RADIATIVE-CONVECTIVE EQUILIBRIUM MODELS OF URANUS AND NEPTUNE

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The presentation by Appleby is largely contained in a paper appearing in the special issue of *Icarus* (1986; <u>65</u>, 383-405). The abstract of that paper is reproduced here.

A study of radiative-convective equilibrium models for Uranus and Neptune is presented, with particular emphasis on the stratospheric energy balance, including the influence of aerosol heating and convective penetration. A straightforward numerical method is employed (Appleby and Hogan, 1984, Icarus <u>59</u>, 336-366) along with standard opacity formulations and the assumption of local thermodynamic equilibrium. A range of models was considered for Uranus, reflecting uncertainties in observational constraints on the middle stratospheric temperatures. The results indicate that a "continuum absorber" could be significant in the stratosphere, despite Uranus' great distance from the Sun. Also, test runs are presented to illustrate the influence of uncertainties in the gas composition and changes in the effective mean insolation. A longstanding theoretical problem for Neptune has been to explain the unexpectedly high stratospheric temperatures without invoking supersaturation of CH_4. The results show that a "continuum absorber" could contribute significantly to the energy balance within a localized stratospheric region; however, it probably cannot provide enough power to explain the observed infrared spectrum, regardless of its vertical distribution. One alternative is "convective penetration" which could arise if, for example, vertical mixing is so rapid that CH_4 condensation cannot occur before the gas is swept upward, above the condensation region. In the example considered here, the CH_4 mixing ratio in the middle and upper stratosphere is equal to that below the condensation region in the troposphere. The infrared emission from this model was found to be in generally good agreement with the observations. Such a model could also apply to Uranus, in lieu of aerosol or other "additional" heating mechanisms, to an extent that is commensurate with weaker convective uplifting.

DR. ORTON: Could you explain why two of your models seem to be able to fit some of these points, but the third seems not to fit the 150-200 micron region?

DR. APPLEBY: Well there are slight differences in the effective temperatures of these models. Since effective temperatures for Uranus and Neptune carry relatively large error bars (±2 K roughly), I don't constrain the models to produce effective temperature to within tenths of degrees in contrast to what I do for Jupiter. That just means that the flux of the one model is probably

a little bit too high, and it could be brought down a bit by changing boundary conditions.

DR. HUNTEN: You seemed very concerned about those four points at 28-30 microns, which is rather a small spread of wavelengths. They must have error bars comparable to the other point which you plotted there. I don't think you can even say that they are defining a flat curve in any sense whatsoever. If you have four points that close together with typical error bars, the slope is almost unconstrained. You are not required to fit the points. You are required to draw a line through the error bars. That's all I'm saying; it doesn't necessarily define a slope.

DR. APPLEBY: That's certainly true to some extent, but variation of two or three degrees seems to be ruled out.

DR. BELTON: Why don't Orton's points have vertical error bars?

DR. ORTON: The error bars are smaller than the squares representing the observations.

DR. BELTON: Then why couldn't you know what wavelength you were looking at?

DR. ORTON: I think that it's fair to say that those aren't really error bars; they are discrete filters that wide.

DR. LUTZ: You showed the JPL version of the Uranus albedo, but our group at Lowell Observatory published a similar albedo, and showed that the geometric albedo does change significantly with time. What does that do to your matching data from various sources, and to your model?

DR. APPLEBY: I believe you are referring to measurements that indicate a brightening of ≈14 percent in the integrated geometric albedo spectrum, comparing data from 1981 versus 1961-1963 (Lockwood *et al.*, 1983, *Astrophys. J.* 266, 402). The uncertainties discussed here, associated with locating the haze-free continuum in the recent data of Neff *et al.* (1984) correspond to differences (haze-free versus 'observed' continuum) that are two to three times greater than this 20-year secular change.