Angular Magnification

Basic Optics, Chapter 22

Transverse Magnification

- But first, let's recall some of the facts about *transverse* magnification…

Transverse Magnification

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  - Transverse magnification refers to the actual sizes of images and objects, **not** to how they appear to an observer
    - How big they *are*, not how big they *look*

Transverse Magnification

But what about objects and images located at

infinity?

Transverse Magnification

Transverse mag = $\dfrac{\textit{Image height}}{\textit{Object height}}$

= $\dfrac{\textit{Image distance (v)}}{\textit{Object distance (u)}}$

But what about objects and images located at

infinity?

Transverse Magnification

Transverse mag = $\dfrac{\textit{Image height}}{\textit{Object height}}$ **= *?***

= $\dfrac{\textit{Image distance (v)}}{\textit{Object distance (u)}}$

So, if the object is at infinity, then the transverse mag is *undefined* mathematically, approaching *zero. (Huh?)*

But what about objects and images located at ***infinity?***

Transverse Magnification

Transverse mag = $\dfrac{\textit{Image height}}{\textit{Object height}}$ **= ?**

= $\dfrac{\textit{Image distance (v)}}{\textit{Object distance (u)}}$

Likewise, if the image is at infinity, then the transverse mag is *infinitely large. (Huh?)*

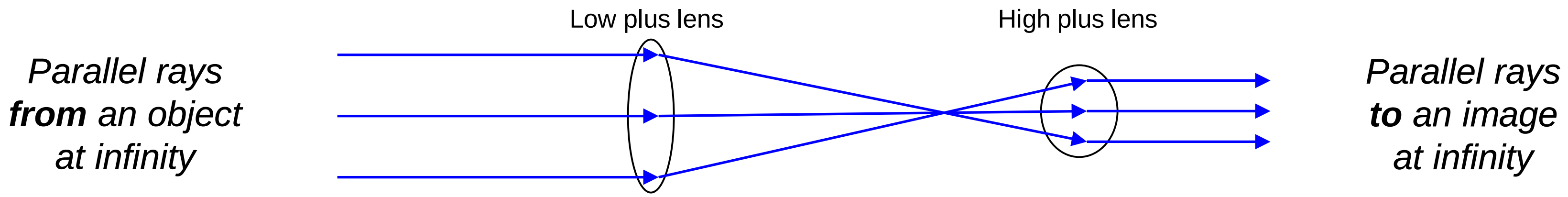
So, if the object is at infinity, then the transverse mag is *undefined* mathematically, approaching *zero. (Huh?)*

But what about objects and images located at

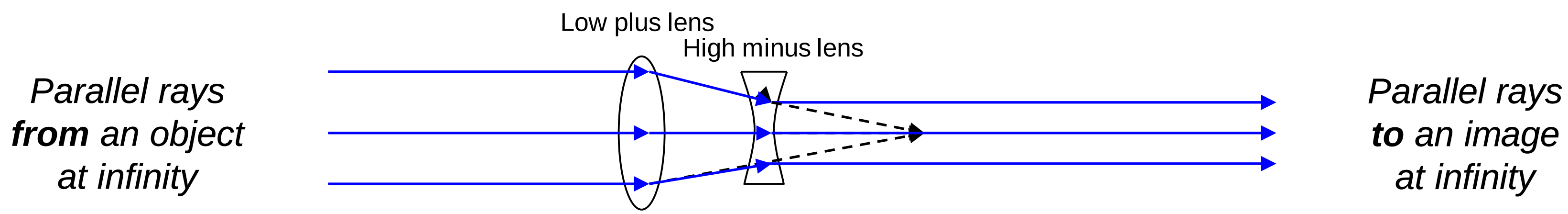
infinity?

Transverse Magnification

- In addition, consider the optics of an *afocal system* (e.g., a telescope)



Astronomical (Keplerian) telescope

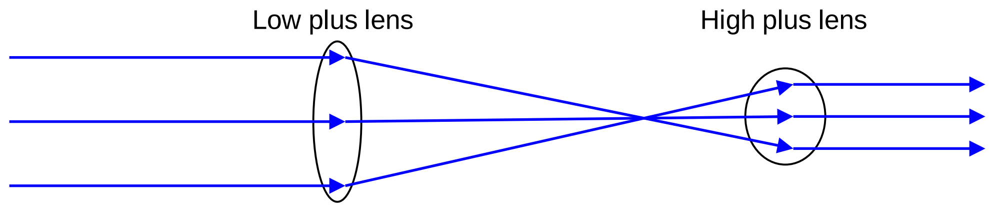


Galilean (terrestrial) telescope

Transverse Magnification

- In addition, consider the optics of an *afocal system* (e.g., a telescope)

Parallel rays ***from*** *an object at infinity*



Parallel rays ***to*** *an image at infinity*

Astronomical (Keplerian) telescope

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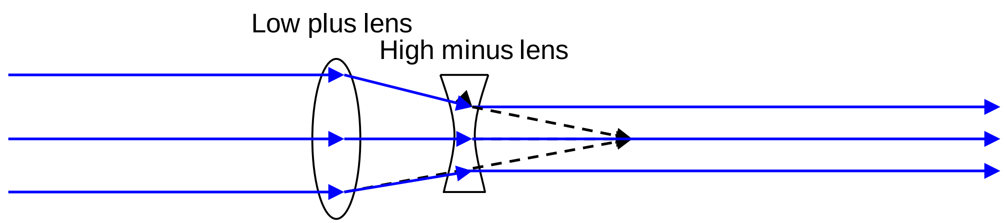


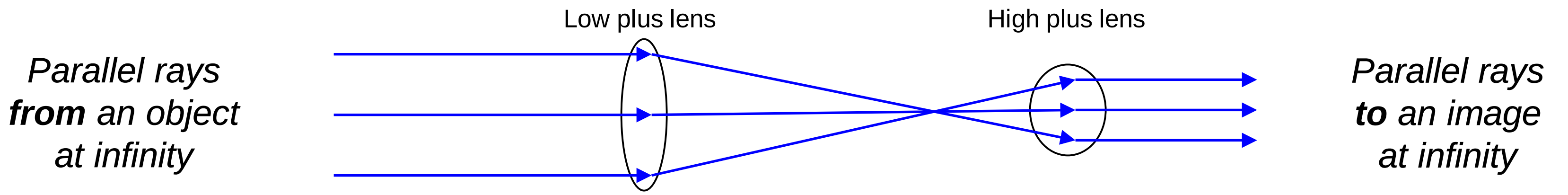
Parallel rays ***to*** *an image at infinity*

Galilean (terrestrial) telescope

Note that focused rays are not involved—that is, telescopes have parallel (i.e., afocal) rays both coming in and going out

Transverse Magnification

- In addition, consider the optics of an *afocal system* (e.g., a telescope)



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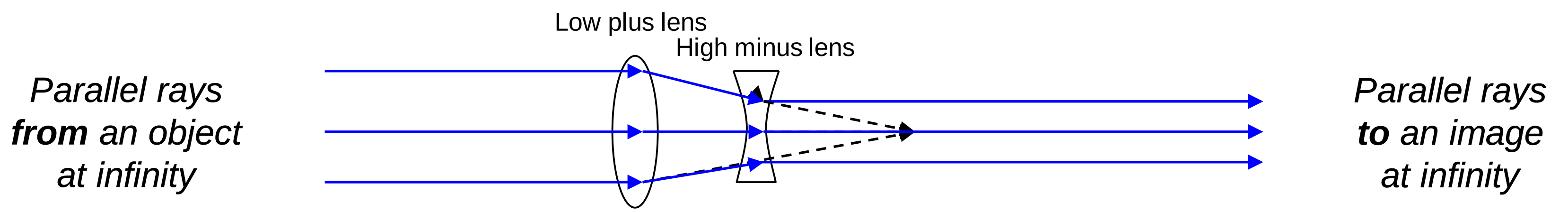


Galilean (terrestrial) telescope

So, for telescopes, the transverse magnification would seem to be:

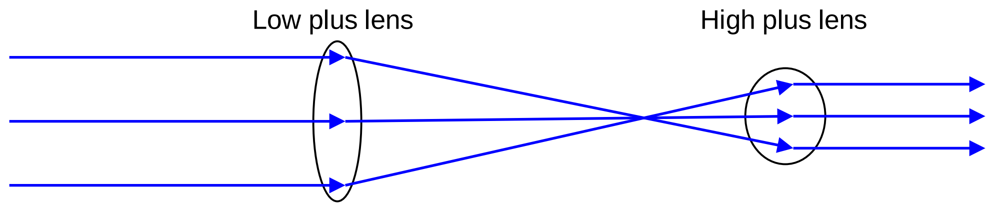
$$\frac{\text{Image distance } (v)}{\text{Object distance } (u)} = \infty/\infty = \mathbf{1.0}$$

In other words, no magnification at all!

Transverse Magnification

- In addition, consider the optics of an *afocal system* (e.g., a telescope)

Parallel rays ***from*** *an object at infinity*



Parallel rays ***to*** *an image at infinity*

Astronomical (Keplerian) telescope

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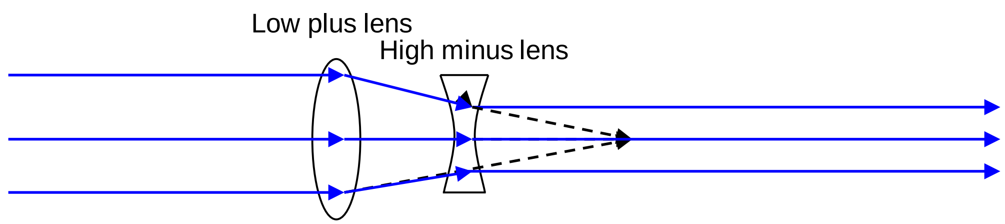


Parallel rays ***to*** *an image at infinity*

Galilean (terrestrial) telescope

So, for telescopes, the transverse magnification would seem to be:

$$\frac{\textit{Image distance (v)}}{\textit{Object distance (u)}} = \infty/\infty = 1.0$$

What good is a telescope that doesn't magnify?

Transverse Magnification

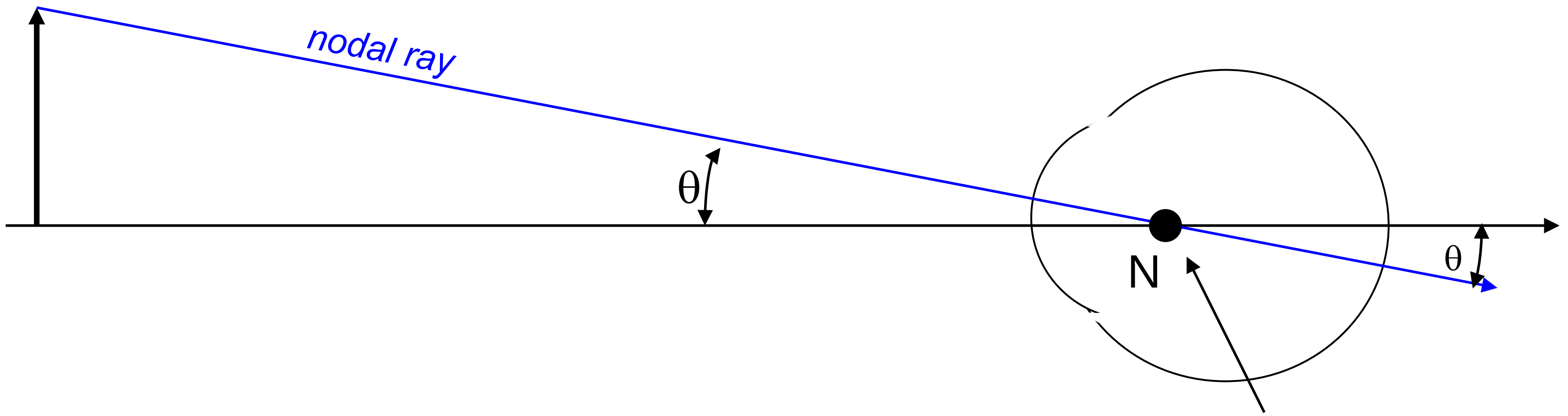
- Clearly, transverse mag cannot meet all our ‘magnification needs’
- We also need a measure that addresses the **apparent** sizes of objects and images, not just **actual** sizes

Angular Magnification

- Clearly, transverse mag cannot meet all our ‘magnification needs’
- We also need a measure that addresses the **apparent** sizes of objects and images, not just **actual** sizes
- That measure is ***angular magnification***
  - How big objects *look*, not how big they *are*

Angular Magnification

- *Angular size* is determined by the angular extent of retina an image subtenses (θ)



Just as in any other optical system, the *nodal point of the eye* determines image location when ray tracing

Angular Magnification

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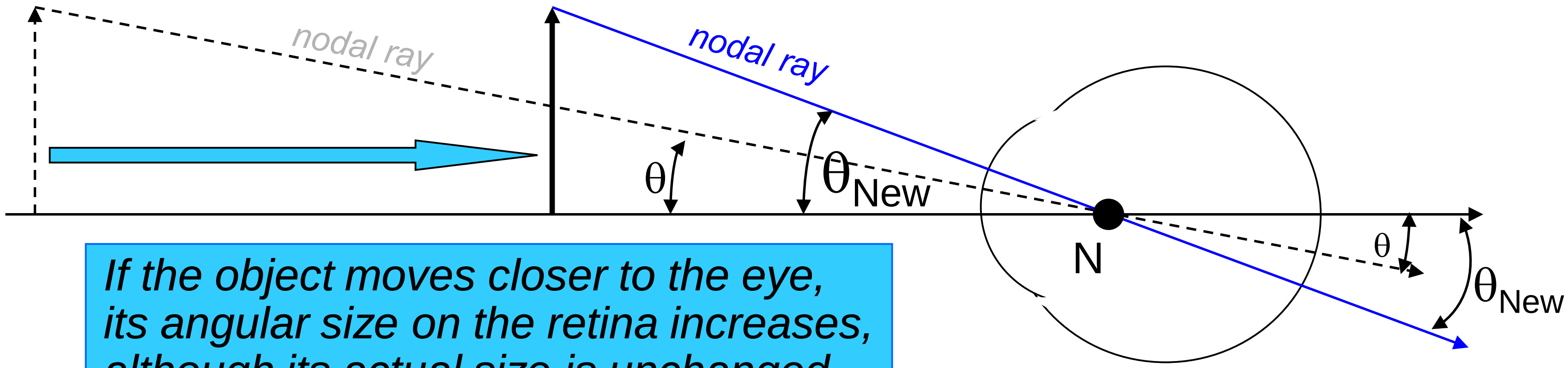

If the object moves closer to the eye, its angular size on the retina increases, although its actual size is unchanged

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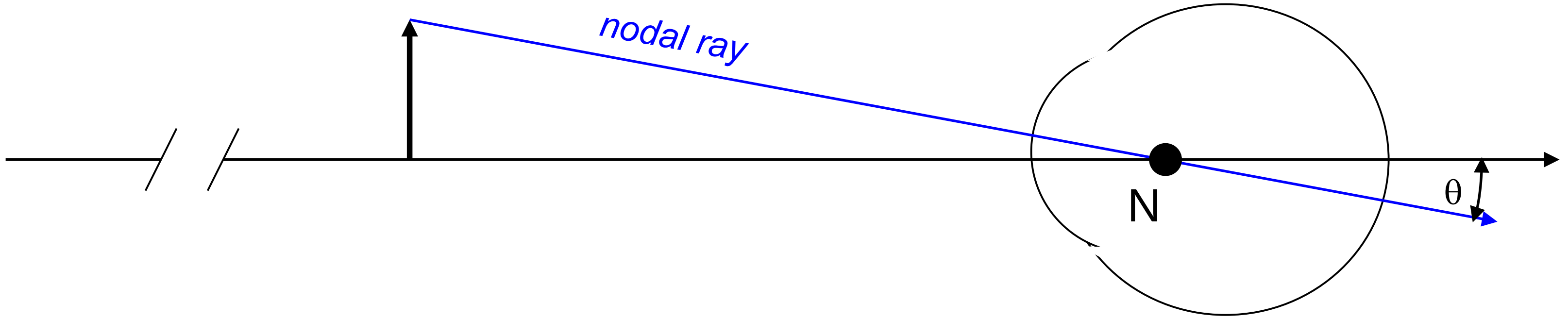

Consider this optical system…

Angular Magnification

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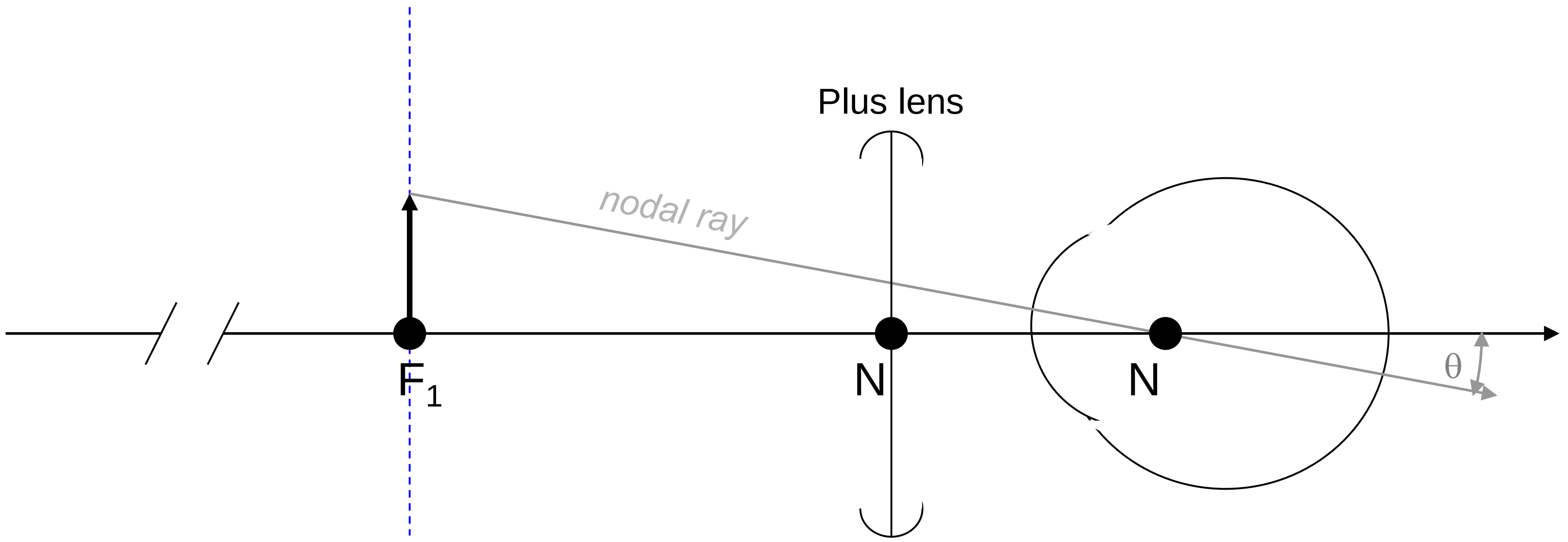


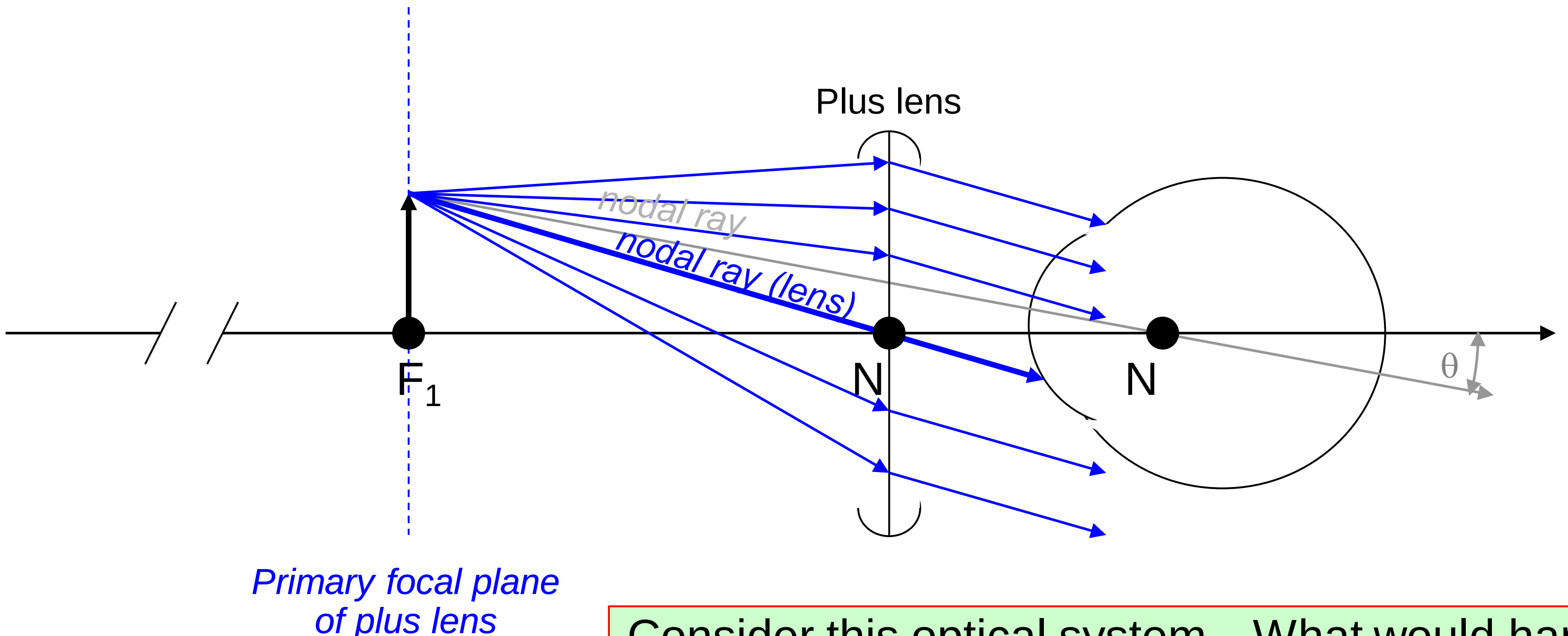
Primary focal plane of plus lens

Consider this optical system…What would happen if we inserted a plus lens such that the object was located at its primary focal plane?

Angular Magnification

- *Angular size* is determined by the angular extent of retina an image subtenses (θ)

All the rays will leave the lens parallel to the nodal ray, and…



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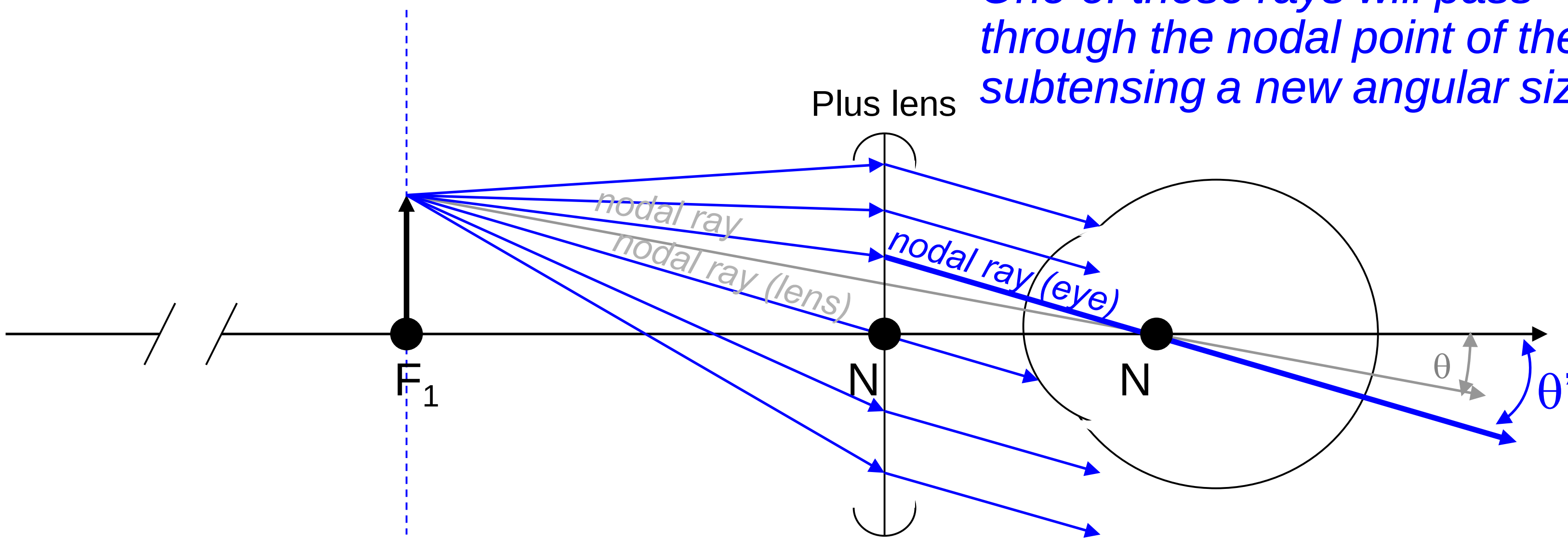
Angular Magnification

- *Angular size* is determined by the angular extent of retina an image subtenses (θ)

All the rays will leave the lens parallel to the nodal ray, and…

One of those rays will pass through the nodal point of the eye, subtensing a new angular size



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We can trace this ray back and see where a magnified virtual image is located

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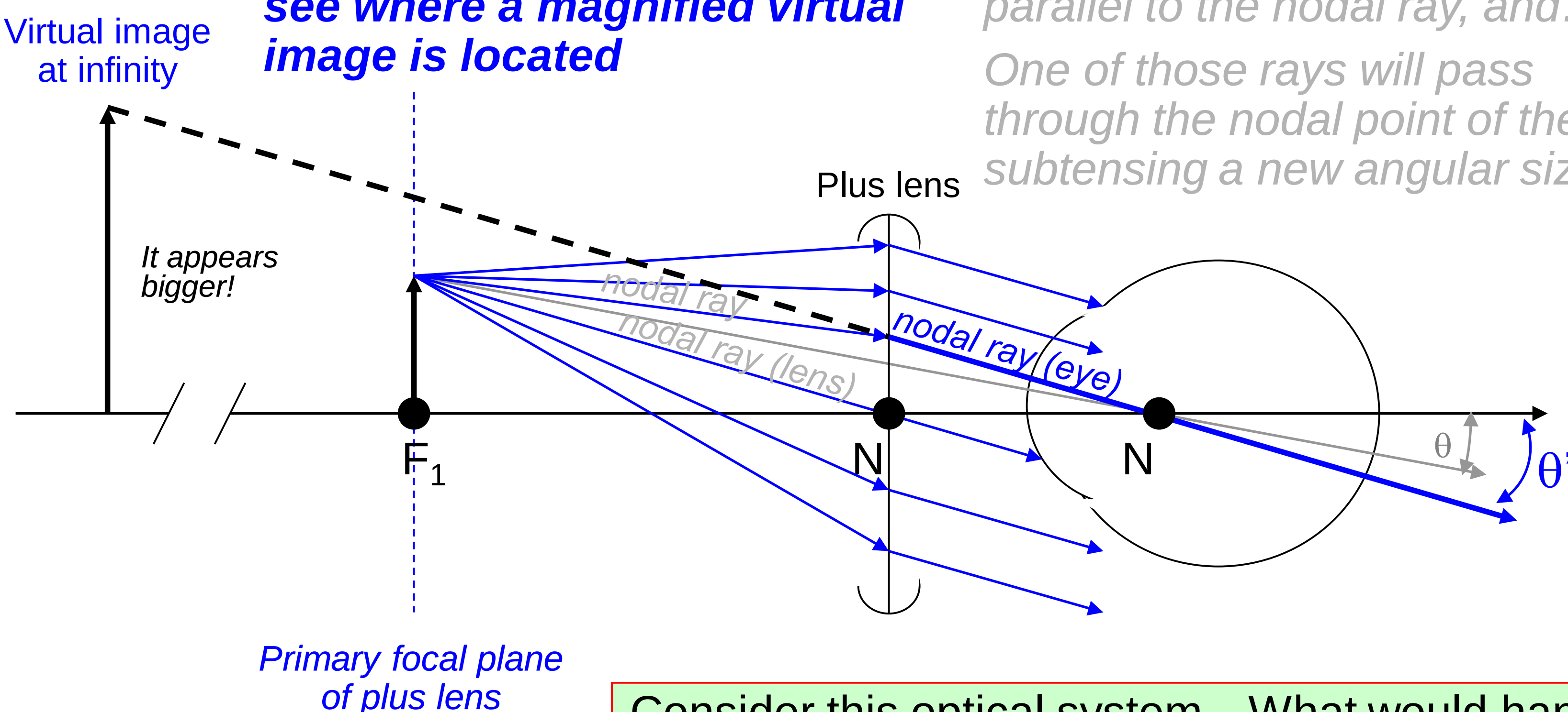

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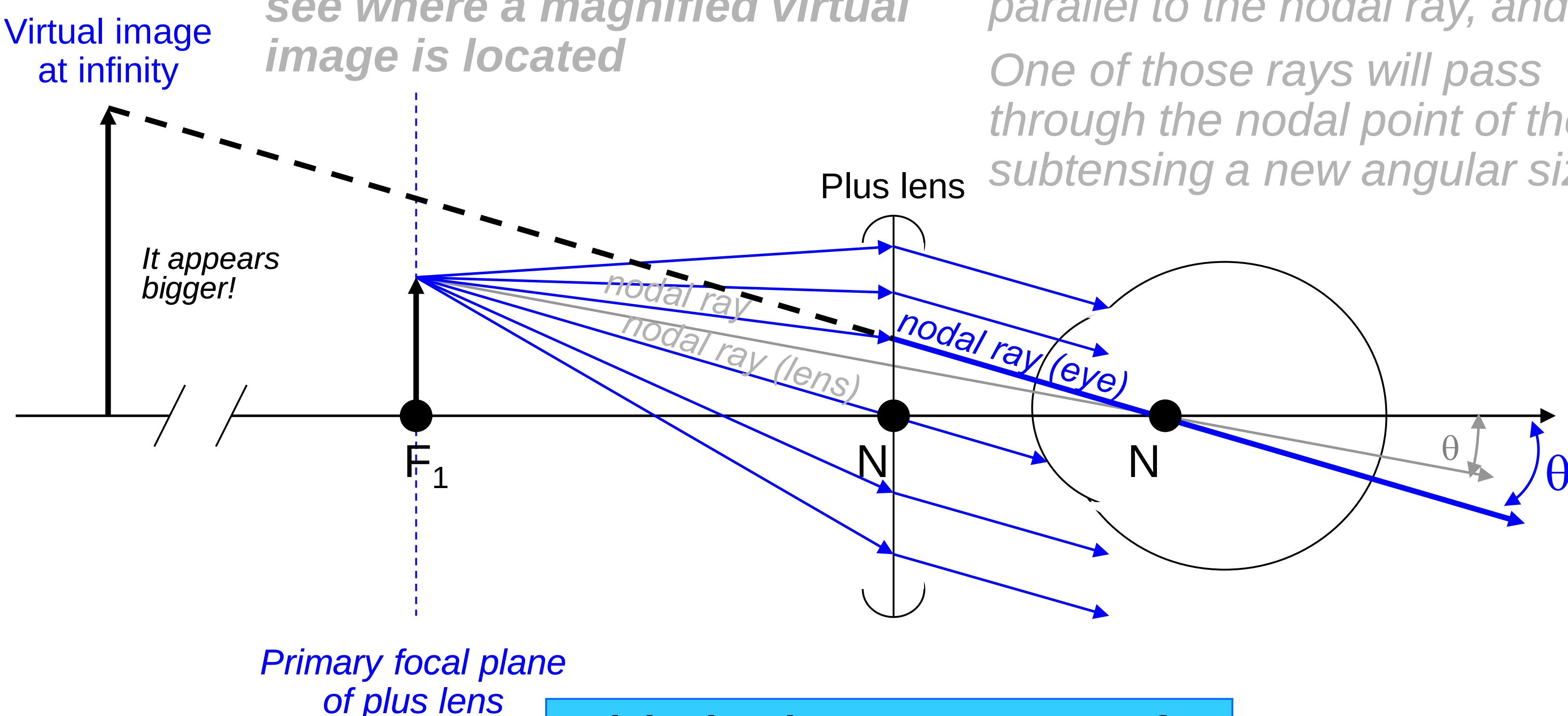
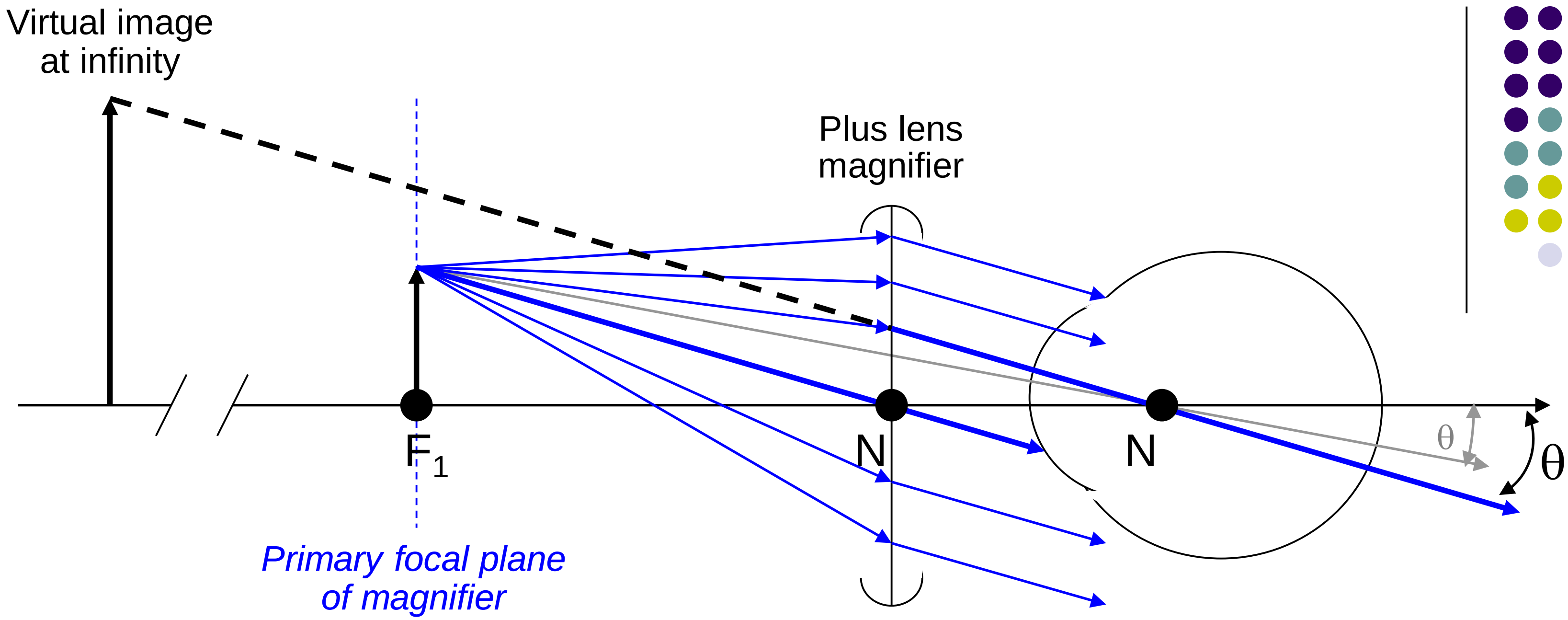
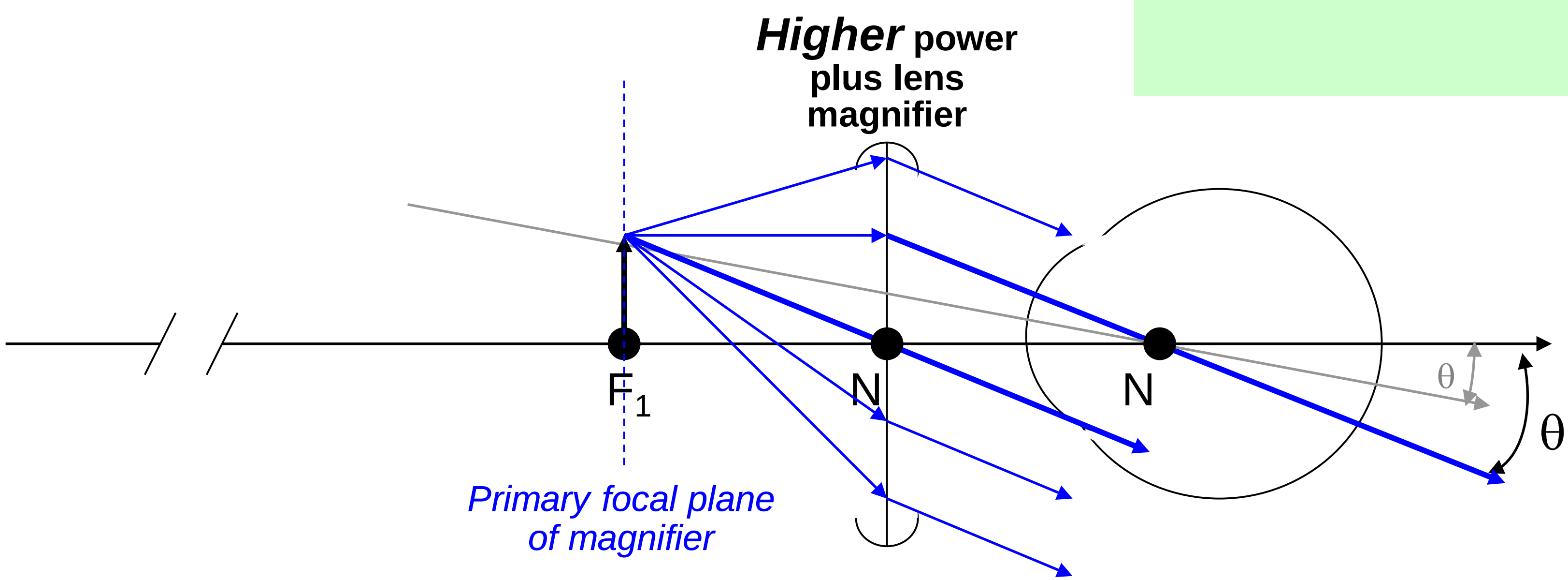
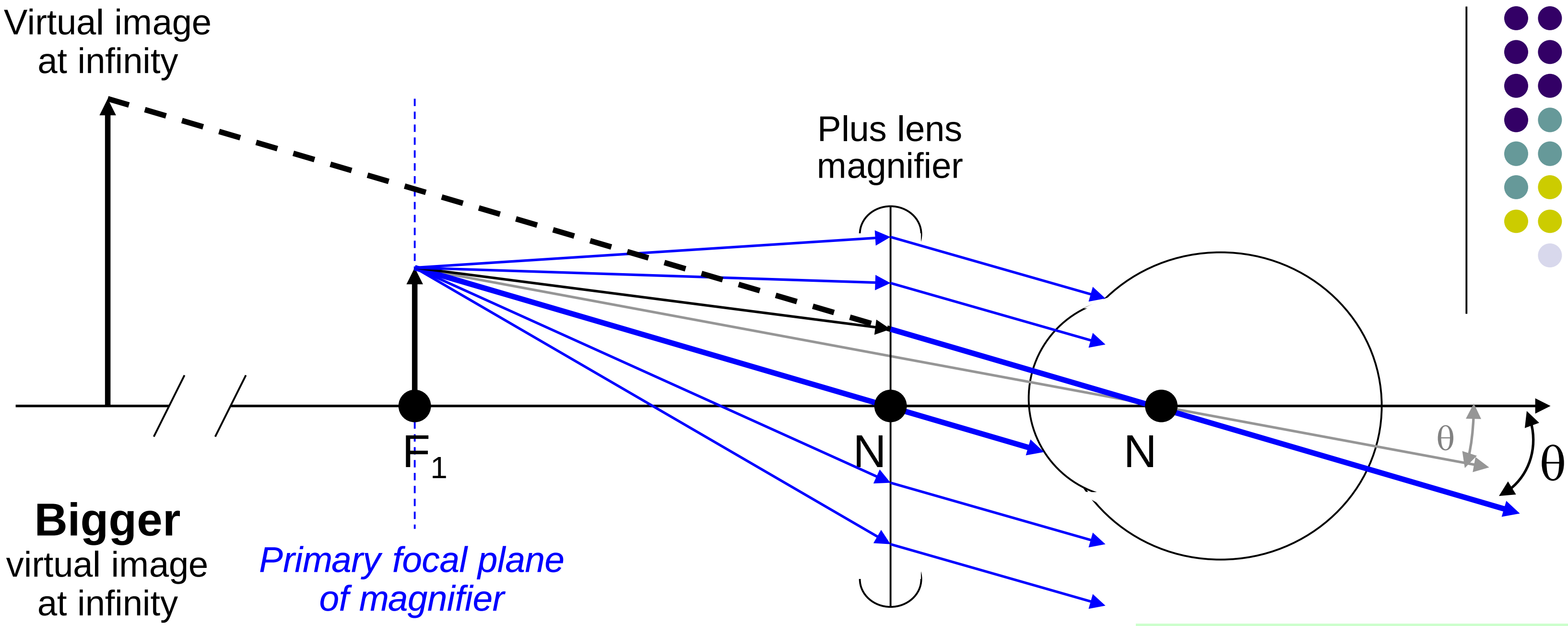


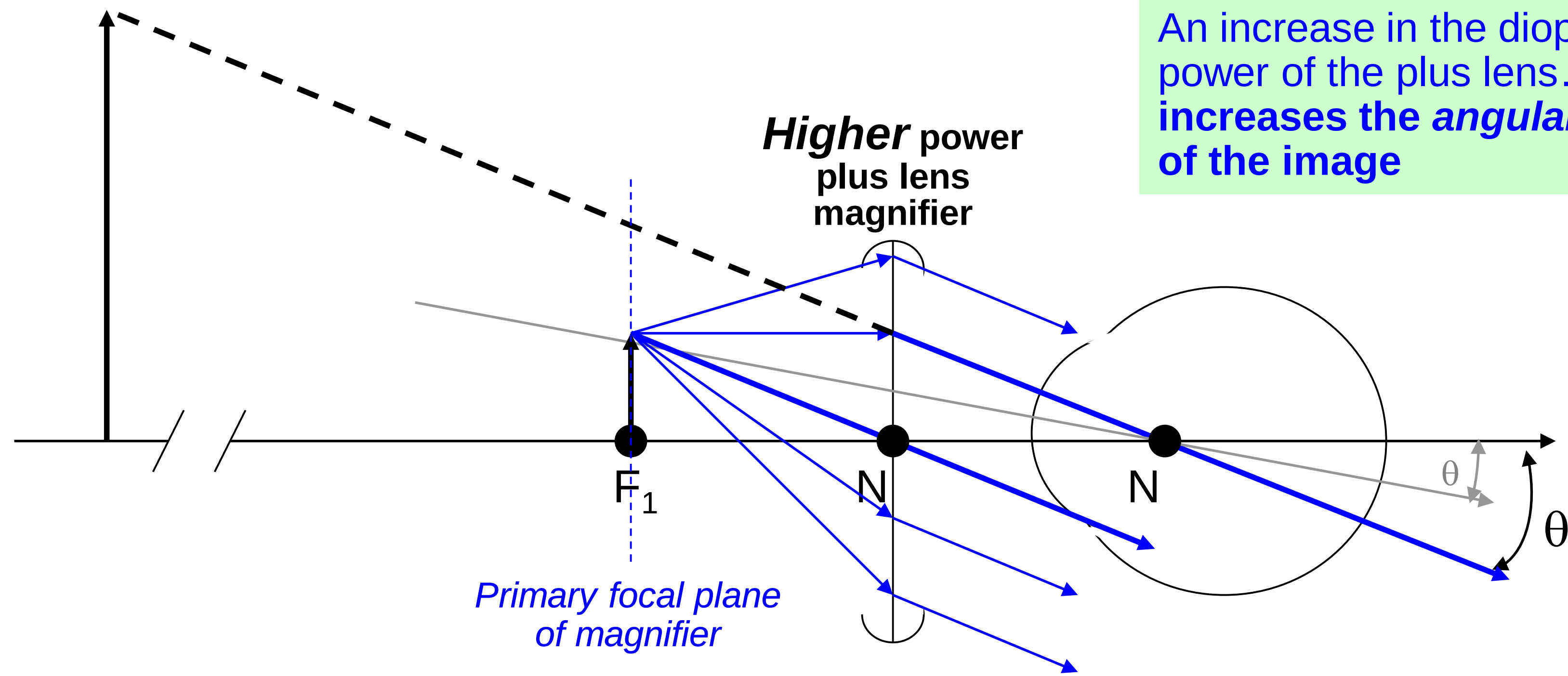
This is the essence of a ***simple magnifier***



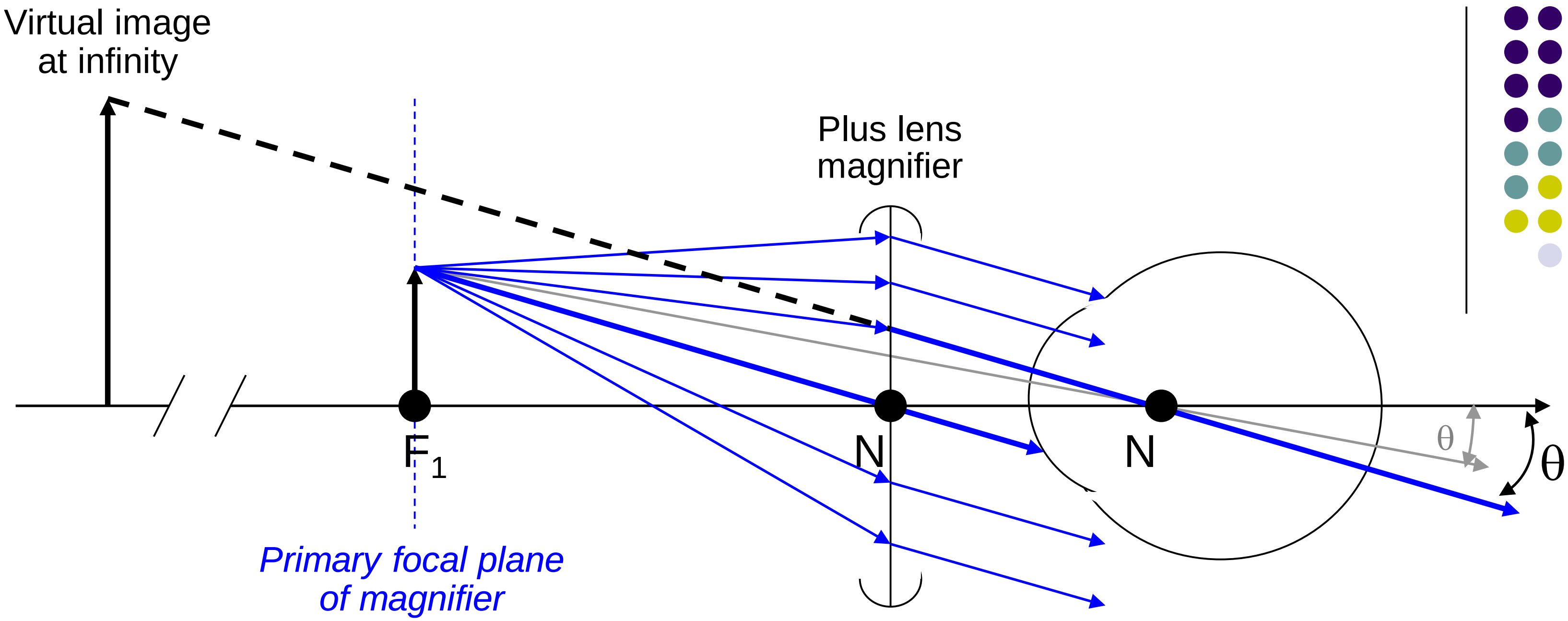
An increase in the dioptric power of the plus lens…

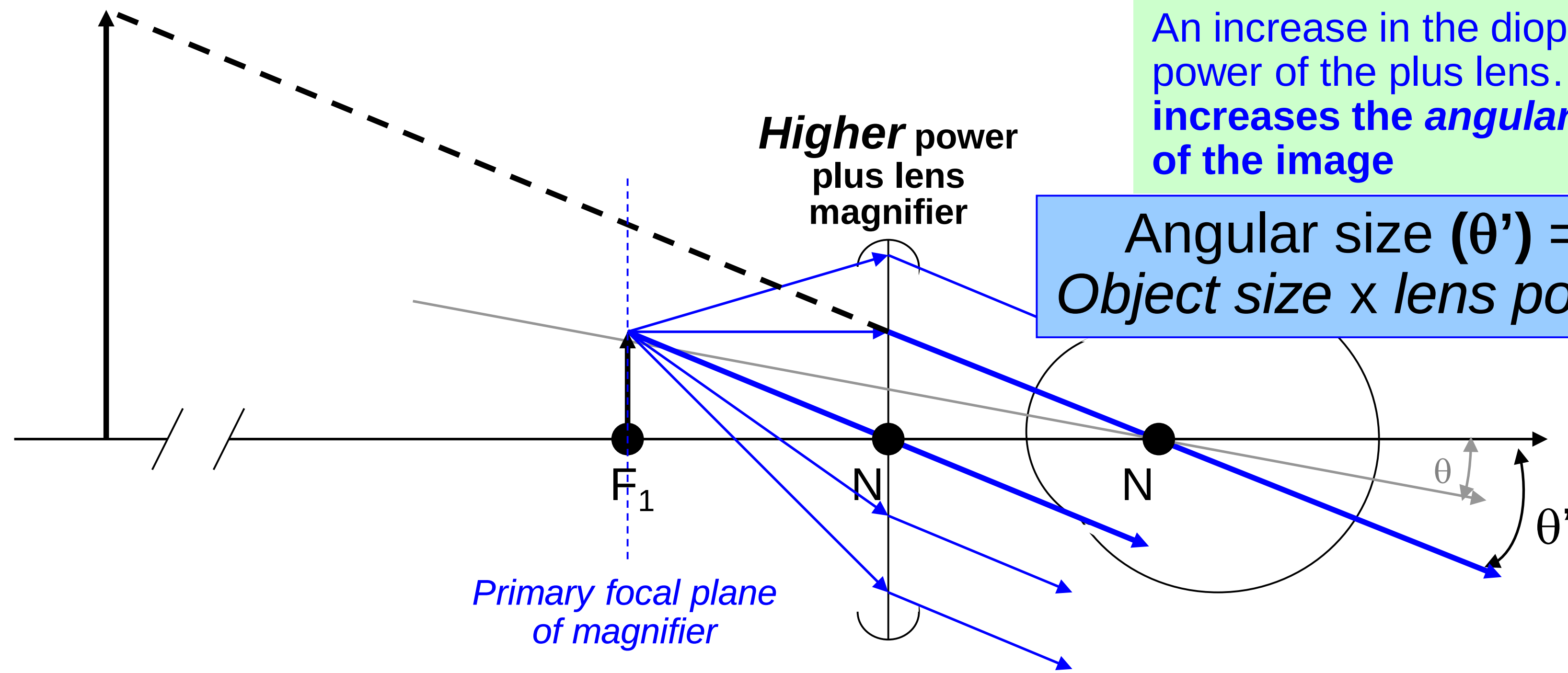






An increase in the dioptric power of the plus lens… **increases the *angular size* of the image**



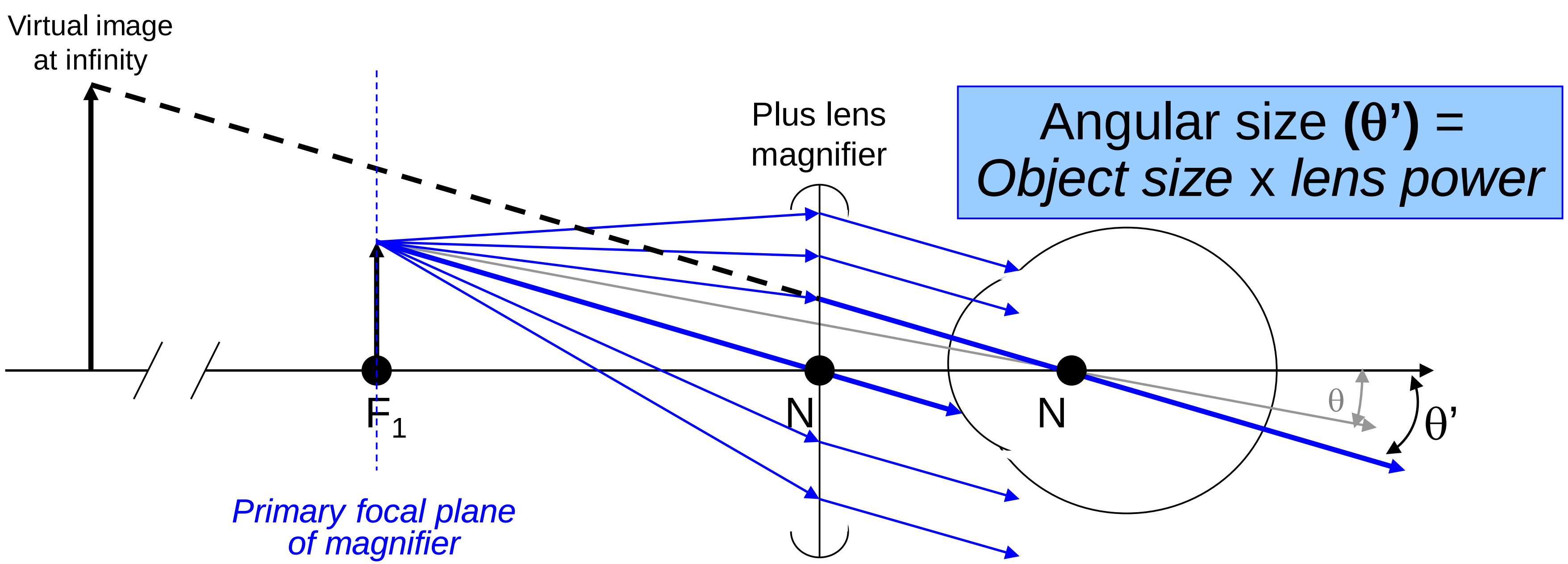


An increase in the dioptric power of the plus lens… **increases the *angular size* of the image**

Angular size **(θ’)** =
Object size x *lens power*

Angular Magnification

- So, angular size is determined by the angular extent of retina an image subtenses (θ)
  - Which, as we have just seen, is a function of object size and lens power

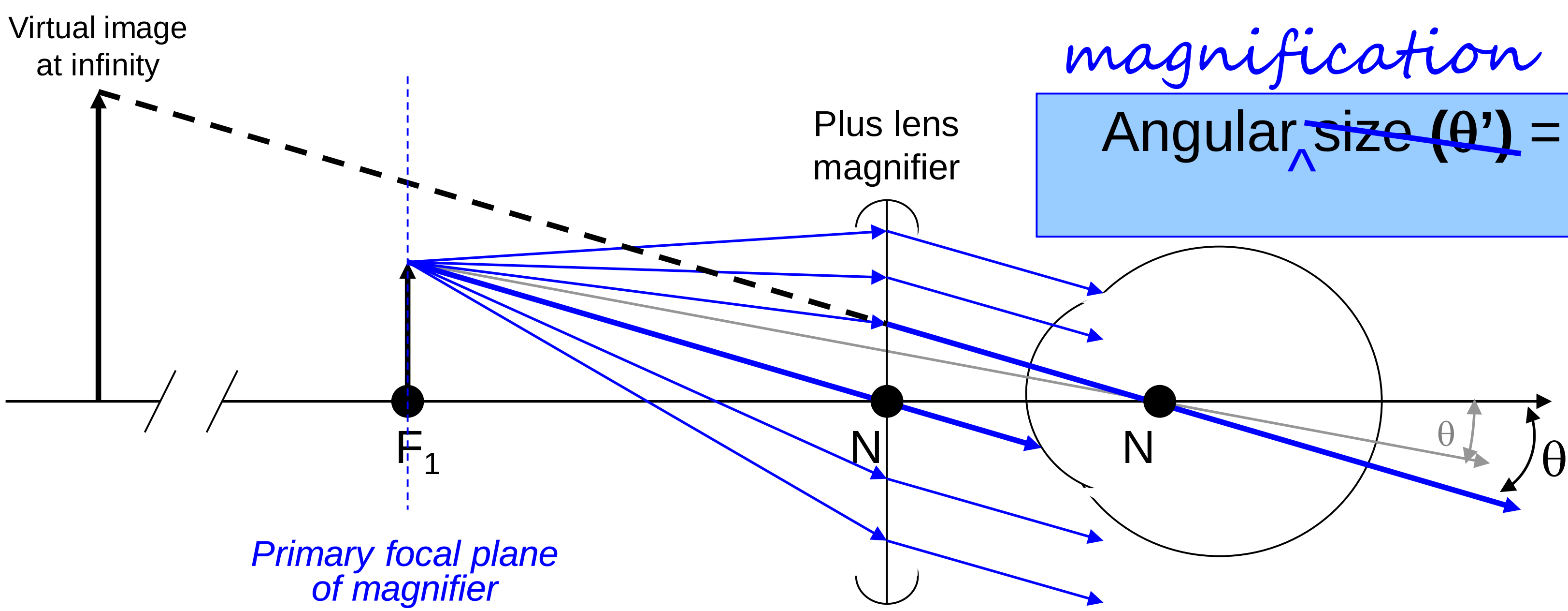


Angular Magnification

- But what about angular ***magnification***?

(Remember, size and magnification are not the same thing!)

Angular magnification ~~size **(θ')**~~ = ?

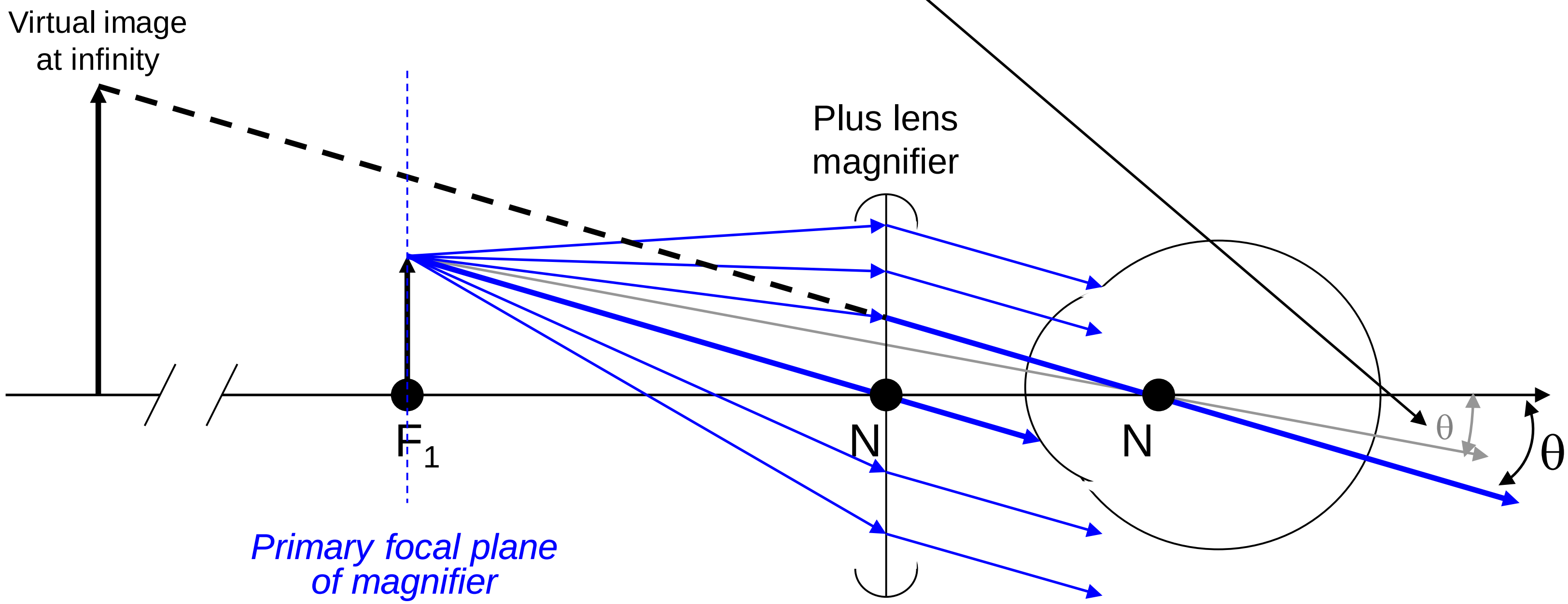


Angular Magnification

- But what about angular ***magnification***?
  - ‘Magnification’ is a relational term, i.e., the retinal image is bigger or smaller relative to *something*

Angular ***magnification*** = θ'/θ

***Unmagnified** retinal angular size*



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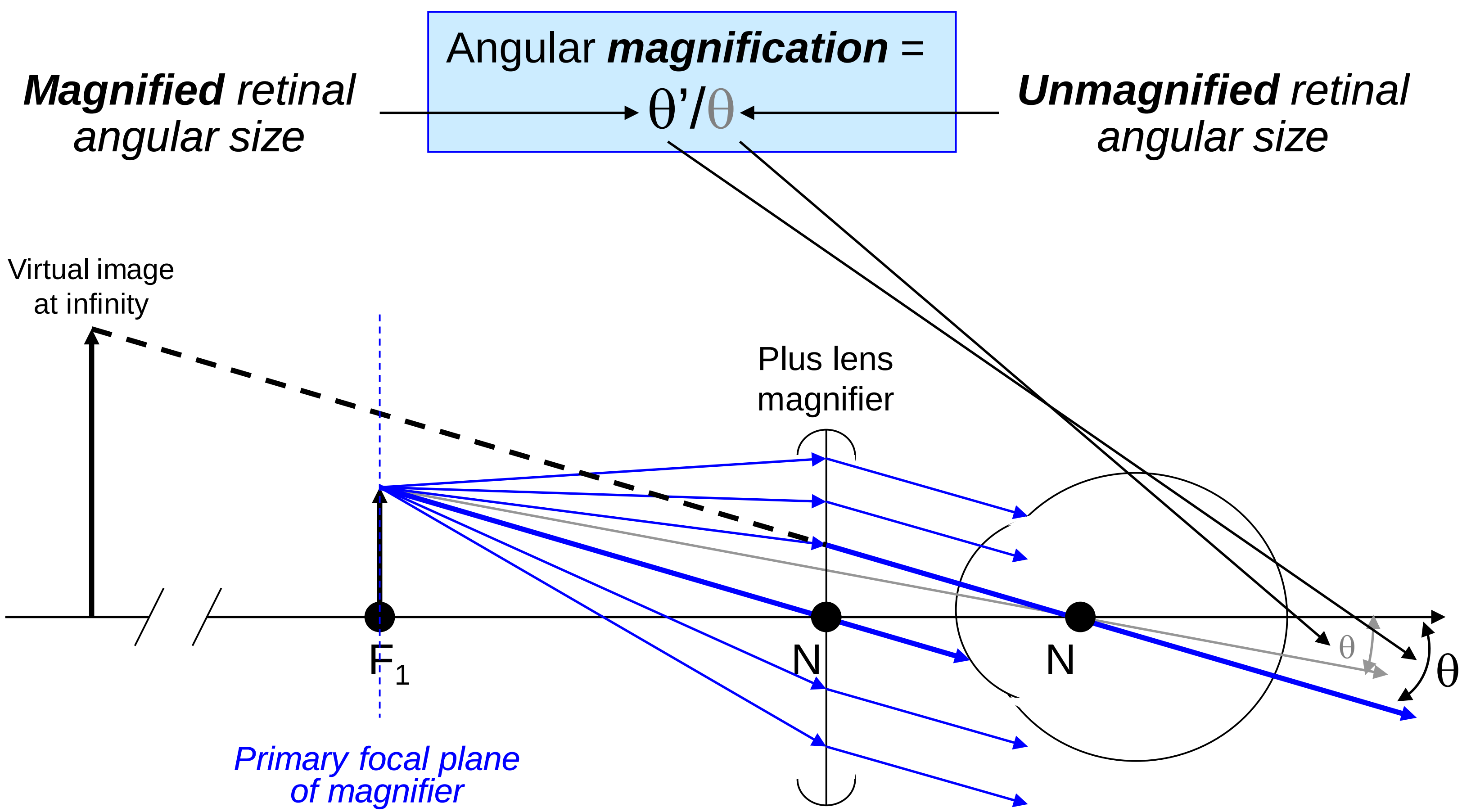

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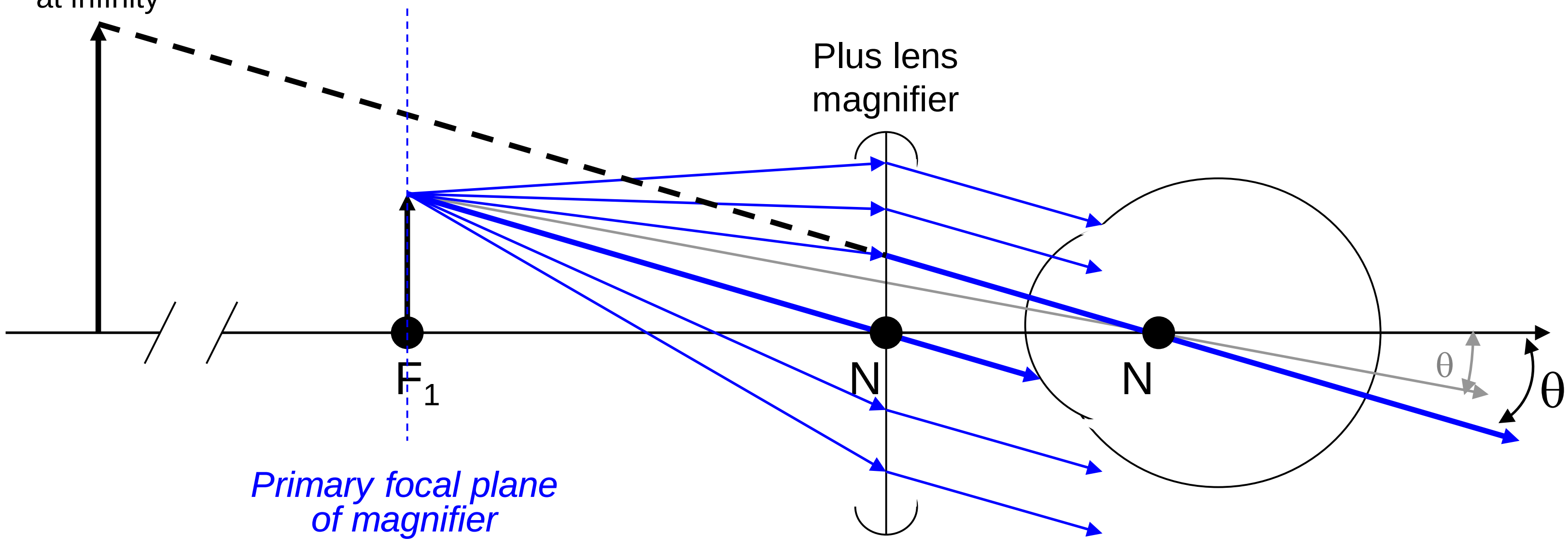
Magnified** retinal angular size* → Angular ***magnification = θ'/θ ← ***Unmagnified** retinal angular size*

But there’s a problem…



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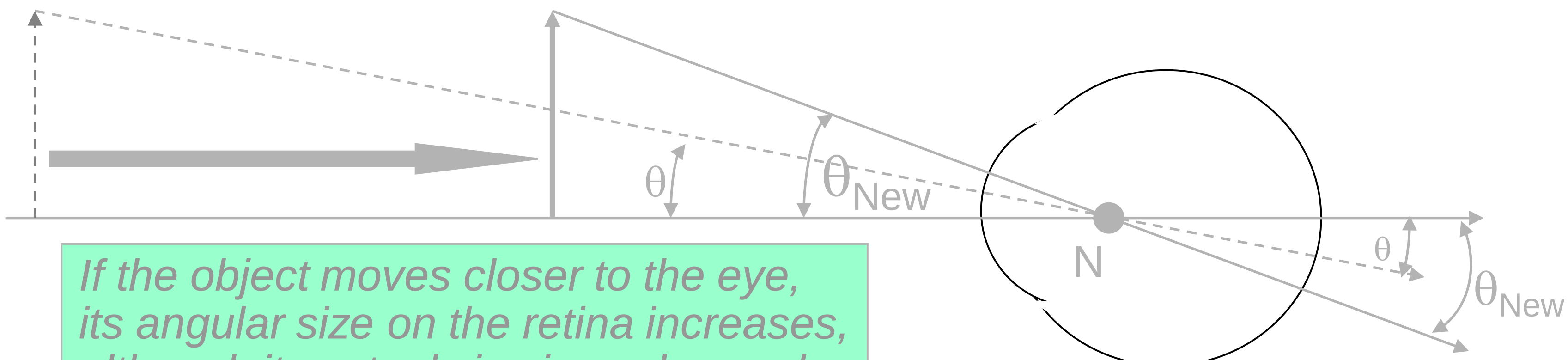


If the object moves closer to the eye, its angular size on the retina increases, although its actual size is unchanged

Recall this slide, where we saw that the angular size of an image also changes with the *distance* between the object and the retina

Angular Magnification

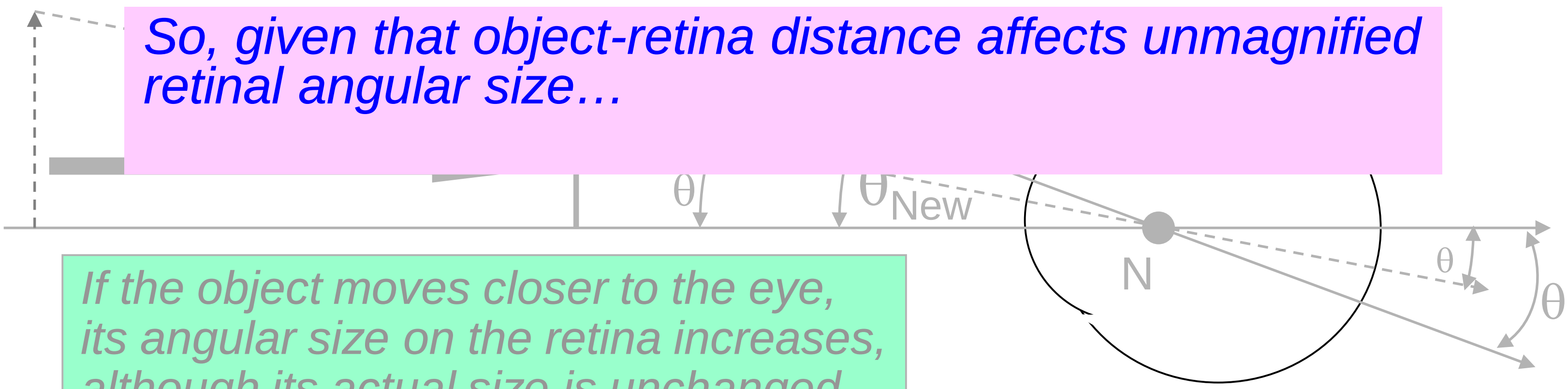
- But what about angular ***magnification***?
  - 'Magnification' is a relational term, i.e., the retinal image is bigger or smaller relative to *something*

Magnified *retinal angular size*

Angular ***magnification*** = θ'/θ

Unmagnified retinal angular size

So, given that object-retina distance affects unmagnified retinal angular size…



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Angular Magnification

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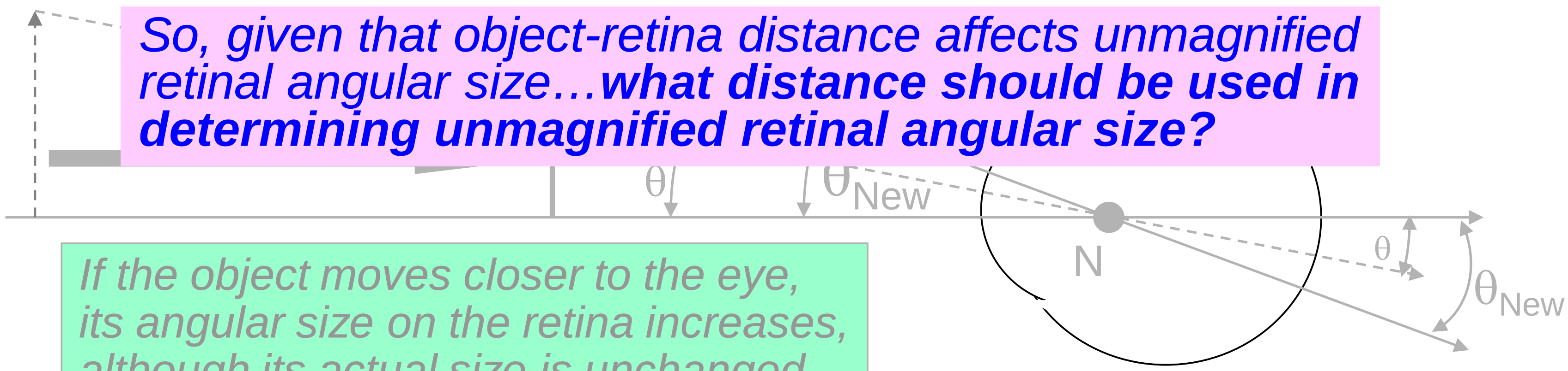
Magnified *retinal angular size*

Angular ***magnification*** = θ'/θ

Unmagnified retinal angular size

*So, given that object-retina distance affects unmagnified retinal angular size…**what distance should be used in determining unmagnified retinal angular size?***



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Angular Magnification

- To determine angular magnification, the object must be at a specific, arbitrary distance

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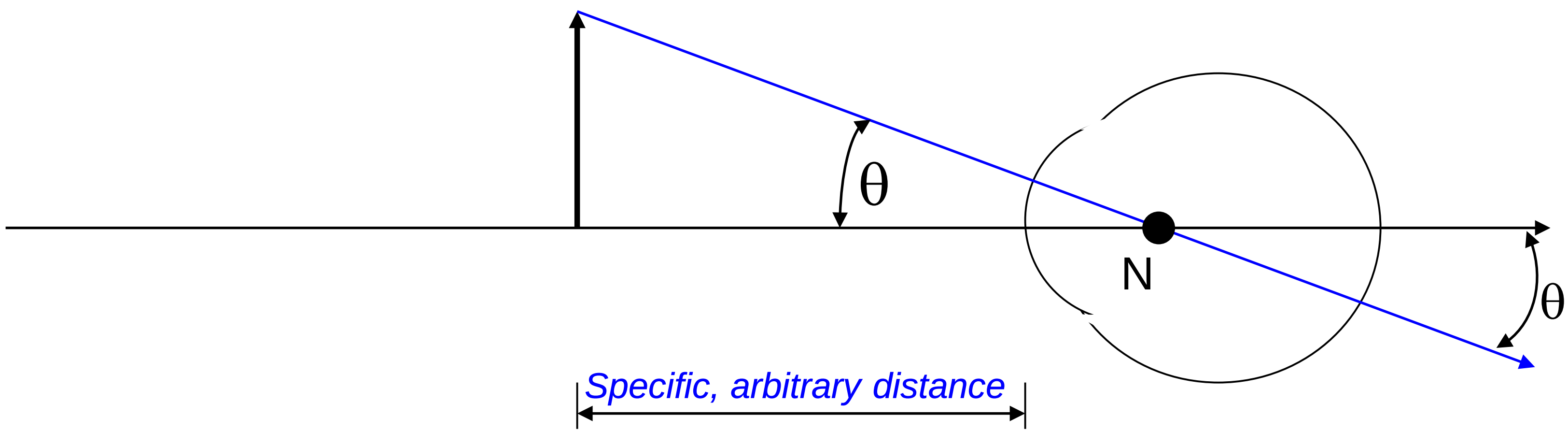
- To determine angular magnification, the object must be at a specific, arbitrary distance

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size*

Unmagnified *retinal angular size (at a specific, arbitrary distance)*



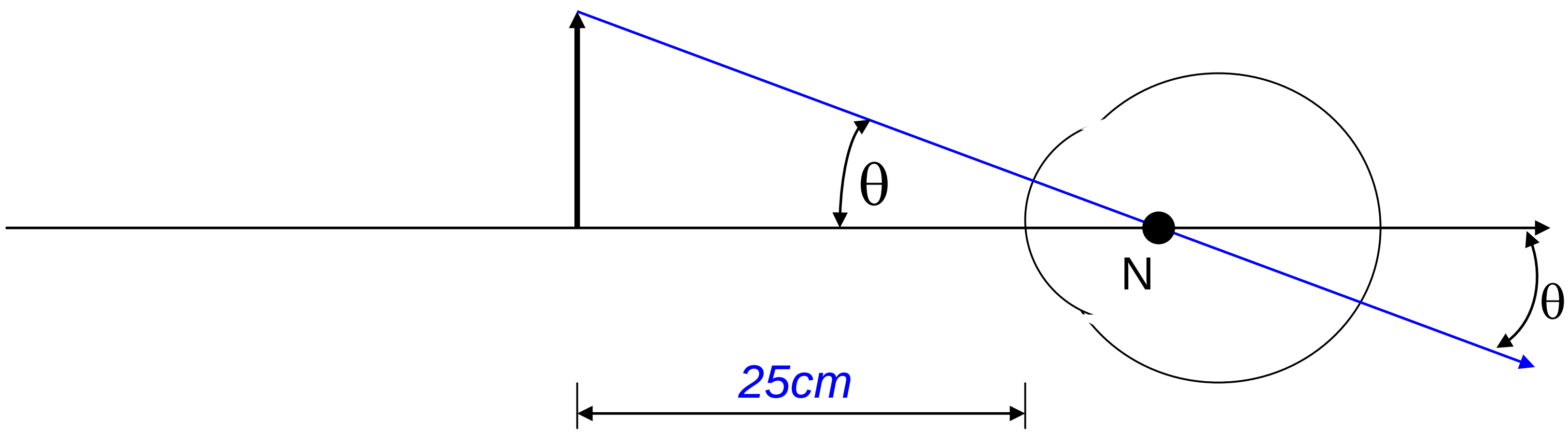
Angular Magnification

- To determine angular magnification, the object must be at a specific, arbitrary distance
  - **A reference distance of *25cm* is the standard**

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size* → θ'

Unmagnified *retinal angular size at 25cm* → θ



Angular Magnification

Magnified *retinal angular size*

Angular ***magnification*** =

θ'/θ

Unmagnified *retinal angular size at 25cm*

Angular Magnification

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size*

Unmagnified *retinal angular size at 25cm*

θ' = Object size x lens power

$\theta = \dfrac{\text{Object size}}{.25\text{m}}$

Angular Magnification

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size*

Unmagnified *retinal angular size at 25cm*

θ' = Object size x lens power

$\theta = \dfrac{\text{Object size}}{.25\text{m}}$

$$\frac{\text{Object size x lens power}}{\dfrac{\text{Object size}}{.25\text{m}}}$$

Angular Magnification

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size*

Unmagnified *retinal angular size at 25cm*

θ' = Object size x lens power

$$\frac{\cancel{\text{Object size}} \times \text{lens power}}{\cancel{\text{Object size}} \,/\, .25\text{m}}$$

$\theta = \frac{\text{Object size}}{.25\text{m}}$

Angular Magnification

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size*

Unmagnified *retinal angular size at 25cm*

θ' = Object size x lens power

$$\frac{\cancel{\text{Object size}} \text{ x lens power}}{\dfrac{\cancel{\text{Object size}}}{.25\text{m}}}$$

$\theta = \dfrac{\text{Object size}}{.25\text{m}}$

= lens power x .25m

Angular Magnification

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size*

Unmagnified *retinal angular size at 25cm*

θ' = Object size x lens power

$\theta = \dfrac{\text{Object size}}{.25\text{m}}$

$$\frac{\cancel{\text{Object size}} \text{ x lens power}}{\dfrac{\cancel{\text{Object size}}}{.25\text{m}}}$$

= lens power x .25m

$$= \boldsymbol{\frac{\textit{lens power}}{4}}$$

Angular Magnification

Angular ***magnification*** = θ'/θ

Magnified *retinal angular size*

Unmagnified *retinal angular size at 25cm*

θ' = Object size x lens power

$\theta = \dfrac{\text{Object size}}{.25\text{m}}$

$$\frac{\cancel{\text{Object}}\text{ size x lens power}}{\dfrac{\cancel{\text{Object size}}}{.25\text{m}}}$$

= lens power x .25m

$$= \boldsymbol{\frac{\textit{lens power}}{4}}$$

So, e.g., a 20D lens is a 20/4 = ***5x magnifier***