# ASTR3010 – FOV Measurements

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## Contents



## 1 Results

$FOV_{\text{Eyepiece 1}} = 12,492\,'' = 208.2\,'$

Pixel $\text{Scale}_{E1} \approx 1.55\,\frac{arcsec}{pixel}$

$FOV_{\text{Eyepiece 2}} = 2,412\,'' = 40.2\,'$

Pixel $\text{Scale}_{E2} \approx 0.30\,\frac{arcsec}{pixel}$

$FOV_{\text{Eyepiece 3}} = 17,100\,'' = 285\,'$

Pixel $\text{Scale}_{E3} \approx 2.12\,\frac{arcsec}{pixel}$

## 2 Assignment

We seek to compute the combined Field of View (FOV) of the Celestron FirstScope Telescope alongside various interchangeable eyepieces (a 4mm eyepiece, a 20mm eyepiece, and a 23mm wide-angle eyepiece) as well as a smartphone (iPhone 14 Pro) camera. We also seek to compute the pixel scaling of images captured with this setup in arcseconds per pixel.

All measurement data is sourced from respective equipment manufacturers' websites.

## 3 Formulas

There are a few formulas we must consider when computing the True FOV of the Telescope-Eyepiece-Smartphone setup.

To compute the true FOV of a telescope and eyepiece, we must divide the apparent FOV of the eyepiece by the combined magnification of the telescope and the eyepiece:

$$\text{FOV}_{true} = \frac{\text{FOV}_{apparent}}{m_{net}}$$

To compute the combined magnification of a telescope and eyepiece, we must divide the focal length of the telescope by the focal length of the eyepiece:

$$m_{net} = \frac{f_{telescope}}{f_{eyepiece}}$$

To compute the FOV of a camera, we must consider the horizontal dimensions of the camera's sensor in addition to its focal length:

$$\text{FOV}_{camera} = 2 \cdot \arctan\left(\frac{H}{2f_{camera}}\right) = 2 \cdot \arctan\left(\frac{\sqrt{x^2\ \text{mm} + y^2\ \text{mm}}}{2f_{camera}}\right)$$

To compute the combined Telescope-Eyepiece-Smartphone FOV, we must divide the true FOV by the magnification of the smartphone camera setup:

$$\text{FOV}_{effective} = \frac{\text{FOV}_{true}}{m_{camera}}$$

To convert FOV measurements from degrees to arcseconds, we must use the conversion from 1 degree to 3600 arcseconds:

$$\text{FOV}_{arcsec} = \text{FOV}_{deg} \cdot 3600$$

To convert FOV measurements from arcseconds to arcminutes, we must use the conversion from 1 arcminute to 60 arcseconds:

$$\text{FOV}_{arcmin} = \frac{\text{FOV}_{arcsec}}{60}$$

Lastly, to compute the pixel scaling in arcseconds per pixel, we must evaluate:

$$\text{Pixel Scaling} = \frac{\text{FOV}_{effective,\, arcsec}}{\text{horizontal pixels across camera sensor}}$$

# 4 Equipment & Measurements

## 4.1 Celestron FirstScope Telescope

The Celestron FirstScope Telescope is an entry-level reflector telescope with a 76mm optical tube and a tabletop Dobsonian-style mount.

$f_{telescope} = 300mm$

## 4.2 Eyepiece 1

The first eyepiece the Celestron FirstScope comes equipped with is a 20mm Symmetrical Ramsden eyepiece.

$f_{E1} = 20mm$

$m_{E1} = 15x$

$\text{FOV}_{\text{apparent, E,1}} = 52°$

## 4.3 Eyepiece 2

The second eyepiece the Celestron FirstScope comes with is a 4mm Symmetrical Ramsden eyepiece.

$f_{E2} = 4mm$

$m_{E2} = 75x$

$\text{FOV}_{\text{apparent, E2}} = 50°$

## 4.4 Eyepiece 3

The third eyepiece being evaluated is a 23mm Wide-Angle Aspheric eyepiece manufactured by *SVBONY*. I purchased this eyepiece to evaluate whether or not a Wide-Angle eyepiece would make photography with a smartphone easier at detriment to image quality and magnification.

$f_{E3} = 23mm$

$\text{FOV}_{\text{apparent, E3}} = 62°$

### 4.5 iPhone 14 Pro Main Camera Lens

$f_{camera} = 24mm$

$m_{camera} = 1x$

The iPhone 14 Pro has a 48 MegaPixel type $\frac{1}{1.28}$ (9.8mm x 7.3mm) camera sensor.

$\therefore\ \text{FOV}_{camera} = 2 \cdot \arctan\left(\frac{\sqrt{9.8^2+7.3^2}}{2\cdot 24}\right) \approx 28.57°$

## 5 Computation

### 5.1 Eyepiece 1

We must first compute the true FOV of the Celestron FirstScope and our 20mm eyepiece (*Eyepiece 1*).

$$m_{net} = \frac{f_{telescope}}{f_{E1}} = \frac{300mm}{20mm} = 15x$$

$$\therefore \text{FOV}_{\text{true, E1}} = \frac{\text{FOV}_{\text{apparent, E1}}}{m_{net}} = \frac{52°}{15} = 3.47°$$

Next, we must evaluate the effective FOV based on smartphone camera parameters:

$$\text{FOV}_{\text{effective, E1}} = \frac{\text{FOV}_{\text{true, E1}}}{m_{camera}} = 3.47°$$

Converting this value to arcseconds, we compute:

$$\text{FOV}_{\text{effective, E1, arcsec}} = 3.47° \cdot 3600\, \frac{arcsec}{deg} \approx 12,492\,''$$

Converting this value to arcminutes, we compute:

$$\text{FOV}_{\text{effective, E1, arcmin}} = \frac{12,492\,''}{60} = 208.2\,'$$

Lastly, we must find the pixel scaling. To do this, we need the number of horizontal pixels across our camera sensor based on the 48 MegaPixel capacity of the camera and the assumption of a 4:3 Aspect Ratio:

$$\text{Pixel Scaling}_{E1} = \frac{\text{FOV}_{\text{effective, E1, arcsec}}}{\text{horizontal pixels across camera sensor}}$$

$$= \frac{12,492\,''}{\sqrt{\frac{48{,}000{,}000\cdot 4}{3}} \cdot \frac{4}{\sqrt{4^2+3^2}}} = \frac{12,492\,''}{8,064px} \approx 1.55\,\frac{arcsec}{pixel}$$

□

## 5.2 Eyepiece 2

Repeating the same process for our 4mm eyepiece (*Eyepiece 2*).

$$m_{net} = \frac{f_{telescope}}{f_{E,2}} = \frac{300mm}{4mm} = 75x$$

$$\therefore \text{FOV}_{\text{true, E2}} = \frac{\text{FOV}_{\text{apparent, E2}}}{m_{net}} = \frac{50^\circ}{75} = \frac{2}{3}^\circ = 0.6^\circ$$

Evaluating the effective FOV based on smartphone camera parameters:

$$\text{FOV}_{\text{effective, E2}} = \frac{\text{FOV}_{\text{true, E2}}}{m_{camera}} = 0.6^\circ$$

Converting this value to arcseconds:

$$\text{FOV}_{\text{effective, E2, arcsec}} = 0.6^\circ \cdot 3600\,\frac{arcsec}{deg} \approx 2,412\,''$$

Converting this value to arcminutes, we compute:

$$\text{FOV}_{\text{effective, E2, arcmin}} = \frac{2,412\,''}{60} = 40.2\,'$$

Finding Pixel Scaling based on the same horizontal pixel value:

$$\text{Pixel Scaling}_{E2} = \frac{\text{FOV}_{\text{effective, E2, arcsec}}}{\text{horizontal pixels across camera sensor}} = \frac{2,412\,''}{8,064px} \approx 0.30\frac{arcsec}{pixel}$$

□

## 5.3 Eyepiece 3

Repeating the above for our 23mm eyepiece (*Eyepiece 3*).

$$m_{net} = \frac{f_{telescope}}{f_{E3}} = \frac{300mm}{23mm} \approx 13x$$

$$\therefore \text{FOV}_{\text{true, E3}} = \frac{\text{FOV}_{\text{apparent, E3}}}{m_{net}} = \frac{62°}{\frac{300}{23}} = \frac{713}{150}^{\circ} \approx 4.75°$$

Evaluating the effective FOV based on smartphone camera parameters:

$$\text{FOV}_{\text{effective, E3}} = \frac{\text{FOV}_{\text{true, E3}}}{m_{camera}} = 4.75°$$

Converting this value to arcseconds:

$$\text{FOV}_{\text{effective, E3, arcsec}} = 4.75° \cdot 3600\,\frac{arcsec}{deg} \approx 17,100\,''$$

Converting this value to arcminutes, we compute:

$$\text{FOV}_{\text{effective, E3, arcmin}} = \frac{17,100\,''}{60} = 285\,'$$

Finding Pixel Scaling based on the same horizontal pixel value:

$$\text{Pixel Scaling}_{E2} = \frac{\text{FOV}_{\text{effective, E2, arcsec}}}{\text{horizontal pixels across camera sensor}} = \frac{17,100\,''}{8,064px} \approx 2.12\frac{arcsec}{pixel}$$

$\square$