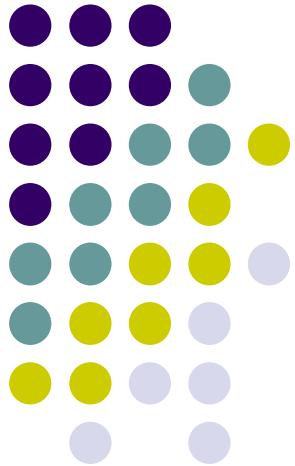
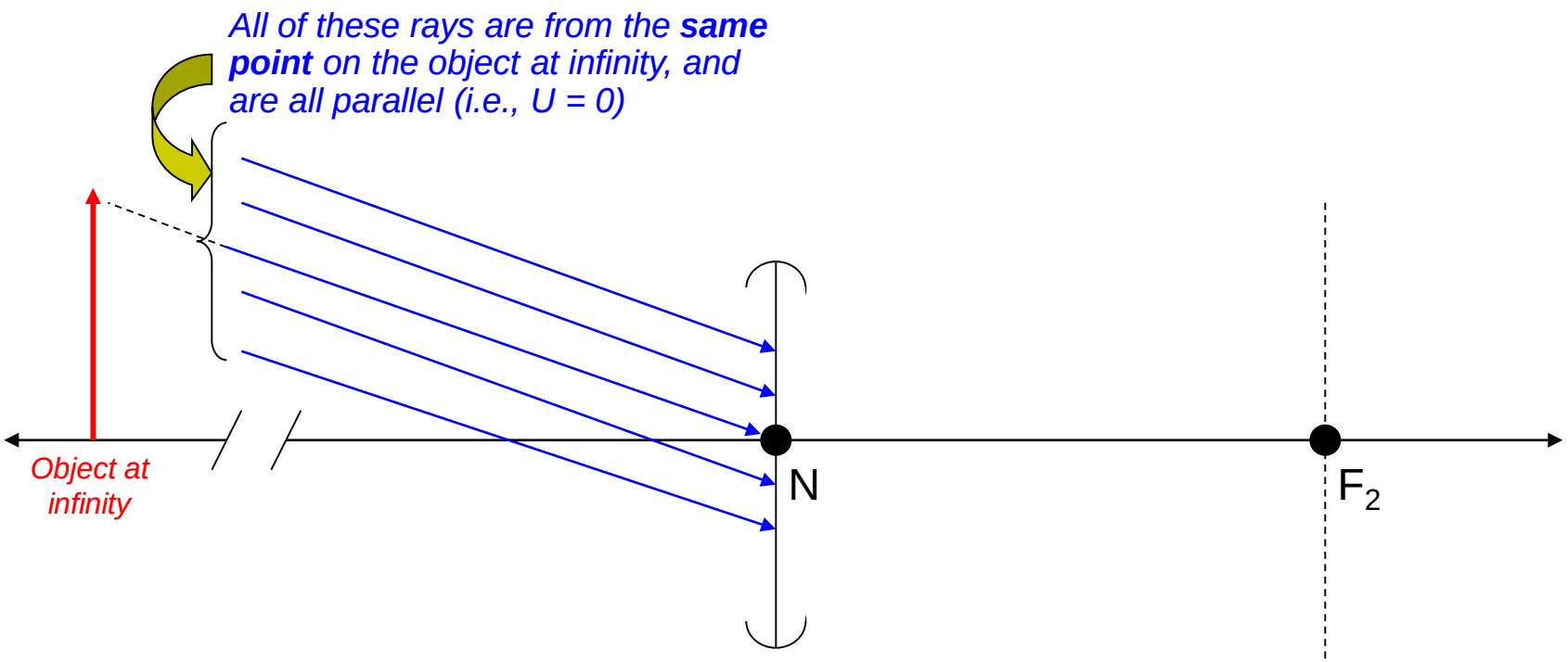
Telescopes

Basic Optics, Chapter 23



Telescopes

Consider an optical system consisting of a single plus lens and an object at infinity:
Where will the rays from the tip of the object be focused?



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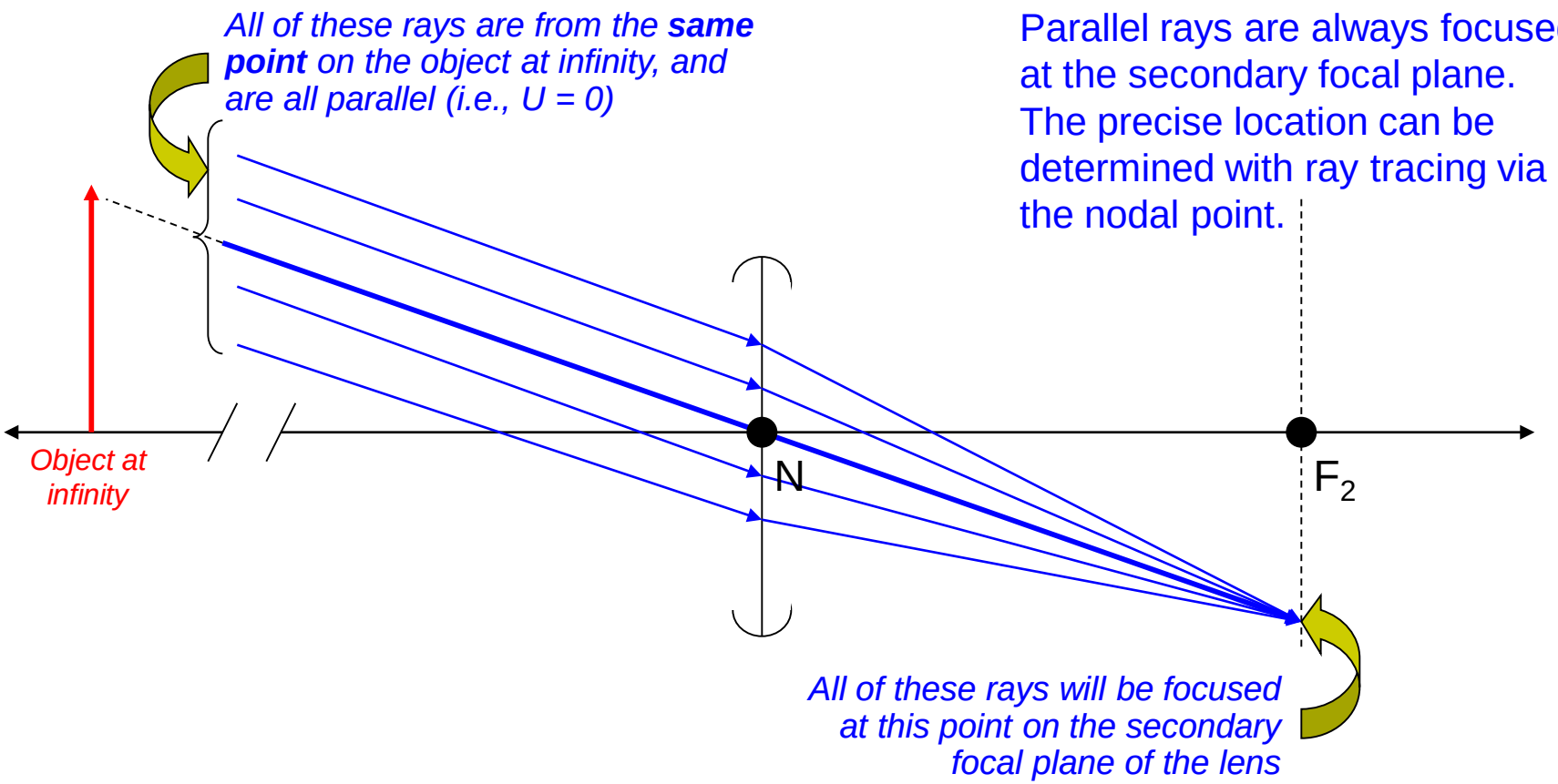

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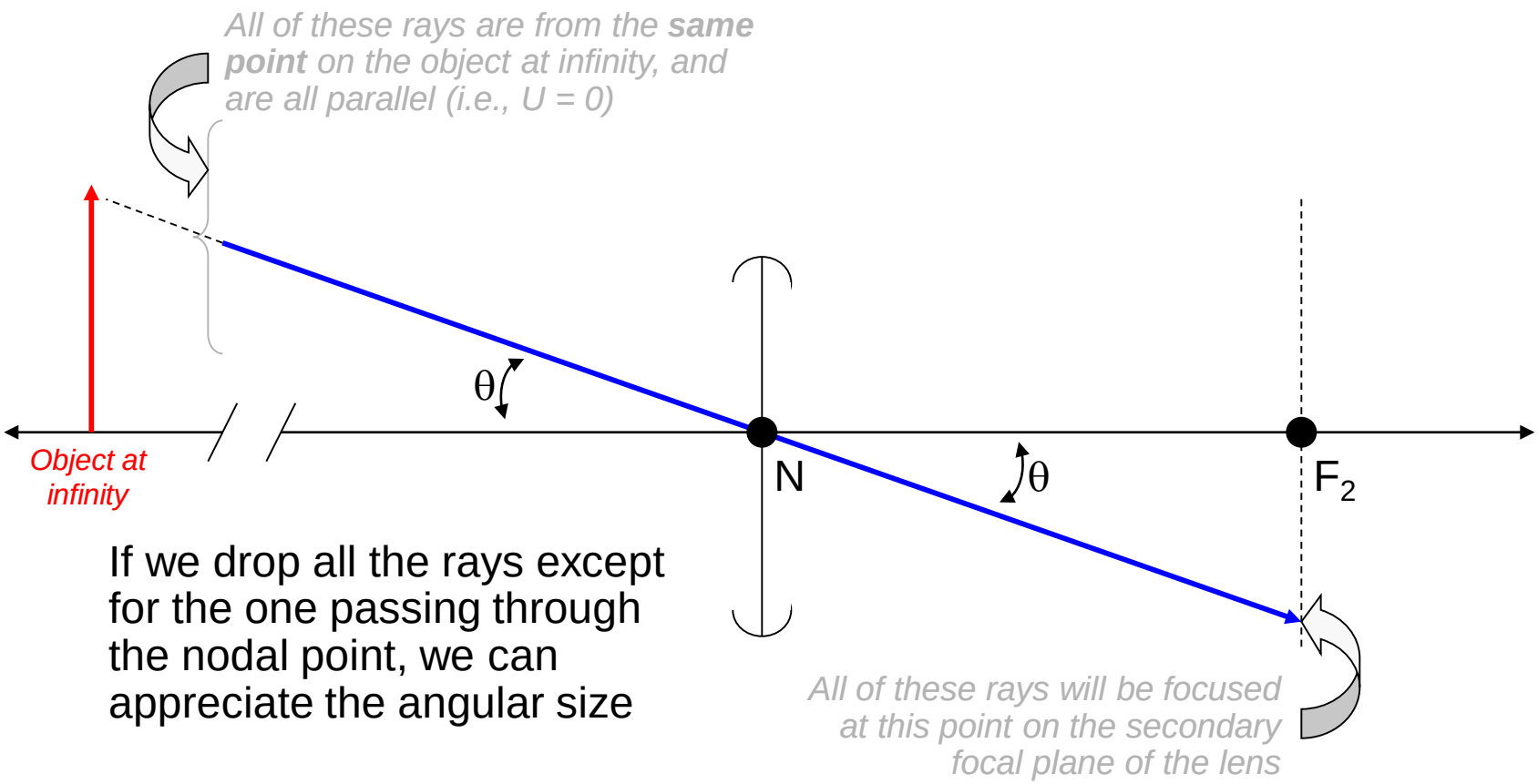
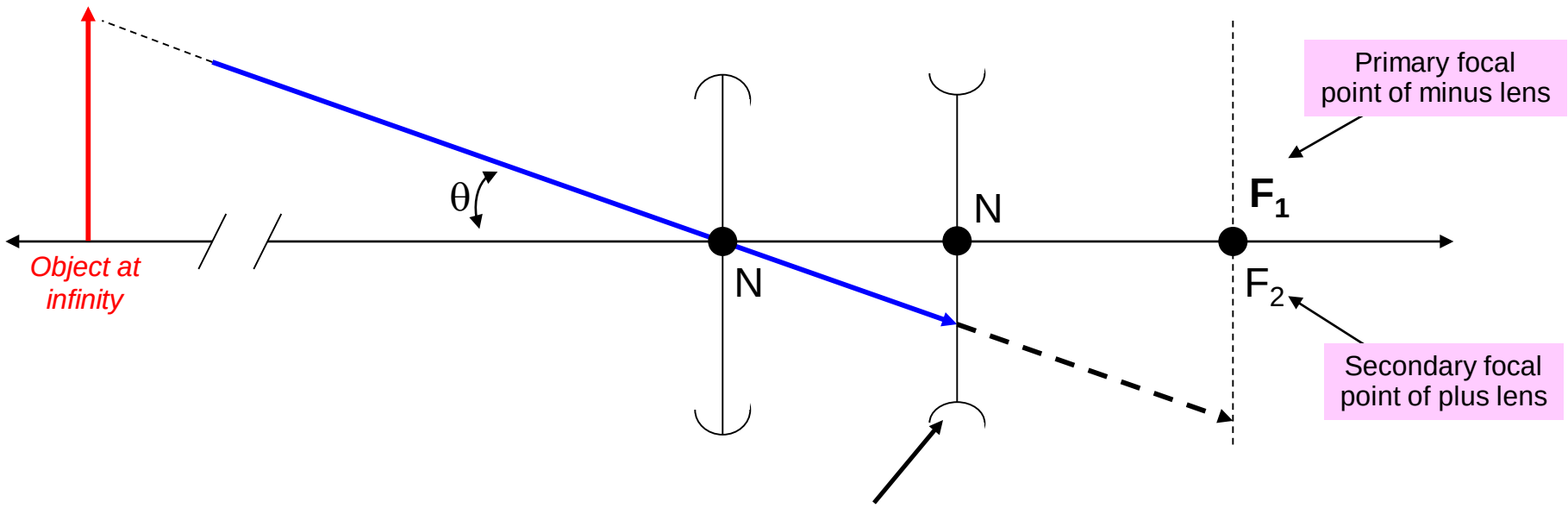


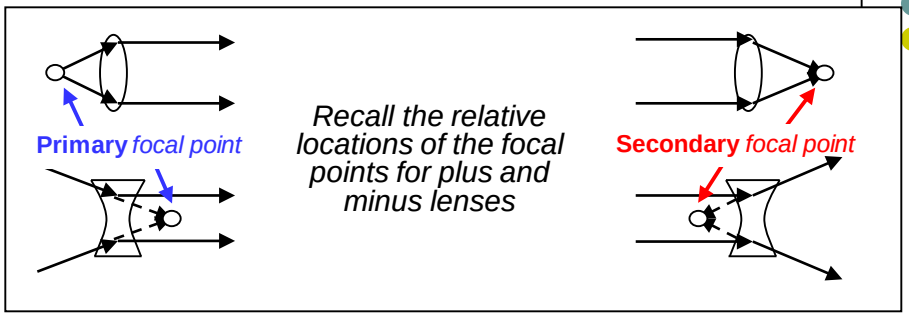
If we drop all the rays except for the one passing through the nodal point, we can appreciate the angular size

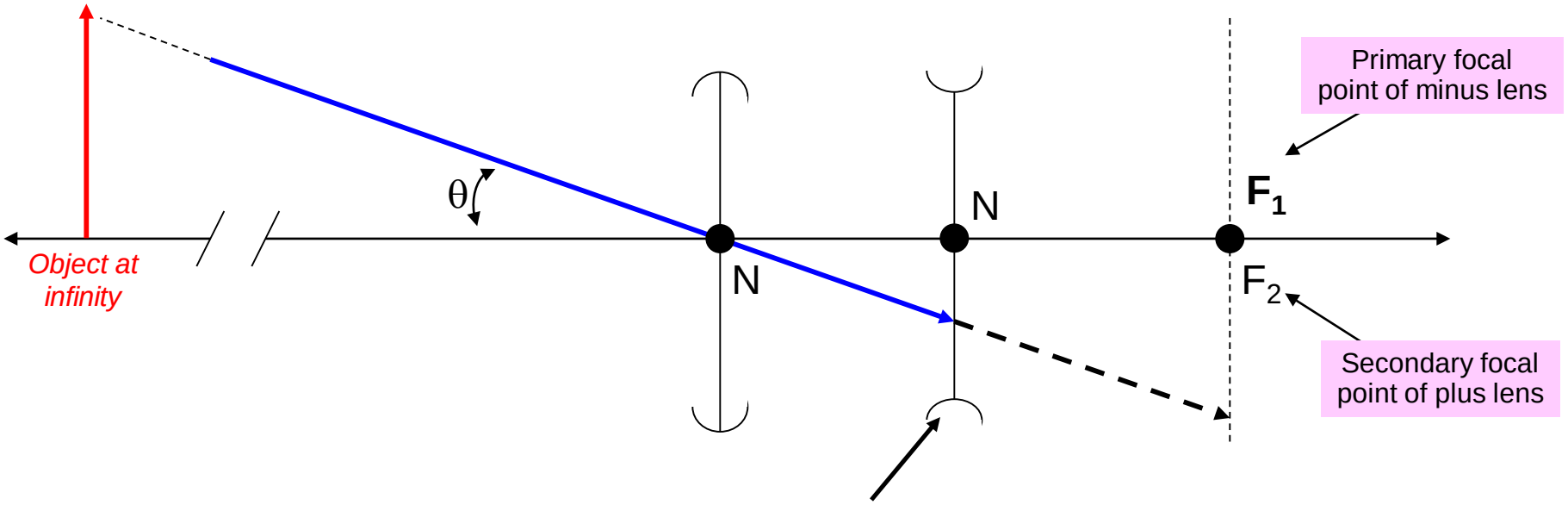
Telescopes



What would happen if we included a **minus lens** located such that its primary focal point/plane coincided with the secondary focal point/plane of the plus lens?

Telescopes





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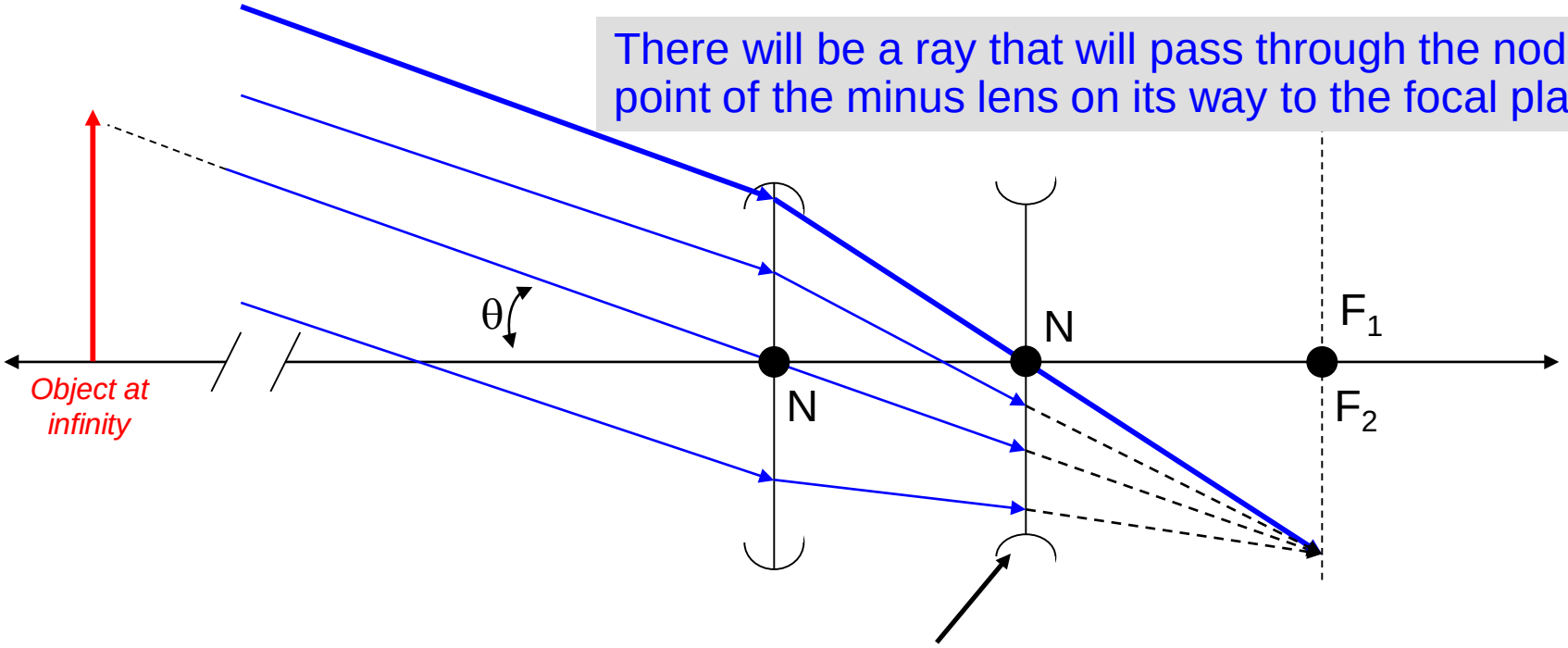
Telescopes

There will be a ray that will pass through the nodal point of the minus lens on its way to the focal plane…



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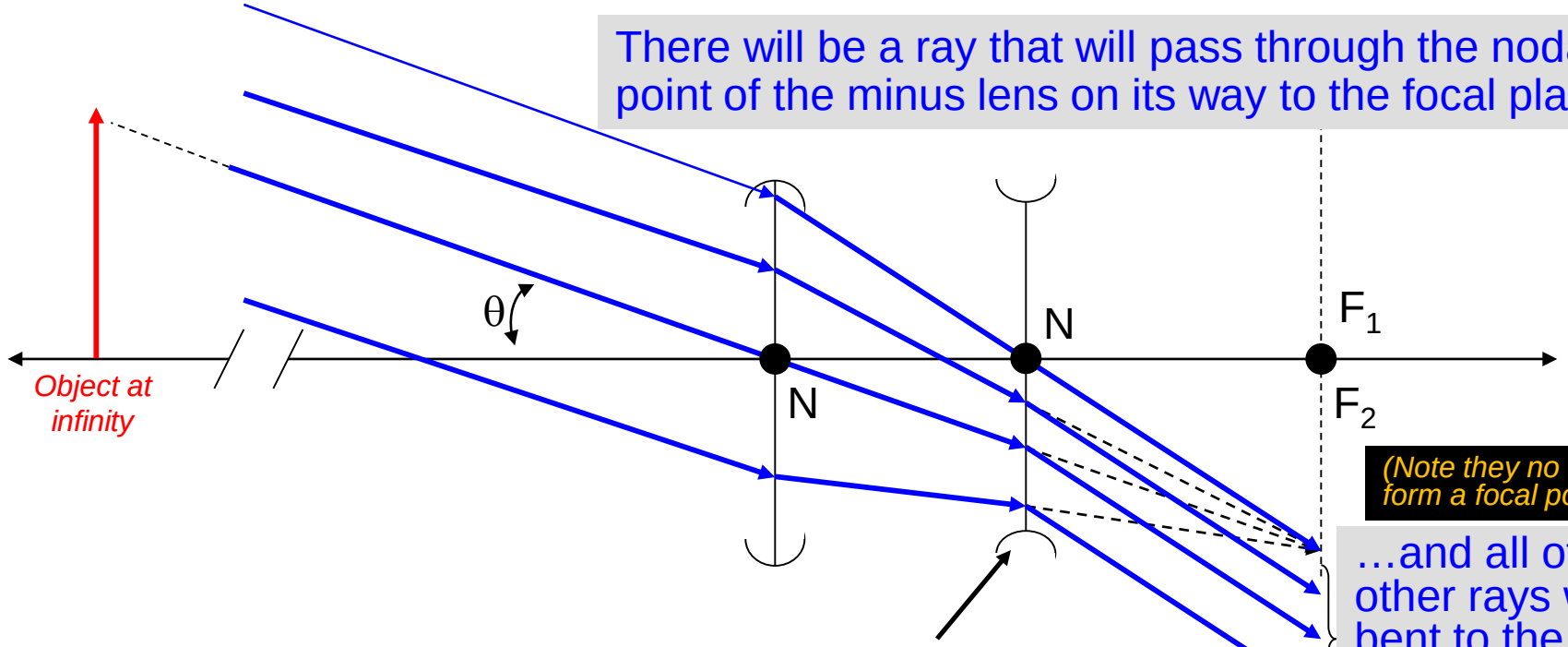

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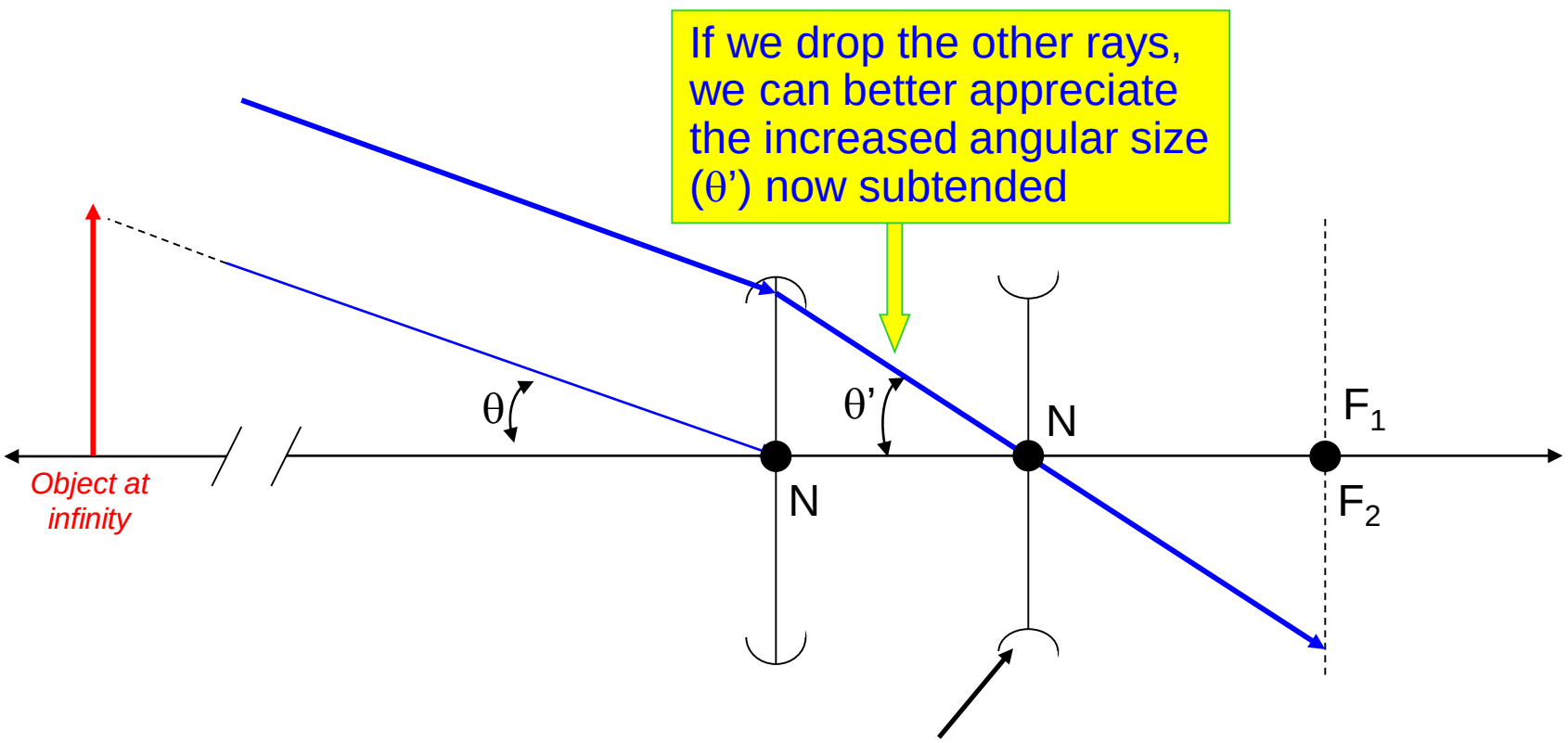

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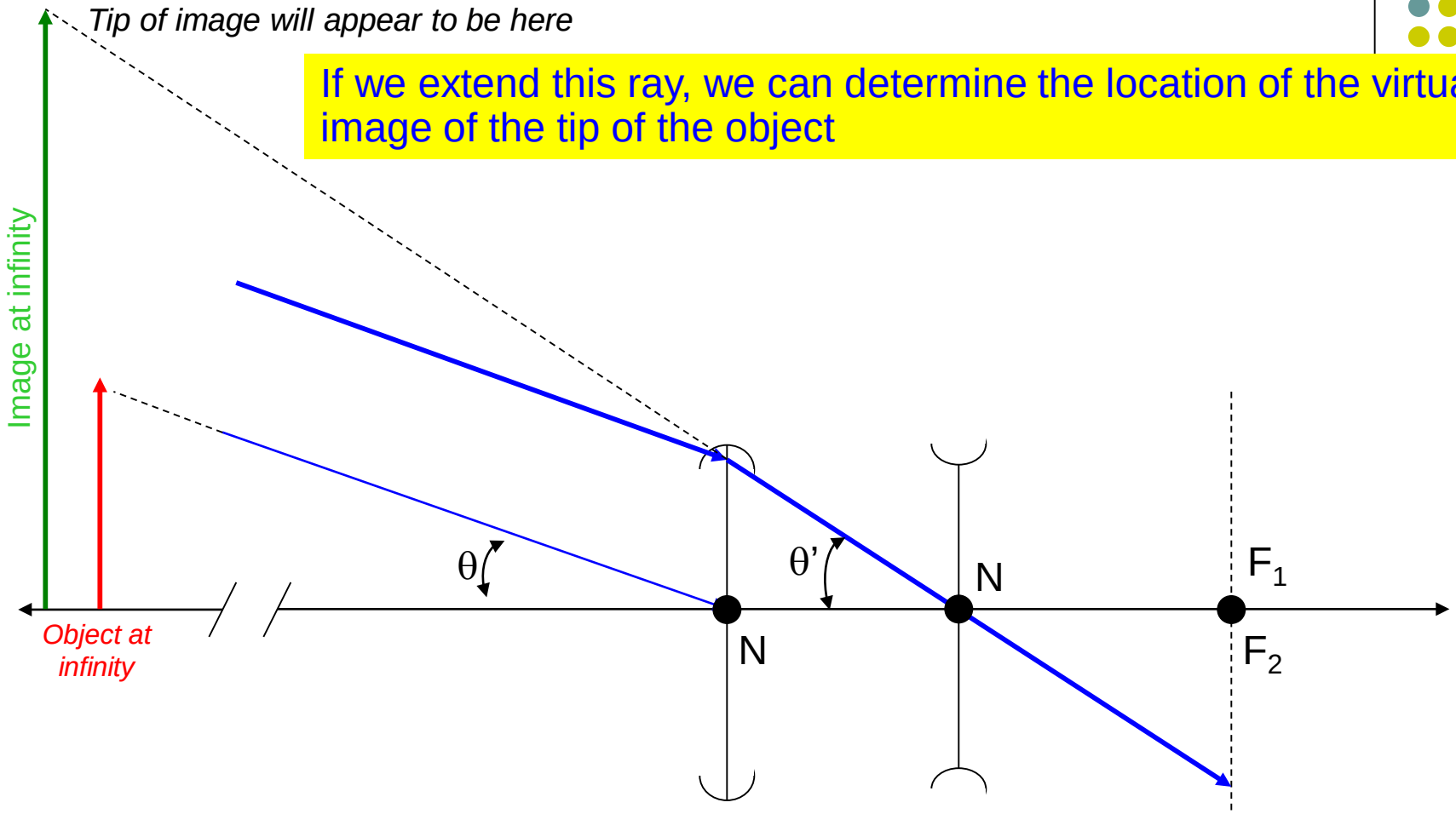
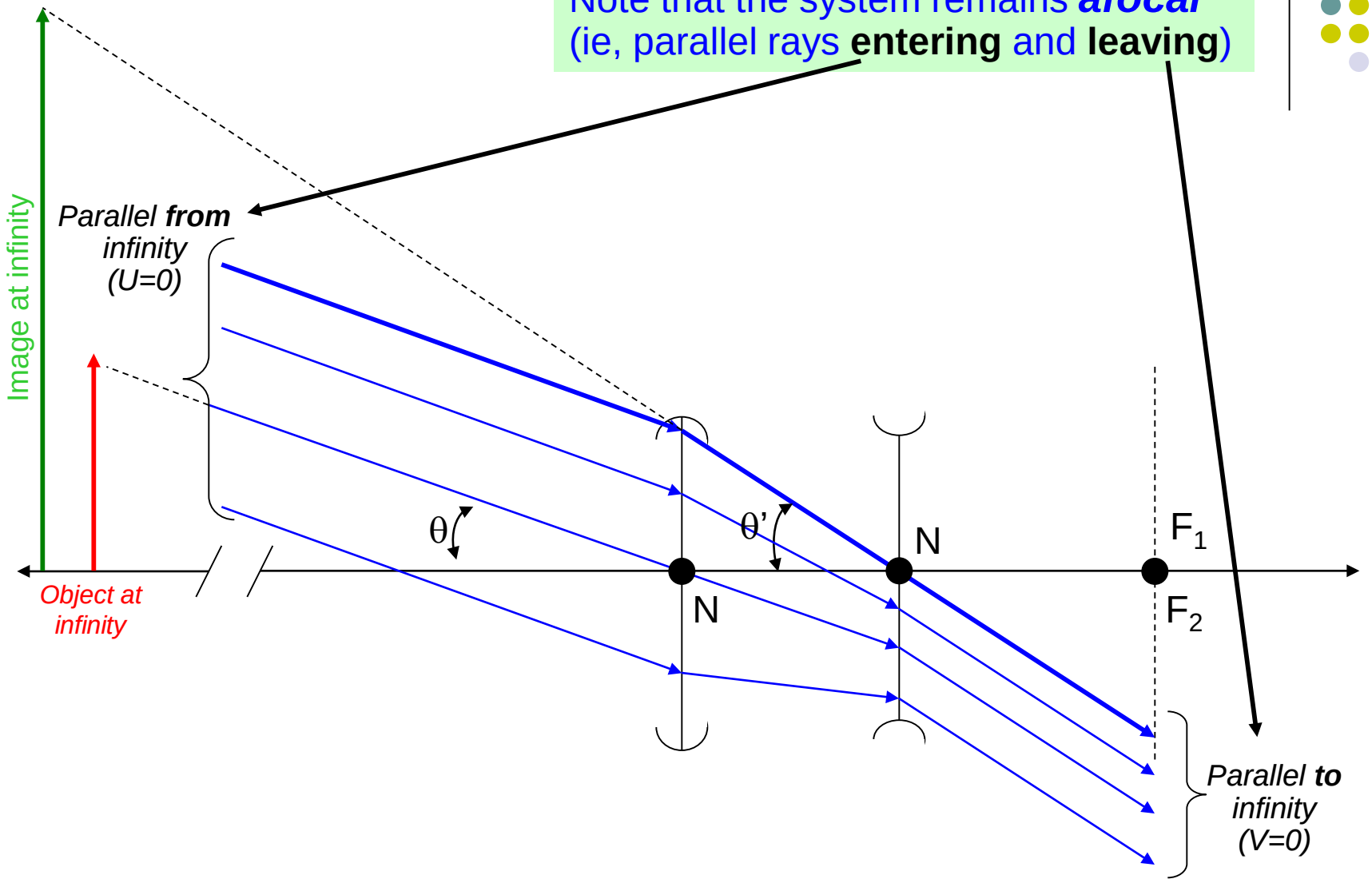

Tip of image will appear to be here
If we extend this ray, we can determine the location of the virtual image of the tip of the object
Image at infinity
θ
θ'
N
F1
N
F2
Object at infinity

Telescopes

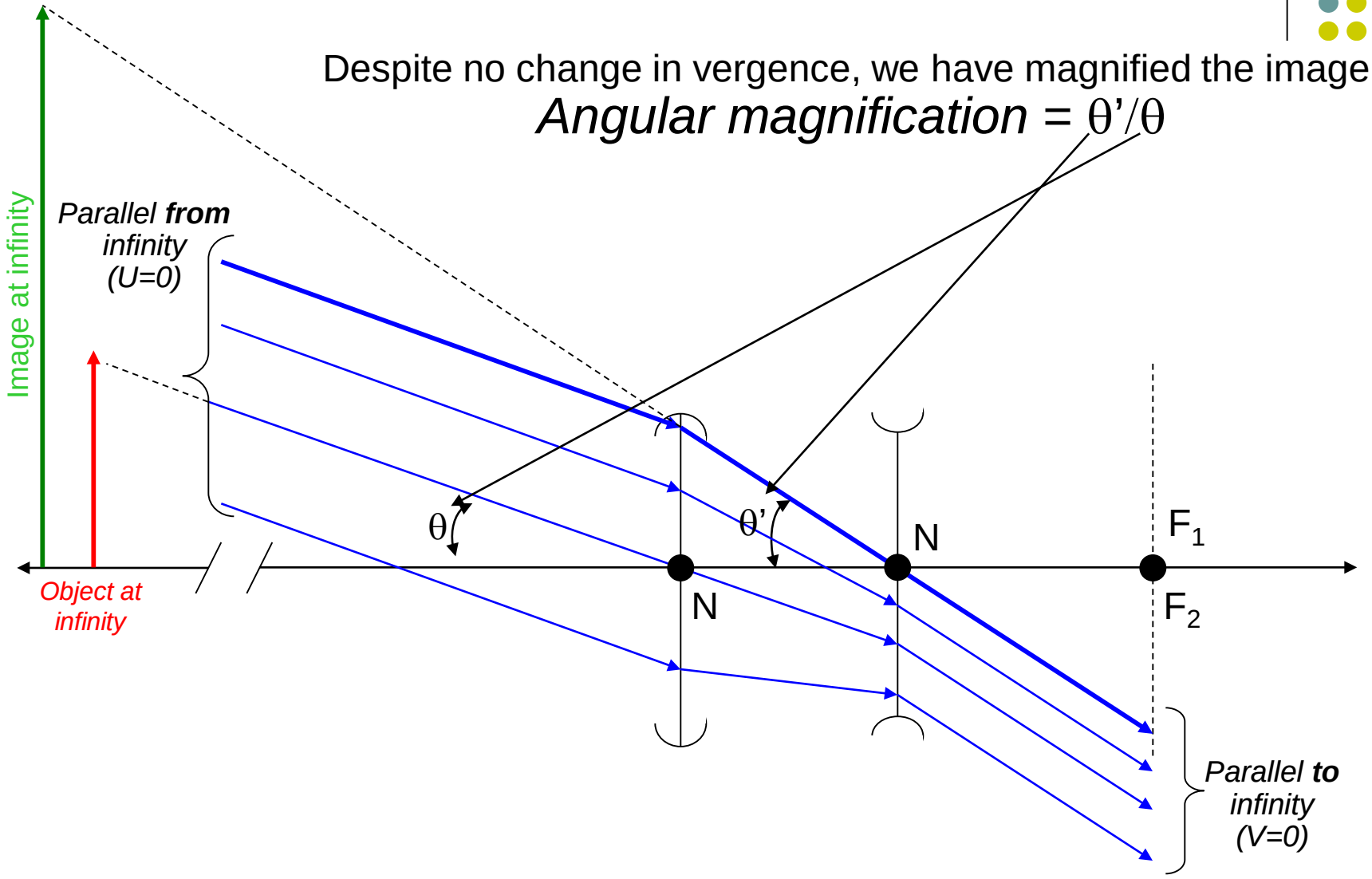
Note that the system remains ***afocal***
(ie, parallel rays **entering** and **leaving**)



Telescopes

Despite no change in vergence, we have magnified the image:

Angular magnification = θ'/θ



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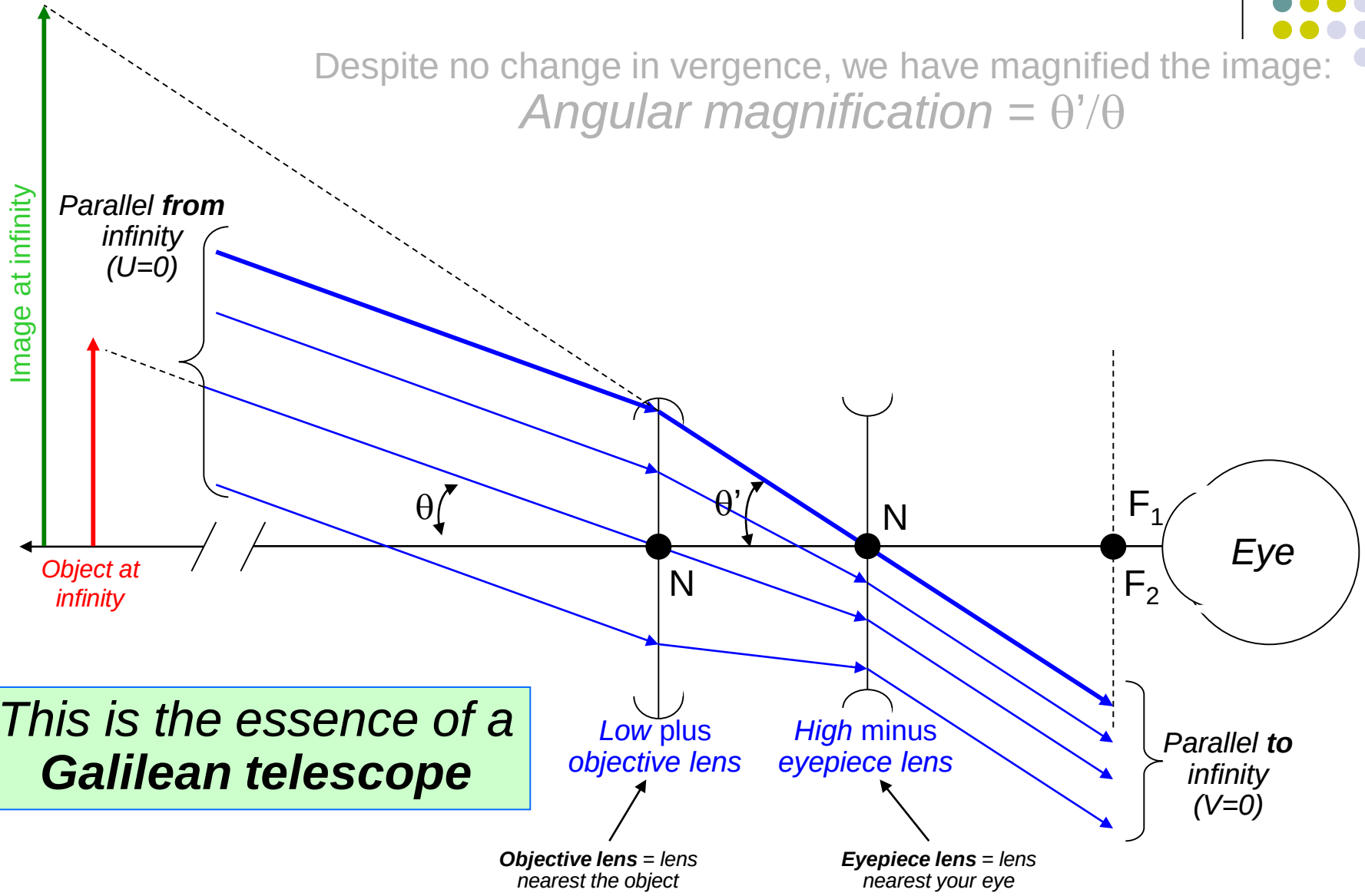
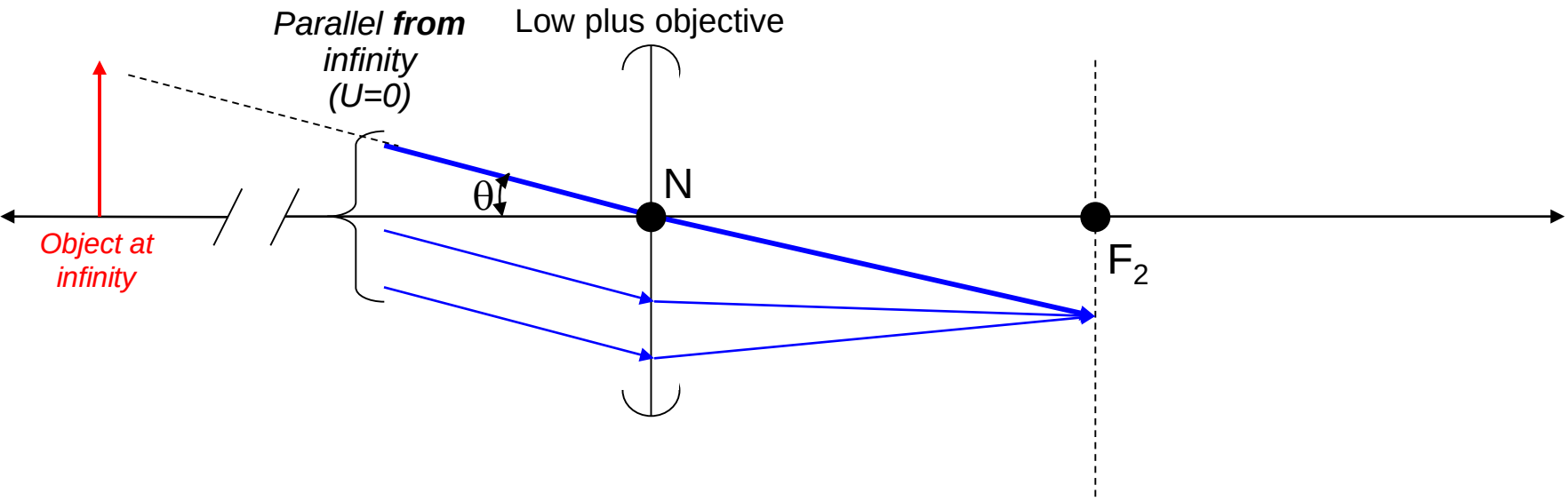


This is the essence of a ***Galilean telescope***

Telescopes



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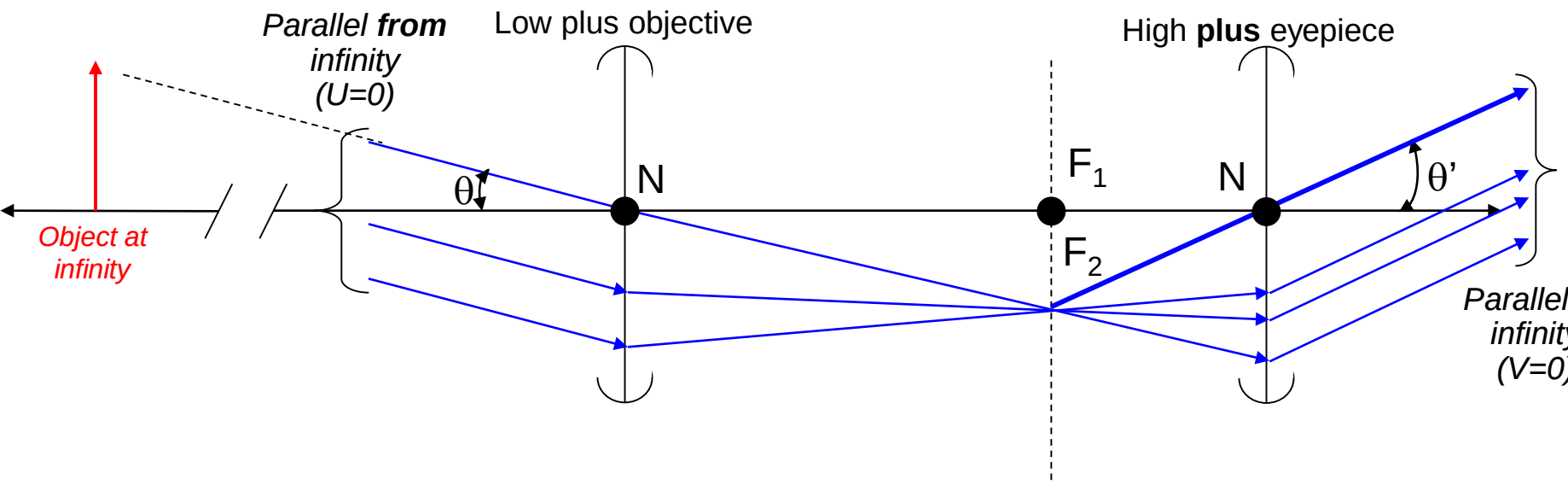
Telescopes



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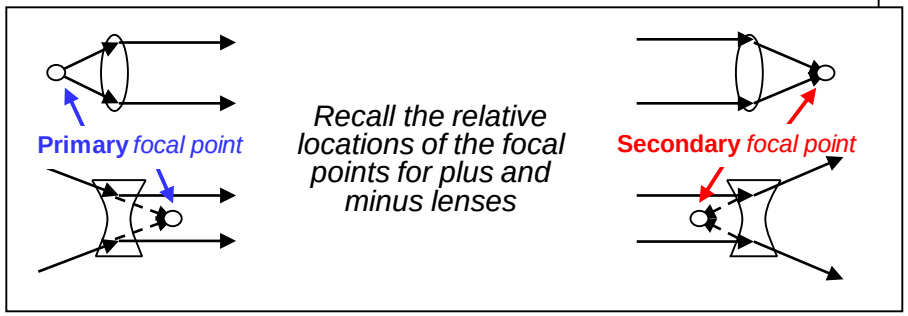
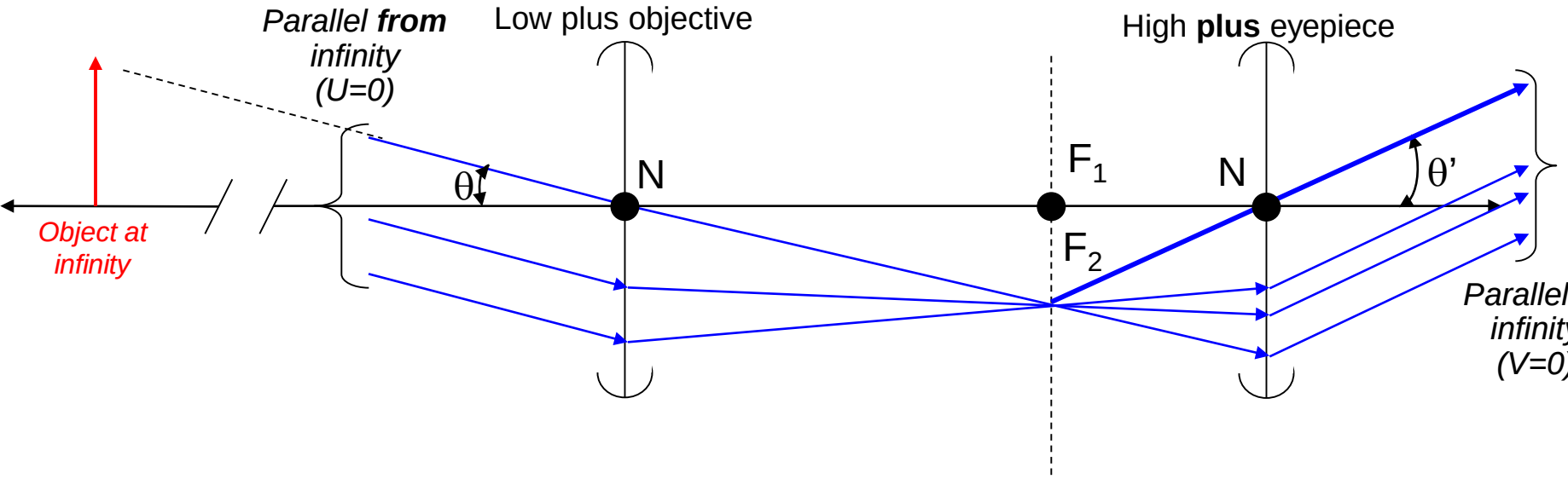
Telescopes





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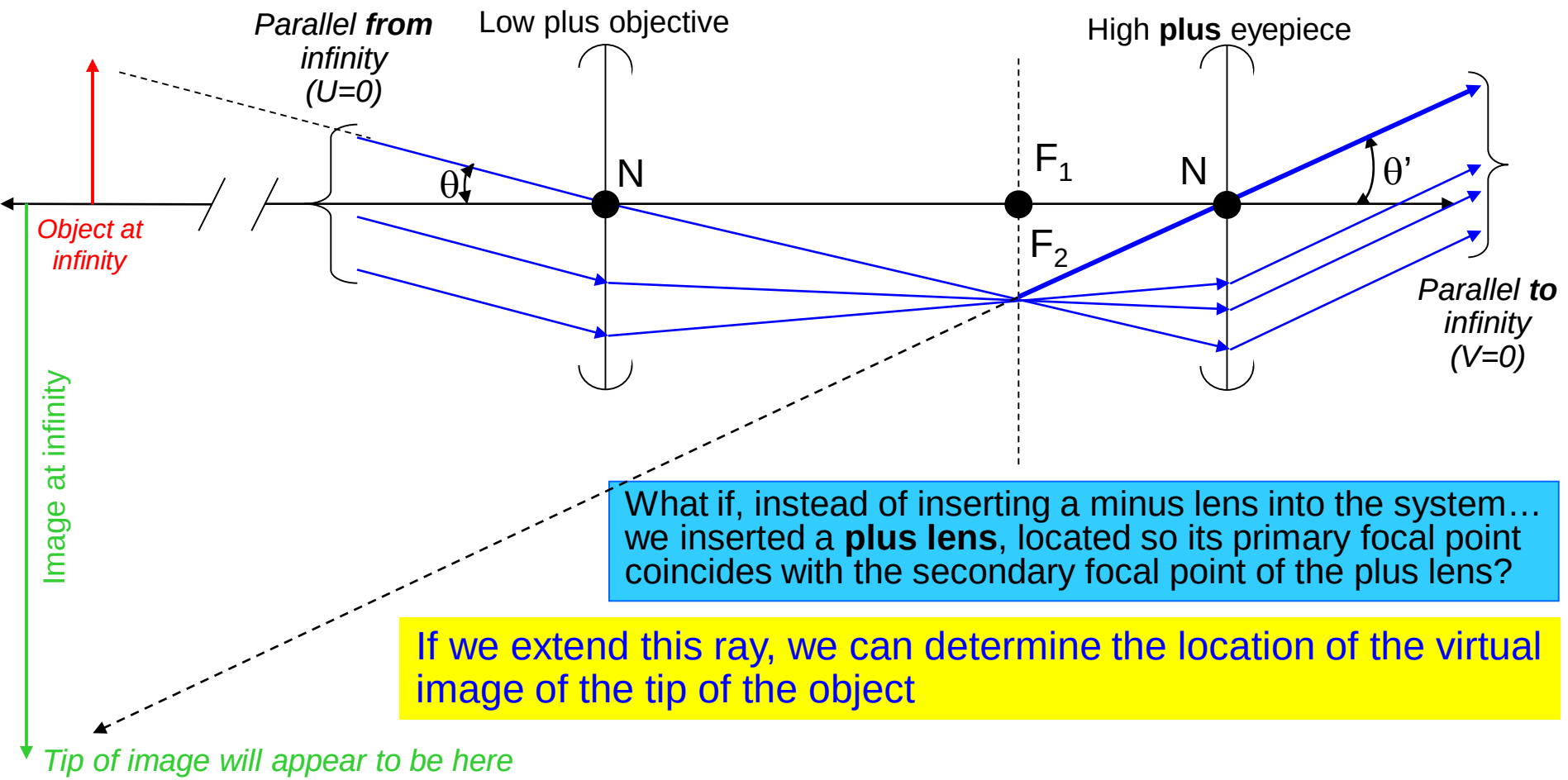

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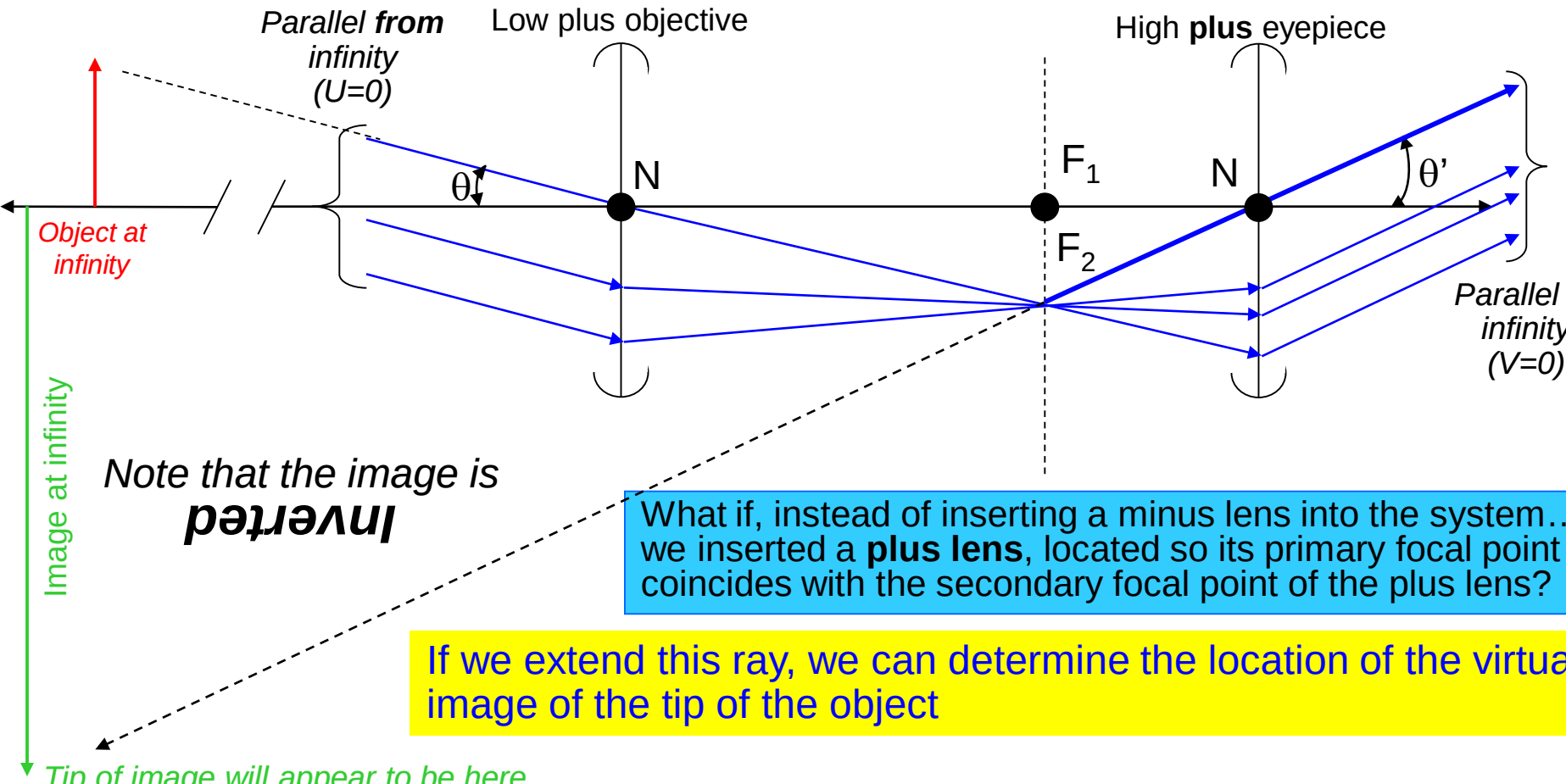

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Telescopes

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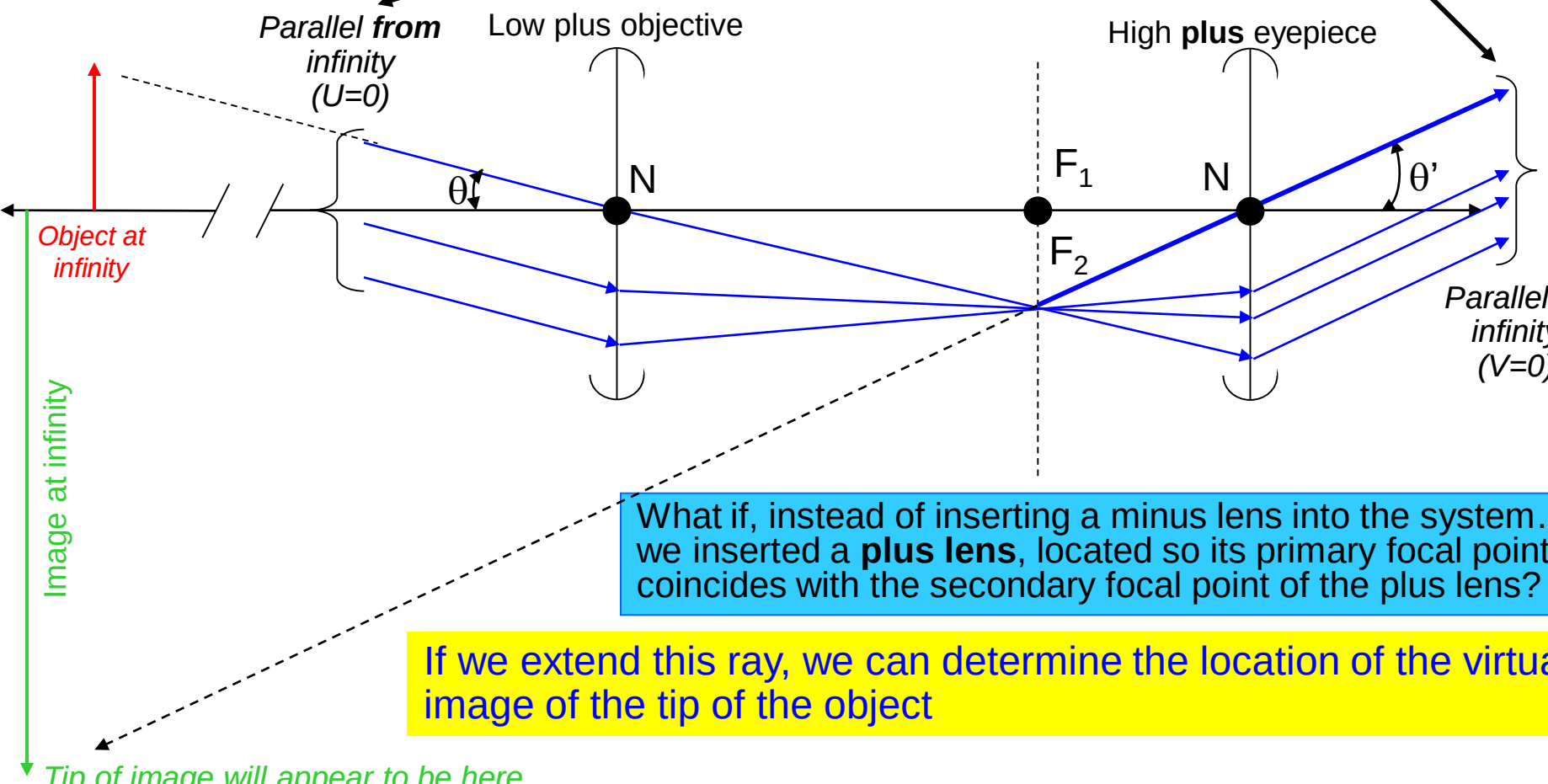

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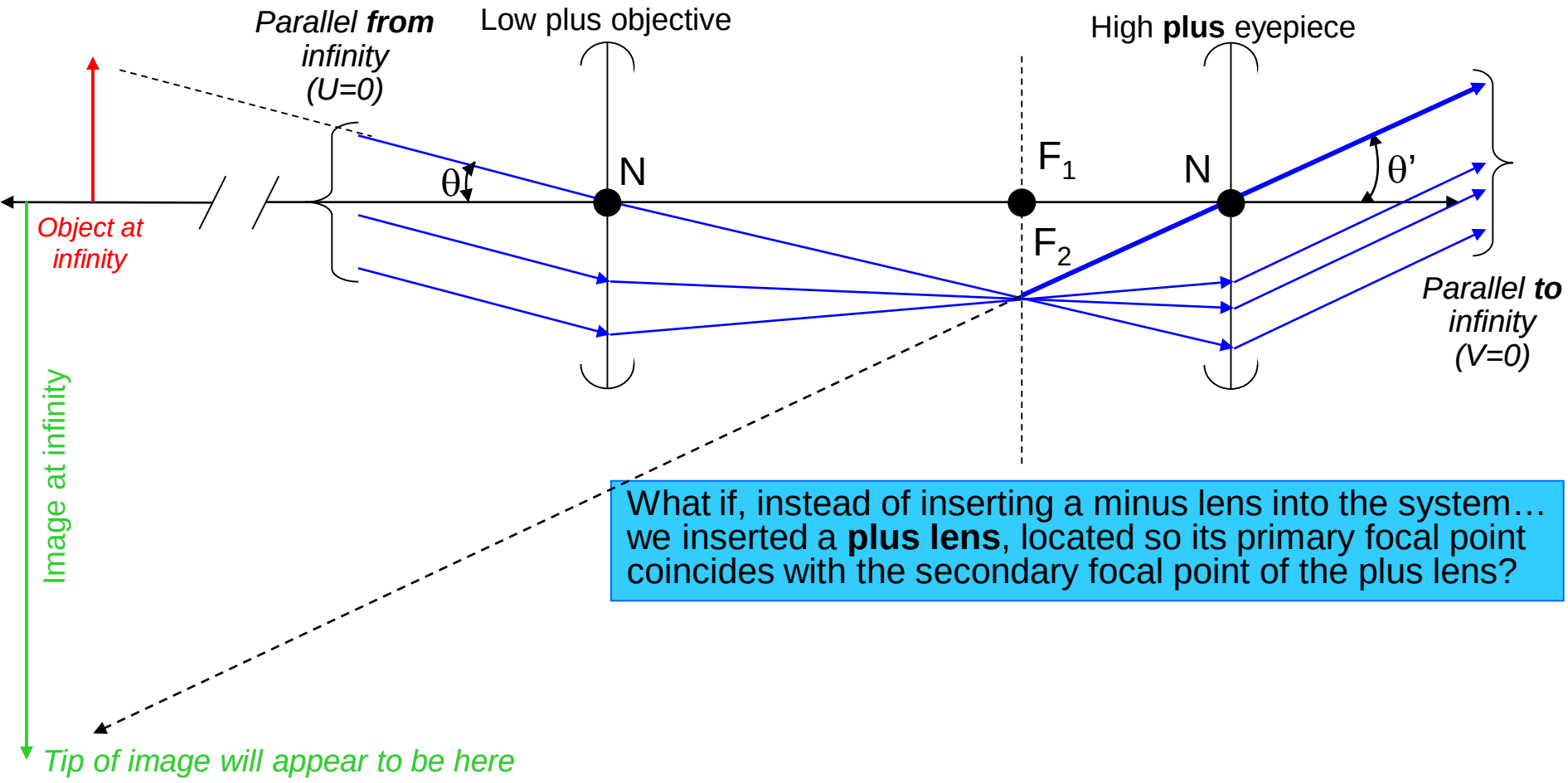

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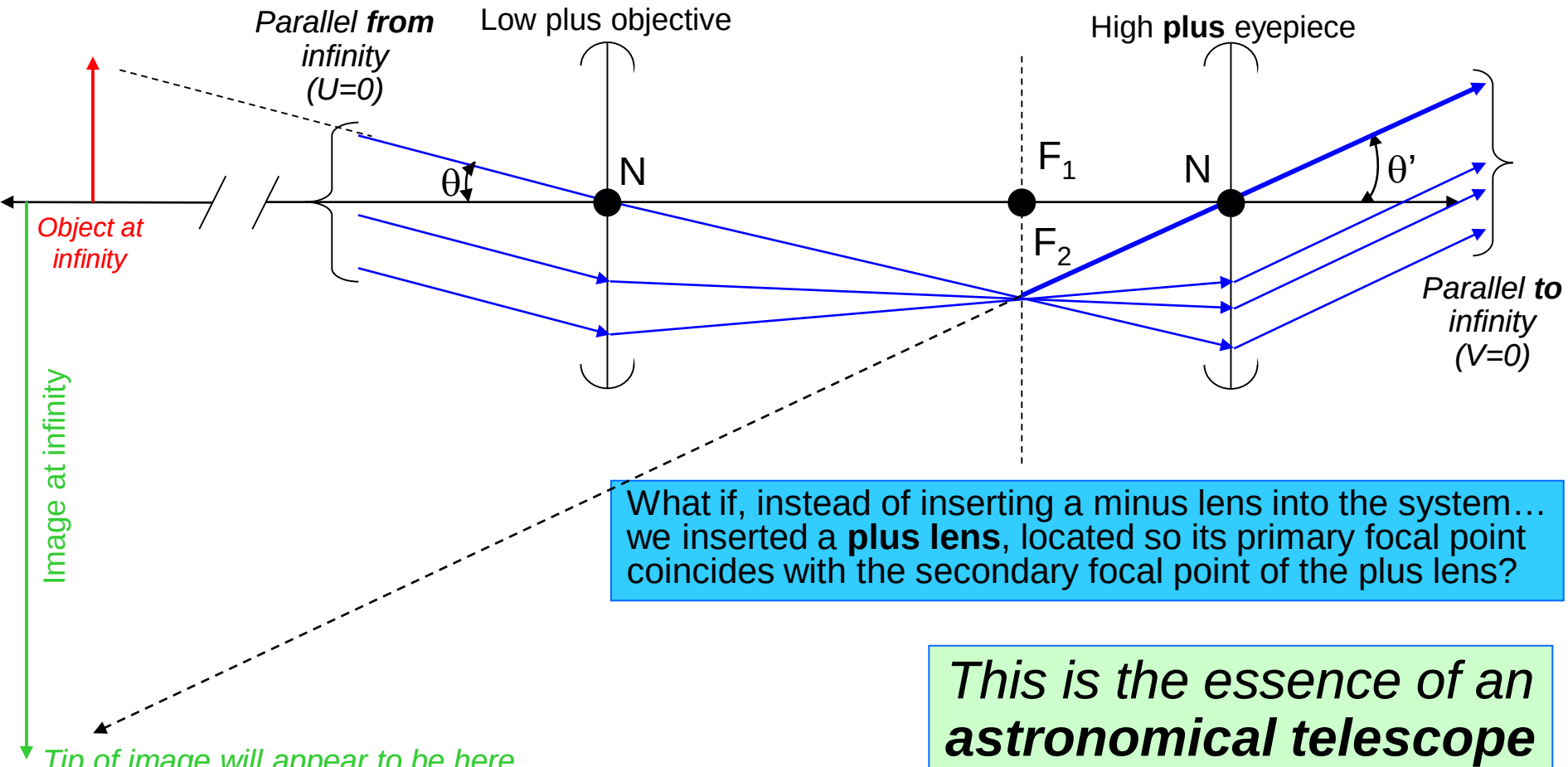


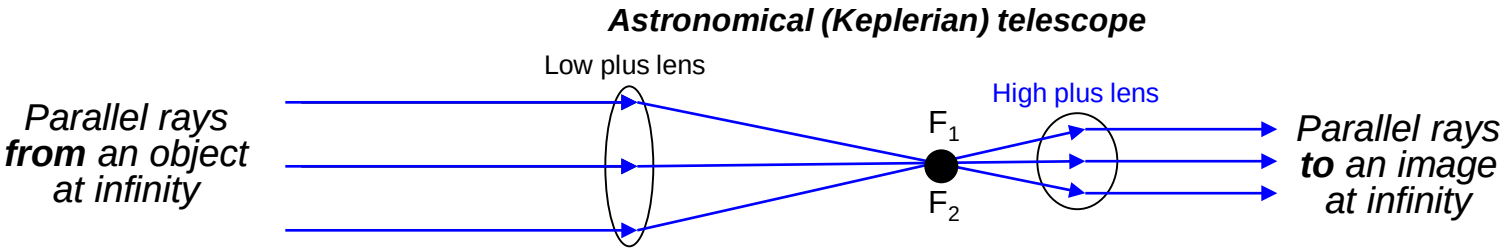
What if, instead of inserting a minus lens into the system… we inserted a **plus lens**, located so its primary focal point coincides with the secondary focal point of the plus lens?

This is the essence of an ***astronomical telescope***

Telescopes

To reiterate: Telescopes come in two basic flavors—those with a high **plus** eyepiece lens, and those with a high **minus** eyepiece lens.

Telescopes



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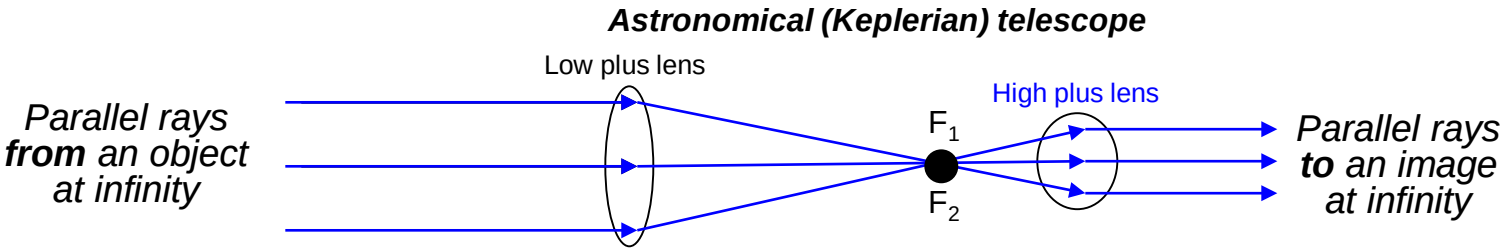
Telescopes



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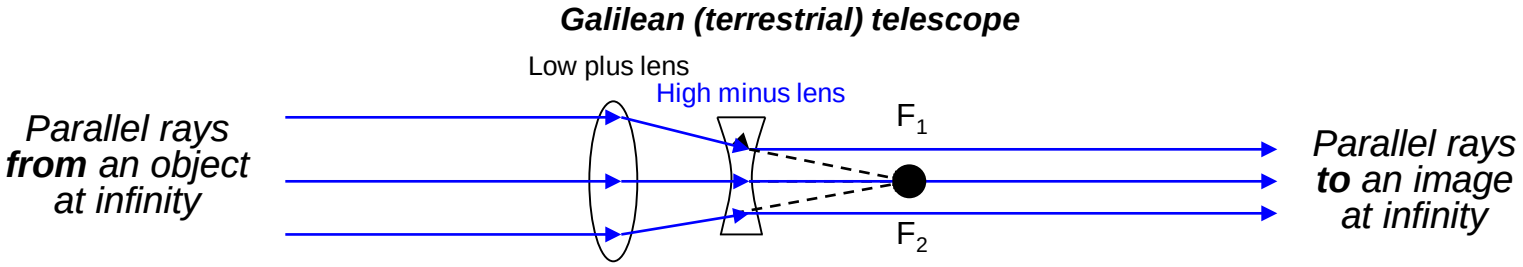
high-minus-eyepiece telescopes are called *Galilean* (or *terrestrial*) telescopes.



Telescopes

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Astronomical telescope
(image is ***inverted***)

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(image is ***inverted***)

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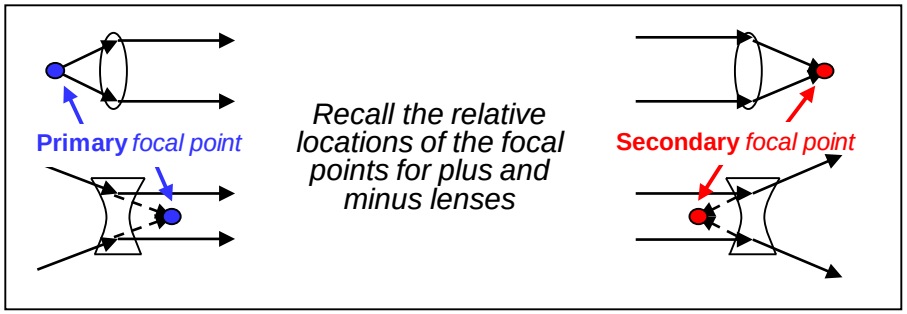
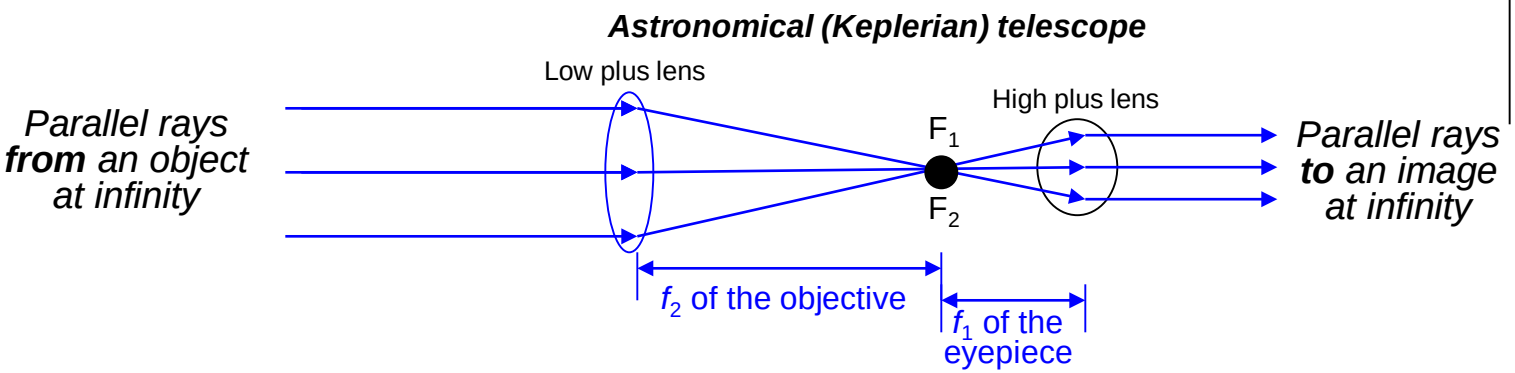
Galilean telescope
(image is ***upright***)

Telescopes

For a telescope to function, the primary focal point of the eyepiece must overlap the secondary focal point of the objective. This determines the separation between the two lenses.



Telescopes



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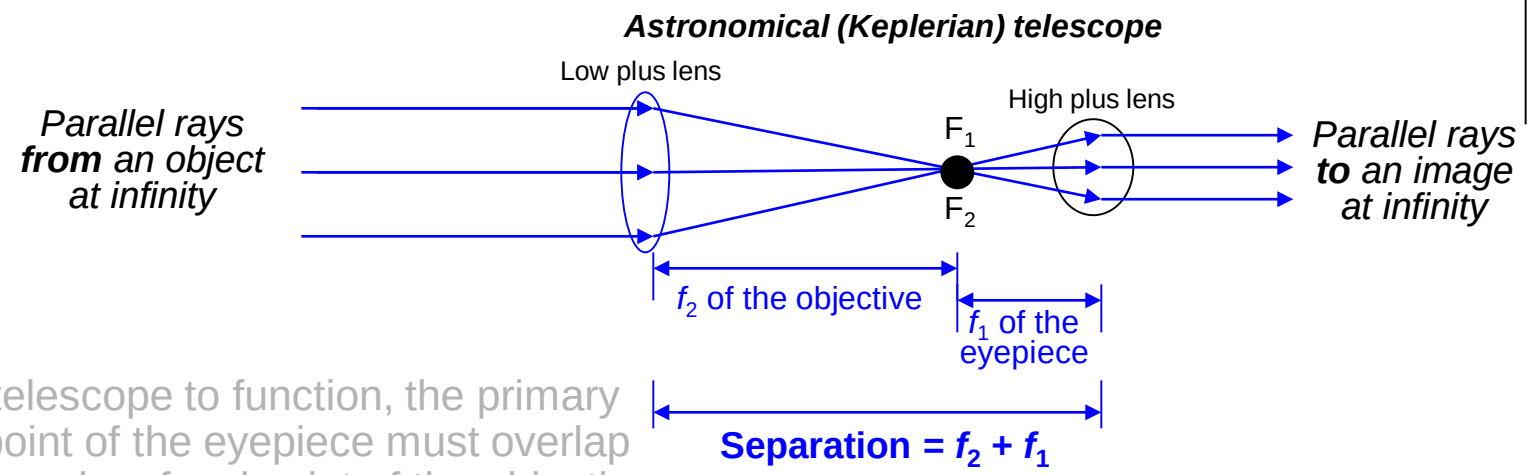
Telescopes



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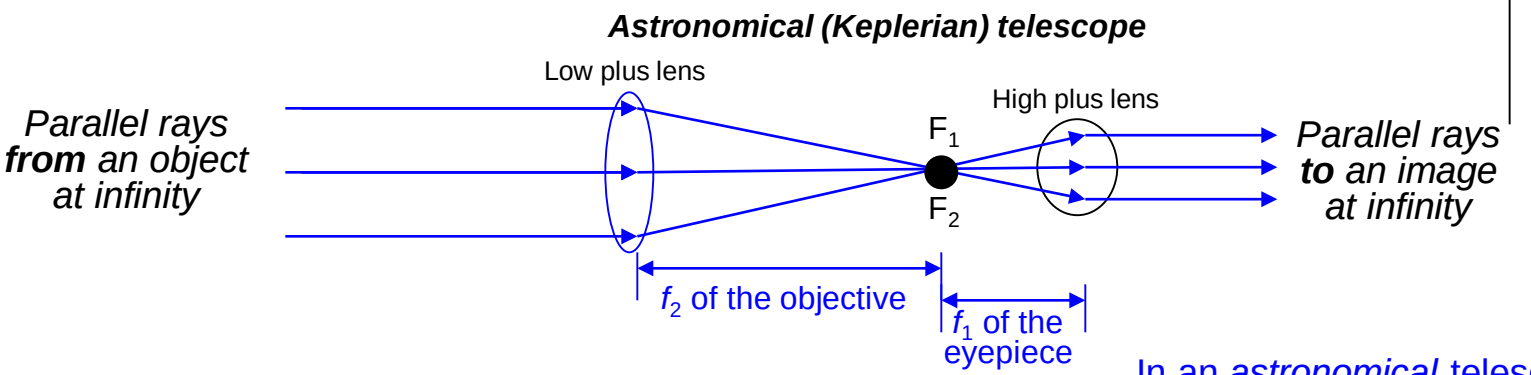
Telescopes



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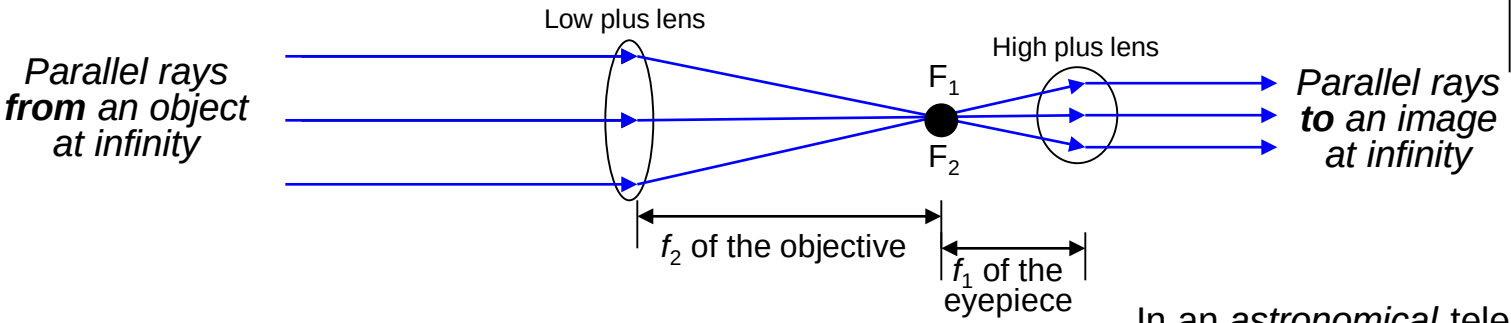
In an *astronomical* telescope, the separation is equal to the **sum** of the focal lengths.

Telescopes

Astronomical (Keplerian) telescope



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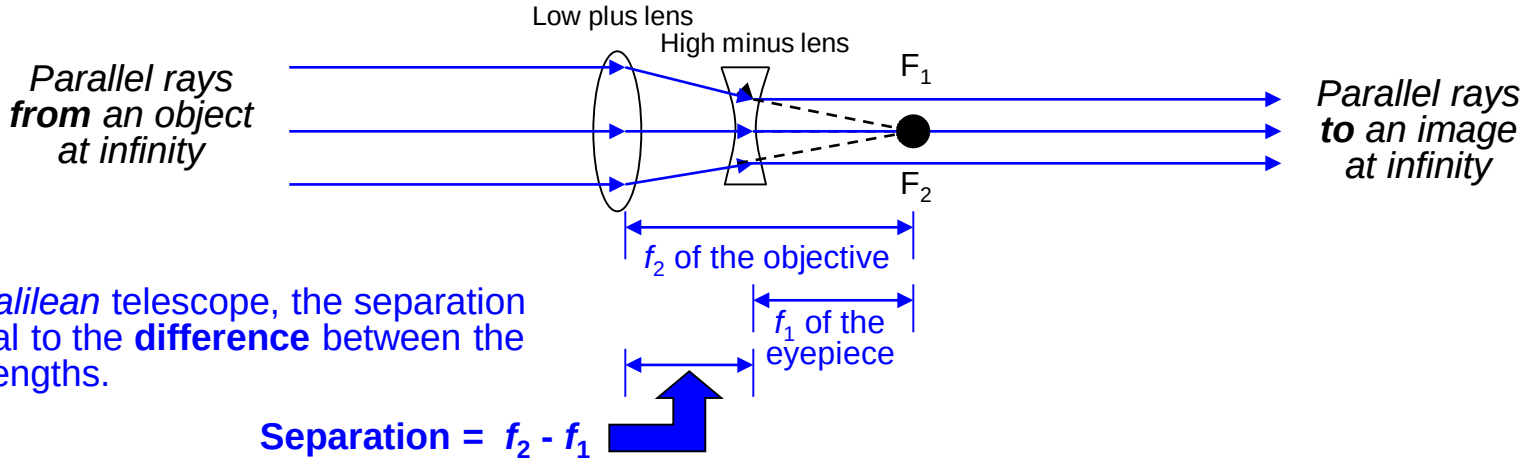
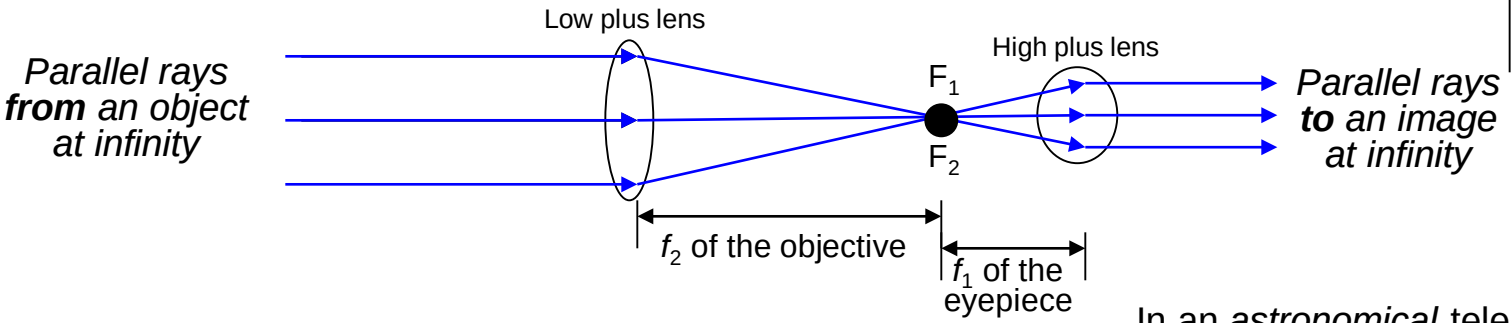
Galilean (terrestrial) telescope



In a *Galilean* telescope, the separation is equal to the **difference** between the focal lengths.

Telescopes

Astronomical (Keplerian) telescope



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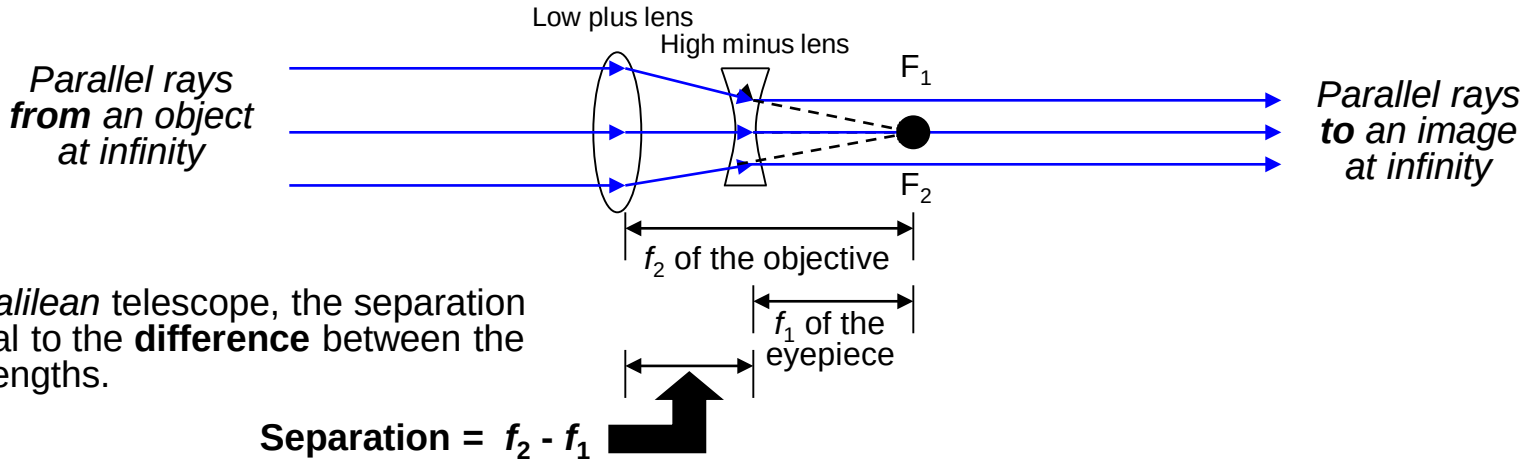
For this and other reasons, Galilean scopes tend to be **smaller** and **lighter** than astronomical scopes.

Galilean (terrestrial) telescope



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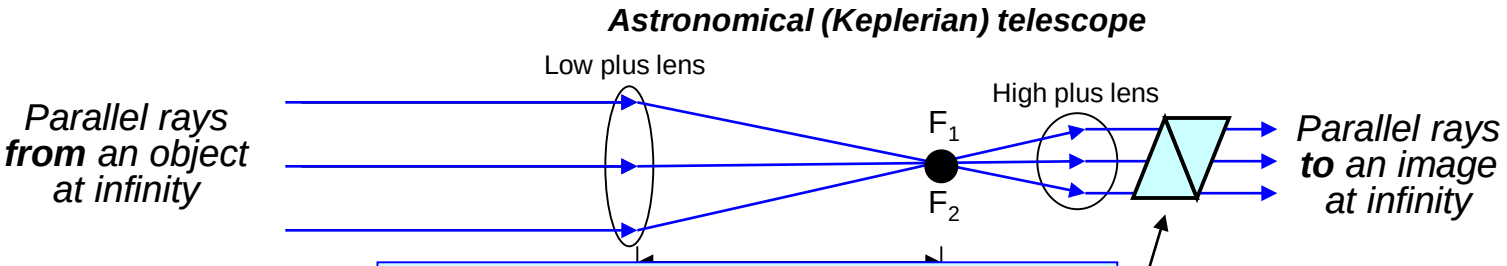
Telescopes



The main other reason being that astronomical telescopes require ***prisms*** to flip the inverted image into the upright position, which add considerably to their size and weight!

For a telescope to function, [illegible] focal point of the eyepiece [illegible] the secondary focal point of [illegible] **This determines the separation between the two lenses.**

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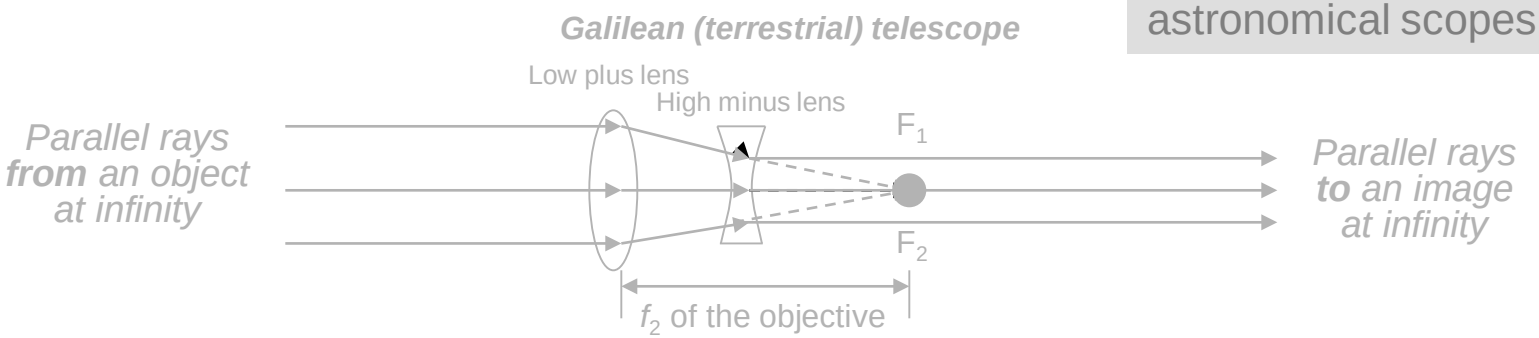
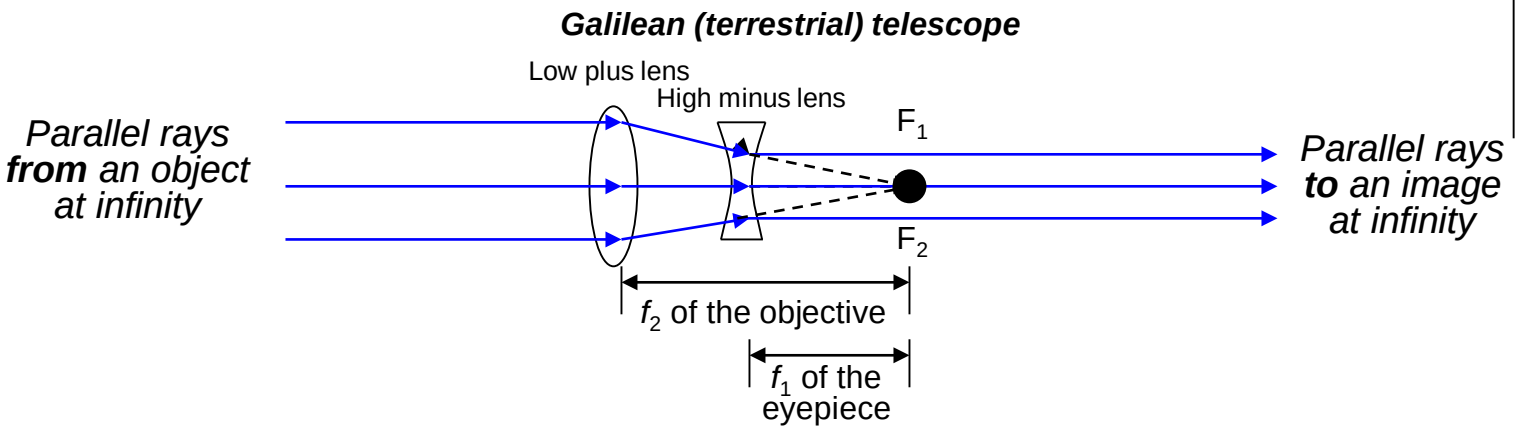


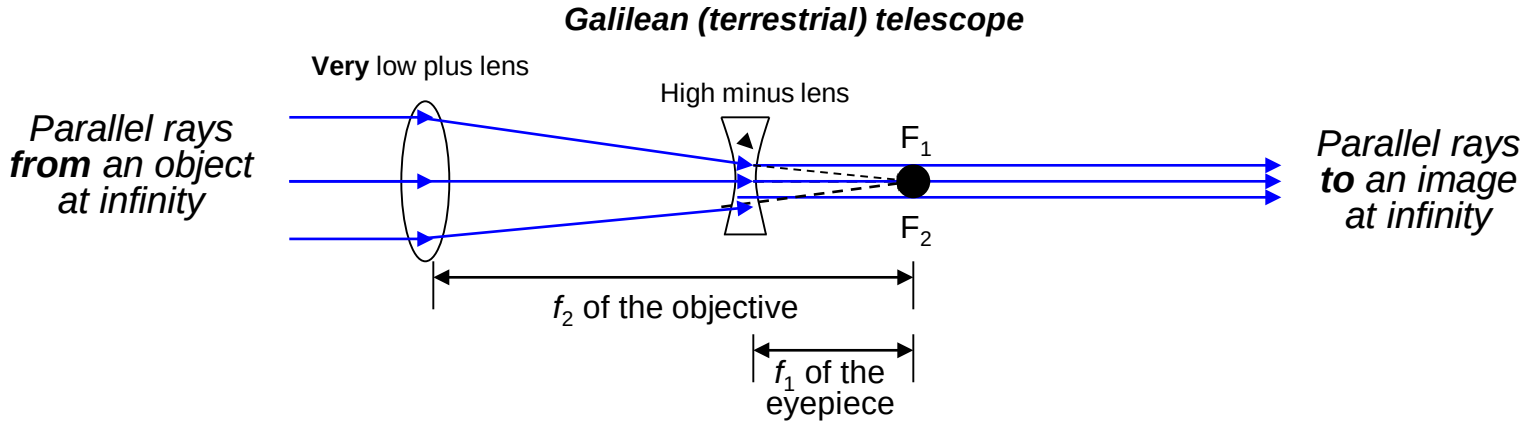
In a *Galilean* telescope, the separation is equal to the **difference** between the focal lengths.

Separation = $f_2 - f_1$

Telescopes



Let's compare two Galilean telescopes. Note the difference in focal lengths.



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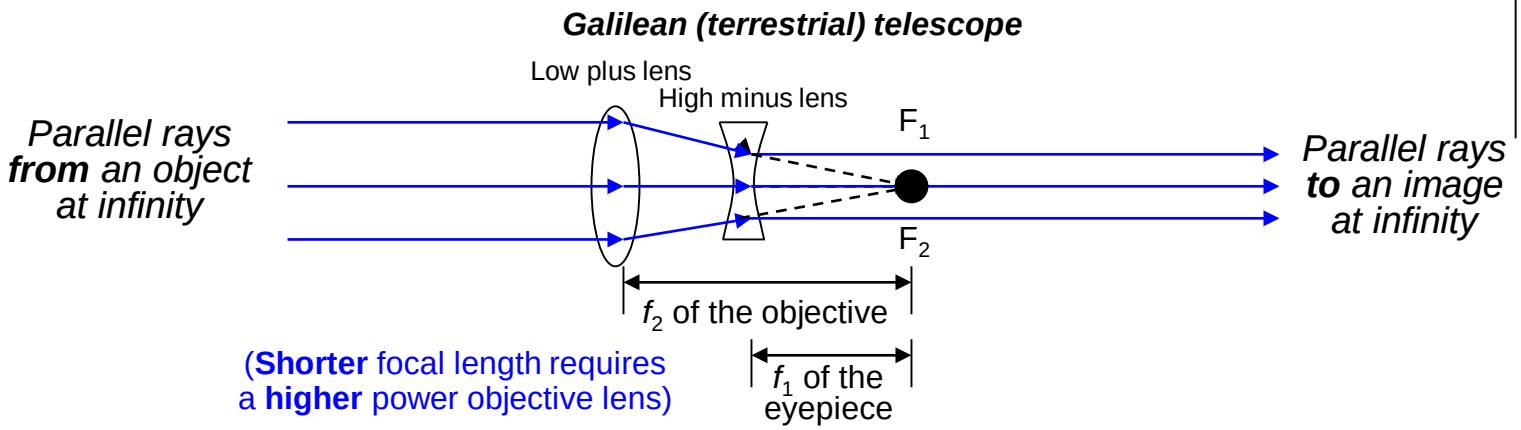
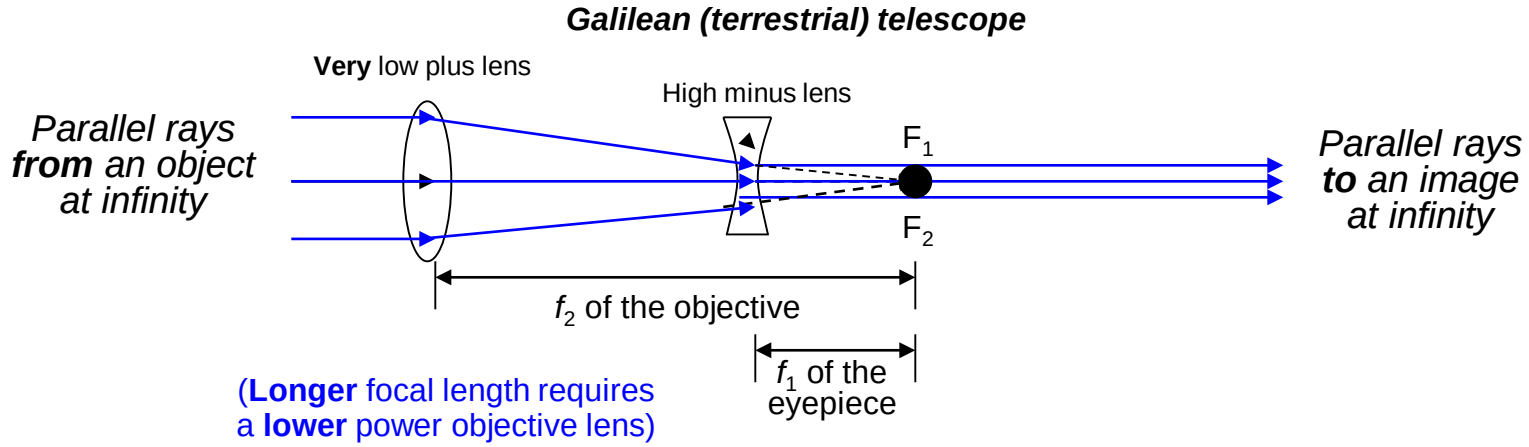


The greater lens separation below necessitates a **decrease** in power for the objective lens (and vice versa). *Will this increase, decrease or leave unaffected the overall power of the telescope?*



Telescopes

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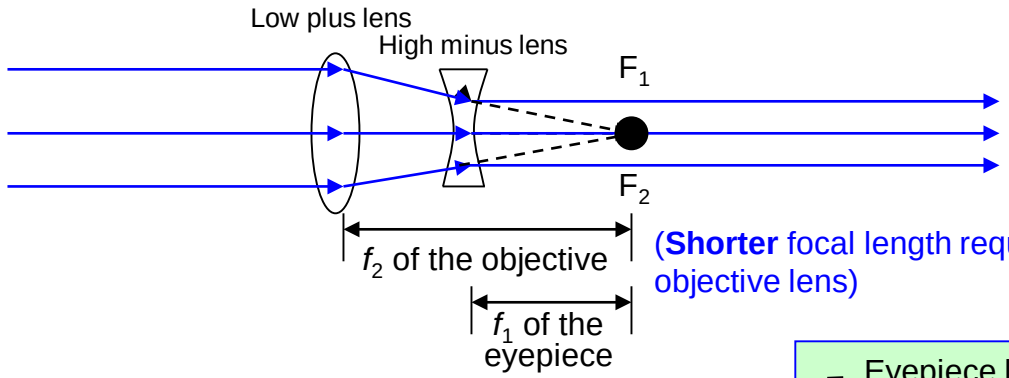


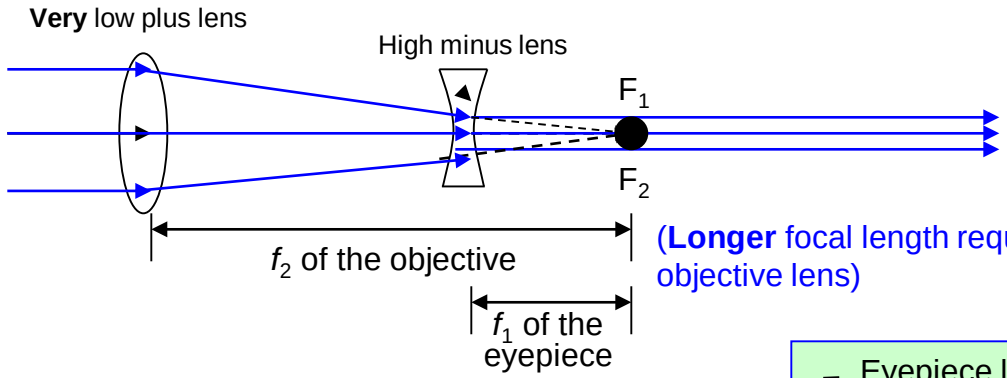
(**Shorter** focal length requires a **higher** power objective lens)

Increase overall power.

$$-\frac{\text{Eyepiece lens}}{\text{Objective lens}} = \frac{\text{Eyepiece lens}}{\textit{Higher number}}$$

= **Lower power**

Galilean (terrestrial) telescope



(**Longer** focal length requires a **lower** power objective lens)

$$-\frac{\text{Eyepiece lens}}{\text{Objective lens}} = \frac{\text{Eyepiece lens}}{\textit{Lower number}}$$

= **Higher power**