A&A 552, C1 (2013)
DOI: 10.1051/0004-6361/201015329e

Astronomy & Astrophysics

The extrasolar planet Gliese 581 d: a potentially habitable planet? *(Corrigendum)*

P. von Paris[1], S. Gebauer[2], M. Godolt[2,⋆], J. L. Grenfell[2], P. Hedelt[1,⋆⋆], D. Kitzmann[2], A. B. C. Patzer[2], H. Rauer[1,2], and B. Stracke[1]

[1] Institut für Planetenforschung, Deutsches Zentrum für Luft- und Raumfahrt, Rutherfordstr. 2, 12489 Berlin, Germany
e-mail: philip.vonparis@dlr.de
[2] Zentrum für Astronomie und Astrophysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

A&A 522, A23 (2010), DOI: 10.1051/0004-6361/201015329

ABSTRACT

We report here that the equation for H_2O Rayleigh scattering was incorrectly stated in the original paper. Instead of a quadratic dependence on refractivity r, we accidentally quoted an r^4 dependence. Since the correct form of the equation was implemented into the model, scientific results are not affected.

Key words. astrobiology – planets and satellites: atmospheres – planetary systems – stars: individual: GL 581 – errata, addenda – planets and satellites: individual: GL 581 d

It was recently brought to our attention (Kopparapu et al. 2013) that in our original paper (von Paris et al. 2010), we stated an incorrect equation for the calculation of the H_2O Rayleigh scattering coefficient $\sigma_{\mathrm{ray,H_2O}}$. Equation (3) in von Paris et al. (2010) shows a $r(\lambda)^4$ dependence of $\sigma_{\mathrm{ray,H_2O}}$, where $r(\lambda)$ is the wavelength-dependent refractivity of H_2O. Instead, as stated in Allen (1973), it should be a $r(\lambda)^2$ dependence. Therefore, the correct equation ($\sigma_{\mathrm{ray,H_2O}}$ in cm^2) reads

$$\sigma_{\mathrm{ray,H_2O}}(\lambda) = 4.577 \times 10^{-21} \left(\frac{6+3D}{6-7D}\right) \frac{r(\lambda)^2}{\lambda^4} \quad (1)$$

where D is the depolarization ratio and λ the wavelength in μm. Our work assumes $D = 0.17$ from Marshall & Smith (1990). The refractivity is calculated as $r(\lambda) = 0.85 r_{\mathrm{dryair}}(\lambda)$ (Edlén 1966). The refractivity of dry air ($r_{\mathrm{dryair}}(\lambda) = n_{\mathrm{dryair}}(\lambda) - 1$) is obtained from an approximate formula for the refractive index $n_{\mathrm{dryair}}(\lambda)$ given by Bucholtz (1995). With this equation, we calculate 2.6×10^{-27} cm^2 for the H_2O Rayleigh scattering cross-section at 0.6 μm, close to the value of 2.32×10^{-27} cm^2 from Selsis et al. (2007) or 2.5×10^{-27} cm^2 from Kopparapu et al. (2013).

The numerical factor 4.577×10^{-21} in Eq. (1) is derived from Allen (1973) in the following way: Allen (1973) states that the Rayleigh cross-section is

$$\sigma_{\mathrm{ray}} = \frac{32\pi^3}{3N^2} \left(\frac{6+3D}{6-7D}\right) \frac{r^2}{\lambda^4} \quad (2)$$

where σ_{ray} is in cm^2 and λ is in μm. N is the number of particles per unit volume, and we took, as stated in Allen (1973), standard temperature and pressure conditions ($T = 273.1$ K, $p = 1.013$ bar). This yielded 4.577×10^{-37} for the wavelength-independent factor $\frac{32\pi^3}{3N^2}$ in Eq. (2). Since N has units of cm^{-3} and the cross section is in cm^2, one must then transform λ from μm to cm, i.e. multiply by 10^{-4}. To the 4th power, this is 10^{-16}, which then results in the factor 4.577×10^{-21}, as stated in Eq. (1).

The correct equation (Eq. (1)) was implemented in the model code, hence the calculations of the H_2O Rayleigh scattering were treated correctly in the model used by von Paris et al. (2010). Therefore the results reported in von Paris et al. (2010) are not affected.

The equation for H_2O Rayleigh scattering reported in Kopparapu et al. (2013, their Eq. (1)) is incorrect. Hence, their statement that "the coefficient in the Rayleigh scattering cross section given in von Paris et al. (2010) should be seven orders of magnitude smaller" (Kopparapu et al. 2013) is also incorrect. We have contacted the authors of Kopparapu et al. (2013) about this, and they subsequently changed the online arxiv.org version (arXiv:1301.6674v2) to correct their equation and the corresponding text, however we point out that the printed journal version remains unchanged.

⋆ Now at Institut für Planetenforschung, Deutsches Zentrum für Luft-und Raumfahrt, Rutherfordstr. 2, 12489 Berlin, Germany.

⋆⋆ Now at Institut für Methodik der Fernerkundung, Deutsches Zentrum für Luft-und Raumfahrt, Oberpfaffenhofen, 82234 Weßling, Germany.

References

Allen, C. 1973, Astrophys. Quant. (The Athlone Press, University of London)
Bucholtz, A. 1995, Appl. Opt., 34, 2765
Edlén, B. 1966, Metrologia, 2, 71
Kopparapu, R., Ramirez, R., Kasting, J., et al. 2013, ApJ, 765, 131
Marshall, B. R., & Smith, R. C. 1990, Appl. Opt., 29, 71
Selsis, F., Chazelas, B., Bordé, P., et al. 2007, Icarus, 191, 453
von Paris, P., Gebauer, S., Godolt, M., et al. 2010, A&A, 522, A23