

Very Important Letter to the Editor

Do we Grasp the Physics of Binary Stars?

Henri M.J. Boffin[1,⋆], A. Wake[2], and W.H.Y. Can't[2], I. Sleep[2]

[1] Extraterrestrial Institute for the Advancement of Earth (EIAE), Secret place, Planet Earth, Solar System
[2] The Improbable Institute, Flatland

ABSTRACT

No!

Key words. binary stars – planetary nebulae – common sense

Watch and see the courses of the stars
as if you ran with them
– Marcus Aurelius

1. A most sublime, interesting, but neglected target

The most tricky part of every scientific paper dealing with observations (or proposal for that matter) is to justify why the authors decided to observe a specific target and not another. In a very rare moment of honesty, we have decided here to not try to come up with any excuse or pseudo-explanation, and go straight to the genuine reason: images were available and they looked extremely nice!

The initial target was thus the planetary nebula Hen 2-37 (PN G274.6+03.5), whose resemblance (see Fig. 1) to the space station of *2001: A Space Odyssey* is astounding and difficult to reconcile with the expelled envelope of a spherical star. Often, however, astonishment is linked with ignorance, which is never bliss, but as DJ Format rapped, *"we know something you don't know, and if we don't share then we don't grow."* So please allow us to grow: traditionally, planetary nebulae[1] are thought to be the swan song of low- and intermediate-mass stars just before they become white dwarfs, doomed to cool for eternity (or until the Big Crunch). This wonderful (and colourful) tale of how a star transmogrify would be perfect if most planetary nebulae didn't show some intricate and multifarious departures from sphericity, featuring jets, rings and other amazing properties. Most astronomers working in this field are cognizant that all these features are the results of binary interactions: when one of the two waltzing stars gets too big, it becomes unable to keep all its material and starts a major environmental pollution, leaking material onto its companion and into the cosmic surroundings. It can then be shown that this will lead to the kind of complex structures displayed by these amazing cosmic bubbles that are planetary nebulae.

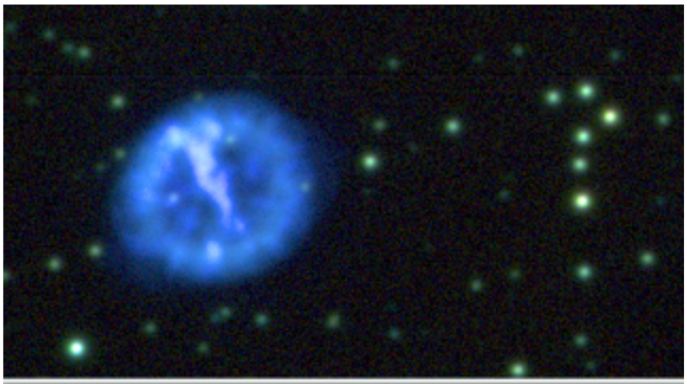

Fig. 1. False-colour composite image showing the planetary nebula Hen 2-37 (PN G274.6+03.5) and its astonishing and wondering environment.

2. Painstaking, but hopefully useful, observations

2.1. Beautiful and informative images

We obtained images in various filters of the planetary nebula Hen 2-37 that were used to analyse its shape and to characterise the hot, moribund star that lies at its centre. The colour-composite image is shown in Fig. 1, while the individual band images are

⋆ As for all his papers, this author is sole responsible for its content, which does not represent in any way or another, not even remotely, the views of his employer, real or supposed. This is an edited version of the original paper.

[1] Planetary nebulae are another example of these misnomers that abound in the scientific literature, as they have indeed nothing to do with planets, contrarily to what the discoverer of the first one thought, due to his poor equipment. However, even when this was clearly shown, astronomers, being obdurate, preferred to keep the name, to make things more confusing and thus oblige us to start every explanation of the phenomenon by stating that these object have nothing to do with planets... as we just did.

shown in Fig. 2. The images were reduced and analysed in the usual way, and we will therefore skip here a tedious description of our methodology. Using the most sophisticated techniques that we could think about, one obtains, after some pages of code written in a computer language that strangely enough is named after a snake that kills by wrapping around and asphyxiating their prey, the position and magnitude of the central star of this jaw-droppingly beautiful ionised nebula. These are indicated in Table 1 for all to admire. We also aimed at complementing our exceptional set of data with data from the WISE satellite. None did exist, unfortunately, so we had instead to resort using the ultrawise methodology (Confucius -500; Plato -375; Ehrmann 1927).

The shrewd reader would have indeed noticed that this dying star is rather faint, and will most likely not be studied in detail for a very long time (but see below), as it would require too much telescope time. However, from our most exceptional observations, and although it is not our intention to beguile the reader with wrong conclusions[2], one seems to be able to assert that the central star is much redder than it ought to be for such a hot star, even accounting for interstellar reddening. As we do not expect it to have only recently consumed all the alcohol that was present in the interstellar liquor cabinet that was the nascent cloud from which it formed, we are led to believe that this object also has a (red) companion, providing another strong corroboration of the importance of binaries in the formation and evolution of planetary nebulae.

3. When we finally reach the purpose of this paper

If the above results must have satisfied the most hard-to-please of our two readers, there is little doubt in our mind that the same readers must have noticed the very uncanny nature of Fig. 1, which even we, ever so concentrated on the above-mentioned high level tasks of attending at the dying star inside Hen 2-37, couldn't miss. Isn't there, in the most surreal way, an eroteme made of stars located next to the object of our interest? **Next to the exact planetary nebulae that astronomers have difficulties to explain, Nature has indicated in the most obvious way that there is really something to wonder about.**

We all know that the human mind has a great disposition at finding in the positions of stars some vague resemblance with a mythological creature, an animal or a device. Constellations are the best examples, but everyone will confess that it takes a vivid imagination to see in some vaguely arranged stars a bear, a Winged Horse, a unicorn, or even a telescope! But the question mark glyph that appears so vividly in our images surely doesn't belong to this category! There is no need to use a machine learning method to confirm the true nature of the interrogative asterism. What's more, and if there was still an ounce of doubt in the most skeptical of all referees, the following argument should leave everyone speechless and fully convinced: not only do the stars form the eroteme, but it is moreover perfectly aligned with the North and there is a clear star to indicate its ball[3]! The probability for this to happen by chance can be computed by any black belt in Bayesian methods and it can be shown to be extremely small.

Of course, as fervent disciples of Galileo Galilei, we couldn't limit ourselves to a simple descriptive approach, and thus didn't hesitate to use a few hundreds of hours of a supercomputer to further our understanding of the cosmic Alcuinesque stroke-over-dot sign. To achieve our quest, we made use of the Gaia DR2 catalogue and identified the stars forming the punctuation sign. Using our own images, we also derived their magnitudes in various

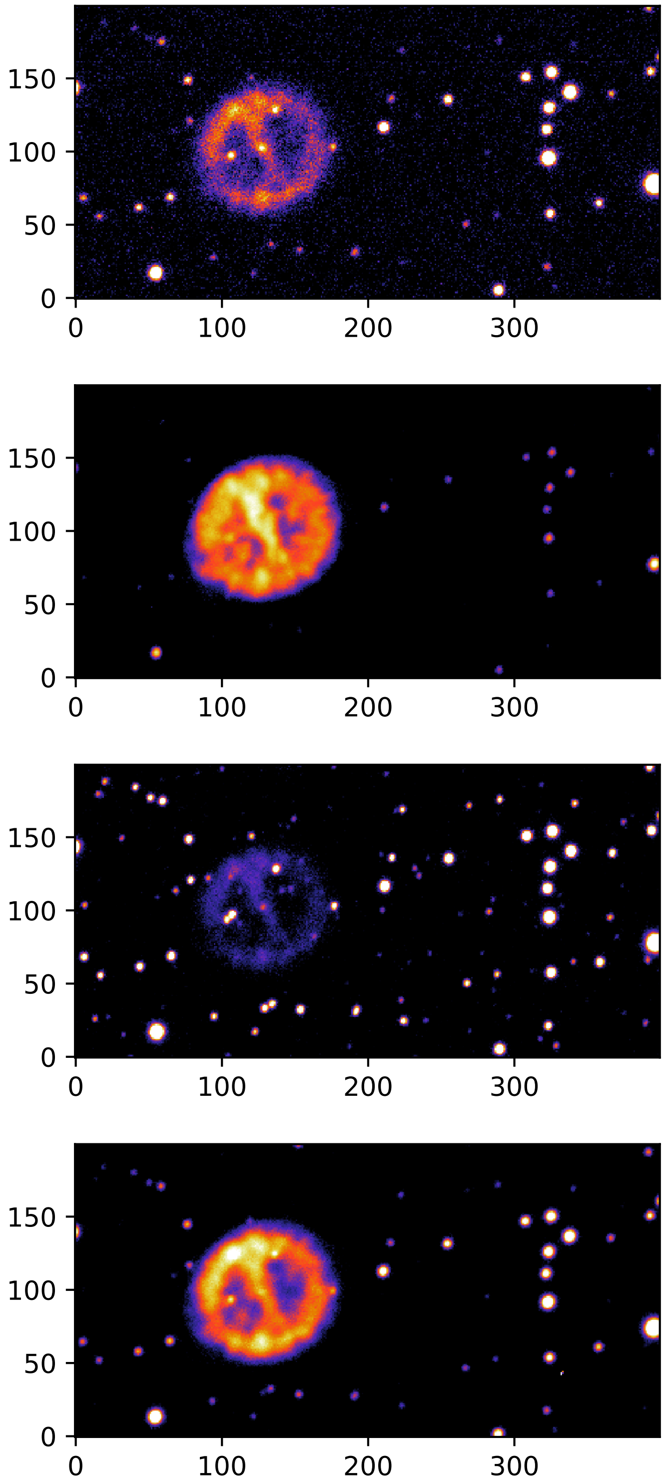

Fig. 2. False-colour images of Hen 2-37. From top to bottom, the images are in the B, V, I and H_α bands. The colours here only indicate the intensity level. It can be seen that the Universe is less doubtful in the V-band than in the other ones. We will ignore here that this is most likely because this band encompasses the [O III] line, which is the brightest line in the planetary nebula, as we are not sure to which wavelengths the Universe is most sensitive to.

[2] But note that because of the nebula contamination, these values have an error of 0.2-0.3 mag.

[3] A question mark can indeed be described by its curl, lobe and ball.

Table 1. Properties of the PN and stellar interrogation mark. We indicate when available the parallax (ϖ) and its error (σ_ϖ), and the magnitude in various Gaia or Johnson bands, the latter being measured on our images.

(Gaia EDR2) ID	R.A.	DEC.	ϖ	σ_ϖ	G	$G_{\rm Bp}$	$G_{\rm Rp}$	B	V	I
5409429876738432384	146.83240	-48.97122	0.207	0.070	16.91	17.382	16.27	18.06	17.15	16.20
5409429881044249984	146.83254	-48.96985	0.306	0.123	17.95	18.56	17.16	19.47	18.35	17.08
5409429881044251008	146.83234	-48.96882	0.076	0.131	17.47	18.12	16.64	19.11	17.86	16.54
5409429881044251136	146.83082	-48.96808	0.139	0.077	17.20	17.62	16.63	18.23	17.41	16.57
5409429881044252160	146.83217	-48.96713	0.315	0.089	17.44	18.09	16.65	19.03	17.83	16.56
5409429881044253056	146.83404	-48.96736	0.338	0.135	18.06	18.75	17.22	19.72	18.47	17.12
Hen 2-37	146.85323	-48.97073	-	-	19.89	-	-	19.6:	20.1:	19.0:

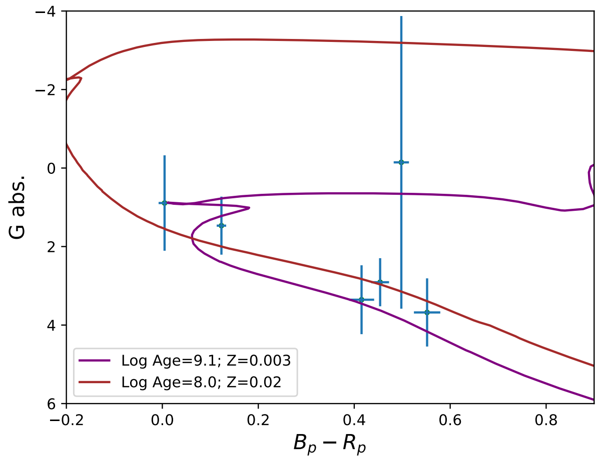

Fig. 3. The Gaia colour-magnitude diagramme of the members of the stellar question mark, showing the absolute G magnitude as a function of the colour $B_p - R_p$. Two sets of evolutionary tracks for two different ages and metallicities (see insert) are indicated.

filters. This is all indicated in the most synthetic fashion in Table 1. We note that luckily, the parallaxes provided for these objects were mostly significant and none were negative. We didn't need thus to change the sign of the parallax before inverting it to get the distances. Our query about this stellar query mark revealed outstanding results. First, it appears that within their error bars, all the stars forming the asterism are at about the same distance – the mean is 3468 ± 150 pc, which is not very far from the estimated distance to Hen 2-37, also around 3 kpc. **The conundrum's indication is thus not a mere projection on sky.** If that wasn't enough, when putting the data in a colour-magnitude diagramme (Fig. 3), there is no doubt that they belong to the same population, given that they can be characterised by one single age. The current accuracy of the data is such that we need to curb our enthusiasm, as this age could be between 100 Myr and 1.25 Gyr, depending on the stars' relative fraction of all elements except hydrogen and helium[4]. Even if this interval may appear to the faint-hearted rather wide, we are convinced that once the metallicity of the stars will be determined, it will shrink as much as the amount of our troubles when we went to group therapy.

Finally, and as a pellucid conclusion to prove that our work wasn't dilatory, we want to draw the attention of the still unconvinced reader to another remarkable fact, illustrated in Fig. 4, and making use in the most cleanest of manners of the proper motions of the stars: 999 years ago and in 999 years from now, the riddle isn't one anymore, as the arrangement of stars take

[4] What astronomers call, strangely enough, "metallicity".

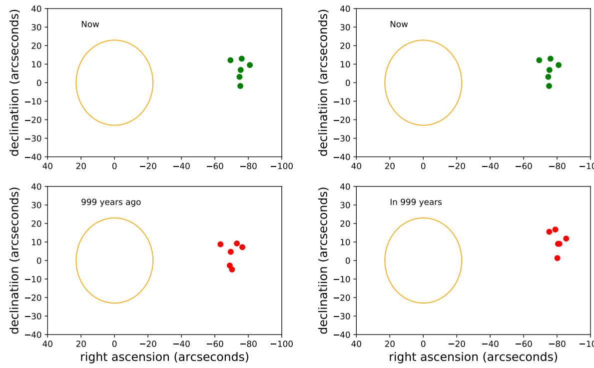

Fig. 4. The positions of the stars forming the cosmic question mark, now (top), 999 years ago (bottom left) and how it will look like in 999 years (bottom right). Clearly, the stellar message was destined to be seen at the current cosmic time.

on some relatively random form. This can be easily understood as the fact that 999 years ago, people didn't really know about planetary nebulae and there was thus no need to understand them (ignorance *is* bliss in fact!). We are therefore convinced that the right hand side part of the figure tells us that in 999 years, we will have understood all the inherent nature of the origin of these fascinating cosmic bubbles. And thus, contrarily to nowadays, we will have finally come to grasp binary stars!

Acknowledgements. This work was done outside of working hours, when the first author was bothered by his co-authors. Using all our astrophysical acumen, it couldn't have been done without an emotional equipoise, a perfect blend of tiredness and delirium. The remarkable asterism described here was brought to the attention of the first author by a small article in an old copy of the ESO Messenger. The idea from the abstract originated from a paper by Noam Soker. Incidentally, let us plea here for authors never to use a question as a title! A title should be an invitation to dream, not a call to drown into boredom. A title should catch interest and predict the content of the paper. Putting a question mark means you haven't really contributed to the long-standing quest for truth of humanity. The question is what scientists ask themselves before starting their work and loosing appetite and sleep. A paper should only been written when a conclusion to this research has been reached, whether positive or negative. There shouldn't be a question mark left then. That is, unless your paper is about a stellar eroteme!

References

Boffin, H.M.J, Whiskey, J.B., Wake, A., Can't, W.H.Y. & Sleep, I., 2014, The Astronomical Enquirer 1, 1; `http://www.eso.org/~hboffin/enquirer.pdf`
Confucius (Kong Zi) 500 BC, Lun yu (Analects) I.1 and XV.24
Ehrmann, M. circa 1927, Poems (with verses such as *"I saw a sunset last evening that was a gross imposition upon modesty"* or *"Speak your truth quietly and clearly; and listen to others, even to the dull and the ignorant; they too have their story."*
Joke, A., Bug, T.H.E., 2000, A&B 1, 1
Plato, 375 BC, Analogy of the Sun, in The Republic