

SWARMS: A Search for Type Ia Supernova Progenitors With the Sloan Digital Sky Survey

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- **SWARMS** is the Sloan White dwarf Radial velocity data Mining Survey. We use the **multiple exposures** (≥ 3 , ~ 15 min each) taken for all the Sloan Digital Sky Survey (SDSS) spectra to **look for radial velocity (RV) shifts** among the $\sim 10,000$ white dwarfs (WDs) in the DR4 SDSS catalog (Eisenstein et al. 06) [Fig. 1].

- **Goal:** Find the **double degenerate WD (DDWD) progenitors of Type Ia SNe** (Webbink 84, Iben & Tutukov 84): WD binaries with $t_{\text{Merge}} < t_{\text{Hubble}}$ and $M_A + M_B > M_{\text{Ch}}$ [Fig. 2].

- **First results from SWARMS:** **SDSS 1257+5428**, a nearby, massive WD with a neutron star or black hole companion (Badenes et al. 09); **SDSS 1436+5010** and **SDSS 1053+5200**, the two detached DDWDs with the shortest periods (Mullally et al. 09).

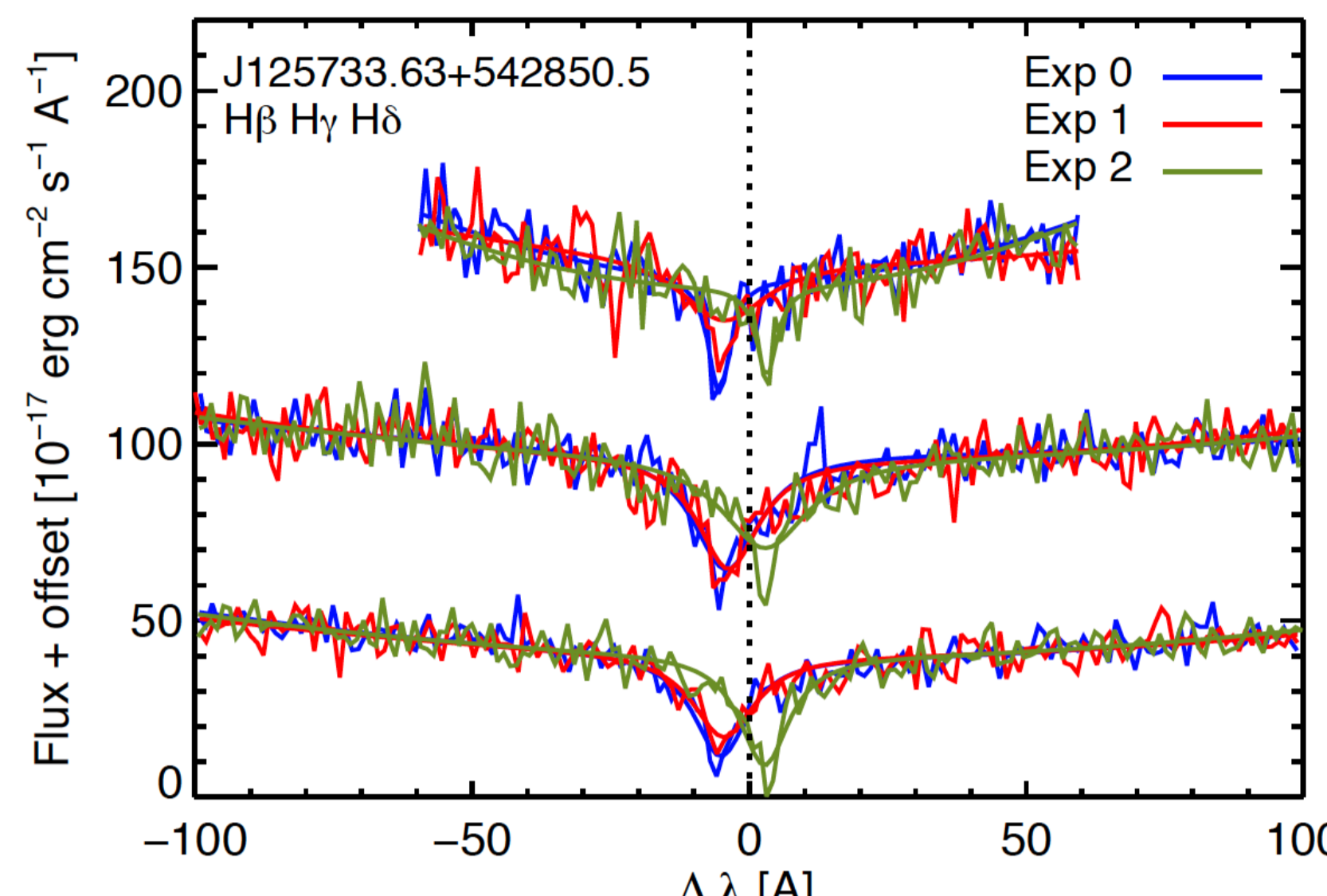


Figure 1: Three individual 15 min. exposures of SDSS 1257+5428 from DR7 of SDSS. The RV shift between exposures 0 and 1 and exposure 2 is $\sim 8 \text{ \AA}$ ($\sim 490 \text{ km s}^{-1}$).

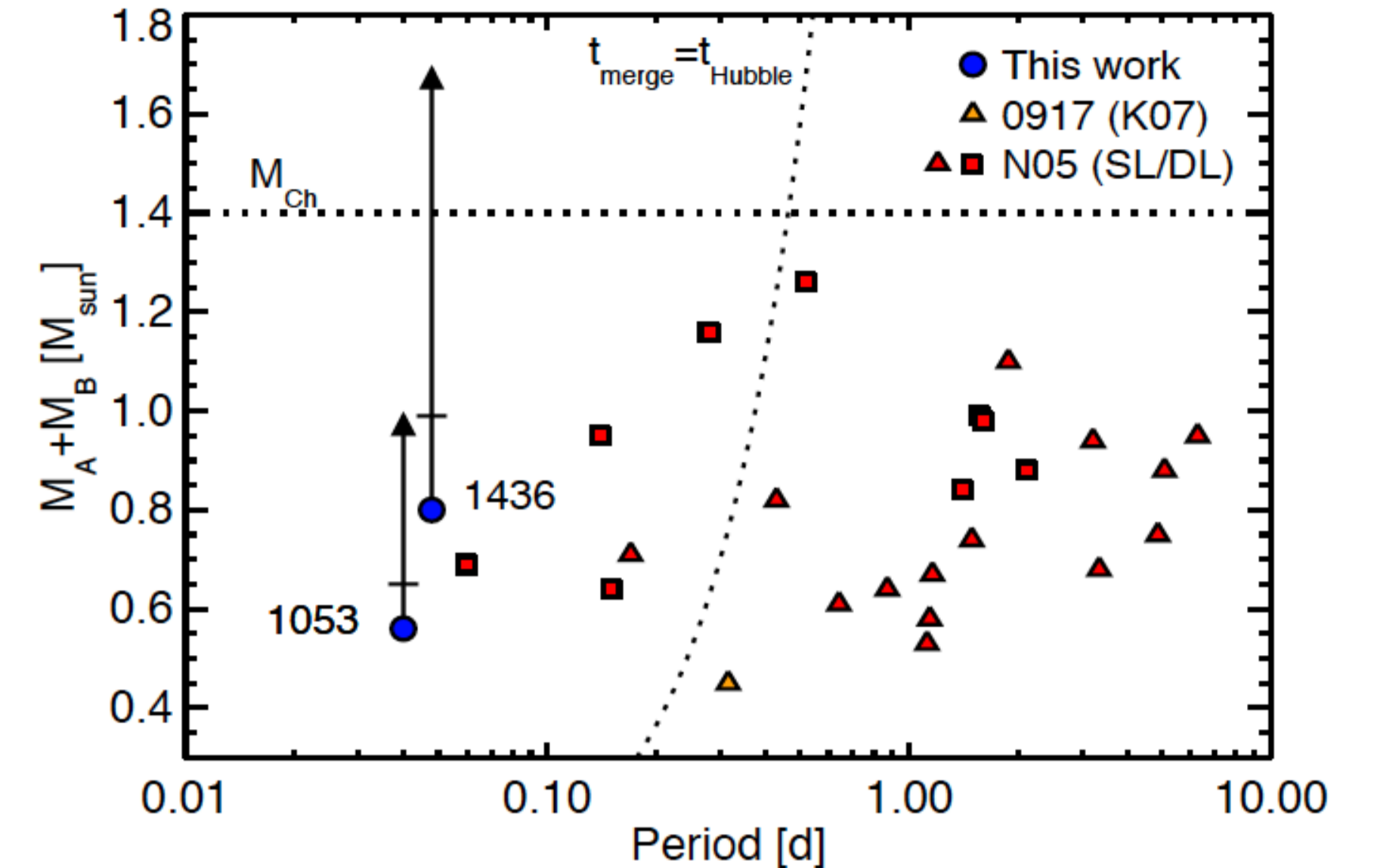
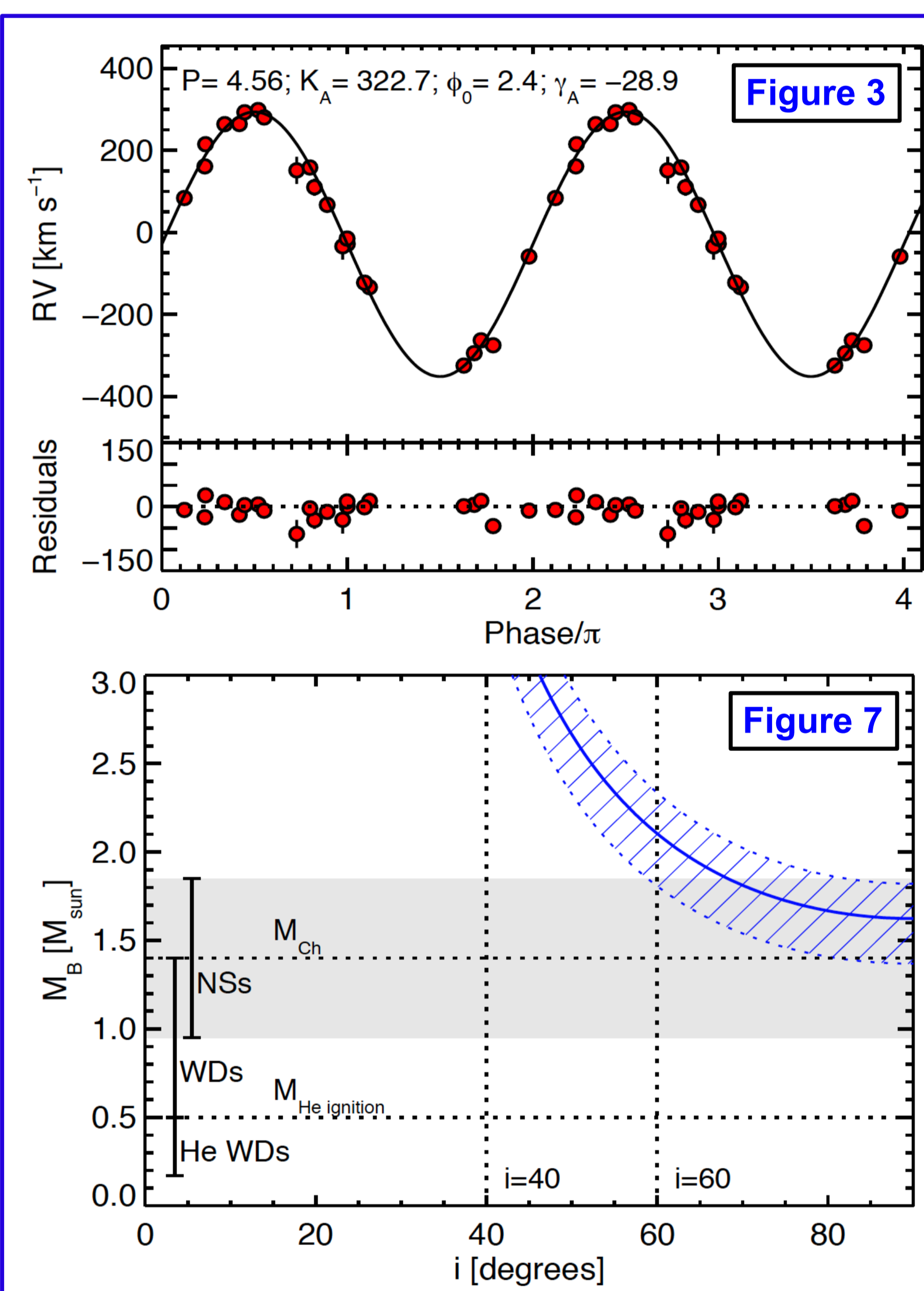


Figure 2: Combined masses for the single-lined (triangles) and double-lined (squares) DDWD systems with known periods from Nelemans et al. 05, Kilic et al. 07a, and this work.



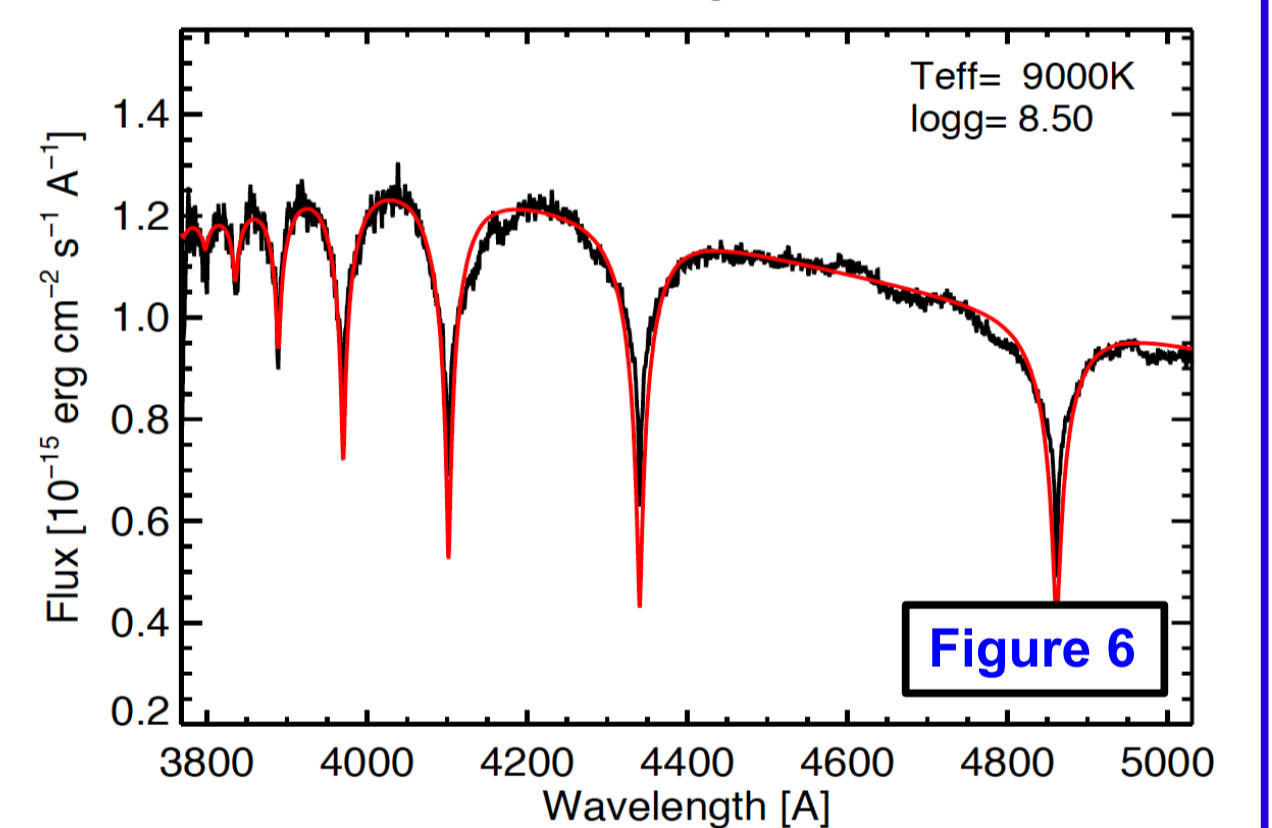
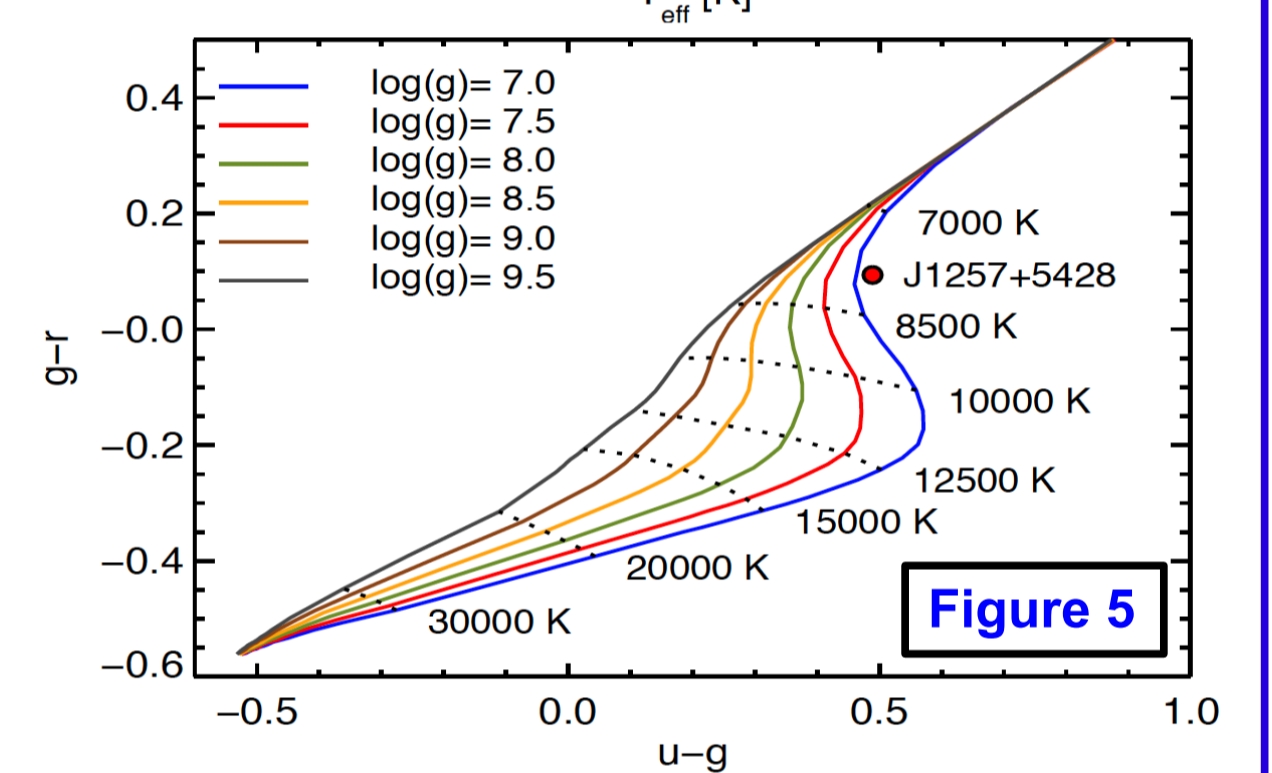
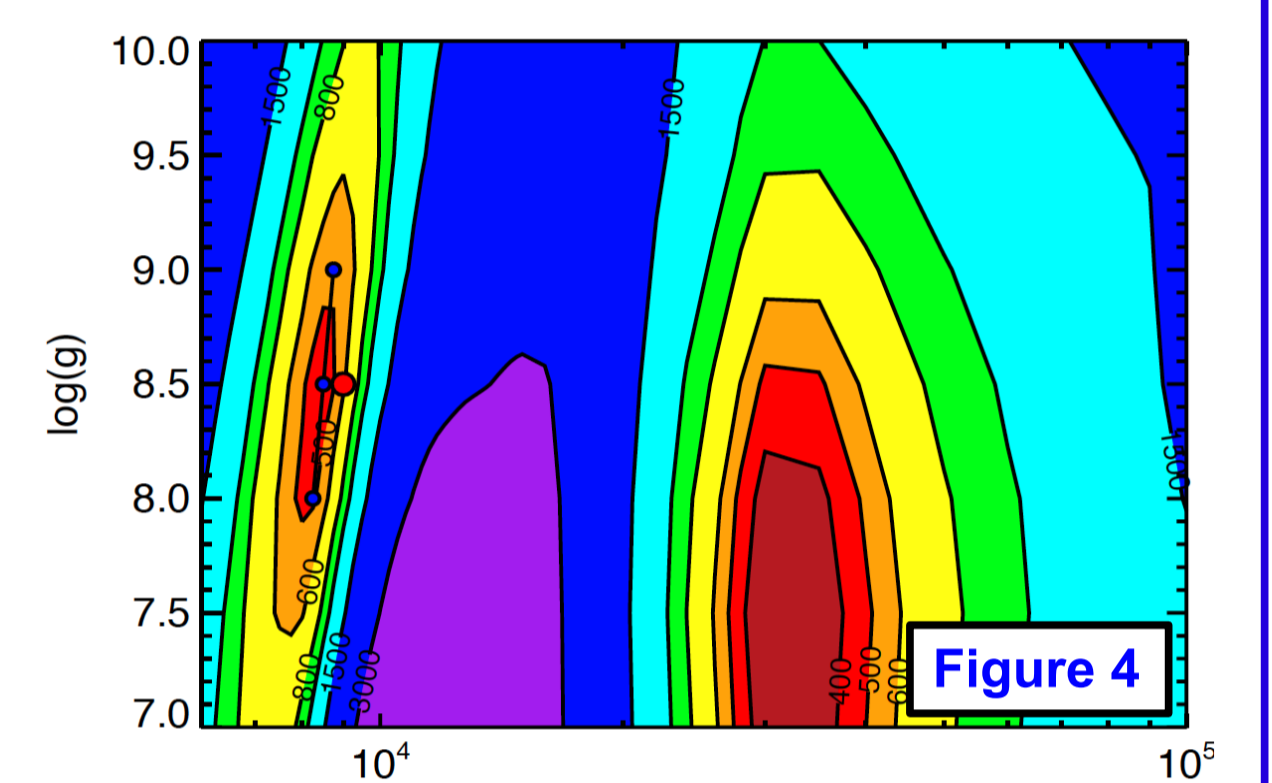
SDSS 1257+5428: The closest neutron star or black hole?

- First binary identified by SWARMS [Fig. 1]. Follow-up observations were performed with the ARC 3.5m telescope at APO on Feb. 2009.

- **Orbit:** RV curve is well described by a circular orbit, with $P = 4.5550 \pm 0.0007 \text{ hr}$ and $K_A = 322.7 \pm 6.3 \text{ km s}^{-1}$ [Fig. 3].

- **Spectrum:** Co-added APO spectrum has proved hard to fit. The χ^2 statistic has two minima in the $[T_{\text{eff}}, \log(g)]$ plane [Fig. 4], but hot ($\sim 30,000 \text{ K}$) solutions are ruled out by the SDSS photometry [Fig. 5]. A model with $T_{\text{eff}} = 9,000 \text{ K}$ and $\log(g) = 8.5$ works best, but the fit is poor [Fig. 6]. Spectral models for WDs (e.g. Finley et al. 97) are known to have problems in this T_{eff} range (Koester et al. 08). Despite the bad fits, a conservative mass estimate for the WD can be determined: $M_A = 0.92 \pm 0.32 M_{\odot}$ (see Badenes et al. 09 for details).

- **Nature of the companion:** From the orbital parameters and the estimated value of M_A , $M_B \sin(i) = 1.62 \pm 0.25 M_{\odot}$ [Fig. 7]. The companion is too massive to be another WD, and must be either a neutron star or a black hole. At a projected distance of $29 \leq D \leq 58 \text{ pc}$, this could be the closest stellar remnant of a SN explosion. Radio and X-ray observations are being planned to explore this possibility.



SDSS 1436+5010 and 1053+5200: The shortest period detached DDWDs.

- Identified as binaries from the SDSS spectra. Kilic et al. (07b) also noticed their potential binarity from the low mass of the WDs ($\sim 0.19 M_{\odot}$).

- **1436+5010:** $P = 1.15238 \pm 0.00014 \text{ hr}$, $K_A = 388 \pm 21 \text{ km s}^{-1}$ [Fig. 8]. RV curve residuals show a linear trend, but eccentric orbit does not improve the fit.

- **1053+5200:** RV curve only has six points, but the period is robustly constrained to $P = 0.960 \pm 0.010 \text{ hr}$, $K_A = 310 \pm 14 \text{ km s}^{-1}$ [Fig. 9].

- Although probably not SN Ia progenitors, these are the detached DDWDs with the shortest periods known [Fig. 2] (see Mullally et al. 09 for details).

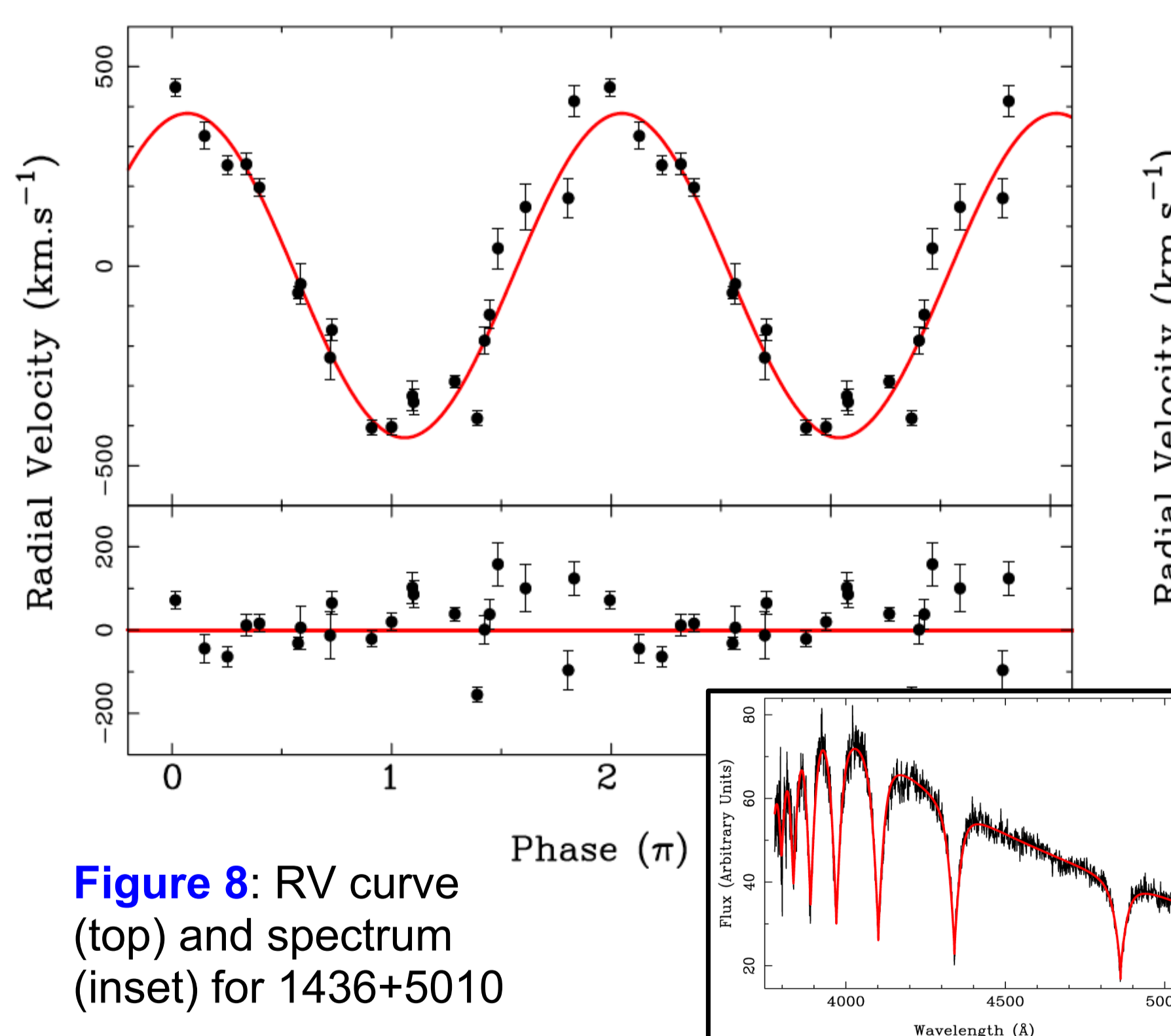


Figure 8: RV curve (top) and spectrum (inset) for 1436+5010

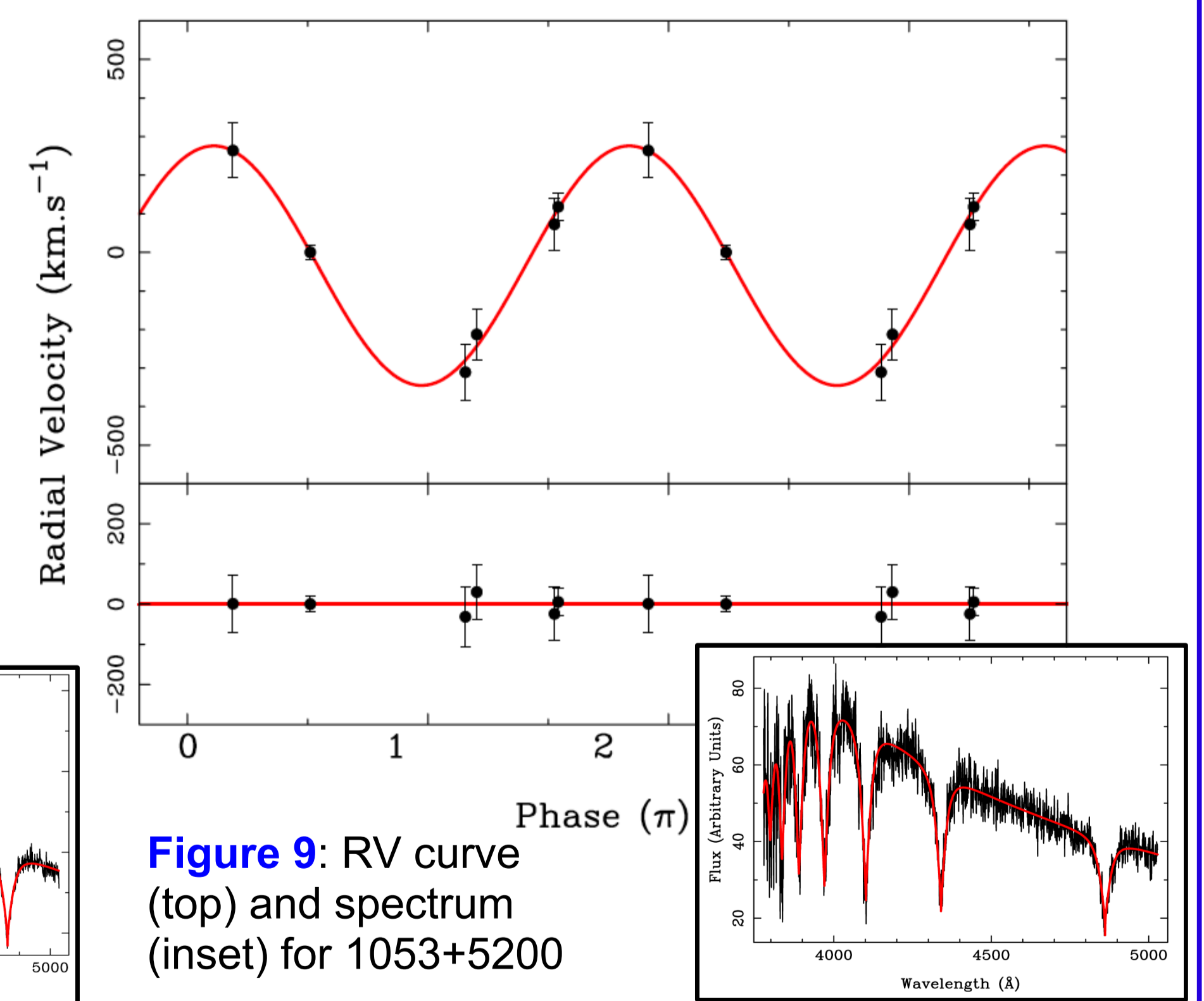


Figure 9: RV curve (top) and spectrum (inset) for 1053+5200

Summary:

- **SWARMS** showcases the potential of the SDSS data base for time resolved spectroscopy of stellar sources (see also Pourbaix et al. 05). Our search is complementary to the SPY project (Napiwotzki et al. 01): we examine WDs with northern declinations at a much lower spectral resolution. We anticipate the discovery of several more DDWDs with short merging times. Here we present the first results from SWARMS:
- **SDSS 1257+5428:** a nearby, massive WD with a dark, very massive companion, probably a neutron star or a black hole (Badenes et al. 09).
- **SDSS 1436+5010 and 1053+5200:** the two DDWDs with the shortest periods known, 1.15 and 0.96 hr (Mullally et al 09).

References:

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- Nelemans et al. 2005, A&A 440, 1087
- Pourbaix et al. 2005, A&A 444, 643
- Webbink, 1984, ApJ 277, 355

Questions? Comments?

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