CaK λ 3,934 of a BL Lac object at $z = 0.13$. However, in view of the morphological evidence described above and shown in Figs 1 and 2, this interpretation does not seem to be tenable. The mean spectral index of the optical continuum of the knot is $\alpha = 1.7 \pm 0.1$ ($F_\nu \propto \nu^{-\alpha}$). The tracings through the nucleus and the knot of F-71 show that in all the colour bands the relative brightness and concentration of light between the jet and nucleus is very similar to those in M87 and its jet[1]. This may be taken as further evidence that both phenomena have the same physical origin.

F-71 and its north-east knot resemble in many respects the situation of the giant elliptical galaxy M87 with its spectacular nonthermal jet. Like M87, F-71 is an elliptical galaxy of the type E0–E1. In M87 the one-sided jet is made up of several nonthermal knots, while in F-71 a single strong knot is visible to one side and a weak feature to the opposite side. The flat and apparently lineless spectrum of the north-east knot corresponds to the nonthermal spectrum of the knots A and B of M87 displayed by Sulentic *et al.*[2]. Intriguingly, the spectral slope $\alpha = 1.7 \pm 0.1$ of the F-71 knot continuum matches exactly that of the knots A and B in the M87 jet, $\alpha = 1.7 \pm 0.2$ (ref. 5). Intrinsically, the scale of the F-71 phenomenon is an order of magnitude larger than in the M87 prototype. In F-71 the north-east knot is much more clearly separated from the main body of the galaxy than the jet in M87, and its luminosity, relative to the galaxy, is much stronger.

The optical data on F-71 described here characterize this source as a galaxy with similar ejection activity as M87, thus warranting further extensive studies, in particular in the radio region.

We thank M. P. Véron-Cetty and P. Véron for looking at the spectrum of F-71 and its knot. This work was supported in part by the Deutsche Forschungsgemeinschaft under grant Fr 325/21-1.

Received 9 January; accepted 27 March 1984.

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Conjugate ionospheric flows on Uranus

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Consideration of the pointing direction and rotation period of the spin of Uranus suggests that a novel kind of day-to-night ionospheric flow system may exist there. For equatorial distances $r < r_c$ ($\approx 2.74 r_p$), the conjugate ionospheric flow from the dayside hemisphere to the nightside hemisphere could become supersonic as it crosses the equator and a shock forms at the termination point; for $r > r_c$, smooth transition at the contact point between the ionospheric flow from the dayside hemisphere and the nightside atmosphere is possible. The rotational effect of Uranus also limits the inner extension of the thermal plasma disk generated from energetic particle sputtering of the ring-particles and satellites. The combined effect of the dynamic transport of the ionospheric plasma and the injection of ring plasma into the upper atmosphere could provide interesting results concerning the ionosphere of Uranus, which is to be explored by the Voyager 2 spacecraft in 1986.

As a result of the slow rotation of Venus, its nightside atmosphere is not subjected to a photoionization effect; however, spaceprobes to Venus have found that it has a very dynamic and sizeable nightside ionosphere[1,2]. Its maintenance has been suggested to result from impact ionization by energetic electrons (100 eV–1 keV) accelerated in the magnetic tail[3,4], or from transport of ionospheric plasma from the dayside to the nightside[1,5]. The ionospheric transport process of Venus, driven by solar heating and solar wind interaction directly with the dayside atmosphere, is unique among the planetary ionospheres. Note that a similar day-to-night ionospheric flow pattern could also occur at Uranus because although Uranus has a rapid spin period (16.31 ± 0.27 h; see ref. 6) its rotational axis is pointing towards the Sun. This means that while one hemisphere is illuminated constantly by sunlight the other is always in darkness. Therefore, only the dayside atmosphere is affected by photoionization—just as for Venus. One major difference between Venus and Uranus, however, is that while Venus has little or no intrinsic magnetic field, Uranus should possess an intrinsic magnetic field of significant strength as recently indicated by the UV observations of enhanced H Lyα emissions at Uranus[7–9]. In fact, Hill *et al.*[10] have postulated that the equatorial surface dipole field should be ≈4 G.

The expected hemispherical flows in the closed field-line region are shown in Fig. 1. In the simplest situation, the photoelectron–H^+ flux streaming out of the dayside hemisphere along a flux tube will cross the equator and then be absorbed at the conjugate point.

Rösler[11] has discussed the presence of such conjugate-point ionospheric flows at the terrestrial ionosphere during solstices at high altitudes. The occurrence of this type of inter-hemispheric flow should be much more widespread at Uranus as a result of the peculiar orientation of its rotational axis at present. Following the standard treatment in solar wind theory, the hydrodynamic equations describing the ionospheric flows (assumed to be isothermal) can be combined into[12]:

$$\frac{1}{2}(M^2 - M_0^2) - \ln\left(\frac{M}{M_0}\right) - \ln\left(\frac{A}{A_0}\right) + \frac{\phi - \phi_0}{c_0^2} = 0 \qquad (1)$$

where $M = u/c$ is the ratio of the flow speed to the sound speed given as $c^2 = 2kT/m$ (kT is the plasma temperature, and m the proton mass), and A is the cross-sectional area of the flux tube. Also we have

$$\phi_g = -\frac{GM}{r} \qquad (2)$$

$$\phi_c = -\frac{\Omega^2 r^2 \cos^2\theta}{2} \qquad (3)$$

where G is the gravitational constant, M the planetary mass ($= 8.7 \times 10^{28}$ g), r the radial distance, θ the latitudinal angle, and Ω the angular rotation frequency ($\Omega = 1.07 \times 10^{-4}$ rad s^{-1}). In

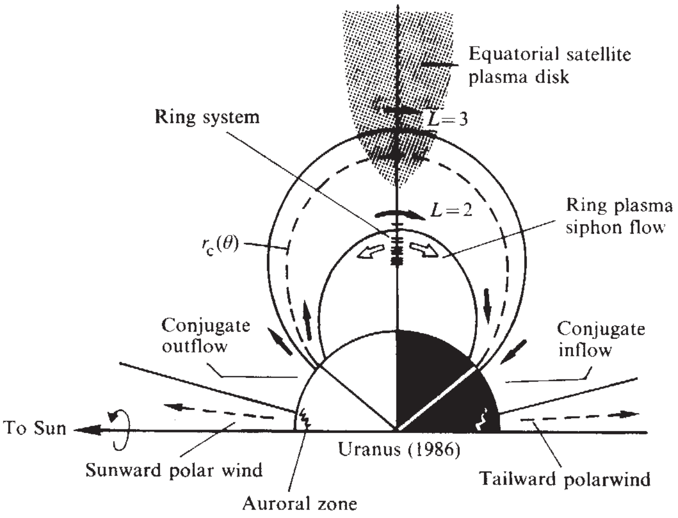

Fig. 1 The conjugate ionospheric flow pattern at Uranus. Such inter-hemispheric flows could coexist with a siphon flow of thermal plasma originates from the equatorial region as a result of energetic charged sputtering, meteoroid bombardment, and photosputtering of the rings and satellites.

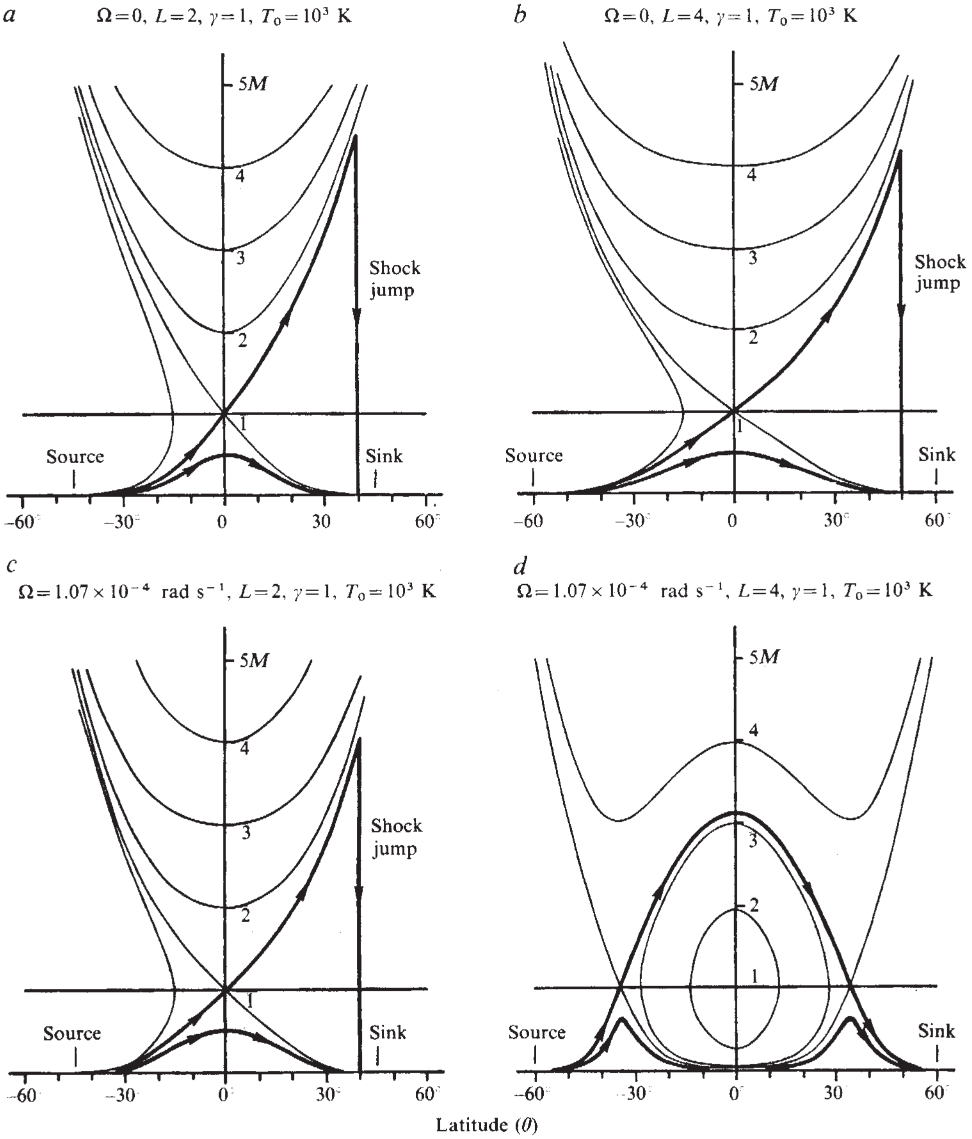

Fig. 2 Examples of isothermal conjugate ionospheric flows at Uranus with the plasma temperature set at $T = 1{,}000$ K. Four cases are considered: *a*, non-rotating case (angular frequency $(\Omega) = 0$) and the field-aligned flow crosses the equator at a radial distance of $2.0r_p$ ($L = 2.0$); *b*, $\Omega = 0$ and $L = 40$; *c*, $\Omega = 1.07 \times 10^{-4}$ rad s^{-1} (rotation period = 16.31 h) and $L = 2.0$; *d*, $\Omega = 1.07 \times 10^{-4}$ rad s^{-1} and $L = 4.0$.

equation (1) $\phi = \phi_g + \phi_c$ and the subscript (0) denotes values corresponding to radial distance r_0 and latitude θ_0 ($r = r_e \cos^2 \theta$ where r_e is the radial distance at the equator).

In the case of a non-rotating planet, several solutions to equation (1) are possible. These include: (1) transition from subsonic flow to supersonic flow before reaching the equator and then going through the reverse transition at the corresponding conjugate point; (2) reaching the sonic point at the equator and then retaining supersonic flow speed all the way to the other hemisphere; (3) retaining subsonic speed at all positions.

All of these solutions could be generated by adopting different sets of pertinent parameters (such as initial flow speed and plasma temperature) for the hydrodynamic flows. A more complete description of them will be presented elsewhere. We have depicted only a subset in Fig. 2 to demonstrate the idea of a conjugate ionospheric flow as well as the potential importance of the planetary rotation in modifying such flows. Figure 2 shows how the ionospheric flow from the dayside hemisphere might go through a sonic point as it crosses the equator or it might remain subsonic all the way to the nightside hemisphere if it starts with a smaller Mach number. In the supersonic flow case, a shock forms at the termination point as the ionospheric plasma slams into the darkside atmosphere. Such flow patterns hold for a wide range of radial distances as shown in Fig. 2*a*, *b*. However, for Uranus, there is an important modification to the flow dynamics at large radial distances; this is because the rapid rotation of the planet means that centrifugal effects begin to have a role in the force balance beyond a certain point. In the simplest possible situation, let us consider first the motion of one single charge particle. In a cold plasma approximation, neglecting the magnetic moment, the balance[13,14] between gravitational and centrifugal accelerations at the equator will define a radial distance (in the case of a perfect dipole field)

$$r_c(\theta) = \left[\frac{2GM \sec^2 \theta}{3\Omega^2}\right]^{1/3} \tag{4}$$

such that the charged particles with zero magnetic moment will be kept to the equator when $r > r_c$ but will be pulled to the topside atmosphere when $r < r_c$. Because r_c $(\theta = 0) = 6.96 \times 10^4$ km ($= 2.74r_p$) we have $\theta_c = 53°$.

In the case of the ionospheric flow, a similar limit could apply. Figure 2 provides the most extreme examples of the modification effect by the centrifugal force on the conjugate ionospheric flow. Briefly, for flows with sonic point at the equator, those originating from latitudes $\theta < \theta_c$, the 'X-point' configuration near the equator remains unchanged. On the other hand, for those originating from latitudes $\theta > \theta_c$, the corresponding X-point configuration could be substituted by the O-point configuration such that the plasma flows should be subsonic as they reach the other hemisphere (see Fig. 2*c*, *d*). Note that the general nature of an O-type flow in a non-rotating planet remains unchanged if the rotational motion of the planet is introduced. In addition to these many possible variations in the flow patterns, the net results are that the dayside upper ionosphere should be constantly in a state of dynamic expansion instead of diffusive equilibrium, and that the nightside atmosphere will receive a supply of ionization in this way, and a nightside ionosphere may be maintained accordingly.

In the case of Saturn, it has been postulated that the ionospheric region with magnetic field lines touching the rings should also approach the condition of free streaming—as a result of the absorption effect of the rings[15]. Because of the narrowness of the rings of Uranus, they would be less efficient in depleting the ambient plasma density in the vicinity of the ring system. The ε ring with a width of 50–100 km, however, should be able to intercept the ionospheric plasma and convert the hydrogen ions to neutralized H atoms. The ε ring should also act as an absorbing barrier in keeping the magnetospheric energetic charged particles from diffusing inward further than $2.4r_p$ (uranian radius). Cheng and Lanzerotti[16] have suggested that energetic particle sputtering of the rings could be an important cause of the thermal plasma in the magnetosphere. The associated production of the sputtered neutrals will generate a thin neutral cloud, reflecting the composition of the ring particles. The subsequent ionization of these heavy neutrals (that is, CH_4, H_2O and their fragments) will form a plasma disk at the equator. Force balance relation as considered in previous studies[14,17] indicates that the thermal plasma disk (if it exists) could be essentially limited to radial distances outside r_c. In other words, as shown in Fig. 1, a 'siphon' plasma flow from the equatorial region to the upper atmosphere should be expected in addition to the conjugate ionospheric flow. The dynamic transport of ionization from one hemisphere to another and the simultaneous loading of the atmosphere with hydrocarbons from the rings could have rather interesting effects on the ionospheric system of Uranus.

Finally, questions may be raised about how the presence of a plasma torus might affect the conjugate flow pattern. The most obvious effect is that the angular velocity of the magnetospheric plasma may be reduced to a value smaller than what is expected of rigid co-rotation, and the corresponding centrifugal force may be less important. In addition, the magnetic field configuration might be significantly changed from that of a dipole field.

Two mechanisms could be relevant here. First, as discussed previously[18] for the case of a rapidly-rotating magnetosphere[18,19], if the plasma density is large enough such that at a certain point the kinetic energy of the co-rotation motion exceeds that of the (dipolar) magnetic field energy, namely $\rho V^2/2 \geqslant B^2/8\pi$, no rigid rotation will be enforced; instead a radial outflow of the magnetospheric plasma stretching the magnetic field outward is expected to occur beyond this critical point. For Uranus, to reach this condition at $L \approx 4$ requires the plasma number density (assumed to be O^+ ions) to exceed $n_c \approx 10^7\ \mathrm{cm^{-3}}$ if the equatorial surface field $B_0 \approx 4$ G, and $n_c \approx 4\times10^4\ \mathrm{cm^{-3}}$ at $L \approx 8$ (the critical values of n_c are a factor of 100 smaller if $B_0 \approx 0.4$ G). But as shown by the Voyager plasma experiments[20] and theoretically demonstrated by Hill[21], in the jovian magnetosphere, non-rigid co-rotation could take place even with much less magnetospheric plasma—simply as a result of angular momentum transfer from the planetary ionosphere to the Io torus plasma. However, a large degree of non-rigid co-rotation ($\Delta\Omega/\Omega \sim 50\%$) only takes place at large distances from the source region of the thermal plasma. In the vicinity of the source region, it is the mechanism of pick-up current which has more immediate effect on the rotational rate of the local magnetospheric plasma.

Following the arguments given in refs 22–24, it can be shown that a reduction of the angular velocity of the magnetosphere will be necessitated by the acceleration of the new ions of satellite or ring origin by a pick-up current system. If the total production rate of the ions is $\dot{M}$, the radial dimension of the source region ΔR, and the integrated ionospheric Pedersen conductivity Σ_p, we have

$$\frac{\Delta\Omega}{\Omega} \approx \frac{\dot{M}L^5}{4\pi B_0^2 \Sigma_p R_0 \Delta R} \qquad (5)$$

For Jupiter, $\dot{M} \approx 1.5\times10^4\ \mathrm{kg\,s^{-1}}$, $L \approx 6$, $\Delta R \approx R_0$ $(=7\times10^7\ \mathrm{m})$ and $\Sigma_p \approx 0.2$ S, we have $\Delta\Omega/\Omega \approx 6\%$ which is in approximate agreement with observations[25,26]. By comparison, for Uranus with $\dot{M}$ assumed to be $\leqslant 10^2\ \mathrm{kg\,s^{-1}}$, $L \approx 4$, $\Delta R \approx R_0$ $(=2.5\times10^7\ \mathrm{m})$ and $\Sigma_p \approx 0.01$ S we have $\Delta\Omega/\Omega \leqslant 1\%$. Therefore, we expect the plasma disk of Uranus within $L \approx 5$ to be rigidly co-rotating and the magnetic field topology to be hardly affected by the mass loading effect of the pick up ions (if $\dot{M} \leqslant 10^2\ \mathrm{kg\,s^{-1}}$). For larger values of L ($\gtrsim 10$), it is more difficult to assess the situation as there are many uncertainties. In any case, one crucial parameter in this problem is the integrated ionospheric Pedersen conductivity Σ_p which is directly related to the whole process of transport of ionization from the dayside ionosphere to the nightside hemisphere.

Received 19 March; accepted 30 April 1984.

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Silicon and aluminium site distributions in 2:1 layered silicate clays

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Although the layer charge in 2:1 phyllosilicate minerals is known to result from the replacement of tetrahedral Si or octahedral Al, Fe and Mg by ions of lower charge, there is only limited information concerning the distribution of layer charge from X-ray crystallographic data[1–3]. Here we use ^{29}Si and ^{27}Al magic angle spinning (MAS) NMR spectroscopy to examine the site distribution of tetrahedral Si and Al in a series of synthetic trioctahedral clays with $(Si/Al)_{tetr}$ values in the range 2.74–7.69. Analysis of the ^{29}Si spectra shows that Loewenstein's rule for Al occupancy of the tetrahedral sheet is obeyed and that there is some short-range ordering for Al sites. The nature of the ordering is explained in part by the results of electrostatic potential energy calculations. In general, strong ^{27}Al resonances are observed for Al in tetrahedral sites, but the resonances due to Al in octahedral sites are considerably weaker than would be expected on the basis of chemical analysis. Consequently, no quantitative analysis of the ^{27}Al spectra is possible.