Applying WCS Coordinates to M29

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In this lab we achieved in applying a coordinate system to images of open galactic cluster M29. By using a reference DSS image, we used Koords, SAO ds9, and AstroImageJ to calculate, align, and apply the WCS coordinate system. From this we calculated the pixel scale to be 1.165(27) ″/p for each axis. We also matched 16 stars to the Tycho-2 catalog. We composed an RGB image using our B, V, and I filter images but it was inaccurate due to inconsistencies in the sharpness of the images.

I. INTRODUCTION

The goals of this lab were to apply WCS coordinates to FITS images of M29 and then compose and RGB image using the B, V, and I filtered photos aligned with the coordinate system. M29 is an open galactic cluster about 1.1 kpc away from our system and approximately 10 Myr old. It contains at least 50 stars and is located about 1.7° from Sadr[1].

The benefit of having a coordinate system applied to the image allows much more research flexibility. With a known position it is possible to automatically find stars from a catalog. It is also useful to be able to align and rotate images to show celestial North and East correctly. It is also great for stacking photos that have all been aligned.

RGB images are great for visually seeing the color of stars. This is great for categorizing stars according to their spectral type. Generally, the hotter the star, the bluer it is visually.

II. DATA ACQUISITION AND SETUP

Observations were made on at the Zaffarano Hall observation deck in Ames, Iowa (−93.647 34°, 42.029 96°, 342 m). The night was mostly clear and the ambient temperature was around 12 °C. The moon was waning that night and had little to no effect on our sight. Observations were made using a Meade 8” reflector telescope with an SBIG ST-402ME CCD camera with internal V, B, and I filters.

Setting up the telescope was the same as previous observations made with the 8” Meade telescope at Zaffarano Hall. We took 15 images of M29, five in each photometric filter from B, V, and I. We used a 20 s exposure for all the images in addition to five dark frames. Getting sharp images was difficult in our observations due to the long exposure time. We needed such long times due to the vaintness of the stars in the cluster, but ambient vibrations on the deck as well as the drift of the equatorial mount caused blurriness and sometimes streaking.

III. DATA ANALYSIS

To process each image, we used AstroIamgeJ’s data reduction facility to create the median dark frame and subtract it from each image. For more information, see our lab report regarding Albireo and its analysis.

A. Calculating and Applying Coordinate System

To apply our coordinate system, we used the program Koords, which calculates the orientation of an image and then maps the coordinate system onto it using a reference image with the coordinates already applied. Koords accomplishes this by pairing the objects in both the reference and target images for at least three objects and then triangulating the orientation. The reference image we used is shown in Figure 2a.

Examples of our corrected images are in Figure 3a, Figure 3b, and Figure 3c. Koords automatically rewrites the FITS headers to describe their alignment correction factors and the pixel scales with keywords ‘CDELT1’ and ‘CDELT2’. Listing C parses this information from every corrected image and reports the 95% confidence interval for the pixel scale in the x and y directions of the image.

B. Catalog Analysis

Using SAO ds9 we analyzed the image for its stars using the Tycho-2 catalog. In order to get the spectral class for these stars, we had to do a similar analysis using the SIMBAD catalog and match those results with the Tycho-2 results.

C. Alignment and RGB Composition

Lastly, we stacked our sharpest B, V, and I images to compose an RGB photo of M29. To align our images we used AstroImageJ which aligned all of our WCS corrected images and saved them as new files. Of these we choose our best from each filter and loaded them into Adobe Photoshop CC. NASA has an automation script[2]. for preparing the filter layers of our image. Although we could have done this in ds9 or AstroImageJ, we felt like we had the most control and ease of use with Photoshop.

The method in which Photoshop composes the image is by applying adjustments to each layer in the file. The adjustment layers made were hue, curve, and levels. Hue adjustment gave the layers their red, green, or blue tone. We used the B image for our blue layer, the V image for our green layer, and the I image for our red layer. The curve adjustment is similar to applying a logorithmic or arcsine scale but instead allows adjusting the curve by grabbing and stretching it. We did not adjust this layer, which left us using a linear scale. The levels layer is the same as the scale adjustment in ds9 or AIJ. For each layer we played with the levels until we achieved fairly white stars and a fairly black background.

IV. RESULTS

Our 95% confidence interval for the image scale in the x-direction (axis 1) was 1.165(27) ″/p and 1.165(27) ″/p in the y-direction (axis 2). The map of the results of the Tycho-2 catalog analysis are in Figure 4 and their corresponding information is in Table II. Note that we had to remove some entries for the Tycho-2 analysis because they appeared physically outside of our image. The aligned B, V, and I images are shown in Figure 3a, Figure 3b, and Figure 3c. Our RGB composed image is in Figure 2b.

V. CONCLUSIONS

In our report on Albireo we calculated the pixel scale using the angular separation of the stars and received 1.0072(91) ″/p. That is similar to our result, with a difference of 15.7%. We conclude the differences can be due to uncertainty in angular separation of the Albireo, the sometimes inconsistent Koords calculations, and the few blurry or streaky images still used in this calculation. We noted that the pixel scale was the same for each axis, which makes sense, because each pixel covers an equal distance in each direction.

Looking through the Tycho-2 catalog, we felt confident in the accuracy of the calculations, although it was mildly inefficient to have to use both the Tycho-2 and SIMBAD analysis tools to get all the information we wanted. Stepping forward, comparing the spectral type to the RGB image was not fruitful. The sharpest I filter image we have is blurrier than the other two layers, which causes an awkward lensing around the bright stars. This could also be an issue with differences in saturation for each filter because we used the same exposure time. On Figure 4 the brightest stars are often low B class stars, though they appear yellow-white in our image, which ought to correspond to a F to G type star.

We also wanted to note some difficulties we had with the Koords program. Not only is it slow, cumbersome, and inefficient for large sequences, but it also is prone to random segmentation errors. This was very frustrating for us, even going through our 15 science images.

ACKNOWLEDGMENTS

Thank you to Dr. Charles Kerton and Brandon Marshall for their guidance and assistance in this work.

REFERENCES

[1] Charles Kerton. *Lab 4: Coordinates in the sky.* Iowa State University Department of Physics and Astronomy, October 2017.

[2] Lars Holm Nielsen and Lars Lindberg Christensen. Fits liberator, October 2017. URL `https://www.spacetelescope.org/projects/fits_liberator/stepbystep/`.

Appendix A: Observation Log

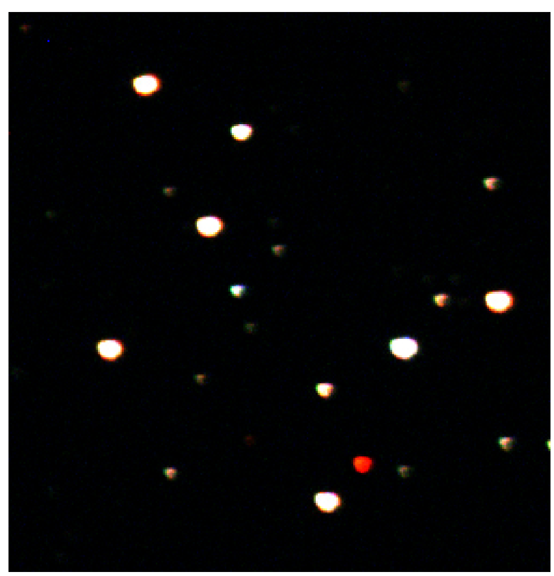
Table I: Observed 13 September 2017 by Miles Lucas and John Brandon

Time	File	N Frames	Object	Filter	Exposure	Camera Temp.	Notes
20:55	M29_V_20s_	5	M29	V	20 s	4.89 °C	
20:59	M29_dark_20s_	5	M29		20 s	5.12 °C	Dark Frames
21:04	M29_I_20s_	5	M29	I	20 s	5.33 °C	
21:06	M29_B_20s_	5	M29	B	20 s	5.33 °C	

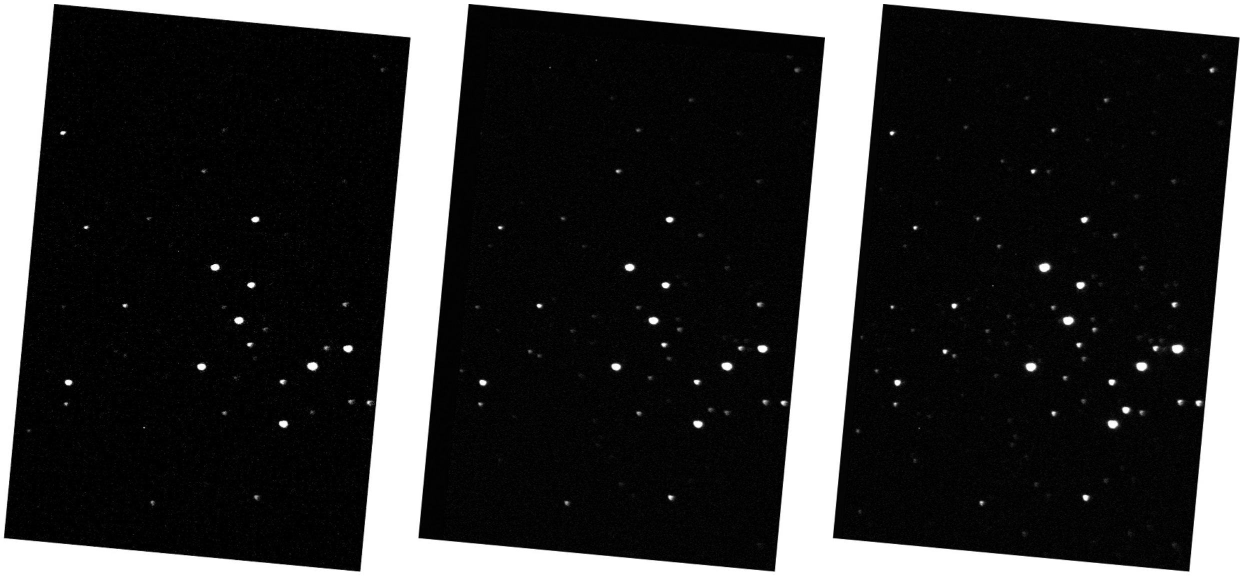
Appendix B: Images and Tables

Figure 1: Using Koords to calculate and apply coordinate system to our photos. The pairs shown in this image were used in every image for calculations.

(a) DSS POSSII image of M29



(b) RGB composed image of M29 from our B, V, and I images cropped to the seven brightest and most recognizable stars



(a) Photometric B (b) Photometric V (c) Photometric I

Figure 3: WCS aligned images with celestial North and East oriented straight up and left on the image

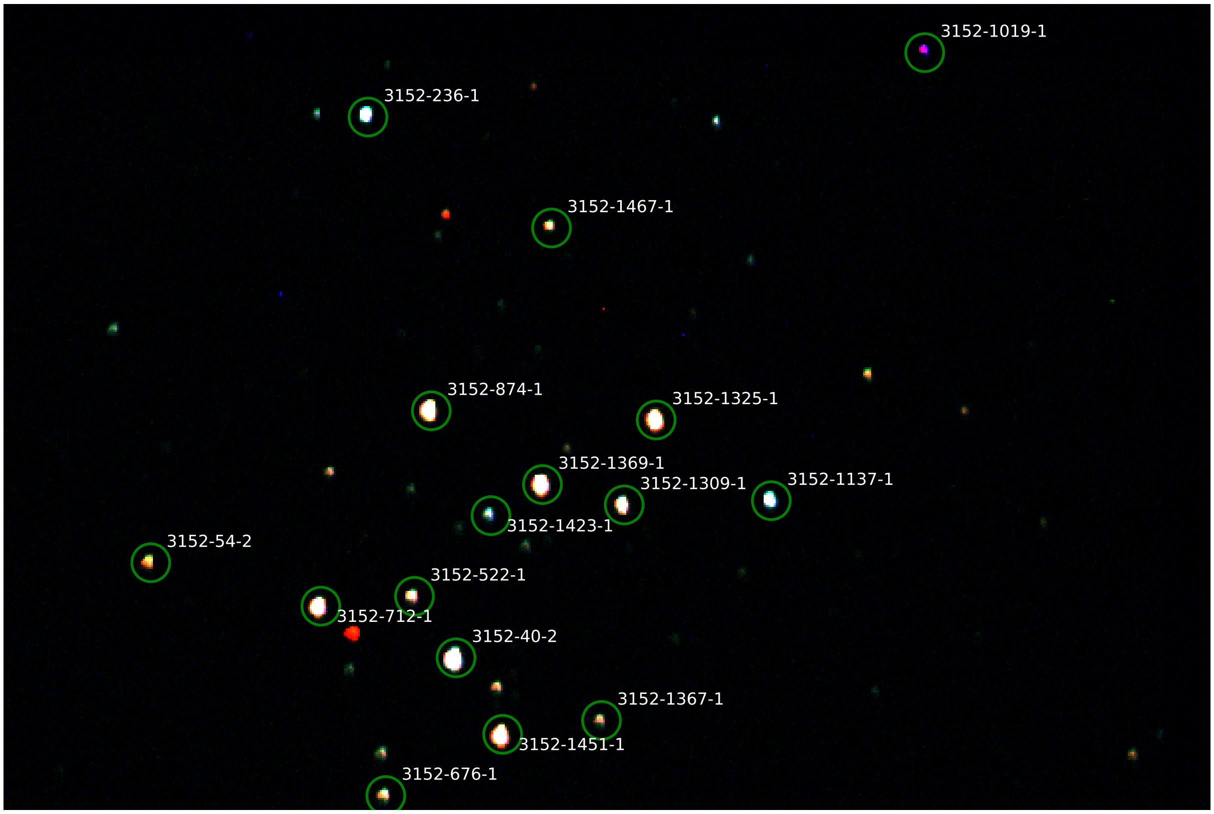


Figure 4: The map of the Tycho-2 stars superimposed on our RGB image[1]

[2] This image was made using python sourced in the Jupyter Notebook from section C.

Table II: Information from the Tycho-2 and SIMBAD analysis of our WCS images

_RAJ2000	_DEJ2000	TYC1	TYC2	TYC3	pmRA	pmDE	BTmag	VTmag	HIP	RA(ICRS)	DE(ICRS)	SP Type
305.962521	38.49286	3152	40	1	-13.3	-11	9.113	8.645	100586	305.96256	38.49288528	F0III
305.994691	38.432574	3152	54	1	-0.9	-5.5	12.964	11.652		305.9946933	38.43258639	B1-1.5V
306.105109	38.485246	3152	236	1	-1.4	-5.2	10.293	10.181		306.1051136	38.48525833	A2
305.979509	38.485578	3152	522	1	-5.8	-7.3	11.823	11.503		305.9795258	38.485595	B2V
305.928488	38.475918	3152	676	1	-2.8	-20.3	12.128	12.094		305.9284961	38.475965	B2V
305.979257	38.466345	3152	712	1	-5.2	-5.6	10.18	9.482	100600	305.9792722	38.4663575	O9.7III(n)
306.027282	38.492559	3152	874	1	-2.8	-4.4	9.923	9.108	100612	306.0272897	38.49256861	B0.2III
306.108385	38.599753	3152	1019	1	-3.4	3.6	11.923	11.358		306.1083947	38.59974472	
305.995611	38.560021	3152	1137	1	1.3	3.3	10.903	10.528		305.9956075	38.56001389	B0
305.99811	38.530005	3152	1309	1	-2.6	-4.9	11.281	10.462		305.9981181	38.53001667	B0.5III
306.019406	38.538139	3152	1325	1	-5	-4.9	9.919	9.016		306.0194203	38.53815	B0.5Ia
305.942678	38.52126	3152	1367	1	-6.7	0	12.019	11.525		305.9426975	38.52126	B4V
306.005409	38.513765	3152	1369	1	-4.8	-7.2	9.746	9.042		306.0054231	38.51378167	O9III
305.998589	38.502686	3152	1423	1	2.1	-4.3	12.056	11.594		305.9985831	38.50269611	B8
305.941504	38.500873	3152	1451	1	-5.5	-5.6	10.198	9.337		305.9415197	38.50088583	B0.2IIIe
306.071835	38.520494	3152	1467	1	1.1	-1	12.76	11.78		306.0718322	38.52049667	G6III

Appendix C: Analysis Scripts

Also see Jupyter Notebook at this Github page.

../src/imscale.py

```
'''
imscale.py

Author: Miles Lucas

This script parses the image scales of given images and reports a confidence interval. The images are expected to
have been coordinate-mapped using koords so that the FITS headers match the keywords

Usage:
$ python src/imscale.py data/science/processed/wcs
Pixel Scale Axis 1: 1.1646511831490212+-0.026936667803169074
Pixel Scale Axis 2: 1.1646511831490212+-0.026936667803169074
'''

import numpy as np
from astropy.io import fits
from glob import glob
import sys
from scipy.stats import norm

def get_interval(data):
    ''' Reports the 95 percent confidence interval using normal distribution '''
    mu = np.average(data)
    stdev = np.std(data)
    alpha = .05
    min_, max_ = norm.interval(1-alpha, loc=mu, scale=stdev)
    range_ = max_ - min_
    #Convert from degrees/pixel into arcseconds/Pixel
    conv_fact = 3600
    # Return an item that is x +- s as opposed to [low, upp]
    return mu * conv_fact, range_/2 * conv_fact

def main(filenames):
    ''' gets the important data from all the headers '''
    # Load the headers and get the data
    hdrs = [fits.getheader(filename) for filename in filenames]
```

```
    key1, key2 = 'CDELT1', 'CDELT2'
    cdelt1 = [hdr[key1] for hdr in hdrs]
    cdelt2 = [hdr[key2] for hdr in hdrs]
    # Get and print the intervals
    inter1 = get_interval(cdelt1)
    inter2 = get_interval(cdelt2)
    print('Pixel Scale Axis 1: {}+-{}'.format(*inter1))
    print('Pixel Scale Axis 2: {}+-{}'.format(*inter2))

if __name__=='__main__':
    if not len(sys.argv) == 2:
        print('Wrong number of arguments\nUsage: imscale.py <folderpath>')
        sys.exit()

    folder = sys.argv[1]
    filenames = glob(folder + '/*.fits')
    main(filenames)
```