# Visual observation of lightning propagation

SIR—Reliable scientific observers[1-3] have reported discerning direction of movement and propagation in long-duration horizontal lightning flashes. With measured velocities between $5.6 \times 10^3$ and $1.1 \times 10^4$ m s$^{-1}$ for horizontal flashes[4], lightning approaches the upper threshold for detection of movement by the human eye.

During a nocturnal thunderstorm over Ann Arbor on 9 June 1985, we were able to observe and photograph cloud-to-air lightning that appeared to propagate so slowly that we were able visually to observe apparent movement. The photograph of one of these lightning flashes reproduced here neither supports nor contradicts the visual observation of propagation, since it represents a time exposure. Because this photograph shows only a large, widely branched lightning flash, we were prompted to review both the physics of the flash and the limitations of the human visual system to better understand what we perceived.

Even a long-duration lightning flash ($\geqslant$ 0.4 s) is too brief to allow interpretation of the observation, since the duration of a perceptual experience is around 0.4 s for the dark-adapted visual system[5], even following the briefest stimuli. The time frame is also too fast to allow the eye to track the flash; so what we must have observed was the temporal ordering of the flash.

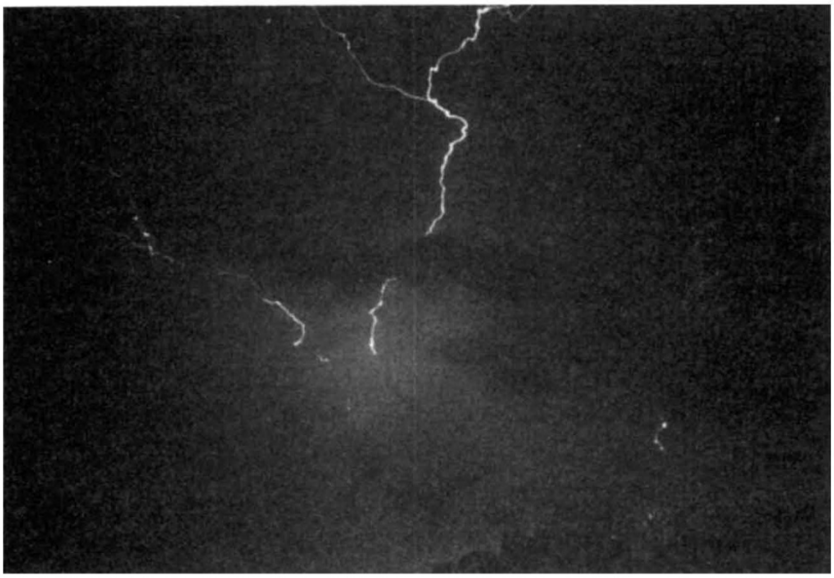
A lightning flash usually consists of successive discharges (strokes) along the same channel, and channel sections have been observed to propagate with a mean pause time of 0.06 s, with about four pause times per horizontal channel[4]. The fovea of the eye is able to determine temporal order perfectly with a pause of 0.3s between the onset of two targets[6]. Thus the time frame of propagation of long-duration horizontal lightning flashes is more than adequate for the visual processing system to resolve temporal ordering. If the mean duration of such a flash is 0.43 s (ref. 4), the flicker rate of the flash would be around 17 Hz, well below the critical fusion frequency, but too fast for the individual strokes to be counted accurately[7].

The initial visual stimulus of the lightning flash shown below was probably a single channel extending downwards from the base of the clouds. The image of the initial and subsequent channels would be renewed in the observer's visual system with each stroke of the flash, enhancing the perception of movement and propagation for the observer.

DENNIS G. BAKER
*Department of Atmospheric and Oceanic Science, University of Michigan, Ann Arbor, Michigan 48109, USA*

ANITA BAKER-BLOCKER
*Advance Science Consultants, Ann Arbor, Michigan 48107, USA*

1. D'Abbadie, A. *Nature* **35**, 342 (1887).
2. Krider, E.P. *Weather* **29**, 24–27 (1984).
3. Brook, M. & Vonnegut, B. *J. geophys. Res.* **65**, 1302–1303 (1965).
4. Brantly, R.D., Tiller, J.A. & Uman, M.A. *J. geophys. Res.* **80**, 3402–6 (1975).
5. Haber, R.N. & Standing, L.G. *Can. J. Psychol.* **24**, 216–229 (1970).
6. McKee, S.P. & Taylor, D.G. *J. opt. Soc. Am.* **A(1)** 620–627 (1984).
7. Ganz, L. *Handbook of Sensory Perception* Vol. 5 (Academic, New York, 1975).



Cloud-to-air discharge emanating from cloud base of about 2 km at 4:30 a.m. EDT on 9 June 1985 at Ann Arbor, Michigan, USA, photographed with a Chinon camera with a 58-mm lens at *f*/1.8, with the shutter held open until after the flash ended, using Kodachrome ASA 25 35-mm slide film.

# Controversial glycosaminoglycan conformations

SIR—The issue of the ring conformation of the α-L-idopyranuronate residue in dermatan sulphate, heparan sulphate and heparin — three important biological classes of glycosaminoglycans — was recently debated by Rees *et al.*[1]. At least for dermatan sulphate, the authors explained how a postulated conformational equilibrium of the iduronate residue between a prevalent $^1C_4$ and a minor $^4C_1$ chair form was compatible with experimental observations, including extreme susceptibility of dermatan sulphate to periodate oxidat-

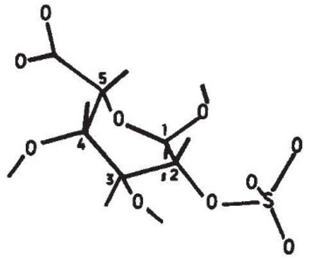


**Fig. 1.** The $^2S_0$ skew-boat conformation for the 2-*O*-sulpho α-L-iduronate residue.

ion. It was stated that "also possible are various distorted chairs and skew boats but these are not discussed here since their consideration would constitute a second order of analysis". This last statement prompts us to air our own views on this controversy

In a recent work[2], a detailed force-field study of the conformational characteristics of methyl 4-*O*-methyl-2-*O*-sulpho-α-L-idopyranosiduronate demonstrated that the ring may indeed adopt three nearly isoenergetic conformations $^1C_4$, $^4C_1$ and the skew boat $^2S_0$. The vicinal coupling constants $^3J_{HH}$ observed for heparin[3] and various heparin oligosaccharides containing ($I_{2S}$), the 2-sulphate iduronate residue[4], were subsequently interpreted[5] in terms of conformeric coupling constants computed by using the Karplus-like equation proposed by Altona and colleagues[6] and the molecular geometry obtained from force-field calculations[2]. For heparin and synthetic oligosaccharide sequences contained in heparin, the $I_{2S}$ residue shows considerable populations of only two conformations, $^1C_4$ and $^2S_0$, the percentage of the skew boat $^2S_0$ found (40 to 64%) being a function of the sequence. A similar analysis has been achieved for the non-sulphated α-L-iduronate residue in dermatan sulphate (D.R.F., A.P. and M.R., unpublished data). The vicinal coupling constants of the iduronate ring observed in dermatan sulphate[7] were computed by means of Altona's relationship[6] relating the $^3J_{HH}$ to the dihedral angles H-C-C-H, which were obtained from force-field calculations on methyl α-L-idopyranosiduronate. The iduronate residue in dermatan sulphate