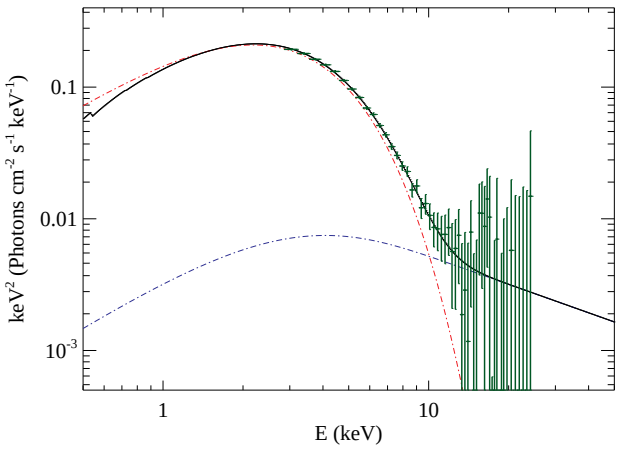

FIG. 1.— A representative fit to a 4 ks exposure of LMC X–3 from 9 December 1998. The black line shows the composite model, including the effects of photoelectric absorption. The red and blue dash-dotted lines show the intrinsic thermal disk and power-law components, respectively.

that the presence of a geometrically-thin, optically-thick disk can be reliably assumed over the luminosity range $L \approx 5 - 30\% L_{\rm Edd}$, where the Eddington-luminosity $L_{\rm Edd} \approx 1.3 \times 10^{38} (M/{\rm M}_\odot)$ erg s^{-1} (McClintock et al. 2013).

3. RESULTS

In our initial run, a total of 391 spectra fulfilling the thermal selection also match this luminosity (thin-disk) criterion. Using the spectra which make both cuts, we obtain a spin $a_* = 0.190 \pm 0.005$ (weighted mean and its 1σ error).

A comprehensive run is now performed to assess the error in spin from uncertainties in the other measurement quantities. For each point along a grid of M, i, and D, we repeat our spectral fits to the pre-selection of 1454 spectra. Mass is sampled from $M : 5 - 11$ M$_\odot$, inclination $i : 60° - 75°$, and $D : 41 - 56$ kpc. The values of $L/L_{\rm Edd}$ depend upon M, i, and D, but typically ~ 400 of these spectra fulfill the luminosity criterion. At *each* gridpoint, the distribution of spin from the selected spectra gives a single, mean spin, and its uncertainty[9]. By applying weights according to the probability of each gridpoint (calculated using the measurements of M, i, and D given in Sections 1,2), results are combined to achieve a composite distribution in spin. This distribution is inclusive of *all measurement errors*.

In previous work, we have assessed the effects of a wide range of systematic errors (Steiner et al. 2010, 2011) and found that only two are significant: the uncertainty in α and the uncertainty in the spectrum of the Crab, which we use as our flux standard (Section 2). We take uncertainty in α into account by repeating the analysis for $\alpha = 0.01$ and $\alpha = 0.1$ and then averaging the spin distributions, weighting them equally. We incorporate a 10% uncertainty in the absolute X-ray flux calibration

[9] As demonstrated in Steiner et al. (2010), the inner disk radius (which corresponds to a particular value of spin) at any grid point has a spread of $< 5\%$, while the mean of the distribution is determined with much greater precision.

TABLE 1
FINAL SPIN DETERMINATION

Confidence Level	Spin Interval	$R_{\rm in}$ Interval
68% (1σ)	$a_* = 0.21 \pm 0.12$	$R_{\rm in}/M = 5.3 \pm 0.4$
90%	$0.21^{+0.18}_{-0.22}$	$5.3^{+0.7}_{-0.6}$
95% (2σ)	$0.21^{+0.21}_{-0.27}$	$5.3^{+0.9}_{-0.8}$
99.7% (3σ)	$0.21^{+0.30}_{-0.44}$	$5.3^{+1.4}_{-1.1}$

NOTE. — Incremental confidence intervals for our final, adopted spin result, which accounts for all sources of error.

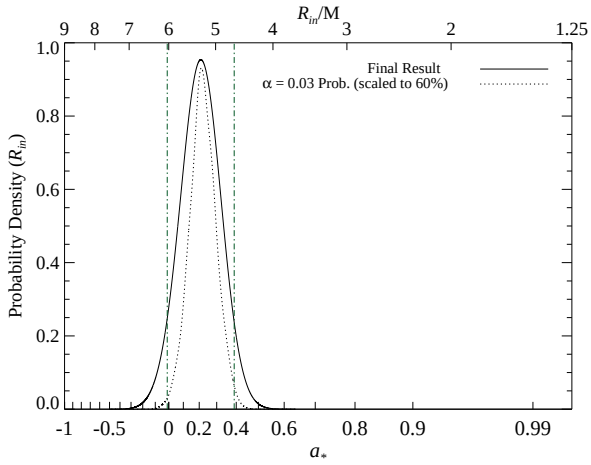

FIG. 2.— The net probability distribution of a_* ($R_{\rm in}$). The abscissa is scaled logarithmically in $R_{\rm in}$, a metric which reflects our measurement scale. The corresponding quantity of chief physical interest, namely a_*, is shown on the lower axis. Our final distribution (solid line) incorporates measurement error and systematic error, most notably uncertainties in the α-viscosity and the absolute flux calibration. The pair of dash-dotted lines indicate the 90% confidence interval. The dotted line shows our result for $\alpha = 0.03$ ignoring the effects of systematic error (where the probability distribution has been rescaled for comparison).

(Toor & Seward 1974) by broadening our distribution in $R_{\rm in}$ using a Gaussian kernel with 5% width. Finally, an additional 2% broadening is used to account for the small variation introduced by adopting a different choice of Comptonization model (Steiner et al. 2010).

The combined result is shown in Figure 2. Our *final* measurement of spin, including all measurement *and* systematic uncertainties is $a_* = 0.21^{+0.18}_{-0.22}$ (90%). For comparison, our measurement without considering systematic errors (using $\alpha = 0.03$) yielded $a_* = 0.21 \pm 0.10$ (90%). Table 1 gives our final determination of spin as measured at several confidence levels, explicitly given because the measurement errors in spin are generally nonlinear.

As a bottom line, LMC X–3 has a precisely determined spin, which is low.

4. DISCUSSION

In Section 3 we considered the effects of all measurement errors and known systematic errors on our estimate of a_* (apart from the assumption that the black hole's spin is aligned with the orbital angular momentum vector; see Section 5.4 in McClintock et al. 2013). In this section we consider the error we incur by our reliance on