Internal heat production in hot Jupiter exo-planets, thermonuclear ignition of dark galaxies, and the basis for galactic luminous star distributions

Astronomical observations of planets orbiting stars other than our sun will inevitably lead to a more precise understanding of our own solar system and as well, perhaps, of the universe as a whole. The discovery of the so-called 'hot Jupiter' exo-planets, those with anomalously inflated size and low density relative to Jupiter, has evoked much discussion as to possible sources of internal heat production. But to date no explanations have come forth that are generally applicable. For example, hot Jupiter exo-planets are found with insufficient eccentricity to be heated internally by tidal dissipation, as originally suggested[1]. Other ideas, such as internal conversion of incident radiation into mechanical energy[2] and on-going tidal dissipation due to a non-zero planetary obliquity[3] also appear to lack general applicability. Charbonneau *et al.*[4] noted that two cases (HD 209458b and HAT-P-1b) suggest at least '... there is a source of internal heat that was overlooked by theoreticians'.

One purpose of the present note is to suggest a source of internal heat production for hot Jupiter exo-planets that indeed has been overlooked by theoreticians and which may be of general applicability. Another purpose is to suggest that the observation of hot Jupiter exo-planets may prove to be the first observational evidence of the correctness of my concept of the ignition of stellar thermonuclear fusion reactions by nuclear fission[5]. Yet another purpose is to discuss implications pertaining to the thermonuclear ignition of dark galaxies, and to suggest that the distributions of luminous stars in galaxies are reflections of the distributions of fissionable elements.

In the late 1960s, astronomers discovered that Jupiter radiates into space about twice as much energy as it receives from the sun. Later, Saturn and Neptune were also found to radiate prodigious quantities of internally generated energy. This excess energy production has been described as 'one of the most interesting revelations of modern planetary science'[6]. Stevenson[7] discussing Jupiter stated, 'The implied energy source ... is apparently gravitational in origin, since all other proposed sources (for example, radio-activity, accretion, thermonuclear fusion) fall short by at least two orders of magnitude ... '. Similarly, more than a decade later, Hubbard[6] asserted, 'Therefore, by elimination, only one process could be responsible for the luminosities of Jupiter, Saturn and Neptune. Energy is liberated when mass in a gravitationally bound object sinks closer to the center of attraction ... potential energy becomes kinetic energy ... '.

In 1990, when I first considered Jupiter's internal energy production, that explanation did not seem appropriate or relevant because about 98% of the mass of Jupiter is a mixture of hydrogen and helium, both of which are extremely good heat-transport media. Moreover, the mass of Neptune is only about 5% that of Jupiter. Having knowledge of the fossil natural nuclear fission reactors that were discovered in 1972 at Oklo, Republic of Gabon, Western Africa[8], I realized a different possibility and proposed the idea of planetary-scale nuclear fission reactors as energy sources for the giant planets[9]. At first I demonstrated the feasibility for thermal neutron reactors in part using Fermi's nuclear reactor theory, i.e. the same calculations employed in the initial design of commercial nuclear reactors and used by Kuroda[10] to predict conditions for the natural reactors that were later discovered at Oklo. Subsequently, I extended the concept to include planetocentric fast neutron breeder reactors, which are applicable as well to non-hydrogenous planets, especially the nuclear georeactor as the energy source[5,11] and the operant fluid[12,13] for generating the earth's magnetic field.

There is a strong terrestrial evidence for the planetocentric nuclear reactor concept. In 1960s geoscientists discovered occluded helium in oceanic basalts which, remarkably, possessed a higher $^3He/^4He$ ratio than air. At that time there was no known deep-earth mechanism that could account for the experimentally measured ^3He, so its origin was assumed to be a primordial ^3He component, trapped at the time of earth's formation, which was subsequently diluted with ^4He from radioactive decay. State-of-the-art numerical simulations of georeactor operation, conducted at Oak Ridge National Laboratory, USA, yielded fission-product helium, as shown in Figure 1, with isotopic compositions within the exact range of compositions typically observed in oceanic basalts[14,15]. For additional information, see Rao[16].

At the pressures which exist near the centre of the earth, density becomes a function almost exclusively of atomic number and atomic mass. Thus, heavy fission products like krypton and xenon are constrained to be trapped forever within the georeactor fission product sub-shell and will be unable to escape, never to be brought to the earth's surface. Helium, on the other hand, can be expected to escape; the similarity in its isotopic composition with helium measured in oceanic basalts stands as evidence for the existence of the georeactor. In principle, another noble gas, neon, is sufficiently light so as to be able to escape from the earth's core, provided it can pass through the inner core. Neon, with a unique isotopic signature, is observed in deep-source basalts, such as those from Hawaii and Iceland[17]. A tantalizing possibility is that the observed neon is georeactor-produced. Regrettably though, fission yield data on neon and its progenitor fission products are too scanty and imprecise to make such a determination.

There are two other potential possibilities for verifying the existence of the georeactor, but each presently lacks sensitivity and resolution: seismic detection and anti-neutrino detection and discrimination[18].

At the beginning of the 20th century, understanding the nature of the energy source that powers the sun and other stars was one of the most important problems in physical science. Initially, gravitational potential energy release during protostellar contraction was considered, but calculations showed that the energy released would be insufficient to power a star for as long as life has existed on earth. The discovery of radioactivity and the developments that followed led to the

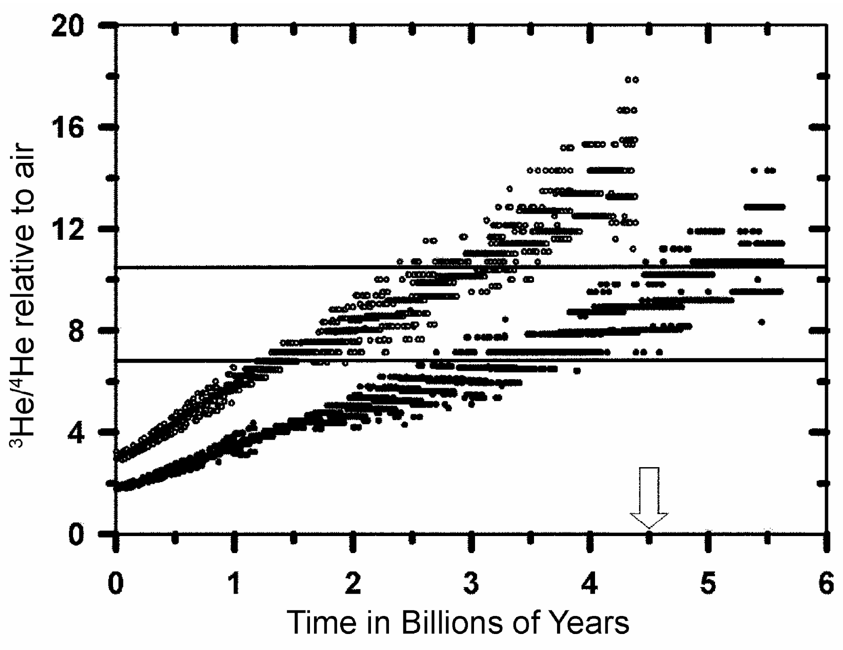

Figure 1. Fission product ratio of $^3He/^4He$, relative to that of air, from nuclear georeactor numerical calculations at 5 TW (upper) and 3 TW (lower) power levels[14]. The band comprising the 95% confidence level for measured values from mid-oceanic ridge basalts (MORB) is indicated by solid lines. The age of the earth is marked by the arrow. Note the distribution of calculated values at 4.5 gigayears, the approximate age of the earth. The increasing values are the consequence of uranium fuel burn-up. Iceland deep-source 'plume' basalts present[34] values ranging as high as 37.

idea that thermonuclear fusion reactions power the sun and other stars.

Thermonuclear fusion reactions are called 'thermonuclear' because temperatures of the order of a million degrees Celsius are required. The principal energy released from the detonation of hydrogen bombs come from thermonuclear fusion reactions. The high temperatures necessary to ignite H-bomb thermonuclear fusion reactions come from their A-bomb nuclear fission triggers. Each hydrogen bomb is ignited by its own small nuclear fission A-bomb.

In 1938, when the idea of thermonuclear fusion reactions as the energy source for stars had been reasonably well developed[19], nuclear fission had not yet been discovered[20]. Astrophysicists assumed that the million degree temperatures necessary for stellar thermonuclear ignition would be produced by the in-fall of dust and gas during star formation and have continued to make that assumption to the present, although clearly there have been signs of potential trouble with the concept[21]. Proto-star heating by the in-fall of dust and gas is offset by radiation from the surface, which is a function of the fourth power of temperature. Generally, in numerical models of protostellar collapse, thermonuclear ignition temperatures of the order of a million degrees Celsius, are not attained by the gravitational in-fall of matter without additional ad hoc assumptions, such as assuming an additional shockwave-induced sudden flare-up[22] or result-optimizing the model-parameters, like opacity and rate of in-fall[23].

After demonstrating the feasibility for planetocentric nuclear fission reactors, I suggested that thermonuclear fusion reactions in stars, as in H-bombs, are ignited by self-sustaining, neutron-induced, nuclear fission[5]. I now suggest the possibility that hot Jupiter exo-planets may derive much of their internal heat production from thermonuclear fusion reactions ignited by nuclear fission.

The discovery of hot Jupiter exo-planets has evoked much discussion as to possible sources of internal heat production, but to date no generally applicable astrophysical explanations have been presented.

One might expect planetocentric nuclear fission reactors to occur within exo-planets of other planetary systems that have a heavy element component, provided the initial actinide isotopic compositions are appropriate for criticality. And, indeed, planetocentric nuclear fission reactors may be a crucial component of hot Jupiter exo-planets. But it is unlikely that fission-generated heat alone would be sufficient to create the 'puffiness' that is apparently observed. For example, as calculated using Oak Ridge National Laboratory nuclear reactor numerical simulation software, a one Jupiter-mass exo-planet without any additional core enrichment of actinide elements could produce a constant fission-power output of $\sim 4 \times 10^{21}$ erg/s for only $\sim 5 \times 10^8$ yrs. Even with that unrealistically brief interval, the fission-power output is orders of magnitude lower than the 10^{26}–10^{29} erg/s needed for the observed puffiness according to hot Jupiter model calculations[1].

Unlike stars, hot Jupiter exo-planets are insufficiently massive to confine thermonuclear fusion reactions throughout a major portion of their gas envelopes. One might anticipate instead fusion reactions occurring at the interface of a central, internal substructure, presumably the exo-planetary core, which initially at least was heated to thermonuclear ignition temperatures predominantly by self-sustaining nuclear fission chain reactions. After the onset of fusion at that reactive interface, maintaining requisite thermonuclear interface temperatures might be augmented to some extent by fusion-produced heat, which would as well expand the exo-planetary gas shell, thus decreasing the density of the exo-planet. Viewed in this context, hot Jupiter exo-planets appear to be stars in the process of ignition, at the cusp of being a star, but unable to fully ignite because their mass is almost, but not quite, sufficient for gravitational containment. Thus, observations of hot Jupiter exo-planets may stand as the first evidence for the correctness of my concept of stellar thermonuclear fusion ignition by nuclear fission chain reactions[5].

The idea that stars are ignited by nuclear-fission triggers opens the possibility of stellar non-ignition, a concept which may have fundamental implications bearing on the nature of dark matter and, as suggested in the present note, on the thermonuclear ignition of dark galaxies, and on the distribution of luminous stars in galaxies universe-wide. As I noted in 1994, the corollary to thermonuclear ignition is non-ignition, which might result from the absence of fissionable elements, and which would lead to dark stars[5].

Observational evidence, primarily based on velocity dispersions and rotation curves, suggests that spiral galaxies have associated with them massive, spheroidal, dark-matter components, thought to reside in their galactic halos[24]. Interestingly, the luminous disc stars of spiral galaxies belong to the heavy-element-rich Population I; the luminous spheroidal stars of spiral galaxies belong to the heavy-element-poor Population II. In spiral galaxies, the dark-matter components are thought to be associated in some manner with the spheroidal heavy-element-poor Population II stars[25,26]. The association of dark matter with heavy-element-poor Population II stars is inferred to exist elsewhere, for example, surrounding elliptical galaxies[27,28]. Because of the apparent association of dark matter with heavy-metal-poor Population II stars, I have suggested the possibility that these dark-matter components are composed of what might be called Population III stars, zero metallicity stars or stars at least devoid of fissionable elements and consequently, unable to sustain the nuclear fission chain reactions necessary for the ignition of thermonuclear fusion reactions.

Although dark matter is thought to be greater than an order of magnitude more abundant than luminous matter in the universe, there has yet to be an unambiguous identification of a wholly dark galactic-scale structure. There is, however, increasing evidence that VIRGOHI 21, a mysterious hydrogen cloud in the Virgo Cluster, discovered by Davies *et al*.[29] may be a dark galaxy. Minchin *et al*.[30] suggested that possibility on the basis of its broad line width unaccompanied by any responsible visible massive object. Subsequently, Minchin *et al*.[31] found an indubitable interaction with NGC 4254, which they took as additional evidence of the massive nature of VIRGOHI 21. If indeed VIRGOHI 21 turns out to be composed of dark stars having approximately the mass of stars found in luminous galaxies, it would lend strong additional support to my concept of stellar thermonuclear ignition by nuclear fission[5].

The existence of a dark galaxy composed of non-brown-dwarf, solar-massive dark stars would certainly call into question the long-standing idea of gravitational collapse as the sole source of heat for inevitable stellar thermonuclear ignition, which after all has no laboratory support, unlike my idea of a nuclear fission trigger[5], which has been demonstrated experimentally with each H-bomb detonation.

For half a century, the concept that elements are synthesized within stars[32] has become widely accepted. In the so-called B^2FH model, heavy elements are thought to be formed by rapid neutron capture, the *R*-process, at the supernova end of the lifetime of a star; there may be another explanation.

The conditions and circumstances at galactic centres appear to harbour the necessary pressures for producing highly dense nuclear matter and the means to jet that nuclear matter out into the galaxy where, as suggested here, the jet seeds dark stars which it encounters with fissionable elements, turning dark stars into luminous stars. Galactic jets, either single or bi-directional, are observed originating from galactic centres, although little is currently known about their nature. Figure 2 is a Hubble Space Telescope image of a 10,000 light year long galactic jet. One such jet was observed to have a length of 865,000 light years.

Consider a more or less spherical, gravitationally bound assemblage of dark (Population III) stars, a not yet ignited dark galaxy. Now consider the galactic nucleus as it becomes massive and shoots its first jet of nuclear matter into the galaxy of dark stars, seeding and igniting those stars which it contacts. How might such a galaxy at that point appear? I suggest it would appear quite similar to NGC4676 (Figure 3 *a*) or to NGC10214 (Figure 3 *b*).

The arms of spiral galaxies, such as M101 (Figure 3 *c*), and the bars which often occur in disc galaxies[33], such as in NGC1300 (Figure 3 *d*), possess morphologies which I suggest occur as a consequence of galactic jetting of fissionable elements into the galaxy of dark stars, seeding the dark stars encountered with fissionable elements, thus making possible ignition of thermonuclear fusion reactions.

The structures of just about all luminous galaxies appear to have the jet-like luminous star features, the imprints of the galactic jets which gave rise to their ignition, the imprints of the distribution of fissionable heavy-element seeds. Therein is the commonality connecting the diverse range of galactic observed structures and the causal relationship which appears to exist.

And what of the dark matter necessary for dynamical stability? The dark matter is the spherical halo of unignited, dark stars, located just where it must be to impart rotational stability to the galactic luminous structure[24].

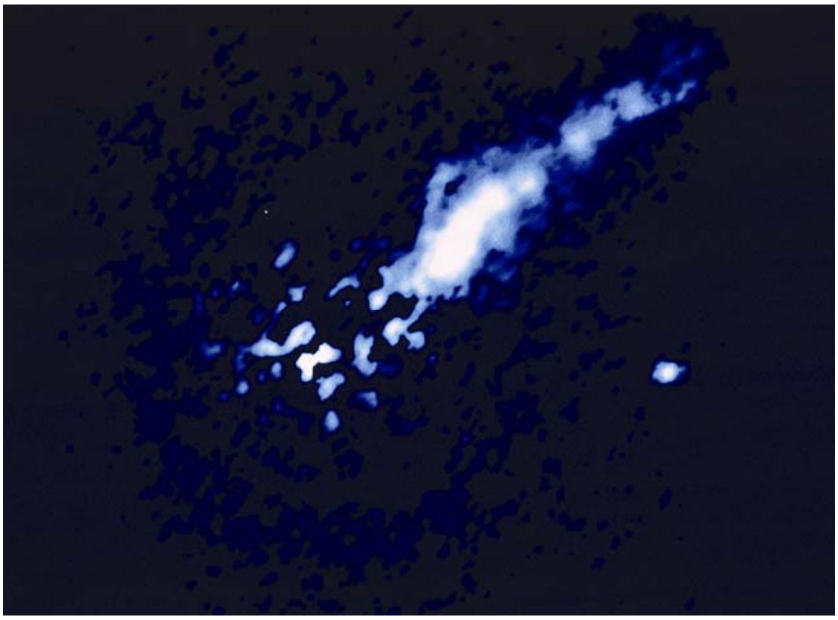

Figure 2. Hubble Space Telescope image of a 10,000 light year long galactic jet. Galaxy light was digitally removed for clarity. Galactic jets as long as 865,000 light years have been observed.

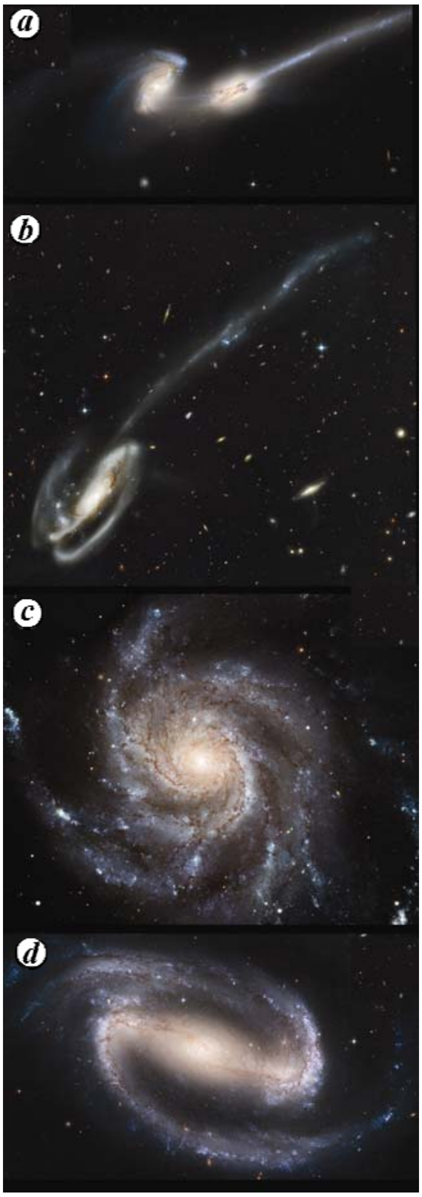

Figure 3. Hubble Space Telescope images of (***a***) anomalous galaxy NGC4676, (***b***) anomalous galaxy, UGC10214, (***c***) spiral galaxy M101 and (***d***) barred spiral galaxy NGC1300.

Since the 1930s, astrophysics has been built upon the concept that thermonuclear reactions in stars are ignited automatically by the heat generated by the collapse of dust and gas during star formation. Not only are there severe problems associated with this concept, because of extreme heat loss at high temperatures, but the observed jet-like distributions of luminous galactic stars is wholly inexplicable within this context. In stark contrast, the variety of morphological galactic forms, especially the prevalence of jet-like arms and bars can be understood in a logical and causally related way from my concept of heavy elements being formed in the galactic centres and jetted into space, where they seed the dark stars that they encounter with fissionable elements, which in turn ignite thermonuclear fusion reactions. From this perspective, the distribution of luminous stars in a galaxy, and consequently the type of galaxy, for example, barred or spiral, may simply be a reflection of the distribution of the fissionable elements jetted from the galactic centre.

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