DETECTION OF A RESOLVED TROJAN BINARY. K.S. Noll[1], W.M. Grundy[2], E.L. Ryan[3], and S.D. Benecchi[4], [1]NASA Goddard Space Flight Center, Code 693.0, 8800 Greenbelt Rd., Greenbelt, MD 20771, keith.s.noll@nasa.gov, [2]Lowell Observatory, [3]University of Maryland/NASA GSFC, [4]Planetary Science Institute.

Introduction: We have reexamined 41 Trojan asteroids observed with the Hubble Space Telescope (HST) to search for unresolved binaries. We have identified one binary, (16974) 1998 WR_{21} with a separation of 53 milliarcsec. The high S/N of the observations and the stability of the HST PSF enable a novel approach to identifying blended binaries using radial profile fitting.

Only two resolved binaries have been previously identified in the Jupiter Trojans population. 617 Patroclus is a tidally-locked binary with nearly equal-size components and a very low density, $\rho=800\pm^{200}_{100}$ kg/m^3 [1]. 624 Hektor consists of a bilobed primary orbited by a small satellite [2]. Density determinations for Hektor vary depending on the methodology. The satellite orbit yields a density of 1000±300 kg/m^3[2] while shape analysis leads to a higher density[3].

Unresolved binaries may also be present in the Trojan population as indicated by lightcurve analysis [4,5]. In two cases, densities have been indirectly derived from shape analysis: Trojan asteroids (17365), and (29314) have large amplitude lightcurves that are consistent with binaries having similar-sized components that are synchronously locked (or in contact), and have densities below 1000 kg/m^3[4]. Many additional Trojans show lightcurve variations that could also be indicative of binary systems [5].

Identification and confirmation of *resolved* binary Trojans is critical because mass-based physical information from the binary orbit could yield more clues to the origin of Trojans. A Trojan Tour is one of six possible New Frontiers missions; additional Trojan binaries provide physical context for planning such a mission and could constitute a potentially high value target because of the opportunity to study two objects and to test models of the primordial nature of binaries.

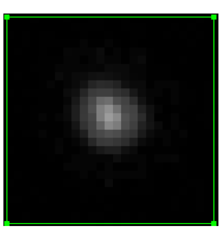

Figure 1: Trojan (16974) 1998 WR_{21} was observed with WFC3 on 03/13/2013. A 1 arcsec region of a single F555W exposure is shown. In all 16 exposures the radial profile is broadened and PSF fitting results in a consistent component separation of 53±3 mas. Relative flux is less consistent because of sub-pixel shifts with f_1/f_2 = 1.7±0.5.

temp ID	#	visit	H	diameter*		err	q_V		err	radius (pix)
1931 YA	1208	12891-01	9.1	100.48	±	1.10	0.041	±	0.006	1.95
1976 UW	2148	10512-05	10.6	37.98	±	0.31	0.064	±	0.003	1.92
1986 TS6	5025	12891-05	10.3	39.84	±	3.64	0.084	±	0.009	1.82
1973 SW1	5041	10512-09	10.6	41.90	±	0.41	0.058	±	0.007	1.97
1990 DK	5436	10512-0a	10.3	37.70	±	0.33	0.086	±	0.013	1.95
1988 TH1	5511	12891-03	10.2	39.77	±	0.42	0.093	±	0.013	1.83
1989 AV2	7119	12891-06	9.7	59.15	±	0.37	0.067	±	0.010	1.81
1973 SY	7543	10512-0f	10.6	42.89	±	0.58	0.055	±	0.004	2.00
5187 T-2	10664	10512-1a	11.1	30.96	±	0.60	0.067	±	0.007	1.93
1973 SL	12658	10512-25	11.2	26.46	±	0.45	0.084	±	0.012	2.09
1998 TL15	12916	10512-26	11.4	22.29	±	1.62	0.098	±	0.017	1.93
1998 WZ5	12921	10512-27	11.0	32.17	±	0.89	0.074	±	0.006	1.94
1996 TH52	13185	10512-29	11.8							2.02
1997 VG1	13230	10512-2a	11.2	23.93	±	0.49	0.102	±	0.007	1.98
1998 SU52	13331	12891-08	10.3	17.68	±	1.54	0.171	±	0.033	1.96
1998 US24	13366	10512-2d	11.2	33.30	±	2.87	0.058	±	0.016	1.93
1998 VU6	13372	10512-2e	10.9	25.42	±	0.38	0.109	±	0.011	1.95
1998 WX9	13379	10512-2f	11.3	21.30	±	0.57	0.107	±	0.022	2.01
1998 XS31	13383	10512-30	11.2	24.27	±	0.70	0.109	±	0.022	1.91
1973 SG1	14792	10512-35	12.2							2.02
1999 XH133	15521	10512-36	11.2	27.94	±	1.15	0.082	±	0.023	1.95
2000 AT177	15535	10512-37	10.6	39.77	±	0.46	0.070	±	0.019	1.96
9612 P-L	15651	10512-38	11.3	24.34	±	0.36	0.099	±	0.021	1.97
1998 WR21	16974	12891-07	9.8	57.34	±	0.33	0.065	±	0.010	2.20
2000 AD75	22059	10512-4c	11.2	25.38	±	0.56	0.100	±	0.015	2.08
1996 RW29	23622	10512-50	11.4							1.97
1998 VD30	23958	10512-52	10.1	46.00	±	1.19	0.076	±	0.013	1.97
2000 AA160	24380	10512-57	11.0	31.61	±	0.27	0.064	±	0.009	1.98
2000 AX193	24403	10512-58	11.0	29.39	±	0.67	0.074	±	0.018	2.01
2000 QL63	24449	10512-5a	11.0	22.79	±	0.72	0.059	±	0.007	1.96
2000 SJ310	24470	10512-5d	10.7	33.07	±	0.31	0.077	±	0.008	1.94
2001 CB35	24537	10512-62	10.9	31.16	±	0.39	0.079	±	0.012	1.98
1999 NE11	31806	10512-6e	11.6	23.79	±	0.23	0.071	±	0.012	1.97
2000 SG348	32480	10512-75	11.2	29.58	±	0.26	0.073	±	0.007	1.93
2000 YQ139	39264	10512-84	10.7	35.94	±	0.36	0.072	±	0.013	2.02
1978 VC7	39474	10512-85	11.7	26.07	±	0.55	0.060	±	0.007	2.21
2000 AS105	41379	10512-87	11.3	31.01	±	0.46	0.061	±	0.015	1.94
2002 CQ134	42367	10512-88	11.0	32.16	±	0.50	0.068	±	0.012	2.00
2002 GK105	55578	10512-93	11.4	22.05	±	0.64	0.110	±	0.016	1.92

Table 1: Trojan asteroids observed with HST. Targets in GO 10512 were scheduled from a longer list of snapshot candidates. Targets in GO 12891 have long rotation periods that might be due to synchronous binary systems. Diameters and visible albedos are from WISE [6]. Diameters of most objects fall in a range of 20 – 40 km. The radius shown is the averaged radius, in pixels, of a fit to the radial profile using IMEXAM in IRAF. Candidates must be consistently wider in all images. (some target averages are skewed by single cosmic ray events identifiable by inconsistent image-to-image radii)

Observations: 41 Trojan asteroids have been observed with the Hubble Space Telescope, 39 successfully. Images were obtained in two observing programs, 6 in GO 12891 (Noll), and 33 in GO 10512 (Merline). Targets were observed with WFC3 (12891) and the ACS/HRC (10512) and are summarized in Table 1.

Analysis: Initial analyses of both data sets did not find any binaries or binary candidates [7,8]. In order to identify candidates for partially resolved binaries we employed an azimuthally averaged radial profile as an initial screening. This approach is less sensitive to changes in the apparent PSF from small shifts in sub-pixel position, focus, and breathing. Candidates are then fit with more traditional PSF-fitting tools. This screening identified only one candidate system that showed a consistently broader radial profile than other targets (Figure 1). (16974) 1998 WR_{21} has an average radial distribution >15% broader than the median. While small, this difference is significant given the high S/N of the observations. Subsequent PSF fitting confirms the binary nature of the target and yields a consistent separation and relative orientation in all sixteen high S/N images.

Trojan Binaries: Only two Trojans, (624) Hektor and (617) Patroclus, are currently known resolved binaries [1-3] where orbits can yield reliable masses and densities. The detection of (16974) makes it only the third binary in the Trojans that is sufficiently resolved that its orbit can be determined. The orbit-derived system mass can be combined with existing WISE thermal and optical data to yield a density. Hektor and Patroclus have very low densities similar to those found in the Kuiper Belt. A low density for (16974) would be suggestive of a possible connection between Trojans, KBOs, and a common origin in the outer protoplanetary disk that could be further explored with spacecraft missions.

The binary fraction in the Trojans inferred from this work is low, $f \leq 5\%$ as previously concluded [7]. Assuming a density of 1000 kg m^{-3} and a detection limit of 0.05 arcsec, HST observations probe to $s \approx 0.015\ R_{Hill}$, less deeply than KBO searches have reached. On the other hand, six of the targets, including the detected binary, were selected because their slow rotation might indicate a tidally synchronized binary system. Given the countervailing biases, we can conclude, at most, that the Trojans could have a binary fraction similar to that found in the dynamically hot transneptunian populations including the Plutinos and the Scattered Disk. The observed binary fraction does not rule out the possibility that the Trojans were scattered from the outer protoplanetary disk to their current location.

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