The Planets of BH1

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ABSTRACT

A star – about the size of the Sun – orbits the nearby black hole BH1. The duo emits a gravitational wave that affects Earth's atmospheric pressure. With this receiving antenna and an extremely narrow-band receiver, we measure and evaluate the signal of the binary system. It is phase modulated with seven different frequencies that obey a simple formation law. The parameters of the PM allow the orbital periods, masses and positions of the planets to be estimated. The unexpectedly high values of the modulation index suggest that gravitational waves propagate slower than the speed of light.

Key words: Gravitational waves, BH1, Black Hole, Extrasolar Planets

1 INTRODUCTION

Binary stars radiate power in the form of a gravitational wave (GW) that slightly deforms all surrounding masses. As a result, the GW changes not only the length of rigid rulers, but also the atmospheric pressure at the earth's surface. The pressure hardly reacts to earthquakes and can be measured continuously with simple means. In order to reduce the influence of local peculiarities and data gaps from individual weather stations, the measured values of about fifty barometers distributed throughout Germany are added (DWD). Because the wavelength of the searched GW is at least a factor of 10^6 higher than the mutual distances between the barometers, all instruments react *in phase* to the GW. This coherent addition significantly improves the S/N of the signals sought and shows spectral lines that would disappear in the noise when analyzing a single data chain. Nearby celestial bodies stimulate the earth and atmosphere to vibrate, the frequencies of which can be found in the tidal potential catalog HW95. Every suspected GW line must be checked to ensure that it is not generated here in the solar system.

The correct evaluation of the modulation of the GW facilitates the reception of weak signals or makes it possible in the first place. Examples from radio technology (GPS) show that the low and noisy signal amplitude of "impossible" antennas can be compensated by a highly developed receiver technology if one knows the modulation of the signal.

Each GW is phase modulated (PM) with at least one frequency because the antenna orbits the sun. The detection of a PM with f_{orbit} = 31.7 nHz is a necessary confirmation that the GW is *not* generated in the solar system. Presumably, most GW sources are orbited by multiple planets and each of them causes a PM with the corresponding sidebands. An example shows how confusing the resulting spectrum of the GW may become.

Figure 1 shows how the spectrum of a single binary system widens with each additional planet. As the power of the GW is distributed over more and more spectral lines, the S/N decreases and the overall signal looks like noise. Since our galaxy contains at least 10^6 binary systems (each with ten planets?) that emit GW in the frequency range 1 nHz to 500 μHz, it is hardly possible to separate the broad spectra from each other. It is pointless trying to identify the at least 100 individual lines in figure 1 at the bottom right. How could one prove that these many lines are sidebands of a single GW with defined phase relationships and not noise?

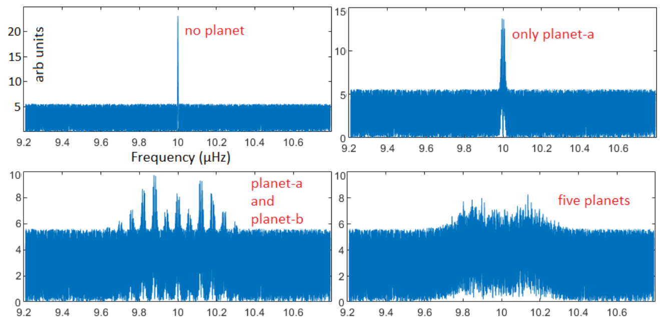

Figure 1. Effect of phase modulation on the bandwidth of the GW signal. Each planet causes a set of specific sideband frequencies. The planet with the highest orbital frequency determines the Carson bandwidth to be processed. Based on previous measurements, in this example the following parameters are preset: f_{GW} = 10 μHz, S/N = 20. Planet-a with f_a = 4 nHz, Planet-b with f_b = 60 nHz, Planet-c with f_c = 40 nHz, Planet-d with f_d = 13 nHz and Planet-e with f_e = 1.3 nHz. The modulation index is $a \approx 2.5$. Unrealistic assumptions of this model: The earth is not moving and the broad frequency range 9 μHz < f_{GW} < 11 μHz contains a single binary system.

Technically formulated: The GW of a binary star system with several planets is a *spread spectrum* signal with unknown modulation frequencies and very low S/N, which is disturbed by other comparable signals of a similar structure. The aim of this investigation is to find the modulation frequencies, to reverse the multiple PM and to regenerate the central spectral line in figure 1 at the top left. From observations with electromagnetic waves we know estimates of the orbital period 185 days Chakrabarti (2023) El-Badry (2023)

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of the binary star system. Near $2f_{orbit}$ we find a strong maximum $f_{GW} = 125.57$ nHz. The sun produces a weak interference frequency at 126.75 nHz (HW95), well outside the processed bandwidth of this GW. In the vicinity of f_{GW} there are several lines with significantly lower amplitudes, caused by planets of the sun.

2 THE PHASE MODULATIONS OF THE GW

The daily rotation of the barometers around the earth axis cannot be measured because the resulting Doppler shift (peak frequency deviation) of approximately 10^{-11} Hz is smaller than the achievable half-width of the spectral lines. The opposite is true for the periods of the Earth around the Sun and the presumed planets around BH1 ($P \approx 1$ year). The periodic Doppler shift should be smaller than

$$\Delta f_{orbit} = f_{GW}\left(\sqrt{\frac{v_{GW}+v_{orbit}}{v_{GW}-v_{orbit}}} - 1\right) \approx 12 \text{ pHz} \quad (1)$$

–v_{GW} is the propagation velocity of the GW, presumably c
–$v_{orbit} \approx 27.2$ km s^{-1}

This frequency resolution requires a sufficiently long observation period T_{min}, which according to Küpfmüller (1924) is calculated as follows:

$$T_{min} \cdot \Delta f \geq 0.5. \quad (2)$$

In order to distinguish individual planetary orbits, a 20-year database of air pressure data provided by DWD is sufficient. This means that the “natural” line width of all spectral lines is approximately 0.8 nHz.

The problem is the much broader spectrum of the phase-modulated signal (figure 1). If you look for planets with orbital period $P > 400$ days, you have to process the signal with the Carson bandwidth $2(a+1)f_{orbit} \approx 200$ nHz (all previous evaluations of planets orbiting other double stars show $a \approx 2.5$). Signal processing with too little bandwidth distorts the PM and prevents decoding of the inner, fast planets. On the other hand, this huge bandwidth allows a noise amplitude to pass through that is a factor of $\sqrt{200/0.8} \approx 16$ higher than with signal processing with the small "natural" line width. This prevents the detection and decoding of weak signals.

3 THE MSH METHOD

A possible solution is the *Modified SuperHeterodyne* (MSH) method. In a usual superheterodyne, the frequency of the auxiliary oscillator is constant in order to transfer the modulation of the signal unchanged to the intermediate frequency. With the MSH method, the frequency of the auxiliary oscillator is modulated so that the intermediate frequency is *constant*. This is easy to monitor and allows a very low bandwidth because no sidebands are transmitted anymore. Probably the biggest advantage of the MSH method is: In the original state, many individual lines, each with a low amplitude, carry the total power of the GW. After the decoding is complete, the total power is concentrated in a narrow region around the central spectral line at f_{GW}. This reconstruction of the monochromatic line from many phase-related spectral lines (de-spreading) improves the S/N and enables the measurement of signals below the noise level. MSH is a coherent detector. To my knowledge, no comparable method has ever been used to remove PM from a signal.

Three influences change the frequency of the auxiliary oscillator:
– the time-proportional frequency drift of the GW source
– the phase modulation caused by the Earth’s orbit
– the PM caused by the planets of the GW source

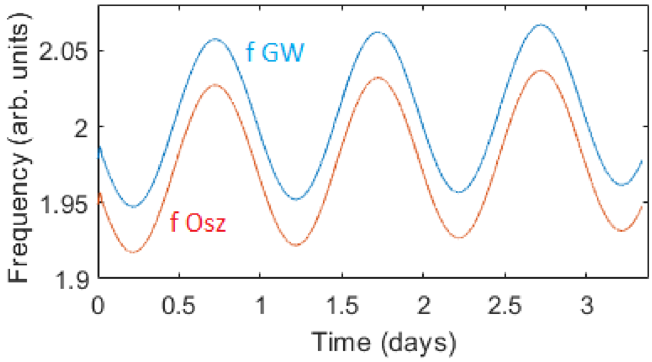

Figure 2. The idea behind the MSH method: A planet ensures that the frequency of the GW oscillates around an average value that slowly increases. If one succeeds to generate an auxiliary frequency f_{Osz} with identical modulation, the difference $f_{GW} - f_{Osz}$ (= vertical distance between the two curves) is constant.

Table 1. The orbital periods P, the orbital frequencies, the modulation indices a, the phases (positions) and the estimated masses of the seven planets of *BH1* and the Earth. The planetary masses are calculated in section 5. Presumed orbital resonance $P_G : P_H \approx 2:3$

Planet	P (years)	f (nHz)	a	ϕ	$m_{planet}/m_{Jupiter}$
B	1.85	17.12	0.534	0.482	0.7074
C	2.52	12.57	0.678	4.24	0.7347
D	4.09	7.76	0.722	2.08	0.5798
E	6.70	4.73	1.574	0.557	0.8957
F	10.76	2.94	2.055	4.30	0.8616
G	30.7	1.03	4.195	0.931	0.8865
H	45.2	0.70	0.058	3.09	0.0099
Earth	1	31.688	3.09	0.27	0.0031

The phase of the auxiliary oscillator is varied using the following function:

$$\phi_{osz} = a_{planet} \cdot sin(2\pi t f_{planet} + \phi_{planet}) \quad (3)$$

– a_{planet} is the modulation index of the PM caused by the planet in a circular orbit around the GW source.
– f_{planet} is the orbital frequency of the suspected planet.
– The phase ϕ_{planet} tells us when the planet is in front of or behind the GW source from our point of view.

It is common practice to convert the signals provided by the antenna as if the antenna were located at the barycenter of the solar system. This is not done for two reasons: There is no additional effort to treat all PMs equally. And to simulate a different reception location of the signal, you need to know exactly how quickly GW spreads. So far there are only speculations. In the sections 4 and 5 we discuss in detail whether the previous assumption is correct.

With a step by step procedure you can find all planets: The frequency of an auxiliary oscillator f_{Osz} is phase modulated with an arbitrary frequency (presumed orbit frequency of a planet). Frequency, amplitude and phase are iterated until the difference frequency $f_{GW} - f_{Osz}$ is constant (Figure 2). Then a planet is discovered and its properties may be calculated from the determined parameters. Repeating this search with different initial values creates a list of all the planets in the binary system (table 1).

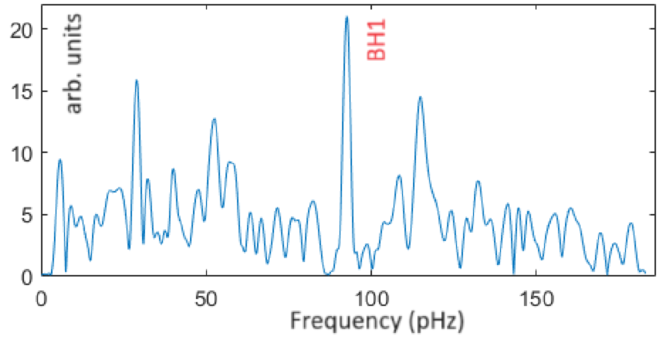

Figure 3. Spectrum of the GW after shifting the frequency to $f_{ZF} = 1/(3000$ hours) and compensating for all PM caused by the planets. This removes the sidebands near the central spectral line 'BH1'. The environment is filled with distorted spectra of other GW (compare with figure 1).

On 2000-01-01, the frequency of the GW was 125.56(9) nHz. Since the GW source *A1–A2* radiates energy, the orbital period $P = 184.34(6)$ days should decrease over the years. Contrary to all expectations, the central pair *A1–A2* orbits each other more and more slowly. The drift of the radiated GW is $\dot{f}_{GW} = (-341 \pm 2) \times 10^{-20}$ Hz/s and was never measured with electromagnetic waves.

4 THE EARTH ORBIT CAUSES A PM

As expected, f_{GW} is also phase modulated with $f_{orbit} = 31.68754$ nHz. From the phase angle $\phi_{orbit} = 0.2696$ it follows that here on Earth, we receive maximum blueshift on every $365 \cdot \phi_{orbit}/2\pi =$ 16th day of the year. According to NRAO, this should take place on the 71th day of the year (error $\approx 15\%$).

The most important key figure of a PM is the modulation index with the definition $a_{orbit} = \Delta f_{orbit}/f_{orbit}$. Here, Δf_{orbit} is the maximum value of the Doppler shift of f_{GW}, which is generated by the movement of the transmitter and/or receiver.

If GW propagated at the speed of light, the modulation index would always be less than 0.00036 using the result of equation 1. Table 1 shows measurement result that is approximately 6000 times higher. There are only two possible explanations for this: The equation 1 does not apply to GW or $v_{GW} < c$.

From the modulation index $a_{orbit} = 3.0892 = \Delta f_{orbit}/f_{orbit}$ follows $\Delta f_{orbit} = 98$ nHz. This frequency deviation contradicts the assumption that GWs travel at the speed of light. Due to the position of *BH1*, the Earth approaches this target with the maximum speed $v_{orbit} = 27200$ m/s. The maximum frequency deviation Δf_{orbit} should be smaller than 11.4 pHz (equation (1)). The actually measured value is about 8600 times larger! A measurement error of this magnitude can be ruled out after careful examination. What is causing the discrepancy? The equations of the PM and the Doppler effect are well founded and confirmed a million times. What remains is the correction of the assumption, that GWs propagate at the speed of light. The calculation of the instantaneous frequency uses the longitudinal Doppler effect, in which the frequency is corrected relativistically. For maximum blueshift applies

$$f_{GW} + \Delta f_{orb} = f_{GW}\sqrt{1 - \left(\frac{v_{orb}}{c}\right)^2} \cdot \frac{1}{1 - \frac{v_{orb}}{v_{GW}}} \approx \frac{f_{GW}}{1 - \frac{v_{orb}}{v_{GW}}} \quad (4)$$

Transforming the equation (4), we get

$$\frac{v_{orbit}}{v_{GW}} = 1 - \frac{f_{GW}}{f_{GW} + \Delta f_{orbit}} = 0.438. \quad (5)$$

With this intermediate result, we calculate

$$v_{GW_1} = \frac{v_{orbit}}{0.438} = 62.1 \times 10^3 \ \frac{m}{s} \approx \frac{1}{4830} c. \quad (6)$$

This result is much lower than the speed of light and is valid for $f_{GW} \approx 125$ nHz and a reveiver in the vicinity of the sun.

5 DO PLANETS ORBIT THE GW SOURCE?

So far, a companion around *BH1* was suspected, but not searched for Hayashi (2023). The fact that the GW of the double star *A1–A2* is phase modulated with several discrete frequencies may be explained most simply by assuming that the binary system is orbited by several planets. The mass of the planets may be estimated from the individual frequency deviations of the PM. Massive planets cause higher values of Δf than light planets.

Considering the GW source *A1–A2* as a star and the planet *B* as a companion, Kepler's third law provides the orbital equation for the two-body system.

$$4\pi^2 (r_A + r_B)^3 = GT^2 (m_{A1} + m_{A2} + m_B) \quad (7)$$

The radii refer to the center of gravity of the trio and the center of gravity theorem $(m_{A1} + m_{A2})r_A = m_B r_B$ applies (we ignore other planets). With the assumed masses $m_{A1} = 9.62 m_\odot$ and $m_{A2} = 0.93 m_\odot$ El-Badry (2023) and the equations (4)...(7), we get an almost linear relationship between m_B and v_{GW}. If we knew the speed v_{GW} in the immediate vicinity of the binary system *A1–A2*, we could calculate the mass of each planet. Previous investigations with known planetary masses resulted in surprisingly low values around $v_{GW_2} \approx 50$ m/s. Using this value, we obtain estimates for the masses of the seven planets (see table 1, right column). It is noticeable that the masses of the planets B...G are approximately the same. With this special feature, BH1 differs from all other planetary systems.

We do not discuss the question why v_{GW_1} (equation 6) is very different from v_{GW_2} because phase modulation analysis cannot provide an answer.

6 DERMOTT'S LAW

For a long time people have been looking for reasons for obvious relations between the orbital periods P of planets. Although there is no deeper justification for the approaches of Dermott (1968) and the Titius-Bode series, they provide good initial values when searching for possible orbital periods. That also applies to

$$P_n = P_0 \cdot e^{k \cdot n} \quad (8)$$

with $n = 1, 2, 3, 4...$ Figure 4 shows the best approximation with $P_0 = 379$ days and $k = 0.4731$.

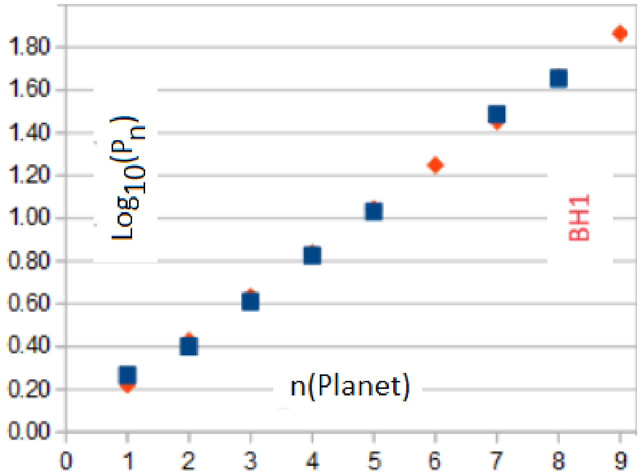

Figure 4. The logarithm of the orbital period of the planets (in years) of *BH1* as a function of their order. The actual values (blue) hardly differ from Dermott's law (red). Despite an intensive search, the PM of the "missing" planets could not be detected.

7 CONCLUSIONS

From a communications point of view, decoding the phase modulations of f_{GW} is a standard task of digital signal processing. The receiving antenna is insensitive to earthquakes and after compensating for all PM the signal can be detected with good S/N (figure 3). No assumptions are needed at any stage of decoding. We need no computationally intensive comparisons with pre-calculated patterns (search templates) based on model assumptions.

The opposite is true for the interpretation of the results from an astronomical point of view: The high values for the frequency deviation (Δf) may be explained by the assumption that gravitational waves at low frequencies around 125 nHz propagate significantly more slowly than the speed of light.

8 DATA AVAILABILITY

The data underlying this article are available from the Deutscher Wetterdienst (DWD). All MATLAB programs including explanations may be requested from the author.

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