DID GALILEO SEE A SALTY PLUME AT EUROPA?

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INTRODUCTION

The CLIPPER mission will be visiting Europa, an icy Jovian satellite, in the late 2020s. One of its main objectives is to study its putative subsurface ocean [1]. Since the first measurements of plasma and fields in the Jovian magnetosphere, suggestions of plume activity have been reported which could represent communication between the surface and subsurface environment, a condition conducive to supporting life [2, 3, 4, 5]

In the Jovian/Saturnian magnetosphere the ambient magnetic field is perpendicular to the corotating plasma, and newborn ions are accelerated perpendicular to the magnetic field which creates a temperature anisotropy that is unstable to the production of ion cyclotron waves (ICWs), a transverse wave with a frequency at the gyrofrequency of the ions producing it. Because the ion gyrofrequency depends on the mass and charge of the ion species, the frequency of the generated magnetic field oscillations can be used as a proxy mass spectrometer to identify the dissociated components.

The closest passes of Europa were made by Galileo in the 1990s. However, instrumental limitations (e.g. the non-instantaneous sampling made by magnetometer and the magnetometers' relatively large quantization) can influence our ability to observe the small, short-lived effects of plumes on the magnetic field.

The transitory nature of plume activity at places like Europa [4], may make our ability to utilize the magnetic field to identify ion species crucially important to future missions to the Jovian and Saturnian systems. By examining the potential and limitations of past, successful missions, we can better understand and prepare for the conditions in the outer solar system.

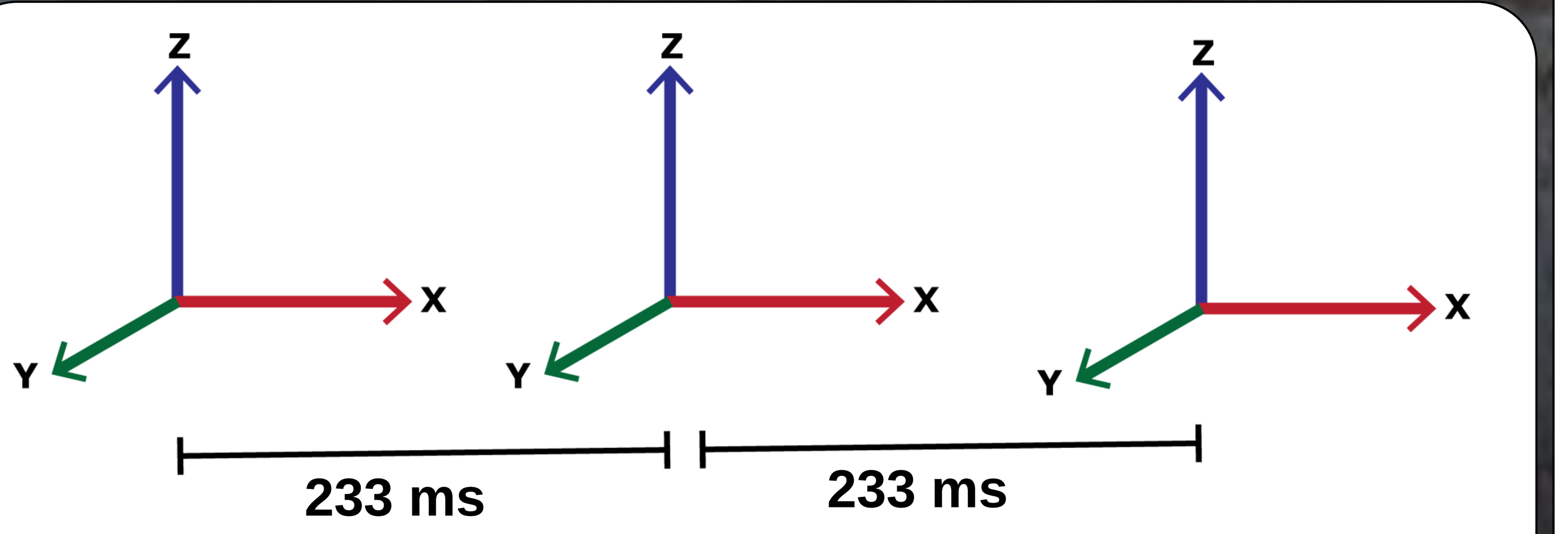

Figure 1. Time between Galileo fluxgate magnetometer LPW vector measurements after May 1996. Prior to that time, the nominal rate was [233, 233, 200] ms.

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EFFECT OF TIME DELAY

Throughout the Galileo mission, there was an approximate 0.2 s lag between the subsequent magnetic field component measurements [5].

This lag, which could introduce erroneous ellipticity measurements, was removed from the data by fitting the data to a piecewise spline. By comparing panels a and b in Figure 2, the effect of the time delay on the measured ellipticity appears to be negligible.

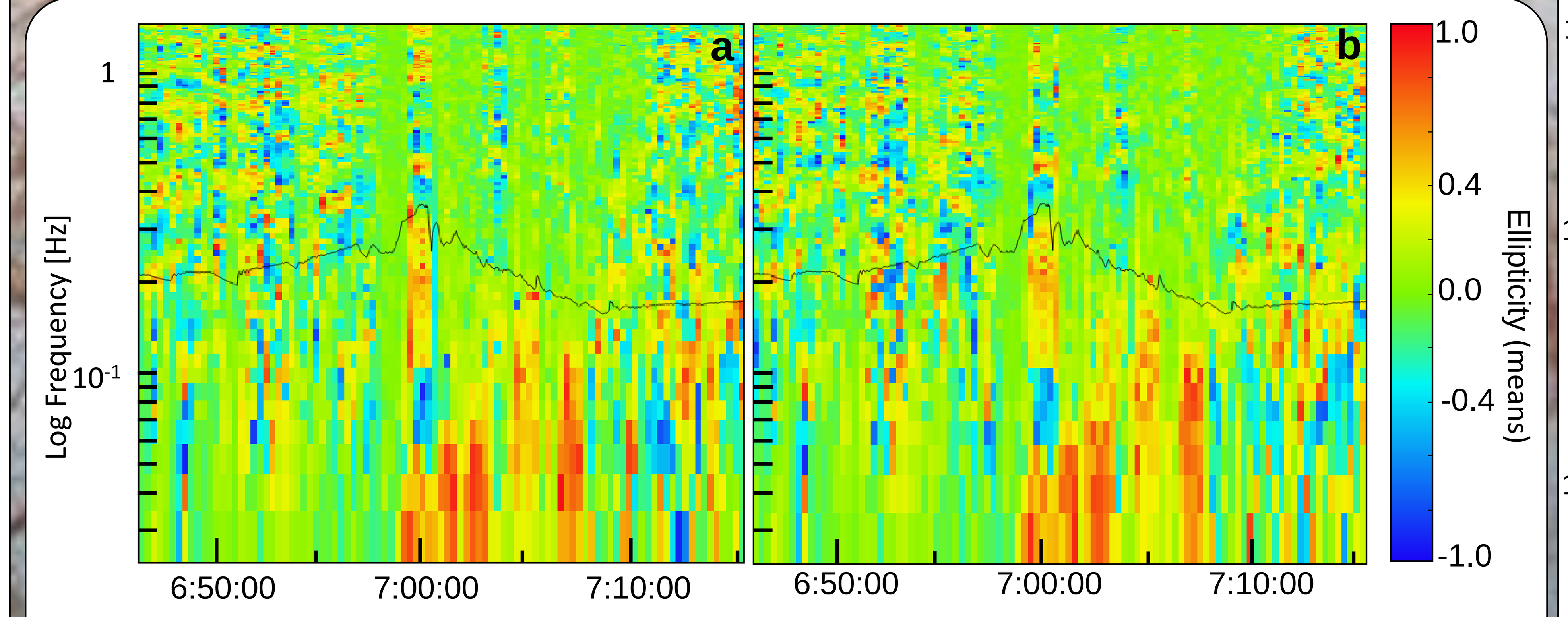

Figure 2. Galileo E12 pass [12/16/1996], which has a potential Cl^- plume (RH) around 7:00-7:03. [6] **a** Original Galileo Data. **b** E12 pass with time delay correction.

EFFECT OF QUANTIZATION

The quantization of the fluxgate magnetometer decreased dramatically in the time between the launch of Galileo and Cassini. Galileo's inboard magnetometer had a digitization of 8 nT for a dynamic range of +16384 nT and a digitization of ¼ nT for a dynamic range of +512 nT. The outboard magnetometer had a digitization of 1/64 nT for the dynamic range of +32 nT. In comparison, the maximum quantization for Cassini's magnetometer was 48.8 pT for the dynamic range of +/- 400 nT, meaning that Cassini is much better designed to measure small oscillation in the field [5].

To quantify this effect, we degraded Cassini passes through the E-ring, which are well-populated with ICW near the water-group frequency [7], to Galileo's instrumentation levels in order to assess the limitations of Galileo's inboard and outboard magnetometer.

From Figure 3 [a, b, c, d], we can see that the main spectra peak observed around the water-group gyrofrequency by Cassini's magnetometer is preserved by Galileo's inboard and outboard magnetometer. However, the small amplitude of the oscillations limits the number of measurements to calculate the 8 nT quantization's ellipticity, which makes it impossible to unequivocally identify the wave as an ion cyclotron wave.

From panel b in Figure 3, we can also see a potential artifact introduced by the large digitization at the higher frequencies. This brings into question past identifications by Galileo of ion cyclotron waves produced by doubly-ionized particles [8], which is the subject of ongoing investigations.

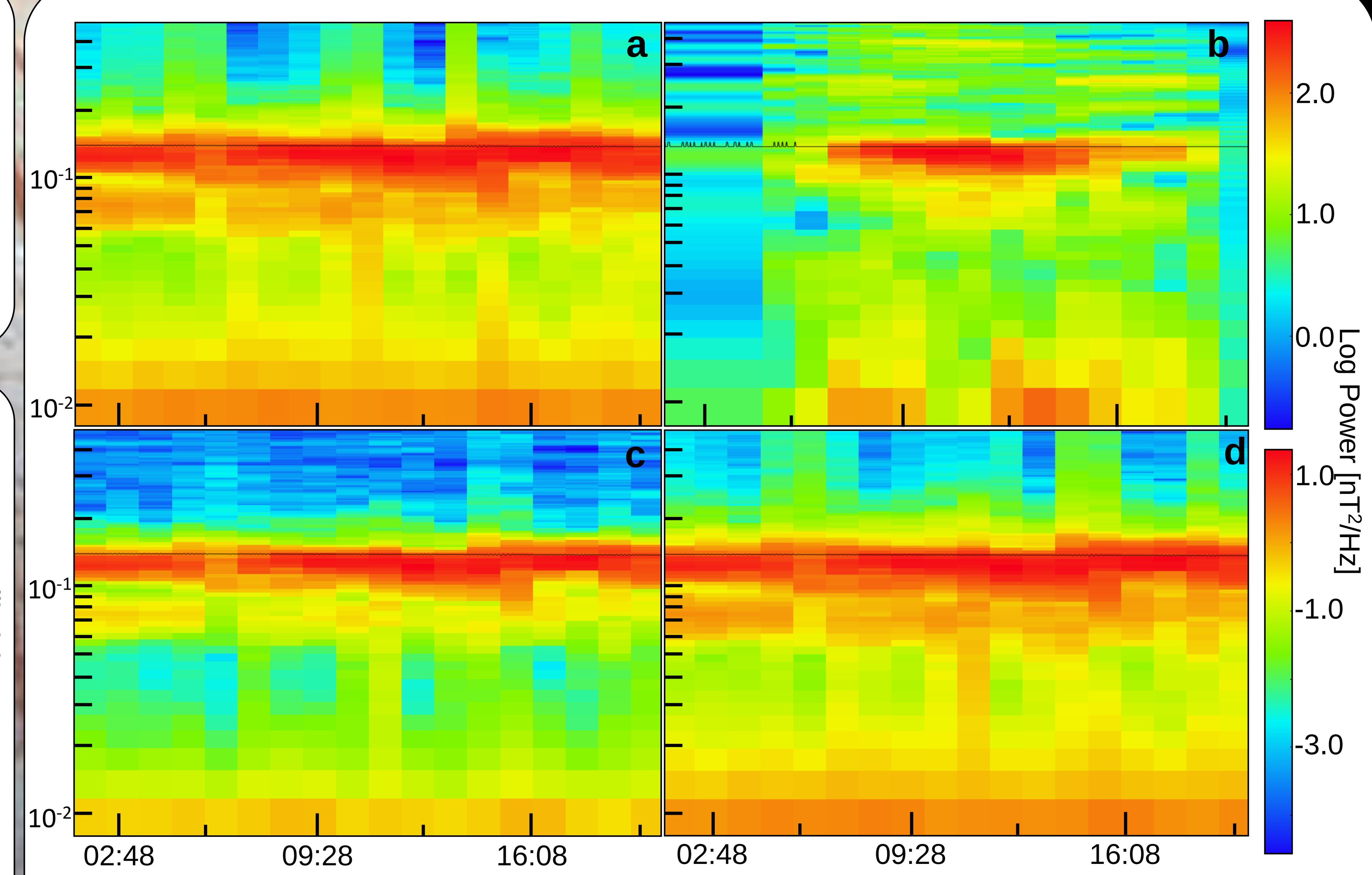

Figure 3. Dynamic Spectra in B_y (duskward) in KSM coordinate system 07:00-07:20 on 01/16/2005. The solid black line designates the H_3O^+ gyrofrequency [near the middle of the water-group frequencies (H_2O^+, O^+, OH^+, O_2^+)].The magnetic dipole is contained with the X-Z plane. **a** Original Cassini Data (48.8 pT quantization). **b** 8 nT quantization. **c** 1/4 nT quantization **d** 1/64 quantization.

APPLICATIONS AND CONCLUSION

Any material evacuated from Europa will be dissociated by the high-energy environment within the Jovian magnetosphere and can produce measurable ion cyclotron waves. Because there is no other significant source of chlorine in the Jovian magnetosphere [9], the existence of right-handed ICWs with a gyrofrequency near Cl^- implies the presence of dissociated saltwater from Europa. In contrast, ionized sulfur compounds may have originated in Io's volcanic plumes [10]. This suggests that Galileo may have passed through a transitory plume of dissociated saltwater, originally derived from Europa's subsurface ocean.

From this study, we can say that Galileo has the capacity to identify the same peaks in frequency-space at the water-group ion cyclotron frequency. However, the loss of ellipticity information limits our ability to definitively characterize it as an ion cyclotron wave.

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