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COMPARISON OF STELLAR ANGULAR DIAMETERS FROM THE NPOI, THE MARK III OPTICAL INTERFEROMETER, AND THE INFRARED FLUX METHOD

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ABSTRACT

The Navy Prototype Optical Interferometer (NPOI) has been used to measure the angular diameters of 41 late-type giant and supergiant stars previously observed with the Mark III optical interferometer. Sixteen of these stars have published angular diameters based on model atmospheres (infrared flux method, IRFM). Comparison of these angular diameters shows that there are no systematic offsets between any pair of data sets. Furthermore, the reported uncertainties in the angular diameters measured using both interferometers are consistent with the distribution of the differences in the diameters. The distribution of diameter differences between the interferometric and model atmosphere angular diameters are consistent with uncertainties in the IRFM diameters of 1.4%. Although large differences in angular diameter measurements are seen for three stars, the data are insufficient to determine whether these differences are due to problems with the observations or are due to temporal changes in the stellar diameters themselves.

Key words: stars: atmospheres — stars: fundamental parameters — stars: late-type

1. INTRODUCTION

Over the last decade, interferometers operating in the optical (Mark III and NPOI) and infrared (IOTA and PTI) have been used to compile large surveys of stellar angular diameters (Mozurkewich et al. 1991; Dyck, van Belle & Thompson 1998; van Belle et al. 1999; Nordgren et al. 1999). These observations span the spectral range from λ451 nm (Mark III) to λ2.20 μm (IOTA and PTI). Comparisons of empirical stellar diameters (especially the variation in diameter with wavelength) to predictions from model atmospheres provide an important test of the validity of those models. However, before using diameters from different telescopes observing at different wavelengths, one must first investigate what, if any, systematic difference exists between diameter measurements from different telescopes observing at the same wavelength. Since each new optical interferometer built has explored new wavelength regimes and/or baseline lengths in order to do new science, there have been few opportunities in the past to compare the results of two large surveys conducted at different interferometers of the same objects at similar or identical wavelengths.

At infrared wavelengths, some limited comparisons have been made. Dyck, van Belle, & Thompson (1998) have compared the uniform-disk diameters of a sample of 22 stars observed at 1.65 and 2.2 μm using CERGA, IOTA, and the FLUOR beam-combiner project at IOTA. Dyck, van Belle, & Thompson (1998) found that diameters across these three data sets were not entirely consistent with one another. On a much more limited scale, van Belle et al. (1999) found substantial differences between the angular diameter measurements for two stars in common with PTI and other interferometers. These results raise the question of whether there are systematic differences between angular diameters measured at different interferometers which could indicate systematic differences in the calibration of the data. Now that angular diameters of late-type stars are being measured on a regular basis using the NPOI (Armstrong et al. 1998; Hajian et al. 1998; Nordgren et al. 1999), an extensive comparison of angular diameters can be made between the NPOI and Mark III interferometer (Mozurkewich et al. 1991; Quirrenbach et al. 1993; Mozurkewich et al. 2001), both of which yield data at optical wavelengths $\sim$800 nm.

A recent limited comparison between 14 uniform-disk stellar diameters measured with the NPOI and Mark III showed only marginal agreement (Nordgren et al. 1999). The average difference in the uniform-disk diameters reported was 2.2 $\pm$ 2.5%, the NPOI diameters being systematically smaller. This paper compares a larger sample of 41 stars and shows that the diameters measured by the two instruments are completely consistent with each other. The variation in limb-darkening with wavelength, coupled with the 60 nm difference in effective wavelengths of the two interferometers, is sufficient to account for the slight difference in uniform-disk diameters reported earlier by Nordgren et al. (1999). Furthermore, the limb-darkened diameters from both interferometers are also consistent with the model atmospheres of Blackwell & Lynas-Gray (1994) and Bell & Gustafsson (1989).

2. NPOI OBSERVATIONS AND CALIBRATION

Beginning in 1998 the NPOI began observing those stars previously observed with the Mark III (Mozurkewich et al. 2001) and having angular diameters that could be measured with the NPOI at that time. Forty-one stars in common with the Mark III have been observed. Of these, 14 of the NPOI measurements were previously published in Nordgren et al. (1999).

The detailed observing strategy and data reduction techniques for measuring stellar uniform-disk diameters at the NPOI is described in Nordgren et al. (1999) and is only briefly described here.

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TABLE 1

ANGULAR DIAMETERS FROM THE NPOI AND MARK III

HR No. (1)	Spec. Type (2)	N_i (3)	NPOI θ_U (mas) (4)	LDC$_N$ (5)	NPOI θ_L (mas) (6)	LDC$_M$ (7)	MrkIII θ_L (mas) (8)
165	K3III	4	3.94 ± 0.04	1.076	4.24 ± 0.06	1.071	4.17 ± 0.06
168	K0IIIa	7	5.29 ± 0.05	1.068	5.65 ± 0.08	1.064	5.72 ± 0.08
617	K2IIIab	17	6.47 ± 0.03	1.073	6.94 ± 0.08	1.068	6.84 ± 0.10
1017......	F5Ib	37	2.97 ± 0.01	1.052	3.12 ± 0.03	1.048	3.23 ± 0.05
1373......	G9.5IIICN	4	2.07 ± 0.07	1.067	2.21 ± 0.08	1.064	2.29 ± 0.03
1409......	G9.5III	2	2.26 ± 0.10	1.067	2.41 ± 0.11	1.064	2.67 ± 0.04
1605......	F0Iae+B	3	2.18 ± 0.08	1.048	2.28 ± 0.09	1.044	2.17 ± 0.03
2473......	G8Ib	42	4.46 ± 0.02	1.070	4.77 ± 0.05	1.066	4.78 ± 0.07
2943......	F5IV-V	3	5.19 ± 0.04	1.046	5.43 ± 0.07	1.043	5.46 ± 0.08
2990......	K0IIIb	20	7.44 ± 0.03	1.068	7.95 ± 0.09	1.064	7.97 ± 0.11
3249......	K4III	27	4.75 ± 0.03	1.080	5.13 ± 0.06	1.075	5.20 ± 0.07
3547......	G9IIIa	2	3.08 ± 0.07	1.067	3.29 ± 0.08	1.063	3.18 ± 0.09
3705......	K7IIIab	16	6.92 ± 0.04	1.084	7.50 ± 0.09	1.078	7.59 ± 0.11
3873......	G1II	2	2.56 ± 0.09	1.055	2.70 ± 0.10	1.051	2.60 ± 0.05
4069......	M0III	3	8.00 ± 0.03	1.086	8.69 ± 0.09	1.080	8.55 ± 0.12
4301......	K0-IIIa	25	6.47 ± 0.03	1.068	6.91 ± 0.08	1.064	7.11 ± 0.10
4335......	K1III	3	3.81 ± 0.05	1.071	4.08 ± 0.07	1.066	4.12 ± 0.06
4377......	K3III	2	4.42 ± 0.05	1.076	4.76 ± 0.07	1.071	4.71 ± 0.07
4434......	M0IIICaI	33	5.87 ± 0.03	1.086	6.37 ± 0.07	1.080	6.47 ± 0.09
4517......	M1III	15	5.18 ± 0.03	1.090	5.65 ± 0.07	1.083	6.26 ± 0.10
4932......	G8IIIab	9	3.03 ± 0.03	1.066	3.23 ± 0.05	1.063	3.28 ± 0.05
5235......	G0IV	15	2.17 ± 0.06	1.052	2.28 ± 0.07	1.049	2.17 ± 0.03
5602......	G8IIIaFe	8	2.33 ± 0.07	1.066	2.48 ± 0.08	1.063	2.47 ± 0.04
5681......	G8III	9	2.59 ± 0.02	1.066	2.76 ± 0.03	1.063	2.75 ± 0.04
5854......	K2IIIb	1	4.50 ± 0.07	1.073	4.83 ± 0.09	1.068	4.78 ± 0.07
6132......	G8IIIab	3	3.13 ± 0.06	1.066	3.34 ± 0.07	1.063	3.68 ± 0.05
6148......	G7IIIaFe	14	3.32 ± 0.07	1.064	3.53 ± 0.08	1.061	3.51 ± 0.05
6212......	G0IV	3	2.37 ± 0.08	1.052	2.49 ± 0.09	1.049	2.33 ± 0.05
6220......	G7III	4	2.35 ± 0.07	1.064	2.50 ± 0.08	1.061	2.64 ± 0.04
6418......	K3II	7	4.87 ± 0.02	1.080	5.26 ± 0.06	1.075	5.27 ± 0.07
7310......	G9III	4	3.10 ± 0.05	1.067	3.31 ± 0.06	1.063	3.27 ± 0.06
7525......	K3II	12	6.63 ± 0.03	1.080	7.16 ± 0.08	1.075	7.24 ± 0.10
7735......	K2II+B3V	20	4.17 ± 0.03	1.077	4.49 ± 0.06	1.072	4.47 ± 0.06
7751......	K3Ib+B3V	11	4.78 ± 0.10	1.080	5.16 ± 0.12	1.075	5.46 ± 0.08
7796......	F8Ib	7	2.87 ± 0.04	1.048	3.01 ± 0.05	1.045	3.03 ± 0.04
8079......	K4.5Ib-II	25	5.19 ± 0.03	1.083	5.61 ± 0.12	1.078	5.80 ± 0.13
8308......	K2Ib-II	3	7.58 ± 0.03	1.078	8.17 ± 0.09	1.073	7.54 ± 0.14
8414......	G2Ib	5	2.94 ± 0.03	1.059	3.11 ± 0.04	1.056	3.20 ± 0.05
8465......	K1.5Ib	3	4.94 ± 0.04	1.077	5.32 ± 0.07	1.072	5.30 ± 0.07
8650......	G2II-III	64	3.06 ± 0.02	1.057	3.23 ± 0.07	1.054	3.26 ± 0.07
8684......	G8III	3	2.37 ± 0.08	1.066	2.53 ± 0.09	1.063	2.49 ± 0.04

Observations with the NPOI alternate between program stars and calibration stars. For each star, squared visibilities are measured every 2 ms for 90 s in each of 32 spectral channels on each of three baselines. These squared visibilities are averaged to yield 90 s scan squared visibilities. For this project, only high signal-to-noise visibilities in the reddest spectral channels are used. The observations have a mean wavelength of 740 nm and cover the spectral range 649 to 849 nm in 10 channels evenly spaced in wave number. As in Nordgren et al. (1999), for small stars (≤ 3 mas) only visibilities obtained on the longest baseline (38 m) are used. For larger stars (>3 mas), where visibilities from this baseline fall near the first null in the visibility function, data from all three baselines are used to constrain the diameter.

To account for the partial resolution of the calibrator, the squared visibility is divided by the expected squared visibility based upon the calibrator's estimated uniform-disk diameter and the projected baseline of the interferometer. The estimated diameter is determined from the surface brightness relations of Mozurkewich et al. (1991). Each squared visibility from each scan of the program star is divided by the squared visibility (corrected for partial resolution) from the scan of the calibrator star taken nearest to it in time (Nordgren et al. 1999).

A uniform-disk diameter is fitted to each calibrated scan of the program star. The mean uniform-disk diameter and standard deviation of the mean is found from the ensemble of all independent scan diameters acquired for a given program star (Nordgren et al. 1999). Using a sample of 50 stars with diameters in the range of 1.5 to 6.5 mas, Nordgren et al. (1999) found a simple relation between the uniform-disk diameter and its uncertainty: $\sigma = 0.308/\theta_U$. In the event that a small number of independent scans (≤ 4) were obtained for a particular star (and therefore that the standard deviation of the mean might not adequately represent the uncertainty in the diameter), the standard deviation of the mean is found from this relation. For each program star listed in Table 1, column (3) is the number of scans obtained with the NPOI (N_i), while column (4) lists the uniform-disk diameter (θ_U) and its uncertainty.

2.1. *Limb-Darkening*

A review of the method used to convert uniform-disk diameters to limb-darkened diameters is given here, while the details of the numerical code associated with the method will appear in a separate paper (Sudol 2001). In this method, a uniform-disk of variable radius and intensity is fitted to a limb-darkened disk in such a manner that the differences between the visibility profiles of the two disks, out to the first null, are minimized, and the total integrated intensities of the two disks are equal.

Quadratic limb-darkening coefficients from Claret, Diaz-Cordoves, & Gimenez (1995) are used to produce a grid of correction terms for 410 model stellar atmospheres ranging from 0.0 to 5.0 in steps of 0.5 in surface gravity [$\log(g)$] and 3500 to 50000 K in steps of 250 K in effective temperature (T_e) in each of the Johnson *UBVRIJHK* bands. For each model $\log(g)$ and T_e, a cubic spline interpolation of the correction terms as a function of wavelength is performed in order to obtain correction terms at 740 nm, the mean wavelength of the observations using the NPOI. For all but the least compact (low surface gravity) and coolest stars (low effective temperature), the correction terms appear to follow a smooth, monotonic function of wavelength. This monotonicity breaks down for stars cooler than M3 where strong TiO absorption bands yield quite different angular diameters as a function of wavelength (Quirrenbach et al. 1993). For this reason, the present sample has been restricted to stars earlier than M3, while the sensitivity of the NPOI restricts the sample to stars later than A.

Spectral types for each star in the sample are obtained from Keenan & McNeil (1989) or from the Bright Star Catalogue (Hoffleit & Jaschek 1982). The spectral type for HR 1017, which is not found in either of these catalogs, is from Morgan (1972). Based on spectral type and Appendices 3 and 4 of Straizys & Kuriliene (1981), a $\log(g)$ and T_e is assigned to each star, interpolating in a linear fashion where necessary. These assigned values of $\log(g)$ and T_e were almost all intermediate to the $\log(g)$ and T_e values in the grid of model atmospheres, so a simple bilinear interpolation of the correction terms is performed for the four models closest in $\log(g)$ and T_e to each star. The variations in correction terms from one model to the next across the four closest models were generally quite small, on average 0.004, and always less than 0.01. The process resulted in correction terms with a precision of ± 0.004. For those stars of "mixed" luminosity class, for example K4.5 Ib-II in the case of HR 8079, and where the assigned values of $\log(g)$ and T_e are largely uncertain, we assign a precision of ± 0.010 to the correction term.

For the 14 stars found in Nordgren et al. (1999), where a different method for determining limb-darkening diameters was used, we have used the quoted uniform-disk angular diameter and recalculated the limb-darkened diameters. For six of those stars, HR 1017, 3249, 4932, 6220, 7525, and 7796, new data were available since the publication of Nordgren et al. (1999), so new values of θ_U were calculated. In each case the difference between the previously published value and the new value is well within the uncertainty in θ_U.

Column (5) of Table 1 lists the limb-darkening correction factor for the NPOI observations (LDC_N), while column (6) lists the resulting limb-darkened diameter (θ_L).

3. COMPARISON OF NPOI AND MARK III ANGULAR DIAMETERS

Between 1988 and 1990 Mozurkewich et al. (2001) observed a sample of 82 stars (2 mas $< \theta <$ 20 mas) using the now decommissioned Mark III interferometer on Mount Wilson. The Mark III observed using discrete, narrowband spectral filters. The most appropriate bandpass for this comparison is their 800 nm filter (which is closest to the NPOI bandpass, differing by only 60 nm, while also providing the highest precision results). But even with matching the wavelengths this closely, the precision of both instruments is good enough that the difference between the measured diameters is dominated by differential limb-darkening between the wavelengths and, possibly, the details of how the limb-darkening corrections have been performed. To address this possibility, new limb-darkened diameters have been calculated from the Mark III uniform-disk diameters of Mozurkewich et al. (2001) using the same procedure outlined in the previous section but at a wavelength of 800 nm. The Mark III limb-darkening correction terms (LDC_M) and the Mark III limb-darkened diameters adopted here are listed in columns (7) and (8) of Table 1.

In Table 2, column (2) is the differences between the NPOI and Mark III limb-darkened diameters ($\Delta\theta_L =$ Mark III $\theta_L -$ NPOI θ_L) in milliarcseconds; column (3) is $\Delta\theta_L$ as a percent of the average θ_L; and column (4) is the deviation ($\Delta\theta_L/\sigma$): the diameter difference divided by the uncertainties in the NPOI and Mark III θ_L added in quadrature.

In order to determine whether the diameters from the two interferometers are consistent, the mean difference in the diameter, $\langle\Delta\theta_L\rangle$, must be less than the rms scatter about zero difference, which must, in turn, be representative of the precision of the individual diameters. With respect to the first requirement, Figure 1 shows $\Delta\theta_L$ as a function of the NPOI θ_L. The mean difference between the two telescopes is 0.6%. The rms scatter of the sample about the mean is $\pm 4.0\%$. This result is consistent with zero difference.

The second requirement is whether the distribution of $\Delta\theta_L$ is consistent with the distribution of the diameter uncertainties. For the 41 stars in common between the Mark III and NPOI the reduced χ^2 fit to zero difference (χ^2_ν) for the deviations in column (4) of Table 2 is 2.24. This result is dominated, however, by only three stars which have deviations greater than 3 σ (HR 4517, 6132, 8308). If these three stars are removed from the sample $\chi^2_\nu = 0.96$ and $\langle\Delta\theta_L\rangle =$ $0.3 \pm 3.0\%$. Figure 2 shows a histogram of the deviations, folded about zero and overlaid with a unit width Gaussian. The core of the distribution is a good fit to a Gaussian, but the wing is slightly elevated by the three stars previously noted.

Following the analysis of Dyck, van Belle, & Thompson (1998), Figure 3 plots the limb-darkened diameters of the NPOI and Mark III against one another. The solid line is the linear least-squares fit to the data. The slope, which is equal to one for identical data sets, is 1.000 ± 0.016. The *y*-intercept, which is zero for identical data sets, is -0.02 ± 0.08 mas.

We conclude from this analysis that (1) there is no systematic difference between the diameter measurements

TABLE 2

DIAMETER DIFFERENCES BETWEEN NPOI AND MARK III

HR No. (1)	$\Delta\theta_L$ (mas) (2)	$\Delta\theta_L$ (percent) (3)	$\Delta\theta_L/\sigma$ (4)
165	-0.07 ± 0.08	-1.6	-0.82
168	0.07 ± 0.11	1.3	0.65
617	-0.10 ± 0.12	-1.5	-0.85
1017	0.10 ± 0.06	3.3	1.85
1373	0.08 ± 0.08	3.6	0.95
1409	0.26 ± 0.12	10.2	2.24
1605	-0.11 ± 0.09	-5.0	-1.19
2473	0.01 ± 0.09	0.2	0.12
2943	0.03 ± 0.10	0.5	0.28
2990	0.02 ± 0.14	0.3	0.16
3249	0.07 ± 0.10	1.4	0.73
3547	-0.10 ± 0.12	-3.2	-0.84
3705	0.09 ± 0.14	1.2	0.67
3873	-0.10 ± 0.11	-3.7	-0.90
4069	-0.14 ± 0.15	-1.6	-0.90
4301	0.20 ± 0.13	2.9	1.61
4335	0.04 ± 0.09	1.0	0.44
4377	-0.05 ± 0.10	-1.0	-0.48
4434	0.10 ± 0.12	1.5	0.84
4517	0.61 ± 0.12	10.3	5.04
4932	0.05 ± 0.06	1.4	0.69
5235	-0.11 ± 0.07	-4.9	-1.48
5602	-0.01 ± 0.09	-0.4	-0.13
5681	-0.01 ± 0.05	-0.4	-0.23
5854	-0.05 ± 0.11	-1.1	-0.48
6132	0.34 ± 0.09	9.7	3.80
6148	-0.02 ± 0.10	-0.6	-0.21
6212	-0.17 ± 0.10	-6.9	-1.65
6220	0.14 ± 0.09	5.4	1.56
6418	0.01 ± 0.09	0.1	0.06
7310	-0.04 ± 0.09	-1.2	-0.45
7525	0.08 ± 0.13	1.1	0.61
7735	-0.02 ± 0.08	-0.5	-0.25
7751	0.30 ± 0.14	5.6	2.08
7796	0.02 ± 0.07	0.6	0.26
8079	0.18 ± 0.17	3.1	1.01
8308	-0.63 ± 0.17	-8.0	-3.75
8414	0.09 ± 0.07	2.7	1.22
8465	-0.02 ± 0.10	-0.4	-0.19
8650	0.03 ± 0.10	0.9	0.30
8684	-0.04 ± 0.10	-1.5	-0.40
Mean	0.03 ± 0.18	0.6 ± 4.0	0.29

made at the NPOI and Mark III, (2) there is no systematic error due to the size of the star (i.e., $\Delta\theta_L$ does not correlate with θ_L), (3) the quoted uncertainties are a good estimate of the accuracy for most of the measurements, and (4) only three stars (less than 10% of the sample) have larger deviations than expected. The data are insufficient to comment on the nature (or cause) of these deviations.

4. COMPARISON OF INTERFEROMETRY TO INFRARED FLUX METHOD

While the results from both interferometers agree quite well, it is possible that there is a systematic error common to both interferometers that the previous analysis would not reveal. There is not a third interferometer operating in the optical bandpass with the same resolution, but a comparison can be made against a set of angular diameters calculated using the infrared flux method (IRFM). Between the IRFM results of Blackwell & Lynas-Gray (1994) and Bell & Gustafsson (1989) there are 16 stars in common with the NPOI/Mark III sample. Repeating the analysis of the previous section, Table 3 presents the IRFM diameters, differences and deviations with respect to each interferometer. Columns (3)–(5) are with respect to the NPOI and denoted by $\Delta\theta_{L,N}$, while columns (6)–(8) are with respect to the Mark

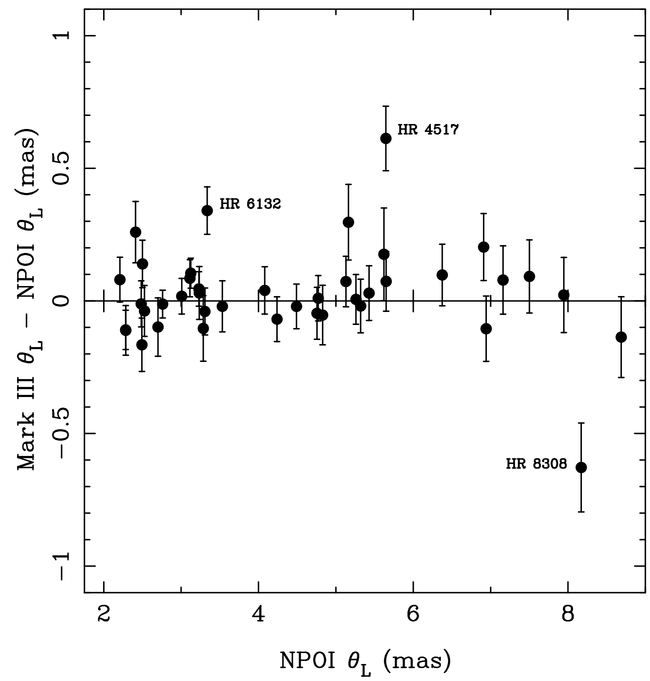

FIG. 1.—Limb-darkened diameter differences between the NPOI and Mark III interferometers. The difference (Mark III θ_L − NPOI θ_L) in milliarcseconds is plotted against the NPOI diameter (NPOI θ_L). Three stars, HR 4517, 6132, and 8303, show large differences.

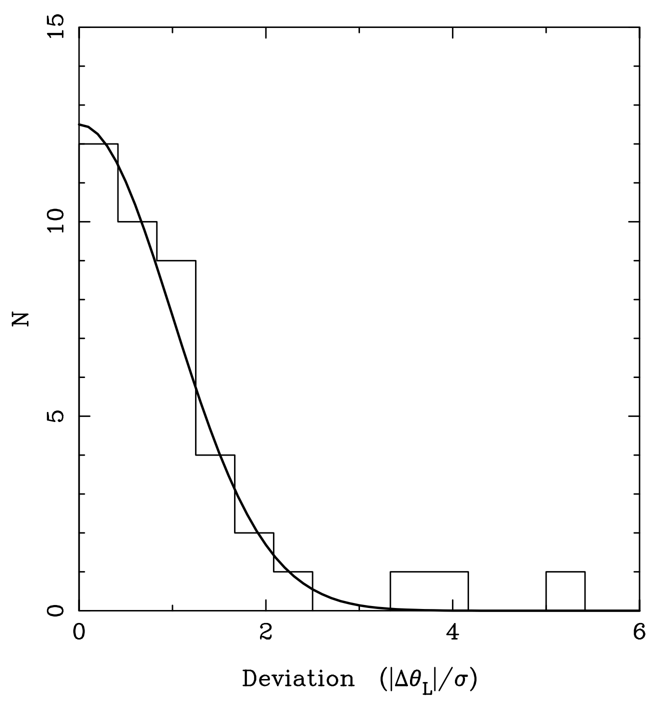

FIG. 2.—Histogram of diameter deviations. The diameter differences are divided by the quadrature sum of the diameter uncertainties. The solid line is a Gaussian curve with unit width.

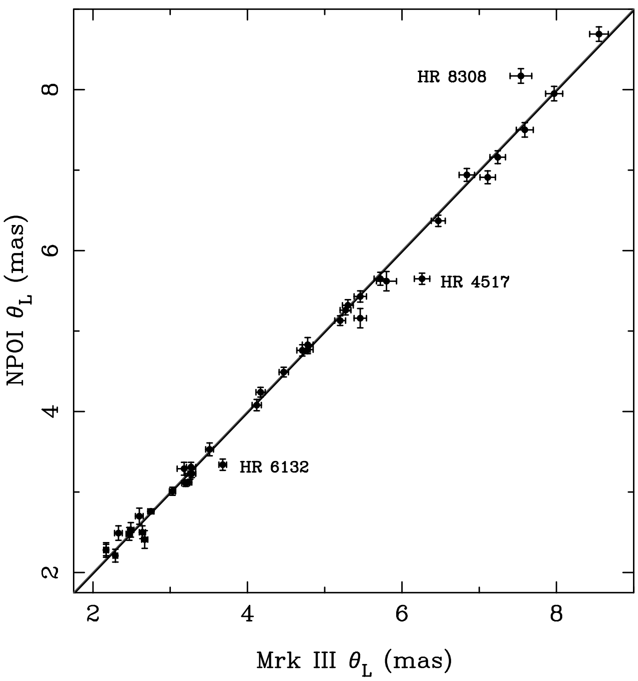

FIG. 3.—Mark III θ_L vs. NPOI θ_L. The line is the linear least-squares fit to the data: $\theta_{\rm NPOI} = 1.000(\pm 0.016) \times \theta_{\rm MarkIII} - 0.02(\pm 0.08)$.

III and denoted by $\Delta\theta_{L,M}$). An uncertainty of 4% is assumed for the IRFM diameters (Blackwell & Lynas-Gray 1994). Note that for HR 6132, one of the three stars with an unusually large deviation in Figures 1 and 2, the IRFM diameter is consistent with the NPOI diameter.

The mean difference between the IRFM and NPOI limb-darkened diameters is $-0.4 \pm 2.8\%$, with $\chi^2_\nu = 0.40$. The mean difference between the IRFM and Mark III limb-darkened diameters is $-1.3 \pm 3.0\%$, with $\chi^2_\nu = 0.60$. While the mean difference between the IRFM and NPOI is half that of the IRFM with respect to the Mark III, the rms

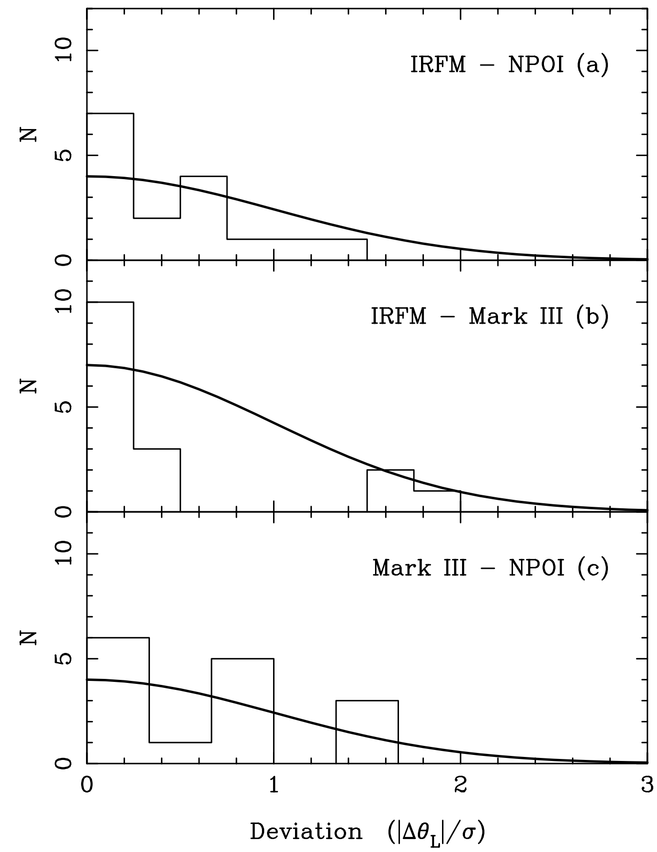

FIG. 4.—Histogram of diameter deviations for the 16 stars in common between the IRFM, NPOI, and Mark III. The three panels compare (*a*) IRFM to NPOI, (*b*) IRFM to Mark III, and (*c*) Mark III to NPOI. Solid lines are Gaussian curves with unit width.

scatters are nearly identical to each other and to the scatter between interferometers. The first two panels of Figure 4 show a histogram of the deviations of the IRFM with respect to each of the interferometers. The bottom panel

TABLE 3

DIAMETER DIFFERENCES BETWEEN IRFM AND INTERFEROMETRY

HR No. (1)	IRFM θ_L (mas) (2)	$\Delta\theta_{L,N}$ (mas) (3)	$\Delta\theta_{L,N}$ (percent) (4)	$\Delta\theta_{L,N}/\sigma$ (5)	$\Delta\theta_{L,M}$ (mas) (6)	$\Delta\theta_{L,M}$ (percent) (7)	$\Delta\theta_{L,M}/\sigma$ (8)
165	4.131	-0.11 ± 0.18	-2.6	-0.62	-0.04 ± 0.18	-1.0	-0.22
617	6.910	-0.03 ± 0.29	-0.5	-0.11	0.07 ± 0.29	1.1	0.25
1373	2.262	0.05 ± 0.12	2.4	0.45	-0.03 ± 0.10	-1.2	-0.28
2473	4.769	-0.01 ± 0.20	0.1	-0.02	-0.01 ± 0.20	-0.3	-0.06
2990	8.028	0.08 ± 0.33	1.0	0.25	0.06 ± 0.34	0.7	0.18
3249	5.170	0.04 ± 0.22	0.8	0.19	-0.03 ± 0.22	-0.6	-0.15
4932	3.300	0.07 ± 0.14	2.1	0.50	0.02 ± 0.14	0.8	0.18
5235	2.210	-0.07 ± 0.11	-3.2	-0.66	0.04 ± 0.09	1.7	0.39
5602	2.461	-0.02 ± 0.13	-0.9	-0.18	-0.01 ± 0.11	-0.5	-0.11
5681	2.769	0.01 ± 0.12	0.3	0.07	0.02 ± 0.12	0.7	0.17
6132	3.438	0.10 ± 0.16	3.0	0.65	-0.24 ± 0.15	-6.7	-1.62
6148	3.481	-0.05 ± 0.16	-1.5	-0.32	-0.03 ± 0.15	-0.9	-0.21
6220	2.610	0.11 ± 0.13	4.3	0.84	-0.03 ± 0.11	-1.1	-0.26
8414	2.972	-0.14 ± 0.13	-4.6	-1.11	-0.23 ± 0.13	-7.3	-1.74
8650	3.030	-0.20 ± 0.14	-6.5	-1.47	-0.23 ± 0.14	-7.4	-1.66
8684	2.503	-0.02 ± 0.13	-0.9	-0.17	0.01 ± 0.11	0.6	0.14
Mean	...	-0.01 ± 0.09	-0.4 ± 2.8	-0.11	-0.04 ± 0.10	-1.3 ± 3.0	-0.31

NOTE.—All IRFM diameters from Blackwell & Lynas-Gray 1994 except for HR 617, HR 3249, HR 4932, and HR 6220 from Bell & Gustafsson 1989.

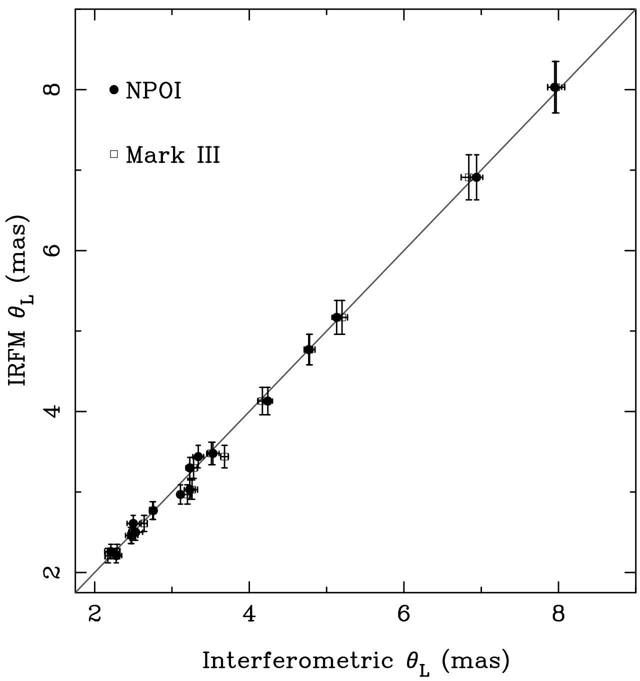

FIG. 5.—Interferometric diameters vs. model atmosphere diameters. Circles show the NPOI vs. IRFM. Squares show the Mark III vs. IRFM. The solid line shows the one-to-one correspondence.

compares the NPOI and Mark III for the sixteen stars in common with the IRFM. Figure 5 reproduces Figure 3 in plotting the calculated IRFM diameters versus those measured from interferometry. The solid line shows the one-to-one correspondence.

The small values of χ_ν^2 with respect to both interferometers indicates that the scatters with respect to the IRFM are less than what the combined uncertainty would indicate. Since Blackwell & Lynas-Gray (1994) acknowledge that a 4% error in the IRFM diameters is conservative, we have found the percent error in the IRFM diameter necessary to yield a χ_ν^2 of unity. For the NPOI comparison an IRFM diameter uncertainty of 0.9% yields $\chi_\nu^2 = 1$, while the Mark III comparison yields an IRFM diameter uncertainty of 1.9%. Taking an average of these two results yields an IRFM diameter uncertainty of 1.4%. We may conclude from the comparisons between the Mark III, NPOI and IRFM that (1) there is no systematic difference between the interferometric results and model atmospheres, and (2) there is evidence that the diameter estimates of the IRFM are more precise by a factor of ~ 3 than that reported by Blackwell & Lynas-Gray (1994).

5. CONCLUSION

There is no evidence of any systematic difference between angular diameters of 41 stars measured using both the NPOI and Mark III interferometers. Furthermore, the reported uncertainties in the angular diameters measured using both interferometers are consistent with the distribution of the differences in the diameters. Sixteen of the stars in this sample have published angular diameters determined using the infrared flux method. Comparison of these angular diameters with diameters from the two interferometers shows that there are no systematic differences between any pair of data sets. The distribution of diameter differences between the interferometric and model atmosphere angular diameters are consistent with uncertainties in the IRFM diameters of 1.4%. Although large differences in angular diameter measurements are seen for three stars, the data are insufficient to determine whether these differences are due to problems with the observations or are due to temporal changes in the stellar diameters themselves.

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