What Sets Resolving Power Is Not the Size of the Aperture but Its Ratio to the Wavelength

— With $\theta = 1.22\lambda/D$, a 2.4 m telescope at 550 nm resolves 5.766820×10^{-2} arcseconds, while a 21 cm radio interferometer spread over 36 km resolves 1.467918 — the separator is whether the extra length of the wavelength can be won back by stretching the aperture — [Paper 775]

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— From thinking to syncing. —

Abstract

Larger telescopes are said to see finer detail. But the formula for fineness contains the wavelength alongside the aperture.For visible light and radio, how much fineness is won back by stretching the aperture is counted.No new theorem or law is claimed. First, 2.4 m in visible light is fine——5.766820×10^{-2} arcseconds at 550 nm (Section 2). **Second, a radio interferometer spread over 36 km does not reach it——1.467918 arcseconds at 21 cm** (Section 2). **Third, and this is the core. 15000 times the aperture cannot win back 381818 times the wavelength——the resolution ratio is 25.454545, equal to the wavelength ratio divided by the aperture ratio** (Section 2). **Fourth, the aperture needed to match grows in proportion to wavelength——9.163636×10^{5} m at 21 cm, 0.071917 of the Earth's diameter** (Section 3). **Fifth, short radio waves across the Earth finally pass——2.567383×10^{-5} arcseconds at 1.3 mm across the Earth's diameter** (Section 3). **Sixth, the separator is whether the extra length of the wavelength can be won back by stretching the aperture——"a bigger telescope sees finer" has no truth value until the ratio to wavelength is stated** (Section 4). **Keywords**: resolving power, diffraction limit, aperture, radio interferometer, ratio of wavelength to aperture, Earth-sized interferometer.

Scope of this paper (scope note): **No new theorem or law is claimed——the diffraction limit $1.22\lambda/D$ of a circular aperture, that an interferometer's resolution is set by its baseline, and that radio needs long baselines are all known (Born and Wolf 1999, Thompson et al. 2017).Only the diffraction limit——atmospheric turbulence, sensitivity, receiver noise and gaps in interferometric images are not treated.The sets are chosen values——the four pairs of wavelength and aperture are set for comparison; real instrument performance is not claimed.Brightness is not treated——light-gathering power and the visibility of faint sources are not treated.No observation is claimed——images of particular sources are not treated.Relation to earlier papers**: **Paper 757 showed that which of three quantities buys the resolution decides what the depth of focus pays——there the resolution of exposure was split into a product of wavelength, numerical aperture and a factor. Here a telescope's resolution splits into the ratio of wavelength to aperture, and radio, which cannot buy fineness with wavelength, must buy it with aperture. Which quantity buys fineness, in exposure and in telescopes.**What is added is **setting the resolution of four pairs side by side by one formula**, **showing the resolution ratio to be $\mathbf{25.454545}$**, **the wavelength ratio divided by the aperture ratio**, **deriving the aperture needed to match the visible telescope at three wavelengths**, and **placing the separator on whether wavelength can be won back by aperture**.

1. Notation and the Question

Setting: **gathering light of wavelength λ with a circular aperture D, the smallest resolvable angle θ is given below. For an interferometer, D is replaced by the baseline.**

$$\theta = 1.22\,\frac{\lambda}{D}, \qquad \frac{\theta_2}{\theta_1} = \frac{\lambda_2/\lambda_1}{D_2/D_1}, \qquad D_{\text{need}} = D_1\,\frac{\lambda_2}{\lambda_1}$$

Angles are in arcseconds; the Earth's diameter is taken as 12742 km.

Question: **does a larger aperture see finer detail at any wavelength?**

2. The Aperture Ratio and the Wavelength Ratio

Computation 2.1: **resolution was derived for four pairs.**

set	wavelength	aperture	resolution
visible telescope	**550** nm	**2.4** m	**5.766820** $\times 10^{-2}$ arcsec
radio interferometer	**21** cm	**36** km	**1.467918** arcsec
Earth-sized interferometer	**21** cm	**12742** km	**4.147312** $\times 10^{-3}$ arcsec
Earth-sized interferometer	**1.3** mm	**12742** km	**2.567383** $\times 10^{-5}$ arcsec

Observation 2.2

this is the core: 15000 times the aperture cannot win back 381818 times the wavelength.The 36 km radio interferometer has 15000.000000 times the aperture of the 2.4 m telescope, but a wavelength 381818.181818 times longer, so its resolution is 25.454545 times worse——the resolution ratio matched the wavelength ratio divided by the aperture ratio to 3.553×10^{-15}**.**

3. The Aperture Needed to Match

Computation 3.1: **the aperture needed to match the 2.4 m visible telescope was derived at three wavelengths.**

wavelength	aperture needed	fraction of the Earth's diameter
21 cm	**9.163636** $\times 10^{5}$ m	**0.071917**
1 m	**4.363636** $\times 10^{6}$ m	**0.342461**
1.3 mm	**5.672727** $\times 10^{3}$ m	**0.000445**

Observation 3.2

the aperture needed grows in proportion to wavelength.At 21 cm it is 9.163636×10^{5} **m; at 1 m, 0.342461 of the Earth's diameter——the longer the wavelength, the closer the aperture must come to the size of the Earth.**

Observation 3.3

short radio waves across the Earth finally pass.At 1.3 mm across the Earth's diameter the resolution is 2.567383×10^{-5} arcseconds, beyond the visible 5.766820×10^{-2}; at 21 cm even an Earth-sized baseline stops at 4.147312×10^{-3}——for radio to win, stretching the aperture is not enough; the wavelength must also shrink.

4. The Separator

Observation 4.1

the separator is whether the extra length of the wavelength can be won back by stretching the aperture.Visible light manages with 2.4 m; radio matches only when stretched to the size of the Earth——"a bigger telescope sees finer" has no truth value until the ratio to wavelength is stated.

Observation 4.2

beside Paper 757.Paper 757 split the resolution of exposure into a product of wavelength, numerical aperture and a factor, and showed that which is used decides what the depth of focus pays——in telescopes too fineness is set by the ratio of wavelength to aperture, and radio, unable to buy it with wavelength, must buy it with aperture.

Observation 4.3

what is not said.Atmospheric turbulence, sensitivity, gaps in interferometric images and real instrument performance are not treated——what is shown is that resolution is set not by the aperture itself but by its ratio to the wavelength.

5. Roll Call and Closing

1. **visible 5.766820×10^{-2} arcsec** (Computation 2.1): **2.4 m.**
2. **radio 1.467918 arcsec** (Computation 2.1): **36 km.**
3. **aperture ratio 15000.000000** (Observation 2.2): **stretched far.**

4. **wavelength ratio 381818.181818** (Observation 2.2): **longer still.**
5. **resolution ratio 25.454545** (Observation 2.2): **the core.**
6. **0.071917 of the Earth at 21 cm** (Computation 3.1): **aperture needed to match.**
7. **0.342461 at 1 m** (Observation 3.2): **longer still.**
8. **Earth-sized at 21 cm 4.147312×10^{-3} arcsec** (Observation 3.3): **not yet past.**
9. **Earth-sized at 1.3 mm 2.567383×10^{-5} arcsec** (Observation 3.3): **past.**
10. **wavelength won back by aperture or not** (Observation 4.1): **the separator; Paper 757.**

Closing: **What sets resolving power is not the size of the aperture but its ratio to the wavelength.A 2.4 m telescope at 550 nm resolves 5.766820×10^{-2} arcseconds, while a 21 cm radio interferometer spread over 36 km stops at 1.467918——with 15000.000000 times the aperture but a wavelength 381818.181818 times longer, its resolution is 25.454545 times worse.Matching at 21 cm needs 0.071917 of the Earth's diameter; at 21 cm even an Earth-sized baseline stops at 4.147312×10^{-3} arcseconds, and only at 1.3 mm across the Earth does radio pass, at 2.567383×10^{-5}——for radio to win, the wavelength must shrink as well as the aperture grow.The separator is whether the extra length of the wavelength can be won back by stretching the aperture——"a bigger telescope sees finer" has no truth value until the ratio to wavelength is stated.Placed among the earlier papers——Paper 757 counted which quantity buys resolution in exposure; this counts telescopes, where radio cannot buy with wavelength and must buy with aperture.To be honest——only the diffraction limit is considered, not the atmosphere, sensitivity, image gaps or real instruments.**

References

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