

The “Three” in Three Primaries Is Not a Property of Light

— A **301**-Dimensional Input Is Reported in **3** Dimensions, Leaving **298** Unseen — The Screen Stands on Those
Unseen Dimensions — [Paper 323]

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— *From thinking to syncing.* —

Abstract

Every device that reproduces colour uses three primaries. This paper asks where that “three” came from—the answer is not from light, but from the number of receptors. No new mathematical theorem and no new law is claimed. First, the input dimension is a choice. **301** at 1 nm steps, **3001** at 0.1 nm (Section 2). Second, the output **3** is not a choice. Because there are three cone types (Section 2). Third, this is the core of the paper. **298** dimensions fall into the kernel—the set of invisible light is **298**-dimensional (Section 3). Fourth, the screen uses that kernel. It reproduces no spectrum at all (Section 4). Fifth, the *L* and *M* peaks are only **30.0** nm apart (Section 4). Sixth, the separator is whether the locus is curved, and that lies outside linearity (Section 5).

Scope of this paper (scope note): No new mathematical theorem and no new law is claimed——trichromacy, metamerism, the CIE system, and gamuts being triangles are all standard. We do not build vision science——all we use is one linear map and the dimension of its kernel. We do not treat perception——colour appearance phenomena (contrast, constancy, adaptation) are not entered. This paper looks only at the receptor stage. We claim no accuracy for the sensitivity curves——420 / 534 / 564 nm are representative literature values, and other definitions give other numbers. We do not classify colour deficiency——the details of dichromacy and anomalous trichromacy are not entered. We do not assess devices——gamut areas are geometric quantities computed from the standardised primaries, not picture quality. Relation to earlier papers: Paper 316 showed the same integer returning from three counts——the 3 here is not a count but the rank of a map, and there is only one place it can come from. Paper 315 showed which dimension is special depends on the question——the 3 here does not change with the question, the opposite case. Paper 306 showed the count of base units is a convention——the count of primaries is not a convention. That is what separates this paper from 306. Paper 276 showed the decibel is a ratio and not a quantity——chromaticity is a ratio too, what remains after dividing out brightness. Paper 321 showed one length answering two questions——this is the same form: one rank setting both what can be seen and what can be built. What is added is tabulating the input and output dimensions in numbers, stating the kernel dimension as 298, giving the L – M separation as 30.0 nm, and putting the reason gamuts stay triangles on convexity.

1. Notation and the Question

Setting: The light entering the eye is a function, an intensity per wavelength $S(\lambda)$. What the eye emits is three numbers.

$$(L, M, S) = \left(\int S(\lambda) \bar{l}(\lambda) d\lambda, \int S(\lambda) \bar{m}(\lambda) d\lambda, \int S(\lambda) \bar{s}(\lambda) d\lambda \right)$$

Observation 1.1

This is a linear map. From a space of functions into $\mathbf{R}^3$, taking only three inner products——everything else is discarded.

Question: Where did the “three” in three primaries come from?

2. The Input Dimension Is a Choice; the Output 3 Is Not

Check 2.1: Sampling 400–700 nm.

Step	Input dimension	Output	Ratio
1 nm	301	3	100.3
0.1 nm	3001	3	1000.3
0.01 nm	30001	3	10000.3

Observation 2.2

The left column is how we measure; the right column is a body. Finer steps raise the input dimension without bound—and the numbers coming out are still three.

Observation 2.3

The real input is infinite-dimensional. 301 is a number that appeared because we chose a step, not a property of light—the countable side and the uncountable side are the two halves of this table.

Check 2.4: Receptor types against the primaries required.

Types	Example	Primaries needed
1	rods alone (night vision)	1
2	dog, cat, most mammals	2
3	human, old-world primates	3
4	most birds, some fish	4
12	mantis shrimp	12

Observation 2.5

In every row the two numbers agree. The count of primaries was not chosen; it equals the count of receptors—a television for birds would have to have four.

Observation 2.6

This is where this paper parts from Paper 306.306 wrote that the count of base units is a convention—the count of primaries is not. Change how you measure and it is still 3.

3. The Core: 298 Dimensions Fall into the Kernel

Setting: Consider the linear map $\mathbf{R}^{301} \rightarrow \mathbf{R}^3$.

Check 3.1: By rank--nullity,

$$\dim(\ker) = 301 - 3 = 298$$

Observation 3.2

This is the core of the paper. Every non-zero vector in that kernel is a difference of light the eye cannot see—differences of spectrum that change the colour not at all, whether added or subtracted, filling **298** dimensions.

Observation 3.3

The set of lights looking identical to a given one is not a point but a 298-dimensional plane. This is metamerism—“the same colour” is nowhere near “the same light”.

Observation 3.4

Finer sampling makes the kernel larger. At 0.1 nm it is 2998-dimensional—the seen dimensions do not increase; only the unseen ones do.

Observation 3.5

This is not a defect but a resource. The next section spends it.

4. The Screen Stands on That Kernel

Setting: An RGB display emits three narrow bands and nothing else.

Observation 4.1

The screen reproduces no spectrum at all. A leaf’s spectrum and a photograph of it are entirely different in $\mathbf{R}^{301}$ ——they merely land on the same point of $\mathbf{R}^3$.

Observation 4.2

Without the kernel there could be no screen. Were the map injective, looking the same would require making the same light——three bands suffice only because there are 298 dimensions to hide in.

Check 4.3: Cone sensitivity peaks (representative literature values, nm).

Type	Peak	Gap to the previous
S	420.0	—
M	534.0	114.0
L	564.0	30.0

Observation 4.4

L and *M* are only **30.0** nm apart. That is 5.3191% of 564 nm, and only 1/3.8 of the *S*--*M* gap——the three are nothing like evenly spaced.

Observation 4.5

The work of separating red from green is done by two receptors 30 nm apart. The smaller the gap, the more the difference is at the mercy of noise——that red--green deficiency is the commonest kind starts here.

Observation 4.6

The 3 is not a convenient design. A design would have spaced them evenly—114 against 30 shows that it is not one.

5. Separator: Whether the Locus Is Curved

Setting: Choosing three primaries makes the reachable colours a triangle in the chromaticity diagram.

Check 5.1: Triangle areas from the standardised primaries (CIE 1931 xy , computed here).

Standard	Triangle area
sRGB	0.112050
Rec.2020	0.211867
Ratio	1.8908

Observation 5.2

Improving the standard leaves it a triangle. 1.8908 times the area, still three sides—what grows is the area, not the number of vertices.

Observation 5.3

Separator—whether the spectral locus is curved.

The locus is	Its convex hull is	Three primaries
straight	possibly a triangle	reach everything
curved (as it is)	not a triangle	leave colours out

Observation 5.4

This is a statement about shape, not about technology. A triangle on three points of the locus lies strictly inside the hull——no three real primaries, however chosen, can cover all of it.

Observation 5.5

The kernel comes from linearity; the gamut limit comes from convexity. Two different properties of one map——by Paper 300's criteria they have different roots, and neither yields the other.

Observation 5.6

A point to write honestly——this paper looks only at the receptor stage. Actual colour appearance depends strongly on surround, adaptation and memory——a long processing chain still follows the landing in $\mathbf{R}^3$.

Observation 5.7

One last thing——it is not that we see 3/301 of the light. It is more exact to say we fail to see 298 dimensions of it——and the screen works because of that failure. Discarding so much is what makes reproduction possible.

6. Roll Call and Closing

1. 301 dimensions at 1 nm (Check 2.1): **Output 3.**
2. The input dimension is how we measure (Observation 2.3): **Not a property of light.**
3. Primaries equal receptors (Check 2.4): **Birds need four.**
4. Parting from 306 (Observation 2.6): **Primaries are not a convention.**
5. The kernel is 298-dimensional (Check 3.1): **The set of unseen differences.**
6. Finer sampling grows the kernel (Observation 3.4): **Not the seen part.**
7. The screen reproduces nothing (Observation 4.1): **It lands on the same point.**
8. L and M are 30.0 nm apart (Check 4.3): **1/3.8 of $S-M$.**
9. sRGB area 0.112050 (Check 5.1): **Rec.2020 is 1.8908 times.**

10. Curved, so uncoverable (Observation 5.4): Shape, not technology.

Closing: Every device that reproduces colour uses three primaries. That “three” is not a property of light——what enters the eye is a function, an intensity per wavelength, **301-dimensional** at 1 nm steps and **3001-dimensional** at 0.1 nm, and the numbers coming out are still three, however fine the sampling. The input dimension is how we measure; the output **3** is a body——one receptor type means one primary, two mean two, and birds have four types, so a television for birds would have to have four. The count of primaries was not chosen; it equals the count of receptors. By rank-nullity the kernel is **298-dimensional**——298 dimensions of spectral difference that change the colour not at all, so that the set of lights looking identical to a given one is not a point but a **298-dimensional plane**. Finer sampling grows only the unseen dimensions. And the screen stands on that kernel——a leaf and its photograph are entirely different in $\mathbf{R}^{301}$ and merely land on the same point of $\mathbf{R}^3$. Were the map injective, looking the same would require making the same light. The cone peaks are 420.0 / 534.0 / 564.0 nm, so L and M are only **30.0 nm** apart——1/3.8 of the S – M gap, and the whole work of separating red from green is done across those 30 nm. A design would have spaced them evenly; 114 against 30 shows it is not one. And three primaries cannot reach everything——the sRGB triangle has area **0.112050** and Rec.2020 has 1.8908 times as much, with the same three sides. One thing separates them——whether the spectral locus is curved. A triangle on three points of a curve lies strictly inside its hull, and this is a statement about shape, not about technology. The kernel comes from linearity and the gamut limit from convexity——two properties of one map, and neither yields the other. One last thing——we fail to see **298 dimensions** of the light, and the screen works because of that failure. Discarding so much is what makes reproduction possible.

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