Observations of Single-Bubble Sonoluminescence in Micro-Gravity and Hyper-Gravity

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Abstract: In the presence of gravity, an SBSL bubble experiences a buoyancy force whose interaction with the Bjerknes force causes vertical translational oscillations. One method of exploring the effects of gravity on SBSL is to compare the light output of SBSL in micro-gravity to the light output in normal gravity or hyper-gravity. These were examined by an experiment aboard NASA’s KC-135A.

INTRODUCTION

Single bubble sonoluminescence (SBSL) in water occurs when a bubble in a standing wave undergoes a rapid reduction in volume. In the presence of gravity, the SBSL bubble experiences a buoyancy force of approximately \( \rho g V(t) \) where \( V \) is the volume, \( \rho \) is the density of water and \( g \) is the acceleration of gravity. There is also a Bjerknes force from the sound field. The time average of these two forces balance at the equilibrium bubble location. If the SBSL apparatus is in normal gravity the bubble’s average position is displaced from the pressure anti-node of the acoustic standing wave [1]. The bubble oscillates vertically in part because it is displaced from the velocity node of the standing wave. Prosperetti [2] has suggested that motion of the bubble relative to the surrounding fluid at the time of its collapse can result in a significantly non-spherical collapse. The effect of relative motion on the final stages of the collapse was previously demonstrated for large (non-luminescing) bubbles [3]. It has also been demonstrated that large acoustically levitated bubbles become oblate and (by inference) their position oscillates relative to the acoustic motion of the liquid at the predicted velocity [4]. Prosperetti [2] has hypothesized that a micro-jet formation during collapse may be important in SBSL light emission. A contrasting hypothesis states that an internal shock-like wave develops with nearly spherical collapse of the bubble and light is given off due to the focusing of energy upon implosion. According to this hypothesis, by increasing the sphericity of the bubble and reducing vertical oscillations, it is plausible that light emission should increase. Matula et al. have also recognized the potential importance of gravity on SBSL [5].

THE EXPERIMENT

One way of modifying the conditions prior to collapse is by removing gravity. This can be done by flying a SBSL apparatus aboard NASA’s KC-135A, which performs parabola’s to give periods of micro-gravity and hyper-gravity. In April of 1997 a team of physics undergraduates from Washington State University flew a SBSL experiment aboard NASA’s KC-135A. The apparatus consisted of a light tight box encasing a levitation cell. A function generator and amplifier operating near 32 kHz drove the levitation cell. Attached to the box was a photomultiplier.
tube (PMT) used to detect the light output of the SBSL bubble. The PMT gives a voltage that is averaged over a 0.4s time interval, which is proportional to the light intensity emitted by the bubble. A laptop computer connected to a voltmeter via GPIB recorded the voltage data. Figure 1 on the previous page shows a schematic of the apparatus as well as a picture of the levitation cell. The effective vertical acceleration of gravity within the aircraft was also recorded.

DATA ANALYSIS/RESULTS

The data that was taken was graphed against the aircraft's effective gravity. Figure 2 is a plot of this graph where the average SBSL intensity is the solid line and the acceleration is denoted by a dashed line. There is an unavailable small time offset that was adjusted so the main transitions in the global record of the SBSL intensity were correlated with the acceleration transitions. This was the only free parameter and the relative time uncertainty was less than 8 seconds. The acceleration scale is shown on the right. The data shows a correlation of higher intensity during the low gravity periods and low intensity during the high gravity periods. In the absence of a bubble the PMT's output was on the order of 2 mV. The reason for the reduction in the light intensity from 760 to 1300 seconds is not known. The relative high noise level of the intensity data is attributed to the problems encountered on sight in Houston with the gas concentration level of the pre-prepared water used. On the day of the flight it was difficult to achieve stable SBSL at the usual intensity before the flight began.

Figure 2: A plot of the average SBSL intensity (solid curve) and the aircraft's vertical acceleration (dashed).

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REFERENCES