

A Lens Can Brighten and Cannot Increase Brightness

— Four Quantities Are Called Brightness and Only One Obeys the Inverse Square: Which Is Why No
Concentration of Sunlight Gets Hotter Than the Sun's Surface — [Paper 214]

Yuuki YAMAGISHI (山岸 勇輝)

Yamagishi Complexity Torus Lab, Japan

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— *From thinking to syncing.* —

ABSTRACT

The single word “bright” points at four separate quantities. This paper sets all four down in numbers for one source and writes what moves and what does not when the detector is moved and when a lens is put in. **NO NEW MATHEMATICAL THEOREM AND NO NEW PHYSICAL LAW IS CLAIMED.** First, moving the detector moves only one of them. Going from 1 to 1000 **m** the irradiance falls from 0.318 to 3.18×10^{-7} while the radiance stays at 1013.211836 without moving a digit (Section 3). Second, putting in a lens raises only one of them. Computed from the thin-lens equation and the magnification alone, the irradiance on the image rises by up to **18225** times while the radiance of the image is exactly 1.0 times the source's (Section 4). Third, this is the core. Because étendue is conserved the concentration ratio cannot exceed $1/\sin^2 \theta = \mathbf{46238.8}$, and the irradiance of $6.29 \times 10^7 \text{ W/m}^2$ reached there gives a temperature of **5771.83 K** — which differs from the Sun's surface at 5772 K by 0.003 % (Section 5). Fourth, magnitude is a fifth way of speaking, and is a logarithmic scale on one of the four. One magnitude is $100^{1/5} = \mathbf{2.51188643151}$ (Section 6). Fifth, a Lambertian full moon would be darker at its limb. The relative radiance falls from 1.0 at the centre to 0.436 at $\rho = 0.9$, which is 0.90 magnitudes down (Section 7).

Scope of this paper (scope note): NO NEW MATHEMATICAL THEOREM AND NO NEW PHYSICAL LAW IS CLAIMED — the distinction between radiometry and photometry, the conservation of étendue, the impossibility of raising radiance with passive optics, Lambert's cosine law and the definition of magnitude are all standard. The second law of thermodynamics is not derived — the concentration limit is obtained from geometry, and its agreement with the second law is only checked. The spectral response of the visual quantities is not treated — the numbers are radiometric. The Moon is not measured — Section 7 gives what a Lambertian sphere would look like, not an observation. The design of nonimaging optics is not discussed. Relation to Paper 01: the first paper of the corpus treated the exponent $n = 2$ of the inverse square itself — what this paper counts is the three that do not obey it. What is added is setting the four quantities down in numbers for one source, moving the detector through five distances and watching the radiance not move, obtaining the radiance ratio of one from the lens equation and the magnification alone, assuming nothing about étendue, deriving the attainable temperature from the concentration limit and setting it against the Sun's surface, and giving the limb darkening of a Lambertian sphere in magnitudes.

1. Notation and Position

There are at least four quantities called the brightness of light.

Quantity	Unit	Per what
Radiant power	W	the whole
Radiant intensity	W/sr	per solid angle
Irradiance	W/m²	per area of the receiver
Radiance	W/m²/sr	per area and per solid angle

Position: In Paper 207 there were three tools for writing polarization and one could not write the question — in Paper 210 there were four speeds of light and only two carried a fence. Here there are four brightnesses and only one obeys the inverse square.

2. One Source, Four Numbers

Take a Lambertian disc of radius **1 cm** radiating **1 W** into a half-space.

Check 2.1:

Quantity	Value	Unit
Radiant power	1.0	W
Radiant intensity (on axis)	0.31830989	W/sr
Radiance	1013.2118	W/m ² /sr
Irradiance at 1 m	0.31830989	W/m ²

Observation 2.2

The on-axis intensity comes to $P/\pi = 0.31830989$ because a Lambertian surface radiates as $\cos \theta$ and the integral of $\cos$ over a half-space is π . Note that π appears and not 4π — this is not a point source.

3. Moving the Detector Moves Only One

Check 3.1:

Distance	Power	Intensity	Irradiance	Radiance
1 m	1.0	0.31830989	0.31830989	1013.211836
2 m	1.0	0.31830989	0.079577472	1013.211836
10 m	1.0	0.31830989	0.0031830989	1013.211836
100 m	1.0	0.31830989	3.1830989×10^{-5}	1013.211836
1000 m	1.0	0.31830989	3.1830989×10^{-7}	1013.211836

Observation 3.2

Only the irradiance obeys the inverse square. Radiance is the ratio of two quantities that both fall as $1/r^2$, so it does not move a digit — what reaches the receiver shrinks at exactly the rate at which the solid angle of the source shrinks.

Observation 3.3

This is why a distant wall does not look darker. Step ten times further from the same wall and the brightness of its surface in the eye is unchanged — what changes is only its size. “Distant things are dim” is true only of things that appear as points.

4. Putting In a Lens Raises Only One

Take a thin lens of focal length f and diameter D imaging a source at u onto v , with $1/u + 1/v = 1/f$, magnification $m = v/u$, and no loss. The image area comes from the magnification and the collected power from the solid angle of the lens — nothing about étendue is assumed.

Check 4.1:

f	u	v	m	Gain in irradiance	Ratio of radiance
0.10	0.5	0.125	0.25	100.0	1.0
0.10	0.2	0.2	1.0	6.25	1.0
0.50	2.0	0.666667	0.333333	900.0	1.0
1.00	10.0	1.11111	0.111111	18225.0	1.0

Observation 4.2

The irradiance on the image rises by eighteen thousand times, and the ratio of radiance is one in every digit carried. The ratio of the two solid angles cancels exactly against the square of the magnification.

Observation 4.3

This is what the title means: a lens can brighten a surface (irradiance) and cannot brighten a source (radiance). And with losses the radiance falls — it never rises.

5. The Core: Concentration Cannot Beat the Sun's Surface

The Sun's angular radius is $\theta = 0.004650484 \text{ rad} = 0.26645311^\circ$. Since the étendue $n^2 A \Omega$ is conserved, the concentration ratio cannot exceed $1/\sin^2 \theta$.

Check 5.1: taking the solar constant as 1361 W/m^2 and $\sigma = 5.670374419 \times 10^{-8}$.

Concentration	Irradiance (W/m^2)	Temperature (K)
1	1361	393.61
100	136100	1244.69
1000	1361000	2213.41
10000	1.361×10^7	3936.06
46238.8 (the limit)	6.2931×10^7	5771.83

Observation 5.2

The Sun's surface is at 5772 K. The limit obtained from geometry alone is 5771.83 K, a difference of **0.003 %**. No lens and no mirror makes a place hotter than the source.

Observation 5.3

This was not derived here from thermodynamics — all that was used is a reckoning of angles and areas. That two separate roads arrive at the same number is itself the content of this section: were the limit passable, heat would move from a cooler body to a hotter one.

6. Magnitude, a Fifth Way of Speaking

Check 6.1: five magnitudes were defined as a factor of a hundred, so one magnitude is $100^{1/5} = 2.51188643151$.

Difference	Ratio of irradiance
1	2.511886432
5	100.0
10	10000.0
24	3.98×10^9
30	1.0×10^{12}

Observation 6.2

Magnitude is a logarithmic scale on one of the four, the irradiance. To call a star faint is to speak of what arrives here, not of how bright its surface is — and the latter does not move with distance, so magnitude can never measure it.

7. A Lambertian Sphere Would Be Dark at the Limb

For a perfectly diffusing sphere lit from the observer's direction, the angle γ between the surface normal and the line of sight satisfies $\sin \gamma = \rho$, where ρ is the fractional distance to the limb, and the radiance goes as $\cos \gamma = \sqrt{1 - \rho^2}$.

Check 7.1:

ρ	Relative radiance	Magnitudes down
0	1.0	0.0
0.3	0.9539392	0.051
0.6	0.8	0.242
0.9	0.43588989	0.902
0.99	0.14106736	2.126

Observation 7.2

A Lambertian full moon would be nearly a magnitude darker at its limb. That the real full moon shows almost no limb darkening is the standard evidence that its surface is not Lambertian. This paper does not measure the Moon — what is given is only the prediction for a Lambertian sphere.

8. The Separator and the Fence

Census 8.1: multiply the distance by ten and see what happens.

Quantity	Factor	Obeys the inverse square?
Radiant power	1	no
Radiant intensity	1	no
Irradiance	1/100	yes
Radiance	1	no

Observation 8.2 (the separator)

What separates the four is per what they are counted — the whole, per solid angle, per area, or per both. And only the one divided by both is moved neither by distance nor by a lens. It does not move because its numerator and denominator fall at the same rate.

Observation 8.3 (the fence)

The fence around “the further away, the dimmer” is that it be said of irradiance. Outside the fence it is false — walls, moons and skies do not darken with distance. And the fence around “a lens can make it brighter” is the same one: radiance cannot be raised.

Observation 8.4

Paper 01, the first of the corpus, treated the uniqueness of the exponent $n = 2$ — what this paper counts is the three that do not obey it. That the exponent is right and which quantity it acts on were two different questions. In Paper 210, of four speeds of light only two carried a fence — here, of four brightnesses only one carries the inverse square.

9. The Census and the Close

What this paper measured:

1. Four numbers set down for one source (Check 2.1).
2. Distance moves only the irradiance (Check 3.1): radiance fixed at 1013.211836.
3. A lens raises only the irradiance (Check 4.1): gain 18225, radiance ratio 1.0.
4. The limiting temperature is 5771.83 K (Check 5.1): 0.003 % from the Sun's surface.
5. Magnitude is a log scale on irradiance (Check 6.1): one magnitude = 2.51188643151.
6. A Lambertian sphere is 0.9 magnitudes down at the limb (Check 7.1).
7. One of the four obeys the inverse square (Census 8.1).

Close: A burning glass sets paper alight. It is tempting to say that the lens makes the light brighter, but what has risen is the irradiance on the paper, and not the radiance of the Sun. And since radiance cannot rise, no apparatus can make a place hotter than the Sun's surface — the limit of 5771.83 K obtained from geometry alone, three parts in ten thousand from the Sun's own 5772 K, is the number of that fact. To brighten can be done. To increase brightness cannot. One phrase stood for two operations, one possible and one not.

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