the Novikov-Thorne model and conclude that it is relatively small. We then compare the low spin of LMC X–3 to the spins of several other sources, tentatively concluding that the Compton component is relatively weak for low spin black holes and strong for rapidly spinning ones.

4.1. *Errors from the Novikov-Thorne Model*

While our earlier study of LMC X–3 (Steiner et al. 2010), and similar studies of other black hole binaries (e.g., Gierliński & Done 2004), provide compelling evidence that the inner disk radius is constant in black hole binaries, it does not prove that this radius is in fact $R_{\rm ISCO}$. The central assumption of the thin-disk model is that the viscous torque vanishes at the ISCO and that no flux is emitted from within this radius. This assumption has been tested by several groups using sophisticated general-relativistic magnetohydrodynamic (GRMHD) codes. The results from two groups are exemplified by three key studies, each aimed at testing the reliability of spin estimates. Results from one group are reported in Noble et al. (2011), and from the other in Kulkarni et al. (2011) and Zhu et al. (2012). Both groups produce synthetic observations of their simulations as they would appear to a distant observer at a range of viewing angles.

Although there are subtle differences in the approaches taken by the two groups, one can make a reasonably direct comparison between Kulkarni et al. (2011) and Noble et al. (2011). Both groups used ad hoc but reasonable cooling prescriptions in post-processing to convert magnetic stresses into radiation. By treating the dissipation as local and thermal, disk spectra have been generated for a nonspinning black hole by Noble et al. and for black holes with a range of spins by Kulkarni et al. From these two works, one concludes that spin measurements systematically *overestimate* the spin, that this effect is most pronounced at high inclination, and that the fractional change in $R_{\rm in}$ is independent of a_*. The deviation of $R_{\rm in}/R_{\rm ISCO}$ from unity is of order ten percent. However, the state-of-the-art analysis has been achieved by Zhu et al. (2012), and its findings differ appreciably, as we now discuss.

Zhu et al. include, as an additional post-processing step, full radiative-transfer through the disk atmosphere in generating the simulated GRMHD spectra. In contrast to the $\sim$ 10% shift in $R_{\rm in}/R_{\rm ISCO}$ reported by Kulkarni et al. (2011) and Noble et al. (2011), Zhu et al. find a much smaller deviation because their more sophisticated approach identifies a hard power-law component of emission that is largely produced inside $R_{\rm ISCO}$. It is this component, which in the earlier work was lumped in with the thermal emission, that was largely responsible for the shift in $R_{\rm in}/R_{\rm ISCO}$. Analyzing their simulated spectra using the model in Section 2, Zhu et al. find that the shift in $R_{\rm in}/R_{\rm ISCO}$ is only $\sim 3\% \pm 2\%$ and that it depends only weakly on inclination, α, and luminosity (see Table 2 in Zhu et al. 2012).

In short, deviations from Novikov-Thorne are likely of minor consequence. For the nominal spin of LMC X–3, a 3% offset in $R_{\rm in}$ would imply $a_* \approx 0.16$ (a shift of $\Delta a_* = -0.05$), or a 0.4σ correction to our final result.

4.2. *A Possible Link Between Spin and Spectral Complexity*

Although the spins of more than a dozen stellar-mass black holes have been measured, only two have spins as low as LMC X–3, namely, A0620–00 and H1743-322 (McClintock et al. 2013). The spectra of A0620–00 and LMC X–3 (at luminosities $> 0.05 L_{\rm Edd}$) are remarkably simple, consisting of a dominant thermal component with Compton power-law and reflection components that are always quite faint. The spectrum of H1743–322 is not as consistently simple. However, for a large sample of 65 thermal spectra, the Compton (and reflection) component of this source is very faint with a mean strength of $f_{\rm SC} = 1.2\%$ (Steiner et al. 2009a), weaker than for any other sources with a spin measurement (apart from A0260–00 and LMC X–3).

The simplicity of the spectra of these three sources contrasts sharply with the spectra of the two extreme-spin sources, Cyg X–1 and GRS 1915+105 (McClintock et al. 2013, and references therein), and to a lesser degree the spectrum of LMC X–1 ($a_* = 0.92^{+0.05}_{-0.07}$; Gou et al. 2009). The spectra of these sources are generally complex; i.e., they show strong rms variability (from their power-density spectra), are strongly Comptonized, and contain prominent reflection features. Comparison with the simple spectra of A0620–00, LMC X–3 and H1743–322 suggests that spectral complexity is correlated with spin.

A prediction of this hypothesis is that the spin of GS 2000+25, whose spectral properties (and outburst light curve) are very similar to that of A0620–00 (Terada et al. 2002), is very low, and that the spin of V404 Cyg, whose spectrum was consistently observed to be strongly Comptonized (Tanaka & Lewin 1995), is quite high. One other source may be able to provide a strong test of our prediction: 4U1957+11. Although the spin and mass are presently unknown, there are indications that the former is likely high and the latter likely low (Nowak et al. 2012), while its spectrum is very thermal and generally only weakly Comptonized. Confirmation of an extreme spin for 4U 1957+11 could decisively rule out this hypothesis.

5. CONCLUSIONS

We have analyzed all 1598 spectra of LMC X–3 collected during the *RXTE* mission. Using a selected sample of ≈ 400 spectra, our precise measurement of black hole mass and inclination (Orosz et al. 2014), and the continuum-fitting method, we derive a strong constraint on the spin of the black hole: $a_* = 0.21^{+0.18}_{-0.22}$ (90% confidence). Our comprehensive error estimate takes into account all known sources of uncertainty, e.g., the uncertainties in M, i, D, α, and in the absolute X-ray flux calibration.

The simple and predominately thermal spectra of LMC X–3 and A0620–00, the black holes with the lowest measured spins, contrast sharply with the complex and strongly Comptonized spectra of GRS 1915+105 and Cyg X–1, the two black holes with near-extreme spin. This comparison suggests a possible link between spin and the degree of spectral complexity, a hypothesis that can be tested, and which predicts a low spin for GS 2000+25 and a high spin for V404 Cyg. The black hole 4U 1957+11 may allow a falsification of the hypothesis, if its spin can be measured.