THE WIRED SURVEY. I. A BRIGHT IR EXCESS DUE TO DUST AROUND THE HEAVILY POLLUTED WHITE DWARF GALEX J193156.8+011745*

JOHN H. DEBES1,6, D. W. HOARD2, MUKREMIN KILIC3,4, STEFANIE WACHTER6, DAVID T. LEISAWITZ1, MARTIN COHEN3, J. DAVY KIRKPATRICK4, AND ROGER L. GRIFFITH4
1 Goddard Space Flight Center, Greenbelt, MD 20771, USA
2 Spitzer Science Center, California Institute of Technology, Pasadena, CA 91125, USA
3 Smithsonian Astrophysical Observatory, Cambridge, MA 02138, USA
4 IPAC, California Institute of Technology, Pasadena, CA 91125, USA
5 Monterey Institute for Research in Astronomy, Marina, CA 93933, USA

Received 2010 October 15; accepted 2010 December 19; published 2011 February 3

ABSTRACT

With the launch of the Wide-Field Infrared Survey Explorer (WISE), a new era of detecting planetary debris around white dwarfs (WDs) has begun with the WISE InfraRed Excesses around Degenerates (WISE) Survey. The WIRED survey will be sensitive to substellar objects and dusty debris around WDs out to distances exceeding 100 pc, well beyond the completeness level of local WDs and covering a large fraction of known WDs detected with the SDSS DR4 WD catalog. In this paper, we report an initial result of the WIRED survey, the detection of the heavily polluted hydrogen WD (spectral type DAZ) GALEX J193156.8+011745 at 3.35 and 4.6 μm. We find that the excess is consistent with either a narrow dusty ring with an inner radius of 29 R_{WD}, outer radius of 40 R_{WD}, and a face-on inclination, or a disk with an inclination of 70°, an inner radius of 23 R_{WD}, and an outer radius of 80 R_{WD}. We also report initial optical spectroscopic monitoring of several metal lines present in the photosphere and find no variability in the line strengths or radial velocities of the lines. We rule out all but planetary mass companions to GALEX1931 out to 0.5 AU.

Key words: circumstellar matter – planetary systems – white dwarfs

1. INTRODUCTION

The Wide-field Infrared Survey Explorer (WISE) is a NASA medium-class Explorer mission that was launched on 2009 December 14 (Wright et al. 2010). WISE mapped the entire sky simultaneously in four infrared (IR) bands centered at 3.4, 4.6, 12, and 22 μm (W1, W2, W3, and W4, respectively) with 5σ point source sensitivities of approximately 0.08, 0.1, 1, and 6 mJy, respectively. WISE has several main goals, namely to take a census of cool stars and brown dwarfs close to the Sun, probe the dustiest galaxies in the universe, and catalog the near-Earth object population (Wright et al. 2010). The WISE mission will also provide crucial information about a diverse range of phenomena in the IR sky at a sensitivity 100 times better than IRAS.

The WISE InfraRed Excesses around Degenerates (WISE) survey is designed to detect infrared excesses around white dwarfs (WDs) using photometry from the WISE catalog. Dust, low-mass companions, and cyclotron radiation from accreting magnetic WDs all emit at mid-IR wavelengths, providing a rich variety of sources to be discovered. There are over 2131 WDs spectroscopically identified in the McCook & Sion catalog (McCook & Sion 1999; Hoard et al. 2007) and over 18,000 identified in the DR7 WD catalog (Kleinman et al. 2010)—many of these objects will be detected with WISE.

Dusty WDs in particular provide information on the future fate of our own solar system, as well as planetary systems around other stars. Planetary systems can survive post-main-sequence evolution and mass loss as a central star becomes a WD (Duncan & Lissauer 1998), though many objects in the inner system are expected to be destroyed through engulfment or evaporation (Villaver & Livio 2007, 2009; Nordhaus et al. 2010). Rocky planetesimals can survive gas drag and sublimation during post-main-sequence evolution (Jura 2003; Reach et al. 2005; Kilic et al. 2006; von Farihi et al. 2010). The presence of dust within a region that should be devoid of any material due to post-main-sequence evolution of the

---

* Based on data gathered with the 6.5 m Magellan Telescopes located at Las Campanas Observatory, Chile.
6 NASA Postdoctoral Program Fellow.
7 Spitzer Fellow.
WD progenitor is challenging to explain. Planetesimals must be perturbed (presumably by a planet) on timescales that range from a few Myr to a few Gyr and tidally disrupted by the central WD (Jura 2003, 2008). The perturbation of planetesimals by the post-main-sequence destabilization of giant planetary systems has been proposed, but to date no quantitative predictions for the lifetime or efficiency of this mechanism have been made (Debes & Sigurdsson 2002).

The circumstantial evidence, however, is compelling. Order of magnitude estimates for the expected number of metal polluted WDs from Debes & Sigurdsson (2002) are consistent with what is observed and is similar both to the frequencies of giant planets in orbit around early-type stars (Johnson et al. 2010) and the estimated frequencies of close-in Earth mass planets (Howard et al. 2010). Post-main-sequence planetary systems provide an important complementary sample to main-sequence planetary systems and will provide crucial compositional information on extrasolar planetesimals impossible with other observational techniques.

Yet several questions about dusty and metal-enriched WDs remain. The lifetime of dust, the exact structure of the dusty disks, and their evolution are all highly uncertain. The answers to such questions may come via large number statistics from which trends and correlations can be identified.

In this respect, the WIRED survey is uniquely positioned to provide a large number of dusty WDs to help answer these and other questions. WISE’s 3σ sensitivity limits of 0.08, 0.1, 0.8, and 6 mJy in the W1, W2, W3, and W4 bands are low enough to detect dusty disks in W1 and W2, such as that detected around G29–38, out to ~140 pc, and its bright silicate feature out to ~55 pc. A WD with $T_{\text{eff}} \sim 10,000$ K, the approximate mean $T_{\text{eff}}$ of the SDSS DR4 survey (Eisenstein et al. 2006), has a $g$ magnitude of ~18 at 140 pc (Bergeron et al. 1995). There are 1800 WDs with $g < 18$ in the DR4 catalog and ~1% of WDs with $T_{\text{eff}} \sim 10,000$ K (or a cooling age of 600 Myr for a 0.6 $M_{\odot}$ WD) harbor dusty disks (Farihi et al. 2010), implying as many as 18 could be detected with the WIRED survey. The DR7 WD catalog will contain twice as many objects as the DR4 catalog; in concert with the McCook & Sion catalog (McCook & Sion 1999; Kleinman et al. 2010), this could mean as many as 60–70 new dusty WDs will be discovered.

In this paper, we present an initial result from the WIRED survey: the detection of a significant IR excess around GALEX J193156.8+011745 (hereafter GALEX1931). This DAZ was recently discovered to have a large amount of metal-rich material in its photosphere, and a possible near-IR excess (Vennes et al. 2010). The nature of the excess was unclear, however, because H and K photometry were consistent with either a brown dwarf or a dusty disk (Vennes et al. 2010). In Section 2, we demonstrate that WISE photometry of known dusty WD disks is consistent with previous Spitzer observations. In Section 3, we report the W1 and W2 flux densities of GALEX1931, rule out any source contamination, and construct plausible models for the excess we observe around GALEX1931, finding a good fit to the photometry if we assume an optically thick dust disk. Finally, we present spectroscopic follow-up of GALEX1931 to verify whether any variability in accretion has occurred on timescales that are long compared to the implied settling time for metals and to place limits on possible companions. We present our conclusions in Section 5. In addition to this work, GALEX1931 has been detected in the mid-IR from the ground (Melis et al. 2011).

### Table 1

| Name       | W1 (μJy) | W2 (μJy) | IRAC1 (μJy) | IRAC2 (μJy) | Reference |
|------------|----------|----------|-------------|-------------|-----------|
| GD 40      | 245 ± 10 | 230 ± 12 | 213 ± 18    | 199 ± 10    | 1         |
| GD 16      | 390 ± 13 | 486 ± 24 | 486 ± 23    | 508 ± 25    | 2         |
| GD 362     | 314 ± 7  | 380 ± 20 | 413 ± 12    | 395 ± 20    | 3         |
| HE 2221-1630| 186 ± 9  | 204 ± 10 | 140 ± 15    | 172 ± 9     | 4         |

References. (1) Jura et al. 2007a; (2) Farihi et al. 2009; (3) Jura et al. 2007b; (4) Farihi et al. 2010.

### 2. CONFIRMATION OF WISE W1 AND W2 FIRST-PASS PHOTOMETRIC MEASUREMENTS

The measurements and images we used from the WISE catalog are co-adds of all available data for GALEX1931 using “First-Pass” processing that used on-orbit performance of WISE as part of the pipeline. To help test this pipeline, we have considered the Spitzer Infrared Array Camera (IRAC) photometry of previously reported dusty WDs that are also detected in WISE. Since most of these systems are consistent with ~1000 K blackbody emission from dust, the peak of their emission occurs at ~3–5 μm and represents a departure in this wavelength range from the spectral slope of Vega that is used to calculate the zeropoints of the WISE photometric system (Wright et al. 2010). Even so, blackbody emission with a temperature of ~1000 K requires corrections at only the ~2% level as given in Table 1 of Wright et al. (2010).

Several dusty WDs have been observed with the IRAC camera aboard Spitzer. The IRAC1 and 2 bands have central wavelengths and passbands ($\lambda_c = 3.6$ and 4.5 μm, respectively) that are quite close to the WISE 1 and 2 bands of 3.35 and 4.6 μm. Published photometry of WD disks in the IRAC bands is listed in Table 1, compared to the equivalent photometry in the WISE bands. This list is a selection from the full set of known dusty disks. The average difference in photometric measures in W1 and W2 is ~12% ± 7% and ~4% ± 9%, respectively. Based on this result, we see no significant offsets between the two bands within the uncertainties and expect that our photometry is accurate to the level reported for absolute WISE photometry. This, however, is a small sample and a full comparison of all known disks and WD photospheres along with comparisons in the W3 band will be included in the full WIRED survey results, to be published at a later date.

### 3. A DUSTY DEBRIS DISK AROUND GALEX1931

#### 3.1. Ruling out Significant Source Contamination

A source centered on GALEX1931’s position (as given in Vennes et al. 2010) is clearly detected with WISE at an S/N ~ 30 in the two bands. The WISE catalog lists detections at W3 (S/N ~ 5) and W4 (S/N ~ 3), but inspection of the WISE images at these bands shows either source confusion or noise, and we take these detections as upper limits to the true flux of GALEX1931. Figure 1 shows the WISE images in W1 and W2. The WISE photometry of GALEX1931 is listed in Table 2. A bright source is located ~16′ to the southeast, but contamination from this source is negligible. At this separation the wings of the W1 and W2 point-spread function (PSF) from the source are ~6% of the peak flux in GALEX1931 and a small fraction of the peak of the PSF (see Figure 11 of Wright et al. 2010). Additionally, the WISE first pass data provide profile...
fit photometry which can deblend and remove any resolved contamination.

GALEX1931 resides within 10° of the galactic plane, where the density of sources is relatively high. This raises the possibility that a contaminating source with a red spectrum could be present within the \textit{WISE} PSF at the coordinates of GALEX1931. For the measured \textit{W1} and \textit{W2} magnitudes of GALEX1931, the predicted combined stellar and extragalactic source counts based on models of the infrared sky for \textit{W1} and \textit{W2} are 4000 and 3600 sources per square degree per magnitude, respectively (Wainscoat et al. 1992; Cohen 1993). Integrated over the \textit{WISE} PSF, with FWHM \approx 6′, this corresponds to a probability of \approx0.03 that a source as bright as GALEX1931 will be found in a given (randomly chosen) PSF in this region of the sky. Thus, for a randomly chosen location, we expect essentially zero sources as bright as GALEX1931 to lie within a \textit{WISE} PSF. Conversely, if we pick a specific location because we do expect to find a source there (i.e., GALEX1931), then there is a high probability that the detected source is the one we are looking for.

This alone cannot rule out the presence of an additional (fainter) contaminating source within the \textit{WISE} PSF. However, if GALEX1931 is contaminated by an object redder than itself, then, unless the contaminating object was exactly coincident with the position of GALEX1931, the centroid of the detected source would shift at longer wavelengths as the contaminating source dominated. This is not observed, but to assess the possibility that there may be fainter sources that contaminate the photometry of GALEX1931, we obtained archival \textit{V}-band images from the EFOSC camera that were used to estimate the \textit{V} magnitude of GALEX1931 (Vennes et al. 2010) and new images in \textit{Ks} with the Palomar 200′ Wide Field Infrared Camera (WIRC). The WIRC image was constructed from seven dithered images taken on 2010 August 29 with 10 s integrations. The images were sky subtracted and combined to create the final image shown in Figure 1.

The EFOSC image shows one source at a separation of \textasciitilde2″ that is within the \textit{W1} and \textit{W2} PSF, denoted as source A. Seeing conditions were poor for our WIRC image, but we were able to resolve A sufficiently from GALEX1931. We then performed relative photometry to determine its \textit{V} – \textit{Ks} colors.

In the \textit{V}-band image, source A is well separated from the GALEX1931 PSF and does not contaminate GALEX1931’s \textit{V} measurement. We therefore estimated the \textit{V} magnitude of source A by measuring the counts in the EFOSC image relative to GALEX1931, which has \textit{V} \approx 14 (Vennes et al. 2010). When this is performed we obtain \textit{V} \approx 18.5 for source A. We estimate that the uncertainty in this value is no more than 10%.

In the \textit{Ks}-band image, source A is heavily contaminated by the seeing disk of GALEX1931, and photometry of GALEX1931 is also contaminated by source A. This required the construction of an empirical PSF from bright sources within the 8′×8′ WIRC field of view in order to isolate each object’s photometry. We chose eight bright sources and median combined them to subtract off the GALEX1931 PSF to perform aperture photometry on source A, and vice versa. From aperture photometry of Source A using different scalings to the empirical PSF, we have determined that 5% errors in scaling (the level at which the subtraction of GALEX1931 is unnoticeable from the background) corresponds to 10% errors in source A’s photometry. This dominates other uncertainties so we adopt this value as the uncertainty in source A’s \textit{Ks} magnitude.

We then performed relative photometry of both source A and GALEX1931, using other sources in the WIRC image that are present in Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006). Of the eight bright sources we chose, six had reliable \textit{Ks} photometry in 2MASS (2MASS J19315790+0117363, J19315456+0117174, J19315382+0117593, J19315292+0118238, J19315111+0116247, and J19315752+0116132). We took the standard deviation of our measured magnitudes for GALEX1931 to estimate the uncertainty in its photometry. Based on our aperture photometry relative to these sources in our WIRC image, we derive an uncontaminated magnitude for GALEX1931 of 14.68 \pm 0.05 and 16.1 \pm 0.1 for source A. GALEX1931’s revised magnitude is 0.23 mag dimmer than reported in the 2MASS source catalog.

Source A is probably stellar. Its \textit{V} – \textit{K} color is 2.4 \pm 0.1, consistent with a mid-\textit{K} spectral-type object. Given its relative faintness compared to GALEX1931 at \textit{Ks}, it is unlikely to

| Name | \textit{Ks} (\textmu Jy) | \textit{W1} (\textmu Jy) | \textit{W2} (\textmu Jy) | \textit{W3} (\textmu Jy) | \textit{W4} (\textmu Jy) |
|------|------------------------|------------------------|------------------------|------------------------|------------------------|
| GALEX1931 | 895 \pm 45 | 1024 \pm 36 | 925 \pm 33 | 640^a | 2097^a |

\textbf{Table 2} \textit{Ks} and \textit{WISE} Photometry of GALEX1931

\textbf{Note.} ^a These flux densities are upper limits.
be a significant source of contamination at the \(W1\) and \(W2\) bands. At these longer wavelengths a K star is well into the Rayleigh–Jeans tail and its flux density is declining roughly as \(\lambda^2\), while GALEX1931’s flux density is increasing from \(K_s\) to \(W1\) in Table 2.

Based on the low probability of a coincident source, good agreement between the \textit{WISE} \(W1\) and \(W2\) positions of GALEX1931 relative to the 2MASS and GALEX positions of GALEX1931, plus source A’s \(V - K\) color, there is little chance that the \(W1\) and \(W2\) detections are due to a source other than GALEX1931.

3.2. The Nature of GALEX1931’s Excess

We next compare the observed photometry of GALEX1931 with an expected WD photosphere. We assume \(T_{\text{eff}} = 20,890\) K, \(\log g = 7.9\), and a distance of 55 pc as inferred by Vennes et al. (2010) through spectral fitting. Using synthetic photometry of DA models, we can compare the expected photometry of GALEX1931 at \(V\), 2MASS \(J\), \(H\), WIRC \(K_s\), \(W1\), and \(W2\) (Bergeron et al. 1995; Holberg & Bergeron 2006). In order to predict the flux densities of the WD photosphere in the \textit{WISE} bands, we extrapolate blackbody emission for \(T_{\text{eff}} = 20890\) K to the \textit{WISE} central wavelengths. Experience with \textit{Spitzer} photometry of WDs at high \(S/N\) shows that small deviations from blackbodies can occur, but are generally not large in magnitude for hotter WDs (Debes 2006; Tremblay & Bergeron 2007).

When we do this we find a small correction of 1% must be made between the WD model parameters reported by Vennes et al. (2010) and the Bergeron models, equivalent to either a slightly larger radius for the WD or a smaller distance. Regardless, we get a good fit to both the \(V\) and \(J\)-band photometry of GALEX1931 and use that to determine the wavelength at which the excess starts.

Within the uncertainties of the 2MASS and \textit{WISE} photometry, the excess starts beyond the \(K_s\) band with an 18\(\sigma\) excess at \(W1\) and continues to the \(W2\) band with an excess that is 22\(\sigma\) above the photosphere. Our new WIRC photometry shows that the excess at \(H\) and \(K\) reported by Vennes et al. (2010) is probably spurious. Inspection of the 2MASS \(K_s\) image indeed shows a slight extension of the PSF at the position of source A and our \(K_s\) magnitude is 0.23 mag fainter, consistent with source A contaminating GALEX1931’s 2MASS photometry.

Several simple models can be fit to the data and since there are two significant measures of the excess photometry, we must restrict ourselves to models that require as few free parameters as possible. None of these models are necessarily correct, but they provide useful examples of what could, and could not, be producing the IR excess.

The simplest model is that of a blackbody emitting at a particular temperature and with a given surface area assuming it is at the same distance as GALEX1931. A good fit is given by a 900 K blackbody with a surface area 800 times larger than the WDs, implying a radius for either a disk or a companion 30 times larger than GALEX1931. This would conclusively rule out the possibility of a companion at the distance of GALEX1931 as the source of the excess, since this would imply a radius for the companion of \(\sim 0.3 \, R_\odot\), too large for a brown dwarf. Conversely, it could mean that a 900 K object with \(R \sim 0.1 \, R_\odot\) is located three times closer than GALEX1931, implying a T dwarf at 18 pc from the Sun. This is, again, an unlikely scenario, as already discussed with regard to the source counts in the vicinity of GALEX1931, not to mention the additional requirement that the T-dwarf would have to be precisely aligned with the position of GALEX1931. In any case, such a scenario is easily tested by additional observations: a T dwarf that close would most likely have high proper motion that could easily be detected with a second epoch of NIR images in the \(K\) band.

If we restrict ourselves to a face-on (\(i = 0\)) optically thick disk following the procedure of Jura (2003), the best fit to the excess at shorter wavelengths is given by a narrow ring with an inner radius of 29 \(R_{WD}\) and an outer radius of 40 \(R_{WD}\) (see Figure 2). In this case, the maximum temperature of the dust is 1100 K.

In reality, the disk likely has non-zero inclination relative to our line of sight. When we produce model disks with varying angles of inclination, the data allow a maximum inclination of 70° (which is constrained by the upper limit flux density in the \(W3\) band; see Figure 2). The emission comes from an optically thick disk that extends from 23 \(R_{WD}\) out to 80 \(R_{WD}\), and the maximum temperature of the dust at the inner edge is 1350 K. If the disk has a true inclination smaller than 70°, then the disk’s outer radius must be smaller.

The radii can be compared within the context of physical processes, such as the sublimation radius of the dust and the tidal disruption radius of minor bodies (Jura 2003, 2008). These radii typically bound the extent of dusty WD disks and are pointed to as primary evidence that the origin of the dust originates from tidally disrupted material that is then accreting onto the host WD after dust sublimation. By definition, we take the inner edges of the disk to correspond to the sublimation radius, since sublimation must compete with other grain removal mechanisms which are poorly known. There exist some dusty WDs that show interior radii much larger than expected for pure dust sublimation, these objects may represent the late stages of dusty disk evolution (e.g., G 166–58 and PG 1225–079; Farihi et al. 2008, 2010). The tidal disruption radius for a WD is given by \(R_{\text{tidal}} \sim (C_{\text{tide}}/\rho_{WD})^{1/3} R_{WD} \sim 44 \, C_{\text{tide}} \, R_{WD}\), assuming a compact asteroid with a bulk density of 3 g cm\(^{-3}\), but could
extend to $\sim 63 C_{\text{tide}} R_{\text{WD}}$ for a porous asteroid with a bulk density of $1 \text{ g cm}^{-3}$ (Davidsson 1999; Jura 2003). $C_{\text{tide}}$ is a parameter of order unity that reflects the details of a particular disrupting body’s rotation and composition. The possibility exists that the disk we observe extends beyond the typical tidal disruption radius assumed for rocky asteroids.

4. SPECTROSCOPIC MONITORING OF GALEX1931’S PHOTOSPHERIC METAL LINES

High-resolution optical spectroscopy of GALEX1931 shows strong absorption features due to Mg, Ca, Fe, O, and Si, implying high rates of accretion for all of these atomic species (Vennes et al. 2010). Vennes et al. (2010) also noted a super-solar abundance of O and a sub-solar abundance of Ca, using this as an argument for the presence of a substellar companion polluting GALEX1931 with a wind (e.g., Debes 2006).

If the spectral lines are due to accretion from either a wind or dust, they may vary on short timescales, especially since GALEX1931’s settling time should be on the order of a few days (Koester 2009) and such variability has been claimed in the past (von Hippel et al. 2007; Debes & L´opez-Morales 2008). To investigate this possibility and to look for new absorption features in this heavily polluted photosphere, we observed GALEX1931 with the MIKE spectrograph on the Clay Telescope on UT 2010 June 16–17, 2010 July 8, and 2010 August 2–3, for a total of 11800 s of integration time on the source. We used a $0'7 \times 5''$ slit which corresponded to a resolution of $\sim 40,000$ at the Ca K line. For an example of some strong metal lines detected in the GALEX1931 photosphere, see Figure 3. Th–Ar comparison lamp spectra were taken near in time to each spectrum of GALEX1931. Bad weather degraded the first night of spectra, but most strong lines were still detected.

Our data were extracted and flat fielded using the MIKE reduction pipeline written by Kelson, with methodology described in Kelson et al. (2000) and Kelson (2003). In order to check for variability among the five nights of observation, we calculated the equivalent width (EW) of every spectral feature in each spectrum that was detected with an EW $> 50$ mÅ. To calculate the EW, we chose a window around the line equivalent to $\pm 3$ times the FWHM of the line as determined by a simple Gaussian fit. We chose several different polynomial fits to the continuum and added any systematic uncertainty in the continuum fit to our uncertainties in the EW calculation. Table 3 shows the individual line EW measurements for each of the nights, as well as an average of the barycentric corrected velocities of the lines (with the exception of the Mg II doublet at 4481 Å) based on Gaussian fits to each detected line.

In order to determine whether the line strengths vary, we assume that the EW of each line is equal to the mean of the observations. We then calculate the $\chi^2$ value of each line for its departure from a constant value. Given the small number of samples for each line, we require $\chi^2 = 40$, equaling a probability of $<10^{-3}$ that the line deviates from a constant value even if our uncertainties were underestimated by $50\%$. From the lines we consider in Table 3, we find no significant variability over our observations. Despite a very short expected settling time of $\sim 6$ days for elements such as Ca (Koester 2009), no change in the accretion rate occurred to the level of $5\%$–$20\%$.

From these five epochs, we can also place upper limits on the mass of any companions that may be present in short orbits.

---

**Table 3**

| Element | Epoch 1 | Epoch 2 | Epoch 3 | Epoch 4 | Epoch 5 | $\chi^2_{\text{const}}$ |
|---------|---------|---------|---------|---------|---------|-----------------|
|         | Jun 16  | Jun 17  | Jul 8   | Aug 2   | Aug 3   |     |
| $\text{Si (3856 Å)}$ | 84 ± 20 | 37 ± 8  | 52 ± 4  | 43 ± 3  | 45 ± 6  | 15.2 |
| $\text{Ca (3933 Å)}$ | 90 ± 20 | 39 ± 13 | 48 ± 4  | 55 ± 3  | 64 ± 6  | 16.0 |
| $\text{Si (4128 Å)}$ | 80 ± 30 | 54 ± 11 | 57 ± 6  | 58 ± 4  | 63 ± 8  | 2.5  |
| $\text{Mg (4481 Å)}$ | 410 ± 40| 390 ± 20| 380 ± 10| 370 ± 30| 410 ± 20| 3.1  |
| $\text{Si (5975 Å)}$ | 30 ± 19 | 59 ± 13 | 47 ± 12 | 56 ± 7  | 50 ± 11 | 2.8  |
| $\text{Si (5979 Å)}$ | 65 ± 25 | 31 ± 6  | 46 ± 6  | 58 ± 4  | 48 ± 10 | 13.8 |
| $\text{Si (6347 Å)}$ | 132 ± 24| 130 ± 10| 135 ± 7 | 128 ± 8 | 136 ± 12| 1.1  |
| $\text{Si (6371 Å)}$ | 128 ± 16| 110 ± 10| 101 ± 7 | 100 ± 6 | 77 ± 10 | 10.0 |

| $V_{\text{helio}}$ (km s$^{-1}$) | 36.80 | 37.16 | 36.75 | 37.15 | 37.27 |     |

---

5
Given that our observations are separated by at most 3 months and with minimum separations of a day, we would be sensitive to radial velocity variations with orbital periods that range from a few hours to ~6 months, or for GALEX1931 with $M = 0.57 \, M_\odot$, orbits with semi-major axes that range from 0.004 AU to 0.5 AU. The standard deviation of the velocities reported in Table 3 is 230 m s$^{-1}$, consistent with the level of epoch-to-epoch precision of MIKE without an iodine cell (Anglada-Escudé et al. 2010). Using this as an upper limit to the velocity semi-amplitude ($K$) for any putative companions, one can compute the upper limit to companion masses between our limiting orbital semi-major axes, given by $M_{\text{companion}} \sin i = M_\star^{1/2} K (r_{\text{orb}} G)^{-1/2}$, where $r_{\text{orb}}$ is the orbital semi-major axis assuming a circular orbit. For all separations we rule out any companion more massive than $\sim 5 M_\oplus / \sin i$. It is possible still to have relatively massive planetary or substellar companions present around GALEX1931, but they would have to be in almost face-on orbits to be undetectable. Furthermore, the lack of any excess at J, H, and $K$ rules out all but substellar mass objects at any separation.

5. CONCLUSIONS

We have detected an infrared excess at 3.35 and 4.6 $\mu$m around the WD GALEX1931 and determined it to be either a very narrow ring of dust or a wider dust ring within the tidal dissipation radius of the WD. Spectroscopic follow-up of GALEX1931 shows no evidence for any close companions down to planetary mass, which lends support to a disk interpretation for the excess. Additionally, we have shown that the rate of accretion from the disk onto the WD does not significantly change at the observed epochs, equivalent to ~8 metal settling times for GALEX1931’s photosphere. GALEX1931 is most likely accreting in the steady-state regime, and the accretion itself does not vary at the level of ~10%–20% from month to month.

We detected GALEX1931 with WISE in the W1 and W2 bands at high S/N, implying that we will be sensitive to similar analogs out to ~180 pc, assuming the WISE sensitivity limits quoted above. GALEX1931 represents a bright example of a larger sample of dusty WDs that will be detected with the WIRED survey.

This research was supported by an appointment to the NASA Postdoctoral Program at the Goddard Space Flight Center, administered by Oak Ridge Associated Universities through a contract with NASA. This work is based on data obtained from (1) the Wide-Field Infrared Survey Explorer, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory (JPL), California Institute of Technology (Caltech), funded by the National Aeronautics and Space Administration (NASA); (2) the Two Micron All Sky Survey, a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center (IPAC)/Caltech, funded by NASA and the National Science Foundation; (3) the Hale Telescope, Palomar Observatory, as part of a continuing collaboration between Caltech, NASA/JPL, and Cornell University; (4) the 6.5 m Magellan Telescopes located at Las Campanas Observatory, Chile; (5) the ESO Telescopes at the La Silla or Paranal Observatories; (6) the SIMBAD database, operated at CDS, Strasbourg, France; and (7) the NASA/IPAC Infrared Science Archive, which is operated by JPL, Caltech, under a contract with NASA. We thank D. Steeghs for obtaining spectra of GALEX1931 on July 7–8 and N. Morrell for obtaining spectra of GALEX1931 on August 2–3. M.C. thanks NASA for supporting his participation in this work through UCLA Sub-Award 1000-S-MA756 with a UCLA FAU 26311 to MIRA.

REFERENCES

Anglada-Escudé, G., Shkolnik, E. L., Weinberger, A. J., Thompson, I. B., Osip, D. J., & Debes, J. H. 2010, ApJ, 711, L24
Bergeron, P., Wesemael, F., & Beaulacp, A. 1995, PASP, 107, 1047
Bonsor, A., & Wyatt, M. 2010, MNRAS, 409, 1631
Chu, Y. et al. 2009, AJ, 138, 691
Cohen, M. 1993, AJ, 105, 1860
Davidsson, B. J. R. 1999, Icarus, 142, 525
Debes, J. H. 2006, ApJ, 652, 536
Debes, J. H., & López-Morales, M. 2008, ApJ, 677, L43
Debes, J. H., & Sigurdsson, S. 2002, ApJ, 572, 556
Dong, R., Wang, Y., Lin, D. N. C., & Liu, X. 2010, ApJ, 715, 1036
Duncan, M. J., & Liessau, J. J. 1998, Icarus, 134, 303
Eisenstein, D. J., et al. 2006, ApJS, 167, 40
Farihi, J., Jura, M., Lee, J., & Zuckermand, B. 2010, ApJ, 714, 1386
Farihi, J., Jura, M., & Zuckermand, B. 2009, ApJ, 694, 805
Farihi, J., Zuckermand, B., & Becklin, E. E. 2008, ApJ, 674, 431
Gänsicke, B. T., Koester, D., Marsh, T. R., Rebbas-Mansergas, A., & Southworth, J. 2008, MNRAS, 391, L103
Gänsicke, B. T., Marsh, T. R., & Southworth, J. 2007, MNRAS, 380, L35
Gänsicke, B. T., Marsh, T. R., Southworth, J., & Rebbas-Mansergas, A. 2006, Science, 314, 1908
Hoard, D. W., Wachter, S., Sturch, L. K., Widhalm, A. M., Weiler, K. P., Pretorius, M. L., Wellhouse, J. W., & Gibianski, M. 2007, AJ, 134, 26
Holberg, J. B., & Bergeron, P. 2006, AJ, 132, 1221
Howard, A. W., et al. 2010, Science, 330, 653
Johnson, J. A., Aller, K. M., Howard, A. W., & Crepp, J. R. 2010, PASP, 122, 905
Jura, M. 2003, ApJ, 584, L91
Jura, M. 2008, AJ, 135, 1785
Jura, M., Farihi, J., & Zuckermand, B. 2007a, ApJ, 663, 1285
Jura, M., Farihi, J., Zuckermand, B., & Becklin, E. E. 2007b, AJ, 133, 1927
Kelson, D. D. 2003, PASP, 115, 688
Kelson, D. D., Illingworth, G. D., van Dokkum, P. G., & Franx, M. 2000, ApJ, 531, 159
Kilic, M., von Hippel, T., Leggett, S. K., & Winget, D. E. 2006, ApJ, 646, 474
Kleinman, S., et al. 2010, in AIP Conf. Proc. 1273, 17th European White Dwarf Workshop, ed. K. Werner & T. Rauch (Melville, NY: AIP), 156
Koester, D. 2000, A&A, 498, 517
Koester, D., Rollenhagen, K., Napwitzki, R., Voss, B., Christlieb, N., Honeier, D., & Reimers, D. 2005, A&A, 432, 1025
McCook, G. P., & Sion, E. M. 1999, ApJS, 121, 1
Melis, C., et al. 2011, ApJ, submitted
Nordhaus, J., Spiegel, D. S., Imligiu, L., Goodman, J., & Burrows, A. 2010, MNRAS, 408, 631
Reach, W. T., Kuchner, M. J., von Hippel, T., Burrows, A., Mullally, F., Kilic, M., & Winget, D. E. 2005, ApJ, 635, L161
Reach, W. T., Lisse, C., von Hippel, T., & Mullally, F. 2009, ApJ, 693, 697
Skrutskie, M. F., et al. 2006, AJ, 131, 1163
Stern, S. A., Shall, J. M., & Brandt, J. C. 1990, Nature, 345, 305
Su, K. Y. L., et al. 2007, ApJ, 657, L41
Tremblay, P., & Bergeron, P. 2007, ApJ, 657, 1013
Vennes, S., Kawka, A., & Németh, P. 2010, MNRAS, 404, L40
Villaver, E., & Livio, M. 2007, ApJ, 661, 1192
Villaver, E., & Livio, M. 2009, ApJ, 705, L81
von Hippel, T., Kuchner, M. J., Kilic, M., Mullally, F., & Reach, W. T. 2007, ApJ, 662, 544
Wainscoat, R. J., Cohen, M., Volk, K., Walker, H. J., & Schwartz, D. E. 1992, ApJS, 83, 111
Werner, M. W., et al. 2004, ApJS, 154, 1
Wright, E. L., et al. 2010, AJ, 140, 1868
Zuckerman, B., Koester, D., Reid, I. N., & Hünsch, M. 2003, ApJ, 596, 477
Zuckerman, B., Melis, C., Klein, B., Koester, D., & Jura, M. 2010, ApJ, 722, 725