The energy balance of Uranus: implications for special creation

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Uranus' thermal behaviour is different from that of the other Jovian planets Jupiter, Saturn and Neptune. It emits significantly less intrinsic energy than these other planets, and the actual net intrinsic emission may be zero. Naturalistic explanations have failed so far to explain this anomalous thermal behaviour. The implications of this fact for special creation continue to be confirmed by modern data.

Uranus' thermal behaviour is a long-standing problem for evolution

Prior to the beginning of the Space Age with the launch of Sputnik in 1957, it was relatively easy to generalize planetary properties to make them appear explicable by evolutionary planetary origins models. The return of Space Age data from planetary flybys, however, has repeatedly contradicted these models.

One major contradiction involves the properties of the Jovian planets. Rather than showing the similarities expected by evolutionary theorizing, these planets have emerged as distinctive, even unique, in ways which evolutionary theorizing cannot explain. During Creation Week God spoke into existence the celestial bodies, including the planets (Genesis 1:14–18). Because the planets did not evolve from a common source, but were individually or 'specially' created, there is no fundamental requirement that planets must show predictable similarities, although certain patterns of similarity do exist. Special creation permits the possibility, and even leads to the expectation, that there might be differences among the planets, which are inexplicable by any evolutionary model of development. The distinctives, which have been observed for the planets, would therefore seem to be evidences of special creation.

One distinctive is Uranus' thermal behavior, long recognized as a difficulty for planetary evolution models. Such models typically assume a primordial heat source resulting from planetary accretion, or postulate the production of internal heat from processes such as gravitational contraction or phase separation. Given that the Jovian planets allegedly evolved along similar lines, one would expect that they would all show similar thermal behavior today, or would at least show a pattern of change from one planet to the next. This is not the case. Uranus especially exhibits a thermal behavior that stands out from the other Jovian planets, and creationists have long cited this fact as evidence for special creation.

For instance, scientists pointed out many years ago that,

> 'Both Jupiter and Saturn have internal heat sources. What of Uranus? Uranus does not … . And Neptune, which is virtually Uranus' twin, has a relatively strong heat source … . How could two almost identical planets, formed in the same way at the same time, be so different in this respect? Evidently they were not formed by natural means. … Uranus and Neptune are clear evidence that [these planets] were created.'[1]

As will be examined in further detail, this remains an accurate statement. The evidence of Uranus for special creation can be cited with confidence. However, evolutionary modellers persist in viewing the Jovian planets as more similar than they really are. The evolutionary assumption of similarity is especially strong when considering Uranus and Neptune. These two planets are usually taken to be virtually identical, yet this assumption has been repeatedly disproved. Furthermore, Neptune of all the Jovian planets has the highest ratio of energy emitted to energy absorbed, yet Uranus has the lowest, with 'little or no energy excess'.[2]

Until the Voyager 2 flyby past Neptune, a mixing model was used to explain the thermal differences between Neptune and Uranus. According to this scenario,

> 'Neptune … suffered a collision late in its formation that stirred the ice and rock of its interior all the way to the center. That mixing helped break down the stratification that would otherwise have greatly inhibited the heat-driven vertical circulation that now carries heat to the surface.
>
> "Uranus" late hit, on the other hand, was way off center, as evidenced by the way it is lying on its side. That kind of collision might have failed to stir up the deep interior, leaving its heat largely trapped there. Because the rotation period provides one indication of how well mixed the interior is, a Neptunian day of 17 hours [versus 17.2 hours for Uranus] would have implied just the difference in mixing between the two planets … to explain the difference in heat leaking out.'[3]

This theory was discredited when Voyager 2 found that Neptune's rotational period is only 16 hours, a period too small to imply the mixing required to explain why Neptune radiates significant excess heat but Uranus does not. There is no firm evidence that Uranus suffered the putative catastrophe, which this model proposes. Even more, evolutionary models in general have failed to explain the properties of the Jovian planets. Of Uranus and Neptune it has been said, 'The substantial difference between the energy balance of Uranus and Neptune is still not completely understood.'[4]

Even of Jupiter and Saturn, the two Jovian planets most often assumed to have been successfully modelled, it has been written that 'all the models of Jupiter (and Saturn) until now are basically incorrect',[5] and that 'existing models for the Jovian interior need to be revised'.[6] Recent studies have not changed these conclusions.

The now-discredited mixing theory assumed that all planets contain primordial heat. However, there is no reason to assume that any of the planets initially had hot interiors. It is clear from Scripture that the Earth was covered with water originally and not molten (Genesis 1:2, 9–10). Evidence from radiohalos is consistent with this.[7] Similarly, Uranus may never have contained the same degree of heat as Neptune. It is only a modeling assumption that gravitational contraction together with phase separation or other mechanisms are the sources of heat for all the Jovian planets. Contrary to this assumption, Ouyed *et al*. note that 'gravitational settling by diffusion' cannot 'account for Jupiter's excess heat'.[8] Neither can phase separation resulting in 'He unmixing', since global oscillation data for Jupiter have confirmed that phase separation is a minor process if it is occurring at all,[8,9] thus confirming earlier indications of its unimportance.[10]

There is the possibility that for Jupiter, and perhaps for Neptune, radioactivity may have been an overlooked heat source. Moreover, radioactivity is thought to supply most of the Earth's internal heat. This last statement is, however, somewhat questionable. To illustrate how little is known about heat generation in planetary interiors, consider this statement about the Earth:

'The decay of radioactive isotopes of uranium and thorium is one of the major sources of the Earth's internally generated heat, but nobody knows just how much this heat source produces … .'[11]

If Neptune's heat were indeed from radioactivity, this could imply the presence of elements there which Uranus does not have, making a stronger case for the planetary uniqueness of Uranus, and in turn a stronger case for special creation.

All planetary interior models are totally 'theoretical',[12] representing conditions that 'cannot be replicated in laboratories'[13] in which internal element abundances can only be estimated. It is nevertheless significant that at most only 15–20% of Uranus' internal energy is estimated to be from radiogenic heating.[14] The actual radiogenic contribution may be even less than this.

Aside from the marked thermal difference between Uranus and Neptune, these two planets differ from the other Jovian planets in several other (related) ways: (1) relative abundance of hydrogen and helium, (2) abundance of heavy elements, (3) density profiles, (4) internal structure, (5) degree of homogeneity, and (6) temperature profiles.[15] It also appears that Uranus is significantly different from Neptune in at least the last two characteristics just mentioned.[15] Rather than being revealed as more like each other, the Jovian planets are emerging as increasingly dissimilar as research progresses.

Table 1. *Thermal Data for the Jovian Planets.*

Planet	Solar Irradiance S, W/m²	Albedo α	Blackbody Temp T, K	Energy Emission[17] Rate H, W/m²	S(1-α)/H
Jupiter	50.50	0.343	110.0	8.301	4.00[18]
Saturn	14.90	0.342	81.1	2.453	4.00
Uranus	3.71	0.300	58.2	0.6505	4.00
Neptune	1.51	0.290	46.6	0.2673	4.01

Pre-Voyager Uranus and Neptune data contradicted evolution.

We now turn to a quantitative consideration of the energy balance of Uranus as compared with the other Jovian planets. Table 1 shows NASA data on solar irradiance, albedo and blackbody temperature for the four gaseous planets.[16]

The blackbody temperatures T in Table 1 have been computed by NASA using the quantity S(1 - α) and the Stefan-Boltzmann equation.[19] This is apparent from the nearly constant ratio (not shown in Table 1) between S(1 - α) and the fourth power of T for each planet.

We could compute **fictitious** energy emission rates H using the given blackbody temperatures. These values of H, in the fourth column of Table 1, are not real, because they do not include thermal emission due to intrinsic luminosity, i.e. internal heat sources. However, if we compare S(1 - α) and H for each planet as in the last column of Table 1, we get nearly constant ratios, with very little difference for any planet from the others. If we (wrongly) drew conclusions about planetary intrinsic luminosity from these ratios, we could conclude that Uranus shows thermal emission behavior no different from the other three giant planets.

In 1984, prior to the Voyager missions to either Uranus or Neptune, Hubbard[20] provided values of planetary 'effective temperatures' for the giant planets computed via the Stefan-Boltzmann equation using intrinsic luminosity and thermal luminosity. These are given in Table 2, along with NASA's current blackbody temperatures repeated from Table 1, and the blackbody temperatures as they were known in 1984.

Uranus is the only planet of the four in Table 2 whose effective temperature and blackbody temperature are nearly matched. For the other planets, the excessive effective temperatures mean that they are radiating more heat than they receive from the Sun.

As of 1984 the radiation of Jupiter and Saturn had been analyzed by Voyager 2, so it is not surprising that the 1984 blackbody temperatures for these two planets agree so

Table 2. *Blackbody and Effective Temperature of the Jovian Plan-*

Planet	1984 Blackbody Temperature, K	Current Blackbody Temperature, K	Effective Temperature, K
Jupiter	109.5 ± 1.6	110.0	124.4 ± 0.3
Saturn	82.5 ± 1.3	81.1	95.0 ± 0.4
Uranus	57	58.2	58 ± 2
Neptune	46	46.6	55.5 ± 2

well with the current values. What is surprising, however, is the agreement between the 1984 and current blackbody temperatures for Uranus and Neptune. In 1984, as Hubbard notes,[21] 'the values of A [used to compute blackbody temperatures, were] obtained from theoretical models', yet they agree well with the current values. The reason for this surprise is that 'it is normally necessary to perform this important measurement from a spacecraft, because when we observe a distant outer planet from the Earth, we see only the component of the sunlight which is scattered back in the Earth's and Sun's direction'.[21] With this theoretical precision existing for A, it would appear also that the intrinsic luminosities for Uranus and Neptune were predicted accurately in 1984, and from them the effective temperatures given in Table 2.

In summary, Uranus' distinctive thermal behavior was well-known before the Voyager flyby, and as discussed in the previous section, was recognized both as a difficulty for evolutionary modeling and as an evidence for special creation.

Post-Voyager thermal data for Uranus still contradict evolution

In a modeling study attempting to resolve 'the still uncertain and debated questions about … the origin of [Jupiter's] excess heat',[22] the 'observed excess heat' for each Jovian planet was compared with the heat hypothetically released by a process of deuterium-deuterium (D-D) fusion in the Jovian planet interiors.[23] The authors of this study, Rachid Ouyed and colleagues, concluded that their model 'might be applicable to the family of the Jovian planets as a whole',[24] a conclusion which presumes a parallel evolutionary history for each of these planets.

Table 3 presents ratios of total emitted power E to total absorbed power A for Jupiter,[25] Saturn,[26] Uranus,[27] and Neptune[2] as utilized in the D-D fusion study.[28] The second column of Table 3 lists the ratios E/A. The relative difference E - A is expressed as a percentage in column three. The quantity (E - A)/E is the fraction of excess energy emitted, and is shown in the fourth column as a percentage. The right hand column lists E/A ratios computed from the Hubbard 1984 blackbody temperature and effective temperature data in the second and fourth columns of Table 2.

The 1984 ratios of E/A for Jupiter and Saturn derived from Table 2 agree with those utilized by Ouyed *et al.* This would be expected since Hubbard's 1984 ratios for Jupiter and Saturn, like those of Ouyed *et al.*, post-date the Voyager flybys of these two planets.

For Neptune, there is not agreement of the Hubbard 1984 E/A ratio with that of Ouyed *et al.* This is because the value of E for Neptune during the 1989 Voyager flyby turned out to be larger than estimated by Hubbard. Thus, Neptune is even more different thermally from Uranus than had been anticipated in 1984. The conclusion that Uranus is thermally distinctive from the other gas giants has been strengthened rather than weakened by post-1984 data.

As for Uranus, the E/A ratio from Table 3 is approximately unity. Indeed, Ouyed has stated that, 'It seems that the giant planets emit more energy than they receive from the Sun … . Uranus seems different in that respect since the ratio is very close to 1.0'.[28] The long-standing problem posed for evolutionary models by Uranus' thermal behavior continues.

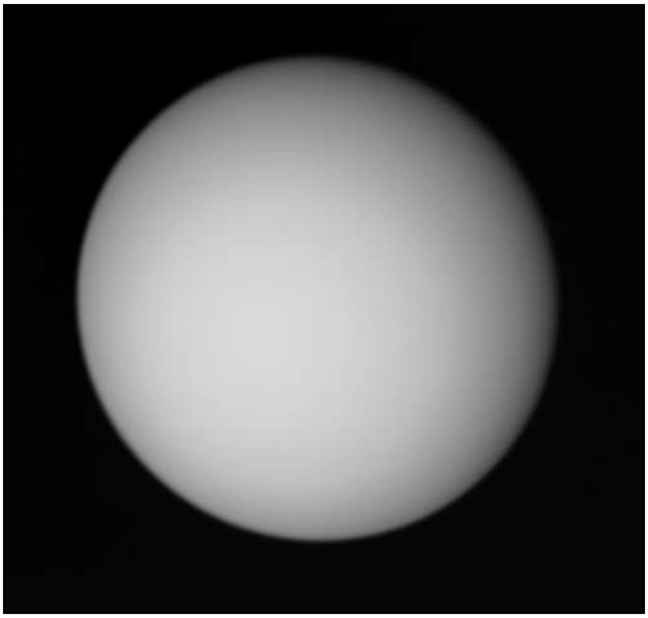
Uranus' thermal distinctiveness is widely recognized

Uranus is virtually always regarded as an anomaly which evolutionary models cannot explain. Pearl and Conrath[2] write that 'ground-based and spacecraft observations have revealed large excess energy fluxes from Jupiter, Saturn, and Neptune but a very small excess from Uranus', noting a few lines later that there may be 'no energy excess'. These same authors conclude elsewhere that 'the full implications of the small internal energy source of Uranus remain to be established',[14] a conclusion echoing the serious problems posed by this phenomenon for planetary evolution.

Pearl *et al.* state that the ratio of emitted to absorbed energy, E/A, for Uranus is 1.06 ± 0.08.[14] It is significant that the range of uncertainty (± 0.08) in this figure is so great that it includes values even less than unity. In other words, Uranus is emitting at most only a relatively small fraction of excess heat, and may be emitting no excess heat at all. With this realization, it is evident why Ouyed, as quoted above, said that the E/A ratio for Uranus is 'very close to 1.0',[28] and why astronomer John D. Fix has stated,

Table 3. *Energy Emission-Absorption Data for the Jovian Plan-*

Planet	E/A (Ouyed *et al.*)	E–A, %	(E–A)/E, %	E/A (Computed from Table 2)
Jupiter	1.67 ± 0.09	67	40	1.67
Saturn	1.78 ± 0.09	78	44	1.76
Uranus[29]	~ 1	~ 0	~ 0	1.07
Neptune	2.70 ± 0.3	170	63	2.12



This pictures of Uranus was compiled from images returned on January 17, 1986, by the narrow-angle camera of Voyager 2. The spacecraft was 9.1 million kilometers from the planet.

'The temperature of Uranus' atmosphere is consistent with heating only by absorbed sunlight … '.[30] Yet the claim is sometimes made that all the Jovian planets 'give off more heat than they receive'.[31] This type of statement minimizes the fact that even if an excess exists for Uranus, it is insignificant by comparison with that of the other gas giants, as we will now see.

From Table 3, the E/A ratio for Jupiter is 1.67, giving an excess energy fraction of 40% in column four. This contrasts with only 6% (at most) for Uranus.[14] Thus Jupiter's excess emission fraction is at least 40/6 ≈ 7 times the excess emission fraction of Uranus. Saturn and especially Neptune are even more dissimilar from Uranus. Saturn's fraction of excess energy is 44/6 > 7 times that of Uranus, and for Neptune it is 63/6 > 10.

Uranus' thermal behavior is simply not the same as that of the other gaseous planets. Indeed, Uranus and Neptune, both commonly paired in evolutionary origins discussions as if they were somehow the most similar of the gas giants, are actually the most **dissimilar** in their thermal balance of any of the Jovian planets. It is no wonder that Fix, after emphasizing Uranus' lack of excess energy, immediately points out that 'Neptune is significantly warmer than it would be if it were heated by sunlight alone', a statement which he amplifies later by writing, '60% of the energy emitted by Neptune comes from internal sources'.[32] This figure of 60% is a rounded value of (E - A)/A for Neptune listed in the fourth column of Table 3.

From recent citations (e.g. Ouyed *et al*.) of the 1.06 E/A ratio for Uranus, one might surmise that it is a new development. Has this ratio been re-assessed from unity to higher values as research progresses? The answer emphatically is no. The 1.06 ratio is an old value, not a new development. It dates from 1990, a few years after the Voyager 2 flyby of Uranus in 1986 when the data were gathered which formed the basis for the 1.06 ratio. In fact, Pearl *et al*. emphasize that this value is 'lower than previous results'.[14] This can be seen from Table 3, where the 1984 E/A ratio is given as 1.07, a conservative value compared to some pre-Voyager 2 predictions[33] as discussed below. Indeed, in 1993 this value was viewed as 'consistent with 1 to the precision of the measurements'.[27]

Since 1990, the 1.06 ratio has been consistently recognized as indicating a very different thermal behavior for Uranus compared with the other gas giants. Before 1986, it was assumed from evolutionary premises that Voyager 2 would show a thermal similarity among these planets. Though it was suspected that Uranus emitted less excess heat than the other giant planets, it was not predicted that Uranus would be so different. Before the analysis of Voyager 2 data was complete, one assessment concluded:

> 'Uranus … seems to have lost most but not all of the internal heat it had when it formed. As much as 30 percent of the heat radiated by the planet may come from its interior rather than from the sun … . [For] Jupiter and Saturn, which are much more massive and have therefore retained more of their internal heat, the figure is at least 70 percent.'[34]

This 70% figure for excess heat emitted by Jupiter and Saturn corresponds to the E - A differences in the third column of Table 3. Of course, these values had already been obtained through earlier Voyager flybys of Jupiter and Saturn, which pre-dated the Uranus flyby of 1986.

But the pre-1986 estimate of 30% excess heat from Uranus corresponds to an emission/absorption ratio of 1.30. Thus the 1.06 ratio computed from the Voyager 2 flyby data was much less than the prediction. This has been described consistently as an anomaly.

To illustrate this last statement, several assessments are discussed below which post-date the Pearl *et al*. paper reporting the 1.06 ratio. This ratio never seems to be merely mentioned. Rather, sources typically dwell on how low it is. An article in the journal *Science* describes it as 'so small'.[15] It does not seem to be at all typical to dismiss this

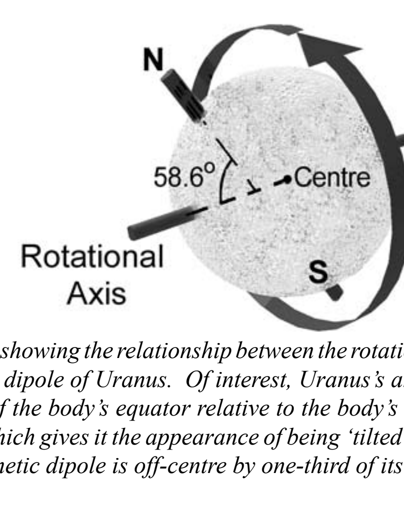
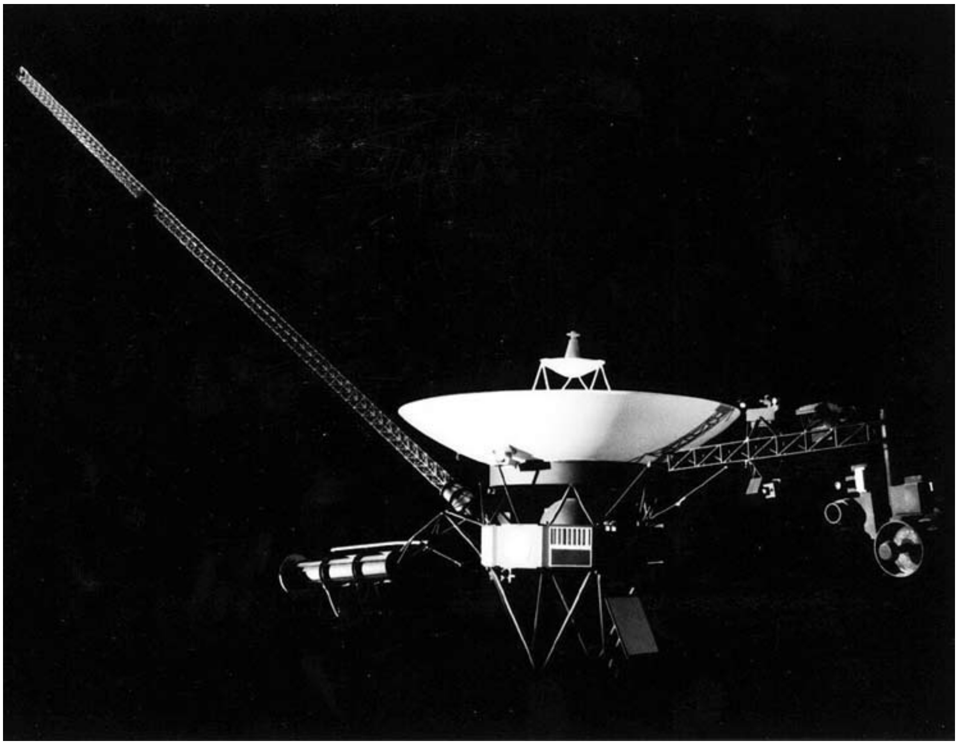


Diagram showing the relationship between the rotational axis and the magnetic dipole of Uranus. Of interest, Uranus's angle of obliquity (the tilt of the body's equator relative to the body's orbital plane) is 97.77° which gives it the appearance of being 'tilted over' on its side. The magnetic dipole is off-centre by one-third of its radius.



On August 20 1977, Voyager 2 was launched to follow its sister craft to Jupiter and Saturn and on to the next planet, Uranus, for an encounter in January 1986. The long boom on the left carries two magnetic-field detectors and stretches 43 feet out from the spacecraft.

ratio as unimportant or somehow similar to the ratios for the other gas giants.

The University of Michigan echoes the assessment of the journal *Science* by stating, 'When the luminosity of the outer planets was calculated, that of Uranus was found to be low, similar to the amount of energy given off by the terrestrial planets, and unlike that of Jupiter and Saturn'.[35] Perth Observatory states that for Uranus, 'There has been no evidence of an internal heat source (unlike the other gaseous planets)'.[36]

The *Encyclopaedia Britannica* specifically discusses the 1.06 ratio. Instead of belittling or dismissing this small ratio, the *Britannica* summarizes the dilemma it poses for evolution in a manner that would be difficult to improve upon. Indeed, the *Britannica's* assessment encapsulates the entire theme of this paper:

> 'Uranus is different from the other giant planets in that it is not radiating a significant amount of excess internal heat … . The ratio of total power radiated to total power absorbed is between 1.00 and 1.06 for Uranus. (The equivalent ratios for the other giant planets are greater than 1.7). Thus the internal heat source on Uranus is no more than 6 percent of the power absorbed. The small terrestrial planets generate relatively little internal heat; the comparable number for the earth is only 10^{-4}.
>
> 'It is not clear why Uranus has such a low internal heat output compared to the other Jovian planets. All the planets should have started warm, when gravitational energy was transformed into heat during planetary accretion. Over the age of the solar system, the Earth and the other smaller objects have lost most of their heat of formation. Being massive objects with cold surfaces, however, the giant planets store heat well and radiate poorly. Therefore, they should have retained large fractions of their heat of formation, which should still be escaping today. Chance events (collisions between large bodies) at the time of formation and the resulting differences in internal structure are one of the explanations that have been proposed to explain differences among the giant planets such as the anomalous heat output of Uranus.'[37]

It should be noted that the collision model mentioned here has been disproved by other Voyager 2 data as discussed previously.[3]

Evolutionary claims about Uranus are misleading

Since the Voyager 2 flybys of Uranus and Neptune, two divergent views have emerged about the thermal behavior of Uranus. One view is that Uranus' thermal behavior is truly distinctive and is especially different from that of Neptune. This is illustrated in the following representative assessment (previously quoted):

> 'The temperature of Uranus' atmosphere is consistent with heating only by absorbed sunlight, whereas Neptune is significantly warmer than it would be if it were heated by sunlight alone.'[30]

Again, 'Uranus radiates away essentially no internal heat, whereas 60% of the energy emitted by Neptune comes from internal sources'.[38]

On the other hand, there is another view of Uranus' thermal behavior. This view claims that the thermal behavior of Uranus is qualitatively no different from that of the other Jovian planets. It has been stated that (1) 'Jupiter, Saturn, Uranus and Neptune all give off more heat than they receive [from the Sun]';[31] (2) 'Uranus and Neptune also produce excess energy … ';[31] (3) ' … all four [Jovian] planets are contracting and releasing gravitational energy'.[31]

It will be shown that this second view is erroneous. No new research has emerged which suggests that this second view is correct. Furthermore, leaving this view uncorrected can lead to misconceptions about the thermal behavior of Uranus, an outcome which has already occurred as we will see.

Since Ouyed has in fact acknowledged that Uranus' E/A is essentially unity,[28] and the distinctive thermal behavior of Uranus has often been acknowledged by others, how is it possible to reach the opposite conclusion, that Uranus' thermal behavior is like that of the other Jovian planets?[31] The source just quoted apparently followed Ouyed's lead in this matter, for Ouyed, though acknowledging the distinctiveness of Uranus' thermal behavior, nevertheless also minimizes this conclusion, opining that, 'Not everyone believes these numbers—that's why they should be taken with a grain of salt'.[28] Why would Ouyed make such a statement? The reason cannot be that these numbers are doubtful, for as we have seen, Uranus' anomalous thermal behavior has been widely recognized.

Uranus' thermal behavior is a serious problem for solar system evolution. If Uranus is truly emitting virtually no internal heat, this indicates the solar system must be young with insufficient time for evolution to have occurred. Indeed, Samec has noted that Ouyed *et al.* were seeking 'to preserve the billion-year age' for the solar system[31] in the face of contrary evidence. Furthermore, Ouyed himself has admitted that the D-D fusion model does not really appear to work:

> 'The main problem we faced with D-D fusion inside the giant planets is the high temperature required to account for the excess heat (2–3 times the maximum temperature Jupiter has ever reached during its life).'[28]

Samec points out the same problem with D-D fusion: 'The present core temperature in "mature" (billion-year) models is less than one-eighth of that needed to support D-D fusion'.[31] Ouyed *et al.* acknowledge that 'a higher temperature [would be required] to account for the observed excess heat' of Jupiter.[39]

In short, Ouyed has proposed a model to save the evolutionary age which even he admits doesn't work, but then acting consistently with his evolutionary framework, he has belittled the problem posed for evolution by Uranus. The dismissive view of Uranus' thermal behavior quoted above[31] then echoes Ouyed's minimizing of the importance of this phenomenon. Fix has said of the Ouyed *et al*. study: 'Given their hypothesis that all the giant planets have D-D fusion going on in them, it would certainly be convenient for Ouyed *et al*. to have a self-luminous Uranus'.[40] Thus Ouyed *et al*. minimized the thermal anomaly of Uranus not because the data demanded it, but to make their D-D fusion model apply consistently to all the Jovian planets.

Aside from the scientific inaccuracy of treating Uranus' thermal behavior like that of the other gas giants, there is the problem of misinformation caused by this erroneous position.

A recent article in *Sky & Telescope* claims that 'Uranus and Neptune release more energy than they receive from the Sun. In other words, they don't simply reflect sunlight; they glow with internal heat.'[41] This statement is totally false. This *Sky & Telescope* article was a 'news piece' presented anonymously. The source for the *Sky & Telescope* piece was another news piece in *Science* in which Uranus and Neptune are linked in the discussion, but with no implication that their thermal behavior is similar.[42] This *Science* news piece in turn referred back to a technical paper which, it turns out, concerns a model for gravitational contraction only in Neptune![43] However, the authors of this technical paper did mention Uranus together with Neptune in the first paragraph of their paper.[44]

Here we have the emergence and growth of a myth. The technical paper in *Science* barely mentions Uranus, then the matching *Science* news piece links Uranus with Neptune more strongly (though without reference to thermal behavior), and finally *Sky & Telescope* picks up on the *Science* news piece and extrapolates the Uranus/Neptune linkage to a total similarity in thermal behavior. This may be amusing, but it is not science. Instead, this is an example of how facts get distorted because of the influence of false assumptions, in this case the presumption that Uranus and Neptune have evolved almost identically.

Conclusion

Uranus is not emitting excess heat in a manner quantitatively similar to the other Jovian planets. There may not be even a qualitative resemblance, for Uranus may possibly be emitting no excess heat at all. Uranus is 'different' in its thermal behavior from the other gas giants—different to the point of being distinctive. Uranus continues to be recognized as unique, and the thermal behavior of Uranus continues to be a valid evidence for special creation.

References

1. Steidl, P.M., Planets, comets, and asteroids; in: Mulfinger, G., *Design and Origins in Astronomy*, Creation Research Society, Norcross, GA, p. 100, 1983.
2. Pearl, J.C. and Conrath, B.J., The albedo, effective temperature, and energy balance of Neptune, as determined From Voyager data, *J. Geophysical Research* **96** (October supplement):18921–18930, 1991; p. 18921.
3. Kerr, R.A., The Neptune system in Voyager's afterglow, *Science* **245**(4925):1450–1451, 1989; p. 1450.
4. Pearl and Conrath, Ref. 2, p. 18930.
5. Guillot, T., Chabrier, G., Gauthier, D. and Moriel, P., Effect of radiative transport on the evolution of Jupiter and Saturn, *Astrophysical Journal* **450**:463–472, 1995; p. 470.
6. Alavi, A, Parrinello, M. and Frenkel, D., *Ab initio* calculation of the sound velocity of dense hydrogen: implications for models of Jupiter, *Science* **269(**5228):1252–1254, 1995; p. 1252.
7. Gentry, R.V., *Creation's Tiny Mystery*, Earth Science Associates, Knoxville, pp. 29–32, 1992. See also Gentry, R.V., Fossil alpha-recoil analysis of variant radioactive halos, *Science* **160**(3833):1228–1230, 1968; and Gentry, R.V., Ion microprobe confirmation of Pb isotope ratios and search for isomer precursors in polonium radiohalos, *Nature* **442**(5414):282, 1973.

8. Ouyed, R., Fundamenski, W.R., Cripps, G.R. and Sutherland, P.G., D-D fusion in the interior of Jupiter? *Astrophysical Journal* **501**:367–374, 1998; p. 369.
9. Nellis, W.J., Ross, M. and Holmes, N.C., Temperature measurements of shock-compressed liquid hydrogen: implications for the interior of Jupiter, *Science* **269**(5228):1249–1252, 1995; p. 1251.
10. Hubbard, W.B., *Planetary Interiors*, Van Nostrand Reinhold, New York, p. 263, 1984.
11. Normille, D., Experiment uses nuclear plants to understand neutrinos, *Science* **284**(5422):1911, 1999.
12. Nellis *et al*., Ref 9, p. 1249.
13. Ouyed *et al*., Ref. 8, p. 368.
14. Pearl, J.C., Conrath, B.J., Hanel, R.A., Pirraglia, J.A. and Coustenis, A., The albedo, effective temperature, and energy balance of Uranus, as determined from Voyager IRIS Data, *Icarus* **84**:12–28, 1990; pp. 12, 27.
15. Guillot, T., Interiors of giant planets inside and outside the Solar System, *Science* **286**(5437):72–77, 1999; p. 74.
16. NASA data at the following websites updated 17 February 2000:
<nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html>
<nssdc.gsfc.nasa.gov/planetary/factsheet/saturnfact.html>
<nssdc.gsfc.nasa.gov/planetary/factsheet/uranusfact.html>
<nssdc.gsfc.nasa.gov/planetary/factsheet/neptunefact.html>
17. H is the energy emission rate computed using the Stefan-Boltzmann equation with emissivity = 1.0. H does not include any internal energy sources.
18. The irradiance S in column 1 is the inverse square value for solar radiation at the semimajor axis distance. It applies only at the point on the planet directly facing the Sun, and is four times the average radiation received over the planet, whereas H is a planetary average. Thus the ratio is 4, not 1, as would be true if S, like H, were an average.
19. Hubbard, Ref. 10, pp. 114–115.
20. Hubbard, Ref. 10, p. 116.
21. Hubbard, Ref. 10, p. 115.
22. Ouyed *et al*., Ref. 8, p. 367.
23. Ouyed *et al*., Ref. 8, p. 373.
24. Ouyed *et al*., Ref. 8, p. 374.
25. Chabrier, G., Saumon, D., Hubbard, W.B. and Lunine, J.I., *Astrophysical Journal* **391**:817–826, 1992; as cited in Ouyed *et al*., Ref. 8, p. 373.
26. Podolok, M., Hubbard, W.B. and Pollock, J.B.; in: Levy, E.H. and Lunine, J.I. (Eds), *Protoplanets III*, University of Arizona, Tuscon, p. 1109, 1993; as cited in Ouyed *et al*., Ref. 8, p. 373.
27. Podolok *et al*., Ref. 26, p. 1113.
28. Ouyed, R., personal communication, January 2001.
29. Podolok *et al.*, Ref. 26, state that E/A 'is consistent with 1 to the precision of the measurements.'; Pearl *et al*., Ref. 14 give E/A = 1.06 ± 0.08, and E - A = 6% for Uranus.
30. Fix, J.D., *Astronomy: Journey to the Cosmic Frontier*, WCB/McGraw-Hill, New York, p. 286, 1999.
31. Samec, R., The age of the Jovian planets, *CEN Tech. J.* **14**(1):3–4, 2000; p. 3.
32. Fix, Ref. 30, pp. 286, 287.
33. Fazio, C.G., Traub, W.O, Wright, E.L., Low, F.J. and Trafton, V, The effective temperature of Uranus, *Astrophysical Journal* **209**:633–637, 1976; as cited in Hubbard, Ref. 10, p. 116.
34. Ingersoll, A.P., Uranus, *Scientific American* **286**(1):38–45, 1987; pp. 39–40. Though this article was published after the 1986 Voyager flyby of Uranus, the Voyager data had not been fully evaluated, and the assessment of Uranus' thermal energy balance in this article reflects pre-flyby conclusions: 'One of the goals of the Voyager 2 mission was to refine the rather uncertain estimate of Uranus' internal heat. The calculation requires the analysis of a large number of observations, however, and it has not yet been completed' (p. 40).
35. The source of heat from within Uranus, at <www.windows.ucar.edu/cgi-bin/tour.cgi?lin.../windows3.html&fr=f&sw=false&edu=hig>, 22 January 2001.
36. Uranus, Perth Observatory, at <www.wa.gov.au/perthobs/hpc2ura.htm>, 22 January 2001.
37. Uranus, *Encyclopeadia Britannica*, at <www.britannica.com/bcom/eb/article/printable/2/0,5722,118802,00.html>, 22 January 2001.
38. Fix, Ref. 30, p. 287.
39. Ouyed *et al.*, Ref. 8, p. 371.
40. Fix, J.D., personal communication, 25 February 2001.
41. Diamond hail in Uranus and Neptune, *Sky & Telescope* **99**(4):24–25, 2000; p. 24.
42. Kerr, R.A., Neptune may crush methane into diamonds, *Science* **286**(5437):25, 1999.
43. Benedetti, L.R., Nguyen, J.H., Caldwell, W.A., Liu, H., Kruger, M. and Jeanloz, R., Dissociation of CH4 at high pressures and temperatures: diamond formation in giant planet interiors? *Science* **286**(5437):100–102, 1999.
44. Benedetti *et al*., Ref. 43, p. 100.

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