OBSERVING REQUEST
University of Arizona Observatories

Year: 2015 **Term:** Jan–Jul **Proposal type:** short-term⋆

Spotting Extrasolar Planetesimal Destruction in Action

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Abstract of Scientific Justification

A total of 38 white dwarfs with excess infrared radiation coming from the debris of extrasolar planetesimals have been identified so far. 7 of them also show calcium triplet emission lines from circumstellar gaseous material. Very recently, we found the infrared fluxes, including K, 3.6 μm and 4.5 μm, have significantly decreased for one white dwarf, which has both circumstellar dust and gas. There are at least two possible scenarios to explain this infrared variability: (i) a recent planetesimal impact onto a pre-existing disk, caused by dynamical instability of the planetary system; (ii) non-steady state accretion from the instability in the circumstellar disk, caused by the interaction of dust and gas. The first hypothesis predicts that infrared variability can occur in any dusty white dwarfs while only dusty white dwarfs with circumstellar gas can be variable in the second hypothesis. In order to discriminate between these scenarios and quantify the incidence of disk variability, we propose to measure JHK fluxes for all dusty white dwarfs that are accessible to UKIRT. WFCAM is ideal for this program due to its large field of view and high sensitivity. This is a continuation of the approved 2014B program to monitor dusty white dwarfs to better understand the infrared variability.

Summary of observing runs requested for this project

Run	Telescope	Cage	Instrument	PI	AO	Nights	Moon	Scheduling Optimal	Scheduling Acceptable	Sharing Poss.	Sharing Adv.
1	UKIRT	PF	WFCAM			1	bright	Jan–July	Jan–July	yes	yes

Scheduling constraints and unusable dates *(up to 4 lines)*: None

no text past this line

A ⋆ appended to the proposal type indicates a continuation proposal; a ⋆ appended to the name of a proposer indicates the proposer is a (graduate) student; a proposer whose name is underlined is certified on the proposed telescope/instrument combination; if a ∗ appears within the PI or AO box in the observations summary table, the instrument is a PI instrument and/or Adaptive Optics are requested – signatures are required on the next page.

Target list (attach list if longer than 26 objects)

#	Object	RA	Dec	mag / color / type / redshift / comment / etc.
1	WD1041+092	10:43:41.5	+08:55:58.2	J=17.9, 60 min
2	WD1116+026	11:19:12.4	+02:20:33.1	J=14.8, 5 min
3	WD1147+2831	11:47:58.6	+28:31:56.2	J=17.5, 45 min
4	WD1150-153	11:53:15.4	-15:36:37.0	J=16.0, 8 min
5	WD J1221+1245	12:21:50.8	+12:45:13.3	J=18.4, 70 min
6	PG1225-079	12:27:47.7	-08:14:38.0	J=14.9, 5 min
7	WD1226+110	12:28:59.9	+10:40:32.9	J=16.9, 12 min
8	WD 1234+5606	12:34:32.6	+56:06:43.0	J=18.3, 70 min
9	WD 1349-230	13:52:44.2	-23:20:05.2	J=16.9, 12 min
10	WD 1455+298	14:58:06.5	+29:37:29.8	J=15.0, 5 min
11	WD 1457-086	14:59:52.7	-08:49:33.1	J=16.0, 8 min
12	WD 1507+3245	15:07:02.0	+32:45:45.1	J=18.2, 60 min
13	WD 1537+5151	15:37:25.7	+51:51:26.9	J=17.8, 45 min
14	WD 1541+650	15:41:44.8	+64:53:56.0	J=15.6, 8 min
15	WD 1551+175	15:54:09.1	+17:21:24.0	J=17.5, 45 min
16	WD J1557+0916	15:57:20.8	+09:16:24.6	J=18.8, 70 min
17	WD J1617+1620	16:17:17.0	+16:20:22.4	K=16.8, 12 min
18	WD 2132+096	21:34:50.8	+09:55:20.0	K=16.2, 8 min

Approval for Instrument Use from PI: N/A

Graduate students *(provide the following information for **each** student named as PI or CoI on the cover page. Have the advisor's signature(s) appear on **all** submitted copies)*

Student's Name	Advisor's Name	Advisor's Signature	2nd-yr	Thesis

Scientific Justification

A total of 38 white dwarfs with excess infrared radiation from an orbiting dust disk have been identified to-date (Farihi et al. 2009, Xu & Jura 2012, Barber et al. 2014, Bergfors et al. 2014). Their spectral energy distribution (SED) can be modeled with a simple geometrically thin, optically thick dust disk within the tidal radius of the white dwarf. It is now widely accepted that these disks are remnants of extrasolar planetesimals that wandered into the tidal radius of the white dwarf and then got disrupted (Jura 2003). In addition, calcium triplet emission lines have been detected around 7 dusty white dwarfs (Gaensicke et al. 2006, Brinkworth et al. 2012). Their distinct double-peaked morphology is indicative of a rotating gas disk. The line profile and strength are variable on timescale of a few years, possibly due to repeated accretion of small planetesimals (Gaensicke et al. 2008, Wilson et al. 2014).

Very recently, we found that the infrared flux of a dusty white dwarf WD J0959-0200 has significantly decreased (Xu & Jura 2014). In the course of 10 years, its J and H fluxes, which mostly come from the stellar photosphere, are almost constant; while the fluxes at 3.6 and 4.5 μm dropped by $\sim$35% and that in K dropped by 20% within one year, as shown in Figure 1. To fit the excess infrared radiation, an opaque disk model is employed with three free parameters, i.e., the inner and outer radii of the disk, R_{in} and R_{out}, and the disk inclination cos i (Jura 2003). For WD J0959-0200, a sudden drop in 3.6 μm, 4.5 μm and K bands indicates an increase of R_{in} from 10.5R_{wd} (white dwarf radius, T_{in} = 1545 K) to 14R_{wd} (T_{in} = 1245 K). This corresponds to a total loss of 3% of the disk surface area and a total mass loss of at least 3×10^{20} g over a few of months, between the first IRAC epoch and WISE observations (see Figure 1). We are witnessing the apparent destruction of a dust disk in action!

In our Spitzer/IRAC data obtained in early September, 2014, we identified a second case where the infrared flux has decreased. The typical lifetime of the dust disk around white dwarfs is on the order of $\sim$$10^5$ yr (Girven et al. 2012). What can cause such significant infrared variability in a relatively short amount of time? There are at least two possible explanations.

- A recent planetesimal impact onto a pre-existing disk. Wyatt et al. (2014) suggest that tidal disruption of small planetesimals around white dwarfs can be nearly continuous and as frequent as once every 30 years. Mutual collisions lead to evaporation of the inner disk material and also non-steady state accretion, which have been observed in a few other white dwarfs (Farihi et al. 2012b, Xu et al. 2014). Under this assumption, in a sample of 38 stars, we would expect one dusty white dwarf to be variable per year.
- Non-steady state accretion from the instability in the circumstellar disk: WD J0959-0200 belongs to the rare category of dusty white dwarfs which also display calcium triplet emission lines from an orbiting gaseous disk (Farihi et al. 2012a). Interactions between the dust and gaseous material can cause rapid changes in the physical conditions of inner region of the disk and evaporate all the hot dust (Rafikov & Garmilla 2012). If that is the case, we would only expect dusty white dwarfs with a gaseous disk to be variable.

Previous searches for infrared variability around white dwarfs have been sporadic – only three white dwarfs have two epochs of K band observations and no variability was found (Kilic & Redfield 2007). In order to distinguish the possible scenarios and quantify the incidence of disk variability, we propose to measure the JHK fluxes for 18 white dwarfs that are accessible to UKIRT in 2015A. 13 targets have previous K band photometry, mostly from 2MASS and UKIDSS, which were taken at least 5 years ago. For the other 5 white dwarfs with no previous K band photometry, these data will provide better constraints to the inner disk temperature and also be an important part of the database of dusty white dwarfs. In addition, all targets have at least one epoch of Spitzer/IRAC data that constrain the SED.

WFCAM is ideal for this program due to its large field of view, which allows for high precision differential photometry. Some of the targets are quit faint (J $>$ 18.0) and the high sensitivty of the detector also enables the observations to be done in a very time efficient manner.

This is a continuation of the approved 2014B program to monitor dusty white dwarfs to better understand the infrared variability.

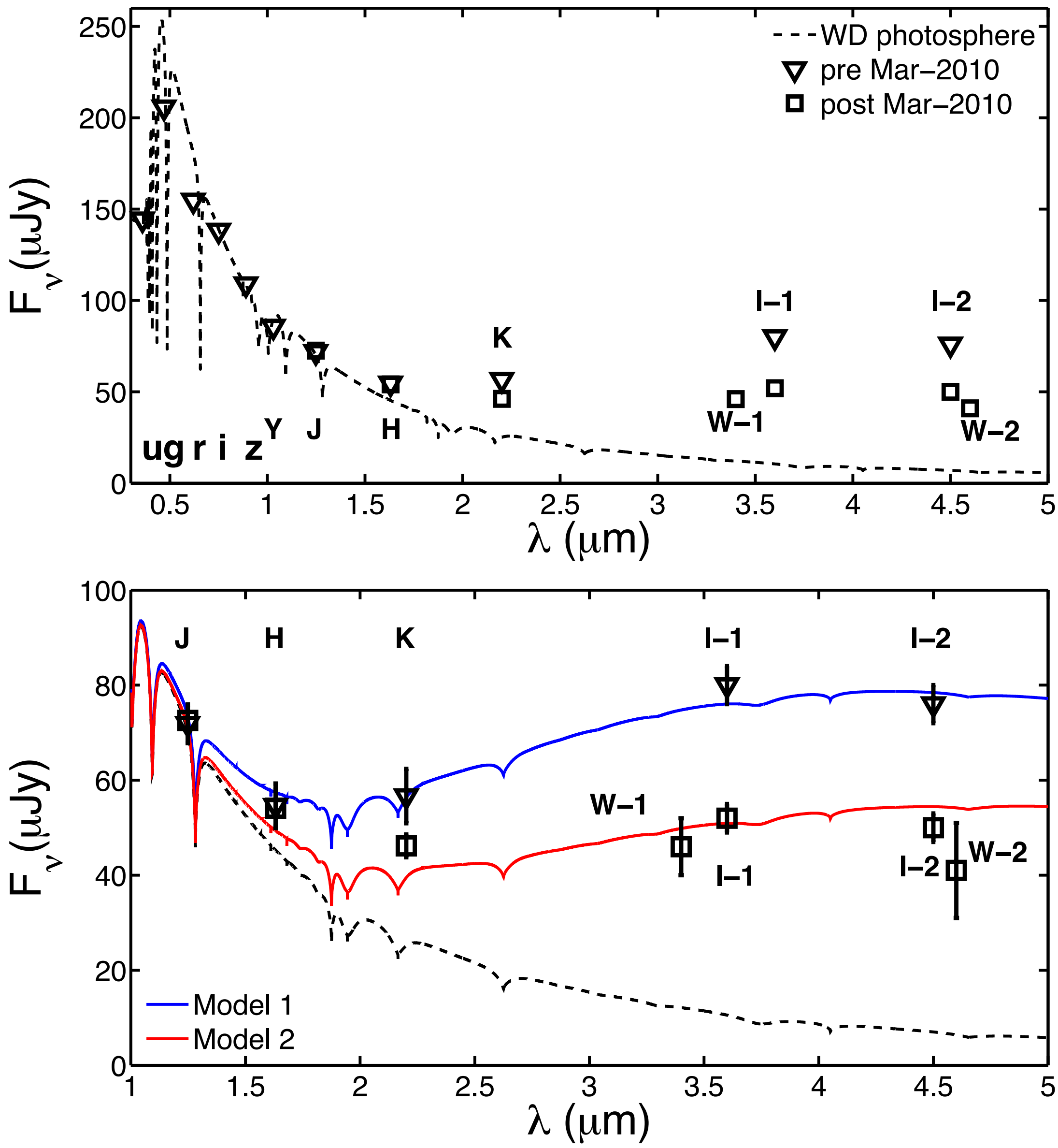

Figure 1: SED fits for WD J0959-0200 with infrared photometric data from the UKIRT (J, H, K), *WISE* (W-1, W-2 = bands 1 and 2, respectively) and *Spitzer*/IRAC (I-1, I-2 = bands 1 and 2, respectively) from Xu & Jura 2014. The upper panel shows the entire SED and the lower panel shows only the infrared part. The black dashed line is the simulated white dwarf spectrum (T=13,280 K, log g=8.06 from Farihi et al. 2012a). The red solid line (model 1) includes flux from WD J0959-0200 and a dust disk with R_{in}=10.5R_{wd} (T_{in} = 1545 K), R_{out}=26.5R_{wd} (T_{out} = 771 K) and cos i =1. The blue solid line (model 2) differs from model A by the inner disk radius R_{in}=14R_{wd} (T_{in} = 1245 K). Model 1 and 2 fits the pre Mar-2010 and post Mar-2010 data points, respectively. Something dramatic must have occurred around March 2010 to cause the rapid destruction of hot dust around WD J0959-0200.

Observing Log: pre Mar-2010, JHK: Dec 2005 (UKIDSS); IRAC: Jan 2010 (Farihi et al. 2012a). post Mar-2010, *WISE*: May 2010 and Nov 2010 (the average flux is shown in the figure); IRAC: Feb 2014 (ID: # 10032, PI: M. Jura); JHK: Mar 2014 (UKIRT, ID: U/14A/D4, PI: M. Jura).

REFERENCES

Barber, S. D., Kilic, M., Brown, W. R., & Gianninas, A. 2014, ApJ, 786, 77
Bergfors, C., Farihi, J., Dufour, P., & Rocchetto, M. 2014, MNRAS, 444, 2147
Farihi, J., Jura, M., & Zuckerman, B. 2009, ApJ, 694, 805
Farihi, J., Gänsicke, B. T., Steele, P. R., et al. 2012a, MNRAS, 421, 1635
Farihi, J., Gänsicke, B. T., Wyatt, M. C., et al. 2012b, MNRAS, 424, 464
Gaensicke, B. T., Marsh, T. R., Southworth, J., & Rebassa-Mansergas, A. 2006, Science, 314, 1908
Gaensicke, B. T., Koester, D., Marsh, T. R., Rebassa-Mansergas, A., & Southworth, J. 2008, MNRAS, 391, L103
Girven, J., Brinkworth, C. S., Farihi, J., et al. 2012, ApJ, 749, 154
Jura, M. 2003, ApJ, 584, L91
Jura, M. 2008, AJ, 135, 1785
Kilic, M., & Redfield, S. 2007, ApJ, 660, 641
Rafikov, R. R., & Garmilla, J. A. 2012, ApJ, 760, 123
Wilson, D. J, Gaensicke, B., Koester, D., et al. 2014, MNRAS, in press, arXiv:1409.2490
Wyatt, M. C., Farihi, J., Pringle, J. E., & Bonsor, A. 2014, MNRAS, 420
Xu, S., & Jura, M. 2012, ApJ, 745, 88
Xu, S., Jura, M., Koester, D., Klein, B., & Zuckerman, B. 2014, ApJ, 783, 79
Xu, S., & Jura, M. 2014, ApJ, 792, L39

Experimental Design & Technical Description *Describe your overall observational program. How will these observations contribute toward the accomplishment of the goals outlined in the science justification? If you've requested long-term status, justify why this is necessary for successful completion of the science.* ***(up to one page)***

We propose to obtain JHK broadband photometry for 18 dusty white dwarfs to look for variability in the infrared. WFCAM onboard UKIRT is ideal for this purpose due to its large field of view, which allows for high precision differential photometry. Some of the targets are quite faint (J $>$ 18.0) and the high sensitivity of the detector also enables the observations to be done in a very time efficient manner. In addition, UKIRT discovered the K band variability in WD J0959-0200, the first one of its kind!

We will use the same observing strategy as we did for WD J0959-0200 in the UKIRT DDT program (ID: U/14A/D4, PI: M. Jura). Absolute flux calibration is not needed and we will do photometric measurement relative to other field stars. A number of exposures will be taken with 10 seconds each to obtain a signal-to-noise ratio of 30 for J and H bands and 40 for K band, which will enable us to identify variabilities on $\sim$ 20% level. The observing time was calculated based on past observing experience with WD J0959-0200, which had a total of 45 minutes including overheads. The on target time was 150 sec, 450 sec and 1250 sec exposures for J (18.32 mag), H (18.18 mag) and K (17.62 mag) band, respectively. The time needed for each target, including overheads, are listed in the target list. A few targets are quite faint and a long exposure is needed to get the desired signal-to-noise ratio. We request a total of 9 hours for this program.

Summary of Time Requested and Awarded *The TAC needs to understand the scope of this project — (1) tell us how many UAO nights you've already had for this project, how many you request this time, and (a good guess of) how many you need to complete the project; (2) if a substantial amount of observing for this project comes from non-UAO telescopes, tell us about that observing, and how the UAO part fits in; (3) if you are collaborating with people who have telescopes, especially if you are part of a large collaboration, tell us who is leading the project, and how UAO time and your participation fit in. (**up to one page**)*

We were awarded 4 hours for this project in 2014B. The program is on-going. We propose for an additional 9 hours to observe dusty white dwarfs that are observable in 2015A. It will motivate our future *Spitzer* program to confirm the infrared variability at longer wavelengths. As shown in Figure 1, the amplitudes in IRAC bands are about twice as big as that in K band.

Previous Use of Steward Facilities *List **all** allocations of telescope time for the present project and allocations for other projects on facilities available through UAO during the past 2 years, together with the current status of the data (cite publications where appropriate). Mark those allocations related to the present proposal (i.e, precede text with* `\related` *command). (**up to one page**)*

Previous telescope allocation for the present project: 4 hours for 2014B.

Previous telescope allocation for the other projects: PI has no other telescope allocation as a PI in the past two years.