

A double debris disc around a white dwarf sculpted by two planetary bodies

Nicola Pietro Gentile Fusillo^{1,2}, Felipe Lagos-Vilches^{3,4}, Boris T.
Gänsicke^{3,5}, Christopher J. Manser⁶, Detlev Koester⁷

¹Dipartimento di Fisica, Università di Trieste, Trieste, Italy.

²INAF-Osservatorio Astronomico di Trieste, Trieste, Italy.

³Department of Physics, University of Warwick, Coventry, UK.

⁴Departamento de Física, Universidad Técnica Federico Santa María,
Av. España 1680, Valparaíso, Chile.

⁵Centre for Exoplanets and Habitability, University of Warwick,
Coventry, UK.

⁶Department of Physics, Astrophysics Group, Imperial College London,
London, UK.

⁷Institut für Theoretische Physik und Astrophysik, University of Kiel,
Kiel, Germany.

* nicolapietro.gentilefusillo@units.it.

Abstract

Many planetary systems survive the metamorphosis of their hosts stars into white dwarfs, as demonstrated by the detection of dusty circumstellar discs around these stellar remnants as well as chemical signatures of planetary debris in atmospheres of these stars. A small fraction of these circumstellar discs also contain gas, detected in the form of emission lines from various ionic transitions (most commonly the near-infrared Ca II triplet). All of the 21 known gas discs exhibit double-peaked line profile characteristic of a rotating flat disc. The mechanism behind the the generation of gas is still debated, but for at least one system it has been linked with the presence of a surviving planetesimal embedded within the dust disc. Here we report the discovery of WD J132800.85–145019.95, a new gas disc system which exhibits quadruple-peaked instead of double-peaked line profiles. These emission lines originate from two separate gaseous rings extending from $0.14 R_{\odot}$ to $0.34 R_{\odot}$ and from $0.54 R_{\odot}$ to $1.93 R_{\odot}$. We propose that

31 this structure results from the presence of two distinct planetary bodies within
 32 these discs, ranging in size from a few km to the size of Pluto. The detection this
 33 stable double-disc presents a new challenge for the current models of debris disc
 34 formation and evolution.

35 Main

36 We identified an infrared excess in the broad-band photometric spectral energy
 37 distribution (SED) of WD J132800.85–145019.95 (henceforth WD J1328–1450) and
 38 subsequently obtained medium resolution spectroscopy using the X-shooter spectro-
 39 graph on the Very Large Telescope (VLT) to probe for atmospheric metal enrichment.
 40 The spectra of WD J1328–1450 contain Ca, Mg and Si absorption lines (Extended
 41 Data Table 1) which unambiguously confirms the accretion of planetary material from
 42 a circumstellar dust disc, as well as Ca II, O I, Mg I and Fe II emission lines from a
 43 metallic gaseous disc (Extended Data Table 2). However, unlike the double-peaked
 44 line profiles of all previously known gas discs, the Ca II and O I emission lines in
 45 WD J1328–1450 exhibit quadruple-peaked profiles (Fig. 1). This unusual morphology
 46 of the emission lines can be explained as a superposition of light emitted from two
 47 distinct gaseous rings around the white dwarf.

48 By comparing the star’s spectrum and photometry with appropriate atmospheric
 49 models (Extended data Fig. 1), we determined the star to have an effective temper-
 50 ature of $T_{\text{eff}} = 17,424 \pm 567$ K, a surface gravity of $\log g = 7.76 \pm 0.19$, and mass of
 51 $M = 0.47 \pm 0.09 M_{\odot}$. These parameters fall well within the typical range of the 21
 52 other published gaseous disc hosts [1]. Keeping the stellar parameters fixed, we fitted
 53 the metal absorption features in the spectrum of WD J1328–1450 and measured the
 54 photospheric abundances for Ca, Mg and Si (Extended Data Table 1). The number
 55 abundance ratios, $\log(\text{Mg}/\text{Ca}) \simeq 0.93$ dex and $\log(\text{Si}/\text{Ca}) \simeq 0.84$ dex, are similar to
 56 those found for most other metal-enriched white dwarfs and broadly compatible with

the composition of rocky bodies in the inner solar system [2]. Given that the bulk chemical composition of the planetary debris around WD J1328–1450 does not appear in any way peculiar, it is unlikely to be related to the unique properties of the discs in this system.

We modelled the emission line profiles of O I, Mg I and Ca II as originating from two concentric and co-planar circular gaseous discs assuming that their surface brightness, as a function of the distance from the white dwarf, follows a power law (Fig. 2). The symmetric profile of the emission lines has remained unchanged for more than 2 years supporting the hypothesis that the gas discs are close to circular and uniform. Under these assumptions, the shape of the Ca II triplet is best reproduced with two discs extending from $0.14^{+0.01}_{-0.02} R_{\odot}$ to $0.34^{+0.02}_{-0.05} R_{\odot}$ and from $0.54^{+0.44}_{-0.16} R_{\odot}$ to $1.93^{+0.10}_{-0.30} R_{\odot}$, with an inclination with respect to the line of sight $i = 77^{+9}_{-13}$ degrees (Fig. 3, Extended data Table 3). Because of the lower signal-to-noise-ratio and blending of the individual line components, modelling of the O I emission triplet is less constraining than the results obtained from the Ca II lines, but it nonetheless results in a consistent double disc configuration (see Methods). In contrast, the Mg I line shows a double peak profile indicative of emission originating only from the inner gas disc (Fig. 2d). If the inner and outer discs shared the same Ca/Mg ratio, we would detect Mg emission from the outer ring at $> 6\sigma$ significance (Extended data Fig. 2). The absence of this detection provides direct, model-independent evidence that Mg is significantly depleted in the outer ring relative to the inner ring. This compositional difference is an important clue given that different planetary materials exhibit distinct Mg/Ca ratios: chondrites range from $\text{Mg/Ca} \simeq 5\text{--}15$, Earth’s mantle has $\text{Mg/Ca} \simeq 8$, while Earth’s crust shows $\text{Mg/Ca} \simeq 1.6$ [3, 4, 5]. The marked difference between the two rings strongly suggests they originate from distinct parent bodies with different formation histories, or alternatively from different structural layers of a differentiated planetesimal (e.g., Mg-rich mantle material versus Mg-depleted crustal material). We note that, whereas the model of two

discs separated by a gap results in a good fit to the observed quadruple-peaked emission lines of WD J1328–1450, a single disc in which a vertical extension results in self-shadowing of the region $R \simeq 0.34 - 0.54 R_{\odot}$ would lead to a similar outcome. However, that scenario is not physically backed up by any existing theoretical model of the debris discs around white dwarfs (see Methods). The dusty component of the debris disc is detected in the form of a strong infrared excess above the flux of the white dwarf (Fig. 4). The fractional infrared flux excess of the dust disc around WD J1328–1450, i.e. the ratio of the flux emitted by the disc and the stellar flux, is $\tau = 2.7\%$, making this one of the brightest dusty debris disc published to date [1, 6, 7]. We modelled the infrared excess using the radiative transfer code MCFOST [8, 9] and obtained a satisfactory fit with a disc having an inner radius of $0.25 R_{\odot}$, outer radius of $2 R_{\odot}$, scale height at the inner edge equal to the white dwarf radius ($0.015 R_{\odot}$), moderate flaring, and outward-increasing dust density. Although the model reproduces the observations, we note that several fit parameters are degenerate and alternative disc configurations may fit the data equally well. Nonetheless, our analysis supports the growing observational and theoretical evidence that dusty debris discs around white dwarfs can develop substantial vertical extensions [11, 12] due to dynamical excitation [12]. The dust discs are expected to be optically thin, as demonstrated by prominent silicate emission features [13, 14] and observations of partial transits [15].

Thermal dust emission cannot provide detailed information on the radial structure of the disc due to its broad blackbody spectral kernel. In contrast the sharp emission lines of gaseous discs contain rich dynamical information on the geometry of the emitting regions. Therefore the quadruple-peaked emission profiles provide strong evidence for two distinct gas discs, whereas the dust continuum flux offers no comparable constraint on the spatial distribution of solid material. One might hypothesize a scenario where a single planetary body opens a gap in both gas and dust, creating two separate discs. However, this would reduce the emitting surface area, making the system’s large

111 IR excess even harder to explain. More fundamentally, a solid body within a dust-
 112 depleted gap could neither clear the gas from that region nor provide a mechanism for
 113 generating the gas in the two discs (see Methods).

114 The two concentric gas discs detected at WD J1328–1450 require both a mech-
 115 anism that generates the gas within each of them, and avoids the radial spreading
 116 of the gas which would close the gap between them. Evidence of strongly localised
 117 gas has been detected in the gas disc of WD J0846+5703, where the sharp double-
 118 peaked emission corresponds to a narrow ring only extending from $\simeq 1.0$ to $\simeq 1.1 R_{\odot}$,
 119 for an adopted inclination of 21 degrees [1]. The most likely mechanism limiting the
 120 radial spreading of gas is the sublimation-condensation equilibrium. After gas is pro-
 121 duced either by dust collision or sublimation, it spreads viscously on timescales $\tau_{\text{visc}} \sim$
 122 $(10\text{--}20)/\alpha$ years [16]. However, as the gas moves outward and cools, it re-condenses
 123 below $T \simeq 1,200 - 1,500$ K [17, 18], creating a confined gas ring near the sublimation
 124 source. The re-condensation timescale is significantly shorter than the viscous spread-
 125 ing timescale [16], limiting the size of the gas disc and in the case of WD J1328–1450,
 126 preventing significant radial mixing between the two rings .

127 Dust sublimation at the inner edge of the disc [16, 19], and a collisional cascade of
 128 dust particles [20, 21, 22] are both alternative hypotheses put forward to explain the
 129 origin of gas in white dwarf debris discs. However the double gas disc configuration of
 130 WD J1328–1450 represents a challenge for both these interpretations. The idea that
 131 all the gas could be generated by sublimation at the inner edge of the dust disc is
 132 incompatible with the existence of a gap in the gas radial distribution. Similarly, in
 133 the collisional cascade scenario, the existence of the gap would require some unknown
 134 mechanism capable of inhibiting collisions and gas spreading, but only in a limited area
 135 of the disc. Another possibility is that WD J1328–1450 is an unresolved double white
 136 dwarf system with each component hosting its own gaseous debris disc. However, this
 137 scenario would require some extremely fine-tuned initial conditions for the existence

138 of the planetary systems (see Methods) and, more importantly, the chances of both
 139 white dwarfs independently being in a state that allows a gaseous debris disc to persist
 140 are extremely small. [23] Therefore, another scenario for gas-generation in two discs
 141 needs to be invoked.

142 In the archetypal gas-disc white dwarf systems SDSS J1228+1040 [24] the double-
 143 peaked emission lines arise from a relatively narrow and eccentric gaseous disc that
 144 precesses with a period of $\simeq 25$ years. This precession period is 100,000s times longer
 145 than the orbital period of the gas, and the fact that the radial and azimuthal intensity
 146 distribution of the gas emission remains constant over decades requires a mechanism
 147 that produces the gas in a stable geometry. Furthermore the detection of a periodic
 148 $\simeq 2$ h signal in the emission lines shape and strength in SDSSJ1228+1040 can only be
 149 explained by the presence of a dense solid body embedded in the disc generating gas
 150 by interaction with the dust [25].

151 Since the double disc structure about WD J1328–1450 requires stable gas genera-
 152 tion at two distinct and confined radial locations, we argue that dust interaction with
 153 a planetesimal analogous to SDSS J1228+1040, is the most likely origin of the gas,
 154 and two gas discs would therefore require two planetesimals on concentric orbits.

155 Though we cannot determine the exact orbits of the two theorized planetesimals
 156 orbiting WD J1328–1450, the inner and outer edges of the two gas discs provide some
 157 stringent limits: the inner planetesimal must be located between $0.14 R_{\odot}$ and $0.34 R_{\odot}$
 158 and outer one between $0.54 R_{\odot}$ and $1.93 R_{\odot}$. In order to survive tidal disruption at such
 159 close distances from the white dwarf, a relatively large body must have an extremely
 160 high density or sufficiently high internal strength[25]. Assuming that the body embed-
 161 ded in the inner disc analogous has no internal strength, it would need to be have a
 162 density higher than any known material, ranging from $\gtrsim 3,600 \text{ g cm}^{-3}$ at the inner
 163 edge to $\gtrsim 252 \text{ g cm}^{-3}$ at the outer edge. In the outer disc the highest required density

164 is $\gtrsim 63 \text{ g cm}^{-3}$, over three times that of the densest exo-planet[26], and physically plau-
 165 sible values are only found closer to the outer edge. Therefore, we conclude that any
 166 planetesimals surviving within the discs must possess some degree of internal strength.

167 Using typical internal strengths for rocky Solar System bodies, we can estimate the
 168 largest planetesimal that could avoid tidal disruption at the distances of the discs. For
 169 an iron-like density ($\rho_{\text{Fe}} = 7.8, \text{ g cm}^{-3}$), a planetesimal in the inner disc could have
 170 maximum diameter of 45 km near the inner edge and 172 km near the outer edge. In
 171 the outer disc, the corresponding limits increase to about 346 km at the inner edge
 172 and 2,340 km at the outer edge. Because the density requirement in the outer disc is
 173 more relaxed, a rocky object with moderate internal strength ($\rho \approx 3.5, \text{ g cm}^{-3}$) could
 174 also remain intact there, allowing maximum sizes up to roughly 3,500 km at the outer
 175 boundary.

176 To put these numbers into perspective, while the upper size of the inner planetes-
 177 imal would be that of a typical asteroid in the asteroid belt of our Solar System, the
 178 maximum size of the outer planetesimal could range from that of Ceres (the largest
 179 asteroid in our Solar System) to that of Pluto or even the Moon, depending on the
 180 distance from the white dwarf.

181 Although gaseous debris discs have been known for two decades, our understanding
 182 of their formation, architecture and long-term evolution remain poorly understood.
 183 The discovery of a stable double debris disc around WD J1328–1450 provides addi-
 184 tional observational constraints for the development of physically more detailed models
 185 for these discs. Our analysis suggests that two dense planetary bodies are required to
 186 sustain this double disc, strengthening the idea that gaseous debris discs may generally
 187 arise from interactions between dust and planetesimals that, at least for some time,
 188 survive the tidal disruption process. The ring-like morphology of this system is strik-
 189 ingly similar to structures commonly seen in protoplanetary discs[27]. Despite clear
 190 differences in scale and in the nature of the central star, WD J1328–1450 provides

191 evidence that similar processes may shape both the formation and the final evolution
192 of planetary systems.

References

- [1] Gentile Fusillo, N. P. et al. White dwarfs with planetary remnants in the era of gaia i: six emission line systems. *Mon. Not. R. Astron. Soc.* **504**, 2707–2726 (2021).
- [2] Xu, S. et al. Compositions of planetary debris around dusty white dwarfs. *Astron. J.* **158**, 242 (2019).
- [3] McDonough, W. F. Compositional Model for the Earth’s Core. *Treatise on Geochemistry* **2**, 547–568 (2003).
- [4] Rudnick, R. L. and Gao, S. Composition of the Continental Crust. *Treatise on Geochemistry* **3**, 1–64 (2003).
- [5] Lodders, K. Solar System Abundances and Condensation Temperatures of the Elements. *The Astrophysical Journal* **591**, 1220–12474 (2003).
- [6] Denny, E. et al. Five New Post-main-sequence Debris Disks with Gaseous Emission. *Astrophys. J.* **905**, 5 (2020).
- [7] Rocchetto, M., Farihi, J., Gänsicke, B. T. & Bergfors, C. The frequency and infrared brightness of circumstellar discs at white dwarfs. *Mon. Not. R. Astron. Soc.* **449**, 574–587 (2015).
- [8] Pinte, C. et al. Monte Carlo radiative transfer in protoplanetary disks. *Astrophys. J.* **459**, 797 (2006).
- [9] Pinte, C. et al. Benchmark problems for continuum radiative transfer. High optical depths, anisotropic scattering, and polarisation. *Astron. Astrophys.* **498**, 967 (2009).
- [10] Swan, A., Farihi, J., Wilson, T. G. & Parsons, S. G. The dust never settles: collisional production of gas and dust in evolved planetary systems. *Mon. Not. R. Astron. Soc.* **496**, 5233–5242 (2020).
- [11] Malamud, U., Grishin, E. & Brouwers, M. Circularization of tidal debris around white dwarfs: implications for gas production and dust variability. *Mon. Not. R.*

- 220 *Astron. Soc.* **501**, 3806–3824 (2021).
- 221 [12] Kenyon, S. J. & Bromley, B. C. Numerical Simulations of Gaseous Disks Gen-
222 erated from Collisional Cascades at the Roche Limits of White Dwarf Stars.
223 *Astrophys. J.* **850**, 50 (2017).
- 224 [13] Reach, W. T. et al. The dust cloud around the white dwarf G29-38. II Spectrum
225 from 5 to 40 μ and mid-infrared photometric variability.. *Astrophys. J.* **693**, 697
226 (2009).
- 227 [14] Reach, W. T. et al. Composition of Planetary Debris Around the White Dwarf
228 GD 362.. *Astrophys. J.* **994**, 195 (2025).
- 229 [15] Vanderburg, A. et al. A disintegrating minor planet transiting a white dwarf.
230 *Nature* **526**, 546–549 (2015).
- 231 [16] Metzger, B. D., Rafikov, R. R. & Bochkarev, K. V. Global models of runaway
232 accretion in white dwarf debris discs. *Mon. Not. R. Astron. Soc.* **423**, 505–528
233 (2012).
- 234 [17] Swan, A. et al. Most white dwarfs with detectable dust discs show infrared
235 variability. *Mon. Not. R. Astron. Soc.* **484**, L109–L113 (2019).
- 236 [18] Rafikov, R. R. Inner Edges of Compact Debris Disks around Metal-rich White
237 Dwarfs. *Astrophys. J.* **760**, 123 (2012).
- 238 [19] Rafikov, R. R. Runaway accretion of metals from compact discs of debris on to
239 white dwarfs. *Mon. Not. R. Astron. Soc.* **416**, L55–L59 (2011).
- 240 [20] Kenyon, S. J. & Bromley, B. C. Numerical Simulations of Collisional Cascades
241 at the Roche Limits of White Dwarf Stars. *Astrophys. J.* **844**, 116 (2017).
- 242 [21] Kenyon, S. J. & Bromley, B. C. Numerical Simulations of Gaseous Disks Gen-
243 erated from Collisional Cascades at the Roche Limits of White Dwarf Stars.
244 *Astrophys. J.* **850**, 50 (2017).
- 245 [22] Swan, A. et al. Collisions in a gas-rich white dwarf planetary debris disc. *Mon.*
246 *Not. R. Astron. Soc.* **506**, 432–440 (2021).

- 247 [23] Manser, C. J. et al. The frequency of gaseous debris discs around white dwarfs.
248 *Mon. Not. R. Astron. Soc.* **493**, 2127–2139 (2020).
- 249 [24] Gänsicke, B. T., Marsh, T. R., Southworth, J. & Rebassa-Mansergas, A. A
250 Gaseous Metal Disk Around a White Dwarf. *Science* **314**, 1908–1910 (2006).
251 *Mon. Not. R. Astron. Soc.* **493**, 2127–2139 (2020).
- 252 [25] Manser, C. J. et al. A planetesimal orbiting within the debris disc around a white
253 dwarf star. *Science* **364**, 66–69 (2019).
- 254 [26] Toledo-Adrón, B. et al. Characterization of the K2-38 planetary system. Unrav-
255 eling one of the densest planets known to date. *Astron. Astrophys.* **641**, A92
256 (2020).
- 257 [27] van der Marel, N., Williams, J. P. & Bruderer, S. Rings and Gaps in
258 Protoplanetary Disks: Planets or Snowlines? *Astrophys. J. Lett.* **867**, L14 (2018).

259 Methods

260 X-Shooter observations and data reduction

261 WD J1328–1450 was identified as a white dwarf candidate based on its *Gaia* DR2
262 parallax and colour[28] and flagged as a potential debris disc host based on the
263 infrared excess detected in its VHS and WISE photometry. We observed the star
264 using X-Shooter, an intermediate resolution echelle spectrograph mounted on the
265 Very Large Telescope at Paranal. On 2021 May 15 we obtained three spectra with
266 exposure times of 1,800 s and 1,750 s in the UVB and VIS arms, respectively. We
267 observed the star again on 2021 June 28 and 2021 July 2 obtaining five spectra
268 with exposure times of 1,171 s and 1,200 s in the UVB and VIS arms, respectively.
269 And finally, we obtained 2 more spectra on 2023 May 12 with exposure times of
270 1,270 s and 1,300 s in the UVB and VIS arms, respectively. All observations were
271 taken using 1.0 and 0.9 arcsec slit widths in the UVB and VIS arms, respectively. All
272 data were reduced using the standard procedures within the REFLEX (version 2.9.1,
273 <http://www.eso.org/sci/software/esoreflex>) reduction tool developed by the European
274 Southern Observatory (ESO). Telluric line removal was performed on the reduced
275 spectra using MOLECFIT (version 1.1.0). In addition to the He lines, the X-Shooter
276 spectra shows absorption lines from Ca II, Mg II, and Si II; and emission lines of Ca II,
277 O I, Mg II and Fe II.

278 In addition to spectroscopy, for the analysis of WD J1328–1450 we used a range of
279 data from wide-area surveys: the parallax measurement from *Gaia* Early Data Release
280 3 (DR3) [29] and photometry from SkyMapper Data Release 2 (DR2) [30], Pan-
281 STARRS DR2 [31], Vista Hemisphere Survey DR6 (VHS) [32], and catWISE2020 [33]
282 (see Supplementary Table 1). We propagated the *Gaia* coordinates of WD J1328–1450
283 to the different epochs of the survey observations using its *Gaia* EDR3 proper motions,

and then used a matching radius of three arcsec to retrieve the astrometry and photometry. We did not include the *Gaia* EDR3 photometry in our analysis because of its extremely broad band-passes.

White Dwarf Parameters

We modelled the spectroscopy and photometry of WD J1328–1450 using white dwarf atmosphere models [34] to determine the main atmospheric parameters, i.e. the effective temperature (T_{eff}) and the surface gravity ($\log g$). Standard techniques to measure these parameters involve fitting either the normalised He line profiles [35] or the photometry and the parallax [36], and both methods proved challenging in the case of WD J1328–1450.

The many broad and blended emission lines result in distortions of the continuum level flanking the He absorption lines, significantly affecting the normalisation process. Given that $\log g$ is particularly sensitive to such distortions of the continuum level resulted in a poorly constrained range $\log g = 7.3$ to 8.7 . A fit to the photometric data and parallax of the star is prone to uncertainties due to contamination by the infrared flux from the dusty debris, a large parallax errors and a correspondingly uncertain reddening, resulting in atmospheric parameters which diverge from those obtained from the spectroscopic fit.

We therefore adopted an iterative fit, where we determine T_{eff} from the spectroscopic data and $\log g$ from the photometric and parallax data. This approach converges on a solution at $T_{\text{eff}} = 17,424 \pm 567$ K, and $\log g = 7.76 \pm 0.19$ independently of the initial values. Adopting the mass-radius relation for a thin H envelope [37] we estimate the mass of white dwarf at $M = 0.47 \pm 0.09 M_{\odot}$ and a cooling age of $\tau_{\text{cool}} = 73^{+49}_{-26}$ Myr.

Photospheric Metal Abundances

Fixing the stellar parameters obtain from this fit, we then computed synthetic spectra for WD J1328–1450 which also include metals. Although the X-Shooter spectrum

310 only reveals absorption lines of Si, Mg, and Ca, we included C, O, Na, Al, P, S, Ti,
 311 and Cr with abundances scaled relative to Ca and adoption a Bulk Earth composi-
 312 tion. The measured abundances of Mg, Si, and Ca are provided in Extended Data
 313 Table 1. Several of the metal lines are blended with emission features which consider-
 314 ably complicated the fitting procedure (Extended Data Fig. 2), and hence our model
 315 does not perfectly replicate all absorption line profiles. The complexity of the under-
 316 lying emission lines introduces systematic uncertainties that are difficult to quantify,
 317 and we stress that the uncertainties quoted in Extended Data Table 1 should be taken
 318 as estimates. Taking the photospheric abundances at face value, we computed the
 319 diffusion time scales of the elements included in our analysis, their downward fluxes
 320 assuming accretion-diffusion equilibrium, and the masses of metals contained within
 321 the convection zone (Extended Data Table 1).

322 The accretion rates measured for WD J1328–1450 are unremarkable when com-
 323 pared to the entire known population of debris-enriched white dwarfs[38]. For
 324 comparison, the accretion rates of Mg, Si and Ca in the gas-disc He-atmosphere
 325 system SDSS J084539.17+225728.0[39] exceed those in WD J1328–1450 by an order
 326 of magnitude. Similarly, the total estimated mass of Ca in the convection zone of
 327 WD J1328–1450 is only 1.53×10^{20} g, a value significantly below what commonly found
 328 for similar objects[40]. The only unusual property in the photospheric pollution of
 329 WD J1328–1450 is the rather low Mg to Si abundance ratio at 0.2, while in other
 330 debris accreting white dwarfs the value is usually between 0.85 and 1.2 [38]. This
 331 could suggest that the material accreted by the white dwarf could be significantly
 332 Mg depleted, but we warrant that our Mg abundance is evaluated from only one line
 333 (Extended Data Table 1) and it is likely blended with an emission feature, leading to
 334 possible underestimation. Though our abundance measurements are subject to some
 335 uncertainties they indicate that, WD J1328–1450, despite its bright and dynamically
 336 active debris disc, does not accrete from it at a high rate. Alternatively, it is possible

337 that the debris disc surrounding WD J1328–1450 only formed relatively recently and
 338 the white dwarfs has only been accreting for one or two diffusion timescale (for the
 339 past 3×10^5 - 6×10^5 yr). In this scenario accretion onto the white dwarfs has yet to
 340 reach a steady state rate, leading to underestimated mean accretion rates. This would
 341 support the idea that we are witnessing a recent disruption event and that the pecu-
 342 liar disc structure of WD J1328–1450 may result from a chaotic early stage in the disc
 343 formation.

344 Emission lines and double disc model.

345 We model the nested double-peaked shape of the emission lines (Supplementary
 346 Table 3) by assuming two concentric and coplanar circular gaseous discs with surface
 347 brightness profiles given by a power-law of the form $f(r) \propto r^{-\alpha}$, r being the distance
 348 from the white dwarf centre [41]. If suffixes $n = A, B$ denote the inner and outer discs
 349 respectively, then the quadruple-peaked emission line profile, $f_{\text{quad}}(v_{\text{obs}})$, as function
 350 of the observed Doppler velocity broadening v_{obs} , is given by

$$f_{\text{quad}}(v_{\text{obs}}) = \int_{R_{\text{in},A}}^{R_{\text{max},A}} \frac{r^{3/2-\alpha_A} dr}{V_K^2(r) \sin^2(i) - v_{\text{obs}}^2} + \int_{R_{\text{in},B}}^{R_{\text{max},B}} \frac{r^{3/2-\alpha_B} dr}{V_K^2(r) \sin^2(i) - v_{\text{obs}}^2}, \quad (1)$$

351 with $V_K(r)$ being the Keplerian velocity at a distance r from the white dwarf, $R_{\text{in},n}$
 352 the locations of the inner edges of the discs,

$$R_{\text{max},n} = \min \left(\frac{GM_{\text{WD}} \sin^2(i)}{v_{\text{obs}}^2} R_{\text{out},n} \right) \quad (2)$$

353 the upper integration limit, G the gravitational constant, M_{WD} the mass of the white
 354 dwarf, $R_{\text{out},n}$ the outer edge of the discs and i the inclination of the disc, where we
 355 define 0° as a face-on disc and 90° as an edge-on disc. The resulting profile in velocity

space is then convolved with a Gaussian of full width at half maximum $FWHM_v = c/R$, where $R = 8,900$ is the spectral resolution of the X-Shooter VIS arm and c the speed of light, to simulate the instrumental response. The profile is then normalised by its total flux $F_{\text{nested}} = F_A + F_B$, with $F_{n=A,B}$ the flux contributions from the inner and outer discs, respectively. We fix $M_{\text{WD}} = 0.47M_{\odot}$ (see Methods, White Dwarf Parameters). The observed nested profiles are fully described by nine parameters: $R_{\text{in},A}$, $R_{\text{out},A}$, $R_{\text{in},B}$, $R_{\text{out},B}$, α_A , α_B , i , the relative contributions of the two discs $\zeta = F_B/F_A$, and the systemic velocity v_{sys} resulting in an overall Doppler-shift of the observations with respect to the laboratory wavelengths of the Ca II triplet.

Using a Bayesian approach, we first fit our model to the calcium triplet by maximizing the logarithm of the probability of the data given the model (i.e. the likelihood). Since each emission line in the calcium triplet is expected to be produced under the same physical conditions, we use a single value for $R_{\text{in},A}$, $R_{\text{out},A}$, $R_{\text{in},B}$, $R_{\text{out},B}$, α_A and α_B . To account for the partial blending of the Ca II lines at 8,498 and 8,542 Å we included the parameter K_{blend} defined as the flux ratio between both lines. This leaves a total of 12 free parameters listed in Extended Data Table 3. The parameter space was sampled with the affine-invariant Markov chain Monte Carlo (MCMC) algorithm implemented in the python package `emcee` using 90 walkers with a chain length and burn-in of $50\tau_{\text{max}}$ and $5\tau_{\text{max}}$ iterations respectively, with τ_{max} being the maximum autocorrelation time between the 12 parameters. To determine the value of τ_{max} , the autocorrelation time was calculated every 50 steps until its estimate changed by less than 1 %.

From the derived posterior distributions shown in Extended Data Fig. 3, the radial extension of the inner gaseous disc goes from ≈ 0.14 to $\approx 0.34 R_{\odot}$, while the outer disc extends from ≈ 0.54 to $\approx 1.93 R_{\odot}$. Our results also suggest a value above 30 degrees for the inclination of the discs, with a mean value of 77 degrees. Interestingly, the

382 surface brightness profile of both discs seems to be quite different; while the emission
383 from the inner disc decreases with distance, the opposite occurs with the outer disc.

384 Another feature derived from our fitting is that our model slightly underestimates
385 the intensity of the blue wing of the nested profiles as shown in Fig. 2. This discrepancy
386 may indicate that the inner disc either deviates from circular symmetry with mod-
387 erate ellipticity, or exhibits a non-uniform gas distribution. However, since the peaks
388 remain symmetric in velocity around the line center in all the observations, we do not
389 find evidence for disc precession which would imply an eccentric orbit. Therefore, the
390 observed flux asymmetry most likely suggests a non-uniform azimuthal distribution of
391 gas in the inner disc, possibly associated with clumpy structures.

392 Unlike the calcium triplet, the blending of the oxygen triplet at $7,774 \text{ \AA}$ did not
393 allow to obtain a good characterization of the inner and outer discs as the fitting
394 becomes highly degenerate (Supplementary Fig. 1). For this reason, we fixed the incli-
395 nation and systemic velocity to the values obtained from the fit of the calcium triplet.
396 As shown Fig. 2, the double-disc model is able to reproduce the main features of the
397 observed profile, and the extension and brightness profile derived for the inner disc are
398 in agreement to those found for the calcium triplet (see Extended Data Table 3). Con-
399 versely, the outer disc parameters are less constrained as their estimates are derived
400 from the central region of the triplet, where the double-peaked structures are more
401 difficult to disentangle.

402 In addition to both triplets, we attempted to fit the Mg I line at $8,806 \text{ \AA}$ using a single-
403 disc model, setting the inclination and systemic velocity as was done for the oxygen
404 triplet (Extended Data Fig. 5). The derived inner disc extension and brightness profile
405 are in good agreement with the above estimates considering its low signal and the
406 possible contamination from a Mg II line at $8,824.318 \text{ \AA}$, i.e. next to the red-shifted
407 peak of the Mg I line.

408 Lack of circumstellar absorption

409 At the inferred inclination of $i = 77^{+9}_{-13}$ degrees, one might expect to detect circumstel-
 410 lar absorption if the gas disc were geometrically thick enough. However, the scale height
 411 of a gas disc in thermal equilibrium with the white dwarf radiation is $H/r \simeq c_s/v_K$.
 412 Where H is the height of the disc and r is its radial extension, c_s is the sound
 413 speed and v_K is the Keplerian velocity. Assuming gas temperatures of $\simeq 3,000$ K and
 414 $\simeq 1,300$ K for the inner and outer discs respectively (based on radiative equilibrium),
 415 and Ca-dominated composition (molecular mean mass $\mu \simeq 40$), we estimate $H/r =$
 416 $0.005 - 0.008$. For circumstellar absorption to be detectable, the line of sight must
 417 intersect the disc material, requiring $i > (90^\circ - \arctan(H/r)) = 89.6^\circ$.
 418 The absence of circumstellar absorption therefore only constrains the inclination to
 419 $i < 89.6^\circ$, consistent with our emission line modelling ($i = 77^{+9}_{-13}$ degrees). This
 420 also implies that the disc cannot have an optically thick component geometrically
 421 thicker than predicted by thermal equilibrium, with $H/r \lesssim 0.49$ (corresponding to our
 422 lower inclination limit of 64°).

423 Evidence of differentiated composition

424 The excitation energy for the O I 8446 Å line is 10.74 eV, while for Mg I at 8806 Å is
 425 only 5.93 eV—approximately half the energy. Since we clearly detect O I emission from
 426 both the inner and outer discs, the excitation conditions in the outer disc must be more
 427 than sufficient to produce Mg I emission if magnesium were present at comparable
 428 abundances. To quantify the expected Mg I emission from the outer disc, we use the
 429 Ca II triplet as a reference. The four-peaked Ca II profiles reveal that the outer disc
 430 produces, on average, 1.22 times more flux than the inner disc. If we assume the outer
 431 and inner discs share the same Ca/Mg abundance ratio, we can predict the expected
 432 Mg I peak flux from the outer disc by scaling the observed inner disc Mg I peak flux
 433 $(1.94 \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ Å}^{-1})$ by this factor, yielding an expected peak flux of

434 $2.37 \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$. However, at the wavelengths where we would expect
 435 Mg I emission from the outer disc, we measure only continuum emission from the inner
 436 disc with an average flux of $(1.58 \pm 0.13) \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ \AA}^{-1}$. The predicted
 437 Mg I peaks would stand $\simeq 6\sigma$ above this continuum level if magnesium were present
 438 at inner-disc abundances (Extended Data Fig. 1). The complete absence of detectable
 439 Mg I emission from the outer disc therefore provides, model-independent evidence that
 440 magnesium is significantly depleted in the outer disc relative to the inner disc.

441 **Infrared excess: circumstellar dust**

442 Using the best fitting model for the white dwarf we can predict the infrared flux of
 443 the isolated white dwarf and use this to characterize the infrared excess due to the
 444 thermal emission of the circumstellar dust. We begin by treating this system in a
 445 similar way to all other known gas-disc hosts, assuming that the infrared excess can
 446 be described as originating from a single dusty debris disc. We adopt the model of
 447 a passive, geometrically thin, optically-thick disc model from [42] (see e.g. [7, 43, 44])
 448 Free parameters in this model are the: temperatures at the inner and outer edges
 449 of the disc, T_{in} and T_{out} , and disc inclination, i . Notably, a significant degeneracy
 450 exists [45] between T_{in} and i and without photometric measurements red-wards of
 451 $4.6 \mu\text{m}$, T_{out} remains poorly constrained. The best fit we achieve with this model is
 452 for a disc with $T_{\text{in}} = 1,943 \pm 102 \text{ K}$, $T_{\text{out}} = 694 \pm 153 \text{ K}$ and $i = 0 \pm 4$ degrees. These
 453 temperature corresponds approximately to a minimum inner edge of $0.10 R_{\odot}$ and a
 454 maximum outer edge of $0.65 R_{\odot}$. The outer edge does not represent the physical limit
 455 for the presence of dust as material beyond this limit can exist, but it would be too
 456 cool to significantly contribute to the observed infrared flux. Despite the fact that this
 457 model of a geometrically thin, optically-thick disc is able to correctly reproduce the
 458 infrared excess, it does not necessarily provide a realistic physical interpretation. In
 459 fact with $i = 0$ degrees the dust disc would be face-on to the observer and, assuming

the dust is co-planar with the gas, this configuration would not produce observable multi-peaked emission lines. For comparison, we recalculated the flat dust disc model this time fixing the parameters to those obtained by modelling the emission lines from the gas-discs, i.e. lower inclination limit of $i = 64$ degrees, inner edge $0.14 R_{\odot}$ and outer edge $1.93 R_{\odot}$ corresponding to temperatures of 1,546 K and 216 K respectively [46]. This model underestimates the observed infrared flux.

As the flat, optically thick dust disc model is unable to simultaneously reproduce the presence of the nested Keplerian profiles and the observed infrared excess, we explore a more physically motivated scenario by modelling the infrared excess with the radiative transfer code MCFOST [8, 9]. Rather than a flat disc, we implemented a finite vertical structure, motivated by the fact that the dust, formed through a collisional cascade, is expected to possess a scale height comparable, or higher than the white dwarf radius [13, 20, 47]. We therefore adopted a scale height at the inner edge of the disc equal to the radius of the white dwarf ($0.015 R_{\odot}$). In addition, the presence of gas in the disc may provide additional vertical support through gas pressure and dynamical coupling with the dust. We therefore also adopted a moderate flaring exponent of $\beta = 1.2$. The dust surface density exponent is set to $p = 1$ (i.e., the surface density increases outwards) to model the fact that dust is primarily produced near or beyond the Roche radius through collisional processing, while the inner regions become depleted by sublimation and collisional vaporization processes [11]. Assuming the dust to be approximately co-located with the gaseous component, we further assume a more refractory dust composition than the standard astronomical silicate mixture [48]. As a proxy for such material, we adopted amorphous carbonaceous dust optical constants [49]. Opacities were calculated using Mie theory for each grain size a , assuming a grain-size distribution of the form [50] $n(a) \propto a^{-3.5}$ with grain sizes ranging from [20, 47] $a_{\min} = 0.5, \mu\text{m}$ to $a_{\max} = 5, \mu\text{m}$. For a disc inclination of 70 degrees,

total dust mass of 5×10^{18} g, and inner and outer edges at $0.25 R_{\odot}$ and $2.0 R_{\odot}$ respectively, the model is able to reproduce an IR excess comparable to the observed one, reaching a maximum temperature of $\simeq 2000$ K at the inner edge, consistent with the sublimation temperature expected for amorphous carbon. Unlike the flat disc model, the vertically extended geometry intercepts a larger fraction of the stellar radiation through its inner rim, leading to more efficient heating of the dust. Similarly, the moderate flaring adopted in the model further increases the amount of intercepted radiation at larger radii. At an inclination of 70 degrees, the inner rim of the disc remains partially visible to the observer, providing an additional contribution to the near-infrared excess. While this demonstrates that such a disc geometry can account for the observed infrared emission, it does not imply that this solution is unique. Given the large number of unconstrained parameters, the problem remains highly degenerate, and alternative combinations of disc composition, scale height, radial extent, and grain-size distribution may provide similarly acceptable fits, and potentially improve the agreement with the observed infrared excess between $1 \mu\text{m}$ and $2.5 \mu\text{m}$.

As a final sanity check, we also modelled the IR-excess as a single blackbody located at the same distance as the white dwarf. The free parameters in this case are the temperature of the blackbody, T_{BB} , and its area, A_{BB} . We find that the SED can be reproduced by a blackbody with $T_{\text{BB}} = 1,314 \pm 34$ K and an area of $2.81 \pm 0.13 \times 10^{21} \text{cm}^2$. This area corresponds to $\simeq 20\%$ the area of the Sun or $\simeq 20$ times that of Jupiter. The presence of such a large, but undetected body is clearly unrealistic confirming that the thermal infrared flux mainly originates from dust. Though unrealistic, this model can also be used to calculate the fractional infrared brightness of the debris disc (τ) as the ratio of the integrated blackbody flux and the white dwarf flux, and compare it to the published values for other similar systems. For WD J1328–1450 we find $\tau = 2.7\%$, one of the largest values among all known white dwarfs with dusty debris [1, 6, 7].

513 **Alternative scenarios causing the double disc structure**

514 **A double white dwarf system.** The relatively low white dwarf mass estimate
515 $M_{\text{WD}} = 0.47 \pm 0.09 M_{\odot}$ raises the possibility that WD J1328–1450 could be a wide,
516 but unresolved double degenerate system hosting a debris disc around each com-
517 ponent and exhibiting therefore the quadruple peak configuration in the combined
518 spectrum. WD J1328–1450 lies at a distance of $\simeq 500$ pc and Gaia reports only a single
519 source. The angular resolution limit of Gaia for reliably resolving binary companions
520 is approximately [51] 0.3 arcsec, corresponding to a projected physical separation of
521 $\simeq 150$ au at the system’s distance. If WD J1328–1450 were an unresolved double white
522 dwarf binary with current separation $\lesssim 150$ au, the main-sequence progenitor binary
523 would have been significantly more compact. During the asymptotic giant branch
524 phase, the stars would have lost 50 – 80% of their mass causing the binary orbit to
525 expand by a factor of $\simeq 2 - 5$ [52]. Working backwards, the pre-mass-loss separation
526 would have been $\simeq 30 - 75$ au. For planets orbiting individual components of a binary
527 (circumstellar orbits), stability demands $a_{\text{planet}} \lesssim 0.3 - 0.5 \times a_{\text{binary}}$, where a indi-
528 cates the semimajor axis of the orbit [53] Hence, planets orbiting each white dwarf
529 individually would need their orbits to be within 10 – 35 au to remain stable. Even
530 though these orbits are plausible, and these planets could survive the stars evolution
531 into white dwarfs, the double disc configuration would require additional coinciden-
532 tal occurrences. Only 0.067% of white dwarfs show gaseous debris discs [23] so the
533 odds of two occurring independently, but simultaneously for the two components of a
534 binary system are extremely low. This, combined with the rarity of close white dwarf
535 binaries hosting dual planetary systems [54, 55], makes this scenario unlikely. More-
536 over, delivering material from surviving planets at these distances to the observed
537 sub-solar-radius disc locations requires fine-tuned dynamical architectures [56, 57],
538 compounding the improbability. We therefore favour the interpretation of single white
539 dwarf hosting two discs.

540 **A single planetesimal in the disc gap.** We considered an alternative scenario
 541 where the double disc structure observed in WD J1328–1450 may be the result of single
 542 planetary body creating a gap both in the dust and the gas disc. This interpretation
 543 is broadly analogous to what seen in protoplanetary discs where a sufficiently large
 544 planetary body can clear a path in a dust disc by accreting the material along its
 545 orbit. Though initially this picture may appear as the simplest solution, it faces a
 546 number of challenges. As mentioned in the main text, assuming that the gap is also
 547 present in the dust disc exacerbates the issue of the IR-excess being too large for a
 548 simple geometrically-thin optically-thick disc. Furthermore, while one could imagine
 549 a large body clearing the dust by directly colliding into it, removing the gas would be
 550 far more difficult. The planet would need enough mass to accrete and trap the gas. At
 551 $0.62 R_{\odot}$, even assuming the planet is entirely made of iron ($\rho = 7.9 \text{ g cm}^{-3}$) and its
 552 internal strength is at the upper bound of what observed for iron bodies (500 Mpa),
 553 its maximum size before undergoing tidal disruption would be 440 km. Even in this
 554 extreme scenario the escape velocity from the surface of this body would be only
 555 $\simeq 1.4 \text{ m/s}$, orders of magnitude below the thermal velocity of the gas in the disc
 556 assuming a conservative temperature of $\simeq 1,000 \text{ K}$. Finally, in this scenario the planet
 557 in the gap would not directly interact with the dust in the two discs on either side
 558 of the gap so a separate mechanism would be required to generate the gas in the two
 559 discs.

560 **Disc self-shadowing.** The quadruple emission features seen in WD J1328–1450
 561 could, in theory, also be explained without invoking a physical gap in the gas distri-
 562 bution. If the inner radius of a flaring disc is truncated at the sublimation radius then
 563 its inner rim, being directly irradiate by the white dwarf, will acquire a higher tem-
 564 perature and vertical scale height compared to a fully-flaring or flat geometry. This
 565 puffed inner region will cast a shadow [58] over part of the disc surface behind it
 566 preventing the photoionization of the gas. This scenario, applied to WD J1328–1450,

would suggest that the puffed inner region is responsible for the line emission between $0.14 - 0.34 R_{\odot}$, the shadowed region would be located between $0.34 - 0.54 R_{\odot}$ and the outer part of the disc beyond $0.54 R_{\odot}$ would have a sufficient vertical height to be out of the shadow and once again exposed to irradiation.

In addition to explaining the observed quadruple emission feature, the vertical extent of the disc and the lack of a need for a gap of material between $0.34 - 0.54 R_{\odot}$ imply a larger amount of dust which would explain the observed high infrared excess. This scenario also naturally explain the opposite behaviour of the brightness profiles derived for both discs. The amount of ionized gas in the puffed region, being directly irradiate by the white dwarf, decreases according to the inverse-square law ($\alpha_1 \gtrsim 2$), while the gas in the outermost non-shadowed region of the disc would progressively intercept more radiation as we move further away from the white dwarf as a consequence of the flared geometry (i.e. $\alpha_2 \lesssim 0$).

However, this interpretation is not without its flaws. Firstly, one needs to question why no other white dwarf with gaseous debris, and even more no other astronomical objects with circumstellar gas discs and double peaked emission lines (like Herbig Ae/Be and T Tauri stars [59, 60, 61]), has ever been observed to have quadruple peaked emission lines. This implies that, for self-shadowing to be plausible, WD J1328–1450 must posses some intrinsic unique properties. For example, the dusty debris disc around WD J1328–1450 is very bright, suggesting a geometry more complex than a simple flat disc which could be a contributing factor to self-shadowing. However, a number of systems with even brighter discs exist. For example WD J0846+5703 has a fractional infrared brightness over twice as large as that of WD J1328–1450, but only shows the typical double peaked emission lines [1]. Alternatively, the flux from the white dwarf and/or the chemical composition of the disc may be the most significant factors in enabling the self shadowing scenario, but again WD J1328–1450 is not special in these regards. In terms of T_{eff} and overall luminosity WD J1328–1450 sits

594 in the middle of the distribution of known gas disc hosts, so the level of irradiation
595 of the disc should not be in any way atypical. Similarly WD J1328–1450, like many
596 other white dwarf with gas discs, displays emission lines of Fe, O, Mg, and Ca and so
597 does not appear to host debris with a peculiar chemical composition. In contrast the
598 gas disc host WD J0529–3401 exhibits over 50 emission lines from a wider range of
599 elements indicative of a more peculiar debris chemical composition, but all these lines
600 only display the typical double peaked profile [1].

601 In conclusion, though disc self shadowing can theoretically explain the quadruple
602 peak line profiles in WD J1328–1450, no direct evidence of this phenomenon exists
603 and there are no observations or arguments to explain why this mechanism would be
604 present only here and not in other similar systems.

605 Correspondence and requests for materials should be addressed to Nicola Gentile
606 Fusillo (nicolapietro.gentilefusillo@units.it).

607 Data availability

608 The X-shooter spectra analysed in the paper (see Methods sections "X-shooter obser-
609 vations and data reduction", "White dwarfs Parameters", "Emission lines and double
610 disc model", as well as Extended Data Figure 2.) are publicly available via the ESO
611 archive https://archive.eso.org/eso/eso_archive_main.html.

612 Code availability

613 The code and the models used to measure the discs parameters and the atmospheric
614 abundances are available from the corresponding author on reasonable request.

615 Acknowledgements

616 We thank the anonymous referees for their constructive review. Based on obser-
617 vations collected at the European Southern Observatory under ESO programmes

618 105.20G8.001, 107.22RX.001, 111.24T9.001. This research made extensive use of
619 Astropy (<http://www.astropy.org>) a community-developed core Python package for
620 Astronomy [62, 63].

621 **Funding statement**

622 This work was supported by the "Rita Levi Montalcini" Programme of the Ministry
623 of University and Research (MUR). This project has received funding from the Euro-
624 pean Research Council (ERC) under the European Union's Horizon 2020 research and
625 innovation programme (Grant agreement No. 101020057). FLV acknowledges support
626 from ANID FONDECYT Postdoctoral Grant No. 3250464

627 **Author contributions**

628 N.P. G.F. initially identified the target, carried out the spectroscopic observations and
629 the data reduction, contributed to the model fitting of the spectrum, to the modelling
630 of the IR excess, and lead the scientific interpretation. F. L.-V. lead the modelling
631 of the quadruple peaked emission lines with a double disk model, contributed to the
632 modelling of the IR excess and contributed the scientific interpretation and manuscript
633 drafting. B. T. G. and C. J. M. contributed to the scientific interpretation and to the
634 manuscript drafting. D. K. lead the atmospheric modelling of the star.

635 **Competing interests statement**

636 The authors declare no competing interests.

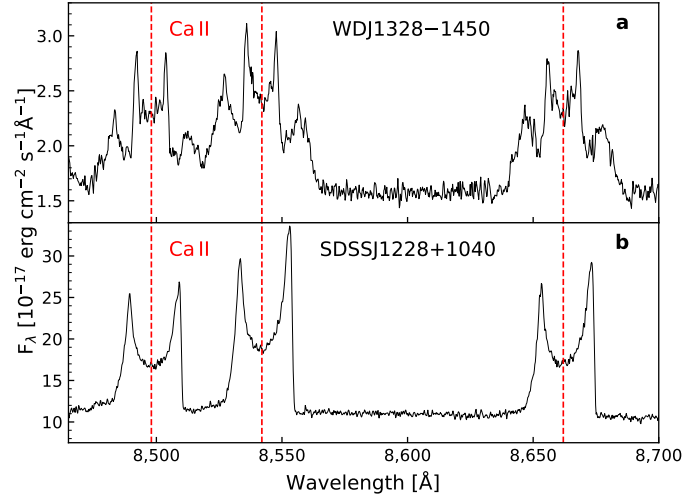


Fig. 1 Quadruple-peaked emission lines in WD J1328–1450. **a** In contrast to the all 21 gaseous discs published to date, the Ca II 8,498, 8,542, and 8,662 Å emission lines (shown as red dashed lines) in the X-shooter spectrum of WD J1328–1450 are quadruple-peaked. **b** The typical double-peaked emission line profiles of the prototype gas disc system SDSS J1228+1040[24]. The morphology of the emission lines in WD J1328–1450 indicates the presence of two concentric discs around this white dwarf.

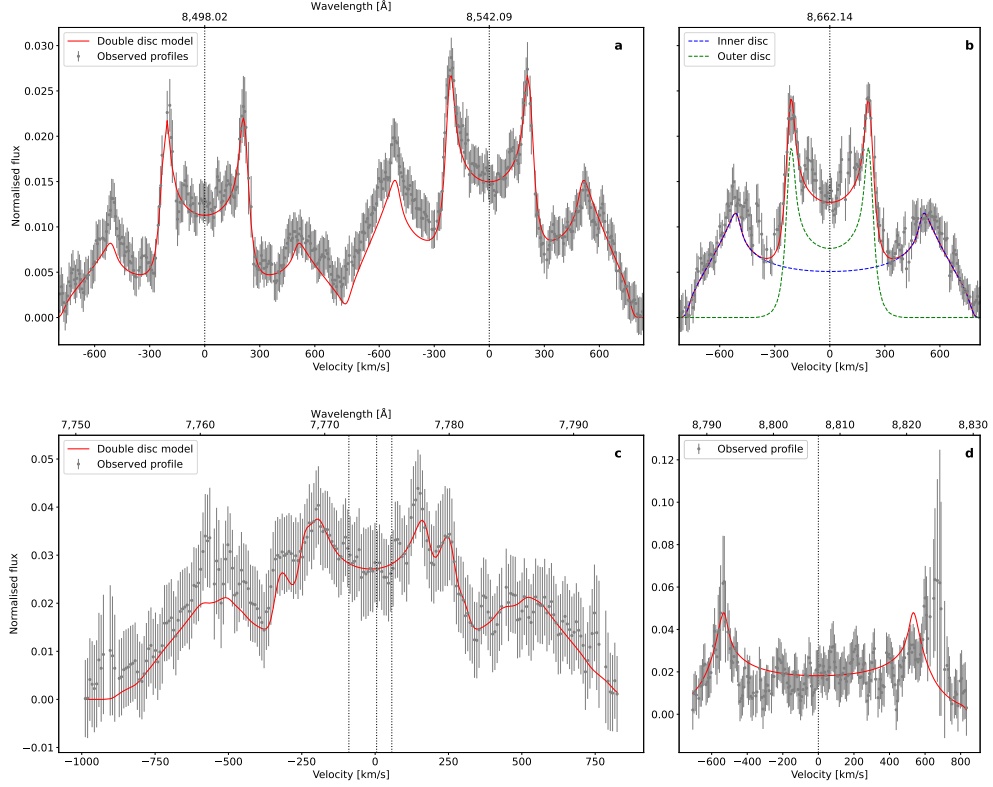


Fig. 2 Double-disc model fits to the Ca II, O I, and Mg I emission lines. X-Shooter spectra of WD J1338–1450 (grey points with 1σ error bars) are shown in velocity space relative to the vacuum rest wavelengths (vertical dotted black lines) of the Ca II triplet (**a**, **b**), and the O I triplet (**c**) and Mg I line (**d**). The red lines show the best-fit double-disc models (see Extended Data Table 5 for more details). **b**, The individual contributions of the inner (blue) and outer (green) discs are also shown for the Ca II 8,662 Å component. The inner disc extends to larger velocities, reflecting its higher Keplerian motion. A small asymmetry in the peak heights suggests a slightly eccentric orbit. **c**, The morphology of the O I 7,774 Å triplet resembles that of the Ca II triplet although the blending of its three components results in a more complex structure. Again, some asymmetry is observed indicating a slightly eccentric inner disc. **d**, The Mg I 8807 Å line is only detected in emission from the inner disc. The red wing of this line is affected by large uncertainties in the data

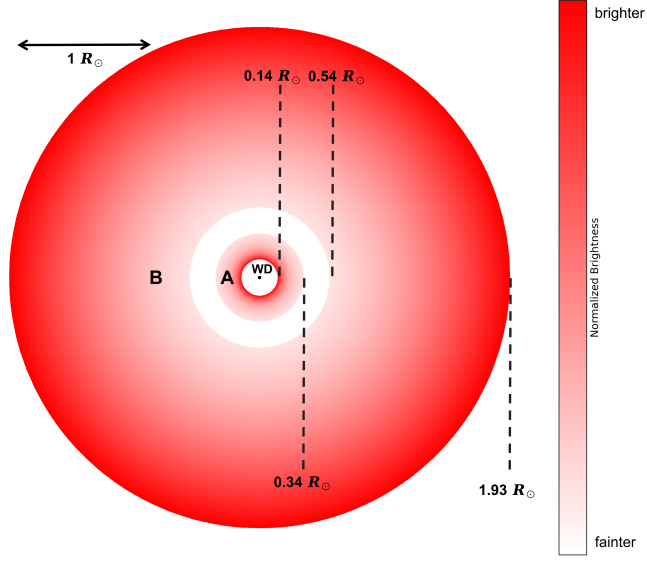


Fig. 3 Schematic top-down view of the radial location of gas based on the line emission profile modelling. The coloured regions indicate the location of the observed Ca II triplet emission. The double disc structure around WD J1328–1450 (inner disc A, outer disc B) and the gap are shown to scale. A $1 R_{\odot}$ bar in the top left corner is shown for size reference. The colour gradient reflects the brightness profile of the discs.

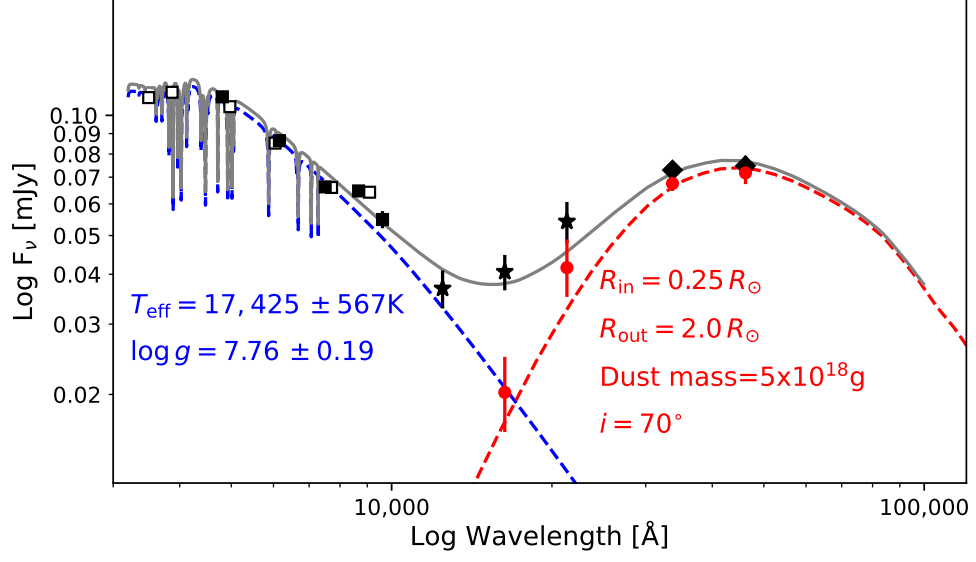


Fig. 4 The infrared excess of WD J1328–1450. The best-fit white dwarf model for WD J1328–1450 (dashed blue line, Extended Data Table 2) is compared to the photometry from Pan-STARRS, Skymapper, VHS, and *WISE* (black full squares, empty squares, stars and diamonds respectively, with 1σ errorbars). The photometric IR excess calculated as IR photometry minus the contribution from the white dwarf in the same bands, is represented by the red points. We modelled this IR excess using MCFOST as a disc having scale height at the inner edge equal to the white dwarf radius ($0.015 R_{\odot}$), moderate flaring, and outward-increasing dust density (dashed red line).

References

- [28] Gentile Fusillo, N. P. et al. A gaia data release 2 catalogue of white dwarfs and a comparison with sdss. *Mon. Not. R. Astron. Soc.* **482**, 4570–4591 (2019).
- [29] Gaia Collaboration et al. Gaia Early Data Release 3. Structure and properties of the Magellanic Clouds. *Astron. Astrophys.* **649**, A7 (2021).
- [30] Onken, C. A. et al. SkyMapper Southern Survey: Second data release (DR2). *Publ. Astron. Soc. Aust.* **36**, e033 (2019).
- [31] Chambers, K. C. et al. The Pan-STARRS1 Surveys. *arXiv e-prints* arXiv:1612.05560 (2016).
- [32] McMahon, R. G. et al. First scientific results from the vista hemisphere survey (vhs). *The Messenger* **154**, 35–37 (2013).
- [33] Marocco, F. et al. The CatWISE2020 Catalog. *Astrophys. J. Suppl. Ser.* **253**, 8 (2021).
- [34] Koester, D. White dwarf spectra and atmosphere models. *Mem. Soc. Astron. Italiana* **81**, 921–931 (2010).
- [35] Bergeron, P. et al. A Comprehensive Spectroscopic Analysis of DB White Dwarfs. *Astrophys. J.* **737**, 28 (2011).
- [36] Gentile Fusillo, N. P. et al. A catalogue of white dwarfs in Gaia EDR3. *Mon. Not. R. Astron. Soc.* **508**, 3877–3896 (2021).
- [37] Bédard, A., Bergeron, P., Brassard, P. & Fontaine, G. On the Spectral Evolution of Hot White Dwarf Stars. I. A Detailed Model Atmosphere Analysis of Hot White Dwarfs from SDSS DR12. *Astrophys. J.* **901**, 93 (2020).
- [38] Williams, J. T. et al. PEWDD: A database of white dwarfs enriched by exoplanetary material. *Astron. Astrophys.* **691**, A352 (2024).
- [39] Wilson, D. J. et al. The composition of a disrupted extrasolar planetesimal at sdss j0845+2257 (ton 345). *Mon. Not. R. Astron. Soc.* **451**, 3237–3248 (2015).
- [40] Koester, D. & Kepler, S. O. DB white dwarfs in the Sloan Digital Sky Survey

664 data release 10 and 12. *Astron. Astrophys.* **583**, A86 (2015).

665 [41] Smak, J. On the emission lines from rotating gaseous disks. *Acta Astron.* **31**,
666 395–408 (1981).

667 [42] Jura, M. A Tidally Disrupted Asteroid around the White Dwarf G29-38.
668 *Astrophys. J. Lett.* **584**, L91–L94 (2003).

669 [43] von Hippel, T., Kuchner, M. J., Kilic, M., Mullally, F. & Reach, W. T. The
670 New Class of Dusty DAZ White Dwarfs. *Astrophys. J.* **662**, 544–551 (2007).

671 [44] Kilic, M., Patterson, A. J., Barber, S., Leggett, S. K. & Dufour, P. The discovery
672 of a debris disc around the DAV white dwarf PG 1541+651. *Mon. Not. R.*
673 *Astron. Soc.* **419**, L59–L63 (2012).

674 [45] Girven, J. et al. Constraints on the lifetimes of disks resulting from tidally
675 destroyed rocky planetary bodies. *Astrophys. J.* **749**, 154 (2012).

676 [46] Brinkworth, C. S. et al. Spitzer Space Telescope Observations of Magnetic Cat-
677 aclysmic Variables: Possibilities for the Presence of Dust in Polars. *Astrophys.*
678 *J.* **659**, 1541–1562 (2007).

679 [47] Ballering, N. P. et al. The Geometry of the G29-38 White Dwarf Dust Disk from
680 Radiative Transfer Modeling. *Astron. J.* **939**, 108 (2022).

681 [48] Draine, B. T. Scattering by Interstellar Dust Grains. II. X-Rays. *Astron. J.*
682 **598**, 1026 (2003).

683 [49] Rouleau, Francois and Martin, P. G. Shape and Clustering Effects on the Optical
684 Properties of Amorphous Carbon. *Astron. J.* **377**, 526 (1991).

685 [50] Mathis, J. S. and Rumpl, W. and Nordsieck, K. H. The size distribution of
686 interstellar grains.. *Astron. J.* **217**, 425 (1977).

687 [51] Lindegren, L. et al. Gaia Data Release 2. The astrometric solution. *Astron.*
688 *Astrophys.* **616**, A2 (2018).

689 [52] Veras, D. et al. The great escape: how exoplanets and smaller bodies desert
690 dying stars. *Mon. Not. R. Astron. Soc.* **417**, 2104–2123 (2011).

- [53] Holman, M. J., and Wiegert, P. A. Long-Term Stability of Planets in Binary Systems . *Astron. J.* **117**, 621-628 (1999).
- [54] Farihi, J. Circumstellar debris and pollution at white dwarf stars . *New Astron. Rev.* **71**, 9-34 (2016).
- [55] Zuckerman, B. The Occurrence of Wide-orbit Planets in Binary Star Systems. *New Astron. Rev.* **791**, L27 (2014).
- [56] Bonsor, A., and Veras, D. A wide binary trigger for white dwarf pollution. *Mon. Not. R. Astron. Soc.* **454**, 53 (2015).
- [57] Veras, D., and Mustill, A. J. and Bonsor, A. The evolution and delivery of rocky extra-solar materials to white dwarfs. *Reviews in Mineralogy and Geochemistry* **90**, 141-172 (2024).
- [58] Dullemond, C. P., Dominik, C. & Natta, A. Passive Irradiated Circumstellar Disks with an Inner Hole. *Astrophys. J.* **560**, 957–969 (2001).
- [59] Thi, W. F. et al. H₂ and CO Emission from Disks around T Tauri and Herbig Ae Pre-Main-Sequence Stars and from Debris Disks around Young Stars: Warm and Cold Circumstellar Gas. *Astrophys. J.* **561**, 1074–1094 (2001).
- [60] Acke, B., van den Ancker, M. E. & Dullemond, C. P. [O I] 6300 Å emission in Herbig Ae/Be systems: Signature of Keplerian rotation. *Astron. Astrophys.* **436**, 209–230 (2005).
- [61] Nidhi, S. et al. Spectroscopic study of Herbig Ae/Be stars in the Galactic anti-centre region from LAMOST DR5. *Mon. Not. R. Astron. Soc.* **524**, 5166–5181 (2023).
- [62] Astropy Collaboration et al. Astropy: A community Python package for astronomy. *Astron. Astrophys.* **558**, A33 (2013).
- [63] Price-Whelan, A. M. et al. The Astropy Project: Building an Open-science Project and Status of the v2.0 Core Package. *Astron. J.* **156**, 123 (2018).