Aeronautics and Space Administration. This is the sixth in a series of articles on positions of X-ray sources obtained with SAS-3.

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Dynamic measurement of matter creation

IF a rotor could be spun so that it had an inertial decay time ~ 10^{11} yr, 10^{18} s, it could test matter creation cosmologies[1–3] at a significant level. The advantage of this method over previous ones[4–8] is that the result is independent of the form in which matter is created, providing it stays in place. We have designed an experiment to test this process; it is under construction and is described here. It consists of an inertially spinning rotor suspended inside another rotor, a modification of the double magnetic suspension[8]. Past measurements or estimates have not unequivocally answered the question of matter creation. Cohen and King[4] established an upper limit of 4×10^{-23} g per g per s on the creation rate of hydrogen in mercury metal. Gittus[5] suggested that matter created in rocks takes the form of interstitial atoms which diffuse into dislocations. Towe[6] disputed this, noting that if mass proportional creation were occurring, 30% of the atoms in old terrestrial rocks would occupy interstitial positions and this would result in lattice disruptions. Gittus[7] later proposed that the matter multiplication rate for crystalline materials could be found by determining the ratio of the shear modulus to the crystal viscosity. He suggested that a reasonable estimate for the sensitivity of the method might be 3×10^{-18} atoms per atom per s, although this has not been tested. In a geophysical argument, Wesson[8] can account for the observed expansion rate of the earth by appealing to a mass proportional matter creation whose rate is 7×10^{-18} g per g per s, but he notes that this is in conflict with the result of Cohen and King; it exceeds Dirac's prediction by several times.

Figure 1 shows the elements of the experiment. Two cylinders of highly temperature-stable ceramic rotate concentrically about the axis of rotation of a precision turntable. The outer cylinder is connected to the turntable which rotates with an integral speed constancy limited only by the precision of the atomic clock. The turntable drive is a 50-pole magnetic-averaging synchronous direct drive and the sensor is a double-plate totally averaging encoder system.

The inner (inertial) cylinder is magnetically suspended from the outer and initially caused to rotate with the outer, after which it is freely rotating. Mass created in the inner cylinder causes it to slow down relative to the outer cylinder. The accumulated phase lag of the inertial cylinder provides an extremely sensitive measure of this relative motion. A synchronised pulsed laser has a split beam, part of which is for sensing the relative angle of the two cylinders and another part of which, when unblocked, provides forward or backward momentum impulses to the inertial cylinder to keep it in phase. The sequences of the pulses constitutes the signal. Before and after experiments calibrate the momentum impulses and also provide estimates of limits on competing energy loss mechanisms when the inertial cylinder is driven up to speed from rest with the turntable stationary.

Three major competing mechanisms for energy loss among among many[9,10] are (1) viscous losses in the residual gas of the vacuum, (2) magnetic hysteresis in the support, and (3) interaction with external magnetic fields. Another consideration is the change in cylinder radius due to thermal expansion, and a further major factor is the wandering of the inertial cylinder about its equilibrium position due to thermal noise.

The viscous losses and magnetic hysteresis are rendered virtually zero by the feedback system described above which allows essentially no relative motion between the cylinders. Shields can reduce asymmetric (hysteresis) effects of external magnetic fields to insignificant levels. Thermal expansion effects are kept negligible if the system is thermally isolated and allowed to come to temperature equilibrium, $\Delta T \leqslant 10^{-3}$ K and by making the cylinder of a material with temperature coefficient $\alpha < 10^{-7}$ K^{-1}. In this case $\Delta r/r < 10^{-10}$ and constitutes a short term variation only, not a steady drift.

The thermal fluctuations can be estimated from standard noise criteria:[11]

$$\tfrac{1}{2}\, I(\Delta\omega_n)^2 = -\tfrac{1}{2}kT, \qquad (1)$$

where I is the inner cylinder moment of inertia, kT is the thermal energy and $\Delta\omega_n$ is the thermally caused fluctuation in velocity.

Then if

$$\Delta\theta_n = \int \Delta\omega_n \,\mathrm{d}t, \qquad (2)$$

is the angle through which the cylinder has random-walked from synchronous position due to noise, we get

$$\Delta\theta_n = (kT/I)^{\frac{1}{2}}\,\tau, \qquad (3)$$

where τ is the duration of the experiment.

The magnitude of the expected change in angle due to mass creation depends on the particular cosmology by which it is predicted. If the newly created matter has the same velocity as the matter in the inertial cylinder, then no effect might be measured even if mass creation existed. But as the newly created matter presumably owes its existence in some way to the Universe as a whole, we might expect its initial state to reflect the overall rotation of the Universe which we presume to be zero. In this case, there would be some 'drag' on the inner cylinder.

There are still many possibilities, three of which we will mention. First, angular momentum, L, is conserved and mass

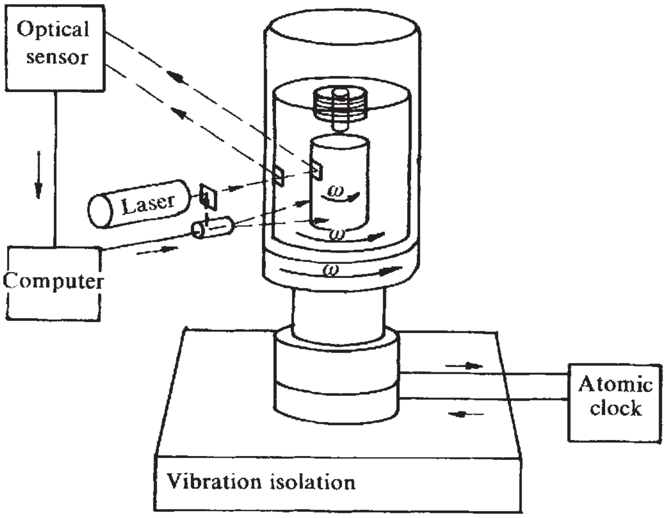

Fig. 1 Two cylinders of temperature-stable ceramic (Zerodur) rotate concentrically in an evacuated region inside an acoustic and magnetic shield. The inner cylinder is magnetically suspended from the outer one which rotates with precise angular velocity ω. Mass created in the inner cylinder tends to slow it down. A feedback system employing laser pulse sensing and photon driving keeps the inner cylinder velocity ω' very near to ω. Forward-backward asymmetry needed in these feedback driving pulses to keep ω' = ω constitutes the signal. With the two cylinders running synchronously, viscous, magnetic hysteresis and other damping effects are kept near zero.

is created with no angular momentum and in such a way that the dimensions of the cylinder remain constant. If I = moment of inertia, M = mass, and r = radius of the cylinder, then L = constant = $I\omega \sim Mr^2\omega$ which gives $\dot\omega/\omega = -\dot M/M$. Second, L conserved; mass created with no angular momentum and density is conserved. As the arguments are dimensional, we will treat the height of the cylinder as the radius, then L = constant = $\rho^{-2/3} M^{5/3}\,\omega$ which gives $\dot\omega/\omega = -5/3\,\dot M/M$.

Third, large numbers hypothesis as for instance in ref. 1. Under the LNH angular momentum is not conserved in atomic units. Velocity and atomic quantities are constant. If the new matter is created such that density, which is an 'atomic' property is constant, then $\omega \sim v/r \sim v(\rho/M)^{1/3}$, or $\dot\omega/\omega = -1/3\,\dot M/M$. (It is possible to analyse a rotor in more than one way under the LNH; for example, the spinning earth is gravitationally bound and, hence, its density is not purely an atomic property. In this case the analysis might proceed more along the lines of an orbit problem and one gets $\dot\omega/\omega \sim -1/2\,\dot M/M$).

In all of these cases we find $\dot\omega/\omega = \Upsilon\dot M/M$ where Υ is a number of order unity. Typical estimates for $\dot M/M$ are 2×10^{-10} $yr^{-1} = 6\times10^{-18}\,s^{-1}$. If the inner cylinder has no initial motion relative to the outer, then after a time τ we would have an angular displacement

$$\delta\theta = \omega\tau^2 = -\Upsilon\omega\dot M/M\,\tau^2. \quad (4)$$

Thus, the lag angle increases quadratically in time. Equations (3) and (4) can be combined to give the signal-to-noise ratio $\delta\theta/\Delta\theta_n$, from which the sensitivity to mass creation is

$$\dot M/M = [(\delta\theta/\Delta\theta)_n\,(kT/I)^{1/2}]/\Upsilon\omega\tau \quad (5)$$

Without feedback, the sensitivity from equation (5) at room temperature, with $I = 25{,}000\,g\,cm^2$ and $\omega = 10\,rad\,s^{-1}$ would be $\dot M/M = 10^{-8}$. Feedback if noiseless and of gain G can reduce the effective temperature[11] by a factor of $\sim (G)^{1/2}$, and the experiment ultimately will be cooled as well. Appropriate feedback will be controlled by a digital processor. Thus the signal-to-noise condition can be met simultaneously with the low damping requirement. To emphasise the level of difficulty of the experiment we note, from the secular decrease in the earth's rotational angular velocity[12], largely due to tidal friction, that the earth itself as a rotor is too dissipative by a factor of 20. Braginsky[13] has shown from noise considerations and fundamental limits on detection sensitivity that mechanical oscillators can in principle have decay times $\sim 10^{-18}$ s. Similar limits apply to rotors and estimates with our parameters are that this can even be improved.

Ultimately, an observed effect would always be suspected of unaccounted-for-damping, yet most damping effects are expected to be linear in time to a close approximation and the signal is quadratic so that it has a distinctive signature. Nevertheless, if an effect is observed the experiment will be repeated at different initial angles, with different cylinders, and at different temperatures.

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Identification of interstellar polysaccharides and related hydrocarbons

Infrared transmittance spectra of several polysaccharides which are suitably calibrated for comparison with astronomical data have been obtained. We show here that a mean 2.5–15 μm spectrum computed from our measurements is remarkably close to that required to explain a wide range of astronomical data, except for two significant points of departure. The required relative opacity at the 3 μm absorption dip is a factor ~1.5 lower than we found in our laboratory measurements: this difference may arise from the presence of water (~10%) associated with terrestrial polysaccharide samples. In the 9.5–12 μm waveband an additional source of opacity seems to be necessary. The close agreement between the spectrum of this excess opacity and the absorption spectrum of propene C_3H_6 points strongly to the identification of hydrocarbons of this type which may be associated with polysaccharide grains in interstellar space.

The presence of interstellar polysaccharides has been deduced[1] by comparing infrared spectra of several galactic infrared sources in the 2–30 μm waveband with model calculations based on transmittance data for cellulose. We show here that the transmittance properties of cotton cellulose gives a good agreement to the observed emission from the Trapezium nebula in the 8–30 μm waveband. But with the adoption of more stringent standards of comparison between observations and theory, we thought it appropriate to 'optimise' the transmittance values over the waveband 2.1–13 μm without departing from the original cotton cellulose data by more than a reasonable margin. In the absence of properly calibrated transmittance data for other polysaccharides we have provisionally assigned our optimal values to a 'notional' interstellar polysaccharide ensemble. It is, therefore, desirable to obtain