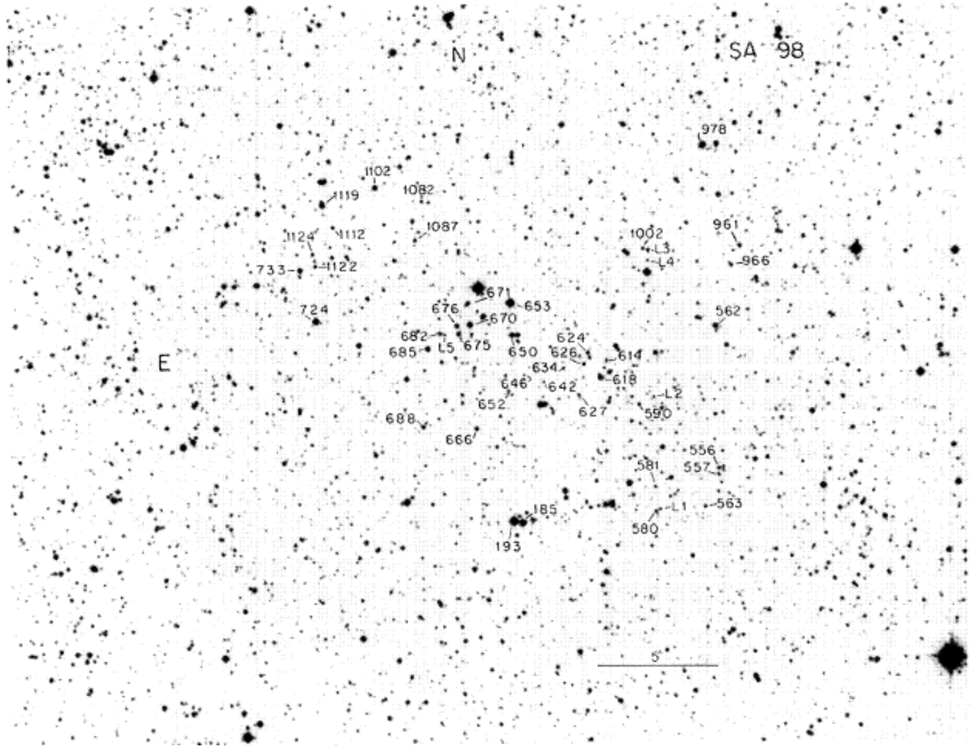
Standard Calibration

SEUNGWU YOO

Goal


N
SA 98
E
978
1102
1119
1082
1124
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1002
961
L3
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966
733
1122
671
724
676
670
653
562
682
685
L5
675
650
626
624
634
614
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L2
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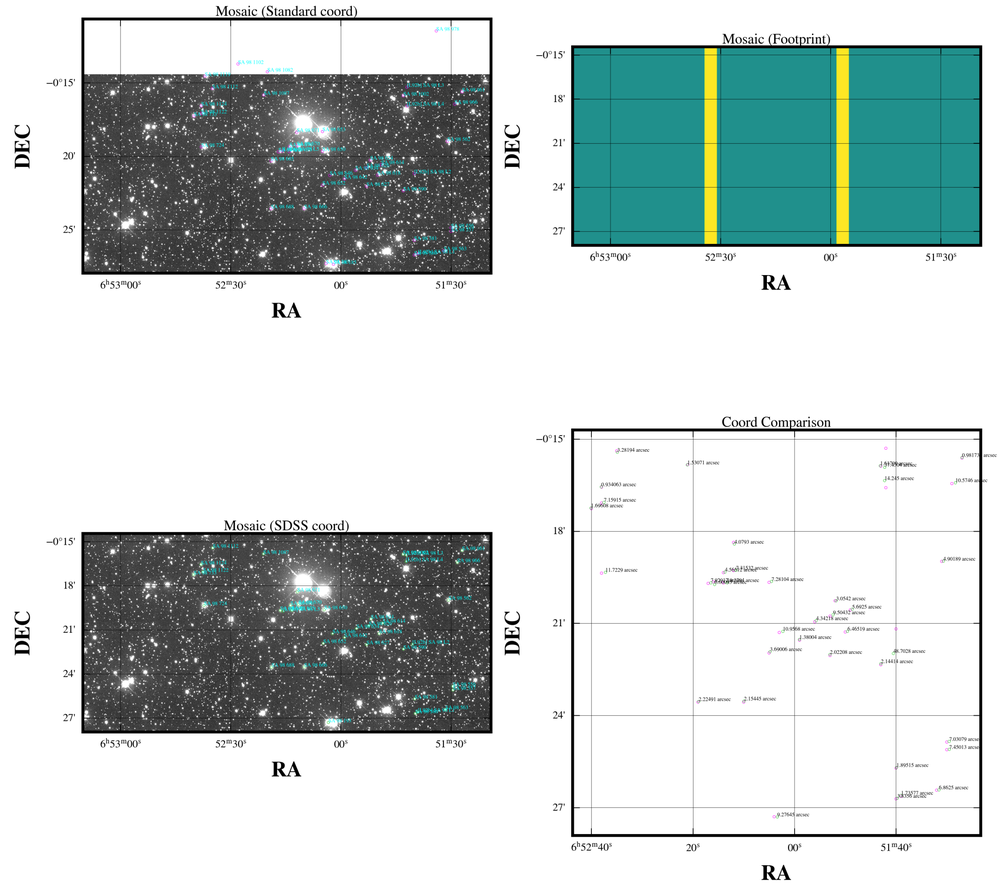
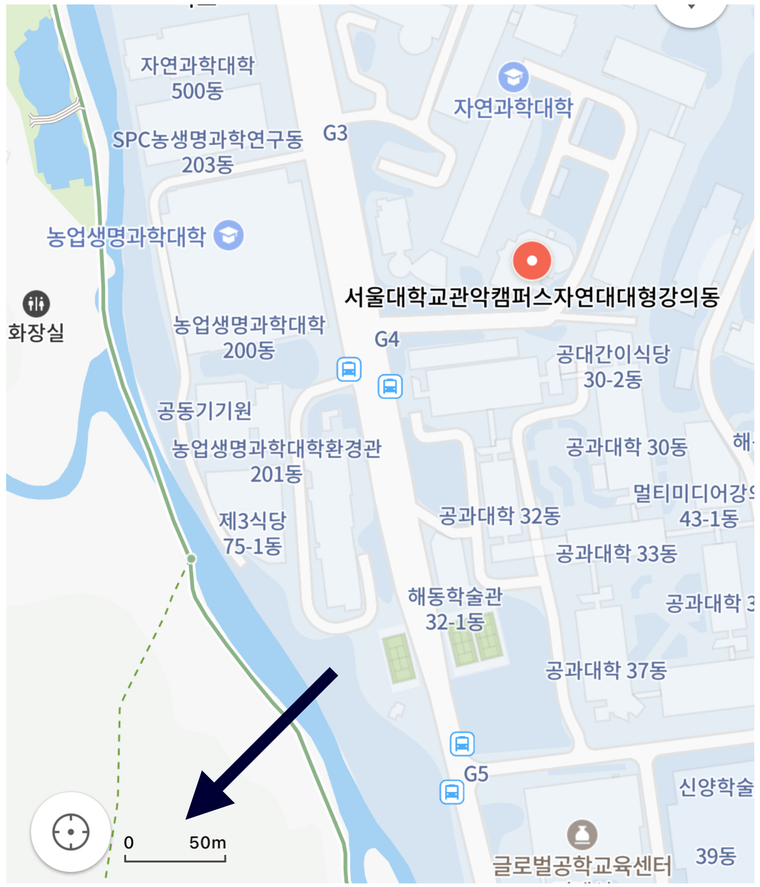
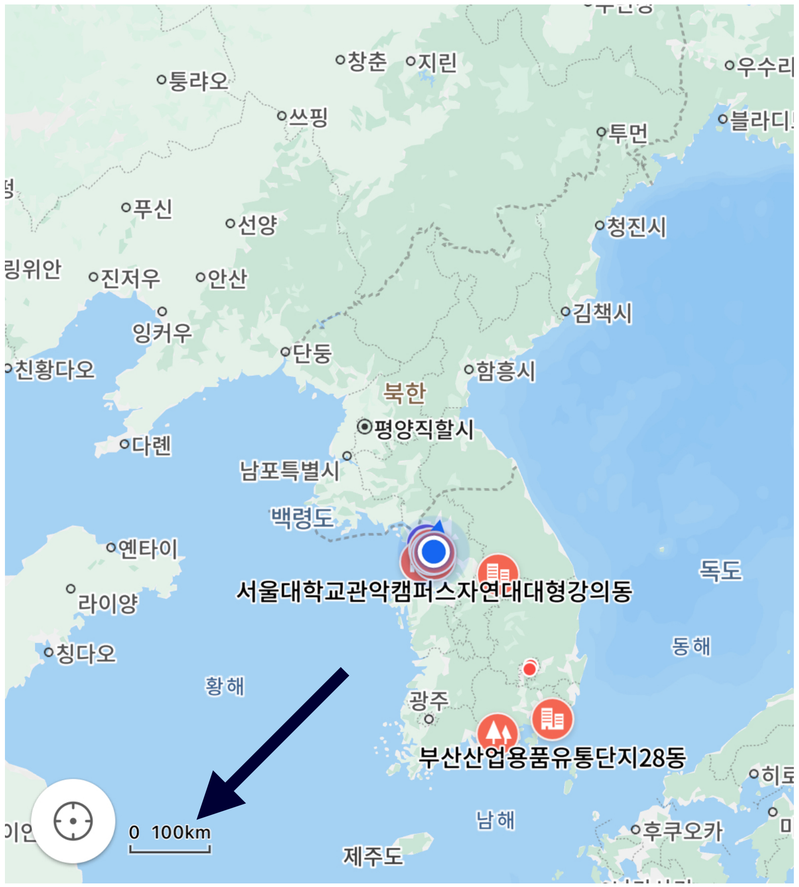
627
590
688
666
556
581
557
185
L1
563
580
193
5'


Mosaic (Standard coord)
Mosaic (Footprint)
Mosaic (SDSS coord)
Coord Comparison
DEC
RA
−0°15'
20'
25'
18'
21'
24'
27'
6h53m00s
52m30s
00s
51m30s
6h52m40s
20s
51m40s

What is Calibration?



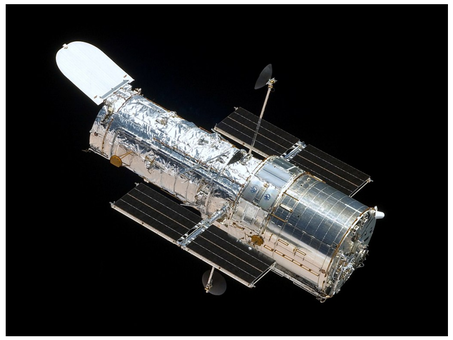


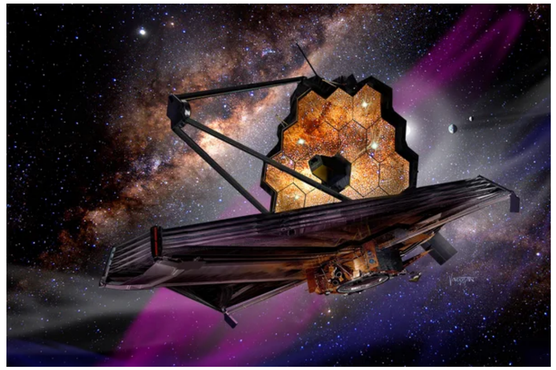
What is Calibration?

Unveil scale or other information of unknown with well-known

Standard Calibration in Astronomy

- **‘The light’ is basic source** of astronomical data including stars, galaxies etc
- Vega, observed by… -> All of them are **same Vega**

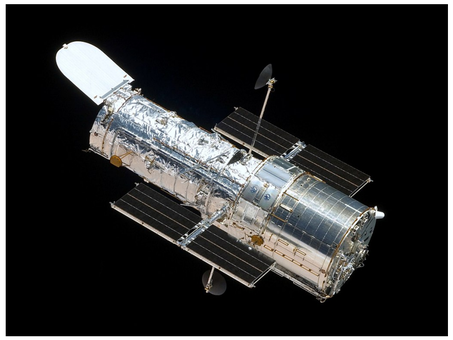
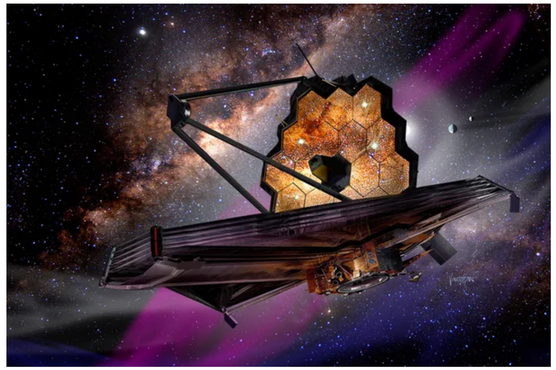




- But the photos of Vega from each telescope **might be different -> Why?**

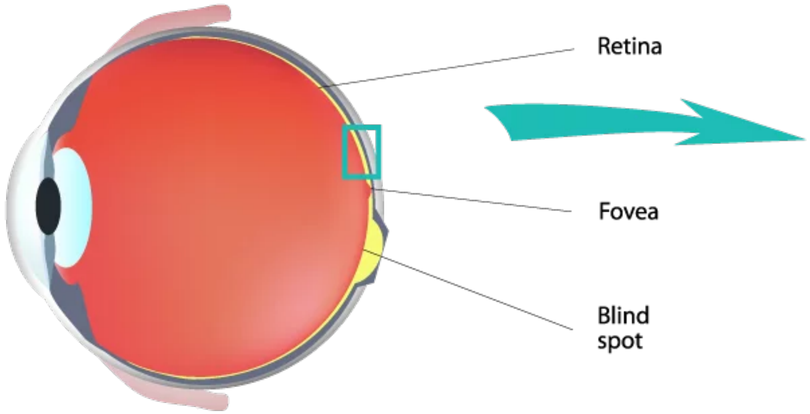
Standard Calibration in Astronomy

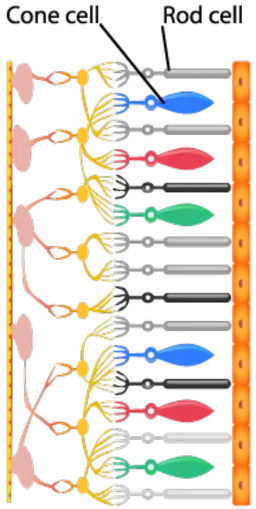
- **‘The light’ is basic source** of astronomical data including stars, galaxies etc
- Vega, observed by… -> All of them are **same Vega**

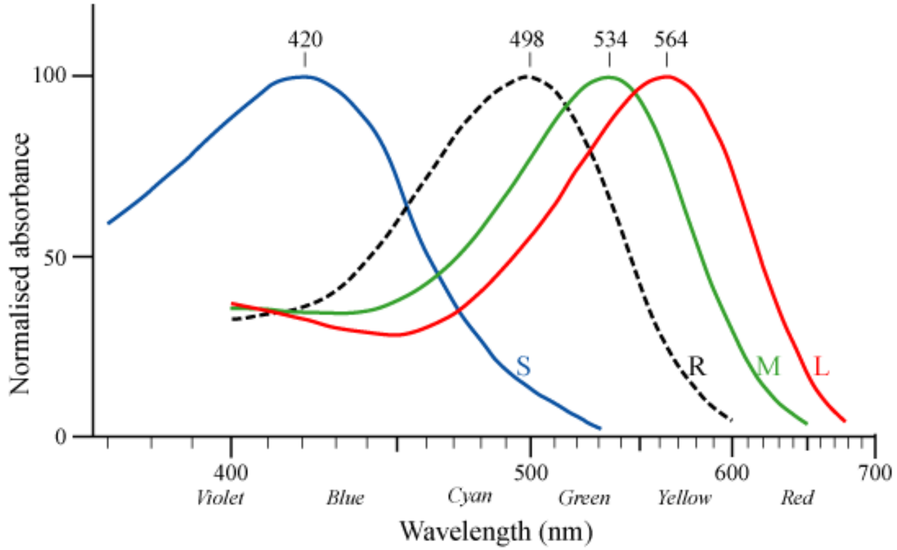




- But the photos of Vega from each telescope **might be different -> Why?**
  - Stars locate at different attitude
  - Using different ‘bands’
  - Many other reasons…

What is Band?

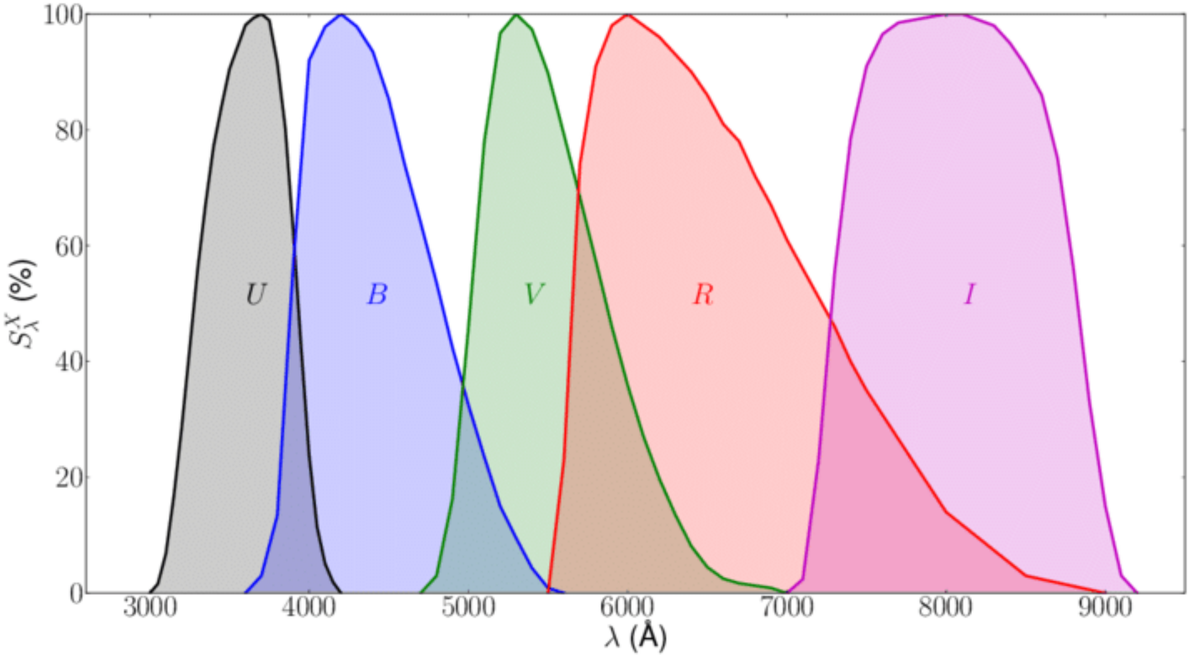


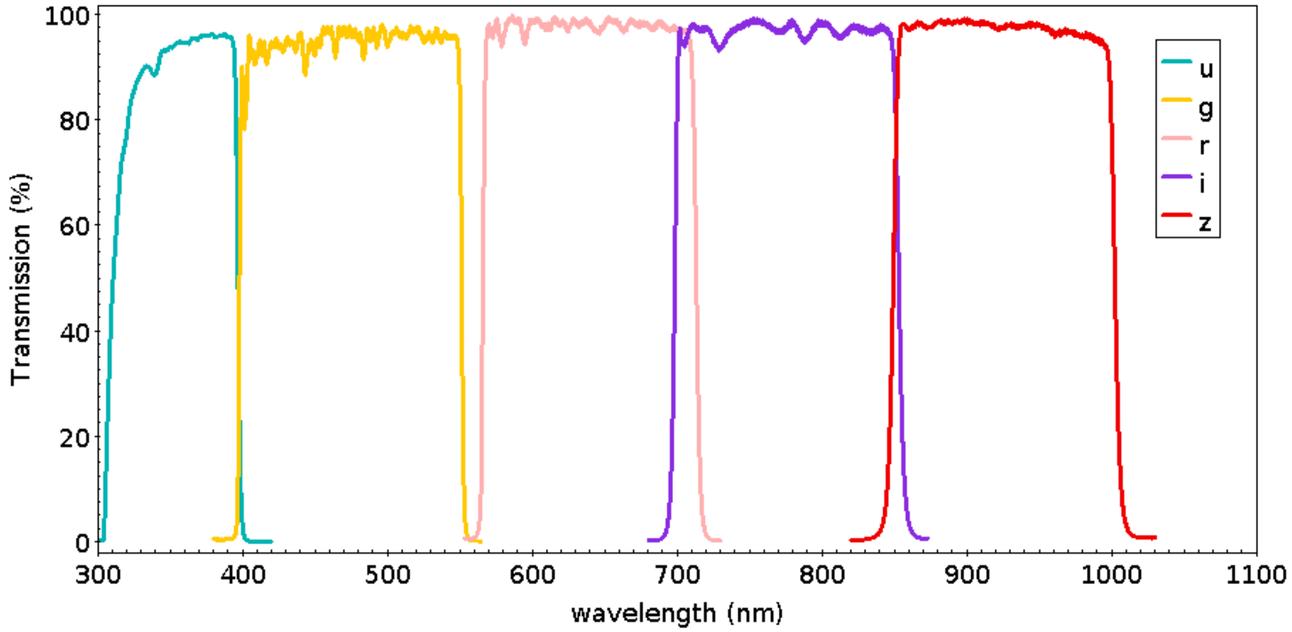




- Our eyes detect the light color with RGB cone cells, each cell has overlapped wavelength area, but reacts for different range. Our brain reproduces color with these three cone cell reactions.
- The observation also, but with more various cone cells, we call them as **‘bands’**

Example of bands





- X-axis means wavelength ($1\ \mathring{\text{A}} = 10^{-1}\ \text{nm} = 10^{-10}\ \text{m}$), Y-axis briefly means reactivity
- There are various bands, from radio to γ-ray. These examples cover Near UV ~ Near IR
- We can choose band systems according to scientific goal.

Magnitude

- Hipparchus ranked the magnitudes of stars on a numerical scale from 1 to 6.
- Today, we define that **magnitude 1 star is 100 times brighter than magnitude 6 star.**

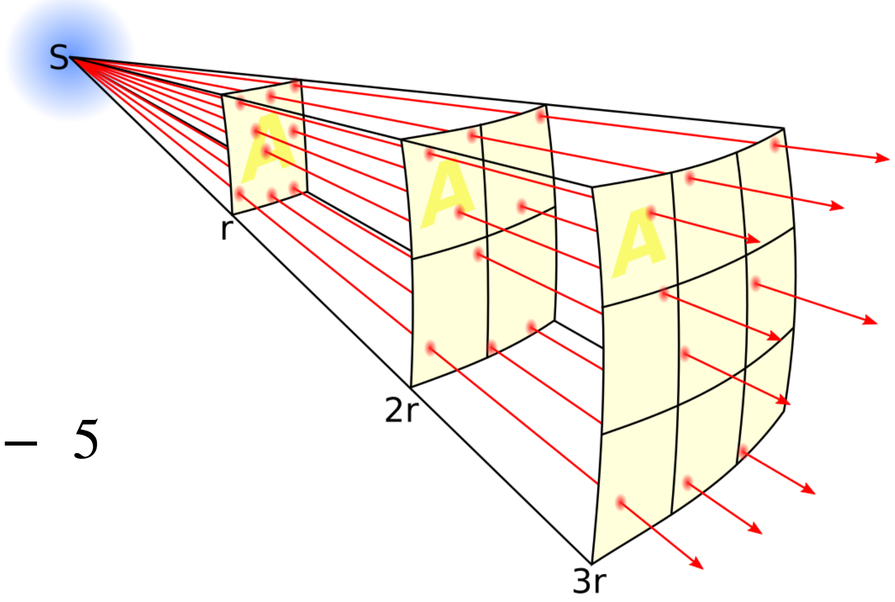
LUMINOSITY, FLUX ↑ ⟷ ↓ **MAGNITUDE**

- Magnitude - Luminosity Formula: $M_1 - M_2 = -2.5 \log \left(L_1 / L_2 \right)$

DIFFERENCE OF MAGNITUDE ⟷ **RATIO OF LUMINOSITY, FLUX**

Apparent and Absolute magnitude

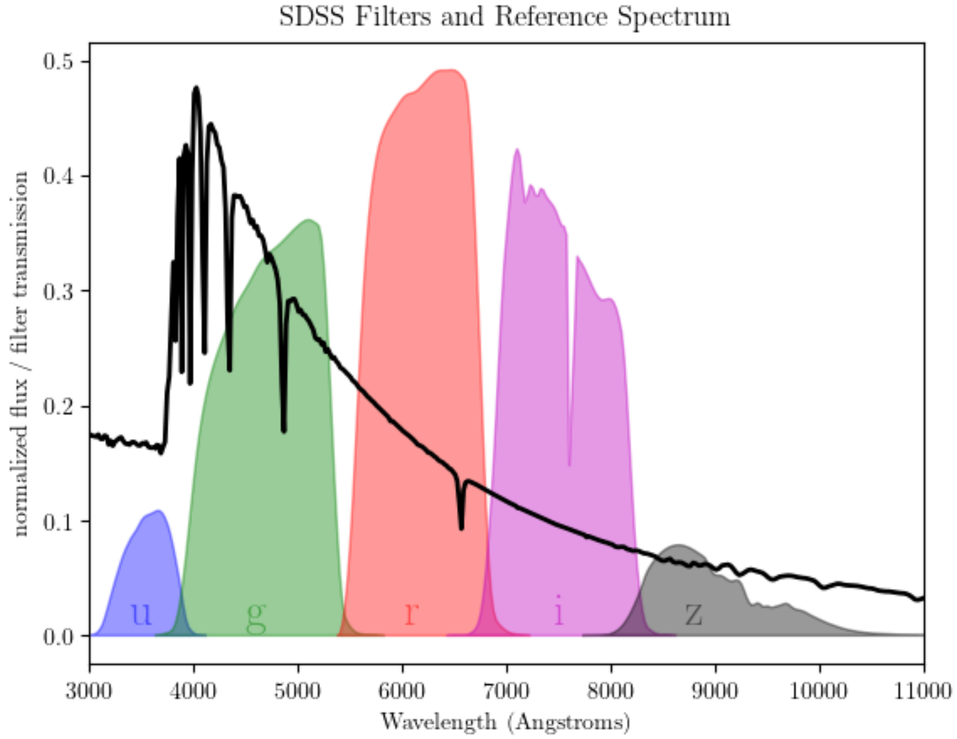
- Apparent magnitude(m): Magnitude of target what telescope observed
- Absolute magnitude(M): apparent magnitude that the object would have **if it were viewed from a distance of exactly 10 pc**



- The flux is reduced as $1/d^2$
- Formula: $m - M = -2.5 \log\left((10pc)^2/(d)^2\right) = 5 \log d - 5$

Color index

- In photometric observation, each band returns different magnitude for same object
- Define color index as difference of magnitude of two bands
- Formula: $C = m_{band,\,1} - m_{band,\,2}$
- The color index is '**distance independent' -> Why?**
  - (If an interstellar extinction isn't considered)



CCD magnitude

- In observation, CCDs are used to ‘record’ photon.
  - The detail things will be addressed in ‘천문관측 및 실험’
- The ‘magnitude’ are calculated with
  - Amount of captured photon / Exposure time

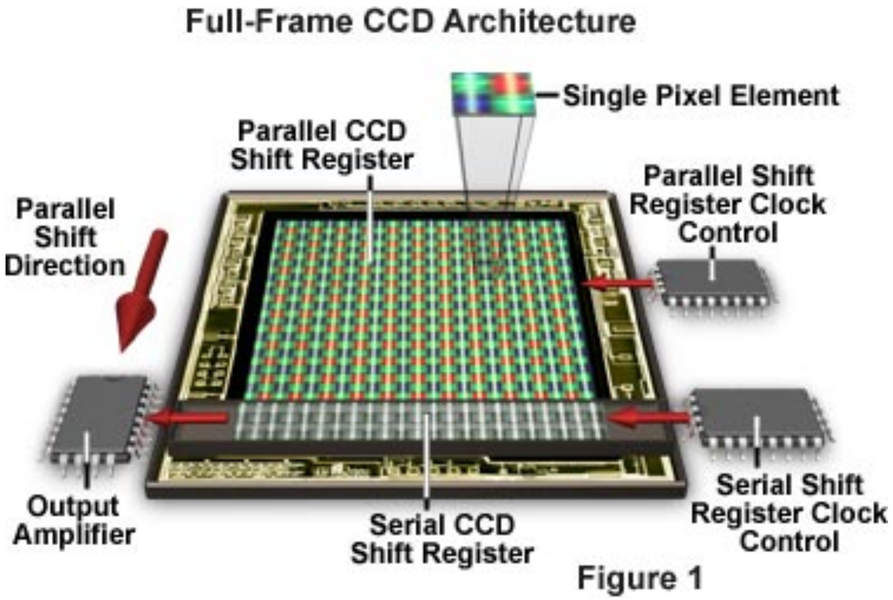


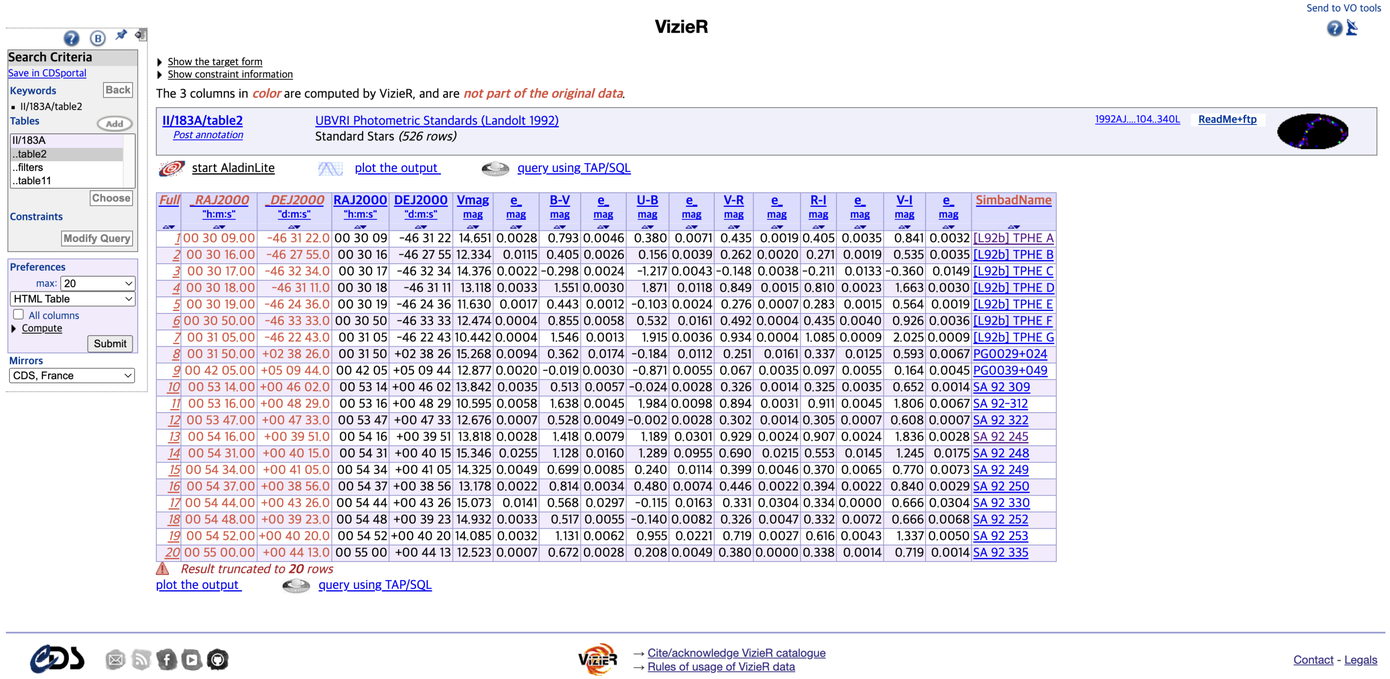
Figure 1

- **Long exposure time can reduce ‘Noise’**
- **But The photon capacity of each pixel is limited**
  - CCD can be saturated! -> What happen when CCD are saturated?

References

- https://skyserver.sdss.org/dr16/en/tools/chart/navi.aspx
  - SDSS DR16 Navigate
- https://articles.adsabs.harvard.edu/pdf/1992AJ....104..340L
  - Catalog of Standard stars from Landolt
- https://classic.sdss.org/dr6/algorithms/sdssUBVRITransform.php
  - Match band u'g'r'i'z' with UBVRcIc
- https://scikit-learn.org/stable/modules/generated/sklearn.linear_model.LinearRegression.html
  - Python Package for linear regression

Landolt standard star catalog



VizieR

Send to VO tools

Search Criteria
Save in CDSportal
Keywords Back
II/183A/table2
Tables Add
II/183A
..table2
..filters
..table11
Choose
Constraints
Modify Query
Preferences
max: 20
HTML Table
All columns
Compute
Submit
Mirrors
CDS, France

Show the target form
Show constraint information

The 3 columns in *color* are computed by VizieR, and are *not part of the original data*.

II/183A/table2 *Post annotation*
UBVRI Photometric Standards (Landolt 1992)
Standard Stars *(526 rows)*
1992AJ....104..340L ReadMe+ftp

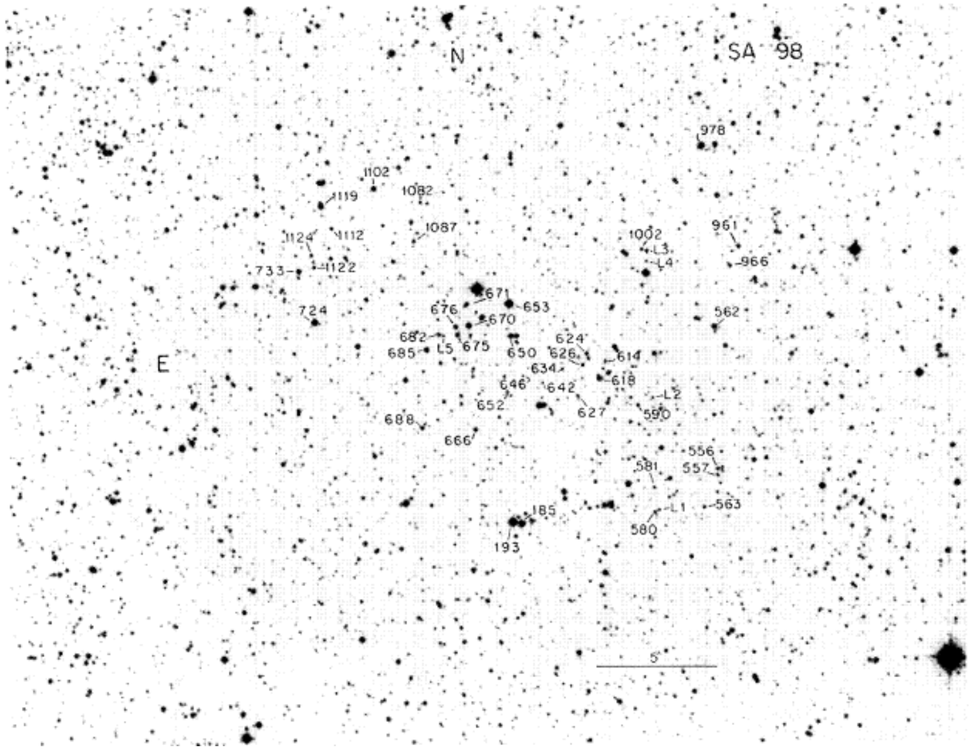
start AladinLite plot the output query using TAP/SQL

Full	_RAJ2000 "h:m:s"	_DEJ2000 "d:m:s"	RAJ2000 "h:m:s"	DEJ2000 "d:m:s"	Vmag mag	e_ mag	B-V mag	e_ mag	U-B mag	e_ mag	V-R mag	e_ mag	R-I mag	e_ mag	V-I mag	e_ mag	SimbadName
1	00 30 09.00	-46 31 22.0	00 30 09	-46 31 22	14.651	0.0028	0.793	0.0046	0.380	0.0071	0.435	0.0019	0.405	0.0035	0.841	0.0032	[L92b] TPHE A
2	00 30 16.00	-46 27 55.0	00 30 16	-46 27 55	12.334	0.0115	0.405	0.0026	0.156	0.0039	0.262	0.0020	0.271	0.0019	0.535	0.0035	[L92b] TPHE B
3	00 30 17.00	-46 32 34.0	00 30 17	-46 32 34	14.376	0.0022	-0.298	0.0024	-1.217	0.0043	-0.148	0.0038	-0.211	0.0133	-0.360	0.0149	[L92b] TPHE C
4	00 30 18.00	-46 31 11.0	00 30 18	-46 31 11	13.118	0.0033	1.551	0.0030	1.871	0.0118	0.849	0.0015	0.810	0.0023	1.663	0.0030	[L92b] TPHE D
5	00 30 19.00	-46 24 36.0	00 30 19	-46 24 36	11.630	0.0017	0.443	0.0012	-0.103	0.0024	0.276	0.0007	0.283	0.0015	0.564	0.0019	[L92b] TPHE E
6	00 30 50.00	-46 33 33.0	00 30 50	-46 33 33	12.474	0.0004	0.855	0.0058	0.532	0.0161	0.492	0.0004	0.435	0.0040	0.926	0.0036	[L92b] TPHE F
7	00 31 05.00	-46 22 43.0	00 31 05	-46 22 43	10.442	0.0004	1.546	0.0013	1.915	0.0036	0.934	0.0004	1.085	0.0009	2.025	0.0009	[L92b] TPHE G
8	00 31 50.00	+02 38 26.0	00 31 50	+02 38 26	15.268	0.0094	0.362	0.0174	-0.184	0.0112	0.251	0.0161	0.337	0.0125	0.593	0.0067	PG0029+024
9	00 42 05.00	+05 09 44.0	00 42 05	+05 09 44	12.877	0.0020	-0.019	0.0030	-0.871	0.0055	0.067	0.0035	0.097	0.0055	0.164	0.0045	PG0039+049
10	00 53 14.00	+00 46 02.0	00 53 14	+00 46 02	13.842	0.0035	0.513	0.0057	-0.024	0.0028	0.326	0.0014	0.325	0.0035	0.652	0.0014	SA 92 309
11	00 53 16.00	+00 48 29.0	00 53 16	+00 48 29	10.595	0.0058	1.638	0.0045	1.984	0.0098	0.894	0.0031	0.911	0.0045	1.806	0.0067	SA 92-312
12	00 53 47.00	+00 47 33.0	00 53 47	+00 47 33	12.676	0.0007	0.528	0.0049	-0.002	0.0028	0.302	0.0014	0.305	0.0007	0.608	0.0007	SA 92 322
13	00 54 16.00	+00 39 51.0	00 54 16	+00 39 51	13.818	0.0028	1.418	0.0079	1.189	0.0301	0.929	0.0024	0.907	0.0024	1.836	0.0028	SA 92 245
14	00 54 31.00	+00 40 15.0	00 54 31	+00 40 15	15.346	0.0255	1.128	0.0160	1.289	0.0955	0.690	0.0215	0.553	0.0145	1.245	0.0175	SA 92 248
15	00 54 34.00	+00 41 05.0	00 54 34	+00 41 05	14.325	0.0049	0.699	0.0085	0.240	0.0114	0.399	0.0046	0.370	0.0065	0.770	0.0073	SA 92 249
16	00 54 37.00	+00 38 56.0	00 54 37	+00 38 56	13.178	0.0022	0.814	0.0034	0.480	0.0074	0.446	0.0022	0.394	0.0022	0.840	0.0029	SA 92 250
17	00 54 44.00	+00 43 26.0	00 54 44	+00 43 26	15.073	0.0141	0.568	0.0297	-0.115	0.0163	0.331	0.0304	0.334	0.0000	0.666	0.0304	SA 92 330
18	00 54 48.00	+00 39 23.0	00 54 48	+00 39 23	14.932	0.0033	0.517	0.0055	-0.140	0.0082	0.326	0.0047	0.332	0.0072	0.666	0.0068	SA 92 252
19	00 54 52.00	+00 40 20.0	00 54 52	+00 40 20	14.085	0.0032	1.131	0.0062	0.955	0.0221	0.719	0.0027	0.616	0.0043	1.337	0.0050	SA 92 253
20	00 55 00.00	+00 44 13.0	00 55 00	+00 44 13	12.523	0.0007	0.672	0.0028	0.208	0.0049	0.380	0.0000	0.338	0.0014	0.719	0.0014	SA 92 335

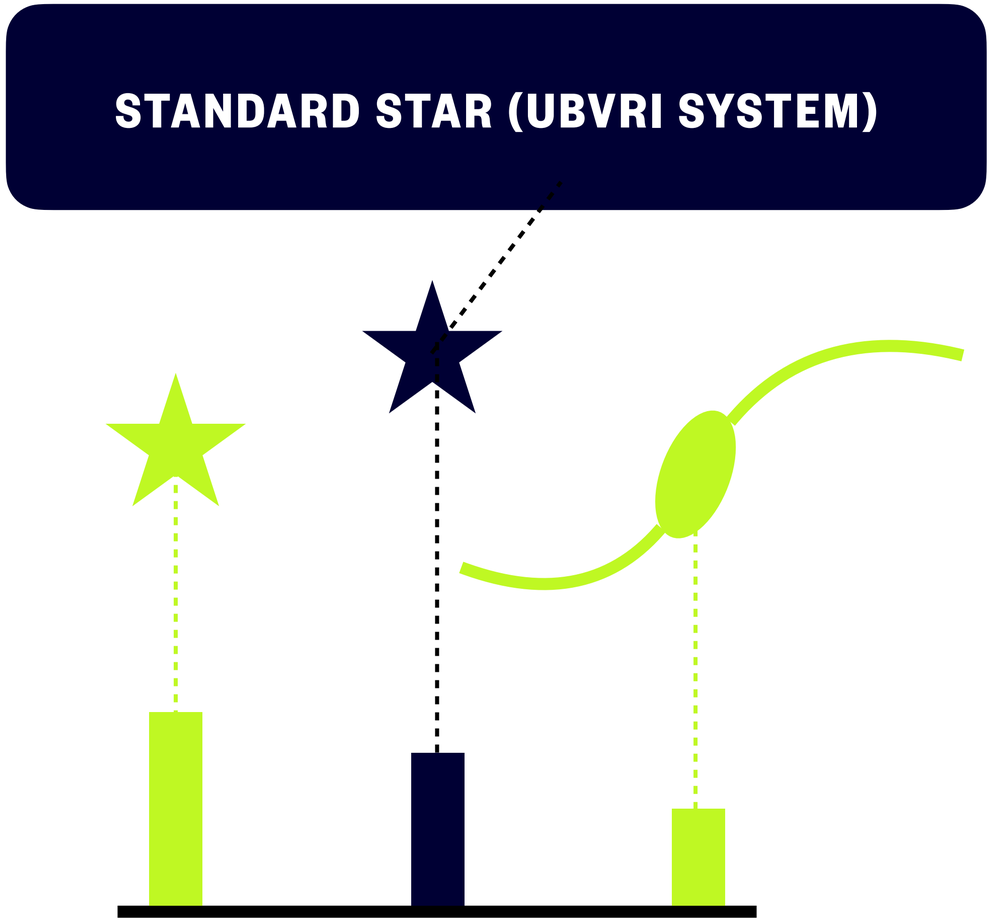
*Result truncated to **20** rows*
plot the output query using TAP/SQL

→ Cite/acknowledge VizieR catalogue
→ Rules of usage of VizieR data

Contact - Legals

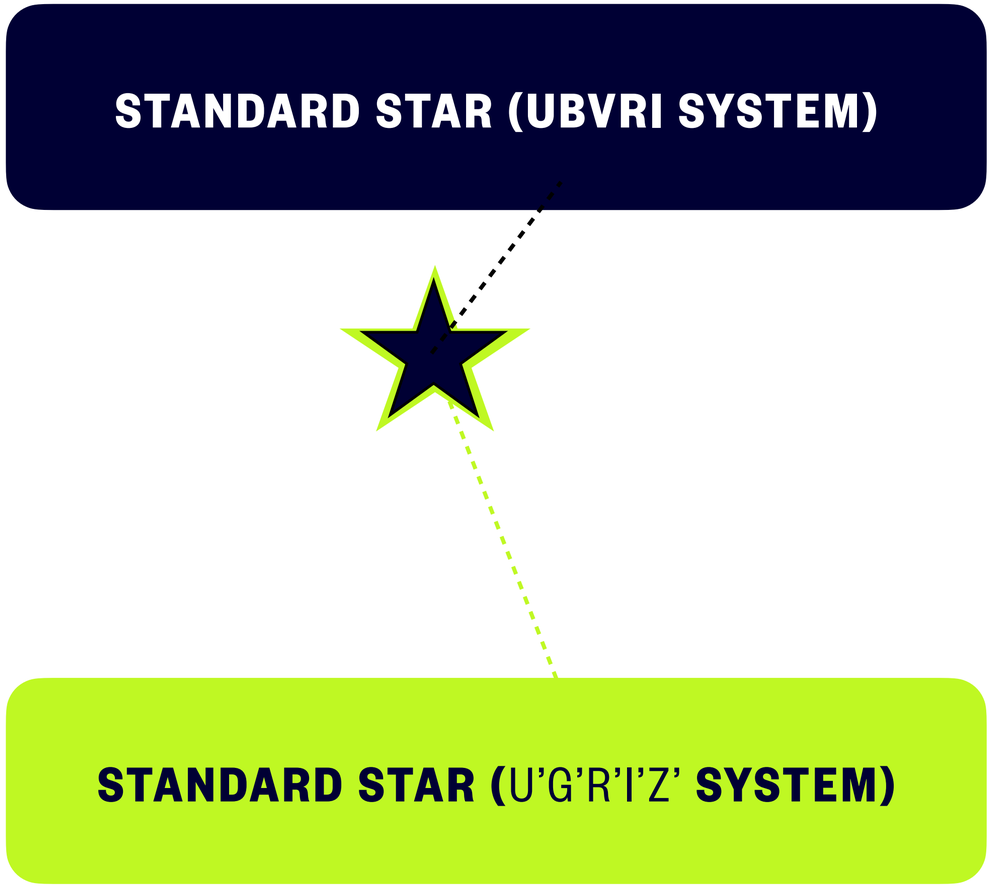


Standard calibration



- In most case, we need standard calibration for observation
- Compare CCD magnitude of target with standard star and calibrate them

Standard calibration



- Some case, we can apply standard calibration to band-to-band calibration
- Today, we will do this band-to-band calibration with 'Landolt standard stars catalog' and 'Sloan Digital Sky Survey (SDSS)'

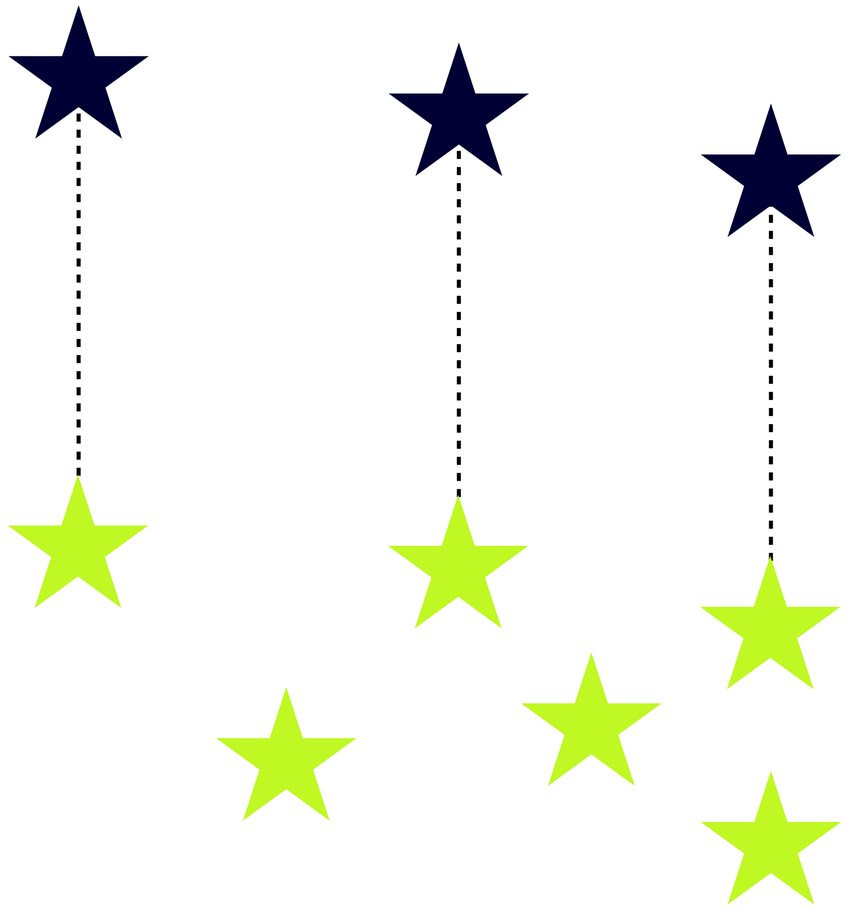
Standard calibration

FORMULA

$$m_{true,\,band} - m_{target,\,band} = k * C_{target} + Z_{band}$$

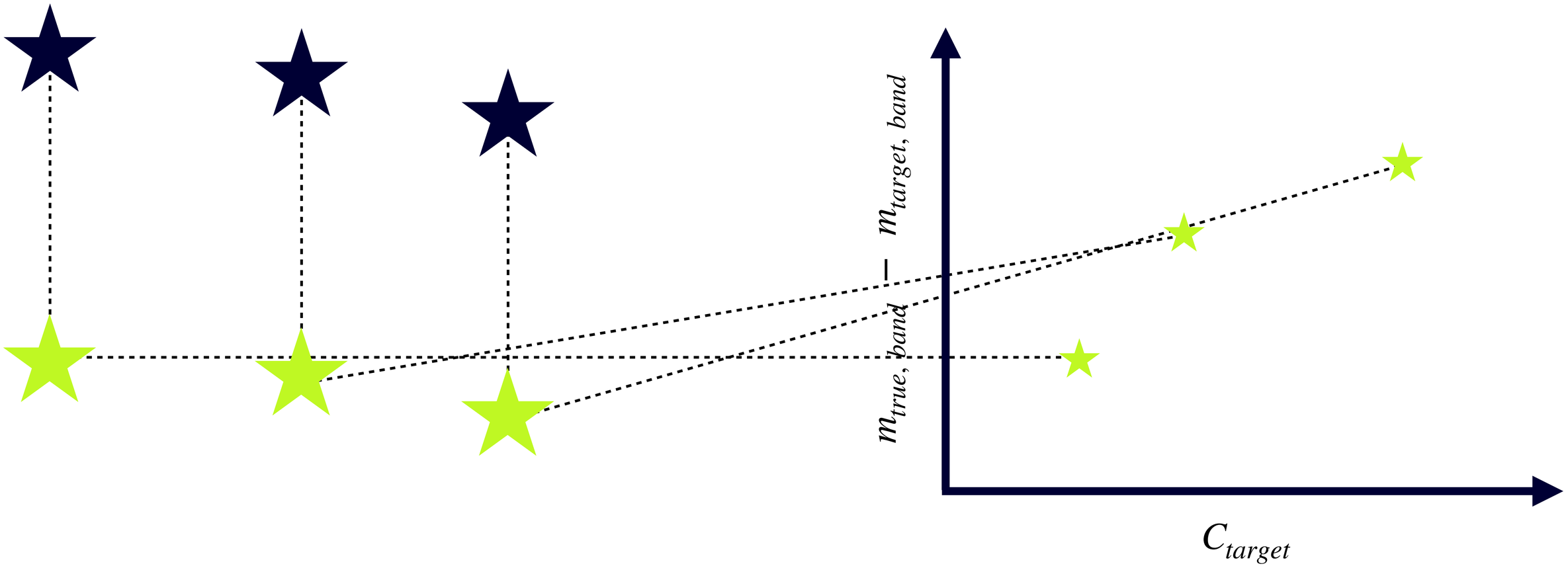
$m_{target,\,band}$	MAGNITUDE OF TARGET STAR	OBSERVED
$m_{true,\,band}$	MAGNITUDE OF STANDARD STAR	ESTIMATED
$C_{target} = m_{band,\,1} - m_{band,\,2}$	COLOR INDEX OF TARGET STAR	OBSERVED
$k,\ Z_{band}$	CALIBRATION PARAMETERS	ESTIMATED

Standard calibration

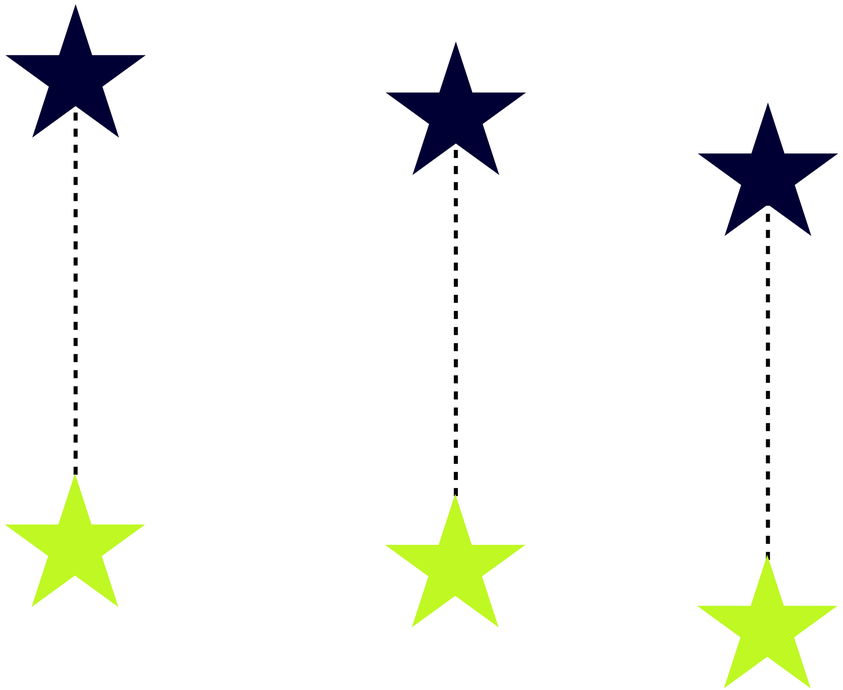


- Find standard stars in field of data
- Usually, we have to do aperture photometry to find ‘stars’, we will learn it next week
- Today, we just match the catalog of stars

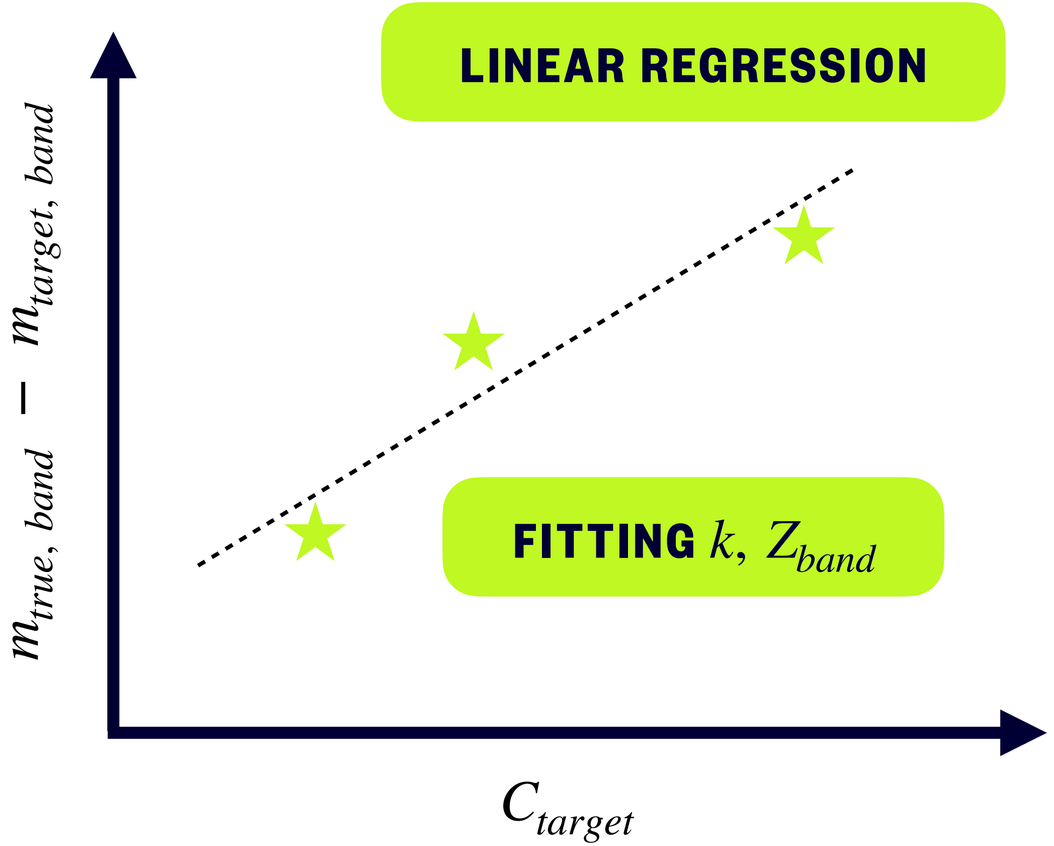
Standard calibration



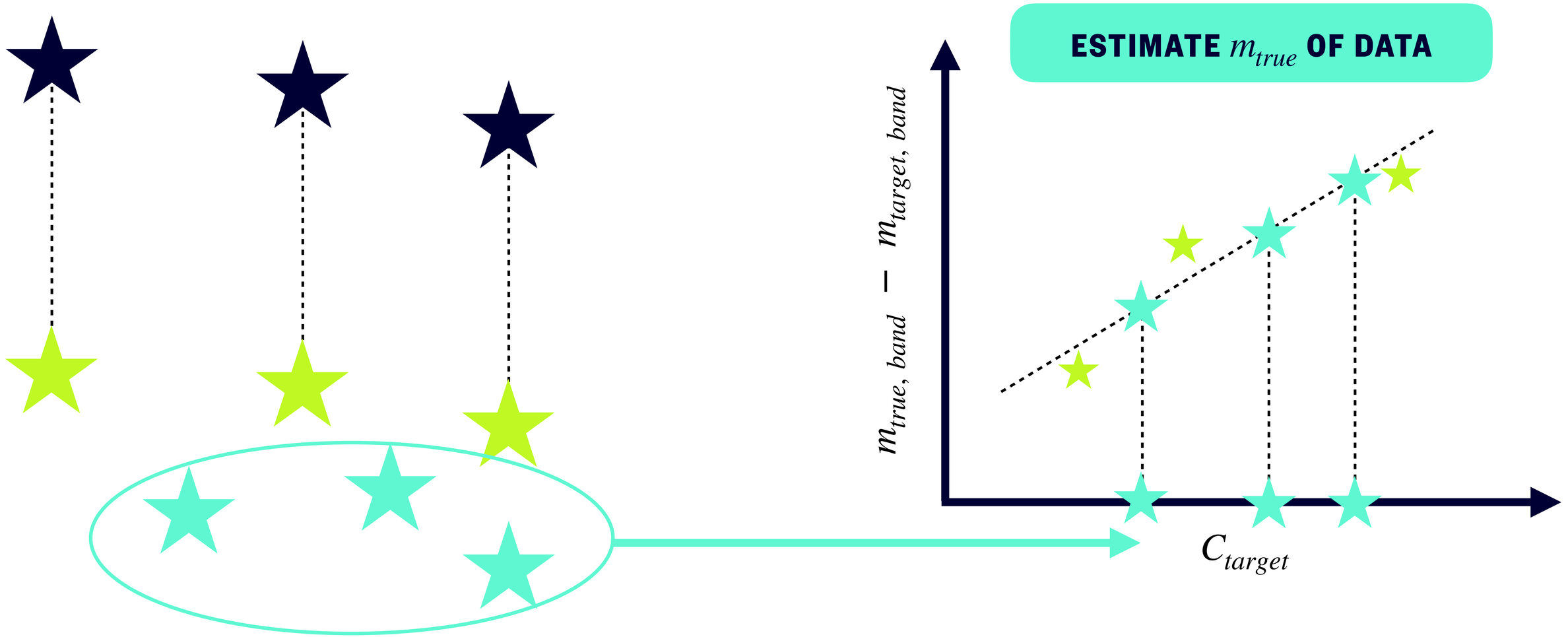
Standard calibration



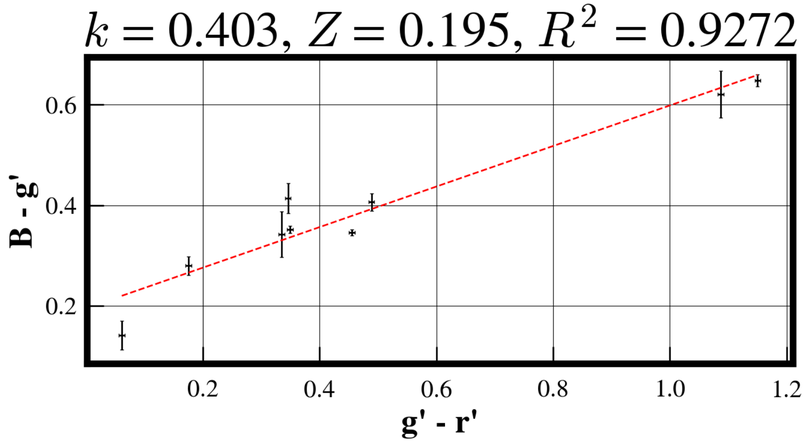
$$m_{true,\,band} - m_{target,\,band} = k * C_{target} + Z_{band}$$

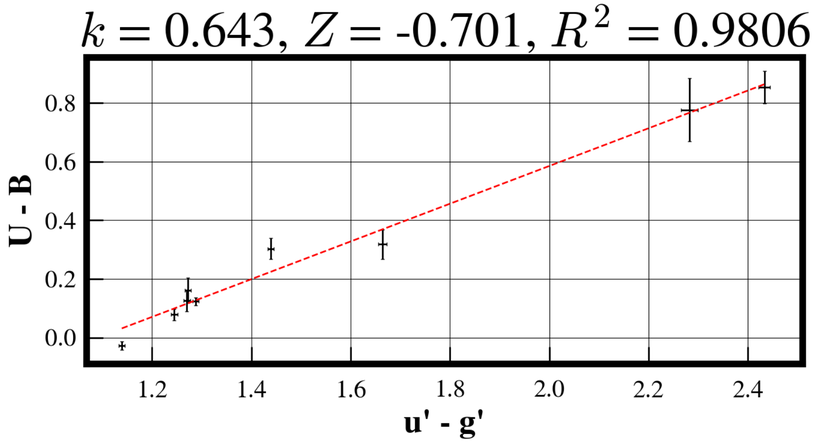


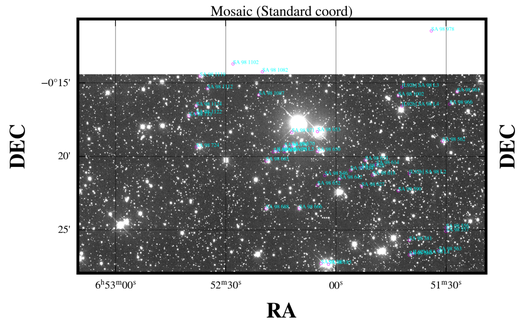
Standard calibration

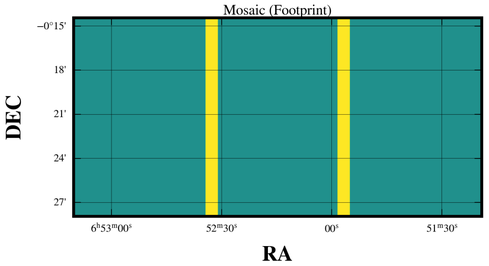


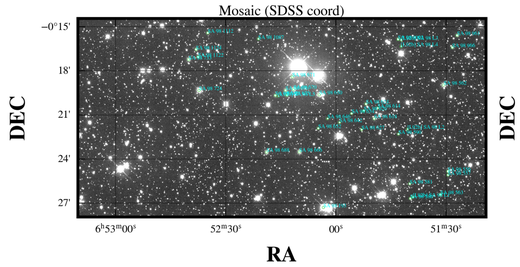
Real Goal

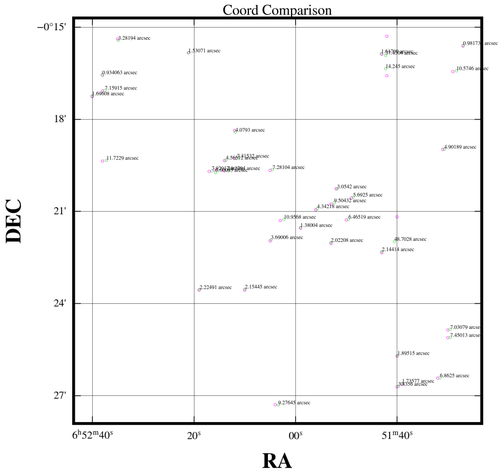

$k = 0.403,\ Z = 0.195,\ R^2 = 0.9272$
B - g'
g' - r'
0.2
0.4
0.6
0.8
1.0
1.2


$k = 0.643,\ Z = -0.701,\ R^2 = 0.9806$
U - B
u' - g'
0.0
0.2
0.4
0.6
0.8
1.2
1.4
1.6
1.8
2.0
2.2
2.4


Mosaic (Standard coord)
DEC
RA


Mosaic (Footprint)
DEC
RA


Mosaic (SDSS coord)
DEC
RA


Coord Comparison
DEC
RA

Practice

- We will practice standard calibration with Landolt standard stars catalog

- Our goal of practice is converting ugriz photometric system to UBVRI photometric system