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A r e   W e b e r ' s   P u l s e s   I l l e g a l   ?

by

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Summary

Implications of Weber's experiment are reconsidered. The way is sketched, along which one arrives at an unprejudiced estimate of the mass loss at the galactic center, if the radiation mechanism is roughly isotropic. Instead of the usually quoted thousand or less solar masses per year, several million solar masses are found. Since Weber's results pose severe limitations to all source models which favour the galactic plane, ways out seem nearly impossible to open.

Are Weber's Pulses Illegal ?

More than a decade ago, Joe Weber set out for the detection of gravitational waves[1]. His spade work has directed attention to a new window, through which we can look to the sky, even through the ground, to our antipodes' sky. No doubt, very soon, in the alternate play of incitation and satisfaction of human curiosity, this window will be flung wide open. Sophisticated contraptions in outer space or at extremely low temperatures will spread out their tentacles to receive the news about collapses or collisions of superdense objects. We will win more insight into gravitation, the weakest interaction, which nevertheless may be able to beat all the others by building global traps, swallowing worlds of complexity, reducing them to barren mass, spin and charge, and radiating away all other information as a ripple on space-time, thus confronting us to the "relativity of existence".

Even if such events are too rare in our own milky way, gravo-astronomers will before long increase sensitivity until the detection rate for signals from neighbouring galaxies surpasses the minimum publication rate at which a physicist can survive. And they will also succeed in detecting the wake of less catastrophic motions, if they tune sharply enough to the periodicity, e.g. of the gyration in some double stars or of the rotation of young pulsars.

However, much closer than those hazy castles in the air, we have Weber's pulses.
What's their shortcoming?
Well, one is the usual defect of pioneer work: one doubts

as long as the experiment has not been confirmed by independent work. This defect may vanish very soon.

The other defect is more dangerous: in all probability the pulses cannot be what physicists call gravitational radiation.

It has been stated frequently, that the pulse rate is too high to be made plausible by any model fitting present theories about gravitation, the structure of our galaxy and the universe. But most published statements of this kind (cf. the review ref. 2) still severely underestimated the difficulties, repeating numbers which may have been dictated by wishful thinking.

To prove this allegation, one has to analyze Weber's procedure of evaluation.[3,4] Let us very shortly follow the line of thought.

The telescope consists of two cylindric aluminium bars, spaced at a distance of about 1000 km. As solid bodies they extract energy from a gravitational wave; as high quality resonators they store it for a long time, ringing like a church-bell. The frequency of their fundamental mode of vibration is 1660 cycles per second. For both cylinders the amplitude of this mode was registered. Because of the delicate mechanical support and isolation, as well as the electronic skill, the electric signals observed represented mainly the thermal noise of the bars. In Weber's procedure, if the amplitudes of both bars increased and crossed a chosen threshold level within a chosen fraction of a second, the event was marked automatically. The rate of accidental coincidences of this kind was determined experimentally by introducing a time shift between the signals from the two devices. It turned out that without this shift the rate was significantly higher. Hence, a common external cause had to be responsible for the majority of the coincidences, that is for about 500 events per year. It is not allowed to hope that only a small fraction of those might be real. Then, there would be no significant result at all!

What was the approximate size of the change in amplitude, or the corresponding average energy absorbed in the bars? A natural unit for this energy is $E_o = kT$, the mean thermal noise energy. Weber proposed that the energy absorbed in his events was about $\frac{1}{20}$ of E_o.

However, if a small fraction of E_o makes the amplitude cross the chosen threshold in the upward direction, the amplitude must have been close to the threshold, on the low side, before the event. Moreover, the amplitude can be lowered as well as increased, depending on the phase relation between noise and signal. Since both bars have to be in the favourable state of both amplitude and phase, the detection probability drops sharply with the incoming energy.

Noise theoretical calculation[5] and numerical simulation on a computer[6] showed that only during about $\frac{1}{12}$ of the time both cylinders could have been ready to register in coincidence an event corresponding to E_o, whereas for $\frac{1}{4}E_o$ the fraction of time already drops to about $\frac{1}{100}$ and for $\frac{1}{16}E_o$ to about $\frac{1}{600}$.

These numbers do not at all depend on an interpretation of the coincidences as gravitational radiation. They show that the assumption of low signal strength does not help reduce the total energy needed. On the other hand, to assume more than E_o would help only very little, and it seemed to be forbidden by the coincidence rate with three cylinders.

The inevitable conclusion is: the rate of incoming events must have been about 12 x 500 = 6000 per year, for signals of the order of the thermal noise, and much higher for smaller signals.

Now, in order to add another factor to this number, let us assume that we deal with gravitational radiation.
For transversal tensor waves, theory predicts a characteristic dependence of the antenna's sensitivity on direction and polarization of incoming waves. Weber reported, that his coincidence rate depends on sidereal time exactly in the way predicted for sources in the direction of the galactic center with mixed polarization. In fact, the whole significance for an astrophysical source rests upon this observation. (At the same time, however, it poses most severe restrictions upon source models, as we will see.)
In order to account for pulses unobserved due to the bar's position relative to the event's direction and polarization, one has to multiply the coincidence rate roughly by a factor of 6.
Hence, the rate must have been about 36 000 per year!

Observers orbiting on a distant sphere around the source can determine the central mass through the balance of gravity and centrifugal force (as we measure the mass of our sun). The mass loss from a source is given by an integral over the sphere and over the duration of radiative activity. (See the text books, e.g. ref. 7,8). The flux through the sphere can be measured e.g. with Weber's antennas. Their change in amplitude and phase determines the spectral density, (i.e. the energy per frequency interval) of a pulse at the resonance frequency $\omega_0 = 10^4$ rad/sec.

The response of a cylinder to a favourably directed and polarized wave can be calculated using the formula for two point masses, since the corrections for excitation in the radial direction and for the continuous mass distribution nearly cancel.[9] If $\Delta\ell/\ell$ is the relative amplitude of the cylinder, procuded by a short wave train in the absence of thermal noise, the spectral density is found to be

$$Z(\omega_0) \approx \frac{c^3}{4\pi^2 G} \left(\frac{\Delta\ell}{\ell}\right)^2 = 10^{37} \left(\frac{\Delta\ell}{\ell}\right)^2 \left[\mathrm{erg}/\mathrm{cm}^2\ \mathrm{rad\,sec}^{-1}\right]$$

At room temperature the r.m.s. value of $\frac{\Delta\ell}{\ell}$ is $4\cdot10^{-16}$. Thus, a typical pulse must have had

$$Z(\omega_0) \approx 2\cdot10^6\ \mathrm{erg/cm^2\ rad\ sec^{-1}}.$$

The bandwidth $\Delta\omega$ of the signals is only known to be larger than $\frac{\omega_0}{20}$.[10] Short pulses from catastrophic events would have a wide spectrum below some cut off frequency.[11,12] Anyway, without further knowledge, one has to assume the "a priori" value $\Delta\omega \approx \omega_o$, for a guess of the total energy flux in a pulse (or in corresponding unobserved ones). The result is

$$2\cdot 10^{10}\ \text{erg/cm}^2 \quad \text{per pulse.}$$

Over the surface of $8\cdot 10^{45}$ cm^2 an isotropic radiator would have lost $1.6\cdot 10^{56}$ erg, or the mass of 80 suns. Since radiation efficiency must be less than $\frac{1}{2}$ [13], more than 200 solar masses would be involved. Light crosses the Schwarzschild radius of this mass in 2 milliseconds. Hence, Weber's frequency would ly already beyond the spectral cut-off. A slight spectral concentration around ω_o and moderately anisotropic emission could help avoid this inconsistency. Nevertheless, the unprejudiced estimate of mass loss from the galactic centre would be about

3 million suns per year.

(Gravo-astronomy would be two billion times more important than all other galactic astronomy. Is this a title to funds?)

Now we have to try and get rid of what we accomplished.
300 words are left.
Observation of stellar orbits excludes a continuous mass loss of more than a few hundred solar masses per year[14]. It is unsatisfying to appeal to accidents ("in space, in spectrum or in time").

The author pointed out [15, 16, 17] that multicomponent quasar models might lead to collision-dominated dense clusters of black holes after a long period of apparent death. Such quasar remnants ("gravars") could radiate strong pulses at extreme rate, but it seems difficult to prevent the redistribution in the galaxy of the majority of the original members. Only a small fraction can reach the "gravar"-stage, and even those contribute a good part of their mass to a final big black hole, instead of radiating it away. Even the remnants of most massive quasars would not be able to radiate longer than a few centuries at the demanded rate.

The only way out would be a source which exclusively favours the galactic plane. In fact a central rotating disk or black hole might afford that. The bending of rays by a disk does not seem promising.[18] However, a past quasar stage in our galactic nucleus would probably have left a huge rotating black hole, say of 10^7 solar masses.[19,20] Many groups of relativists are working hard to get the needed kind of radiation out of it.[21,22,23,24] Most embarrassing, Weber found mixed polarization with high significance - a preferment of the plane cannot extend to polarization.[25] For radiation from orbiting bodies, relativistic forward bundling and a spectral shift to high harmonics of the fundamental frequency are intimately connected with linear polarization.

The first is needed to reduce energy requirements, the second is needed to beat the long timescale of a huge black hole, the third is forbidden.

If Kerr's geometry is tricky enough to allow this combination, there remains still the question how to feed the gullet in a natural, non accidental way, tens of thousands times per year.

It may turn out that Weber's pulses are illegal according to the laws of nature. To the known laws, of course.

List of References

1) Weber, J., 1960, Phys. Rev., 117, 306

2) Press, W.H. and Thorne, K.S., 1972, to be published. Caltech preprint OAP-273

3) Weber, J., 1970, Phys. Rev. Letters 25, 180

4) Weber, J., 1970, Plenarvorträge der Physikertagung Hannover. Shortened version in Phys. Rev. Letters 24, 276

5) Kafka, P. and Meyer, F. 1971, unpublished.

6) Kafka, P. and Winkler, W., 1971, unpublished.

7) Landau, L. and Lifshitz, E.M.: "The Classical Theory of Fields".

8) Misner, C.W., Thorne, K.S., and Wheeler, J.A.: "Gravitation". (San Francisco: W.H. Freeman Publishers, 1972, to appear)

9) Kafka, P. and Meyer, F., 1971, Mitteilungen der Astronom. Ges. 31, 129

10 Weber, J., 1971, paper presented to "GR6"-conference at Copenhagen.

11) Kafka, P., 1970, Physik in unserer Zeit 1, 186

12) Gibbons, G.W., and Hawking, S.W., 1971, Phys. Rev. D4, 2191.

13) Hawking, S.W., 1971, Phys. Rev. Letters 26, 1344.

14) Sciama, D.W., 1969, Nature 224, 1263

15) Kafka, P., 1969, Mitteilungen der Astron. Ges. 27, 134

16) Kafka, P., 1970, Nature 226, 436

17) Kafka, P., 1971, in: External Galaxies and Quasistellar Objects (D.S. Evans ed.), 296 (IAU-Symposium No 44, Uppsala 1970)

18) Lawrence, J.K., 1972, Ap.J. 171, 483

19) Lynden-Bell, D., 1969, Nature 223, 690

20) Bardeen, J.M., 1970, Nature 226, 64

21) Misner, C.W., 1972, Phys. Rev. Letters 28, 994

22) Misner, C.W., Breuer, R.A., Brill, D.R., Chrzanowski, P.L., Hughes III, H.G., and Pereira, C.M., 1972, Phys. Rev. Letters 28, 998

23) Teukolsky, S.A., 1972, to be published. Caltech-preprint OAP-269

24) Press, W.H., 1971, Ap.J. 170, L105

25) Tyson, J.A., and Douglass,D.H., 1972, Phys. Rev. Letters 28, 991

Biographical Sketch.

Peter Kafka was born in 1933 in Berlin, Germany. He grew up in Germany and Czechoslovakia, studied Physics in Erlangen and Berlin from 1952 to 1957, lived as a casual laborer from 1957 to 1962 and obtained a diplom-degree in physics at the University of Munich in 1965. After a short assistantship in this university he joined the Max-Planck-Institut for Physics and Astrophysics in Munich, where he worked since 1965 in cosmology and other problems of relativistic astrophysics. Several times he visited the United States and other countries on occasion of summer schools or conferences.

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If Kerr's geometry is tricky enough to allow this combination, there remains still the question how to feed the gullet in a natural, non-accidental way, four times every hour.

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List of References

1) Weber, J., 1960, Phys. Rev., 117, 306

2) Press, W.H. and Thorne, K.S., 1972, to be published. Caltech preprint OAP-273

3) Weber, J., 1970, Phys. Rev. Letters 25, 180

4) Weber, J., 1970, Plenarvorträge der Physikertagung Hannover. Shortened version in Phys. Rev. Letters 24, 276

5) Braginskii, W. B., 197o, "Fizicheskie Eksperimenty s Probnymi Telami", Moskwa 197o.
Kafka, P. and Meyer, F., 1971, unpublished.

6) Kafka, P. and Winkler, W., 1971, unpublished.

7) Landau, L. and Lifshitz, E.M.: "The Classical Theory of Fields".

8) Misner, C.W., Thorne, K.S., and Wheeler, J.A.: "Gravitation". (San Francisco: W.H. Freeman Publishers, 1972, to appear)

9) Kafka, P. and Meyer, F., 1971, Mitteilungen der Astronom. Ges. 31, 129

10 Weber, J., 1971, paper presented to "GR6"-conference at Copenhagen.

11) Kafka, P., 1970, Physik in unserer Zeit 1, 186

12) Gibbons, G.W., and Hawking, S.W., 1971, Phys. Rev. D4, 2191.

13) Hawking, S.W., 1971, Phys. Rev. Letters 26, 1344.

14) Sciama, D.W., 1969, Nature 224, 1263

15) Kafka, P., 1969, Mitteilungen der Astron. Ges. 27, 134

16) Kafka, P., 1970, Nature 226, 436

17) Kafka, P., 1971, in: External Galaxies and Quasistellar Objects (D.S. Evans ed.), 296 (IAU-Symposium No 44, Uppsala 1970)