AGN monitoring

- Mrk421 Photometry & Polarimetry -

Astronomical Observation and Lab. 1

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What is an AGN?

- Active Galactic Nucleus

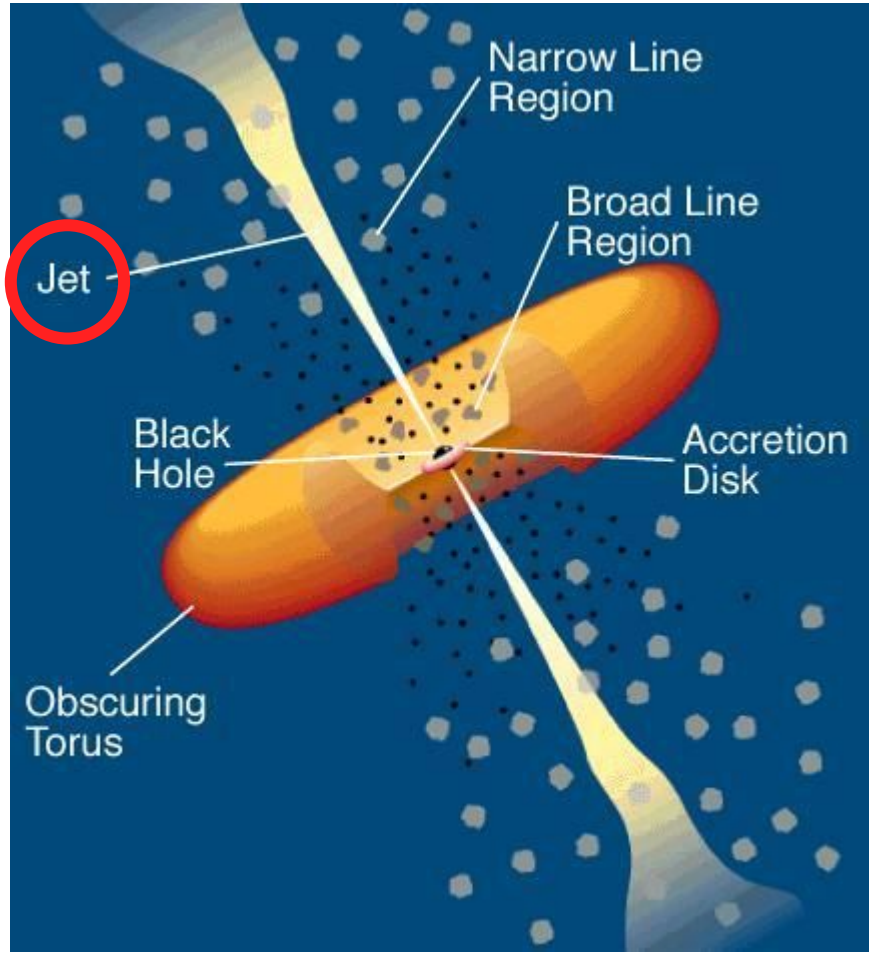
- Compact region at the center of a galaxy with higher luminosity

- Result from the accretion of matter by a SMBH at the center

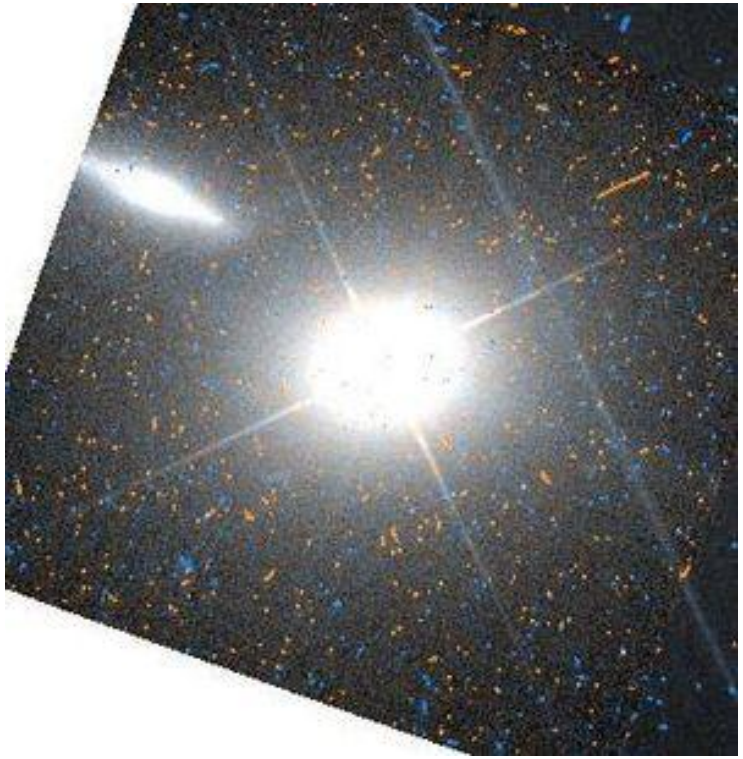
- Most luminous persistent sources of electromagnetic radiation

What are Blazars?

- AGNs that have a jet aligned with the observer
- Polarization variability studies may provide information on the structure and magnitude of the magnetic fields



Markarian 421 (Mrk 421)



- A blazar located in the constellation Ursa Major (큰곰자리)
- Strong source of gamma ray
- Magnitude g'=13.804, r'=13.090, i'=12.805
- About 397 million LY apart (z=0.0308)
- RA 11h04m27s , Dec +38°12´
- Companion Galaxy (Mrk 421-5)

Wikipedia "Markarian 421" https://en.wikipedia.org/wiki/Markarian_421, 2018-06-13

Importance Of Studying Mrk 421

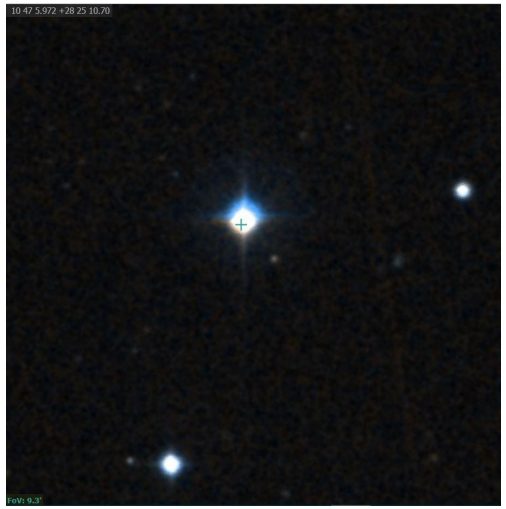
- Provides a phenomenological picture of the physical mechanism driving the observed patterns.
- The spectral curvature is relevant to the understanding of radiative mechanisms.
- One of the closest and most studied blazars.
- Excellent candidate to study physical processes within blazar jets and correlations among different energy bands.

Methodology – 1. Photometry

1) Selection of standard stars

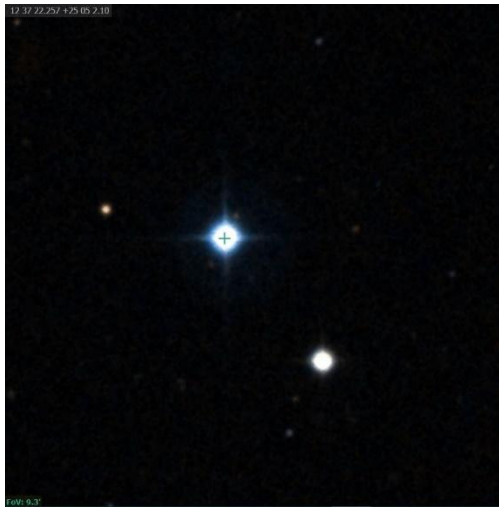
First day (4/17)

HIP 52181	Feige 34	10:39:37	+43:06:09.2
HIP 52771	BD+29 2091	10:47:23	+28:23:56.0



Second day (5/8)

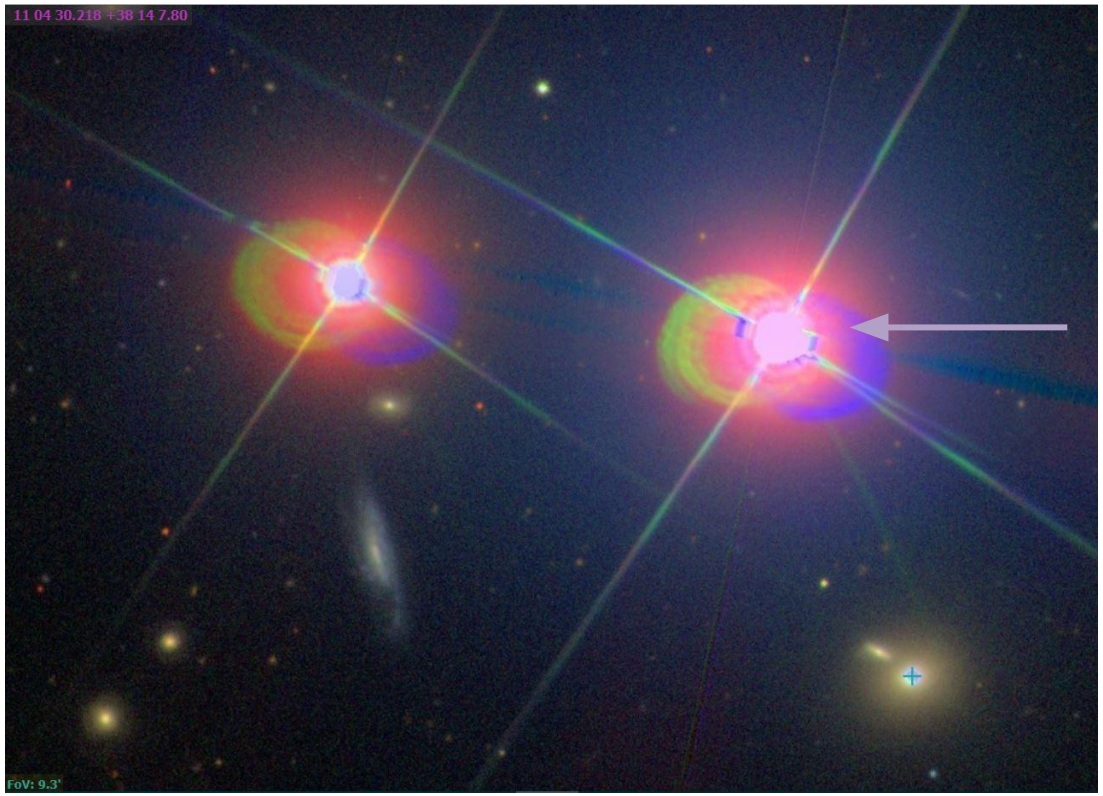
HIP 61602	Feige 66	12:37:24	+25:03:59.9
HIP 66441	BD+30 2428B	13:37:14	+30:05:14.2



Simbad, “HIP52181”,”HIP52771”, “HIP61602”,”HIP66441”, http://simbad.u-strasbg.fr/simbad/, 2018-06-13
Captured image

1. Photometry

2) 51 UMA



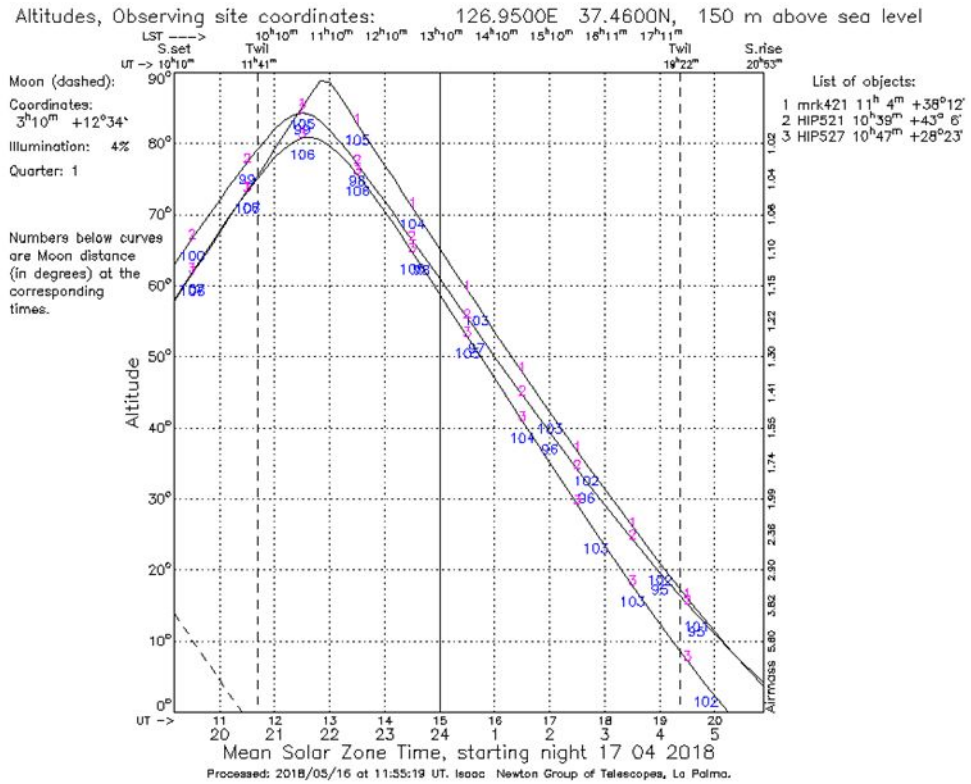
Simbad, “mrk421”, http://simbad.u-strasbg.fr/simbad/, 2018-06-13
Captured image

Right Ascension:	$11^h04^m31^s$ [2]
Declination:	+38°14'28" [2]
Distance:	80.6 parsec 262.7 lightyears [1]
Proper motion (speed):	71.3 mas/yr [1]
Proper motion (pos ang):	271.6°

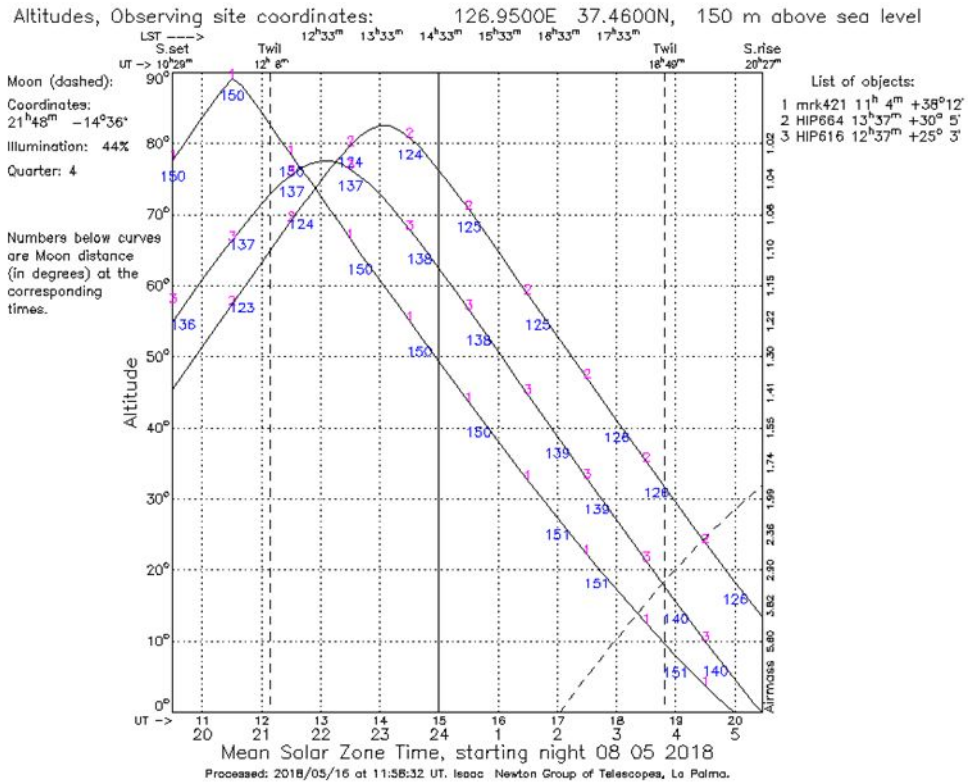
Magnitudes				
u	g	r	i	z
7.31	7.83	7.54	9.67	7.88
Magnitude uncertainties				
err_u	err_g	err_r	err_i	err_z
0.00	0.00	0.00	0.01	0.00

1. Photometry

3) Observation schedule



Altitude-time graph of first day (4/17)



Altitude-time graph of second day (5/8)

1. Photometry

4) Processing

- TA's lecture note codes & TRIPOLpy

jupyter nbviewer

JUPYTER FAQ

AO_LectureNotes / Python_Photometry.ipynb

Photometry with Python

In this lecture note, I will use a data from Ishigakijima Astrophysical Observatory telescope.

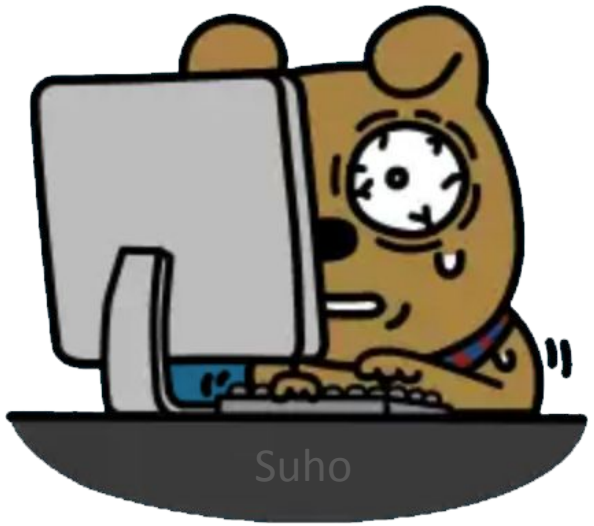
It has already been preprocessed and WCS implemented

Things we will learn (numbers here are not equal to the section numbers):

1. How to deal with MEF (Multi Extension FITS) file in the format of HDU (Header Data Unit)
   - I will assume you know what FITS is.
   - Detailed explanation can be found at this astropy document
   - Simply put, *FITS = image data format used in astronomical society*.
2. Split one extension of FITS file
3. Crop the image by centering the comet while conserving the WCS (World Coordinate System) information
   - I will assume you know what WCS is.
   - Detailed explanation can be found at this astropy document
   - Simply put, *WCS = information or parameters which allows you to convert the image x y coordinate to real coordinate, such as RA and DEC.*
4. Find UCAC4 stars which are within the FOV
   - UCAC4 information: USNO
   - Find "UCAC4" at VizieR and look what each column means
5. Do aperture photometry to get the instrumental magnitude of the stars.
6. Do aperture photometry to get the instrumental magnitude of the comet as a function of radius.

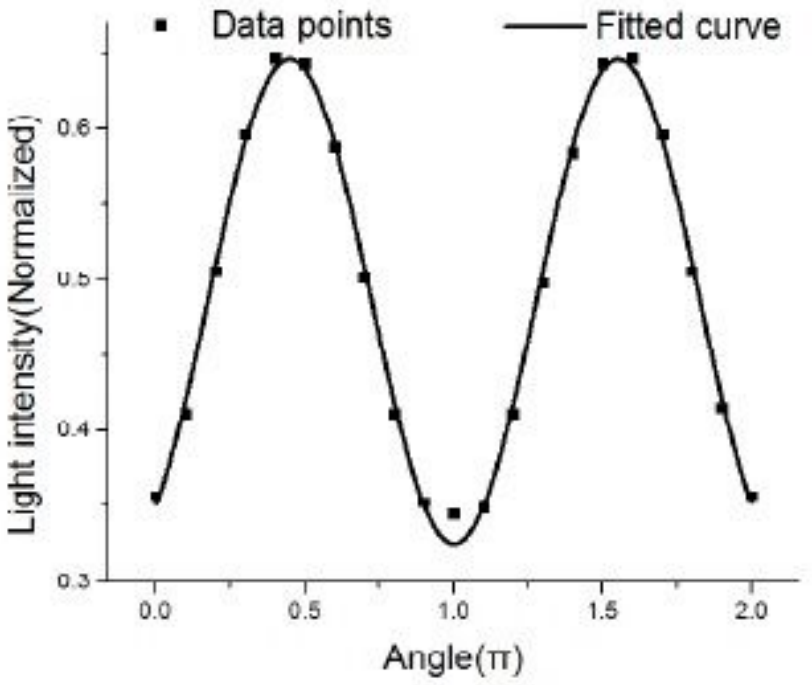
I will try **NOT** to explain too much detailed technical issues, such as "what does `hdul[0].header` mean?". Please find the answers by yourselves at the linked reference websites! You will learn a lot from there!

Before going into the procedures, let be briefly introduce `astropy.io.fits` module, and `astroquery.jplhorizons` module.



2. Polarimetry

- AGN emission is polarized
- The purpose is to calculate the degree of polarization



ResearchGate, “How can I measure the linear degree of polarization at 90 degrees?”, 2018-16-13, https://www.researchgate.net/post/How_can_I_measure_the_linear_degree_of_polarization_at_90_degrees2

2. Polarimetry

2) What is the degree of polarization (P) ?

:Portion of polarization

- Perfectly polarized = 100%, non-polarized = 0%
- $P = \frac{\sqrt{Q^2 + u^2}}{I}$

($Q = I_0 - I_{45}$, $u = I_{22.5} - I_{67.5}$, $I = [I_0+I_{22.5}+I_{45}+I_{67.5}]/2$)

2. Polarimetry

3) Observation schedule

Usual photometry with
variation of polarization degree
(0° / 22.5° / 45° / 67.5°)

Polarization Degree

61cm 망원경 관측 LOG BOOK 2018 년 04 월 17일 화요일 / 페이지

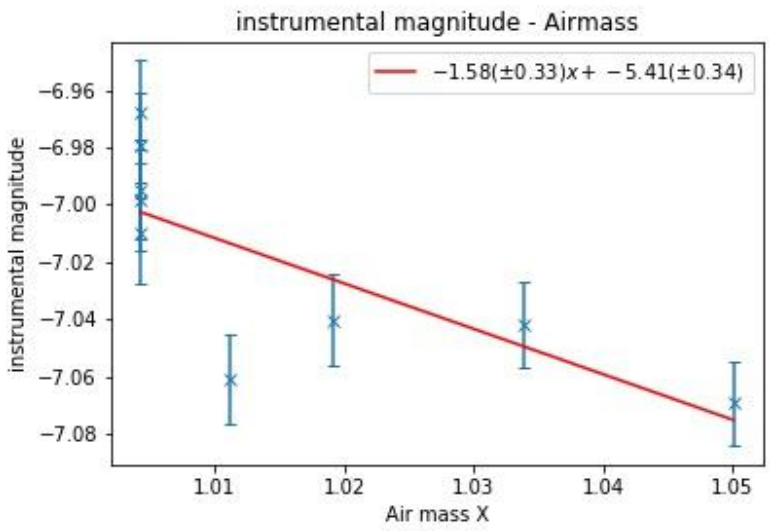
관측자 : 김동화 유수호 세드릭 | 과제명 : AO 1 | 기기 : TRIPOL

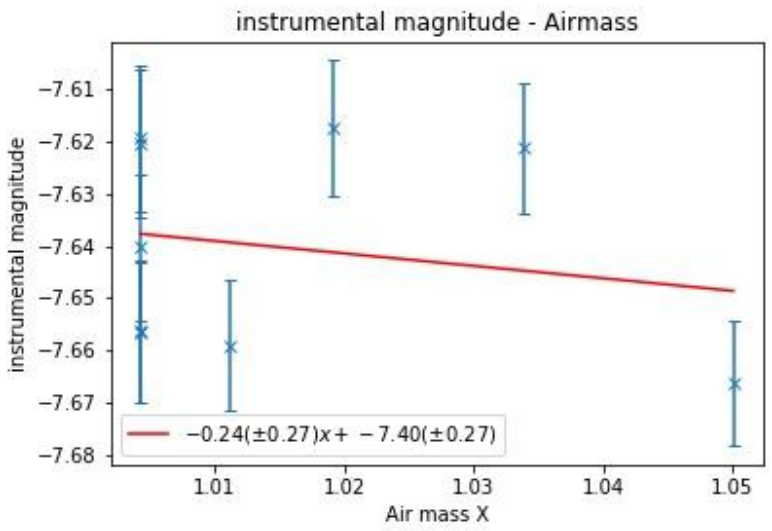
날 씨	온 도	습 도	풍 속	풍 향	부경 위치	평균 시상
	°C	%	m/s	°		4~5 "

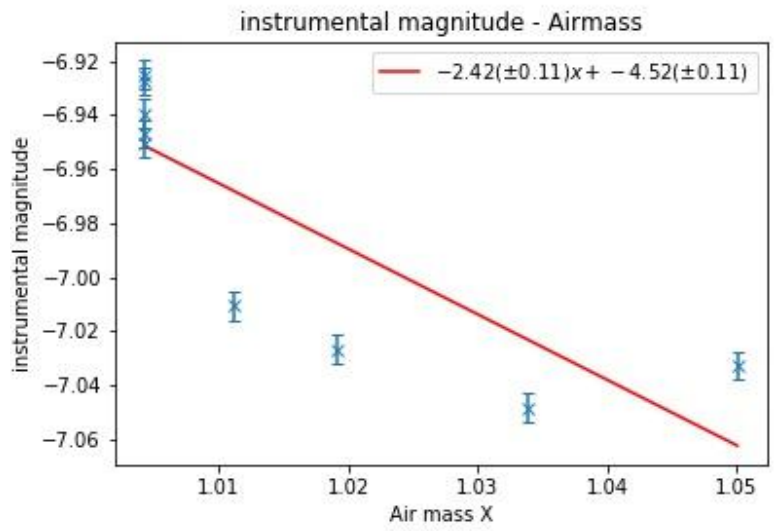
화일번호	관측 대상 (α, δ)	노출시작	노출	필터	ALT	AZI	시상	비 고
1	Mrk421	:						Test
2~6	focus	21 : 08	1					focus
7~11	Mrk421	21 : 26	180x5		84°	181°		X:226 Y:358
12~16	HIP52771	21:58	120x5		77°56'	207.5°		X:320.9, Y:328.6
17~21	HIP52181	22:18	120x5		79°56'	300.5°		X:378.6 Y:264.7
22	Mrk 421	22:38	180		81°	227.5°		X:257 Y:238 HWP:0°
23	Mrk 421	22:42	180		80°	227.5°		X:257 Y:236.5 HWP:22.5°
24	Mrk421	22:45	180		80°	227.5°		X:257 Y:236.5 HWP:45°
25	Mrk421	22:49	180		79°	227.5°		X:257 Y:236.5 HWP:67.5°
26	Mrk421	22:53	180		78.5°	227°45'		X:254 Y:236.5 HWP:0°
27	Mrk421	22:57	180		77.5°	227°30'		X:252.7 Y:235.1 HWP:22.5°
28	Mrk421	23:01	180		77°	228°		X:252.7 Y:235.1 HWP:45°
29	Mrk421	23:07	180		75.5°	228°		X:252.7 Y:235.1 HWP:67.5°
30	Mrk421	23:11	180		75°	228°		X:252.7 Y:235.1 HWP:0°
31	Mrk421	23:14	180		74°	228.5°		X:252.7 Y:235.1 HWP:22.5°
32	Mrk421	23:18	180		73.5°	228°40'		X:252.7 Y:235.1 HWP:45°
33	Mrk421	23:22	180		72°40'	229°		X:252.7 Y:235.1 HWP:67.5°
34	Mrk421	23:26	180		72°	229°		X:255.6 Y:242.2 HWP:0°
35	Mrk421	23:30	180		71°	229°		X:255.6 Y:242.2 HWP:22.5°
36	Mrk421	23:33	180		70.5°	229.5°		X:255.6 Y:245 HWP:45°
37	Mrk421	23:37	180		70°	230°		X:255.6 Y:246.4 HWP:67.5°
38~43	HIP52771	23:47	120x6		61.5°	269°		X:373.9 Y:223.8
	[redacted]	:						(6) Image 40 → telescope moved slightly

Results

1) Extinction coefficient (Mrk 421 on April 17th, g' r' i' band in order)



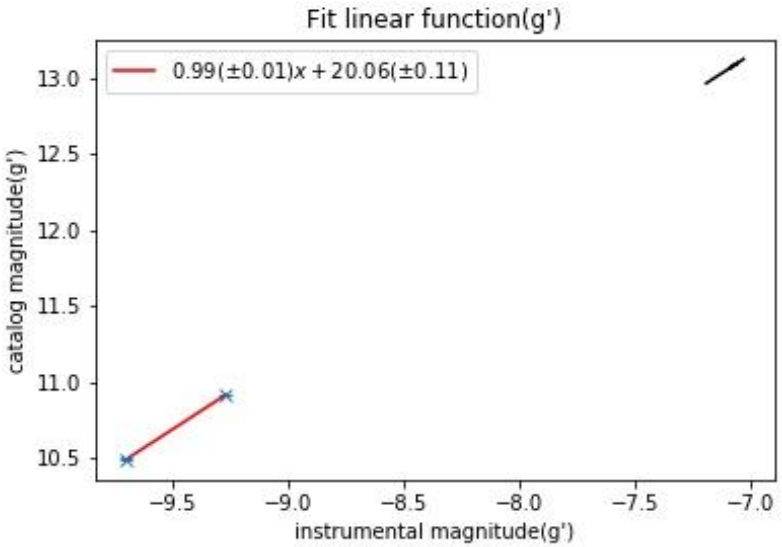


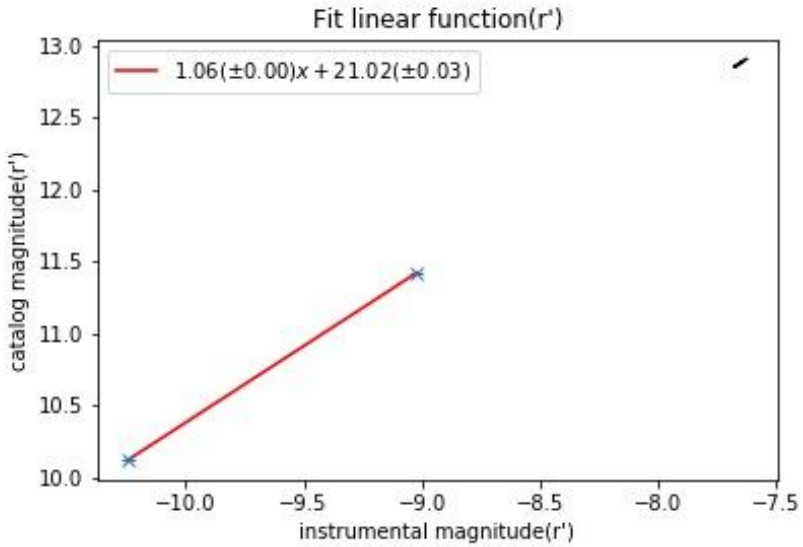


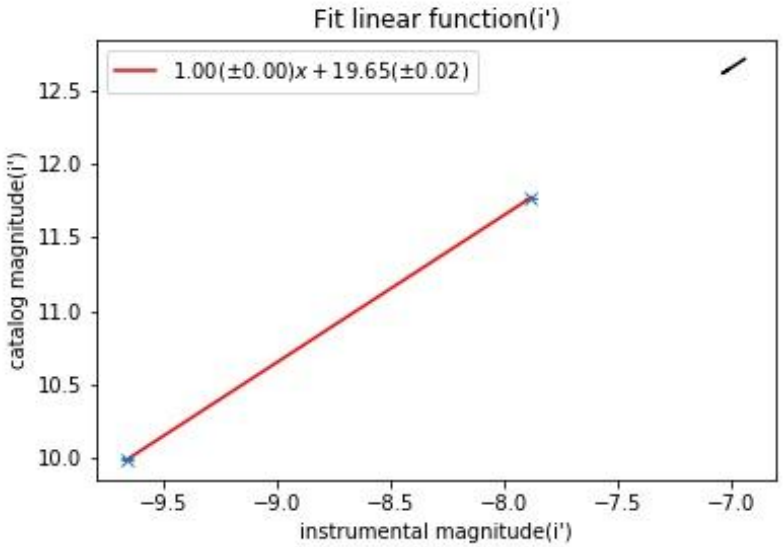
No linear relation found

Results

2) Linear fitting (g' r' i' band in order) - April 17th

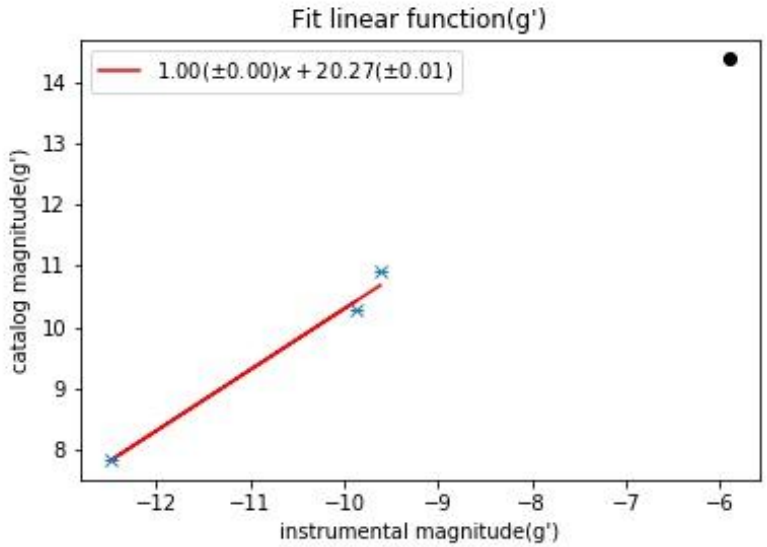


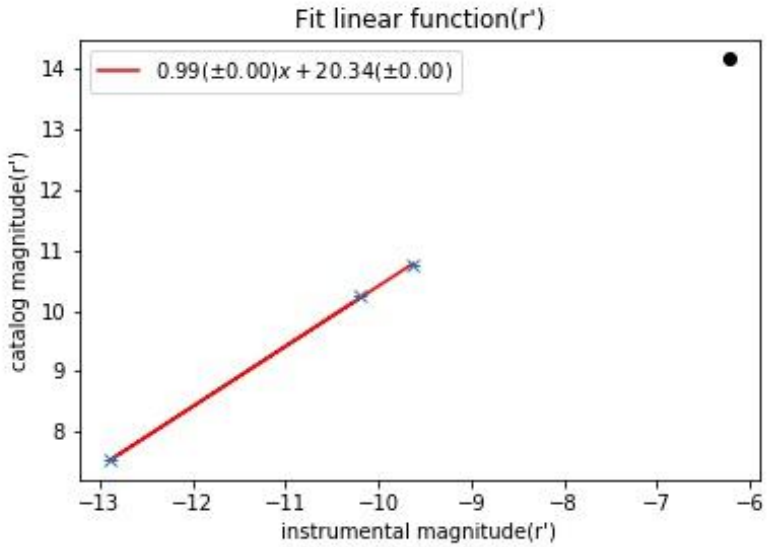


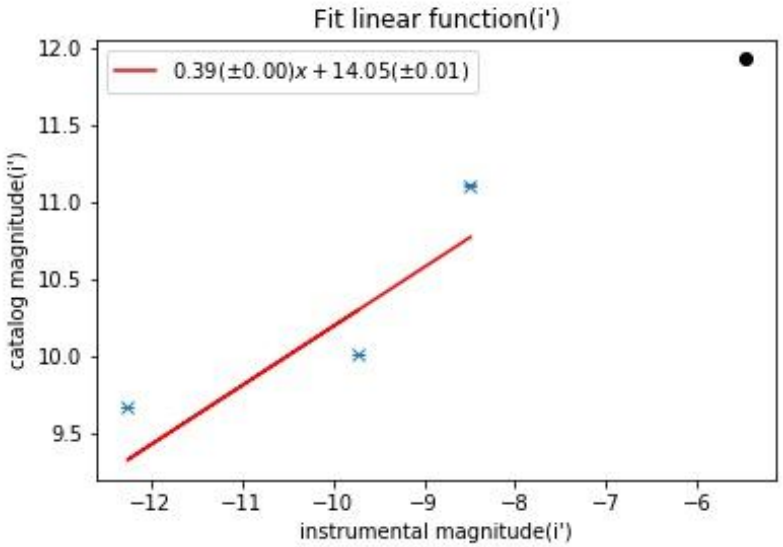


Results

2) Linear fitting (g' r' i' filter in order) - 8th of May (51 UMa included)

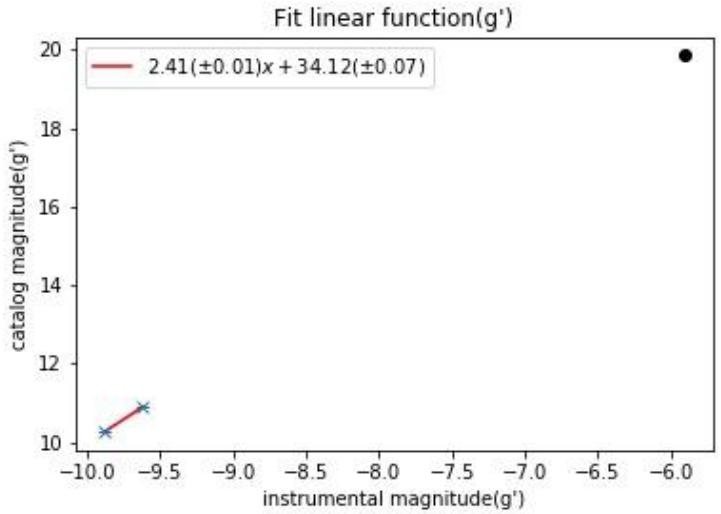


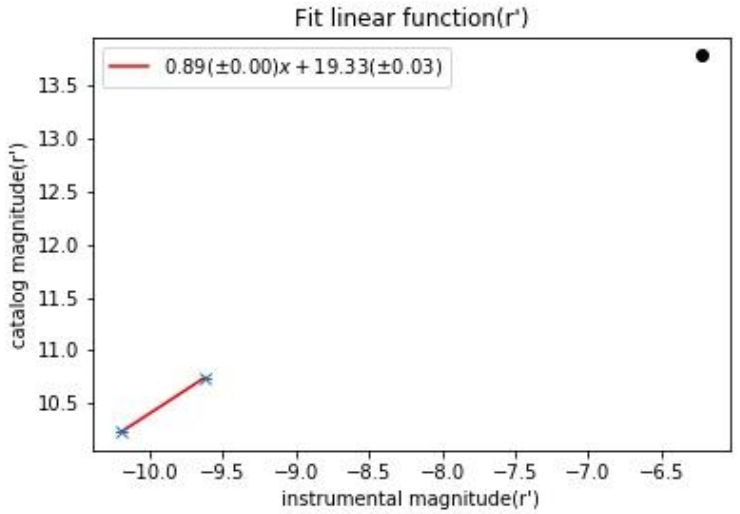


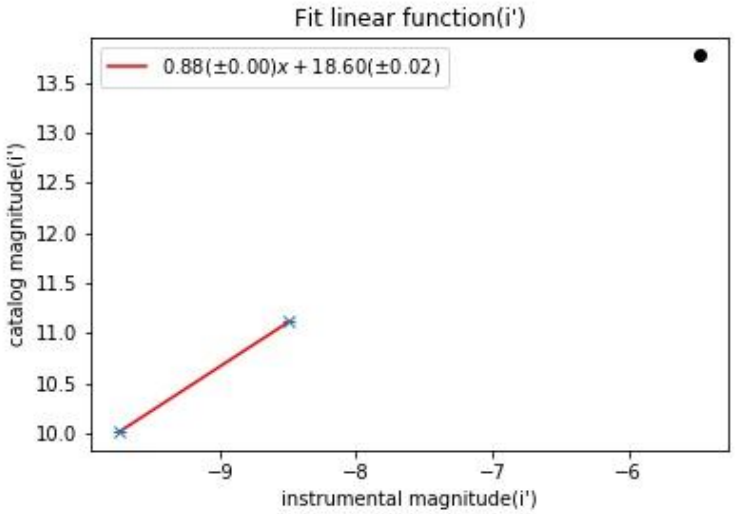


Results

2) Linear fitting (g' r' i' filter in order) - 8th of May (51 UMa not included)







Standard stars nor 51 UMa are reliable

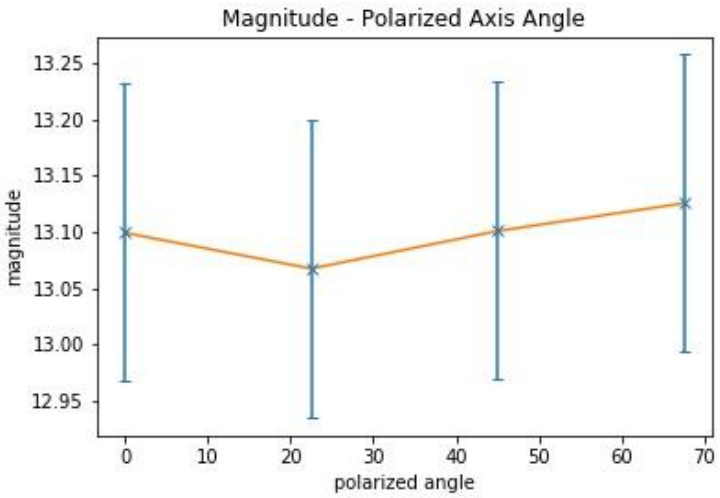
Results

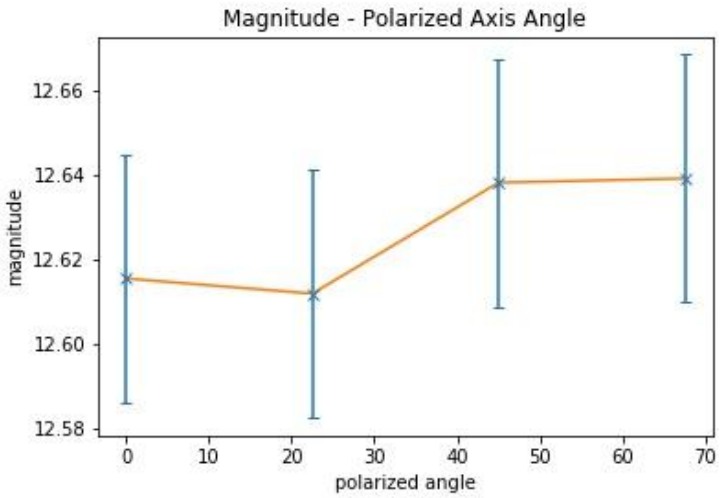
3) Photometry results (magnitudes)

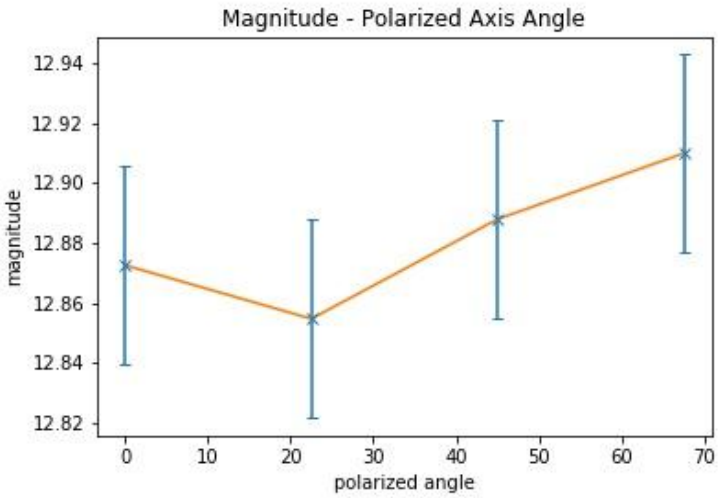
	g’	r’	i’
17th of April	13.10	12.89	12.71
8th of May (51 UMA included)	14.38	14.15	11.93
8th of May (51 UMA not included)	19.86	13.77	13.77
Category	13.80	13.09	12.81

Results

4) Magnitude - polarized axis angle (g' r' i' filter in order)







	g'	r'	i'
P(%)	2.675	2.473	1.636
Previous Research (R band)	Primary data source showed an average of 3.62%±0.10% with intranight fluctuations of 1~2% [5]		

Conclusion

- Failed to measure extinction coefficient
- Second day standard stars were not reliable (as data analysis is inconclusive), it is necessary to observe more stars. It might be a result of similar brightness characteristics
- 51 UMa does not have enough observation data to be used as a standard star and SDSS data mentions that it is highly unreliable. So it is better not use as one and previous researches recommends the same as well.
- Polarized observation data is not quite satisfying, probably due to the companion galaxy's emission, issue that couldn't be resolved.
- First observation night provided acceptable data, measurements show small variations from the category magnitude little difference from the category magnitude is measured. This might be due to polarization issues and variance of AGN luminosity.
- More observations in a longer period of time are needed in order to obtain more reliable information on Mrk 421 behaviour. As well as possible jet activity, accretion matter, opening opportunities for other kind of researches.
- Corrections to coding are necessary for future observations, leading to better data analysis and, therefore, more reliable results.

Thank you !
감사합니다!
¡Gracias!
ありがとう

References

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