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CLOSE BINARIES WITH INFRARED EXCESS: DESTROYERS OF WORLDS?

M. Matranga [1], J. J. Drake[1], V. L. Kashyap[1], M. Marengo [2], and M. J. Kuchner [3]
[1] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA
[2] Department of Physics and Astronomy, Iowa State University, Ames, IA 50011, USA
[3] NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory Greenbelt, MD 20771, USA

veys at 70 μm and a disk fraction of 10% for F, G, and K stars with ages up to 3 Gyr or so (Bryden et al. 2006; Hillenbrand et al. 2008).

One other group of stars with IR excesses has remained inconspicuous. The RS CVn class of tidally interacting close binaries, in which at least one component has generally reached the sub-giant evolutionary phase (Hall 1976), was discovered by IRAS to have an IR excess occurrence rate of about 40%—twice as high as main-sequence stars and 3–4 times higher than giants (Busso et al. 1987, 1988; Scaltriti et al. 1993; and references therein). The observed excesses typically amounted to several percent of the stellar bolometric luminosity and corresponded unusually large 4% of its bolometric luminosity and has an unusually high temperature of 650 K (Song et al. 2005). Song et al. (2005), Rhee et al. (2008), and Zuckerman et al. (2008) suggest the warm dust in BD +20 307 likely arises from recent pulverizing collisions between planets or planetesimals. That such close binaries can harbor planetary systems has been demonstrated by the planet around HW Vir (Lee et al. 2009).

Here, we present a Spitzer photometric survey of a small sample of 10 RS CVns to probe deeper into the purported IR excesses of this class.

2. OBSERVATIONS AND DATA ANALYSIS

The data presented in this Letter were obtained by the Spitzer Space Telescope (Werner et al. 2004; Gehrz et al. 2007) as part of the General Observing program PID 20713. Infrared Array Camera (IRAC; Fazio et al. 2004) observations were made in High Dynamic Range mode between 2005 July and December. Targets were observed in 3.6, 4.5, 5.8, and 8.0 μm bands for 12 s in each position of a 12 point Reuleaux pattern dither map, for a total effective integration time of 124.8 s. Multiband Imaging Photometer (MIPS; Rieke et al. 2004) observations were obtained in the 24, 70, and 160 μm bands in photometry mode between 2005 November and 2007 January, with an exposure time of 10 s, repeated for two cycles (24 μm) or three cycles (70 and 160 μm). Reduced image mosaics were

Table 1
Summary of Photometric Data for the Program Stars

Target	Magnitude						Excess	
	3.6 μm	4.5 μm	5.8 μm	8.0 μm	24 μm	70 μm	L_{dust}/L_{bol} (10^{-2})•	Prev. Work
AR Lac[15,3]	4.23 ± 0.02	4.28 ± 0.03	4.24 ± 0.03	4.25 ± 0.03	4.07 ± 0.08	> 3.06	< 2.0	...
AR Psc[1,2]	4.82 ± 0.03	4.87 ± 0.03	4.83 ± 0.03	4.81 ± 0.03	4.69 ± 0.05	> 3.26	$1.5^{+0.4}_{-0.4}$	...
CF Tuc[3,4]	5.38 ± 0.03	5.42 ± 0.03	5.41 ± 0.04	5.37 ± 0.04	5.20 ± 0.05	4.65 ± 0.51	< 2.3	Y[a,b]
II Peg[2,5,6]	4.53 ± 0.03	4.56 ± 0.03	4.54 ± 0.04	4.51 ± 0.04	4.28 ± 0.04	3.75 ± 0.56	$19^{+0.5}_{-0.4}$	Y[b,c]
TY Pyx[7]	5.20 ± 0.03	5.27 ± 0.03	5.26 ± 0.03	5.26 ± 0.04	...	...	< 1.7	N[d]
UV Psc[8]	7.22 ± 0.04	7.19 ± 0.04	7.22 ± 0.05	7.13 ± 0.05	6.99 ± 0.07	> 4.50	< 1.9	...
UX Ari[2,3,9]	3.92 ± 0.03	3.91 ± 0.02	3.87 ± 0.02	3.89 ± 0.02	3.54 ± 0.04	3.09 ± 0.30	$0.7^{+0.2}_{-0.2}$	Y[e] - N[a]
V471 Tau[10,11]	7.19 ± 0.03	7.20 ± 0.03	7.18 ± 0.04	7.15 ± 0.04	7.05 ± 0.07	> 2.55	< 2.4	...
WY Cnc[12,13]	7.44 ± 0.03	7.45 ± 0.04	7.41 ± 0.05	7.40 ± 0.05	7.31 ± 0.07	> 2.97	< 2.2	Y[b]
XY Uma[14]	7.16 ± 0.02	7.17 ± 0.03	7.15 ± 0.05	7.11 ± 0.04	7.13 ± 0.07	> 3.42	< 1.9	...

Notes. MIPS magnitudes from aperture photometry using the following source radii and sky background annuli: 16 μm: 7.0 source, 18–39 background, and aperture correction factor 2.04. 24 μm: 13 source (6 for V471 Tau), 20–32 background, and aperture correction factor 1.17 (1.70 for V471 Tau). • Measured dust luminosity values and 3σ upper limits.
References. BVRIJHK photometry: (1) Cutispoto et al. 2001; (2) Messina 2008; (3) Busso et al. 1988; (4) Cutispoto 1991; (5) Scaltriti et al. 1993; (6) Byrne et al. 1998; (7) Busso et al. 1987; (8) Kjurkchieva et al. 2005; (9) Alekseev & Kozhevnikova 2004; (10) Ibanoglu 1989; (11) Ibanoglu et al. 2005; (12) Milano et al. 1986; (13) Heckert et al. 1998; (14) Kjurkchieva et al. 2000; (15) Rodono et al. 1986. Previous work excesses from the literature: (a) Busso et al. 1988; (b) Scaltriti et al. 1993; (c) Rodono et al. 1998; (d) Busso et al. 1987; (e) Verma et al. 1983.

Our analysis procedure was similar to that followed by Busso et al. (1987, 1988); Scaltriti et al. (1993) and involved comparison of stellar model fluxes, fitted to observed optical and near-IR photometry, with the *Spitzer* IR photometry. For each binary listed in Table 1, we modeled BVRIJHK photometry culled from literature with a spectral energy distribution (SED) model comprising the sum of two Kurucz photospheric models[4] (one for each stellar component in the case of double-lined spectroscopic binaries, weighted by stellar radius and effective temperature according to $r^2 T_{eff}^4$). Since surface spots resulting from magnetic activity on RS CVns can give rise to detectable secular photometric changes (thus leading to some having been designated as variables), we adopted photometric uncertainties that generally encompassed observed ranges of variations for each star. For dwarfs stars, we adopted the effective temperature—radius relation of Gray (1992) with initial values for effective temperature from the literature; for more evolved components, we culled values for temperature, radius and mass, and surface gravity from the literature. Final radius and effective temperature model parameters for each system were honed by exploring the grid of Kurucz models using a χ^2 minimization.

Final stellar parameters are listed in Table 2. Comparison of adopted Kurucz models with *Spitzer* photometry revealed satisfactory fits for all but the three sources: AR Psc, II Peg, and UX Ari. For these systems, no combination of Kurucz photospheres could reproduce the measured IRAC and MIPS fluxes: in all three cases, the observed IR fluxes were too high compared to the predicted model fluxes. Including a blackbody as an additional component, fitting the temperature and normalization as free parameters (see Table 2), greatly improved the SED model fits. Results are illustrated in Figure 1, together with *IRAS* Faint Source Catalog v2.0 12 μm fluxes.[5] In agreement with earlier studies (e.g., Scaltriti et al. 1993), the best-fit blackbody temperatures lie in the range 1300–1900 K with an uncertainty of 200–300 K. The low-level 70 μm emission in II Peg is consistent with the long wavelength tail of the hot blackbody excess, while that for UX Ari hints at the possible presence of additional cold dust. For other binaries that do not show a detectable IR excess, we have estimated 3σ upper limits. Assuming a nominal blackbody temperature of 1500 K, we find that for these systems the blackbody luminosity must be less than 2%–25% of the bolometric luminosity (see Table 1).

Table 2
Stellar Parameters and Best-fit Model Results

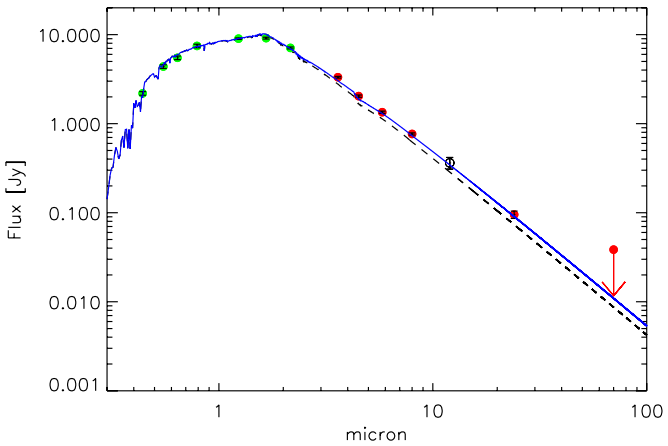
Target	Sp. Type[a]	P (day)[a]	Best-fit Models			
			Photospheres		Dust	
			T_{eff} (K)[b]	R_2/R_1	T_{BB} (K)[c]	T_{grain} (K)[d]
AR Lac	G2IV/K0IV	1.98	5750/4750	2.4	...	...
AR Psc	K1IV/G7V	12.25	4500/5250	0.8	1900^{+300}_{-300}	1400^{+250}_{-300}
CF Tuc	G0V/K4V	2.80	6500/4750	3.1	...	...
II Peg	K2IV/M2V	6.71	4500	...	1700^{+250}_{-300}	1200^{+200}_{-200}
TY Pyx	G5IV/G5IV	3.20	5750/5500	0.6	...	...
UV Psc	G5V/K2V	0.86	5500/5250	1.1	...	...
UX Ari	G5V/K0IV	6.44	5250/4750	3.6	1300^{+200}_{-200}	...
V471 Tau	K2V/DA	0.52	5500	...	...	...
WY Cnc	G5V/K0V	0.83	5500/3500	0.8	...	...
XY Uma	G5V/K5V	0.48	5750/4250	0.7	...	...

Notes.
[a] Spectral types and periods from Strassmeier et al. 1993.
[b] Based on Kurucz models; the error associated with the best-fit photospheric temperatures is ± 250 K.
[c] Blackbody dust temperature.
[d] Grain emissivity law dust temperature (see the text).

To estimate more realistic dust temperatures, non-blackbody circumstellar dust with an emissivity law of the type $\epsilon = 1$, λ_0; $\epsilon = (\lambda_0/\lambda)^q$, $\lambda > \lambda_0$, where λ_0 corresponds approximately to the grain size and q is a parameter of order unity, depending on grain type, as described by, e.g., Backman & Paresce 1993, was used. In general, fits using a grain emissivity law (Table 2) required lower temperatures. For both II Peg and AR Psc, the best-fit values of λ_0 and q are 3 μm and 1, respectively, whereas for UX Ari these parameters were not well constrained by the data.

We note two systems in Table 1 for which we find no significant excess at levels below earlier *IRAS*-based detections; either the earlier detections were spurious or the excesses have waned in the intervening years.

[4] http://wwwuser.oat.ts.astro.it/castelli/grids.html
[5] http://irsa.ipac.caltech.edu


10.000
1.000
0.100
0.010
0.001
Flux [Jy]
1
10
100
micron

4. CONCLUSIONS

A *Spitzer* survey of 10 tidally interacting binary systems nds IR excesses for 3. The excesses are consistent with signi cant amounts of warm dust close to the central stars. A numerical model for the steady-state distribution of dust in II Peg nds a clearing radius of 0.22 AU, consistent with the observed optical-IR SED, and suggests that the warm dust temperatures result from inward migration of dust due to PR drag and central clearing caused by dynamical perturbations.

Reported *IRAS* excesses for CF Tuc and WY Cnc are not con rmed by *Spitzer*, indicating a possible waning of dust in the last few decades. This is consistent with PR drag, for which we nd the timescale for dust depletion around II Peg could be as short as a decade or so, suggesting ongoing dust production. We echo the suggestion of Rhee et al. (2008) that dust could arise from collisions of planetary bodies and speculate that these old binaries can enter epochs in which they destabilize the orbits of their planets through shrinkage of their own binary orbit due to magnetically driven angular momentum loss.

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REFERENCES

Alekseev, I. Y., & Kozhevnikova, A. V. 2004, Astrophysics, 47, 443
Aumann, H. H., et al. 1984, ApJ, 278, L23
Backman, D. E., & Paresce, F. 1993, in Protostars and Planets III, ed. E. H. Levy & J. I. Lunine (Tucson, AZ: Univ. Arizona Press), 1253
Bryden, G., et al. 2006, ApJ, 636, 1098
Busso, M., Scaltriti, F., Origlia, L., Persi, P., & Ferrari-Toniolo, M. 1988, MNRAS, 234, 445
Busso, M., Scaltriti, F., Persi, P., Robberto, M., & Silvestro, G. 1987, A&A, 183, 83
Byrne, P. B., et al. 1998, A&AS, 127, 505
Cutispoto, G. 1991, A&AS, 89, 435
Cutispoto, G., Messina, S., & Rodonò, M. 2001, A&A, 367, 910
Eggleton, P. P., & Kiseleva-Eggleton, L. 2002, ApJ, 575, 461
Eker, Z. 1992, ApJS, 79, 481
Fazio, G. G., et al. 2004, ApJS, 154, 10
Frasca, A., Biazzo, K., Taş, G., Evren, S., & Lanzafame, A. C. 2008, A&A, 479, 557
Gehrz, R. D., et al. 2007, Rev. Sci. Instrum., 78, 011302
Gray, D. F. (ed.) 1992, The Observation and Analysis of Stellar Photospheres, Vol. 20 (Cambridge: Cambridge Univ. Press)
Hall, D. S. 1976, in Astrophysics and Space Science Library, IAU Colloq. 29, Multiple Periodic Variable Stars, ed. W. S. Fitch (Dordrecht: Reidel), 287
Heckert, P. A., Maloney, G. V., Stewart, M. C., Ordway, J. I., Hickman, A., & Zeilik, M. 1998, AJ, 115, 1145
Hillenbrand, L. A., et al. 2008, ApJ, 677, 630
Ibanoğlu, C. 1989, Ap&SS, 161, 221
Ibanoğlu, C., Evren, S., Taş, G., & Çakırlı, Ö. 2005, MNRAS, 360, 1077
Kjurkchieva, D., Marchev, D., & Ogloza, W. 2000, A&A, 354, 909
Kjurkchieva, D. P., Marchev, D. V., Heckert, P. A., & Ordway, J. I. 2005, AJ, 129, 1084
Kuchner, M. J., & Holman, M. J. 2003, ApJ, 588, 1110
Lee, J. W., Kim, S., Kim, C., Koch, R. H., Lee, C., Kim, H., & Park, J. 2009, AJ, 137, 3181
Marengo, M., Stapelfeldt, K., Werner, M. W., Hora, J. L., Fazio, G. G., Schuster, M. T., Carson, J. C., & Megeath, S. T. 2009, ApJ, 700, 1647
Messina, S. 2008, A&A, 480, 495
Mestel, L 1984, in Cool Stars, Stellar Systems, and the Sun, ed. S. L. Baliunas & L. Hartmann (Lecture Notes in Physics, Vol. 193; Berlin: Springer), 49
Milano, L., Mancuso, S., Vittone, A., Dorsi, A., & Marcozzi, S. 1986, Ap&SS, 124, 83
Ottmann, R., Pfeiffer, M. J., & Gehren, T. 1998, A&A, 338, 661
Rhee, J. H., Song, I., & Zuckerman, B. 2008, ApJ, 675, 777
Riddick, F. C., Roche, P. F., & Lucas, P. W. 2007, MNRAS, 381, 1077
Rieke, G. H., et al. 2004, ApJS, 154, 25
Rodono, M., et al. 1986, A&A, 165, 135
Rodono, M., et al. 1998, in ASP Conf. Ser. 154, Cool Stars, Stellar Systems, and the Sun, ed. R. A. Donahue & J. A. Bookbinder (San Francisco, CA: ASP), 1446
Scaltriti, F., Busso, M., Ferrari-Toniolo, M., Origlia, L., Persi, P., Robberto, M., & Silvestro, G. 1993, MNRAS, 264, 5
Schuster, M. T., Marengo, M., & Patten, B. M. 2006, SPIE, 6270, 627020
Song, I., Zuckerman, B., Weinberger, A. J., & Becklin, E. E. 2005, Nature, 436, 363
Stark, C. C., & Kuchner, M. J. 2008, ApJ, 686, 637
Strassmeier, K. G., Hall, D. S., Fekel, F. C., & Scheck, M. 1993, A&AS, 100, 173
Verma, R. P., Ghosh, S. K., Iyengar, K. V. K., Tandon, S. N., Daniel, R. R., Sanwal, N. B., & Rengarajan, T. N. 1983, Ap&SS, 97, 161
Weinberger, A. J. 2008, ApJ, 679, L41
Werner, M. W., Uchida, K. I., Sellgren, K., Marengo, M., Gordon, K. D., Morris, P. W., Houck, J. R., & Stansberry, J. A. 2004, ApJS, 154, 309
Wilner, D. J., Dowell, C. D., Holman, M. J., & Kuchner, M. J. 2003, BAAS, 35, 1415
Wood, B. E., Müller, H.-R., Zank, G. P., Linsky, J. L., & Redfield, S. 2005, ApJ, 628, L143
Wright, A. E., & Barlow, M. J. 1975, MNRAS, 170, 41
Wyatt, S. P., & Whipple, F. L. 1950, ApJ, 111, 134
Zuckerman, B., Fekel, F. C., Williamson, M. H., Henry, G. W., & Muno, M. P. 2008, ApJ, 688, 1345