利用蓋婭數據研究星團

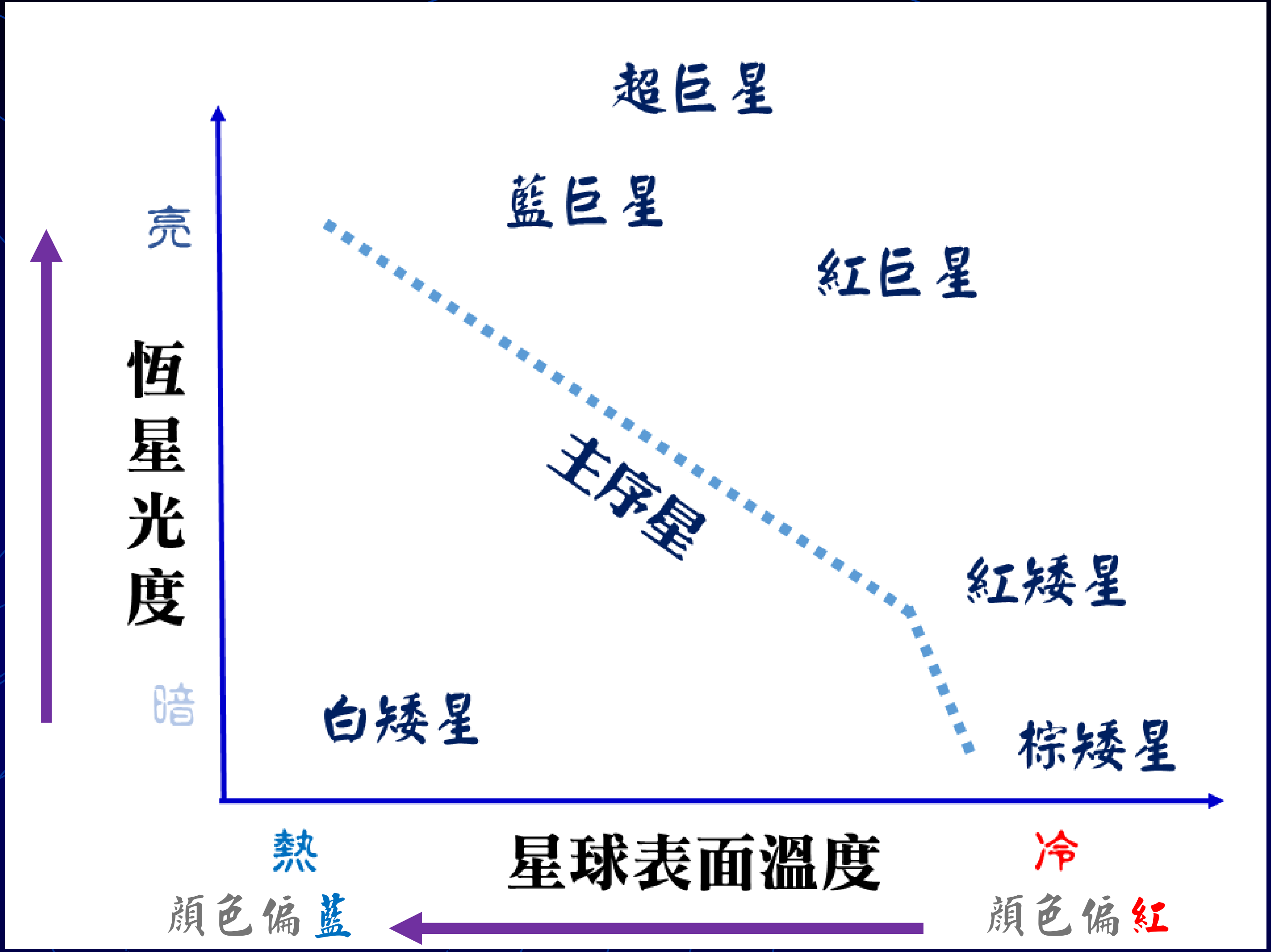
陳文屏
2024.11.15

- ✓ 赫羅圖
- ✓ 蓋婭望遠鏡
- ✓ 指認星團成員星——以M67為例

量化恆星的工具
—— 赫羅圖

Ejnar Hertzsprung 及 Henry Norris Russell (~1910)

HRD 可以是
光譜型態 versus 絕對星等
表面溫度 vs 光度
顏色 vs 星等

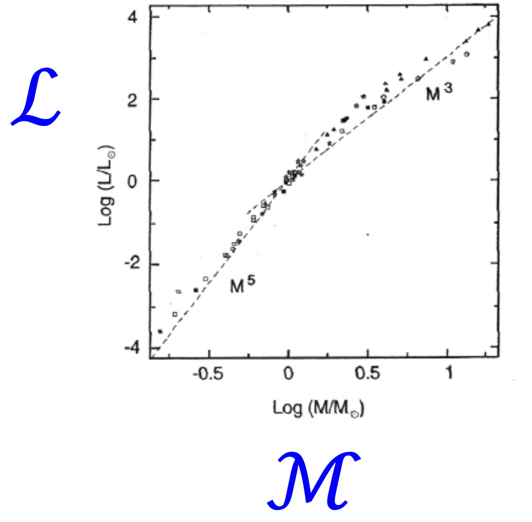

超巨星
藍巨星
紅巨星
亮
恆星光度
主序星
紅矮星
暗
白矮星
棕矮星
熱
星球表面溫度
冷
顏色偏藍
顏色偏紅

O B A F G K M L T Y

習慣上橫軸溫度 T 向左增加
縱軸光度 $\mathcal{L}$ 向上增加

光度：多會發光；功率
亮度：看起來多亮；視星等
（光度、距離、消光）
放在標準距離來比亮度：絕對星等（光度）

$$\underbrace{\mathcal{L}}_{\text{恆星光度}} = \underbrace{4\,\pi\,\mathcal{R}^2}_{\text{表面積}}\ \underbrace{\sigma\,T^4}_{\text{單位面積輻射功率}}$$



主序 (main-sequence)

□ 主序星質量越大，半徑稍大，光度非常強 $\boxed{\mathcal{L} \propto \mathcal{M}^{3\sim5}}$ **質光關係**

□ 大質量恆星→ 核反應快（得多）→ $\mathcal{L}\uparrow\uparrow\uparrow$

→ 大量能量通過表面 $4\,\pi\,\mathcal{R}^2$ → $T\uparrow$

小質量恆星 → 核反應相對較慢 → luminous $\mathcal{L}\downarrow$ → $T\downarrow$

➔HR 圖上左上到右下「穩定恆星」構成的「主序」帶狀結構

主序＝恆星（中央穩定核融合）的質量序列

但（全波段）光度怎麼測量？溫度呢？

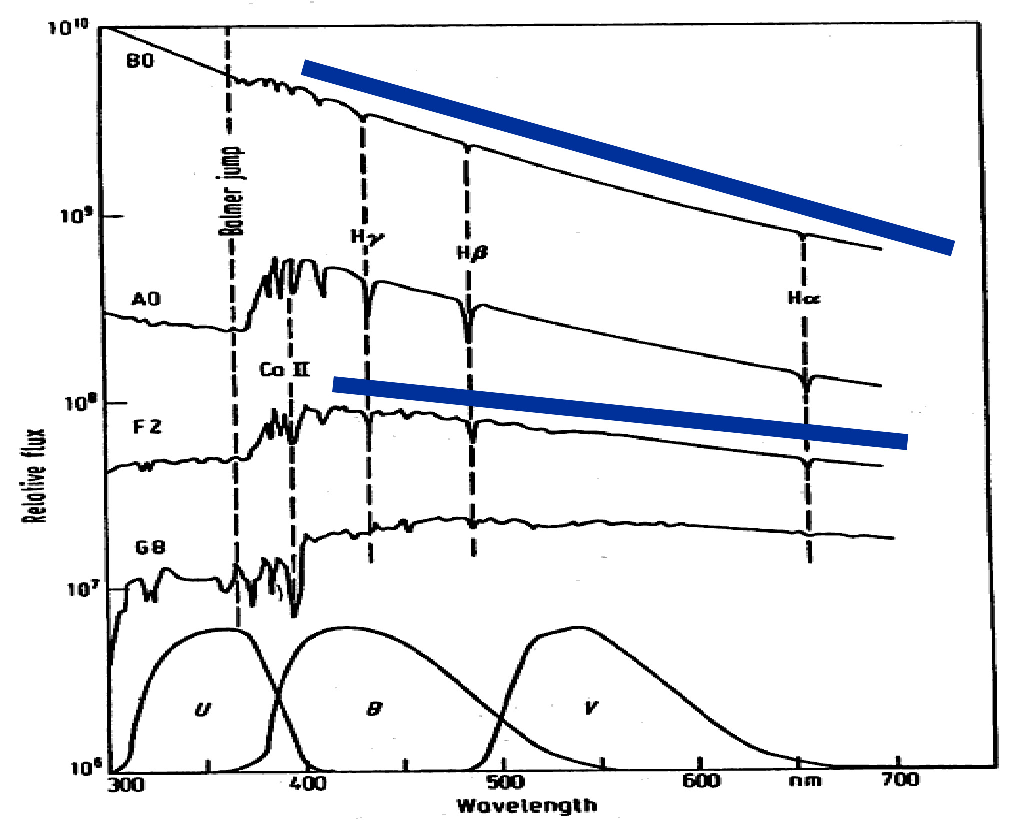
實務上，以兩個可觀測（恆星表面）的物理量，例如「顏色」與「星等」 color-magnitude diagram (CMD) 來代表 HRD

不同溫度的恆星 → 例如在*B*跟*V*兩個波段的亮度比（斜率）不同

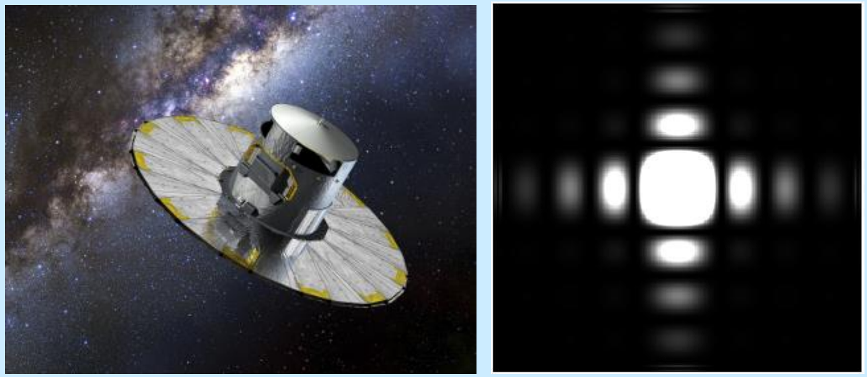
亮度比＝星等差 $(m_B - m_V)$

例如以*V*星等代表亮度，以（*B*−*V*）代表表面溫度

因為星星遠近距離不同，CMD 該用絕對星等



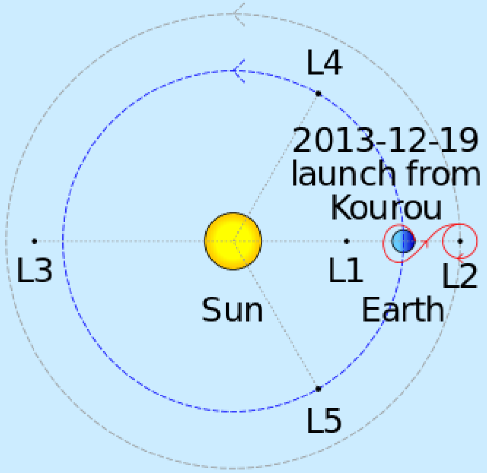
Gaia (Space Telescope) 蓋婭太空望遠鏡



1.45 m × 0.5 m primary

✓ 2013 to 2025? by ESA

✓ High-precision astrometry (position)
→ distance + motion
→ 3D map of MW and beyond;
quasars, exoplanets



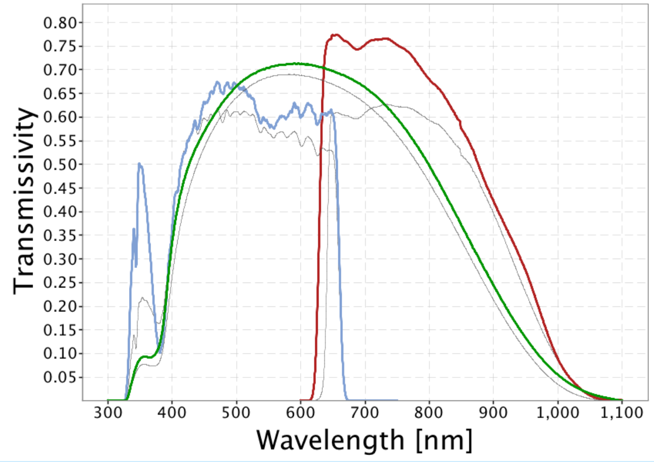
Orbit @Sun-Earth L2;
with Webb, Euclid

✓ 精確位置（的變化）
→計算恆星的自行、週年視差

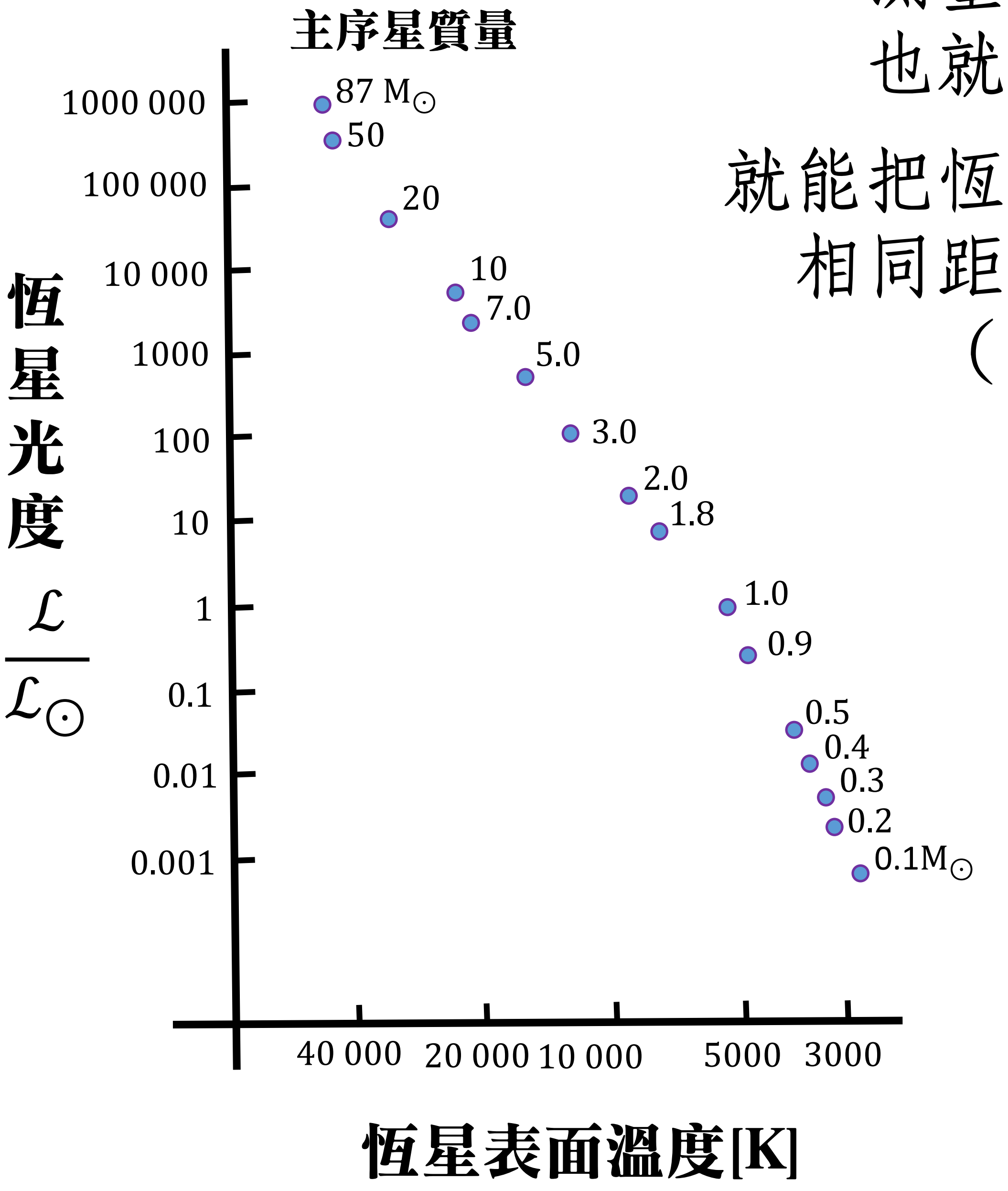
✓ 精確亮度；極限約20 mag (1% MW)

✓ *G*, *BP*, *RP* photometry + spectroscopy
→ $L, T_{\mathrm{eff}}, g,\ [M/H]$, and RV

✓ Latest DR3 in 2022.06

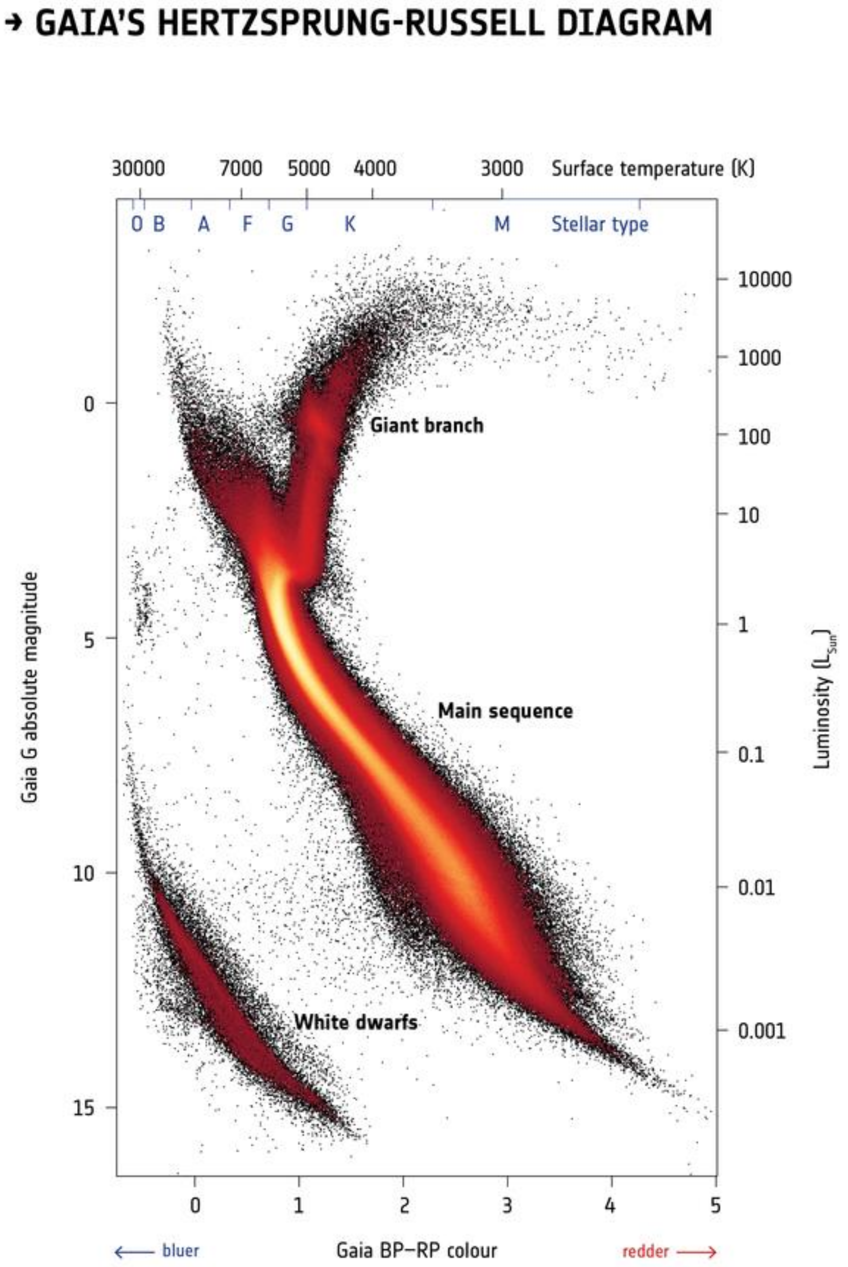


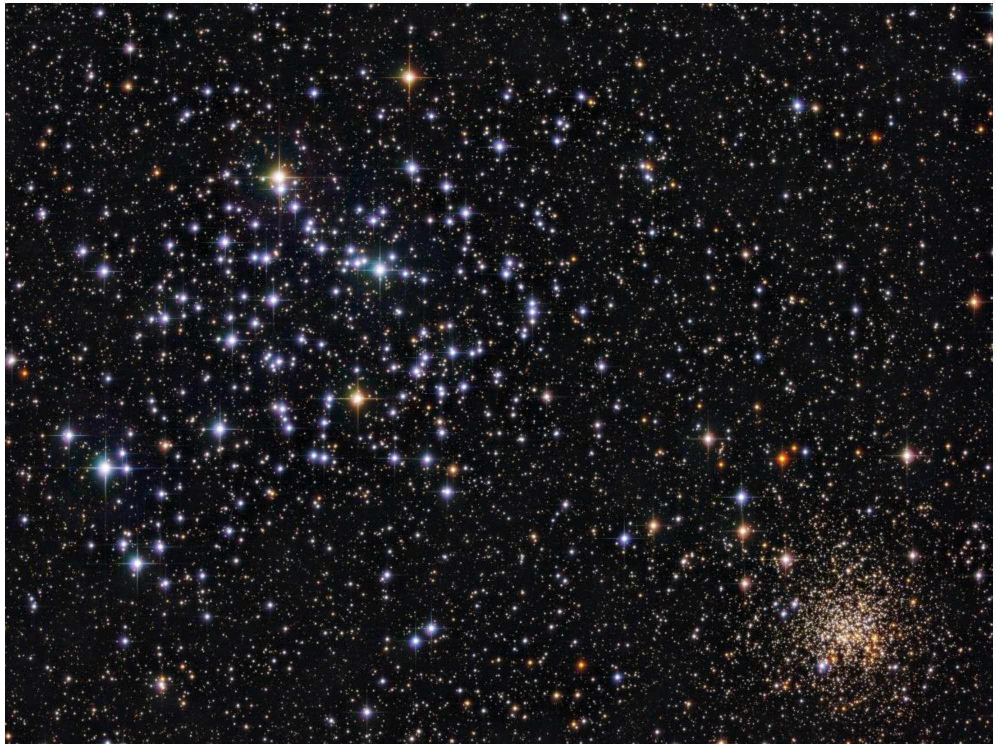
(green: G; blue: G_{BP}; red: G_{RP}), defining the Gaia DR2 photometric system. The thin, grey lines show the nominal, pre-launch passbands published in Jordi et al. 2010, used for Gaia DR1.



Gaia 測量週年視差，
也就能估計距離

就能把恆星假如放在
相同距離來比亮度
（絕對星等）





星團的成員星源於同一團星際雲氣，各自引力收縮而形成

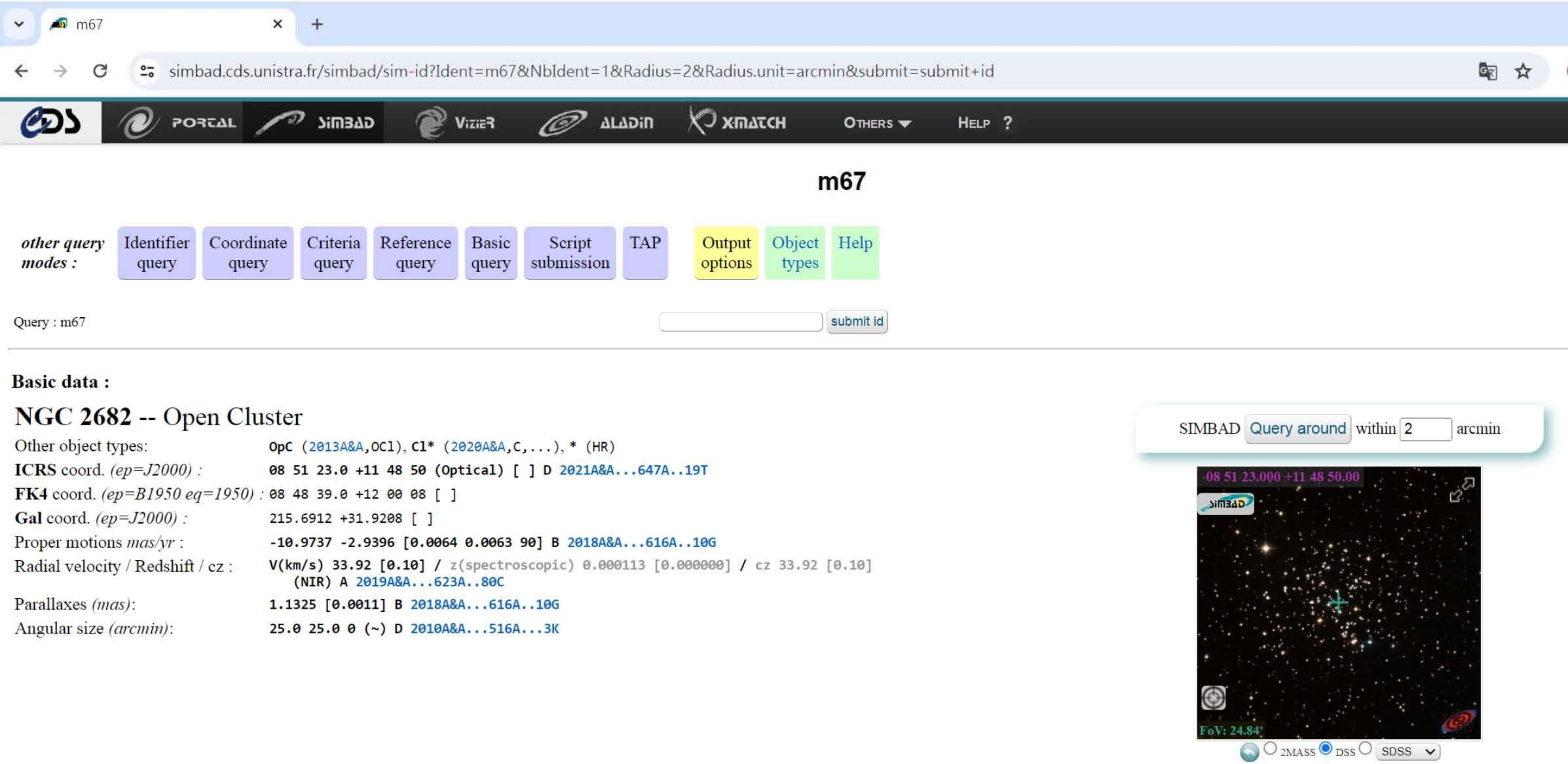
大質量恆星光度強、溫度高（顏色偏藍）

低質量恆星光度弱、溫度低（顏色偏紅）

- □ 成分相同
- □ 距離相同
- □ 運動相同
- □ 年齡相同（但因為質量不同，演化各異）

星團成員彼此引力交互作用，大質量成員減速，而「沉澱」集中在中央區域；小質量成員則加速，而分布在比較大的體積內，甚至可能被拋出

受到周圍天體引力影響（分子雲、其他星團等等），星團受到引力（潮汐力）拉扯而變形，甚至撕裂而分解


m67
simbad.cds.unistra.fr/simbad/sim-id?Ident=m67&NbIdent=1&Radius=2&Radius.unit=arcmin&submit=submit+id
PORTAL
SIMBAD
VizieR
ALADIN
XMATCH
OTHERS
HELP ?
other query modes :
Identifier query
Coordinate query
Criteria query
Reference query
Basic query
Script submission
TAP
Output options
Object types
Help
submit id
SIMBAD
Query around
within
2
arcmin
08 51 23.000 +11 48 50.00
SIMBAD
FoV: 24.84'
2MASS
DSS
SDSS

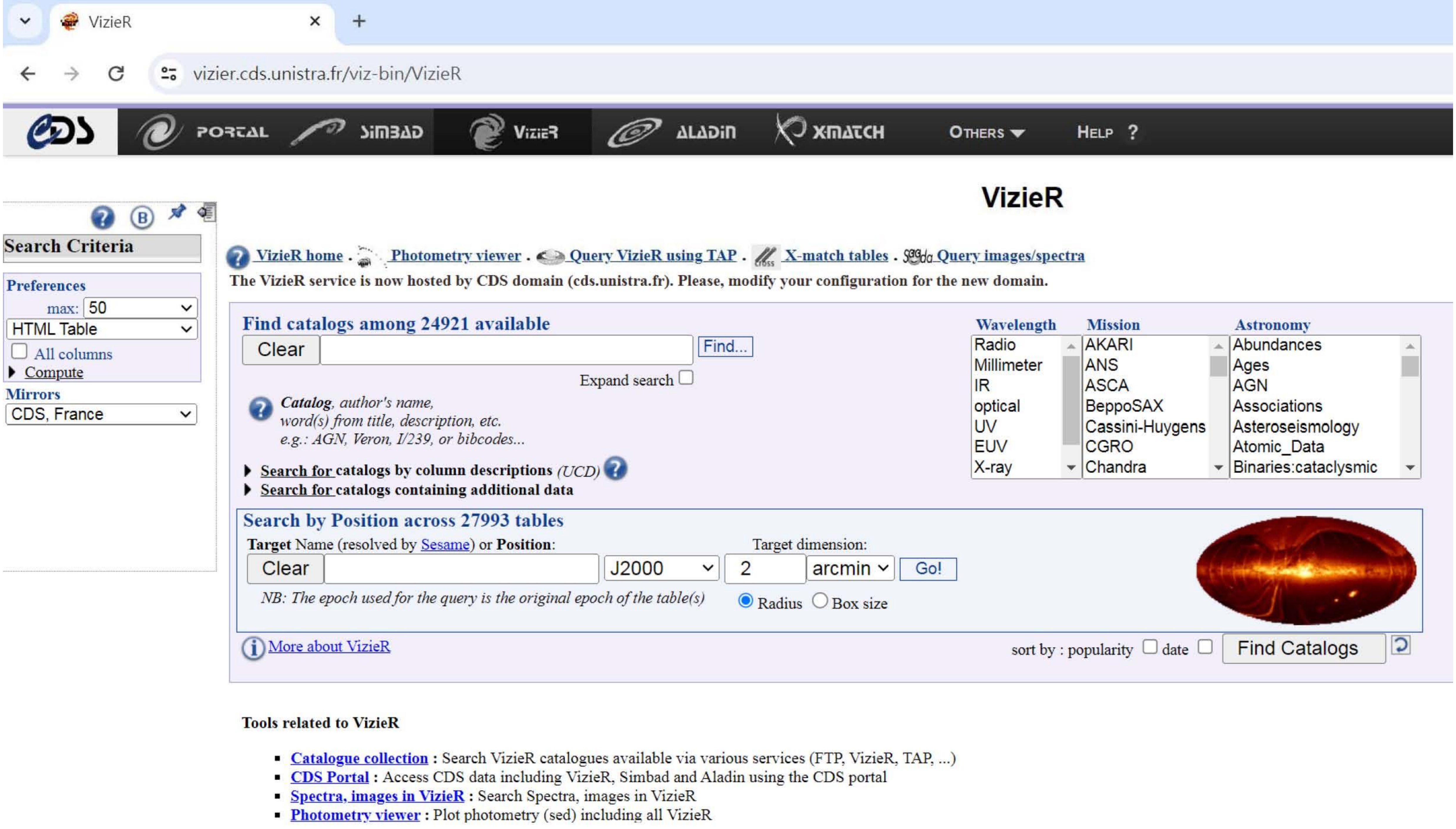
m67

Query : m67

Basic data :

NGC 2682 -- Open Cluster

Other object types:	OpC (2013A&A,OCl), Cl* (2020A&A,C,...), * (HR)
ICRS coord. *(ep=J2000)* :	08 51 23.0 +11 48 50 (Optical) [ ] D 2021A&A...647A..19T
FK4 coord. *(ep=B1950 eq=1950)* :	08 48 39.0 +12 00 08 [ ]
Gal coord. *(ep=J2000)* :	215.6912 +31.9208 [ ]
Proper motions *mas/yr* :	-10.9737 -2.9396 [0.0064 0.0063 90] B 2018A&A...616A..10G
Radial velocity / Redshift / cz :	V(km/s) 33.92 [0.10] / z(spectroscopic) 0.000113 [0.000000] / cz 33.92 [0.10] (NIR) A 2019A&A...623A..80C
Parallaxes *(mas)*:	1.1325 [0.0011] B 2018A&A...616A..10G
Angular size *(arcmin)*:	25.0 25.0 0 (~) D 2010A&A...516A...3K


VizieR
vizier.cds.unistra.fr/viz-bin/VizieR
CDS
PORTAL
SIMBAD
VIZIER
ALADIN
XMATCH
OTHERS
HELP ?
Search Criteria
Clear
Find...
Clear
Go!
Find Catalogs

VizieR

VizieR home . Photometry viewer . Query VizieR using TAP . X-match tables . Query images/spectra

The VizieR service is now hosted by CDS domain (cds.unistra.fr). Please, modify your configuration for the new domain.

Preferences

max: 50

HTML Table

☐ All columns

Compute

Mirrors

CDS, France

Find catalogs among 24921 available

Expand search ☐

***Catalog**, author's name,*
word(s) from title, description, etc.
e.g.: AGN, Veron, I/239, or bibcodes...

Search for catalogs by column descriptions *(UCD)*

Search for catalogs containing additional data

Wavelength	Mission	Astronomy
Radio	AKARI	Abundances
Millimeter	ANS	Ages
IR	ASCA	AGN
optical	BeppoSAX	Associations
UV	Cassini-Huygens	Asteroseismology
EUV	CGRO	Atomic_Data
X-ray	Chandra	Binaries:cataclysmic

Search by Position across 27993 tables

Target Name (resolved by Sesame) or **Position**: J2000

Target dimension: 2 arcmin

NB: The epoch used for the query is the original epoch of the table(s)

● Radius ○ Box size

More about VizieR

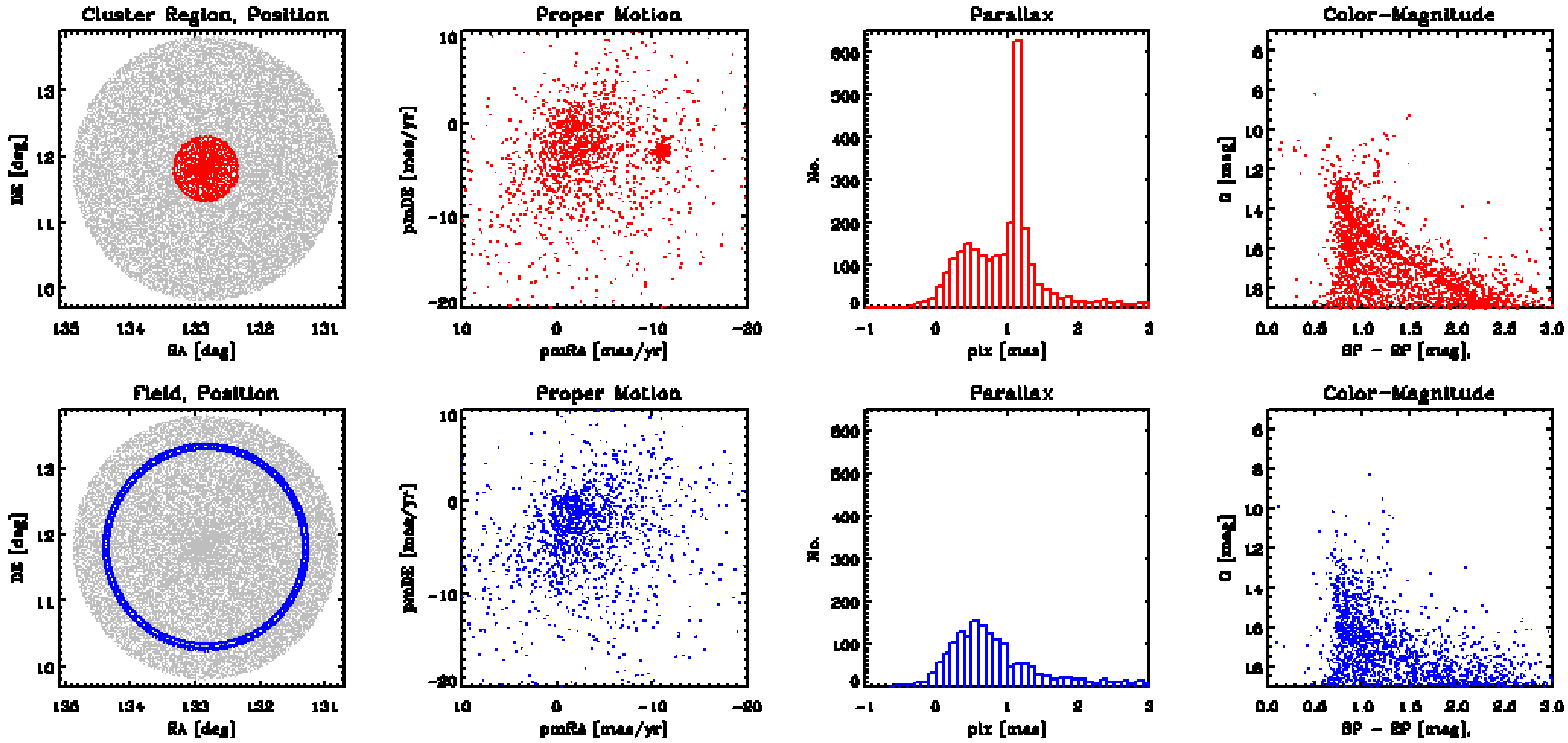
sort by : popularity ☐ date ☐

Tools related to VizieR

- **Catalogue collection** : Search VizieR catalogues available via various services (FTP, VizieR, TAP, ...)
- **CDS Portal** : Access CDS data including VizieR, Simbad and Aladin using the CDS portal
- **Spectra, images in VizieR** : Search Spectra, images in VizieR
- **Photometry viewer** : Plot photometry (sed) including all VizieR

星團區＝成員＋場星

以視星等繪製CMD



參考區＝場星

視星等

絕對星等

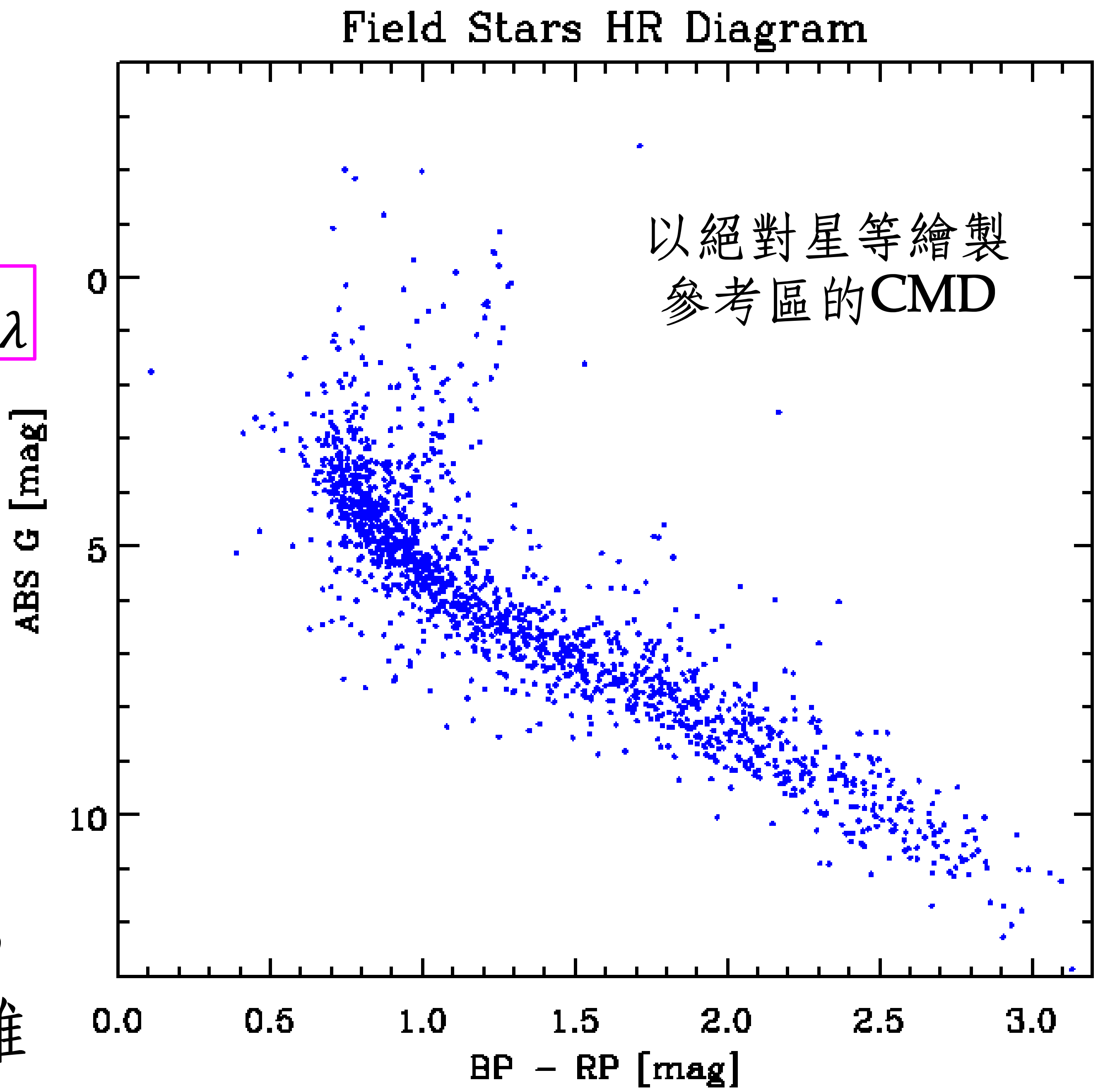
$$m_\lambda - M_\lambda = 5\ \log d_{\mathrm{pc}} - 5 + A_\lambda$$

距離

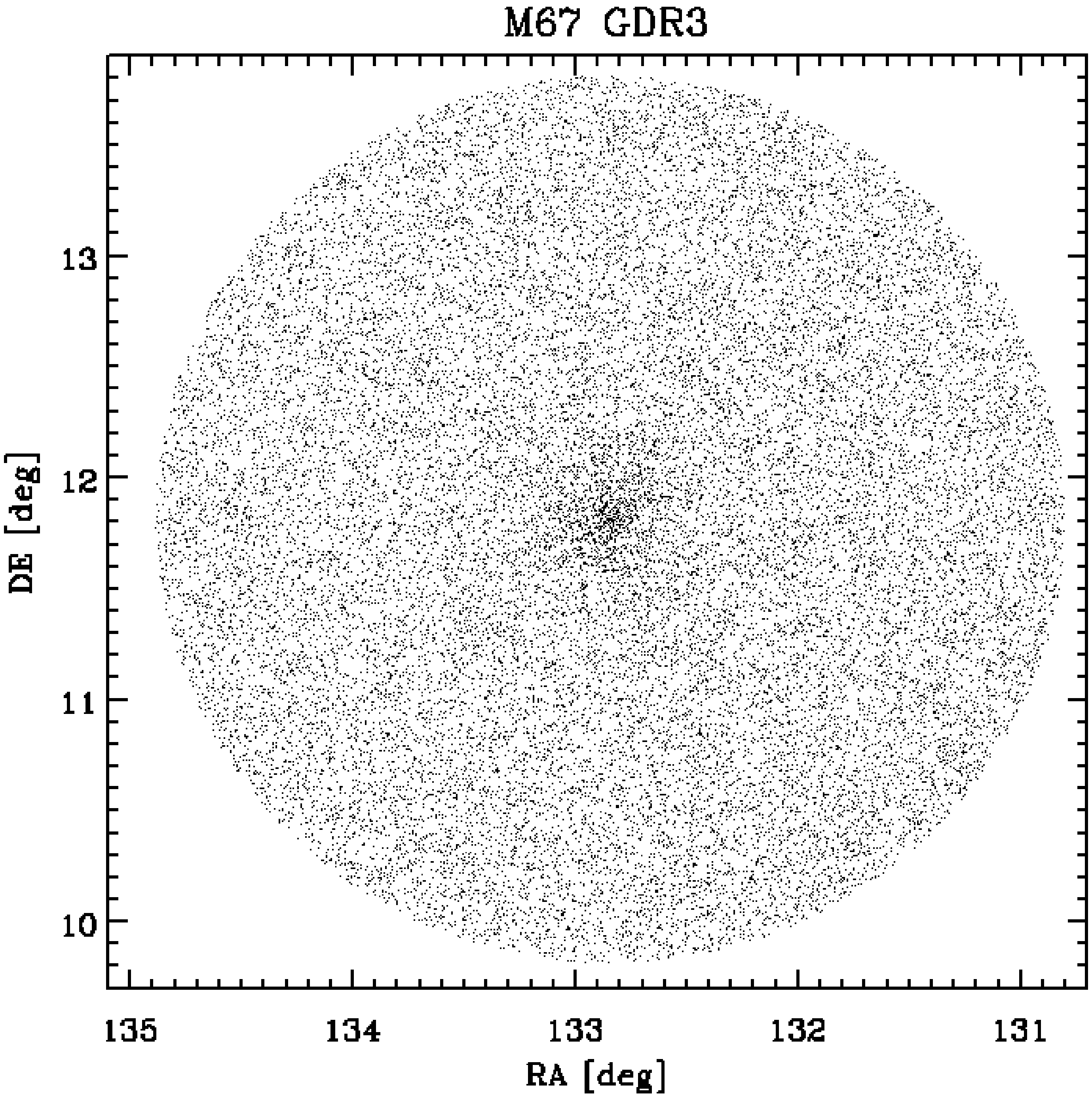
消光

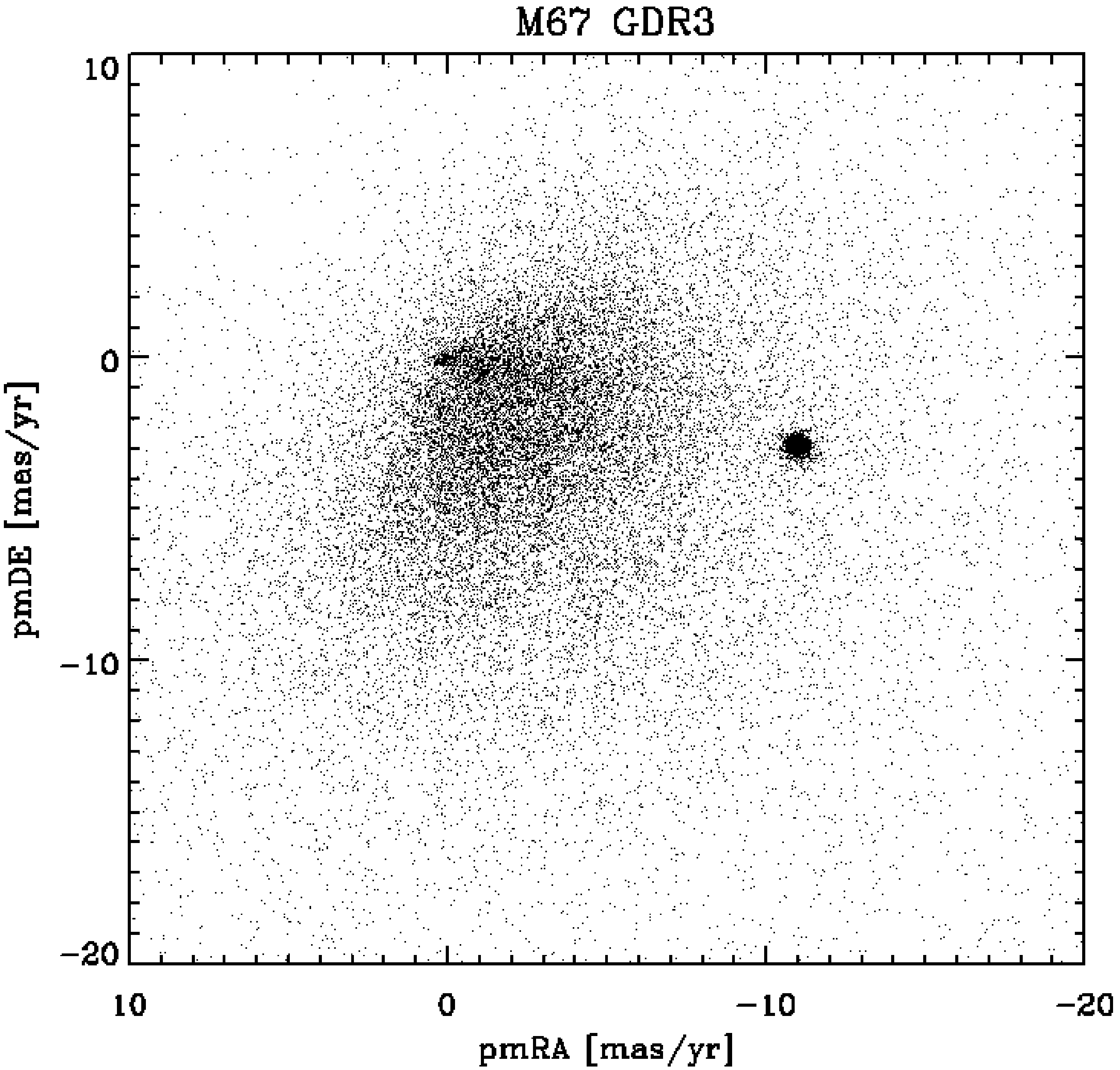
不計消光的話，
當$d = 10\ \mathrm{pc}, m = M$

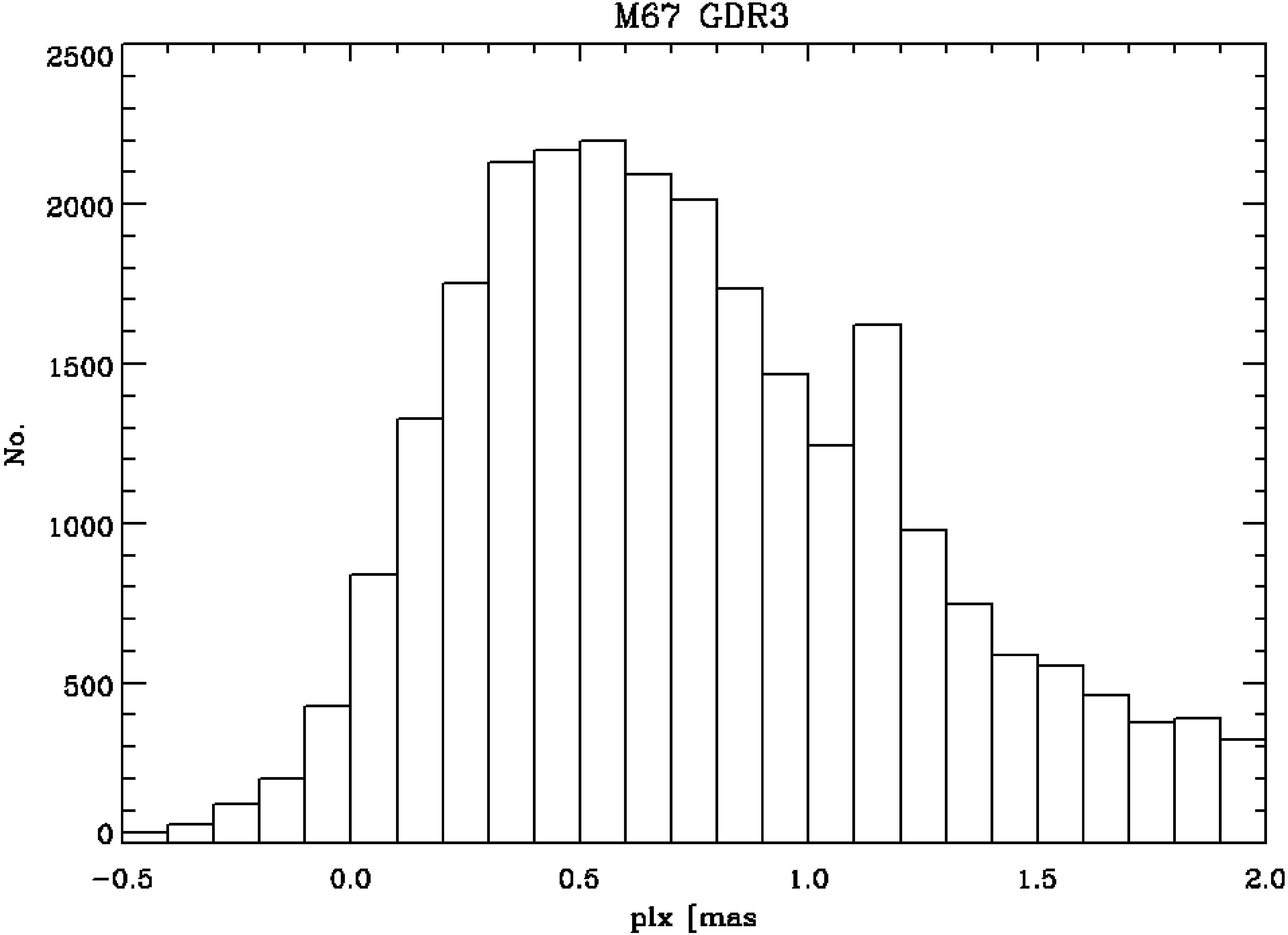
10 pc 是標準距離，
恆星不在該距離



以絕對星等繪製
參考區的CMD

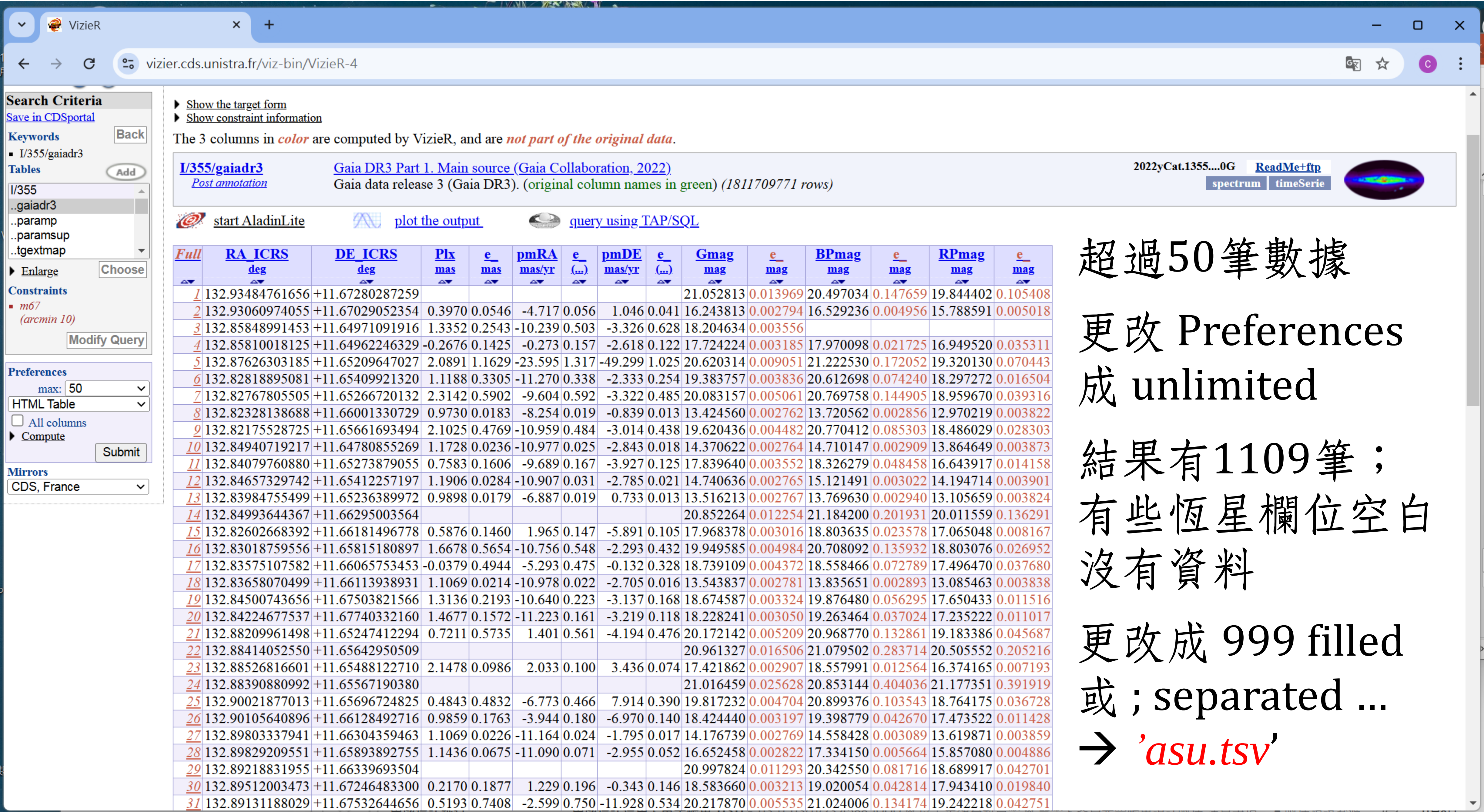

M67 GDR3
DE [deg]
13
12
11
10
RA [deg]
135
134
133
132
131


M67 GDR3
pmDE [mas/yr]
10
0
−10
−20
pmRA [mas/yr]
10
0
−10
−20


M67 GDR3
No.
plx [mas
2500
2000
1500
1000
500
0
−0.5
0.0
0.5
1.0
1.5
2.0

- ✓ Google ‘vizier gaia dr3’
- ✓ Target: m67 (default 2’; max: 50, HTML table)

  數據有很多欄位，每欄代表一個物理量
- ✓ 跟我們最相關的有，坐標 (RA, DE), 週年視差角 (Plx),
  自行運動 (pmRA, pmDE), 視星等 (Gmag, BPmag, RPmag) …
  以及相對應的誤差
- ✓ 自己下載10’ 角分的數據；或從這裡下載
  https://www.astro.ncu.edu.tw/~wchen/Tmp/asu.tsv



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

I/355/gaiadr3 Gaia DR3 Part 1. Main source (Gaia Collaboration, 2022)
Post annotation
Gaia data release 3 (Gaia DR3). (original column names in green) *(1811709771 rows)*
2022yCat.1355....0G

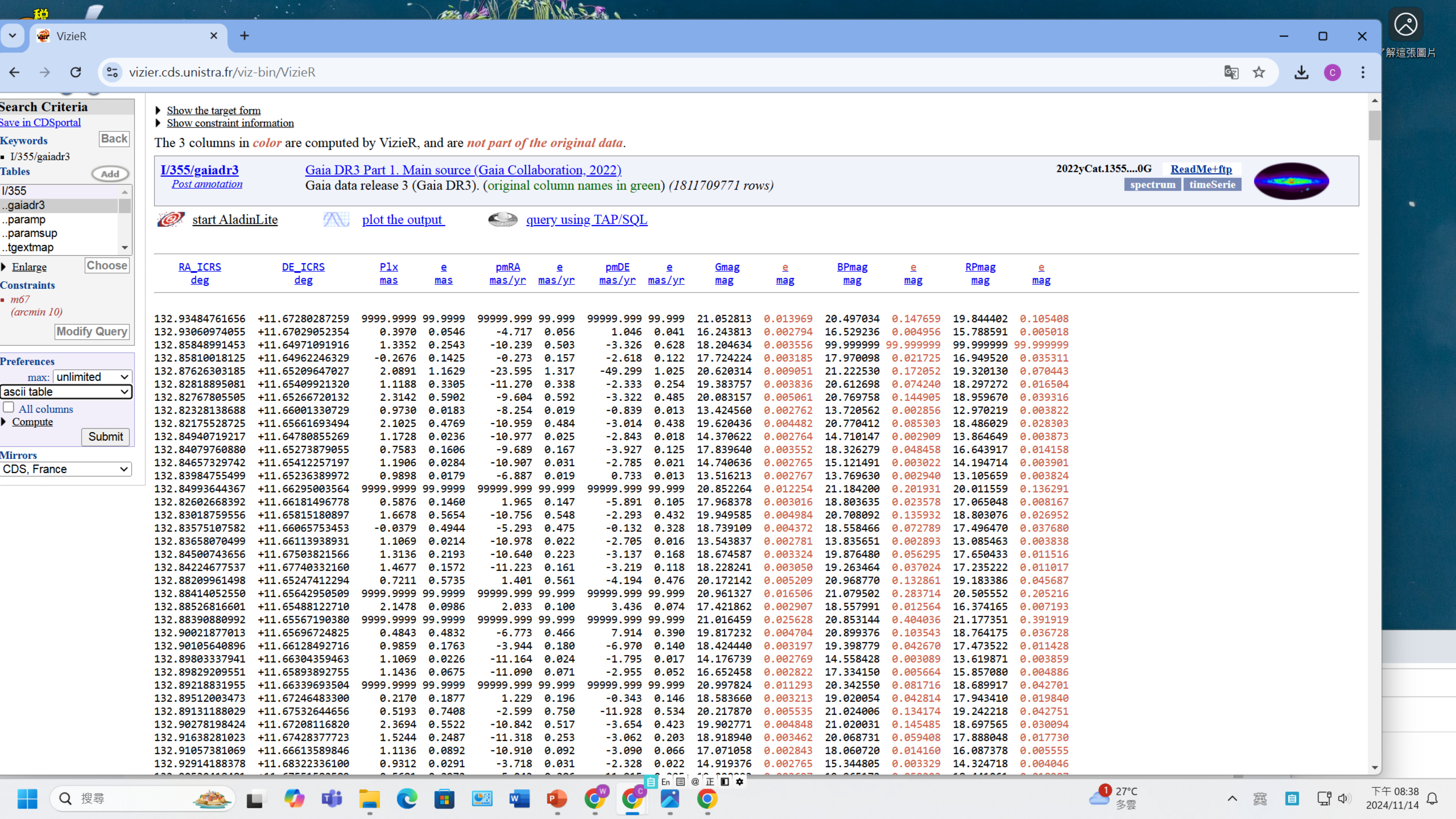
Full	RA_ICRS deg	DE_ICRS deg	Plx mas	e_ mas	pmRA mas/yr	e_ (...)	pmDE mas/yr	e_ (...)	Gmag mag	e_ mag	BPmag mag	e_ mag	RPmag mag	e_ mag
1	132.93484761656	+11.67280287259							21.052813	0.013969	20.497034	0.147659	19.844402	0.105408
2	132.93060974055	+11.67029052354	0.3970	0.0546	-4.717	0.056	1.046	0.041	16.243813	0.002794	16.529236	0.004956	15.788591	0.005018
3	132.85848991453	+11.64971091916	1.3352	0.2543	-10.239	0.503	-3.326	0.628	18.204634	0.003556				
4	132.85810018125	+11.64962246329	-0.2676	0.1425	-0.273	0.157	-2.618	0.122	17.724224	0.003185	17.970098	0.021725	16.949520	0.035311
5	132.87626303185	+11.65209647027	2.0891	1.1629	-23.595	1.317	-49.299	1.025	20.620314	0.009051	21.222530	0.172052	19.320130	0.070443
6	132.82818895081	+11.65409921320	1.1188	0.3305	-11.270	0.338	-2.333	0.254	19.383757	0.003836	20.612698	0.074240	18.297272	0.016504
7	132.82767805505	+11.65266720132	2.3142	0.5902	-9.604	0.592	-3.322	0.485	20.083157	0.005061	20.769758	0.144905	18.959670	0.039316
8	132.82328138688	+11.66001330729	0.9730	0.0183	-8.254	0.019	-0.839	0.013	13.424560	0.002762	13.720562	0.002856	12.970219	0.003822
9	132.82175528725	+11.65661693494	2.1025	0.4769	-10.959	0.484	-3.014	0.438	19.620436	0.004482	20.770412	0.085303	18.486029	0.028303
10	132.84940719217	+11.64780855269	1.1728	0.0236	-10.977	0.025	-2.843	0.018	14.370622	0.002764	14.710147	0.002909	13.864649	0.003873
11	132.84079760880	+11.65273879055	0.7583	0.1606	-9.689	0.167	-3.927	0.125	17.839640	0.003552	18.326279	0.048458	16.643917	0.014158
12	132.84657329742	+11.65412257197	1.1906	0.0284	-10.907	0.031	-2.785	0.021	14.740636	0.002765	15.121491	0.003022	14.194714	0.003901
13	132.83984755499	+11.65236389972	0.9898	0.0179	-6.887	0.019	0.733	0.013	13.516213	0.002767	13.769630	0.002940	13.105659	0.003824
14	132.84993644367	+11.66295003564							20.852264	0.012254	21.184200	0.201931	20.011559	0.136291
15	132.82602668392	+11.66181496778	0.5876	0.1460	1.965	0.147	-5.891	0.105	17.968378	0.003016	18.803635	0.023578	17.065048	0.008167
16	132.83018759556	+11.65815180897	1.6678	0.5654	-10.756	0.548	-2.293	0.432	19.949585	0.004984	20.708092	0.135932	18.803076	0.026952
17	132.83575107582	+11.66065753453	-0.0379	0.4944	-5.293	0.475	-0.132	0.328	18.739109	0.004372	18.558466	0.072789	17.496470	0.037680
18	132.83658070499	+11.66113938931	1.1069	0.0214	-10.978	0.022	-2.705	0.016	13.543837	0.002781	13.835651	0.002893	13.085463	0.003838
19	132.84500743656	+11.67503821566	1.3136	0.2193	-10.640	0.223	-3.137	0.168	18.674587	0.003324	19.876480	0.056295	17.650433	0.011516
20	132.84224677537	+11.67740332160	1.4677	0.1572	-11.223	0.161	-3.219	0.118	18.228241	0.003050	19.263464	0.037024	17.235222	0.011017
21	132.88209961498	+11.65247412294	0.7211	0.5735	1.401	0.561	-4.194	0.476	20.172142	0.005209	20.968770	0.132861	19.183386	0.045687
22	132.88414052550	+11.65642950509							20.961327	0.016506	21.079502	0.283714	20.505552	0.205216
23	132.88526816601	+11.65488122710	2.1478	0.0986	2.033	0.100	3.436	0.074	17.421862	0.002907	18.557991	0.012564	16.374165	0.007193
24	132.88390880992	+11.65567190380							21.016459	0.025628	20.853144	0.404036	21.177351	0.391919
25	132.90021877013	+11.65696724825	0.4843	0.4832	-6.773	0.466	7.914	0.390	19.817232	0.004704	20.899376	0.103543	18.764175	0.036728
26	132.90105640896	+11.66128492716	0.9859	0.1763	-3.944	0.180	-6.970	0.140	18.424440	0.003197	19.398779	0.042670	17.473522	0.011428
27	132.89803337941	+11.66304359463	1.1069	0.0226	-11.164	0.024	-1.795	0.017	14.176739	0.002769	14.558428	0.003089	13.619871	0.003859
28	132.89829209551	+11.65893892755	1.1436	0.0675	-11.090	0.071	-2.955	0.052	16.652458	0.002822	17.334150	0.005664	15.857080	0.004886
29	132.89218831955	+11.66339693504							20.997824	0.011293	20.342550	0.081716	18.689917	0.042701
30	132.89512003473	+11.67246483300	0.2170	0.1877	1.229	0.196	-0.343	0.146	18.583660	0.003213	19.020054	0.042814	17.943410	0.019840
31	132.89131188029	+11.67532644656	0.5193	0.7408	-2.599	0.750	-11.928	0.534	20.217870	0.005535	21.024006	0.134174	19.242218	0.042751

超過50筆數據

更改 Preferences
成 unlimited

結果有1109筆；
有些恆星欄位空白
沒有資料

更改成 999 filled
或 ; separated ...
→ *'asu.tsv'*



Search Criteria

Save in CDSportal

Keywords Back

- I/355/gaiadr3

Tables Add

I/355
..gaiadr3
..paramp
..paramsup
..tgextmap

Enlarge Choose

Constraints

- *m67*
(arcmin 10)

Modify Query

Preferences

max: unlimited
ascii 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*.

I/355/gaiadr3 *Post annotation* Gaia DR3 Part 1. Main source (Gaia Collaboration, 2022)
Gaia data release 3 (Gaia DR3). (original column names in green) *(1811709771 rows)*

2022yCat.1355....0G ReadMe+ftp spectrum timeSerie

start AladinLite plot the output query using TAP/SQL

```
    RA_ICRS         DE_ICRS        Plx       e        pmRA      e        pmDE      e        Gmag       e        BPmag       e        RPmag       e
      deg             deg          mas      mas      mas/yr   mas/yr    mas/yr   mas/yr     mag       mag        mag       mag        mag       mag

132.93484761656 +11.67280287259 9999.9999 99.9999 99999.999 99.999 99999.999 99.999 21.052813  0.013969 20.497034  0.147659 19.844402  0.105408
132.93060974055 +11.67029052354    0.3970  0.0546    -4.717  0.056     1.046  0.041 16.243813  0.002794 16.529236  0.004956 15.788591  0.005018
132.85848991453 +11.64971091916    1.3352  0.2543   -10.239  0.503    -3.326  0.628 18.204634  0.003556 99.999999 99.999999 99.999999 99.999999
132.85810018125 +11.64962246329   -0.2676  0.1425    -0.273  0.157    -2.618  0.122 17.724224  0.003185 17.970098  0.021725 16.949520  0.035311
132.87626303185 +11.65209647027    2.0891  1.1629   -23.595  1.317   -49.299  1.025 20.620314  0.009051 21.222530  0.172052 19.320130  0.070443
132.82818895081 +11.65409921320    1.1188  0.3305   -11.270  0.338    -2.333  0.254 19.383757  0.003836 20.612698  0.074240 18.297272  0.016504
132.82767805505 +11.65266720132    2.3142  0.5902    -9.604  0.592    -3.322  0.485 20.083157  0.005061 20.769758  0.144905 18.959670  0.039316
132.82328138688 +11.66001330729    0.9730  0.0183    -8.254  0.019    -0.839  0.013 13.424560  0.002762 13.720562  0.002856 12.970219  0.003822
132.82175528725 +11.65661693494    2.1025  0.4769   -10.959  0.484    -3.014  0.438 19.620436  0.004482 20.770412  0.085303 18.486029  0.028303
132.84940719217 +11.64780855269    1.1728  0.0236   -10.977  0.025    -2.843  0.018 14.370622  0.002764 14.710147  0.002909 13.864649  0.003873
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132.84657329742 +11.65412257197    1.1906  0.0284   -10.907  0.031    -2.785  0.021 14.740636  0.002765 15.121491  0.003022 14.194714  0.003901
132.83984755499 +11.65236389972    0.9898  0.0179    -6.887  0.019     0.733  0.013 13.516213  0.002767 13.769630  0.002940 13.105659  0.003824
132.84993644367 +11.66295003564 9999.9999 99.9999 99999.999 99.999 99999.999 99.999 20.852264  0.012254 21.184200  0.201931 20.011559  0.136291
132.82602668392 +11.66181496778    0.5876  0.1460     1.965  0.147    -5.891  0.105 17.968378  0.003016 18.803635  0.023578 17.065048  0.008167
132.83018759556 +11.65815180897    1.6678  0.5654   -10.756  0.548    -2.293  0.432 19.949585  0.004984 20.708092  0.135932 18.803076  0.026952
132.83575107582 +11.66065753453   -0.0379  0.4944    -5.293  0.475    -0.132  0.328 18.739109  0.004372 18.558466  0.072789 17.496470  0.037680
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132.84500743656 +11.67503821566    1.3136  0.2193   -10.640  0.223    -3.137  0.168 18.674587  0.003324 19.876480  0.056295 17.650433  0.011516
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132.88209961498 +11.65247412294    0.7211  0.5735     1.401  0.561    -4.194  0.476 20.172142  0.005209 20.968770  0.132861 19.183386  0.045687
132.88414052550 +11.65642950509 9999.9999 99.9999 99999.999 99.999 99999.999 99.999 20.961327  0.016506 21.079502  0.283714 20.505552  0.205216
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132.90105640896 +11.66128492716    0.9859  0.1763    -3.944  0.180    -6.970  0.140 18.424440  0.003197 19.398779  0.042670 17.473522  0.011428
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132.89218831955 +11.66339693504 9999.9999 99.9999 99999.999 99.999 99999.999 99.999 20.997824  0.011293 20.342550  0.081716 18.689917  0.042701
132.89512003473 +11.67246483300    0.2170  0.1877     1.229  0.196    -0.343  0.146 18.583660  0.003213 19.020054  0.042814 17.943410  0.019840
132.89131188029 +11.67532644656    0.5193  0.7408    -2.599  0.750   -11.928  0.534 20.217870  0.005535 21.024006  0.134174 19.242218  0.042751
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132.91638281023 +11.67428377723    1.5244  0.2487   -11.318  0.253    -3.062  0.203 18.918940  0.003462 20.068731  0.059408 17.888048  0.017730
132.91057381069 +11.66613589846    1.1136  0.0892   -10.910  0.092    -3.090  0.066 17.071058  0.002843 18.060720  0.014160 16.087378  0.005555
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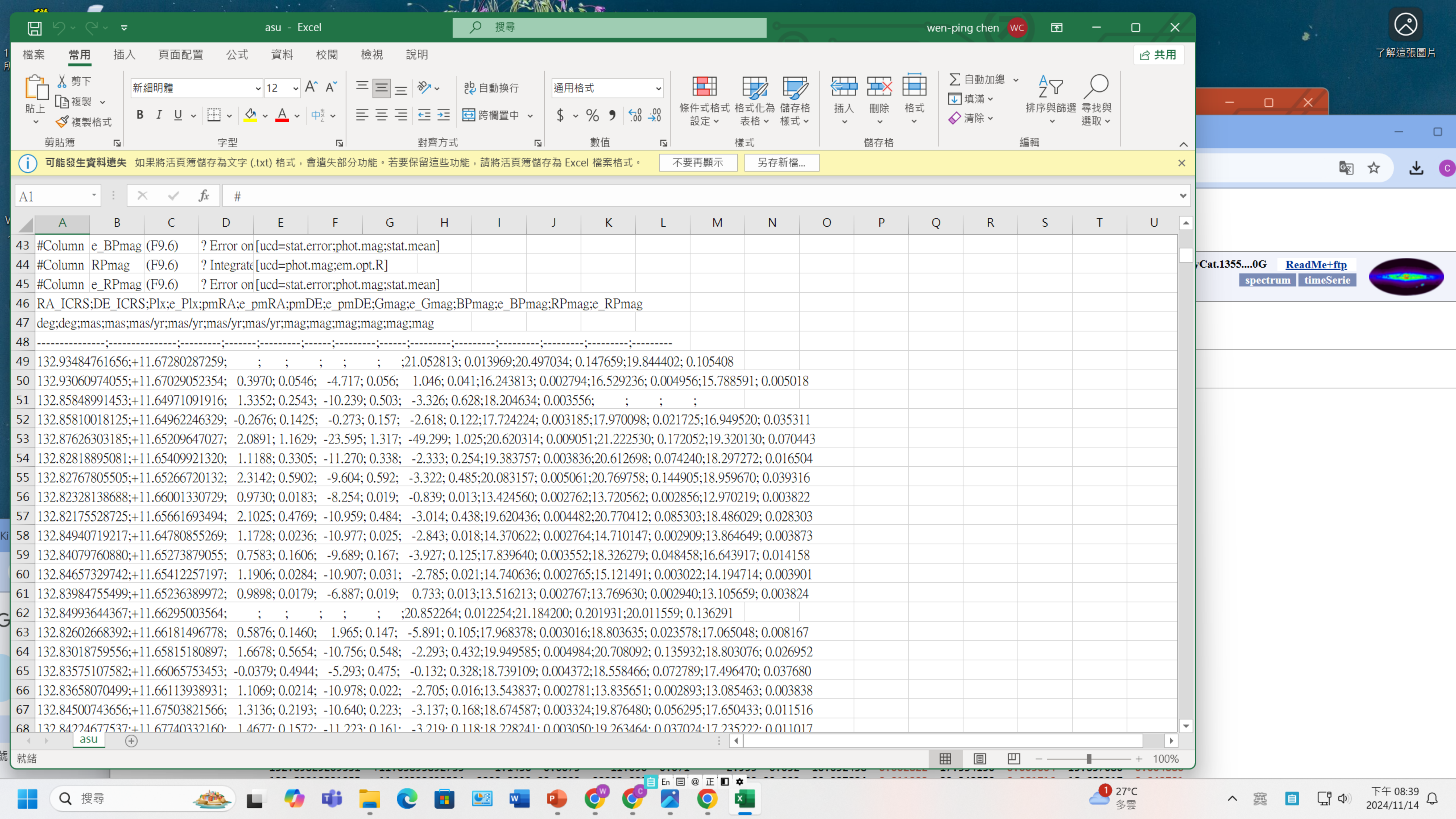

可能發生資料遺失 如果將活頁簿儲存為文字 (.txt) 格式，會遺失部分功能。若要保留這些功能，請將活頁簿儲存為 Excel 檔案格式。

A1: #

```
43 #Column  e_BPmag  (F9.6)  ? Error on [ucd=stat.error;phot.mag;stat.mean]
44 #Column  RPmag    (F9.6)  ? Integrate [ucd=phot.mag;em.opt.R]
45 #Column  e_RPmag  (F9.6)  ? Error on [ucd=stat.error;phot.mag;stat.mean]
46 RA_ICRS;DE_ICRS;Plx;e_Plx;pmRA;e_pmRA;pmDE;e_pmDE;Gmag;e_Gmag;BPmag;e_BPmag;RPmag;e_RPmag
47 deg;deg;mas;mas;mas/yr;mas/yr;mas/yr;mas/yr;mag;mag;mag;mag;mag;mag
48 ---------------;---------------;---------;-------;---------;------;---------;------;---------;---------;---------;---------;---------;---------
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51 132.85848991453;+11.64971091916;  1.3352; 0.2543; -10.239; 0.503;  -3.326; 0.628;18.204634; 0.003556;         ;         ;         ;
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60 132.84657329742;+11.65412257197;  1.1906; 0.0284; -10.907; 0.031;  -2.785; 0.021;14.740636; 0.002765;15.121491; 0.003022;14.194714; 0.003901
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63 132.82602668392;+11.66181496778;  0.5876; 0.1460;   1.965; 0.147;  -5.891; 0.105;17.968378; 0.003016;18.803635; 0.023578;17.065048; 0.008167
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- ✓ Excel 可以處理這樣的檔案
- ✓ 前48行解釋數據格式；數據從第49行開始；每個欄位由 ‘;’ 符號分開 …
- ✓ 寫程式 … 否則 以 excel 整理成適當格式（一個數字一格）
  - 繪製坐標圖（橫軸為 RA 赤經，縱軸為 DE 赤緯）

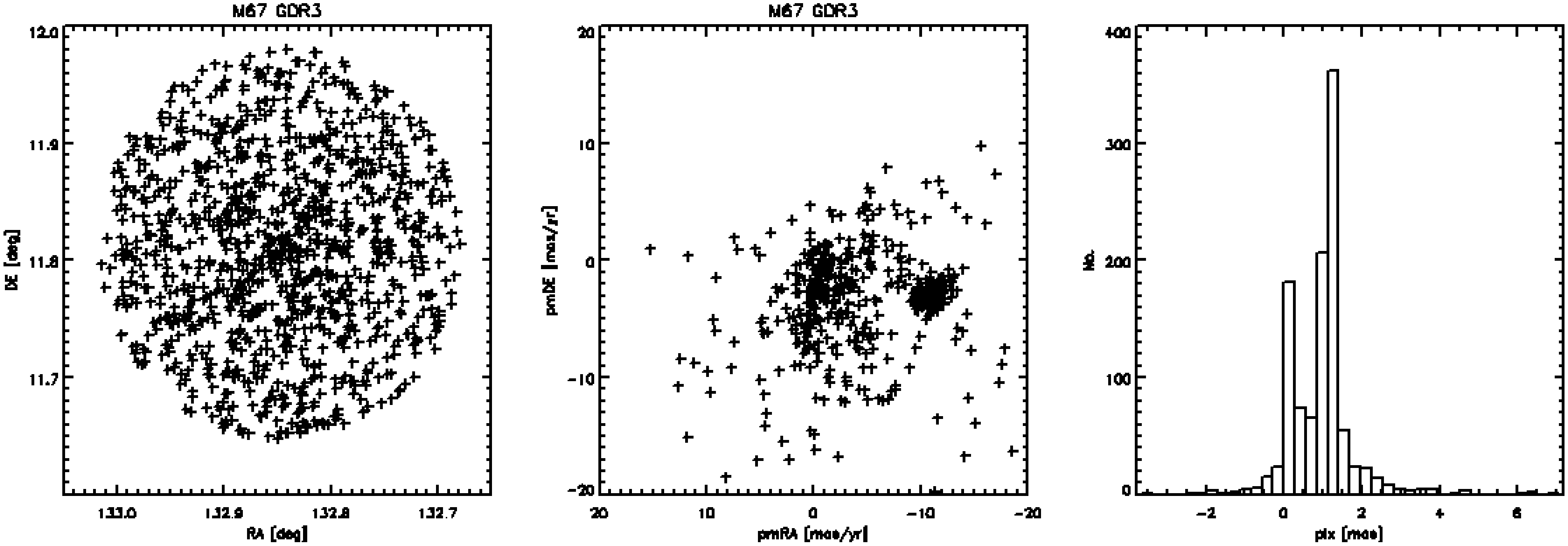
    繪製自行運動向量圖 （橫軸為 pmRA，縱軸為 pmDE ）

    繪製週年視差角分布（長條圖）
  - 以星團中心為圓心，計算每顆星離中心的角距離

    SQRT[(ra – rao)*(ra – rao) + (de – deo)*(de – deo)]

    IF … 排序？

    試試看半徑 2’ 之內的樣本有何不同



✓ 成員候選星：（天球）空間分布、PM，且plx 都群聚的星球