AS4 Letter of Intent:
A time-domain spectroscopic survey of white dwarfs within 1 kpc

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We propose an AS4 project to obtain optical spectra of 30-100% of the half-million white dwarfs (WDs) within 1 kpc that will be identified by *Gaia*. WDs, the end state of 95% of all stars, and the current state of most of the stars ever formed with initial mass $M > 1.2M_{\odot}$, are important and useful in a multitude of applications: as tracers of Galactic structure and star-formation history, as sources of gravitational waves, as progenitors of type Ia supernovae (SNe Ia), and as fossil probes of the planetary systems around stars. However, only a tiny and incomplete fraction of the local (< 1 kpc) population of WDs is known at present. Most of the $\sim 20,000$ spectroscopically confirmed WDs have been discovered in SDSS, as an accidental byproduct of obervations of color-selected quasar candidates.

This situation is about to change, thanks to *Gaia*. By 2020, *Gaia* will have identified, via proper-motions and parallaxes, 500,000 WDs within 1 kpc to $G = 20$ mag. This census will be 100% complete to 50 pc (i.e. it will include all WDs, including the oldest and coolest ones), and 50% complete to 300 pc. However, as detailed below, the power of the *Gaia* WD sample will emerge only if it is supplemented with ground-based medium-resolution spectroscopy of the WDs, which we propose here. At $V = 20$, the sky density of these nearby WDs will range from 5 deg^{-2} at the poles to 40 deg^{-2} in the plane. Typically, 70 fibers per current (7 deg^2) SDSS field could be filled with $D < 1$ kpc WD targets to $V = 20$ mag. Some of the other programs that may run in parallel in an SDSS-V MOS survey, utilizing the remaining fibers, will likely be time-domain programs requiring repeated observations. Repetitions will add crucial information for the WDs as well, as they will permit the detection of close WD binaries via the radial-velocity variations. Flexibly with other programs, any repetition pattern will be good for this purpose, whether just the current SDSS splitting of every epoch into two consecutive exposures for cosmic-ray removal, or also additional epochs at arbitrary cadence.

Gaia will be a superb WD discovery machine, but its very-low-resolution ($R = 100$) spectra will be insufficient in most cases to determine the WD atmospheric composition (H or He), preventing accurate determinations of masses, radii, and cooling ages. Precise determination of these parameters, which are essential to derive the WD luminosity function and the local star-formation history, requires intermediate resolution ($R = 2000 - 5000$) ground-based spectroscopic followup of the gravity/pressure-sensitive Balmer and He lines. Similarly, the *Gaia* data will give only five of the six phase-space coordinates of every WD (sky position, distance, proper motion), and a ground-based spectrum is required for the radial velocity (based on the narrow NLTE core of the Hα line). The WD cooling age, when added to the WD progenitor's main-sequence lifetime (which can be estimated based on the WD mass and the initial-to-final mass relation for WDs), gives the total age of every WD, rendering the WDs powerful Galactic clocks for reconstructing Galactic kinematics, star-formation and structure-formation history within the local 1 kpc. Spectroscopic followup of the *Gaia* WD sample is therefore essential in order to exploit the tremendous potential of this sample. To utilize the WD sample over the whole sky, we propose replicating a BOSS spectrograph for the LCO 2.5m and conducting parallel WD surveys at APO and LCO. Robotic fiber positioners will naturally make the survey all the more efficient.

Some of the science applications of the proposed *Gaia*-AS4 WD survey follow, telegraphically. The overconstrained modeling of WD masses and radii (based on distances, photometry, and spectra) will permit modeling the distribution of core compositions of WDs, with implications for stellar evolution and mass loss. Wide binaries identified by *Gaia* consisting of a WD and an evolved star (a sub-giant or a giant, for which ages can be determined from the photometry and the spectra) can help populate the important but still poorly known initial-final-mass relation for WDs. In WD-MS wide binaries (at least 10% of all binaries), the WD provides a clock and the MS star a measurement of metallicity, for a reconstruction of Galactic metal-production history. A large fraction of WDs are in so-called post-common-envelope or pre-CV binaries consisting of a WD and an M star in a close orbit. Such binaries, important for understanding interacting binary evolution, CVs, and SNe Ia, will be identified photometrically by *Gaia* colors, but their properties and periods will require multi-epoch spectra. As found in SDSS WDs, but here on an order-of-magnitude larger sample, the spectra will reveal brown-dwarf companions to WDs, and possibly even the first planets around WDs, via weak Hα emission. The full phase-space information of the sample's WDs will give a clear kinematic separation of the WD population into Galactic components (bulge, halo, thin/thick disk), and the WD mass function separated by WD age and by Galactic component will allow a reconstruction of the star-formation histories and initial mass functions of each component. Studies of current samples of WDs suggest that about 5% of WDs are in close (separation $a <$ few $R_\odot$) double-WD systems. These nearby DWDs are important as the potential progenitors of SNe Ia, but also as the main foreground sources of gravitational waves for the space-based LISA. The proposed program will identify these DWDs by means of RV variations, characterize their distributions in separation and component masses, and measure their merger rate. A large fraction of WDs are tidally shredding and actively accreting the gas and rocky remains of their former planetary systems. The recent discovery with the K2 mission of a disintegrating asteroid around a WD, with a constantly changing signature of its transiting debris, suggests that our repeated spectroscopy could reveal changes in, or even the appearance or disappearance of, the photospheric metal lines seen in some WDs and which trace such debris-accretion. The program could quantify the occurrence of this phenomenon. More fundamentally, it is still not settled why some WDs have helium (rather than H) atmospheres, or mixed (H+He) atmopheres. A large, complete, sample is the way to address this. Accreting WDs in interacting binaries in the form of CVs, novae, AM CVn binaries, etc., could be additional targets for this program, after being discovered either by *Gaia*, or by an assortment of transient surveys that will be operational by the 2020s, such as ZTF, ATLAS, BlackGEM, and LSST. Multi-epoch spectroscopy will permit the classification and physical study of those systems as well.

Several upcoming MOS surveys—WEAVE, DESI, and 4MOST—plan to obtain spectra of *Gaia* WDs. However, WEAVE will likely observe only a fraction of the WDs, and the current planning is limited to $g < 18.5 - 19$ mag for DESI, and to $g < 19 - 19.5$ mag for 4MOST (due to the short planned exposure times). Importantly, the forthcoming surveys will also have a large gap at "intermediate" Galactic latitudes of $5^\circ < |b| < 25^\circ$. Finally, our proposed program introduces the time-domain aspect, absent in the other programs, with its potential to map WD binarity . In summary, an AS4 spectroscopic survey of the local WD population would fill a big gap in our view of the local neighborhood, and create a legacy dataset with applications in a very broad range of astrophysics.