

These analogies have their limits. ‘Stratosphere’ is an odd term to use for a hot Jupiter — the planet undergoes intense heating by its star that varies from its equator to its poles, driving vigorous winds that churn the upper atmosphere<sup>7</sup>. And it remains unproven that brown dwarfs and hot Jupiters have a common heritage (formation mechanism, evolutionary history, and so on). The claimed detections of TiO and/or VO were all made at fairly low spectral resolutions, satisfying the threshold of plausibility to different degrees<sup>8–11</sup>, and are subject to an extensive debate in the literature concerning temperature inversions<sup>12–19</sup>.

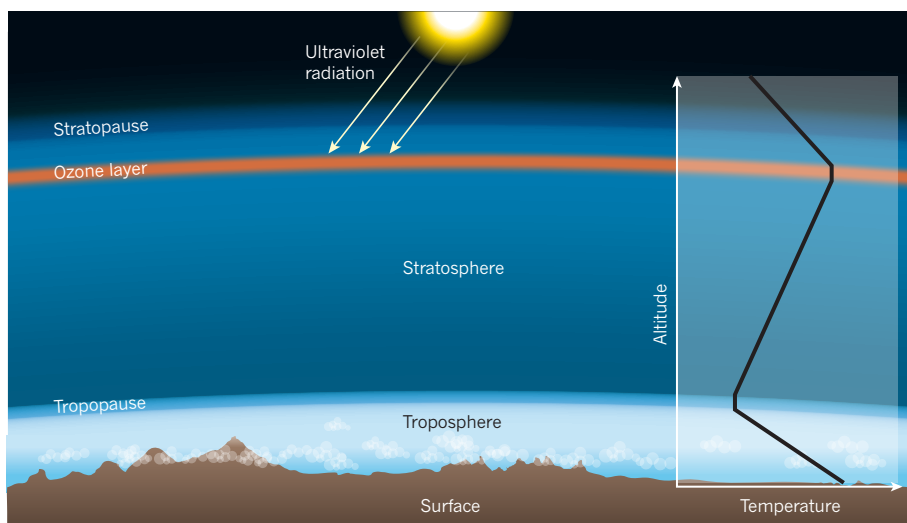
Evans and colleagues used the Wide Field Camera 3 (WFC3) on board the Hubble Space Telescope, which has become the standard go-to instrument for detecting water on exoplanets. They obtained a thermal spectrum for WASP-121b that covered a range of wavelengths from 1.1 to 1.6 micrometres. Although the spectral resolution was insufficient to resolve the individual spectral lines of molecules, the authors could trace the shape of molecular bandheads — spectral features caused by large numbers of unresolved lines melding together.

The authors observed bandheads at wavelengths of about 1.2 and 1.4  $\mu\text{m}$ . Of particular interest is the 1.4- $\mu\text{m}$  bandhead that is associated with water and that forms a blunt peak, rather than a trough. Evans *et al.* interpreted this bandhead as being due to water seen in emission, rather than in absorption. In an atmosphere in which the temperature decreases with altitude, water would be seen in absorption. To be seen in emission requires the existence of a temperature inversion and

therefore a strong absorber of stellar radiation that causes the upper atmosphere to be heated. The 1.2- $\mu\text{m}$  bandhead is consistent with the presence of VO, but the definitive detection of this molecule remains elusive. The recorded WFC3 spectrum is blind to the absence or presence of TiO.

To claim that a spectral feature is seen in emission rather than absorption requires the use of a reference. Evans and colleagues analysed their WFC3 spectrum using a technique called atmospheric retrieval. In this technique, the abundances of molecules are free parameters in the analysis, which means that chemically implausible abundances are permitted. The authors then used the measured spectra of two brown dwarfs, spanning roughly the same range of wavelengths as the WFC3 spectrum, as references. These brown-dwarf spectra have deep absorption features near 1.4  $\mu\text{m}$  associated with hot water vapour in the objects’ atmospheres. A limitation of the authors’ work is that atmospheric retrieval does not treat radiation, chemistry and atmospheric motion self-consistently, but this is an ideal that currently eludes all practitioners of the craft.

As the number of claimed detections of TiO and VO in hot Jupiters continues to increase, the presence of these molecules could be tested by other means. The chemistry of hot Jupiters is sensitively controlled by the planets’ carbon-to-oxygen ratio<sup>20</sup>. Besides being water-poor and methane-rich, carbon-rich atmospheres also have abundant carbon monoxide, which sequesters most of the oxygen atoms available, leaving few for TiO and VO to form. Therefore, if TiO and VO are the extrasolar



**Figure 1 | Atmospheric temperature inversion.** The lower atmosphere above Earth’s surface is divided into two distinct regions: the troposphere and the stratosphere. The stratosphere contains the ozone layer, which absorbs ultraviolet radiation from the Sun. This absorption causes the stratosphere to heat up and exhibit a temperature inversion, whereby atmospheric temperature increases with altitude. By contrast, the temperature decreases with altitude in the troposphere, and is roughly constant in the boundaries above the troposphere and stratosphere (the tropopause and stratopause, respectively). Evans *et al.*<sup>3</sup> report that, like Earth, the atmosphere of the exoplanet WASP-121b features a temperature inversion, suggesting that the exoplanet’s atmosphere contains an analogue of Earth’s ozone layer.



## 50 Years Ago

The advantages of achieving the *in vitro* synthesis of active enzymes in a well characterized system are many ... All our evidence suggests that the appearance of lysozyme activity observed in the *in vitro* system has the characteristics of *de novo* synthesis ... the chief contribution ... is that the *in vitro* translation in a well characterized RNA dependent system can be sufficiently accurate to yield active proteins, and that this can be done using RNA extracted by standard techniques from cells infected by a DNA phage.

From *Nature* 5 August 1967

## 100 Years Ago

*Soil Conditions and Plant Growth.* By Dr. E. J. Russell — This book is, as the title implies, concerned with the relationship between soil and plant. After an introductory historical account of the subject the author describes the constitution of the soil and the various factors of plant growth. In the development of these topics and of the question of the relation of the plant to its soil environment, the reader is kept constantly in touch with the best original work at home and abroad. The author ... has also added a chapter on the colloidal properties of the soil, in which he brings the reader abreast of the recent ... work on the interaction of dilute acids and soil colloids ... The study of the relationship between soil and plant is exceedingly complex ... It is a pity that so much labour should have been expended during past years in haphazard manual trials, designed to instruct the farmer, but yielding generally a scanty harvest of accurate information. Soil investigators owe a debt to Dr. Russell and his predecessors ... for enlarging the study of the soil into a respectable field of scientific activity.

From *Nature* 2 August 1917