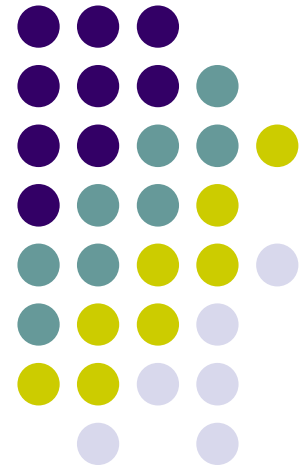


Telescopes

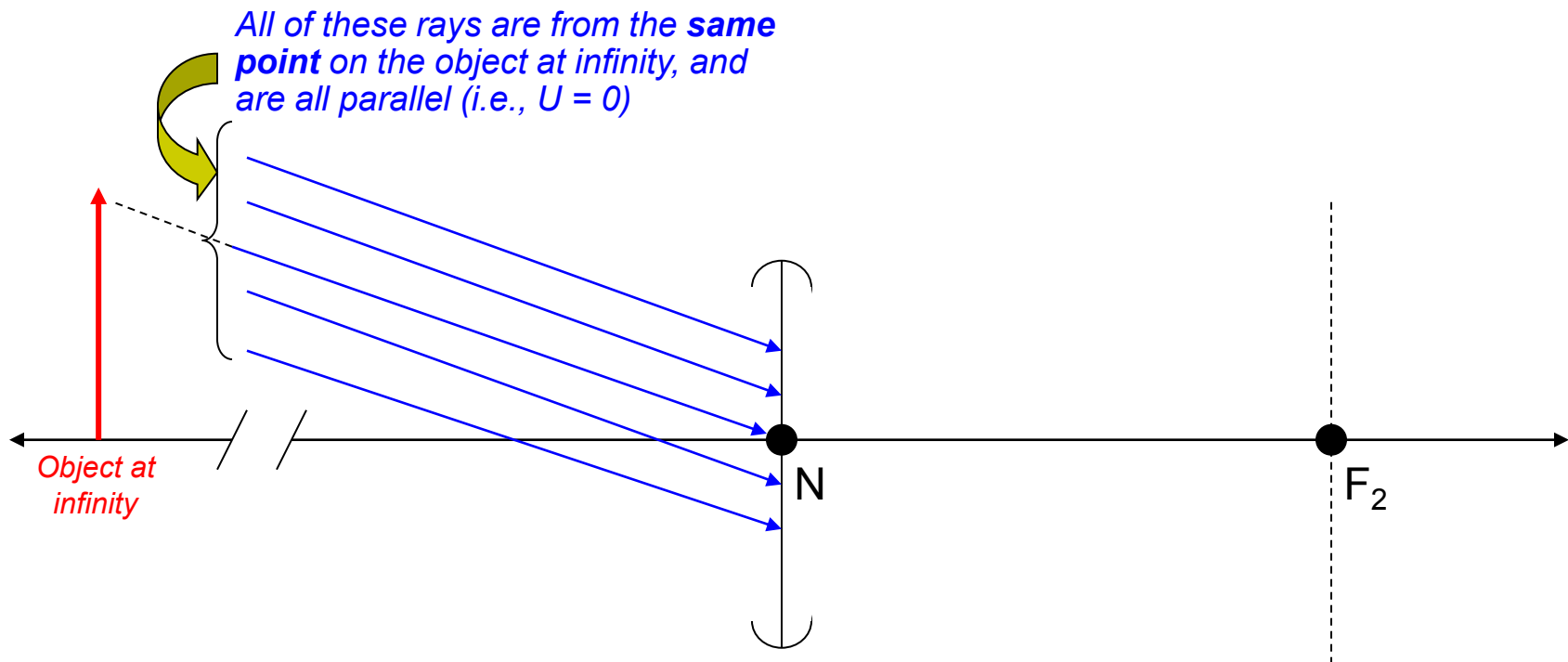
Basic Optics, Chapter 23



Telescopes



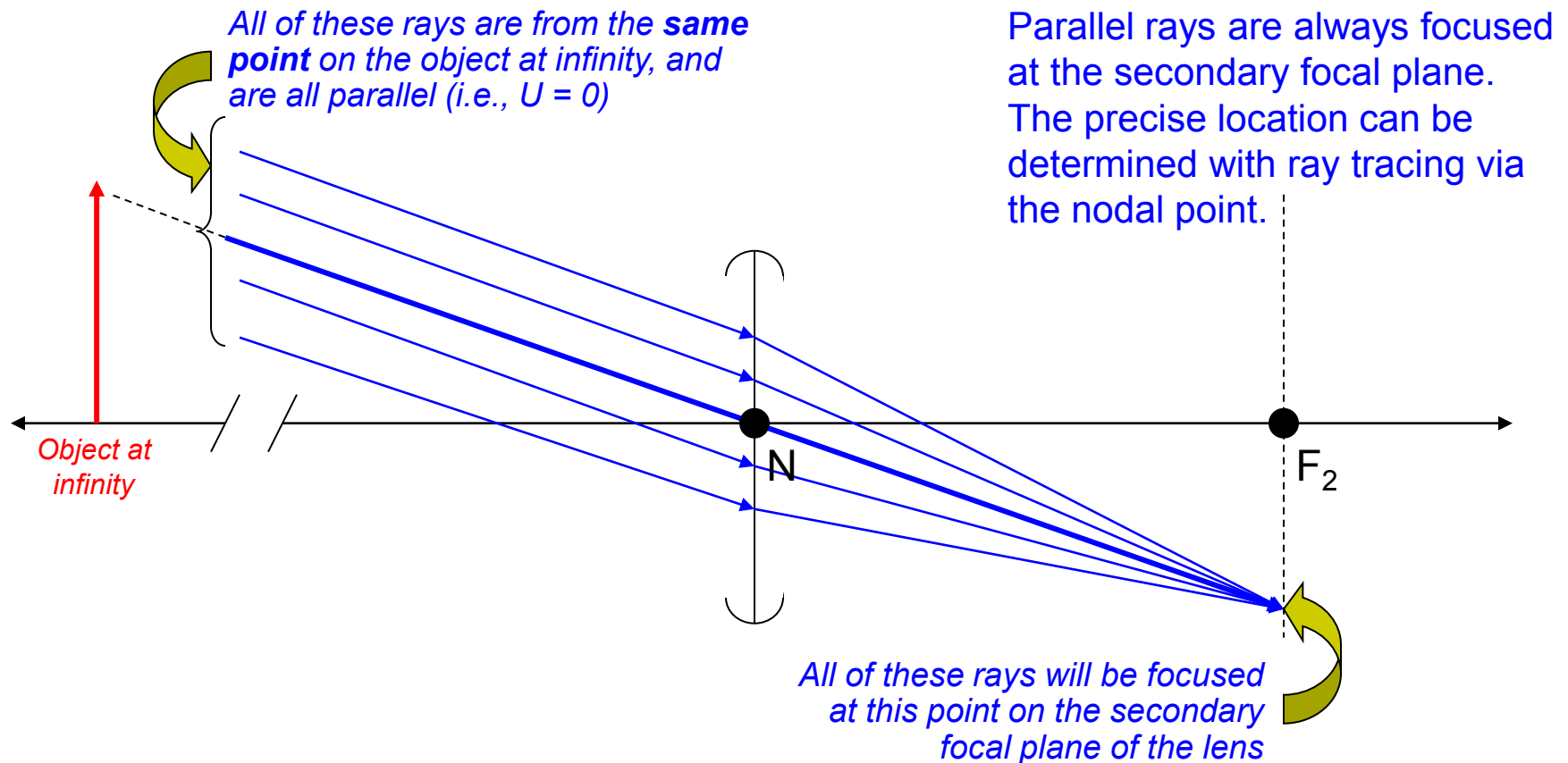
Consider an optical system consisting of a single plus lens and an object at infinity:
Where will the rays from the tip of the object be focused?



Telescopes



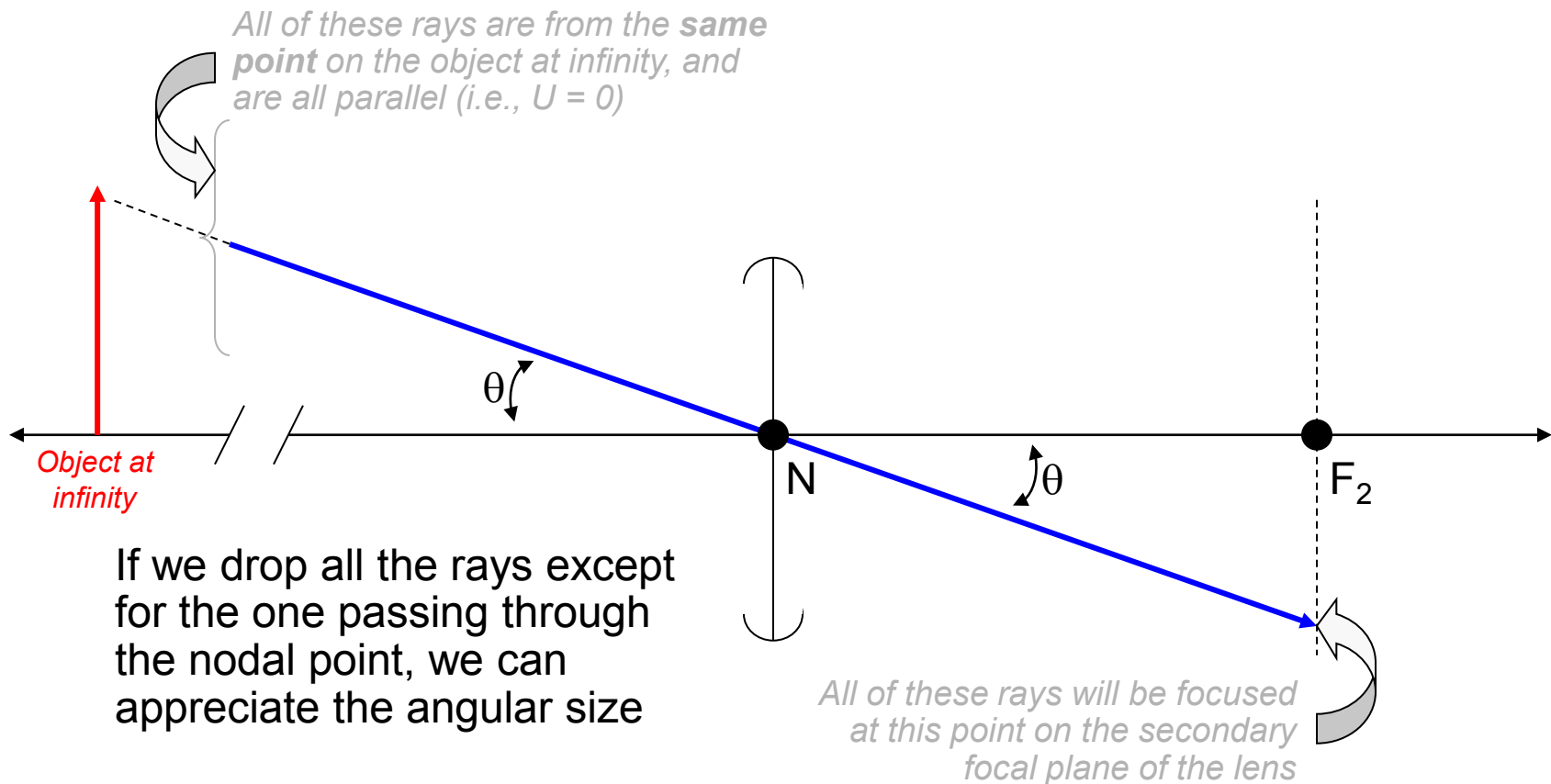
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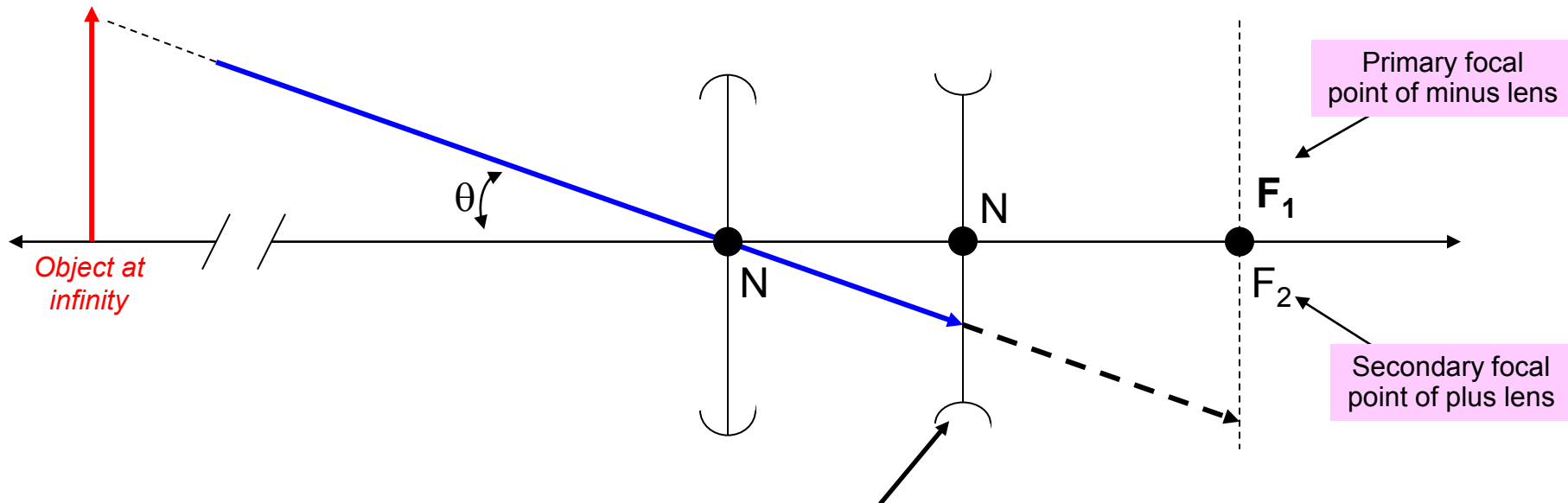
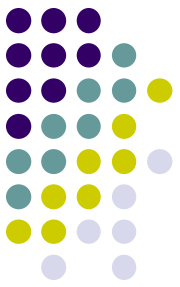
Telescopes



Consider an optical system consisting of a single plus lens and an object at infinity:
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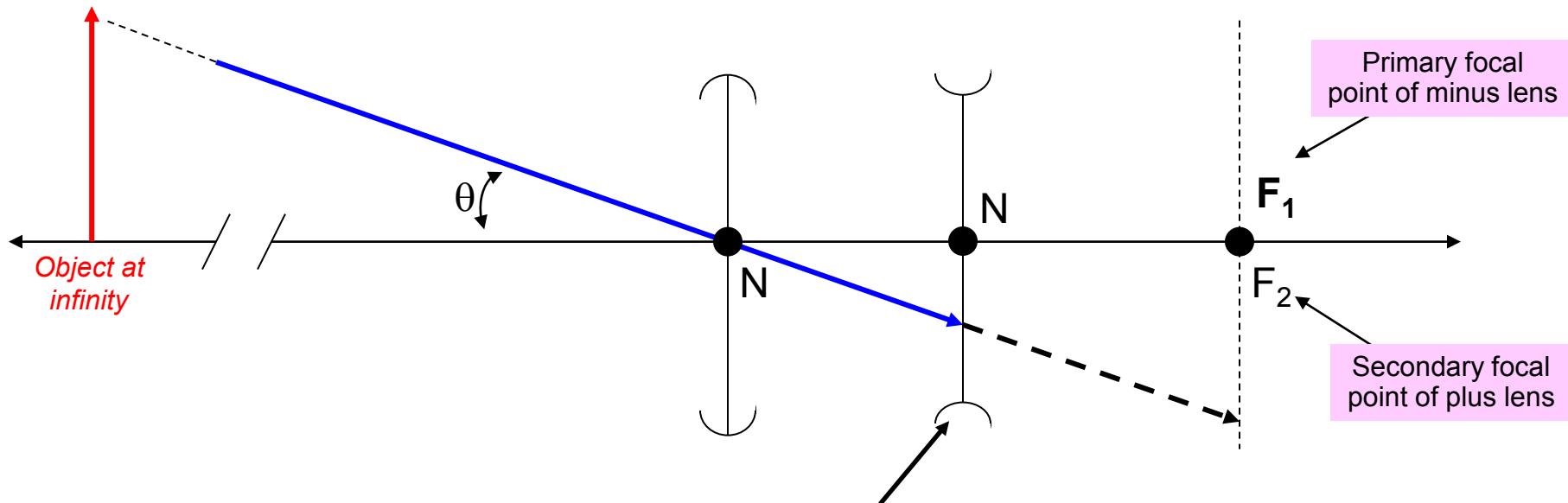
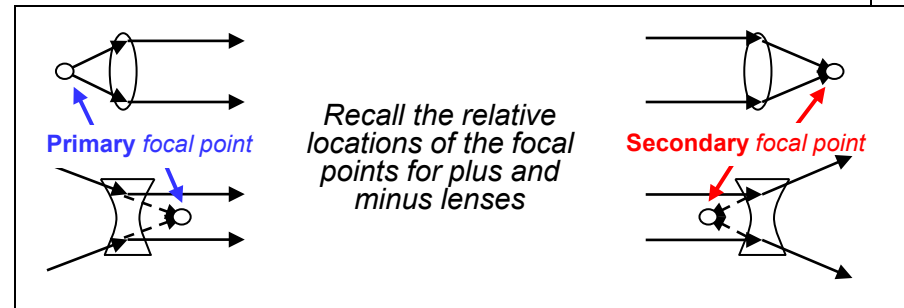


Telescopes



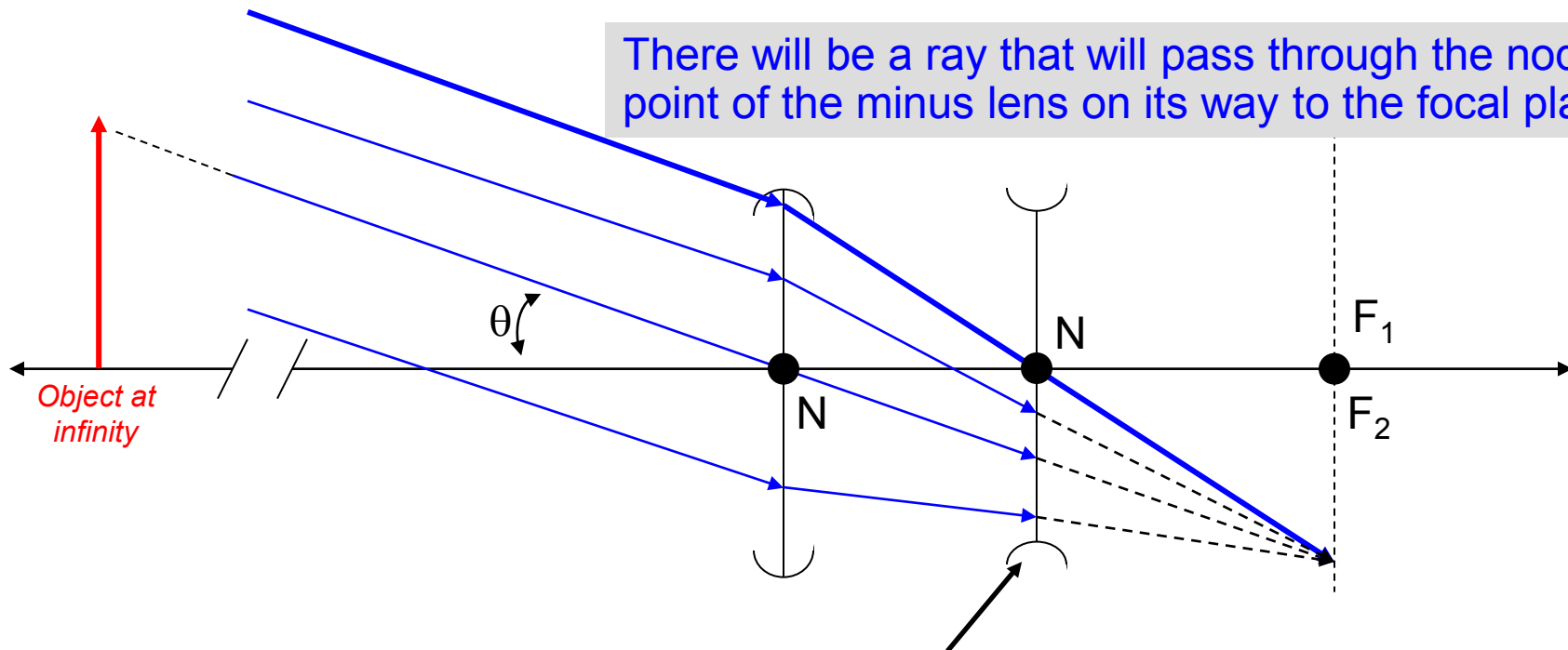
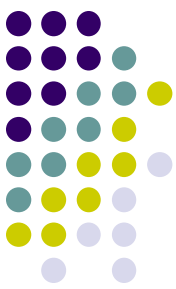
What would happen if we included a **minus lens** located such that its primary focal point/plane coincided with the secondary focal point/plane of the plus lens?

Telescopes



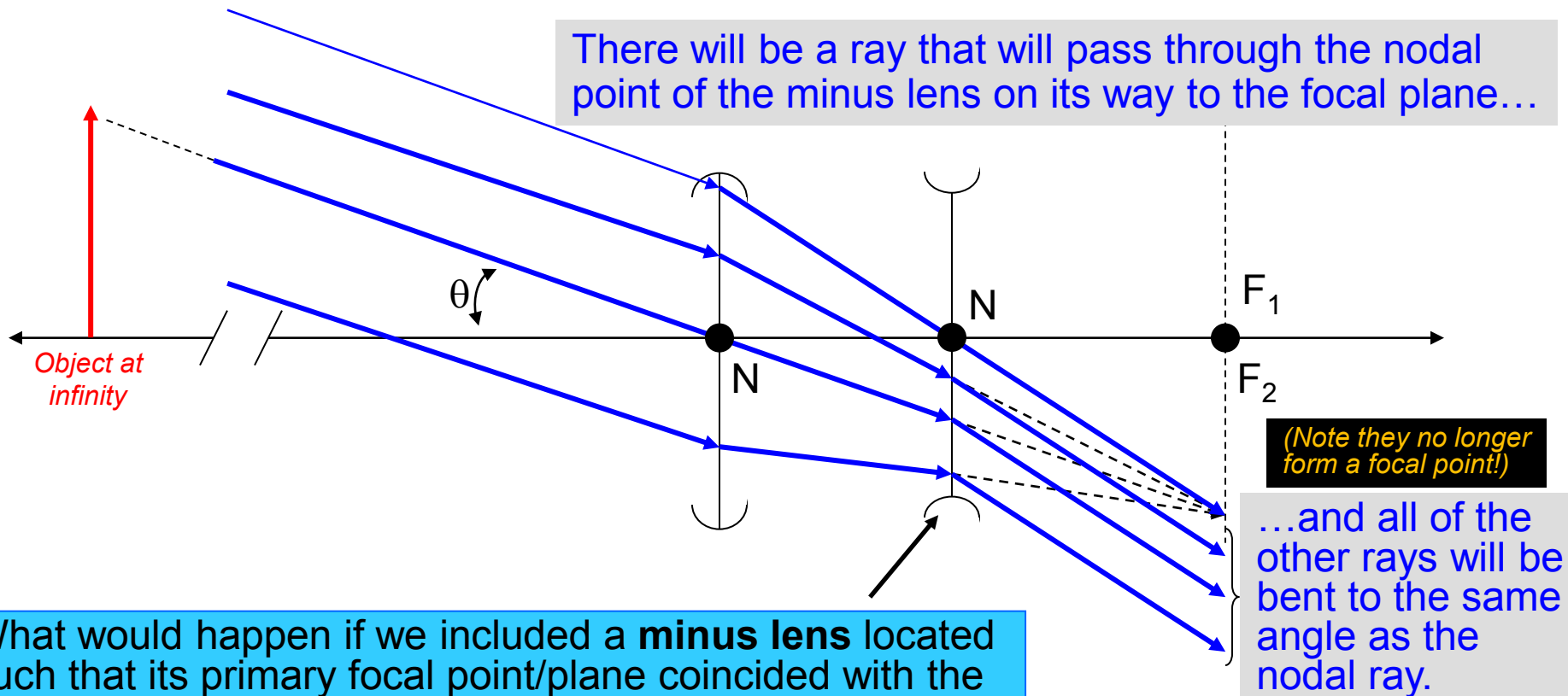
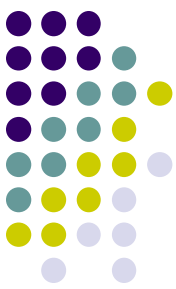
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Telescopes

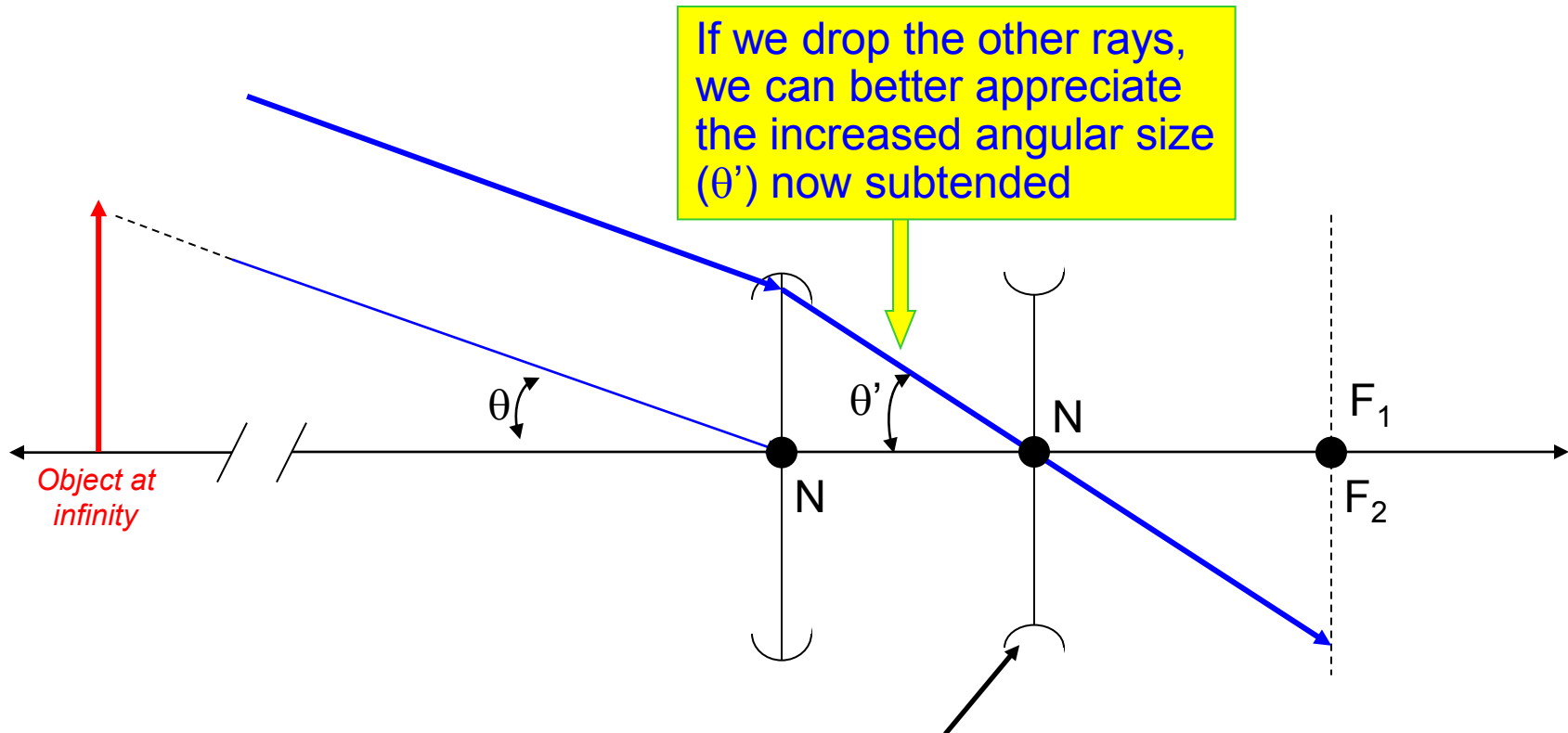
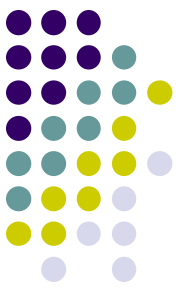


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Telescopes

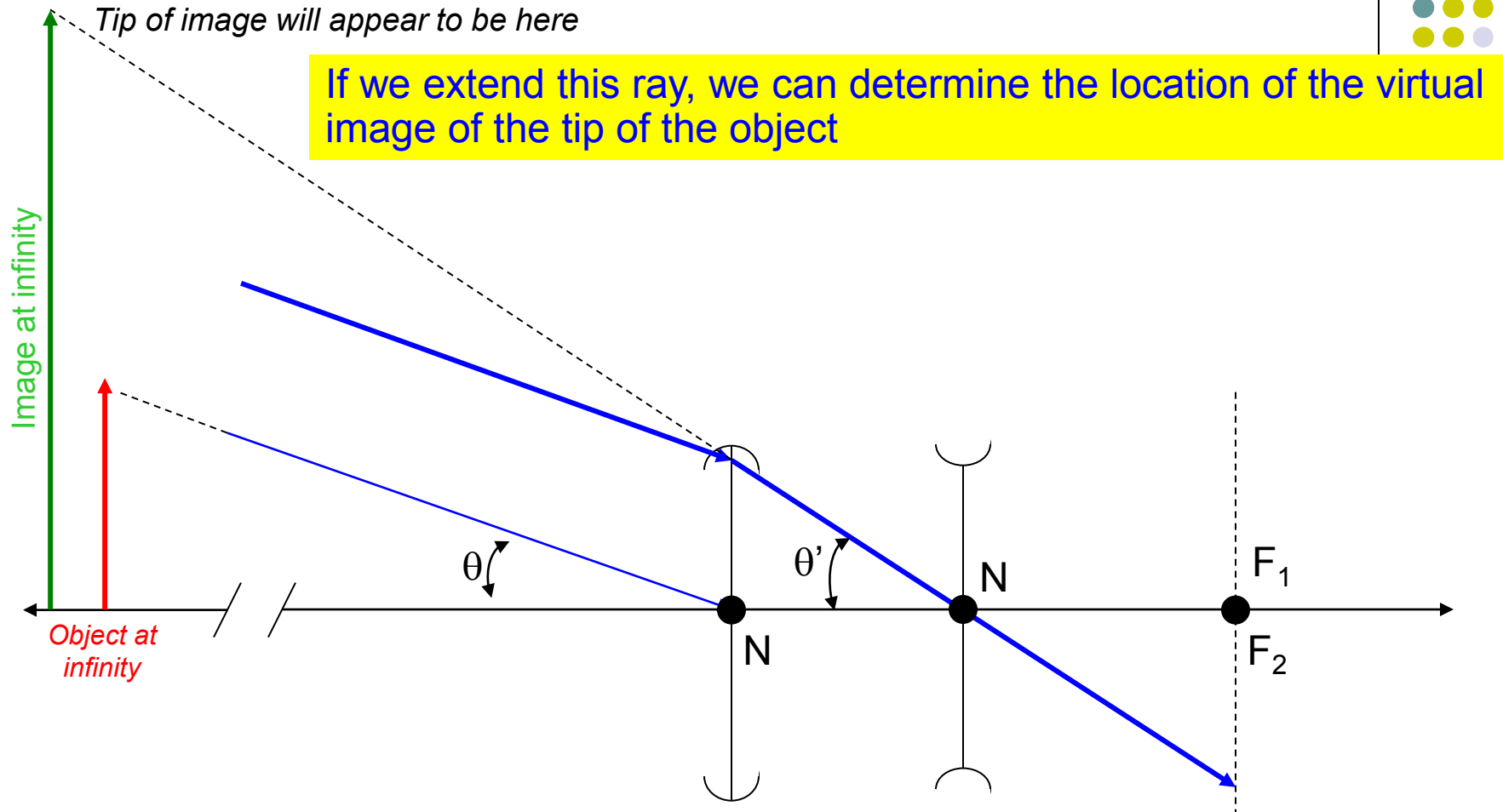


Telescopes



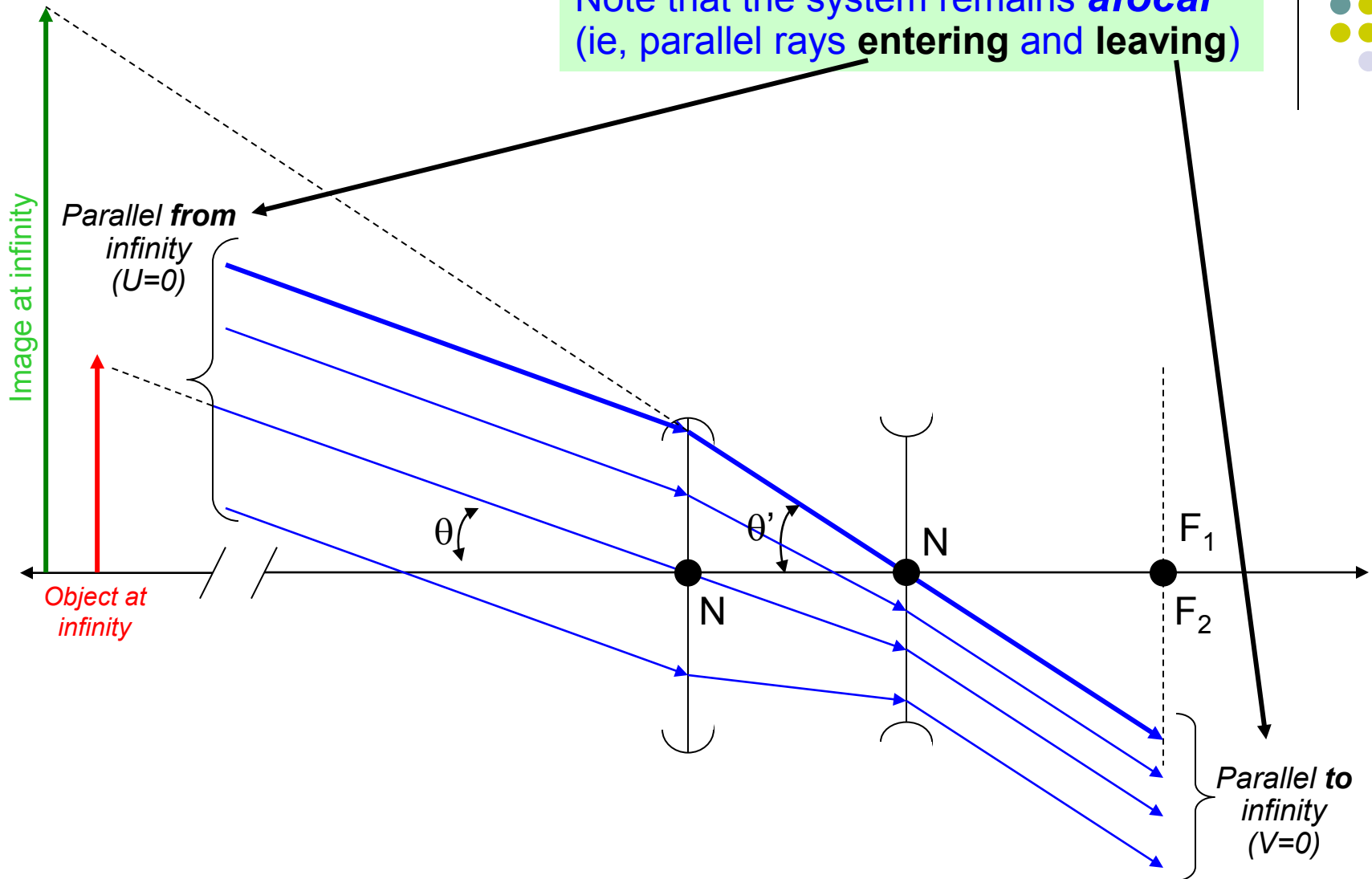
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Telescopes

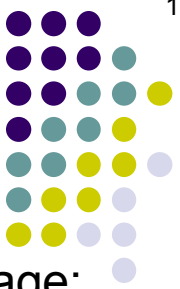


Telescopes

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

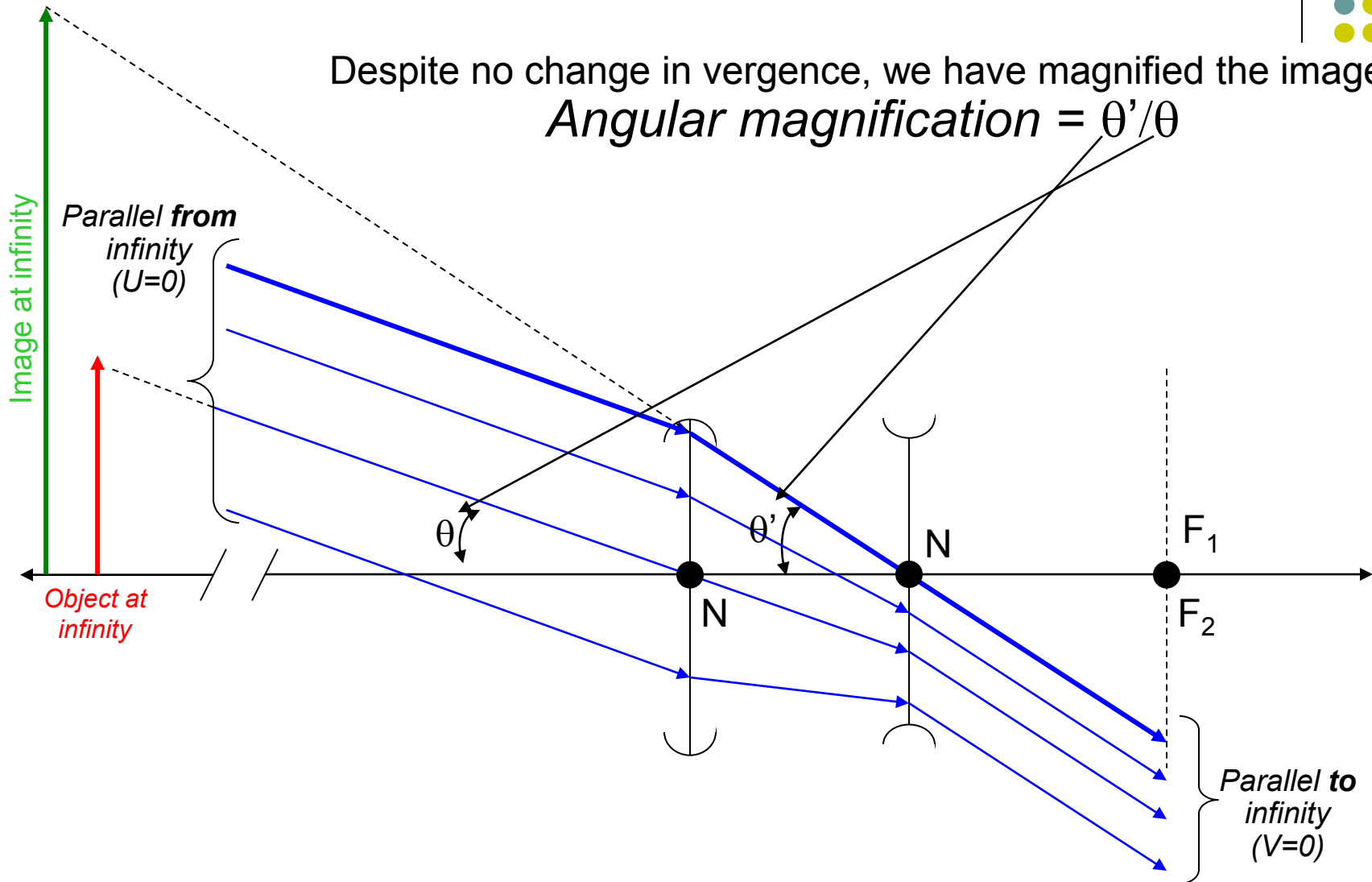


Telescopes

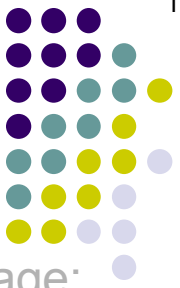


Despite no change in vergence, we have magnified the image:

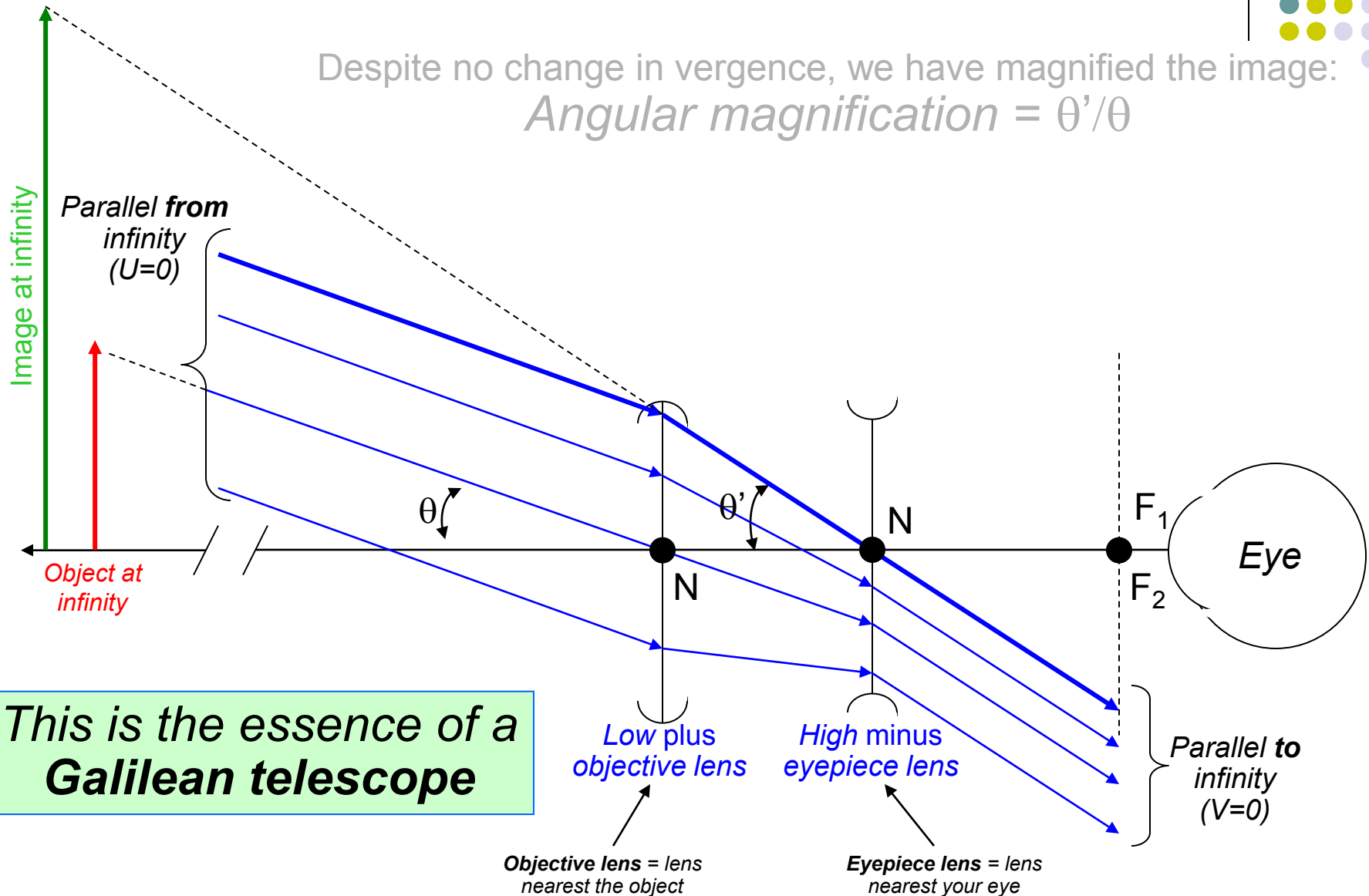
$$\text{Angular magnification} = \theta' / \theta$$



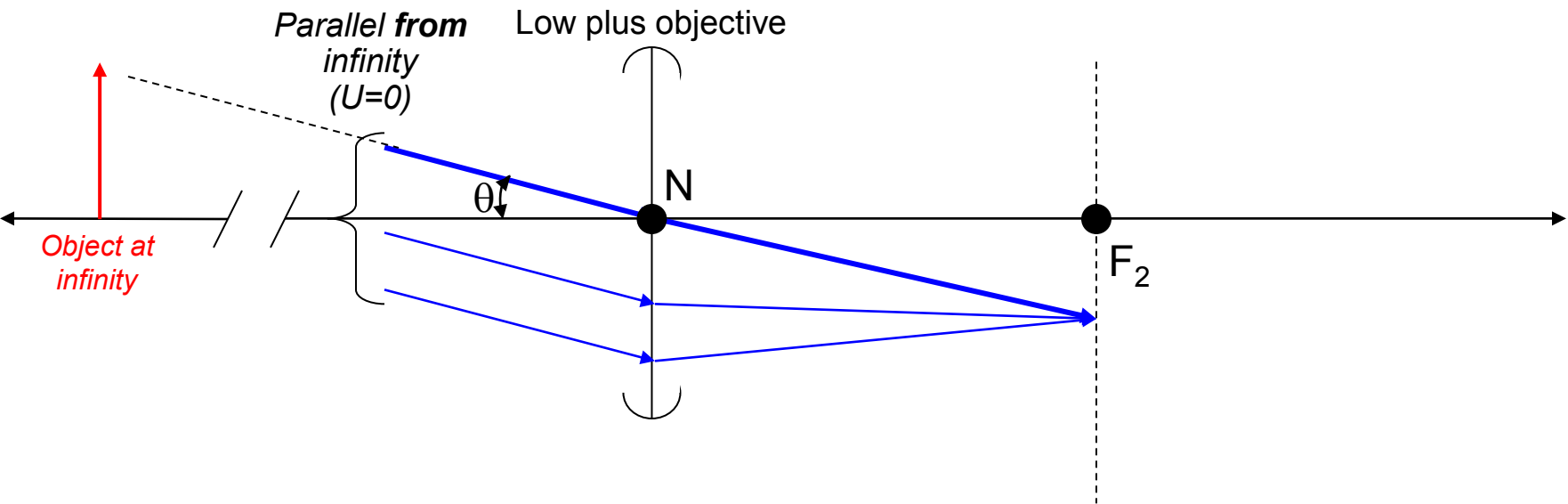
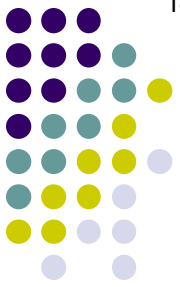
Telescopes



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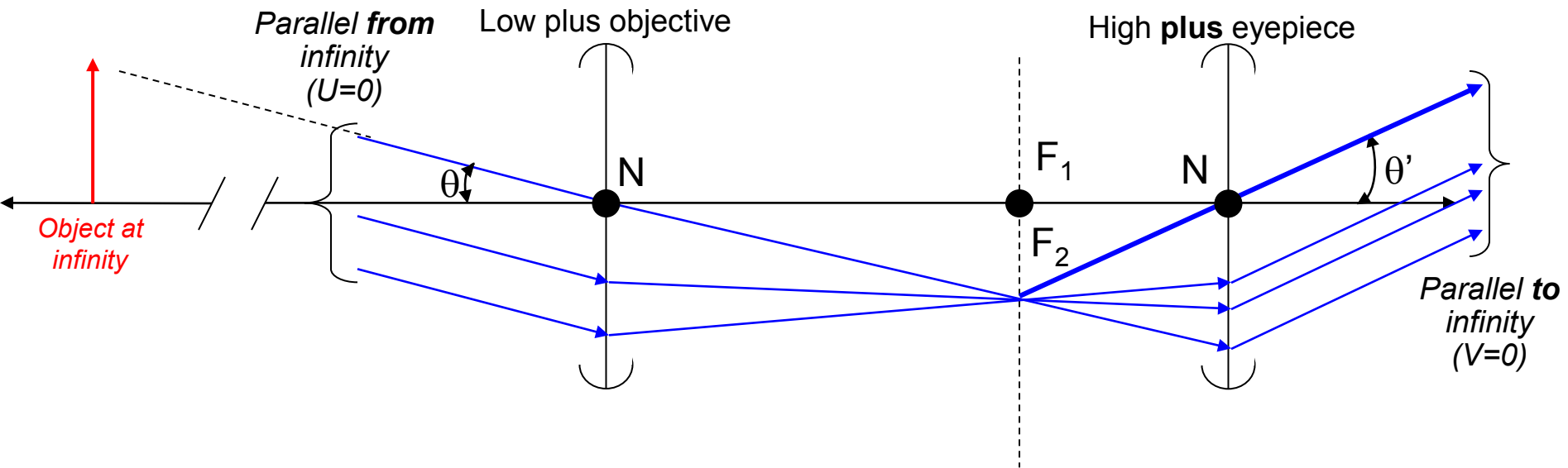
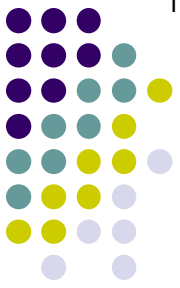


Telescopes



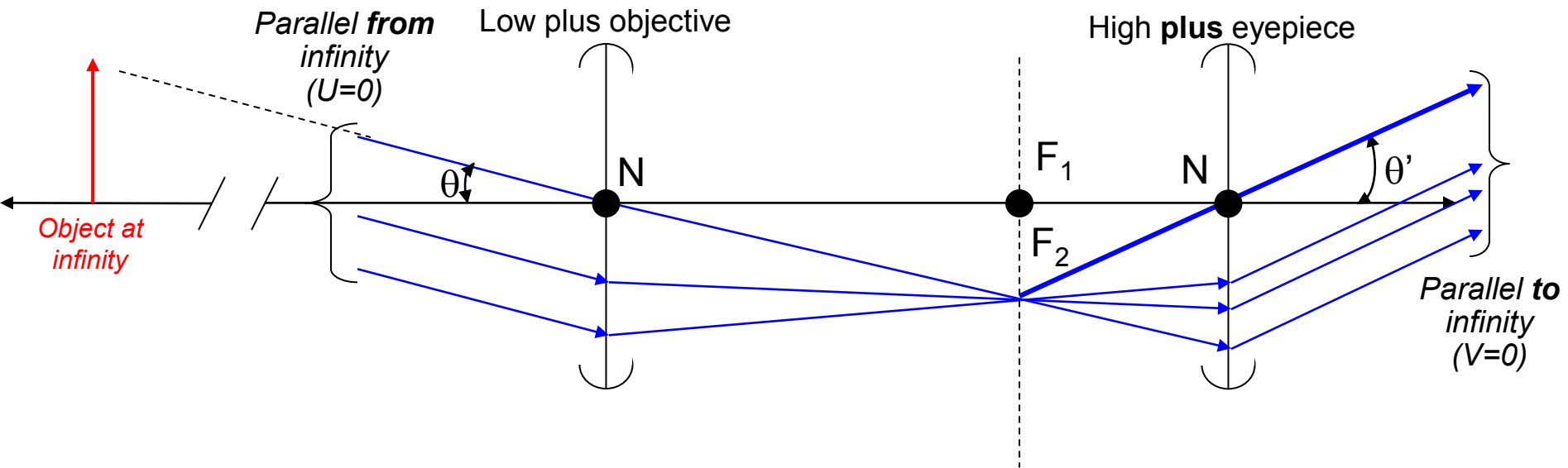
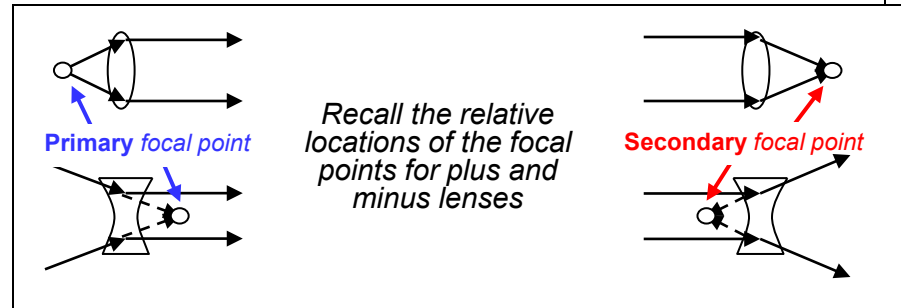
What if, instead of inserting a minus lens into the system...

Telescopes



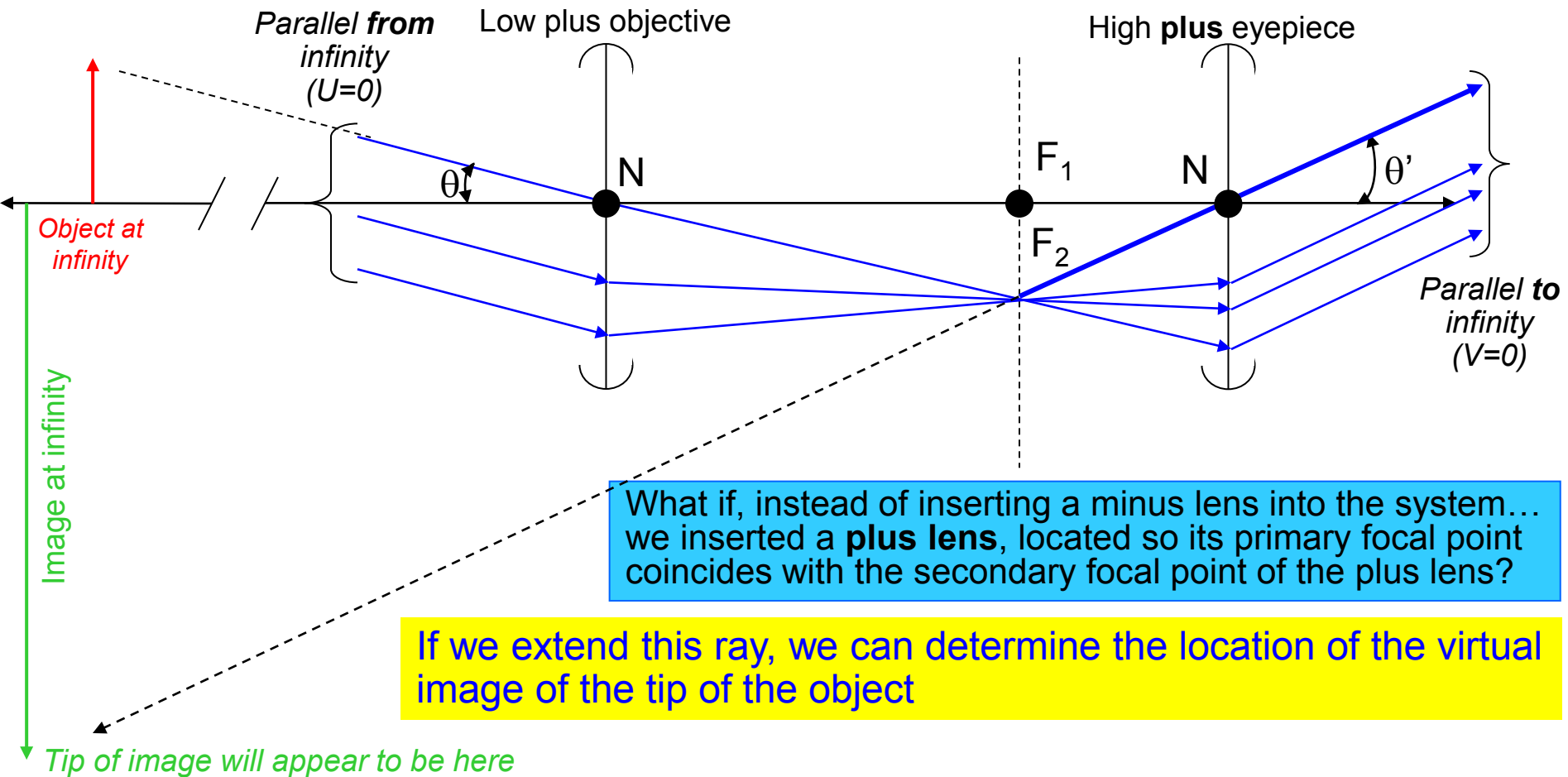
What if, instead of inserting a minus lens into the system... we inserted a **plus lens**, located so its primary focal point coincides with the secondary focal point of the plus lens?

Telescopes

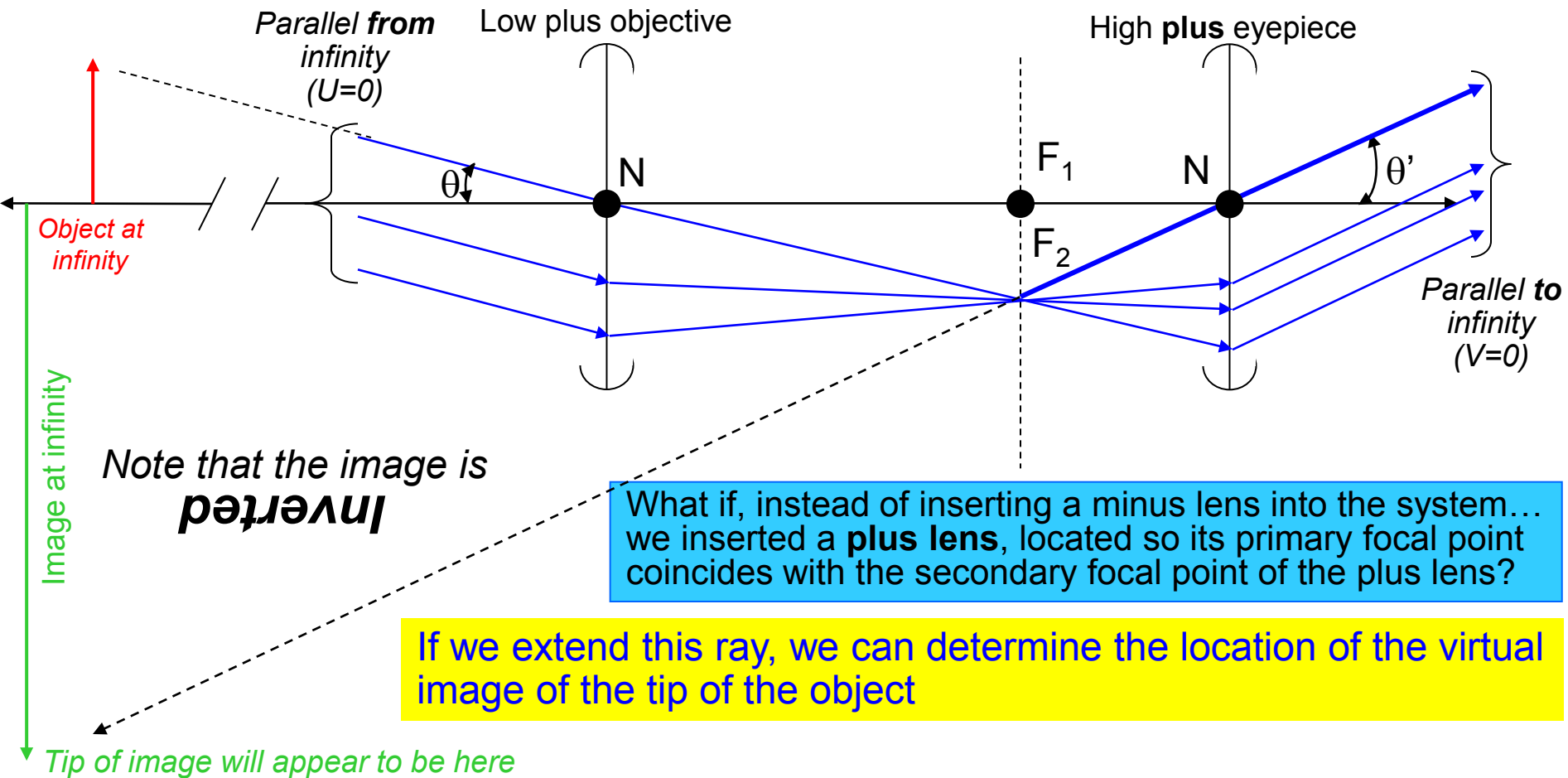
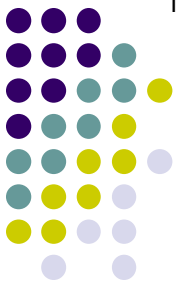


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Telescopes

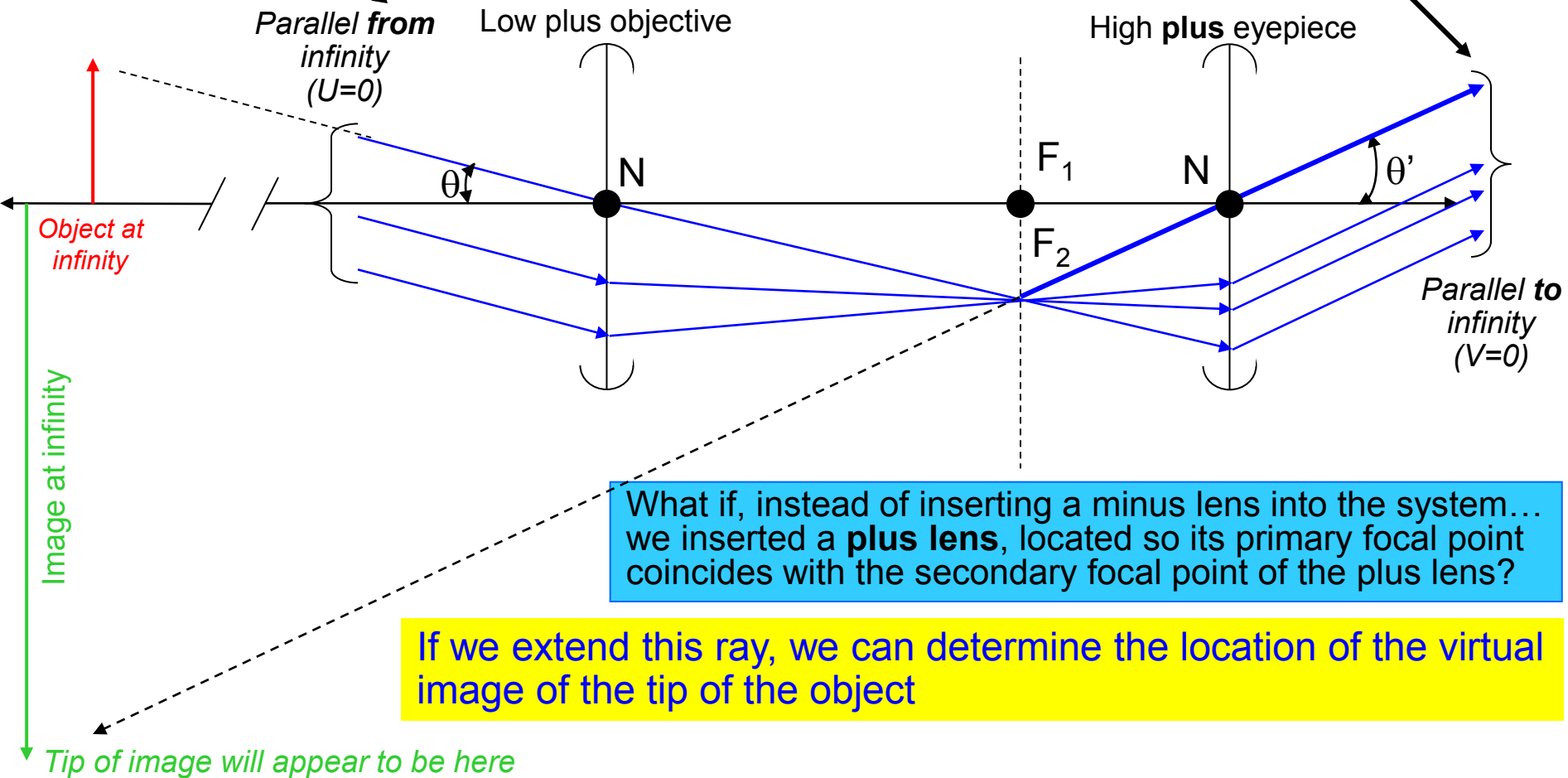


Telescopes



Telescopes

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

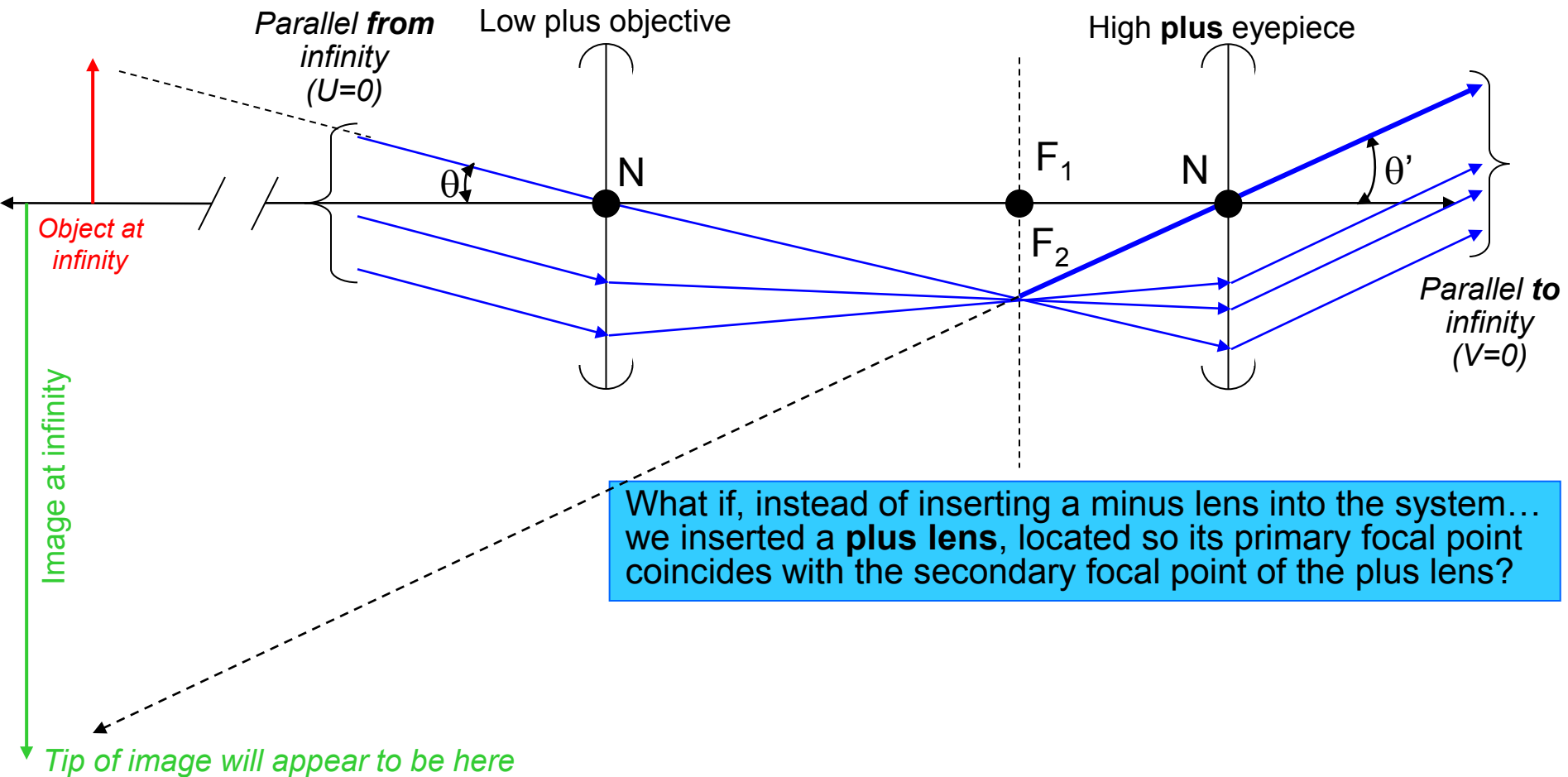


Telescopes



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

$$\text{Angular magnification} = \theta' / \theta$$

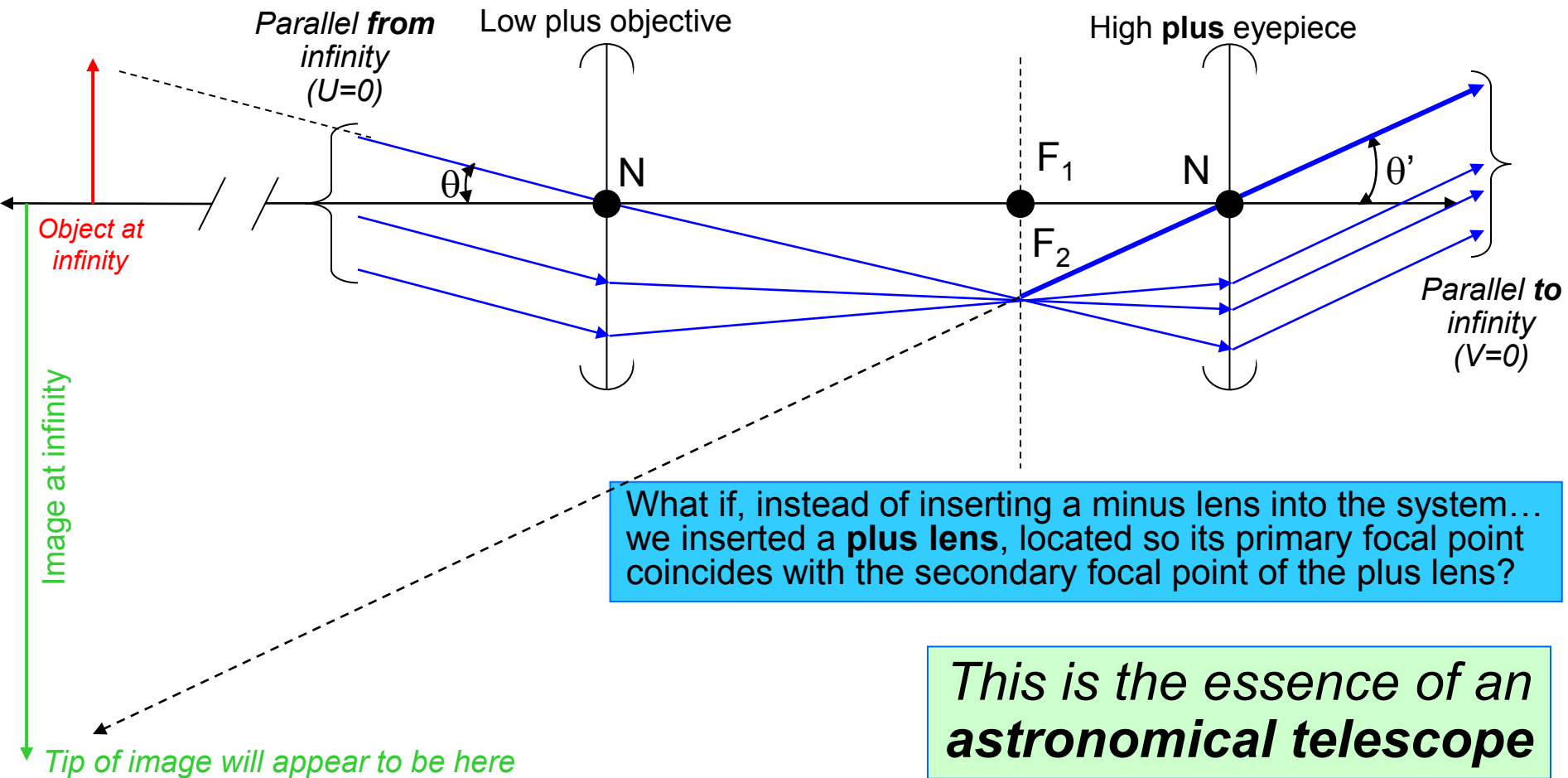


Telescopes

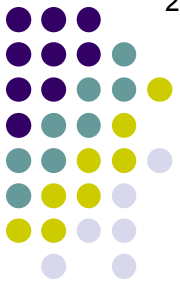


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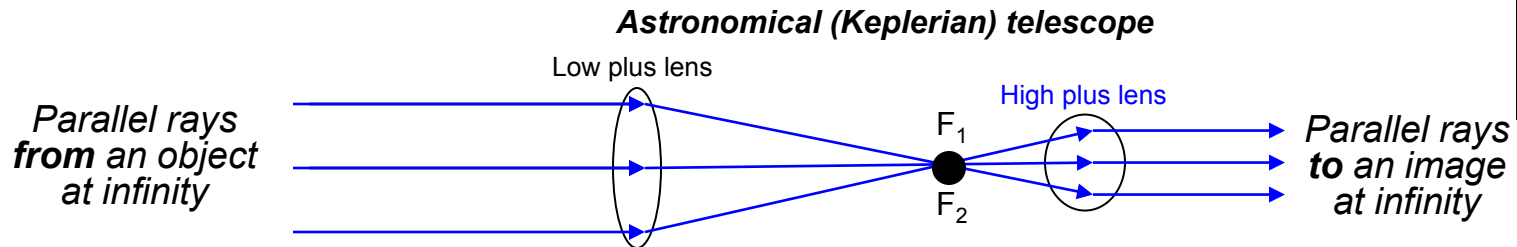
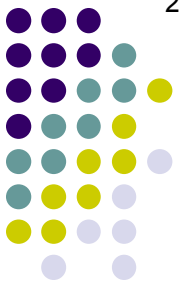


Telescopes



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

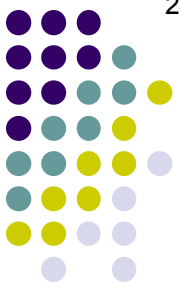
Telescopes



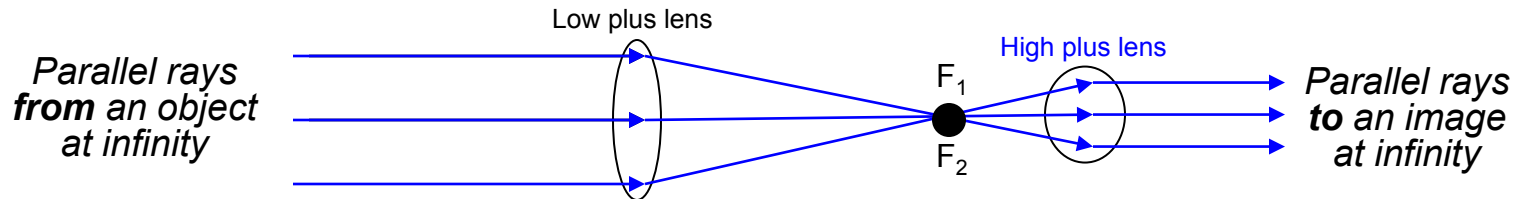
To reiterate: Telescopes come in two basic flavors—those with a high **plus** eyepiece lens, and those with a high **minus** eyepiece lens.

High-plus-eyepiece telescopes are called *astronomical* (or *Keplerian*) telescopes;

Telescopes



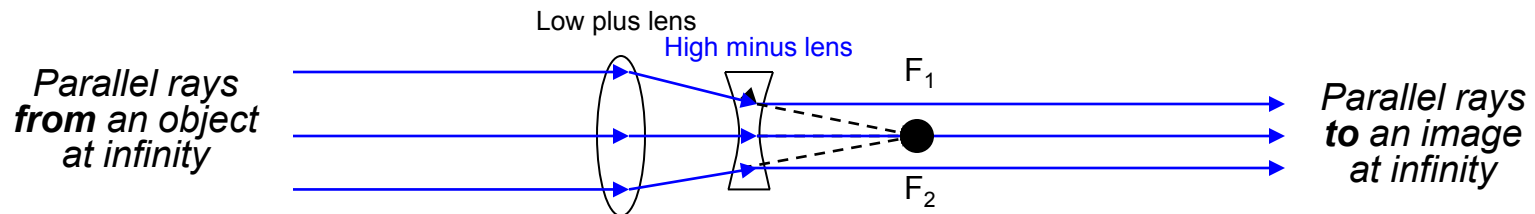
Astronomical (Keplerian) telescope



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

High-plus-eyepiece telescopes are called *astronomical* (or *Keplerian*) telescopes;
and
high-minus-eyepiece telescopes are called *Galilean* (or *terrestrial*) telescopes.

Galilean (terrestrial) telescope



Telescopes

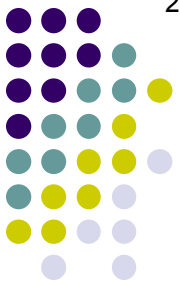
Angular magnification = θ'/θ is difficult to work with.



Telescopes

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Fortunately, for reasonably small angles, this can be well approximated by:



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$$\text{Angular magnification} = \frac{\text{Eyepiece lens}}{\text{Objective lens}}$$



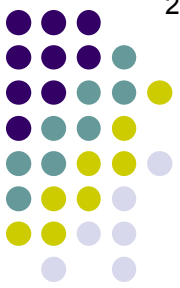
Telescopes

Angular magnification = θ'/θ is difficult to work with.

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Don't forget this minus sign! It keeps the magnification value consistent with our image orientation sign convention



Telescopes

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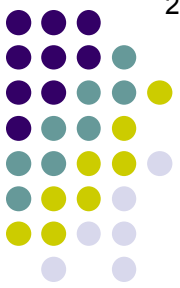
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$$\text{Angular mag} = - \frac{\text{Eyepiece lens}}{\text{Objective lens}} = - \frac{\text{Plus}}{\text{Plus}} = (-)$$

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



Telescopes

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Fortunately, for reasonably small angles, this can be well approximated by:

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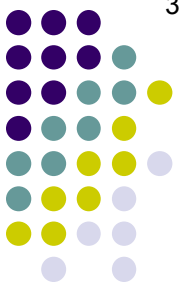
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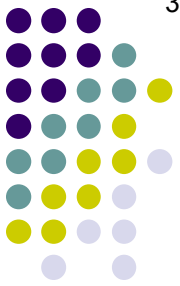
Astronomical telescope
(image is ***inverted***)

$$\text{Angular mag} = - \frac{\text{Eyepiece lens}}{\text{Objective lens}} = - \frac{\text{Minus}}{\text{Plus}} = (+)$$

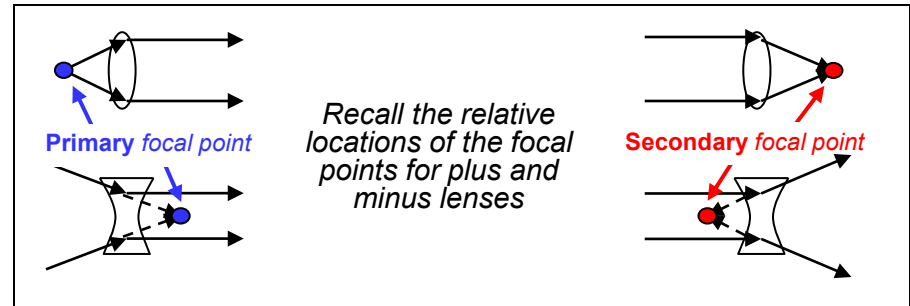
Galilean telescope
(image is ***upright***)



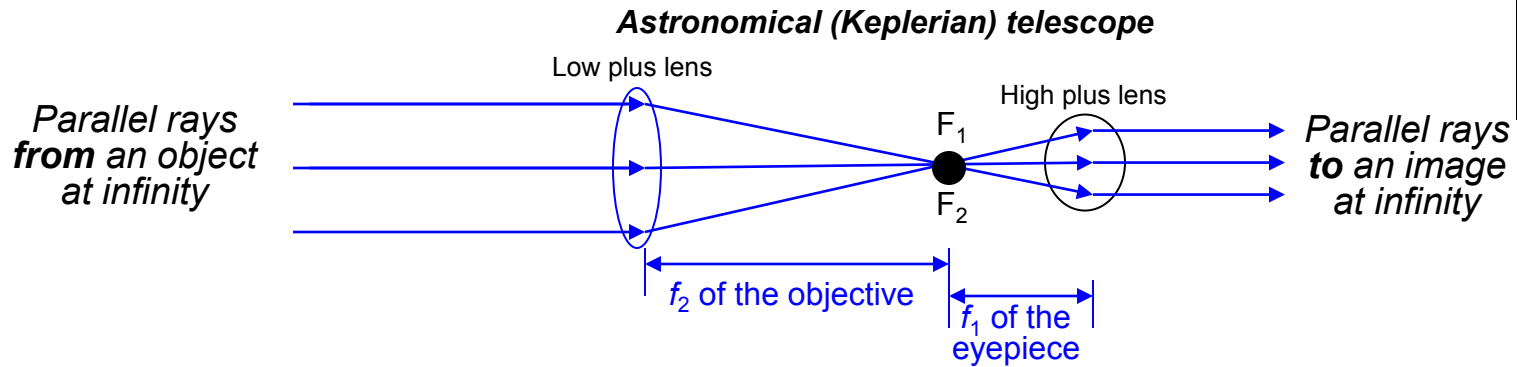
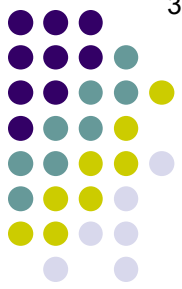
Telescopes



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.

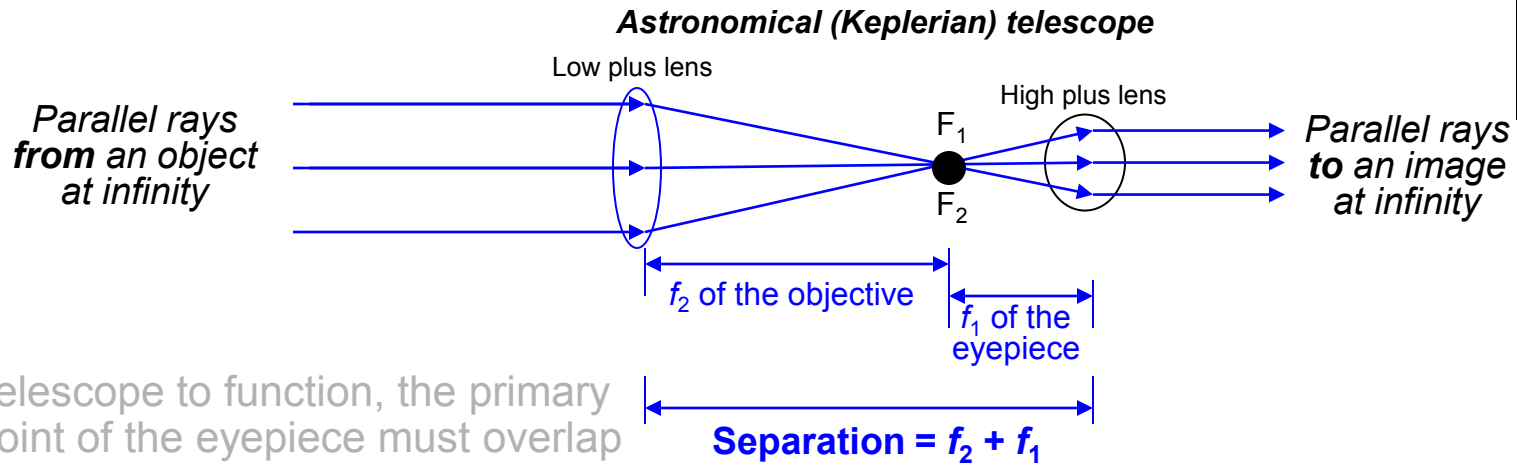


Telescopes



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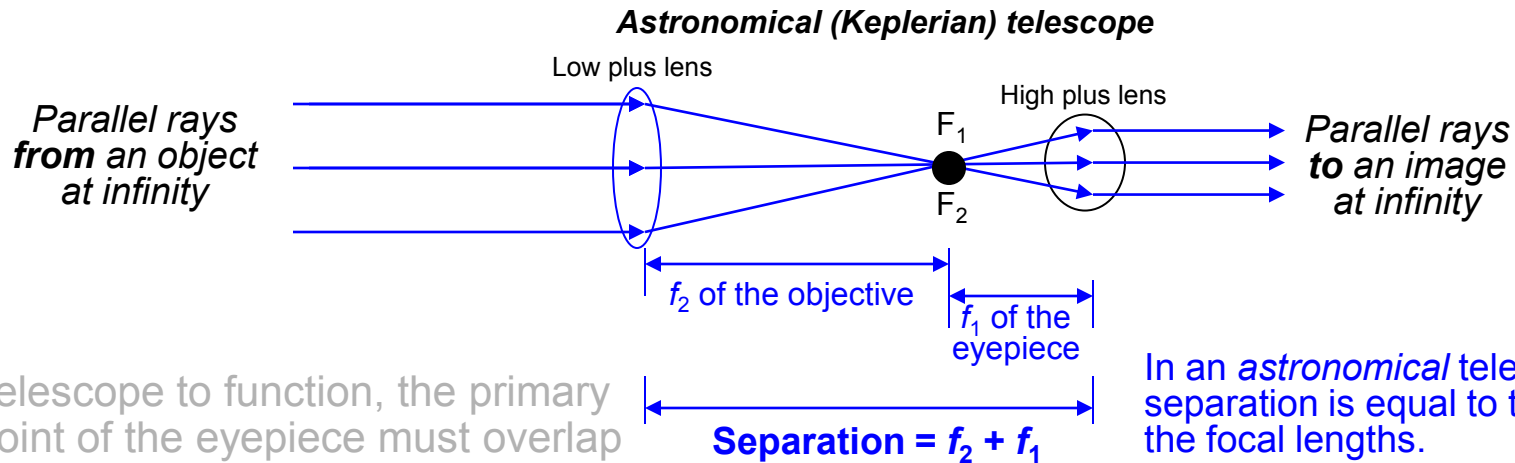
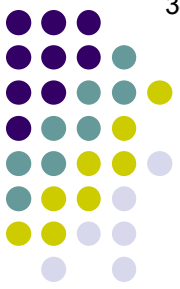
Telescopes



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

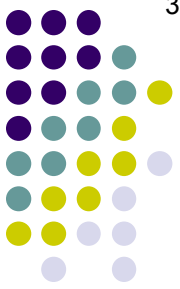


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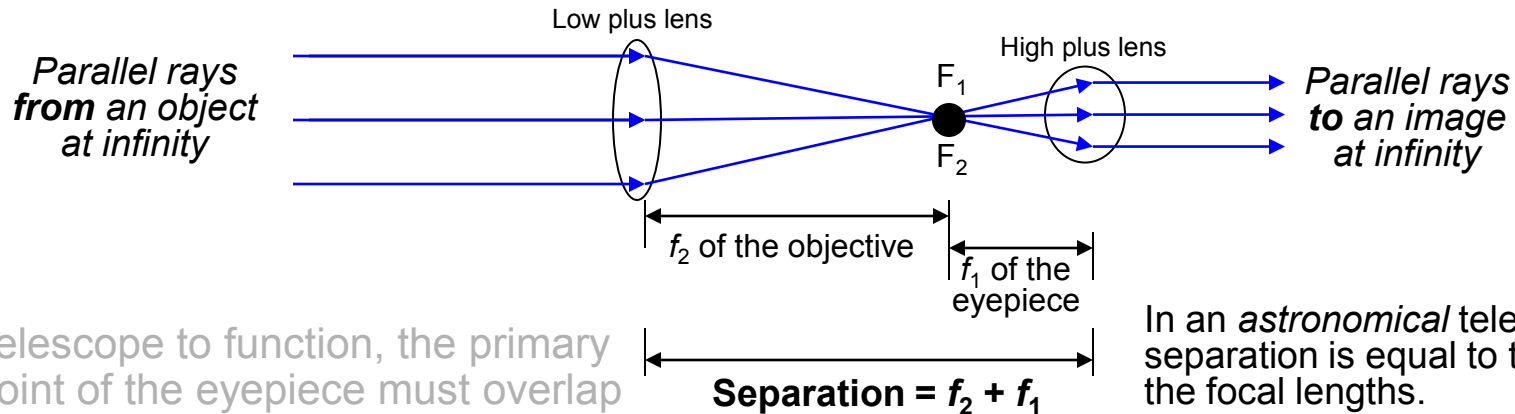
This determines the separation between the two lenses.

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

Telescopes



Astronomical (Keplerian) telescope

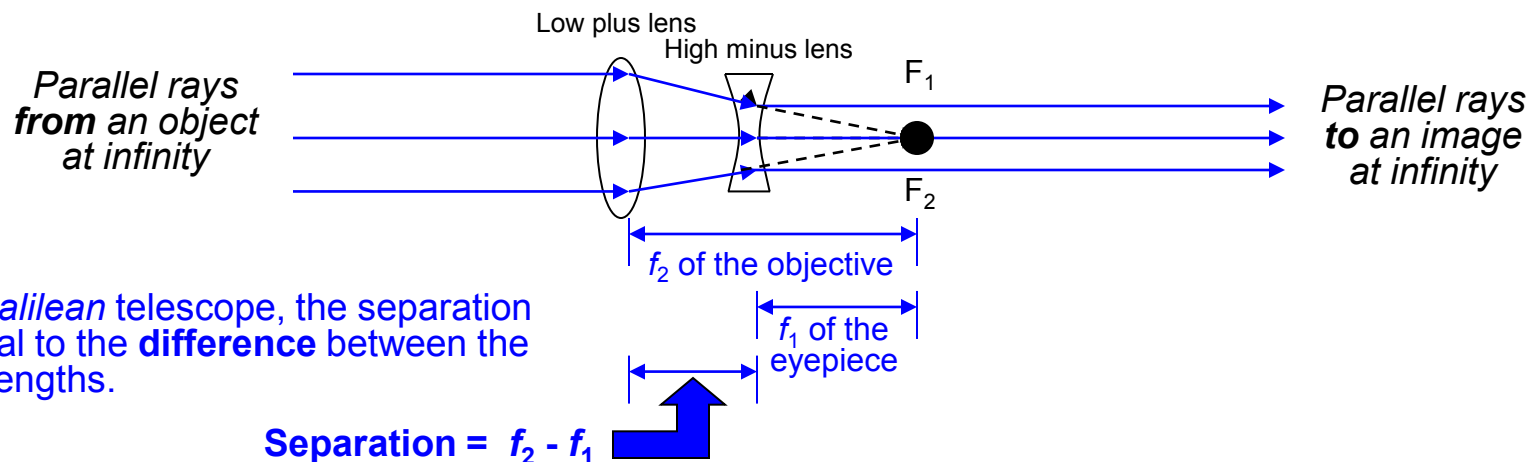


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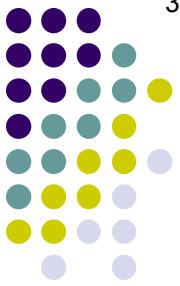
This determines the separation between the two lenses.

Galilean (terrestrial) telescope

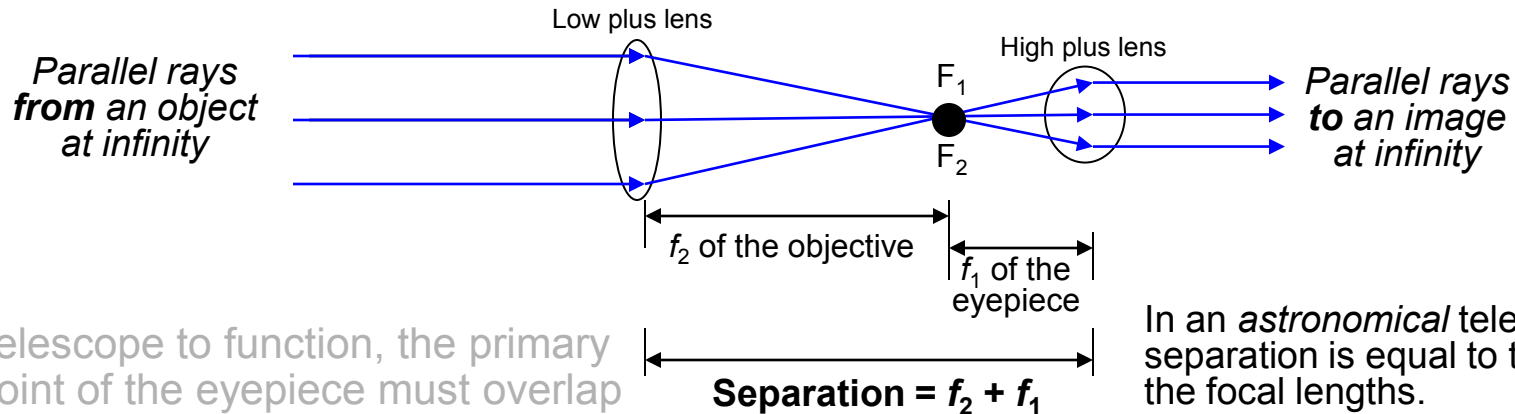


In a *Galilean* telescope, the separation is equal to the **difference** between the focal lengths.

Telescopes



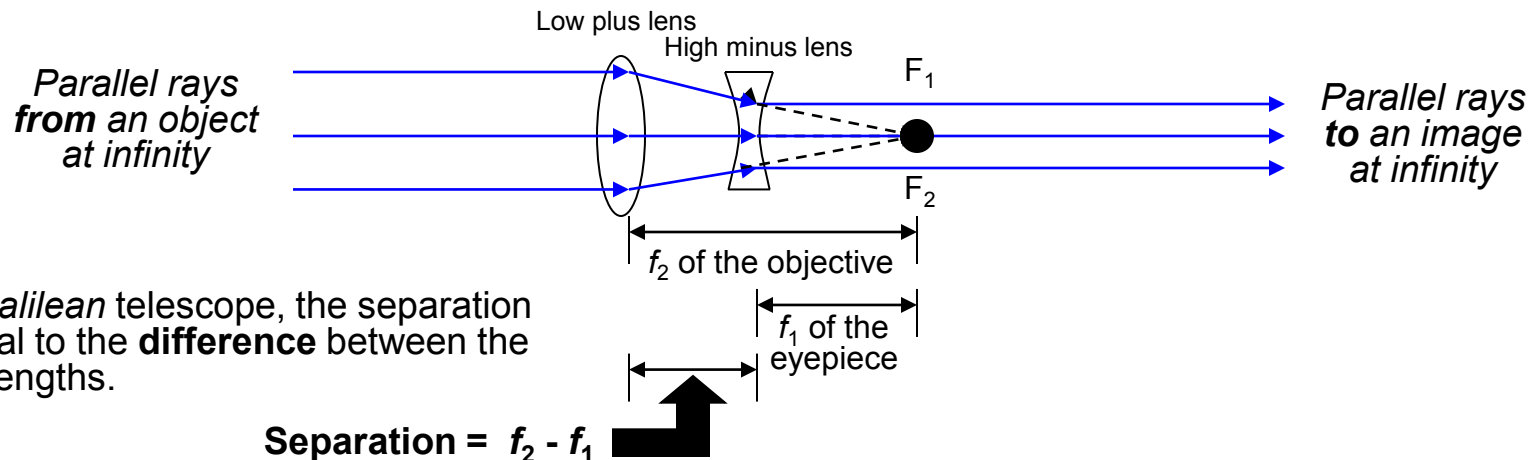
Astronomical (Keplerian) telescope



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

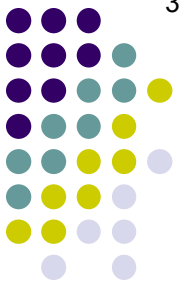
For this and other reasons, Galilean scopes tend to be **smaller and lighter** than astronomical scopes.

Galilean (terrestrial) telescope

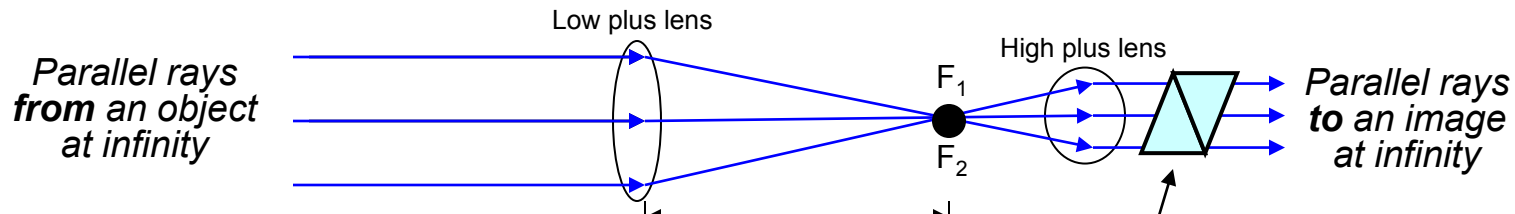


In a *Galilean* telescope, the separation is equal to the **difference** between the focal lengths.

Telescopes



Astronomical (Keplerian) telescope

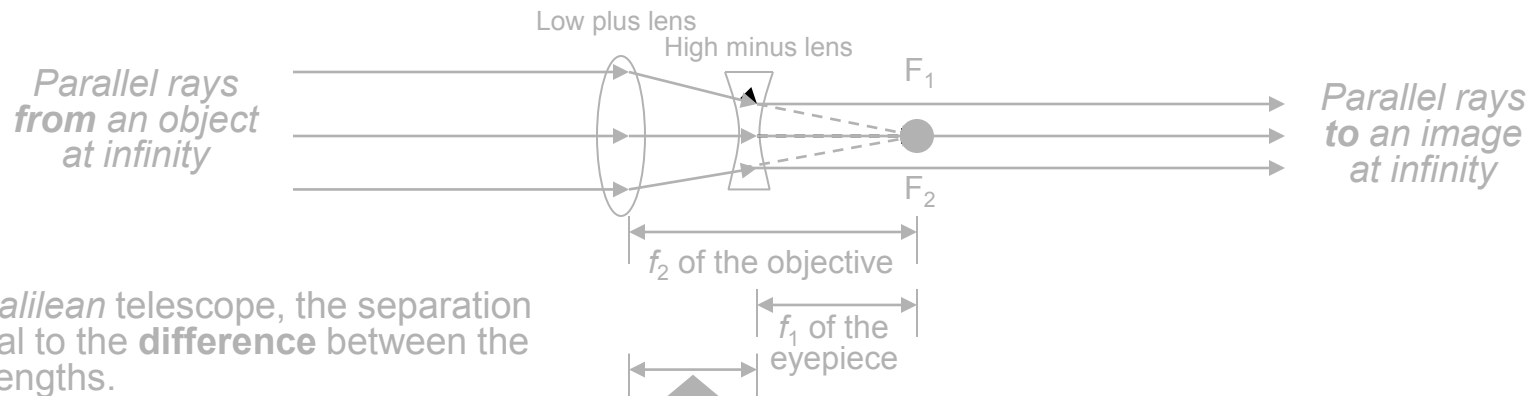


The main other reason being that astronomical telescopes require **prisms** to flip the inverted image into the upright position, which add considerably to their size and weight!

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

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

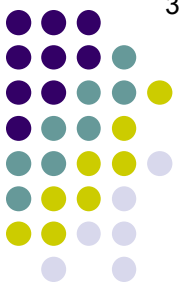
Galilean (terrestrial) telescope



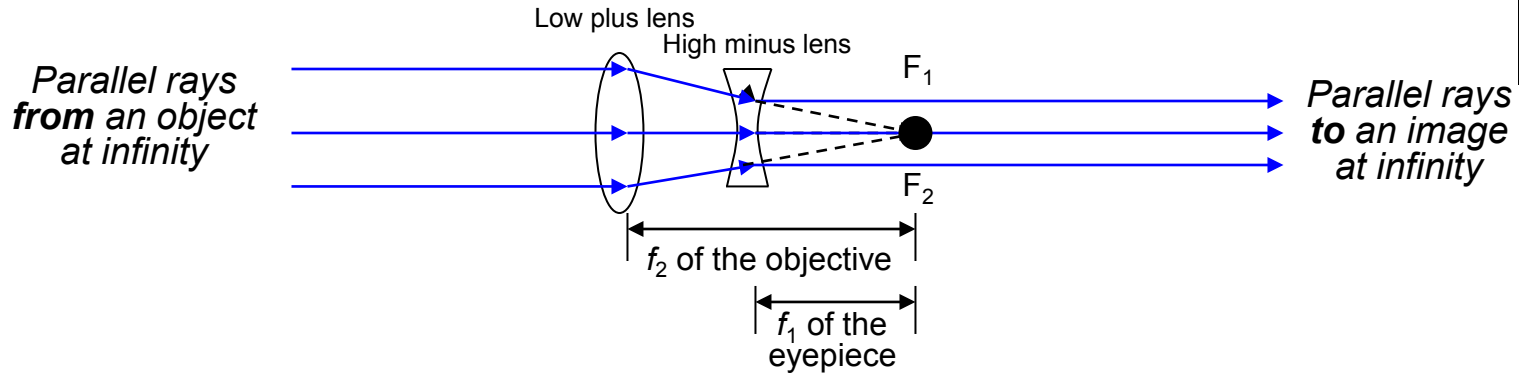
Separation = $f_2 - f_1$

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

Telescopes

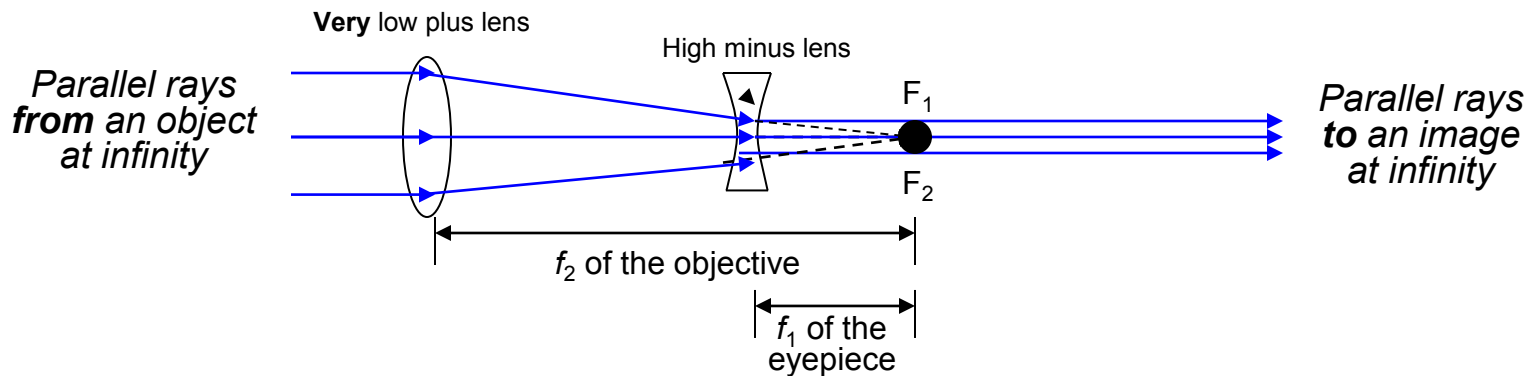


Galilean (terrestrial) telescope



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

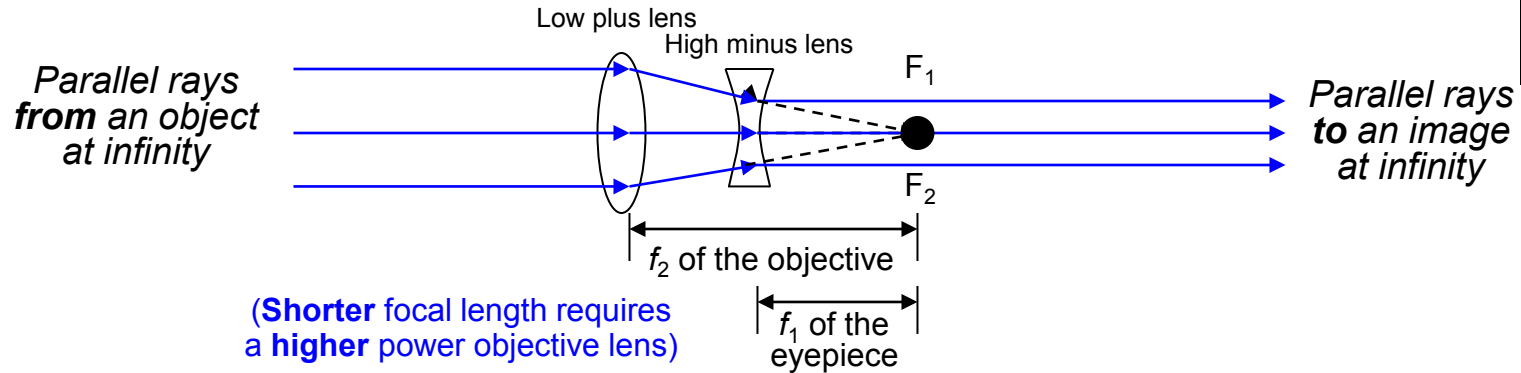
Galilean (terrestrial) telescope



Telescopes

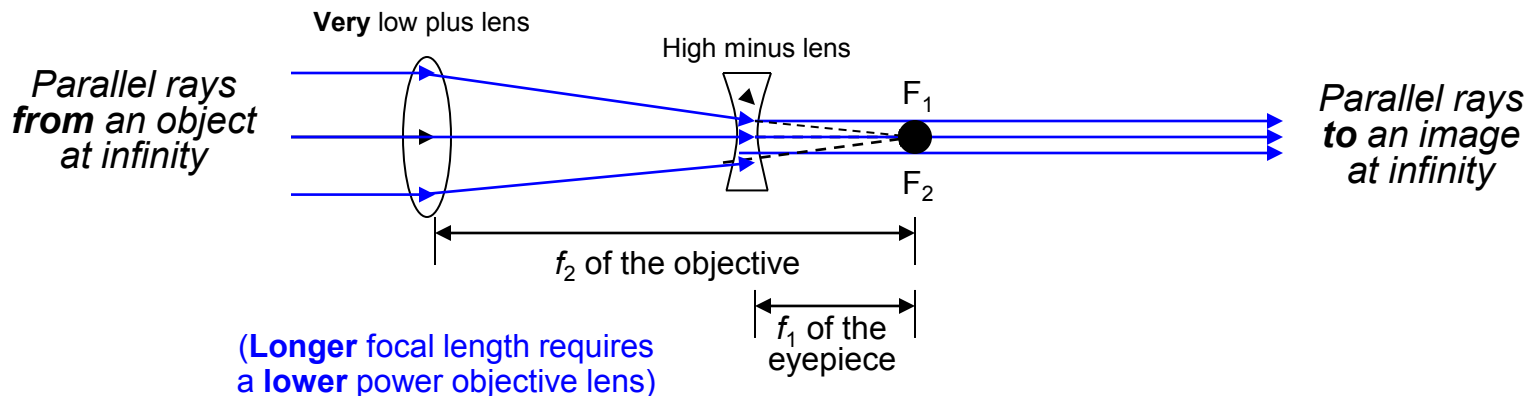


Galilean (terrestrial) telescope



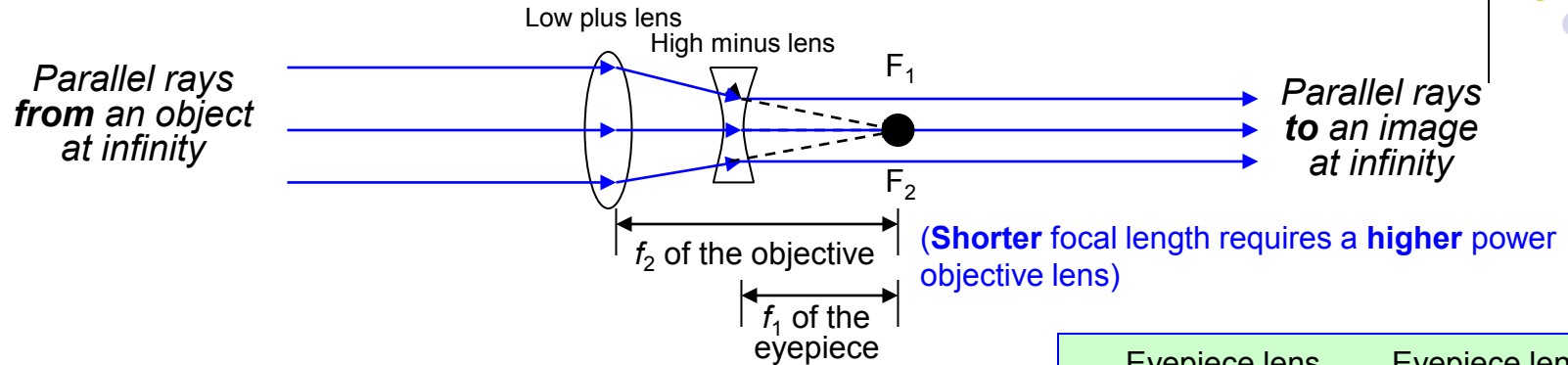
The greater lens separation below necessitates a **decrease** in power for the objective lens (and vice versa). Will this increase, decrease or leave unaffected the overall power of the telescope?

Galilean (terrestrial) telescope



Telescopes

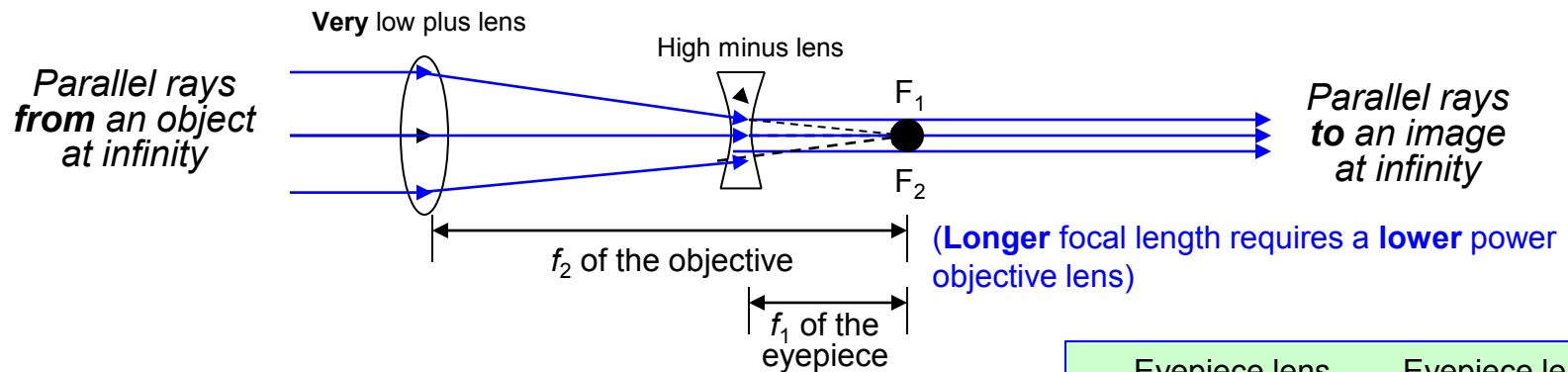
Galilean (terrestrial) telescope



Increase overall power.

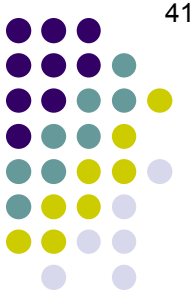
$$- \frac{\text{Eyepiece lens}}{\text{Objective lens}} = \frac{\text{Eyepiece lens}}{\text{Higher number}} = \text{Lower power}$$

Galilean (terrestrial) telescope



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

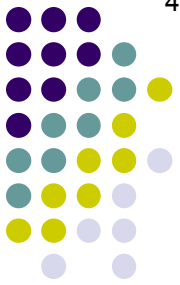
Telescopes



Compare and contrast the two basic telescope configurations

	Field of view				
Galilean					
Astronomical					

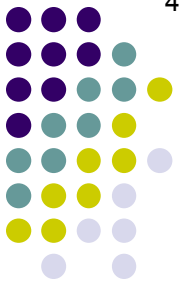
Telescopes



Compare and contrast the two basic telescope configurations

	Field of view				
Galilean	Smaller				
Astronomical	Larger				

Telescopes



Compare and contrast the two basic telescope configurations

	Field of view	Maximum practical magnification			
Galilean	Smaller				
Astronomical	Larger				

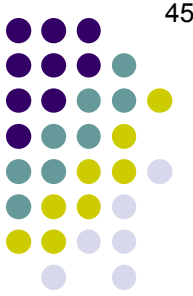
Telescopes



Compare and contrast the two basic telescope configurations

	Field of view	Maximum practical magnification			
Galilean	Smaller	4x			
Astronomical	Larger	10x			

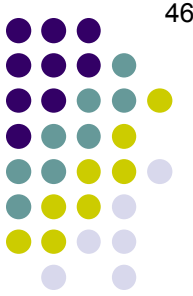
Telescopes



Compare and contrast the two basic telescope configurations

	Field of view	Maximum practical magnification	Relative size		
Galilean	Smaller	4x			
Astronomical	Larger	10x			

Telescopes



Compare and contrast the two basic telescope configurations

	Field of view	Maximum practical magnification	Relative size		
Galilean	Smaller	4x	Small/light		
Astronomical	Larger	10x	Large/heavy		

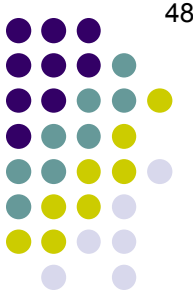
Telescopes



Compare and contrast the two basic telescope configurations

	Field of view	Maximum practical magnification	Relative size	Image orientation	
Galilean	Smaller	4x	Small/light		
Astronomical	Larger	10x	Large/heavy		

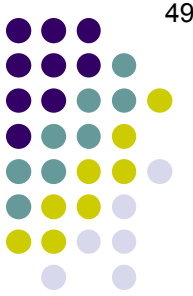
Telescopes



Compare and contrast the two basic telescope configurations

	Field of view	Maximum practical magnification	Relative size	Image orientation	
Galilean	Smaller	4x	Small/light	Upright	
Astronomical	Larger	10x	Large/heavy	Inverted (unless prisms used)	

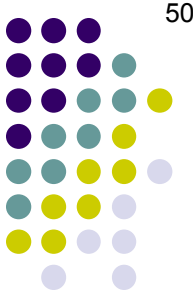
Telescopes



Compare and contrast the two basic telescope configurations

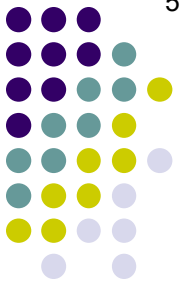
	Field of view	Maximum practical magnification	Relative size	Image orientation	Relative cost
Galilean	Smaller	4x	Small/light	Upright	
Astronomical	Larger	10x	Large/heavy	Inverted (unless prisms used)	

Telescopes



Compare and contrast the two basic telescope configurations

	Field of view	Maximum practical magnification	Relative size	Image orientation	Relative cost
Galilean	Smaller	4x	Small/light	Upright	Cheap
Astronomical	Larger	10x	Large/heavy	Inverted (unless prisms used)	Expensive



*At this juncture, you should assess your Optics knowledge by taking Quiz 5 (slide-set BO31). **After that, resume the tutorial with slide-set BO24.***