Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Off-world weather report.*

Trying to determine the behaviour of the atmosphere of a hot Jupiter – a gas giant so close to its star that it is either tidally locked or caught in a slow orbital resonance with its star – is a tricky business. We have no precedents here in our Solar System. But it is possible to explore what exoplanet atmospheres *might* be like, based on some Solar System examples.

To establish some basic principles here, we can anticipate that a lot of exoplanet meteorology will be about atmospheric circulation (wind), which is affected by:

- mean stellar flux (that's how much sunshine, or sorry for the off-worlders listening, starshine), the planet receives over its orbital period;
- then there's the eccentricity of the planet's elliptical orbit and its axial tilt – both of which could influence any seasons that occur during one of the planet's orbital periods. For a planet with an almost circular orbit like Earth – seasons largely result from axial tilt. But for a planet with a very eccentric elliptical orbit, the whole planet might freeze over at apoapsis and then heat up again at periapsis;
- and then there's the question of how long the Sun stays in the sky over a particular part of the planet – which is dependent on how long the planet takes to rotate on its axis and its orbital period;
- and then finally there's surface gravity and magnetic field – because without enough of either a planet might not have much of an atmosphere – here think of Mercury, the Moon and Mars.

Now, all these specifications for atmospheric behaviour are all potentially measurable on exoplanets with current or foreseeable technologies, like the James Webb Space Telescope, which then allow us to make some robust guesstimates of the behaviour of different exoplanets' atmospheres.

This is because all these things contribute to what drives atmospheric circulation and makes winds. In a nutshell, it's mainly about thermal gradients - which arise longitudinally from day-night temperature variation and latitudinally from equator to pole temperature variation. And there's also the Coriolis effect which arises from planetary rotation. That's all you really need to determine the behaviour of a planet's upper atmosphere.

Some key examples in our Solar System include Venus – which, although not tidally locked like a hot Jupiter would be, has such a slow rotation – it takes 243 Earth days to go around once - that its dynamics virtually match those of a tidally locked planet.

Interestingly, Venus' upper atmosphere 'super-rotates', meaning it circulates in the same direction as the planet's rotation but much faster - in Venus' case at sixty times the speed of the planet's rotation.

It's likely that these winds are driven by the large temperature gradient that will exist between the day and night sides of such a slowly rotating planet. It's also speculated that the solar wind (the outpouring of high energy particles from the Sun) might also give Venus' upper atmosphere a mechanical push.

Earth though, with its rapid rotation, is a whole different story. Earth has much less potential difference between its day and night side temperatures – and its magnetic field diverts much of the solar wind away from the atmosphere. So, Earth's weather systems are more strongly influenced by the actual rotation of the planet and also by the temperature gradient between the equator and the poles. The nett result is lots of circular weather systems with their direction determined by the Coriolis effect – counter-clockwise in the northern hemisphere and clockwise in the southern.

And of course in the Solar System, we do have gas giants, even if they aren't hot Jupiters. Being so far from the Sun, dayside-nightside and equator-to-pole temperature gradients have little influence on our cold Jupiter other gas giants' atmospheric circulation. The most significant issues are each planet's rotational speed and each planet's size.

For any planet, the atmosphere at the equator has to cover a much bigger circumference than the atmosphere at the poles. So the atmosphere that's rotating at higher latitudes can't quite keep up with the atmosphere at the equator – and so different sections of the atmosphere split off into their own little horizontal flows – so for a big Jupiter-sized planet you end up with around twenty delineated cloud bands and zones.

The zones, which are the whitish stripes on Jupiter, are high altitude ammonia-filled clouds which whip around the planet faster than the bands, which are lower and more colourful cloud.

Jupiter and Saturn's larger radius exceeds what's called their Rhines scale, forcing the bulk flow of their rotation-driven atmospheres to break up into distinct bands with turbulent eddies and whirlpools between them.

However, the smaller radius of Uranus and Neptune allows the bulk of their atmospheres to circulate as an unbroken whole – and yes, Uranus' atmosphere does circulate around its equator even though the planet is on its side.

For Neptune though, partly because it's cooler, with less vertical turbulence, but mostly because it's smaller with less horizontal turbulence, its atmosphere has much less turbulent flow than Jupiter – so it doesn't break up into bands and zones and perhaps that lower turbulence goes some way to explaining why Neptune has the fastest stratospheric wind speeds in the Solar System.

So all these things we've learnt from our Solar System are useful in trying to determine how the atmosphere of a hot Jupiter might behave. Being so close to their star, it's likely these planets will be partly or fully tidally locked – so the main driver for atmospheric circulation will be, like Venus, the dayside-nightside temperature gradient. So a super-rotating stratosphere is plausible.

From there, mathematical modelling suggests that - because the atmosphere is driven by the temperature gradient - rather than being flung around the planet by its planet's rotation, a hot Jupiter's Rhines scale, the point at which horizontal flow develops significant turbulence, is much bigger than a hot Jupiter's radius, so its rotating atmosphere won't break up into multiple bands and zones that we see on our Jupiter.

And hey, one more thing? You might have heard that the coloured southern equatorial band of our Jupiter disappeared in May 2010. Well, don't worry – it's still there. Those higher altitude white ammonia clouds have just closed over the lower coloured cloud temporarily. This has happened before in the 1970s and the 1990s. So we expect the southern band will appear again soon and perhaps stay around until it disappears again in the 2030s.

It’s, you know, *turbulence*.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where we know which way the wind blows. No ads, no profit, just good science. Bye.