What Chooses the Colour of an Aurora Is Not the Composition of the Air but a Race Between Lifetime and Density

— The upper level of the green line at **557.7** nm lives **0.7** seconds and that of the red at **630.0** nm lives **110**, a ratio of **157.142857** whose logarithm is **5.057155** — the separator is whether colour is set by matter or by a race between lifetime and density — [Paper 690]

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— From thinking to syncing. —

Abstract

The green and the red of an aurora come from the same oxygen atom. They separate in altitude because the time taken to radiate races against the rate of collisions.What fixes the difference in altitude is counted here in closed form.No new theorem or law is claimed. First, and this is the core. The difference in altitude is the logarithm of the ratio of lifetimes——the ratio 157.142857 has logarithm 5.057155, and the difference is the scale height times that (Section 2). **Second, composition drops out of that expression——the absolute density, the collision cross-section and the thermal speed all vanish, leaving the scale height and the ratio of lifetimes** (Section 2). **Third, the number agrees with what is seen——at $H = 30$ km it is 151.714659 km, in the same range as the observed separation between green at 100 to 150 km and red at 200 to 400 km** (Section 2). **Fourth, solving it again by another route returns the same value——bisection on a density profile gives a difference of 151.714659 km, agreeing with the closed form** (Section 3). **Fifth, these transitions are extraordinarily slow to begin with——the green probability of 1.428571 per second is 1.428571×10^{-8} of a typical allowed transition at 10^{8} per second, and the red is a further 157 times slower** (Section 3). **Sixth, the separator is whether colour is set by matter or by a race——two colours from one atom separate in altitude because the same race is decided in two different places** (Section 4). **Keywords**: aurora, forbidden transition, collisional quenching, excited-state lifetime, scale height, colour and altitude.

Scope of this paper (scope note): **No new theorem or law is claimed——the forbidden transitions of atomic oxygen, their lifetimes, collisional quenching and the confinement of the red emission to high altitudes are all standard (Chamberlain 1961, Rees 1989).Excitation is not treated——the energy of precipitating electrons, their penetration depth and excitation cross-sections are not treated; excitation is taken as having happened and only what follows is examined.Nitrogen emission is left out——the blue and violet from molecular nitrogen are not included; only the two atomic oxygen lines are examined.The atmosphere is not claimed——density and temperature profiles, the scale height and the collision cross-section are representative, and the scale height is shown across 20 to 40 km.Observations are not treated——altitude measurements of real aurorae and the classification of their forms are not the subject.Relation to earlier papers**: **Paper 323 showed that the "three" in three primaries is a property of the receiver and not of light——there the appearance of colour was fixed by the receiver; here the altitude of a colour is fixed by a race between the lifetime of the emitter and the density around it. Both are faces of the same point, that colour is not an attribute of matter.Paper 668 showed that the one word "luminescence" hides a factor of 10^8 in lifetime between fluorescence and phosphorescence——there a difference in lifetime showed up in brightness and in how quickly the light dies; here the same kind of difference shows up in the height at which the light is emitted. A difference in time is translated into a difference in space.**What is added is **showing the altitude difference to be the logarithm of the lifetime ratio, showing composition to drop out of it, putting it at $\mathbf{151.714659}$ km for $H = 30$ km, obtaining the same value by closed form and by bisection**, and **placing the separator on matter against a race**.

1. Notation and the Question

Setting: **an excited atom either radiates within its lifetime τ or is robbed of its excitation by a collision first. The collision rate is proportional to the number density, which falls exponentially with height.**

$$\nu(z) = n(z)\sigma v, \qquad n(z) = n_0 e^{-(z-z_0)/H}, \qquad \nu(z_{\text{quench}}) = \frac{1}{\tau}, \qquad \Delta z = H \ln \frac{\tau_{\text{red}}}{\tau_{\text{green}}}$$

Neither n_0 nor σ nor v survives into the expression on the right. Everything below follows from that.

Question: **why do two colours from the same oxygen atom separate in altitude?**

2. The Difference Is the Logarithm of the Lifetimes

Computation 2.1: **green is 557.7 nm with a lifetime of 0.7 seconds and red is 630.0 nm with 110 seconds; the ratio is 157.142857 and its logarithm 5.057155.**

Computation 2.2: **the difference in altitude was derived for each scale height.**

scale height	difference in altitude
20 km	101.143106 km
30 km	151.714659 km
40 km	202.286212 km

Observation 2.3

this is the core: composition has dropped out of the expression.The absolute number density, the collision cross-section and the thermal speed all cancel when the difference of two altitudes is taken——it is not “green because oxygen”. Two levels of one atom separate in altitude by their ratio of lifetimes alone.

Observation 2.4

the prediction is therefore robust.Getting the cross-section wrong by a factor of two, or the density by a factor of ten, does not move the difference; only the scale height does——rewritten so that the uncertain quantities cancel, a coarse input still gives the right answer.

Observation 2.5

set against what is seen.Green appears at 100 to 150 km and red at 200 to 400 km, a separation of about 150 km, in the same range as the 151.714659 km predicted for $H = 30$ km——what agrees is not the altitude but the difference, and only that is free of composition.

3. Solved Again, and the Slowness

Computation 3.1: without the closed form, bisection on the density profile puts the quenching altitudes at 275.737995 km for green and 427.452654 km for red, a difference of 151.714659 km, agreeing with the closed form.

Observation 3.2

the altitudes themselves cannot be trusted; the difference can.The density and cross-section taken here are only representative, so 275 km disagrees with the observed green at 100 to 150 km——the difference is nonetheless right, and one must read which numbers depend on the inputs and which do not.

Computation 3.3: **the transition probability is the reciprocal of the lifetime, 1.428571 per second for green and 0.009091 for red. Against a typical allowed transition at 10^{8} per second these are 1.428571×10^{-8} and 9.090909×10^{-11}.**

Observation 3.4

that slowness is why these colours exist only high up.An allowed transition radiates in 10^{-8} seconds, faster than collisions even at the density near the ground——being forbidden is what makes the race with quenching possible at all.

4. The Separator

Observation 4.1

the separator is whether colour is set by matter or by a race between lifetime and density.If matter sets it, the colour does not depend on place; if a race sets it, the same matter shows different colours in different places——an aurora is the second kind, and altitude is choosing the colour.

Observation 4.2

beside Paper 323.Paper 323 showed the “three” in three primaries to be a property of the receiver rather than of light——there the appearance of colour was fixed by the receiver; here the altitude of a colour is fixed on the emitting side. Both are faces of the same point.

Observation 4.3

beside Paper 668.Paper 668 showed that the one word “luminescence” hides a factor of 10^8 in lifetime between fluorescence and phosphorescence, and counted how that governs the initial brightness and the rate of dying away——there a difference in lifetime emerged on the side of time; here the same kind of difference emerges, through a logarithm, on the side of space. Even a ratio as small as 157.142857 becomes 151.714659 km once its logarithm is taken and multiplied.

Observation 4.4

what is not said.Excitation and nitrogen emission are not treated, and density and cross-section are representative——what is shown is that only the difference in altitude is free of the inputs.

5. Roll Call and Closing

1. **lifetime ratio $\mathbf{157.142857}$** (Computation 2.1): **$\mathbf{110/0.7}$.**
2. **its logarithm $\mathbf{5.057155}$** (Computation 2.1): **the heart of the difference.**
3. **$\mathbf{151.714659}$ km at $H = 30$ km** (Computation 2.2): **the core.**
4. **$\mathbf{101.143106}$ km at $H = 20$ km** (Computation 2.2): **only the scale height counts.**
5. **composition drops out** (Observation 2.3): **density and cross-section cancel.**
6. **bisection gives $\mathbf{151.714659}$ km** (Computation 3.1): **closed form confirmed.**
7. **but the altitude is $\mathbf{275.737995}$ km** (Computation 3.1): **that one cannot be trusted.**
8. **green probability $\mathbf{1.428571}$ per second** (Computation 3.3): **a forbidden transition.**
9. **$\mathbf{1.428571} \times 10^{-8}$ of allowed** (Computation 3.3): **slow enough to race.**
10. **matter or race** (Observation 4.1): **the separator; Papers 323 and 668.**

Closing: **What chooses the colour of an aurora is not the composition of the air.The lifetimes of green at 0.7 seconds and red at 110 stand in a ratio of 157.142857 whose logarithm is 5.057155, and the difference in the altitudes at which quenching bites is the scale height times that and nothing else——the absolute density, the cross-section and the thermal speed all cancel.At $H = 30$ km it is 151.714659 km, in the same range as the observed separation between green at 100 to 150 km and red at 200 to 400 km.Solving instead by bisection on a density profile returns the same 151.714659 km, while the altitude itself, 275.737995 km for green, is dragged by the representative inputs and disagrees with observation——which numbers depend on the inputs and which do not must be read apart.The**

green transition probability of 1.428571 per second is 1.428571×10^{-8} of an allowed one, and only that slowness makes a race with quenching possible.The separator is whether colour is set by matter or by a race between lifetime and density.Placed among the earlier papers——in Paper 323 the appearance of colour was fixed by the receiver; here the altitude of a colour is fixed on the emitting side.To be honest——excitation and nitrogen emission are not treated, and density and cross-section are representative.

References

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