1. INTRODUCTION

The majority of the known stellar mass black hole candidates (BHCs) are transient low-mass X-ray binaries. These systems remain in quiescence for periods of months to tens of years and occasionally show outbursts (X-ray novae; see, e.g., Chen, Shrader, & Livio 1997) that are the result of a sudden increase in the mass accretion rate that generally lasts for a few months (Lasota et al. 1996). During an outburst, various spectral and variability properties are observed that seem to a great extent, but not uniquely, to be determined by the mass accretion rate (see, e.g., Tanaka & Lewin 1995; Homan et al. 2001; Nowak 2002). Although the appearance of black hole X-ray binaries is often categorized into four to five canonical states, they in fact appear to go through a continuous range of states whose properties are determined by the interplay between the two dominating spectral components: a soft thermal disk component and a hard nonthermal power-law component attributed to a Comptonizing medium (Sunyaev & Trümper 1979) whose origin remains unclear but is often thought to be an outflow and/or corona surrounding the inner accretion disk (Markoff, Falcke, & Fender 2001; Haardt & Maraschi 1993).

The variability properties of BHCs are strongly related to the relative contribution of the disk and the nonthermal components (van der Klis 1995a; Tanaka & Lewin 1995). When the latter dominates (hard state), the power spectra of BHCs show a strong band-limited noise component on which are often superposed one or more quasi-periodic oscillations (QPOs). When the contribution of the nonthermal component to the spectrum decreases (intermediate state), the noise becomes weaker and the QPOs become more prominent, while their frequencies increase from typically 0.1 to 10 Hz. When the thermal component dominates the spectrum (soft state), variability is very weak (typically only a few percent rms; see, e.g., Homan et al. 2001).

In addition to low-frequency QPOs (LF QPOs; ~0.1–10 Hz), five BHC systems have also shown high-frequency QPOs (HF QPOs) with frequencies of 40 Hz and higher (for a recent overview, see Remillard et al. 2002b). They are mainly observed when neither the thermal nor the nonthermal component dominates the spectrum. Unlike the kHz QPOs that are observed in the neutron star low-mass X-ray binaries (van der Klis 2000) and whose frequencies are variable and correlated to those of QPOs at lower frequency, our view on HF QPOs in BHCs is less complete and has evolved considerably during the past six years. Currently, three of the five sources have shown pairs of HF QPOs, sometimes simultaneously detected: GRO 1655−40 shows a pair at 300 and 450 Hz (Strohmayer 2001a; see also Remillard et al. 1999); GRS 1915+105 at 41 and 67 Hz (Strohmayer 2001b; see also Morgan, Remillard, & Greiner 1997) and another at 164 and 328 Hz (Remillard et al. 2002b, not detected simultaneously with the other pair), and XTE J1550−564 at 184 and 272 Hz (Miller et al. 2001; Remillard et al. 2002a). Note that in the case of XTE J1550−564 there is also evidence for a peak at 92 Hz (Remillard et al. 2002a) and that single peaks at intermediate frequencies are also found (Homan et al. 2001; Remillard et al. 2002a). The frequencies of the 102–284 Hz peaks in XTE J1550−564 reported by Homan et al. (2001) seemed to correlate with the frequency of the LF QPOs, although Remillard et al. (2002e) dispute this. In XTE J1859+226 (Cui et al. 2000; Markwardt 2001) and 4U 1630−47 (Remillard & Morgan 1999), only single peaks are detected that are consistent (at a 3 σ level) with having a constant frequency.
Although several detailed models had already been proposed to explain the frequencies of the HF QPOs (some of which will be discussed in § 4), recently much interest has been sparked by the apparent harmonic ratios of the frequencies in the HF QPO pairs (3 : 5 and 1 : 2 in GRS 1915+105, 2 : 3 in GRO J1655–40, and 1 : 2 : 3 XTE J1550–564), which, according to Abramowicz & Kluźniak (2001), might be suggestive of resonances between orbital and epicyclic motion in the Kerr metric. In any case, the frequencies of the HF QPOs strongly suggest that they find their origin in the inner parts of the accretion flow, close to the innermost stable circular orbit (ISCO). When eventually the mechanism behind these oscillations is understood, their properties can be used to study the effects of general relativity and constrain the mass and spin of the black hole. Already such constraints can be made; for example, assuming that the highest observed frequencies are caused by Keplerian motion at the ISCO, for at least two of the above sources, GRO J1655–40 and XTE J1550–564, the derived values of the masses of the black holes (5.5–7.9 $M_\odot$ and 9.7–11.6; Shahbaz et al. 1999; Orosz et al. 2002) and the highest observed frequencies imply that the black holes must be spinning. The models proposed thus far to explain the frequencies of the HF QPOs all have in common that their interpretation of the highest observed frequency requires even larger spin values than the ones based on the above simple assumption.

In this paper we report our search for high-frequency QPOs in the X-ray transient XTE J1650–500. This source was first detected with the Rossi X-Ray Timing Explorer (RXTE) on 2001 September 5 (Remillard 2001). Follow-up observations (Markwardt, Swank, & Smith 2001; Revnivtsev & Sunyaev 2001; Wijnands, Miller, & Lewin 2001) revealed a hard X-ray spectrum, strong variability, and QPOs around a few Hz, marking the source as a black hole candidate. Optical and radio counterparts were identified by Castro-Tirado et al. (2001) and Groot, Udalski, & Miller (2001). Optical follow-up observations performed when the source was close to quiescence, in 2002 October, revealed an orbital period of 0.212 days and a mass function that requires an inclination $<40^\circ$ for the black hole mass to be larger than 3 $M_\odot$ (Sánchez-Fernández et al. 2002). XMM-Newton observations performed near the peak of the outburst revealed the presence of a broad, skewed Fe K line that suggests the compact object in this system may be a Kerr black hole (Miller et al. 2002). Kalemci et al. (2002) studied the variability properties during a $\sim$20 day interval centered around a transition from the soft to the hard state that occurred on 2001 November 18. In the power spectra they found LF QPOs between 4 and 9 Hz but also broad bumps around 25 and 80 Hz. No HF QPOs were found, however. During the later stages of the outburst a 14 day period was found in the All-Sky Monitor ASM light curves, which is probably the disk precession period (Tomsick et al. 2002). In this paper we report the detection of high-frequency variability in this source and, in particular, the detection of a 250 Hz QPO. A more detailed spectral and variability study of the outburst will be presented elsewhere.

2. OBSERVATIONS AND ANALYSIS

The data used in this paper were taken with the proportional counter array (PCA; Jahoda et al. 1996) on board RXTE (Bradt, Rothschild, & Swank 1993). The observations of XTE J1650–500 were performed between 2001 September 6 and 2001 November 22. A total of 85 pointed observations were made, amounting to $\sim$185 ks. The data used in our analysis were in the following modes: “Standard 2,” which has a time resolution of 16 s and covers the 2–60 keV PCA effective energy range with 129 energy channels, and “E125us_64M_0_1s/E64us_64M_0_1s” (event modes), which provide a time resolution of 2$^{-13}$ or 2$^{-14}$ s in 64 energy channels covering the same energy range as the Standard 2 mode.

The Standard 2 data were used to create a light curve, a hardness-intensity diagram (HID) and a color-color diagram (CD). Only data from proportional counter units (PCUs) 0 and 2 were used since these were the only two (of the five) that were always operational during our observations. The observations were background-subtracted, but no dead time corrections were applied ($<3.6\%$). Two colors were defined; a soft color, which is the ratio of counts in the 5.8–10.0 and 2.5–5.8 keV bands (Standard 2 [i.e., 0–128] channels 10–19 and 2–9), and a hard color, which is the ratio of counts in the 13.8–18.4 and 2.5–5.8 keV bands (channels 29–39 and 2–9). The “intensity” used for the HID was the count rate in the 2.5–20.5 keV band (channels 2–44).

Fast Fourier transforms (FFTs) of the event mode data (from all the active PCUs) were performed to create power spectra with a frequency range of 0.0625–4096 Hz in the 7.5–22.2 keV band (“absolute” [i.e., 0–254] channels 15–49). This energy range was chosen since high-frequency variability in black hole low-mass X-ray binaries is in general most significantly detected in a similar energy range—an additional advantage of this energy range is that it does not introduce the instrumental broad high-frequency features found by M. Klein-Wolt, J. Homan, & M. van der Klis (2003, in preparation) in the lowest energy channels. The data were not background-subtracted, and no dead time corrections were applied prior to the FFT; the effects of dead time were accounted for by our power spectral fit function (see below). Power spectra were averaged based on time, colors, or count rate, and normalized according to the recipe described in van der Klis (1995b). Prior to fitting the power spectra, the dead time-modified Poisson level was subtracted using the method of M. Klein-Wolt et al. (2003, in preparation), which uses the analytical function from Zhang (1995) and Zhang et al. (1995) as a basis. They found that this function often fails to describe the high-frequency part of the power spectrum where no contribution from the source is expected and, instead of improving the fit at high frequencies by varying the parameters of this function (which leads to unacceptable values, for example, the instrumental dead time and very large events window), the Zhang function is scaled to provide the best fit to the power spectrum in the 1000–4000 Hz range.

Following a current trend initiated by Olive et al. (1998) and Nowak (2000), we fitted the resulting power spectra with a sum of Lorentzians, each given by $P(\nu) = (r/\Delta)\left[1 + \left(\nu - \nu_0\right)^2\right]^{-1}$, where $\nu_0$ is the centroid frequency, $\Delta$ is the half width at-half-maximum, and $r$ is the integrated fractional rms (from $-\infty$ to $\infty$). Instead of $\nu_0$ and $\Delta$ we will quote the frequency at which the Lorentzian attains its maximum in $\nu P(\nu)$, $\nu_{\text{max}}$, and the quality factor, $Q$, where $\nu_{\text{max}} = \nu_0(1 + 4Q^2)^{1/2}$ and $Q = \nu_0/2\Delta$ (Belloni, Psaltis, & van der Klis 2002). The fractional rms amplitudes quoted in this paper are the integrated power between 0 and $\infty$. Errors on fit parameters were determined using.
\[ \Delta \chi^2 = 1. \] Upper limits on the strength of the Lorentzians were determined by fixing the Q and/or \( \nu_{\text{max}} \), but not the rms amplitude, to values similar to those obtained in another power spectrum and using \( \Delta \chi^2 = 2.71 \) (95% confidence).

3. RESULTS

Figure 1 shows the 2.5–20.5 keV light curve and HID of the outburst of XTE J1650–500. The first few observations were done during the final stages of the rise, when the source was very hard. After reaching a peak on September 10 (day 3), a more or less exponential decline followed, lasting for \( \sim 8 \) days, during which the spectral hardness changed considerably. The period between September 25 (day 18) and October 7 (day 30), which clearly shows up as a dent in the light curve, marks a transition from the hard to the soft state—during this period the day-to-day variations in count rate and hardness were more erratic than before and after, while both show an overall decrease. After this transition the changes were smoother, and around October 17 (day 40) the count rate started to decline exponentially again. A minimum in the hardness was reached around November 1 (day 51). After November 16 (day 70) the source showed a remarkable hardening accompanied by a strong increase in count rate. Part of the decline (\( \sim 20 \) days centered on our last observation) is discussed in Kalemci et al. (2002).

Our initial search for high-frequency variability was conducted by selecting a few groups of power spectra based on their position in the HID with the aim to get an idea of how the variability changed along the track in the HID and also to increase the sensitivity to high-frequency features. Six selections were made whose location in the light curve and HID is indicated by Roman numerals I–VI. The horizontal branch (hereafter hard branch) made up by groups I and II was split in two parts since power spectral properties are known to correlate well with spectral hardness and we wanted to avoid too much smearing of frequencies. Group III represents the transitional zone discussed above, which stands out clearly in both the light curve and HID. Group IV encompasses all the observations in the vertical soft branch and groups V and VI represent the last two observations. We note that, apart from the one between groups I and II, all the group boundaries in the HID coincide with considerable changes in the shape of the low-frequency part of the power spectrum.

Figure 2 shows the power spectra of groups I–III and VI in a \( \nu P(\nu) \) representation—the power spectra of groups IV and V are not shown since at high frequencies they were dominated by statistical errors. A summary of the fit parameters can be found in Table 1. The first three selections all show power at high frequencies, with the most eye-catching feature being the narrow QPO in selection III. The Lorentzian fit to this peak gives a \( \nu_{\text{max}} \) of 250 ± 5 Hz, a \( Q \) value of 5.0 ± 1.2, and an rms amplitude of 5.0 ± 0.4% (6.0 \( \sigma \) detection), making XTE J1650–500 the sixth black hole candidate to show such coherent high-frequency variations. In selections I, II, and VI, high-frequency variability is found at lower frequencies (\( \nu_{\text{max}} = 53–139 \) Hz) with a lower coherence (\( Q = 0.25–1.4 \)), whereas only upper limits could be determined in selections IV and V. Note that for the power spectrum of selection II, two Lorentzians were needed to fit the high-frequency part, one with properties similar to that of selection I and one that was much narrower and at a considerably higher frequency. The properties of the \( \sim 50 \) and 250 Hz features do not change significantly when using the nonscaled Zhang function for the subtraction of the Poisson level.

To determine whether the frequency of the high-frequency variability changed within our selections, we made additional selections on hard and/or soft color. Dividing group III in two parts, based on position in the CD (not shown), we found QPOs with frequencies of 245 ± 5 Hz (\( Q \approx 4.9 \)) and 270 ± 10 Hz (\( Q \approx 5.3 \)), for the spectrally hard and soft part, respectively. This frequency difference has a significance of 2.2 \( \sigma \). Dividing the hard branch, consisting of groups I and II, into four parts reveals that the broad feature around 50 Hz has a frequency consistent (\( \sim 1 \) \( \sigma \)) with

![Figure 1](https://example.com/figure1.png)

**Figure 1.**—(a) Light curve and (b) hardness-intensity diagram of the outburst of XTE J1650–500. Count rates are in the 2.5–20.5 keV band, and the hard color in (b) is the ratio of counts in the 13.8–18.4 keV band and 2.5–5.8 keV bands. Each point represents a 16 s interval. The six groups for the power spectral analysis are indicated by Roman numerals I–VI and are separated by vertical lines in (a) and plotted alternately in black and gray in (b). The general motion of the source in the HID is counterclockwise.
being constant. The $\sim 140$ Hz feature in group II seems to move from $109 \pm 9$ Hz, in the hard part of that group, to $168 \pm 15$ Hz in the soft part. Both these peaks are significantly detected ($>3 \sigma$), have $Q \sim 1$, and have frequencies that are more than $3 \sigma$ apart. Although this might suggest a continuous change in frequency from the hard part of group II to the soft part of group III, we note that the four frequencies detected in the subselections of groups II and III are consistent (within $3 \sigma$) with frequencies that are $1$, $2$, and $3$ times the frequency of the QPO detected in group III, i.e., 250 Hz. Unfortunately, dividing our data into smaller selections to test the presence of intermediate frequencies did not result in significant detections. The 250 Hz QPO is only significantly ($>3 \sigma$) detected in a few of the 33 observations of group III. Combining those individual observations leads to a detection with a significance that is lower than that of the detection in the whole group, suggesting the QPO is also present in (some of) the other observations.

The strength of the 250 Hz QPO seems to increase with energy; rms amplitudes of $<0.85\%$, $4.5\%$, and $<12.1\%$ were found in, respectively, the 2–6.2, 6.2–15.0, and 15.0–60 keV bands.

The low-frequency part of the power spectra also shows considerable changes between the different groups. Except for the first observations, all power spectra of groups I and II show low-frequency QPOs, whose frequency smoothly increases with hardness from $\sim 1$ to $\sim 8$ Hz. The low-frequency part of group III generally show a QPO around 6 and/or 9 Hz, although in a few observations no QPO is detected at all. In groups IV and V no low-frequency QPOs are detected—they reappear in group VI with a frequency of $\sim 5.5$ Hz. In general, the frequencies and $Q$ values of the Lorentzians increase when the spectrum softens and decrease when the spectrum hardens; however, there is clearly no one-on-one relation between hard color and frequencies (see Figs. 1a and 2). Although there is a trend for both the high- and low-frequency QPOs to increase with hardness, the low number of simultaneous detections does not allow us to tell whether they show a tight correlation. We stress once more that large numbers of observations were used for the average power spectrum of each group; a detailed analysis of the structure of the low-frequency part of the power spectrum, and its dependence on energy, is beyond the scope of this work and will be presented elsewhere.

4. DISCUSSION

Our detection of a 250 Hz QPO makes XTE J1650–500 the sixth BHC to show such high-frequency variations. The properties like $Q$ and rms amplitude fall in the range observed for other sources. As was already mentioned in § 1, HF QPOs in black hole systems are predominantly observed when neither the nonthermal nor the thermal component completely dominates the energy spectrum—they have yet to be detected in the soft or hard state. XTE J1650–500 seems to be no exception to this; a preliminary analysis of the energy spectra shows that the 250 Hz QPO was detected when the contribution of the thermal component in the 2–200 keV range varied between $\sim 50\%$ and $\sim 70\%$ ($\sim 10\%–70\%$ when including the marginal detections at $\sim 110$ and $\sim 170$ Hz). Interestingly, this group of observations also bridges the gap between two major branches in our HID, a hard branch (groups I and II) and a soft branch (group IV).
The erratic changes in count rate and hardness in this transitional zone, as opposed to the smooth changes in the soft and hard branches, indicate that part of the accretion flow had become unstable. Although it is not clear from our analysis what part of the accretion flow this would be, our results suggest that the HF QPOs in XTE J1650–500 are enhanced when these instabilities in the accretion flow (with a timescale of apparently hours to days) occur.

In addition to the 250 Hz QPO, we have also found a broad feature around 50 Hz. This feature is present in the hard branch where its frequency was consistent with being constant. At the moment that the 250 Hz QPO was detected, the 50 Hz feature had disappeared, suggesting that at least to some extent the mechanisms behind them are connected. Although the above might suggest that the broad 50 Hz peak had evolved into the QPO at 250 Hz, the two subselections of group II suggest otherwise; they show peaks at ~110 and ~170, which are present simultaneously with the 50 Hz peak. However, the constant frequency of this broad peak is remarkable, especially since the LF QPOs (and possibly also the HF QPOs, see below) show clear changes in their frequency. Four of the eight power spectra of XTE J1650–500 shown in Figure 2 of Kalemci et al. (2002) also show broad peaks, three around 80 Hz and one around 25 Hz, and broad peaks at similar frequencies are also found in GX 339–4 and Cyg X-1 (Nowak 2000). It is not clear whether these broad peaks are the same as the 50 Hz peaks we found.

The frequency behavior of the 250 Hz QPO itself is not clear either. There are indications that the frequency increased from ~110 to ~270 Hz with decreasing spectral hardness, but the four independent frequencies that were measured (~110, ~170, ~245, and ~270 Hz) are also consistent with being 1 : 2 : 3 harmonics of each other. In a sense, this behavior is similar to what was found in XTE J1550–564; also, in that source the frequency of the HF QPO seemed to increase with decreasing spectral hardness (Homan et al. 2001), whereas it was found later by Remillard et al. (2002a) that when combining power spectra according to the type of LF QPO, the majority of the detected HF QPOs appeared to have frequencies that were consistent with being 1 : 2 : 3 harmonics of each other (with the relative strength of the harmonics being related to spectral hardness). However, in XTE J1550–564, HF QPOs were also found at frequencies that did not obey this harmonic relation. We also note that in the case of XTE J1650–500 the relation between HF QPOs and the type of LF QPO is not as strong as in XTE J1550–564, since the power spectra of group III showed considerable changes in the coherence and relative strength of the various low-frequency components, while the frequency and harmonic content of the HF QPO did not change significantly.

Most models proposed to explain HF QPOs in black holes (Nowak et al. 1997; Stella, Vietri, & Morsink 1999; Cui, Zhang, & Chen 1998; Psaltis & Norman 2001; Abramowicz & Kluzniak 2001) have in common that the oscillations are produced in the accretion disc. Some of them predict stable frequencies (Nowak et al. 1997), whereas others interpret them as the black hole counterparts of the kHz QPOs in neutron star sources and try to predict and explain their frequencies with respect to those of the LF QPOs. Unfortunately, the limited number of detections of HF QPOs in this source does not allow us to make strong statements about any of the models. Stable frequencies are still possible if one interprets the different frequencies as harmonics of each other as suggested by Abramowicz & Kluzniak (2001) for the pairs of peaks in GRS 1915+105 and GRO J1655–40. On the other hand, the different frequencies might also reflect real changes in the frequency. As noted by other authors, it might well be possible that more than one of the above mechanisms are at work at once. The broad and possibly stable feature around 50 Hz has not been specifically addressed by the current models.

If we simply interpret the maximum observed frequency of 270 Hz QPO as being due to Keplerian motion at the ISCO of a Schwarzschild black hole, we derive a mass of 8.2 \( M_\odot \). For a black hole with a lower mass no spin is required (and the radius of the Keplerian orbit has to be larger than that of the ISCO), whereas for more massive black holes it is. Since the properties of the broad, skewed Fe K line detected with XMM-Newton (Miller et al. 2002) suggest that the black hole has a near maximum angular momentum, the mass of the black hole might well be much larger than 8.2 \( M_\odot \). Assuming a mass ratio for the companion star and the black hole of 0.1, the derived mass function for the system (Sánchez-Fernández et al. 2002) would then imply an inclination lower than 27°, which is considerably lower than the values derived for GRS 1915+105 (~70°; Greiner, Cuby, & McCaughrean 2001), GRO J1655–40 (~70°; Greene, Bailyn, & Orosz 2001 and references therein), and XTE...
If we assume that the nonmodulated X-ray emission is isotropic, this suggests that the mechanism responsible for the HF QPOs in black hole X-ray binaries does not produce highly beamed modulated radiation.

J. H. acknowledges support from Cofin-2000 grant MM02C71842. J. M. M. is grateful for the support of the NSF. M. K. acknowledges support from the Netherlands Organization for Scientific Research (NWO). W. H. G. L. is grateful for support from NASA.

REFERENCES

Abramowicz, M. A., & Kluzniak, W. 2001, A&A, 374, L19
Belloni, T., Psaltis, D., & van der Klis, M. 2002, ApJ, 572, 392
Bradt, H. V., Rothschild, R. E., & Swank, J. H. 1993, A&AS, 97, 355
Castro-Tirado, A. J., Kilmartin, P., Gilmore, A., Petterson, O., Bond, I., Yock, P., & Sanchez-Fernandez, C. 2001, IAU Circ., 7707, 3
Chen, W., Shrader, C. R., & Livio, M. 1997, ApJ, 491, 312
Cui, W., Shrader, C. R., Haswell, C. A., & Hynes, R. I. 2000, ApJ, 535, L123
Cui, W., Zhang, S. N., & Chen, W. 1998, ApJ, 492, L53
Greene, J., Bailyn, C. D., & Orosz, J. A. 2001, ApJ, 554, 1290
Greiner, J., Cuby, J. G., & McCaughrean, M. J. 2001, Nature, 414, 522
Groot, P., Udalski, A., & Miller, J. 1993, A&AS, 97, 355
Haardt, F., & Maraschi, L. 1993, ApJ, 413, 507
Homan, J., Wijnands, R., van der Klis, M., Belloni, T., van Paradijs, J., Klein-Wolt, M., Fender, R., & Mendez, M. 2001, ApJS, 132, 377
Jahoda, K., Swank, J. H., Giles, A. B., Stark, M. J., Strohmayer, T., Zhang, W., & Morgan, E. H. 1996, Proc. SPIE, 2808, 59
Kalemci, E., Tomsick, J. A., Rothschild, R. E., Pottschmidt, K., Corbel, S., Wijnands, R., Miller, J. M., & Kaaret, P. 2002, ApJ, submitted (astro-ph/0205470)
Lasota, J.-P., Narayan, R., & Yi, I. 1996, A&A, 314, 813
Markoff, S., Falcke, H., & Fender, R. 2001, A&A, 372, L25
Markwardt, C. 2001, Ap&SS, 276, 209
Markwardt, C., Swank, J., & Smith, E. 2001, IAU Circ., 7707, 2
Miller, J. M., et al. 2001, ApJ, 563, 928
———. 2002, ApJ, 570, L69
Morgan, E. H., Remillard, R. A., & Greiner, J. 1997, ApJ, 482, 993
Nowak, M. A. 2000, MNRAS, 318, 361
———. 2002, preprint (astro-ph/0207624)
Nowak, M. A., Wagoner, R. V., Begelman, M. C., & Lehr, D. E. 1997, ApJ, 477, L91
Olive, J. F., Barret, D., Boirin, L., Grindlay, J. E., Swank, J. H., & Smale, A. P. 1998, A&A, 333, 942
Orosz, J. A., et al. 2002, ApJ, 568, 845
Psaltis, D., & Norman, C. 2001, ApJ, submitted (astro-ph/0001391)
Ren, J. H., acknowledges support from Cofin-2000 grant MM02C71842. J. M. M. is grateful for the support of the NSF. M. K. acknowledges support from the Netherlands Organization for Scientific Research (NWO). W. H. G. L. is grateful for support from NASA.

J. H. acknowledges support from Cofin-2000 grant MM02C71842. J. M. M. is grateful for the support of the NSF. M. K. acknowledges support from the Netherlands Organization for Scientific Research (NWO). W. H. G. L. is grateful for support from NASA.