Radio-Controlled Model Boat Samples Air and Plankton

Abstract. *A radio-controlled model boat obtained surface samples of plankton and of air over water; it was especially useful in obtaining samples of neuston in water less than 15 centimeters in depth. It can be used to sample highly radioactive areas. The boat functions best in calm water or where surface currents are less than 3 knots.*

A radio-controlled model boat (Fig. 1) was built, similar to Ewing's (*1*), of balsam sheets 4 to 7 mm in thickness; the hull was patterned after a Coast Guard cutter, 95 cm long and 25 cm in beam. The completed weight was about 6.8 kg. The boat was powered by twin 12-volt d-c motors and twin counter-rotating 2.5-cm screws. Maximum speed in calm water was about 5 knots; sampling speed, from 2 to 3 knots. Electricity was supplied by 12 to 14 1.2- to 1.4-volt Nicad batteries (*2*). The motors required about 14 volts, and the radio-controlled servos operated on 6 volts supplied by a 6-volt Medco battery pack (*3*). Figure 1 shows the internal construction. Steering, forward and reverse movements, and the sampling equipment were controlled by three Transmite servos (each 9.4 by 5 by 2.5 cm), two small electric motors, two gear trains, and a receiver, all of which are available at most hobby shops.

Radio-control 6- and 10-channel Kraft transmitters (27.7 Mc/sec), with receiver (5 by 5 by 6.5 cm), were used; they could activate as many as five servos within 1.6 km (maximum). The safest range for sampling was about 0.4 km because the boat was invisible without binoculars more than 0.8 km away.

An air-sampling pump was constructed from a Thimbledrom model-airplane engine having 0.8-cm^3 displacement. Discarding the fuel system, we connected one end of a length of Tygon tubing (the suction line) to the intake port; the other end was connected to a nipple penetrating the rubber stopper of a glass vial (94 by 24 mm) that served as the air-sample container. A second nipple through the stopper was connected, by way of a stopcock, with the neck of an aluminum funnel, the open end of which pointed in the direction of travel. The pump was driven by an electric motor (18-volt; 15 : 1 gear reduction) at 500 rev/min; air was sampled at about 1400 to 2800 cm^3/min. A radio signal caused the servo to open the stopcock and switch-on the pump—and to reverse those actions after a 10- to 15-minute period of sampling.

The power supply described provides for maximum sampling periods of 20 to 25 minutes. However, toward the end of the sampling period, as the battery weakens, the sampling rate decreases, and the remaining power may not suffice to return the boat to shore with the samples. Recharging of the battery pack requires 24 to 48 hours, so one should have three or four packs available. The radio receiver must be tuned and the radio-control system must be carefully checked before each field operation. The plankton net can be cleaned and a new battery pack and a sterile air sampler installed within about 10 minutes, for further sampling.

The air-sample container is mounted on a frame, 50 cm above water and 15 cm ahead of the boat, to avoid contamination by spray. The neustron sampler consists of a 5- by 6.2-cm No. 25 plankton net which, on receipt of a radio signal, is lowered into the water

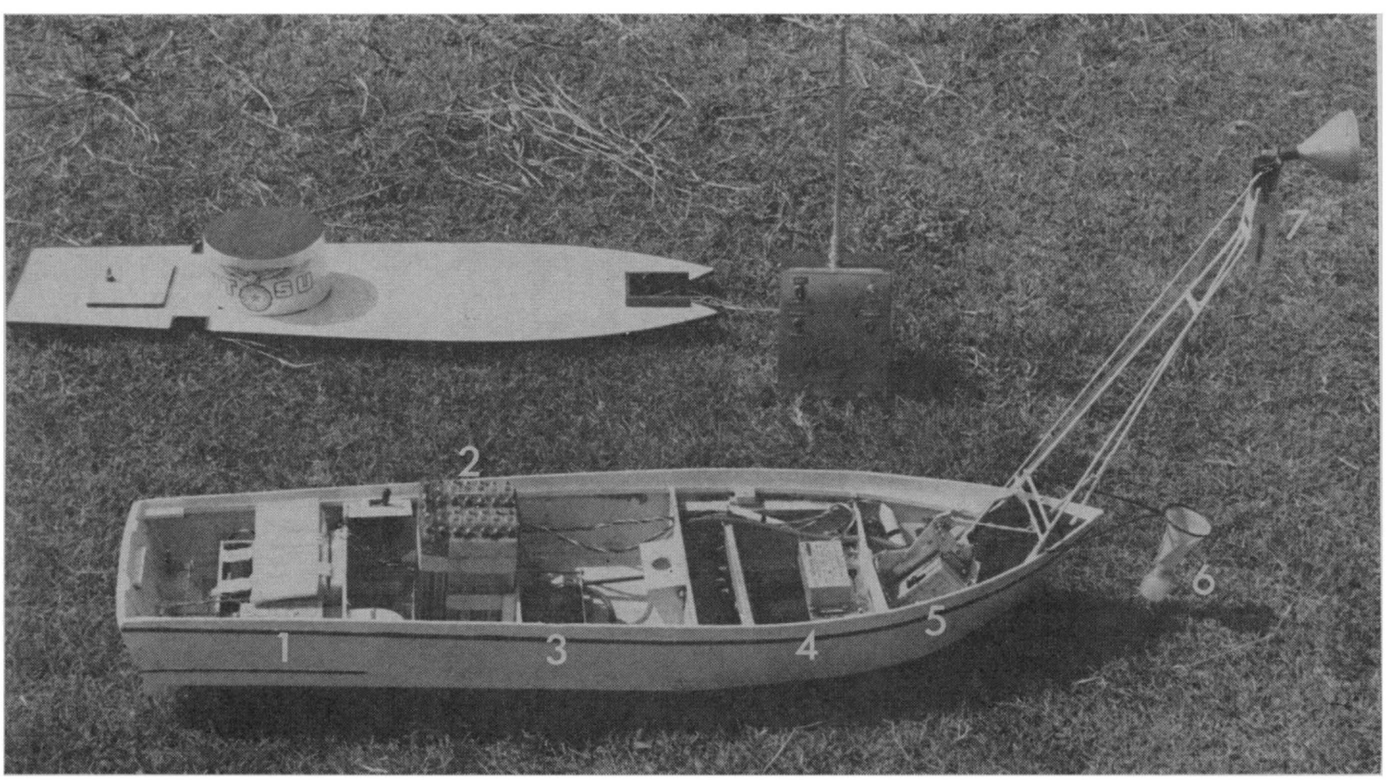

Fig. 1. The model boat; behind are the removable deck and the transmitter. Components: *1*, steering servo, radio receiver, and 6-volt battery pack; *2*, power supply, 16.8 to 19.6 volts; *3*, air pump; *4*, electric motors and forward-reverse servo; *5*, servo controlling air and plankton samplers; *6*, plankton sampler; *7*, air sampler.

when the air sampler is turned on. Plankton samples were obtained from the surface film to a depth of about 2.5 cm.

The boat has successfully obtained neuston samples in shallow water (7.5 to 15 cm), and small-volume samples of air. Similar models could be constructed for specific sampling duties.

HAROLD E. SCHLICHTING, JR.
Department of Biology, North Texas State University, Denton
JAMES E. HUDSON, JR.
Texas Electronics Company, Dallas

References and Notes

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2. From Edmund Scientific Co., Barrington, N.J.
3. Model Engineering and Development Co., 11602 Anabel Ave., Garden Grove, Calif.
4. Supported by PHS grant AP00137 and the North Texas State University Faculty Research Fund.

20 December 1966

Intensity Fluctuations of a Relativistically Expanding Source

Abstract. *It is shown that the relation between the size of an object and the period of a fluctuation in its brightness must be modified if the surface whose brightness is fluctuating is expanding at a relativistic velocity, in the sense that faster fluctuations are possible for the expanding surface.*

It is well known that the size of a stellar object limits the frequency and amplitude with which the apparent brightness can vary (*1–3*). In a recent paper, Rees (*4*) has discussed the apparent diameter of a relativistically expanding source and shows that this diameter can grow with a velocity much greater than c. In Rees's model, radio variations are due principally to changes in the apparent diameter of the source, not to fluctuations in the surface brightness. However, if t is the time since the explosion of the object, that is, the time since an extrapolation of the apparent diameter passed through zero, then the logarithmic rate of change of the apparent area with respect to time is $2/t$ regardless of whether the expansion is relativistic or not. Rees obtains rapid variations, therefore, by assuming his source to be very young (about 3 years old, in his example). It is shown below that a relativistically expanding surface whose brightness is a function of time is not constrained by Terrell's conclusion that of a fluctuation of period T in an object with constant radius R only a fraction $cT/\pi R$ is observable. Rapid fluctuations in the brightness of a relativistically expanding object are therefore possible for two reasons: that the object is young or has a young component, as proposed by Rees, or that the surface brightness is fluctuating, as suggested here.

Consider, as does Terrell (*1*), an object whose surface brightness is fluctuating. The fluctuations will be damped because of the retardation of the signal from the limb of the object with respect to the signal from the center of the disc. For a relativistically expanding object, however, the relation between the diameter of the object and the retardation to the limb is modified, and more rapid fluctuations are possible. The first thing to be done is to define what is meant by the diameter. One might take the retarded diameter, as suggested by Terrell (*2*), the size of the observable disc, assumed resolvable, as proposed by Rees, or a diameter computed from the light output and a surface brightness in the rest frame of the apparent surface. Since the retarded diameter is not observable, it will not be considered. The disc size is easiest to use, and is, therefore, discussed first.

Since detailed calculation will be required for each particular model, only a very schematic model is discussed below. Consider first a non-expanding star, and imagine that it is dark, but that it emits a short pulse of light. An observer will see the emitted light spread over a time R/c, so that the time over which the pulse is spread, divided by the diameter, is

$$\Delta t/D = 1/2c \quad \text{(stationary)}$$

Now consider a relativistically expanding spherical surface whose radial velocity is βc which also emits a pulse of light at a time when the radius of the star in its own rest frame is R. If ρ is the distance from the observer to the center of the star, the observer will first see the light at a time $(\rho - R)/c$ after it is emitted. The apparent limb of the star is only a distance $(1 - \beta)R$ further from the observer than the center of the disc, and so the light pulse will cease a time $(1 - \beta)R/c$ after it begins. On the other hand, the apparent diameter of the disc, if it can be resolved, is $2R/\gamma$, where, $\gamma = (1 - \beta^2)^{-\frac{1}{2}}$, so that

$$\Delta t/D = \gamma(1 - \beta)/2c$$
(expanding, resolved)

It is evident that for a relativistically expanding surface the pulse is spread over a much shorter time than for a stationary one.

Terrell's considerations have attracted so much attention, however, not because they may give rise to a contradiction between the fluctuation rate and size of the resolved disc of a quasar, but rather because they may give rise to a contradiction between the fluctuation rate and the luminosity of the object. The surface brightness is fixed by other considerations and the diameter calculated from the luminosity and this brightness exceeds the upper bound calculated from the fluctuation rate. Since the number of photons leaving the star is proportional to $4\pi R^2$ and, neglecting intergalactic absorption, all the photons leaving the star will appear at some possible observation site, the diameter computed by an observer from the number of photons he sees and an emittance he has computed will be $2R$, greater by a factor γ than the diameter he would see if he could resolve it. The time delay is unaltered, so that now

$$\Delta t/D = (1 - \beta)/2c$$
(expanding, calculated),

an even smaller result.

The Doppler shift of the emitted light varies between γ at the apparent limb and $\gamma(1 + \beta)$ at the center of the disc. Another factor of approximately $\gamma^{-1/2}$ would, therefore, appear in $\Delta t/D$ if D were computed from the energy output rather than from the number of photons observed. Since the spread of the Doppler shift is so great, it is clear that the considerations above cannot apply to the optical line spectrum. A careful application to the radio spectrum would require an assumption about the spectral index and a detailed calculation of Doppler shifts and relativistic solid angle transformations across the disc of the object. Qualitatively, however, a velocity within one part in 1000 of the velocity of light would be required to eliminate the discrepancy of a factor of 1000 (*3*) between the diameter of CTA 102 deduced from the radio luminosity and that deduced from the