHz with signal off taking 127 scans 16,384 long that are averaged resulting in frequency interval per bin of 3.72 kHz. The antenna had a N-S polarization. Notice the noise floor is ∼ -71 db in the pass band.**

cies.

Initially, the Southwest antenna was mounted vertical on a pole 7 ft above the ground on the edge of precipice. The data were monitored periodically a number of times each day for a number of months in a wide range of weather and wind conditions. The measurements occurred in a radio quiet zone and the 1400 to 1427 MHz frequency range is reserved for radio astronomy. Eventually this antenna was placed at the focus of a 1 meter parabolic reflector aimed toward the zenith and make polarization measurements of the emission. This reduced signals from the ground which can also produced both 1420 MHz signal and the hydroxol lines at 1612, 1665, 1667, and 1720 MHz.

There is an advantage to using a software defined receiver with a large sample set that will allow very narrow atomic emissions to be detected in noise where a traditions detector with a band pass of a few kilo Hertz would not detect. average for the FFT transform and it hides a great deal of interesting data that is in the noise. In 6 Figure 1,048,576 samples are taken for each of 127 FFTs averaged. The output data for 16,384 scans has a resolution of 3.72 kHz while the 1,048,576 has a resolution of 58.17 Hertz. This is quiescent baseline data, however, in the large sample set there an array of signals including a set of 6 signals spaced ∼ 6.5 MHz that look to be broadened with similar fine structure. None of this is resolved with the smaller sample set. Since these very sharp signal are in the reserved quiet part of the spectrum they are not man made.

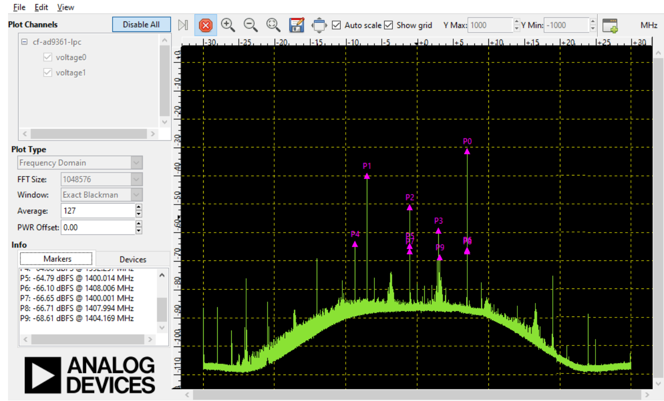
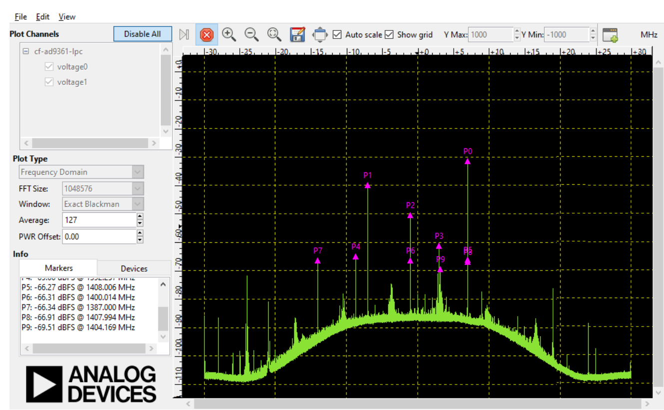


Figure 6 **Center frequency 1401 MHz with the signal off taking 127 scans 1,048,576 long that are averaged resulting in frequency interval per bin of 57.22 Hz. Notice the noise floor is ∼ -86 db in the pass band. There is the beginning of a band ending at 1380 MHz. In the below figure the antenna polarization was changed to E-W the saturation band starting seen at 1380 is suppressed. Both figures with more than a million samples per scan show 7 additional peaks that are spaces at approximately 6.5 MHz that do not show up in Figure 5. This is a second low level molecular feature does not top out at 1420 MHz but has been found approaching 1500 MHz.**



II. DATA

The most noticeable feature about the intense data band 1380-1420 MHz is that the bands shape is highly variable, note Figures 1 and 7. Since we are dealing with an antenna that has a small viewing angle and a background source of radiation that varies in frequency and intensity as function of location in the sky this should not be a surprise. Since the atmospheric attenuation at these frequencies is very low the source of the radiation is important in defining the structure of these bands. Our experimental resolution of the line widths are limited to something less that 60 Hz., however, the real line widths from the slow spontaneous transitions rate of neutral hydrogen ,$n_s = 2.87\ 10^{-15} sec^{-1}$ are much narrower (Rohlfs and Wilson, 2000). The molecules absorbing and re-radiating this energy are concentrating a smeared very weak spectrum whose broad red shifted fields are transformed into very strong fields with very narrow line widths producing an apparent gain factor of many orders of magnitude. Even with a line width of 10 Hz and a line spacing of 30 kHz the net gross gain is on the order of 3000, which is most like a allot less than the real gain. The atmosphere is in a sense acting as an image intensifier to produce these signals.

$$\Delta\omega \simeq n_s \tag{1}$$

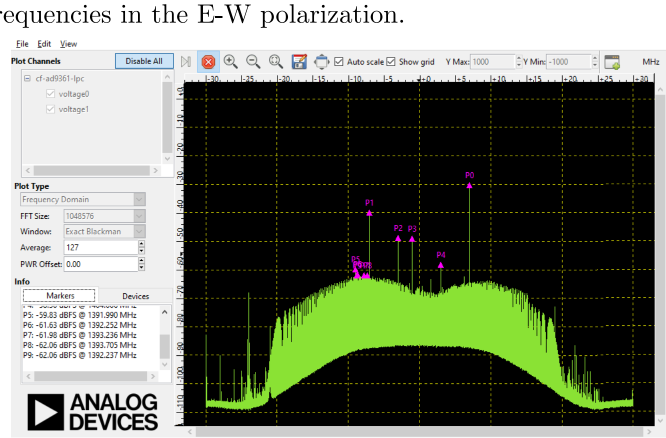
Just from the perspective of the narrowness of these lines measured automatically removes any consideration of a man-made origin of these spectra.

A. Magnetic Polarization

The polarization with respect the earth's magnetic field is significant in that there appears to be a magnetic preferential alignment for the emitting molecules aligned along the earth's magnetic field. An example is present in Figure 6 where strong band signals are not active. However, in the N-S spectrum the band from 1380-1400 MHz is just barely above noise and it is missing in the E-W polarization data.

There is in addition at least six narrow peaked emission bands spaced approximately 6.5 MHz apart that are also constructed of sets of very sharp emission lines that have FWHM line widths of less than 50 Hz, and these are spaced at 52.28 kHz rather than 31.6 kHz found in the more intense bands. These peaks show no polarization effects.

When the intense 1380-1420 MHz bands are on there is also a strong effect due to polarization in both a shape change an a partial reduction in amplitude in the E-W spectrum. There appears to be a shift in energy from the higher frequencies in the N-S polarization to the lower frequencies in the E-W polarization.



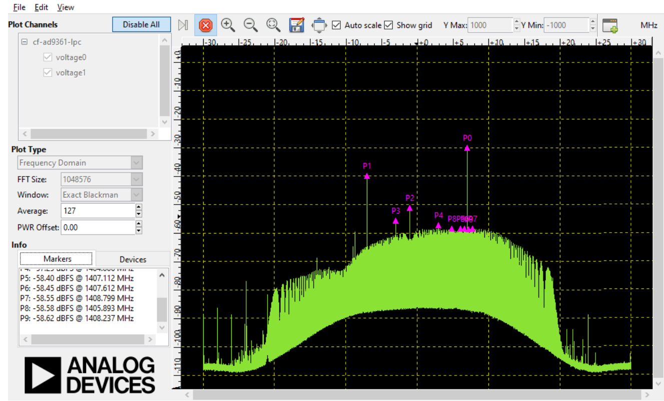


Figure 7 **Similar settings as the previous two spectrum with the antenna oriented with a N-S polarization. Below the antenna is oriented in a E-W polarization. There is a major increase in the energy emitted in the N-S orientation along with a change in the distribution of energy between the two separate bands above and below 1400 MHz.**

B. Additional Bands

A few additional bands that had similar shape to the two bands at 1380-1420 MHz were found at lower frequencies, see figures

Table I **Similar Excitation Bands. The problem is only the 1400-1427 MHz region of the spectrum is reserved for radio astronomy. The lower frequency band over lap spread spectrum transmission. The start frequency is selected from the end that shows the modulation pattern because a wobble instability of the bonding hydrogen will not be damped out at the lower angular momentum states. This is simply an assumption about the mechanics of the molecule that generates these signals.**

MHz start	direction in freq.	Comment
1420	↓	Figure 1 & 4
1380	↑	Figure 1 & 4
1218	↑	Figure 6
1241	↑	Figure 6
852	↓	Figure 7

C. Isolated Line Daily Frequency Variation

What caught our attention initially was a band that topped out 1420 MHz and extended down to 1380 MHz that was symmetrical about a center point 1400 MHz, Figure 1. The reason it caught our attention is the band edge states appeared to be testing the top of a set of rotational states with a principle lines at both end and one in the center. The spectrum also looked like a saturation of a large collection of rotational transitions driven from

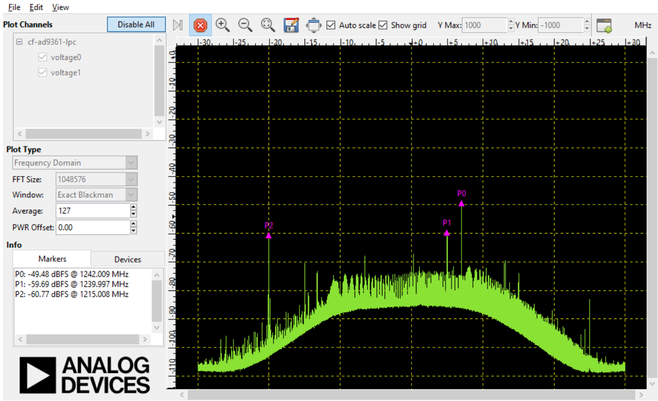


Figure 8 **Center frequency 1235 MHz. There are two bands one starting at 1218 MHz and the other at 1241 MHz and they partially overlap.**

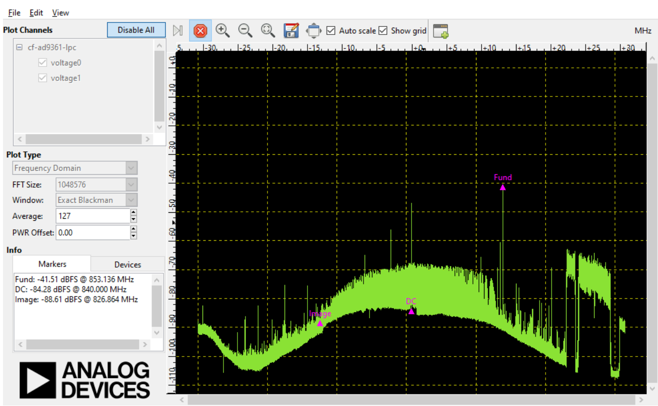


Figure 9 **Center frequency 1235 MHz. There are two bands one ending at 1218 MHz and the other at 1241 MHz and they partially overlap. The raised baseline on the left is due to commercial radio traffic.**

an external source. The only problem was molecular rotational bands are not normally found with such low energies in the UHF region of the RF spectrum. These data require a molecule that could sweep up a very weak and broad signal moving downwards from 1420.4 MHz and reprocess it in many very narrow emissions. This led our thinking to the point of view that whatever rotation was taking place had to alter the scale of a hydrogen 1S state very slightly in a molecule, expanding the wave function and driving down the electron density at the proton to reduce the splitting between the triplet and singlet state whose emission topped out at 1420.016 MHz from 1420.4 MHz.

III. WHERE & HOW

The earth's local magnetic field is only a partial guide in determining the type of transitions that are being detected. The earths field will be a maximum of 80 micro

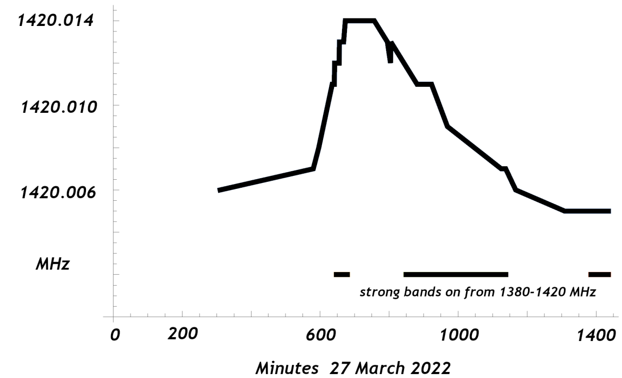


Figure 10 **Typical 24 hr frequency variation in the 1420 MHz frequency emission line. There were three events where the dense band of emissions below 1420 MHz came on with increases of 20 db or more are indicated by the three horizontal line segments. Those were typical times for the events. Antenna was pointed towards the zenith with a N-S polarization with the measurements starting at midnight at 1420.005 MHz. This patterned of frequency shift may be a measure of the change in altitude of the active emitting cloud.**

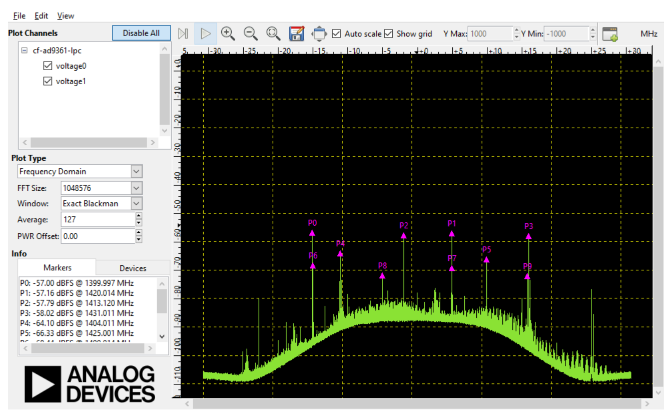


Figure 11 **Center frequency 1415 MHz. The two of the three principle lines at 1420 and 1400 MHz are recorded early morning.**

Tesla at the surface and decreases with altitude to 10s of nano Tesla at the geosynchronous orbit level. The line pairs found at 1400 and 1420 are a little more than 10 kHz apart and in a magnetic environment with the electron spin polarized for a $J = 0$ rotational state there should be only a single transition. So if there are a pair of lines it is possible they represent two different populations of the active molecule at two different altitudes. This concept is not too far fetched because there are two minimum temperature regimes in the atmosphere's temperature profile. One occurs at 10 to 20 km in the stratosphere with a temperature $\sim 220^o K$ and the other beginning at 80 km at the bottom of the thermosphere with a temperature of

$\sim 190^o K$. In table II the magnetic field is computed for the measured line splittings for the the line at 1420 and 1400 MHz. These cold layers in the atmosphere provide a region where weak chemical bonds can form and persist.

Table II **Two principal lines and their splitting 23:20 UT 21 March 2022 with on rotational bands. Note the 1400 emission is much stronger. With the earth field below 1 micro Tesla the split state appear as two different populations at two different altitudes in units of the earth radius R_e.**

MHz	db	MHz	db	kHz	nano Tesla	**J**
1420.008	-55.46	1419.991	-68.14	17	610	0
1399.997	-47.05	1400.008	-57.03	11	357	0
1374.999	-60.05					

A. Quantum Mechanics of a Weak Polarization Bond

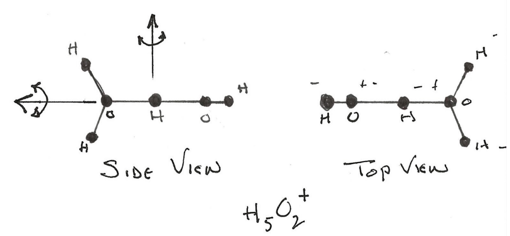
The raw material for generating these transitions appears to be 1S hydrogen atom operating within a molecular structure that possess two rotational modes. With one rotational mode having and extremely low moment of inertia. The question is how a single hydrogen 1S can operate as a binding element in a molecule comes directly from the fact the 1S state has only a single symmetrical degree of freedom for the variation of the electron's density function. This variation in response to a perturbation that can only depend upon the radial variable. It is not a plastic orbital and cannot be deformed to break its spherical symmetry under weak polarization (Wallace and Wallace, 2020). This statement also rules for the normal higher energy chemical bonds that combine states with appropriate symmetries. From the displaced origin of the 1420.4 MHz line being shifted to 1400 MHz implies the electron density at the proton has been reduced by a polarization to a more positive companion. From the altitudes where these two distributions could be, isolated at these altitudes from the local weather. This was evident in there was little correlations of the onset of the bands with surface weather. In the atmosphere other than oxygen, nitrogen, and water vapor, there is an expectation of a hydronium concentration from evaporation (Pollack, 2013).

IV. WHAT

The high altitude low pressure and low temperature region is ideal for to allow weakly bonded species to exist for long times. The presence of the three very sharp group of lines at 1420.01 and 1399.997 MHz, indicated that atomic hydrogen has found a bond that only slightly reduces the electron density at the proton. Also, it implies that the region is rich in local magnetic perturbations that drives emissions via the magnetic dipole transition. The large volume makes up for the low density of the atmosphere in terms of the emissions that are generated. From the data it appears that an individual molecule is responsible for the strong spectra as these isolated lines are closely associated with 1420.4 MHz hydrogen emission. The other part of the story about the absorbing molecules is they have to have some physical flexibility to absorb over a range of frequencies.

A. The Molecules

A hint of the chemistry that occurs is the timing of the saturation of approximately 1200 states associated with the 1400 MHz version of the species that occurs in the late afternoon through the evening and then usually shuts down before midnight. During the day through evaporation with the solar input the earth develops a negative charge and hydronium H_3O^+ is pumped into the atmosphere (Pollack, 2013). Combining water vapor with hydronium produces a molecule of $H_5O_2^+$ with a geometry with two rotational modes and a perturbed 1S hydrogen at its center. The positive charges to minimize the total electrostatic energy will be forced out to the four extremal protons. The two proton groups at each end will also oriented so their planes are perpendicular to each other to reduce the electrostatic potential.



The fractional charge distribution assures that only a polarization bond can be generated. With any axial rotation strong magnetic fields are created by local currents from the rotating polarized end groups. The central hydrogen 1S state is expanded slightly to move the transition down by 400 kHz. 1S state has only one degree of freedom to polarization and that is to radially change its charge distribution. This energy change in the 1S state will contribute to the weak bonding to the two end water molecules. This will also be the case for the hydronium molecule. The second rotational mode perpendicular to the axis of the molecule will produce a much great frequency shift in forcing the the 1S state to enlarge with increasing angular momentum, thus producing the lower frequency bands.

The molecular structure of $H_5O_2^+$ also must be a strong absorber of radiation and this is most probably made possible by the flexibility of the weak structural bonding. The modulation at the start of the bands may hint at this structural flexibility of the molecule. With the magnetic field the rotating molecule can produce will enhance the absorption cross section.

$$H_3O^+ + H_2O \rightarrow {}^{(\frac{\pm}{4})}H_2O \;\; H \;\; OH_2^{(\frac{\pm}{4})}$$

$$^{(\frac{\pm}{4})}H_2O \;\; H \;\; OH_2^{(\frac{\pm}{4})} \;\; + \;\; e^- \rightarrow H + 2H_2O \tag{2}$$

$$^{(\frac{\pm}{4})}H_2O \;\; H \;\; OH_2^{(\frac{\pm}{4})} \;\; + \;\; OH^- \rightarrow 3H_2O$$

The magnetic fields produced by the molecules will actively drive magnetic dipole transitions in this population of molecules.

The more ubiquitous narrow bands that are spaced at approximately 6.5 MHz might very well be due to hydronium that has a more robust presences. I has two principle axis of rotation whose moment of inertia are not as great as found for $H_5O_2^+$ axis that is perpendicular to the long axis. This would allow the separate bands to be more closely spaced. Hydronium would not be easily polarized as it would not support as strong a magnetic field by rotation.

The mechanism that forms this seven component radical $H_5O_2^+$ also introduce the mechanism to liberate atomic hydrogen into the upper atmosphere where it can be lost. This can occur when excited to the highest angular momentum state. If this is the case then the atomic hydrogen concentration should rise after these clouds of radicals are driven into these quantum states. This becomes a problem for the hydrogen liberated in the stratosphere as it will reduce the ozone concentration. The ozone hole is found in the southern hemisphere around Antarctica where the weather dynamics move a great deal of water vapor into the atmosphere and the external sources of 1420 MHz radiation from space are much stronger than in the northern hemisphere. These radiation sources operate for many more hours of the day. Once the ozone holes are formed then the produced atomic hydrogen has an escape path through the atmosphere to space. This loss path has to be considered for the earth's hydrogen budge which may not be a very limited resource (Toulhoat and Zgonnik, 2022).

V. ACKNOWLEGEMENT

To Mitchell Swartz for introducing us to the use of software defined radios to investigate the spectrum of hydrogen and its isotopes (Swartz, 2020). Hervé Toulhoat for his discussion on planetary hydrogen on the underestimation of the amount of hydrogen the earth had trapped during its formation. Also to Brooks Pate for his background discussion on molecular spectra.

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