4. Nacu, E. & Tanaka, E. M. *Annu. Rev. Cell Dev. Biol.* **27,** 409–440 (2011).
5. Singer, M. *Q. Rev. Biol.* **27,** 169–200 (1952).
6. Lheureux, E. *J. Embryol. Exp. Morphol.* **38,** 151–173 (1977).
7. Meinhardt, H. *J. Embryol. Exp. Morphol.* **76,** 115–137 (1983).
8. Niswander, L., Jeffrey, S., Martin, G. R. & Tickle, C. *Nature* **371,** 609–612 (1994).
9. Zúñiga, A., Haramis, A.-P. G., McMahon, A. P. & Zeller, R. *Nature* **401,** 598–602 (1999).
10. Sugiura, T., Wang, H., Barsacchi, R., Simon, A. & Tanaka, E. M. *Nature* **531,** 237–240 (2016).

This article was published online on 27 April 2016.

ASTROPHYSICS

Illuminating brown dwarfs

Objects known as brown dwarfs are midway between stars and planets in mass. Observations of a hot brown dwarf irradiated by a nearby star will help to fill a gap in our knowledge of the atmospheres of fluid planetary objects. SEE LETTER P.366

ADAM P. SHOWMAN

The illumination received from a nearby star has a crucial role in shaping an atmosphere's three-dimensional temperature structure, chemistry, climate and weather. Less obviously, the irradiation of one star by another nearby star — as commonly occurs in tightly orbiting binary star systems — can lead to observable[1] temperature differences between the illuminated star's 'dayside' and its 'nightside'. However, only a few observations have documented the effect of stellar irradiation on the atmospheres of a class of object that is intermediate in mass between stars and planets: brown dwarfs. On page 366 of this issue, Hernández Santisteban *et al.*[2] present intriguing observations to characterize the atmosphere and estimate the day–night temperature difference for a brown dwarf irradiated by a nearby star.

When Sun-like stars reach old age, their outer layers expand, allowing them to engulf nearby, closely orbiting companions. Small stars or brown dwarfs often survive this ordeal, but friction caused by the orbital movement of the companion through the tenuous outer layers of the star provides a drag on the companion, causing it to spiral slowly inward. The outer layers of the bloated star eventually puff off into space, leaving behind a stellar remnant called a white dwarf, which is typically Earth-sized but half as massive as the Sun. By the end of this process, the companion's orbit has often shrunk to the point that the two objects nearly touch.

The system characterized by Hernández Santisteban *et al.*, dubbed J1433, is just such a system, consisting of a white and a brown dwarf. The objects are so close that they orbit each other every 78 minutes. The gravity from the white dwarf distorts the shape of the brown dwarf and leads to a trickle of mass from the companion, which slowly accretes onto the white dwarf.

The closeness of the white and brown dwarfs means that they cannot be resolved individually in images. However, the white dwarf has a temperature that exceeds 13,000 kelvin (more than double the temperature at the surface of the Sun), which causes most of its radiation to escape at short, ultraviolet wavelengths. By contrast, the brown dwarf's surface temperature is about 2,400 K, and most of its radiation escapes in the near-infrared region of the spectrum. Although the white dwarf emits a greater total energy flux, the cooler but larger brown dwarf dominates the system's flux in the near infrared. Radiation in this wavelength range thus allows the brown dwarf's atmosphere to be characterized. Hernández Santisteban *et al.* obtained high-resolution spectra that extended from the ultraviolet to the infrared, allowing the authors to tease apart light from the two objects.

To determine how irradiation affects the brown dwarf, the authors tracked how infrared light from the brown dwarf changes throughout its orbit. The system's orbital plane lies nearly in the line of sight to Earth, implying that the brown dwarf's day and night hemispheres rotate in and out of view throughout the orbit. The researchers' observations show that the average dayside temperature is about 57 K warmer than the average nightside temperature. The hottest dayside region is about 200 K warmer than the coolest nightside region.

These observations are important, given the substantial effort over the past two decades to understand the atmospheres of irradiated exoplanets called hot Jupiters — Jupiter-mass planets that orbit very close to their stars and that are blasted by starlight. Hot Jupiters commonly have daysides many hundreds of kelvins hotter than their nightsides[3,4]. But they are typically about 1,000–10,000 times dimmer than their host stars in the infrared, making their observation extremely difficult. The fact that brown dwarfs in systems such as J1433 are brighter in the infrared than their white-dwarf

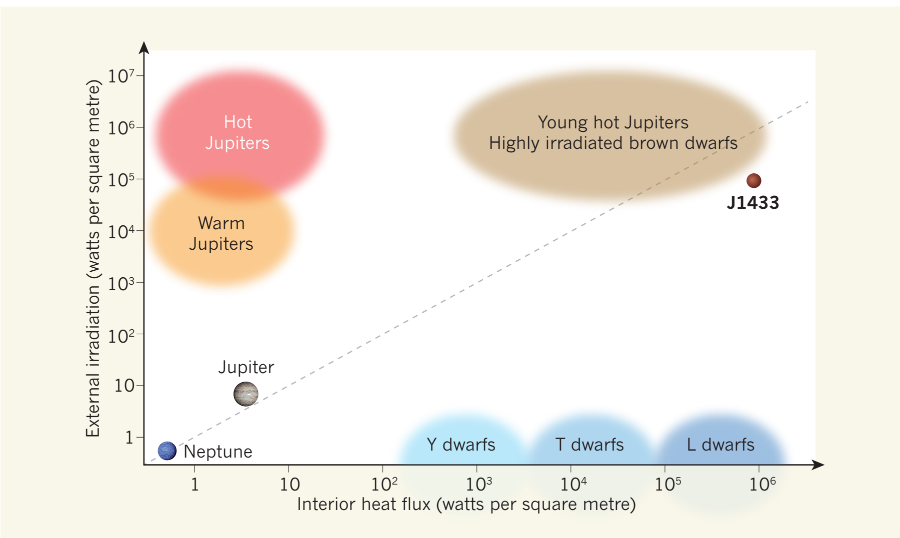

Figure 1 | A wide parameter space for fluid planetary bodies. Fluid planets and brown dwarfs (which are intermediate between planets and stars) are subject to a broad range of internal heat fluxes and external irradiation from nearby stars. Giant planets in our Solar System, such as Neptune and Jupiter, have low internal and external heat fluxes[8]. Warm and hot Jupiters — Jupiter-sized exoplanets — have much higher external irradiation[9], whereas Y-, T- and L-type brown dwarfs have much higher internal fluxes[10]. Hernández Santisteban *et al.*[2] report observations of J1433, a system in which a brown dwarf occupies a tight orbit around a white dwarf star. This brown dwarf has high internal flux and experiences high external irradiation. Observations of other J1433-like brown dwarfs and of young hot Jupiters will therefore provide information that will build a complete picture of atmospheric dynamics in fluid planets and brown dwarfs. Ellipses indicate approximate ranges; the broken grey line indicates equal internal and external fluxes.

primaries suggests that the atmospheres of these irradiated objects can be more easily characterized than can those of hot Jupiters, which might allow insight into the workings of the harder-to-observe planets. Several other white dwarf–brown dwarf binaries are known to exist, and may yield constraints on the climate of irradiated fluid objects that are at least as good as those from J1433 (refs 5, 6).

J1433-like systems also allow comparisons with other brown dwarfs. Most known brown dwarfs are isolated and receive no irradiation, so they gradually lose heat from their interiors and cool off over billions of years. This heat is transported through their interiors by convection, which drives an active atmospheric circulation that manifests as patchy, time-variable clouds that cause significant changes in infrared flux over time[7]. Much work is being done to understand this variability and the processes that control the surface patchiness. The extent to which these dynamical processes will be modified by external irradiation is unknown; future observations of J1433 and other irradiated brown dwarfs[5,6] will help to answer this question.

The giant planets in our Solar System (such as Jupiter, Saturn and Neptune) experience internal and external heat fluxes that are weak and comparable to each other[8]. By contrast, hot Jupiters receive external fluxes about a thousand to a million times greater than their expected internal fluxes[9], and thereby show us how atmospheric circulation responds when external forcing dominates. Isolated brown dwarfs represent the opposite extreme, transporting enormous internal fluxes but typically receiving negligible external irradiation. These types of body therefore constrain three corners of a broad parameter space of external irradiation and internal heat flux that spans many orders of magnitude in both parameters (Fig. 1). Until a few years ago, we lacked observational constraints on the atmospheric behaviour of substellar objects at the fourth corner of that parameter space — those subject to enormous external irradiation and internal heat flux that are comparable to within a factor of ten.

J1433 and related brown dwarf–white dwarf binaries fill that gap, and could prove crucial in the quest to understand how atmospheric circulation depends on internal and external forcing. The small day–night temperature difference inferred by Hernández Santisteban *et al.* relative to that of many hot Jupiters[3,4] almost certainly results from the intense heat supplied to the atmosphere from the brown dwarf's interior, but the interaction of the internal and external forcings could have myriad other consequences that remain poorly understood.

The J1433 system is interesting in other ways. Hernández Santisteban *et al.* argue that the brown dwarf began life as a star, but became a brown dwarf after losing mass to the white dwarf — a history that might affect its internal structure and atmospheric circulation. Moreover, because of the fortuitous orbital alignment of J1433 with the line of sight to Earth, the brown and white dwarfs eclipse each other once per orbit, providing an opportunity to characterize the atmospheric composition and thermal structure in the way that is commonly done for hot-Jupiter systems. ■

Adam P. Showman *is in the Department of Planetary Sciences and Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721, USA.*
e-mail: showman@lpl.arizona.edu

1. Davey, S. & Smith, R. C. *Mon. Not. R. Astron. Soc.* **257,** 476–484 (1992).
2. Hernández Santisteban, J. V. *et al. Nature* **533,** 366–368 (2016).
3. Stevenson, K. B. *et al. Science* **346,** 838–841 (2014).
4. Komacek, T. D. &. Showman, A. P. *Astrophys. J.* **821,** 16 (2016).
5. Steele, P. R. *et al. Mon. Not. R. Astron. Soc.* **429,** 3492–3500 (2013).
6. Casewell, S. L. *et al. Mon. Not. R. Astron. Soc.* **447,** 3218–3226 (2015).
7. Artigau, E., Bouchard, S., Doyon, R. & Lafrenière, D. *Astrophys. J.* **701,** 1534–1539 (2009).
8. Ingersoll, A. P. *Science* **248,** 308–315 (1990).
9. Baraffe, I., Chabrier, G. & Barman, T. *Rep. Prog. Phys.* **73,** 016901 (2010).
10. Marley, M. S. & Robinson, T. D. *Annu. Rev. Astron. Astrophys.* **53,** 279–323 (2015).

STRUCTURAL BIOLOGY

Snapshots of transcription initiation

The enzyme RNA polymerase II, along with several transcription factors, initiates DNA transcription. Analyses reveal the structures involved in this process in human and yeast cells at high-resolution. SEE ARTICLES P.353 & P.359

STEVEN HAHN & STEPHEN BURATOWSKI

The initiation of DNA transcription involves a fascinating interplay between RNA-synthesizing RNA polymerase (Pol) enzymes, transcription factors and DNA. The Pol II complex is of particular interest because it synthesizes all messenger RNA in eukaryotic (nucleus-bearing) cells. The size and flexibility of Pol II complexes present huge challenges for structural biologists, but two studies in this issue, by He *et al.*[1] (page 359) and Plaschka *et al.*[2] (page 353), exploit advances in cryo-electron microscopy to produce near-atomic-resolution snapshots of the Pol II machinery.

The bacterial Pol machinery is a streamlined system that contains only four Pol subunits and a single transcription factor, sigma[3]. Because Pol active sites are highly evolutionarily conserved[4], bacterial Pol has been used to establish a general model of Pol action. This model suggests that Pols and their transcription factors first associate with the promoter region of double-stranded DNA, which lies immediately upstream of the sequences to be transcribed, to form a structure called the closed complex.

Next, around 10–13 base pairs of the promoter unwind, positioning the DNA strand to be transcribed at the Pol active site in an open complex (open and closed refer to the state of the DNA). Pol subunits form channels for incoming nucleotides and the exiting mRNA, and create a deep cleft for the template strand. A mobile clamp domain traps DNA in the active site during the transition from the closed to the open complex. Finally, the structure contorts into an initial transcribing complex, maintaining contacts with promoter DNA while downstream DNA is pulled into the active site as RNA starts to be synthesized.

In comparison with bacteria, the archaeal and eukaryotic transcription machineries are complex, with 12–17 Pol subunits and up to 6 transcription factors. In the Pol II system, the transcription factors TBP, TFIIA, TFIIB, TFIIE, TFIIF and TFIIH are all required and, between them, perform the same functions as bacterial sigma[5,6]. Years of biochemical, molecular and structural studies have probed the roles of each transcription factor to piece together a model of eukaryotic transcription initiation[7].

Many features of this model are brought to life in the current work. Both groups assembled purified transcription factors and Pol II on nucleic-acid scaffolds — on double-stranded promoter DNA for the closed complex, double-stranded DNA containing an unwound 'bubble' for the open complex, and a bubble with a short annealed RNA to resemble the initial transcribing complex. He *et al.* used a complete set of human factors and all three scaffolds, whereas Plaschka *et al.* used all the yeast (*Saccharomyces cerevisiae*) factors except TFIIH to visualize the closed and open complexes. Despite these differences, the positions of transcription factors and the trajectory of the nucleic acids show excellent agreement between the