Кросс-отождествление и параметризация объектов в фотометрических обзорах

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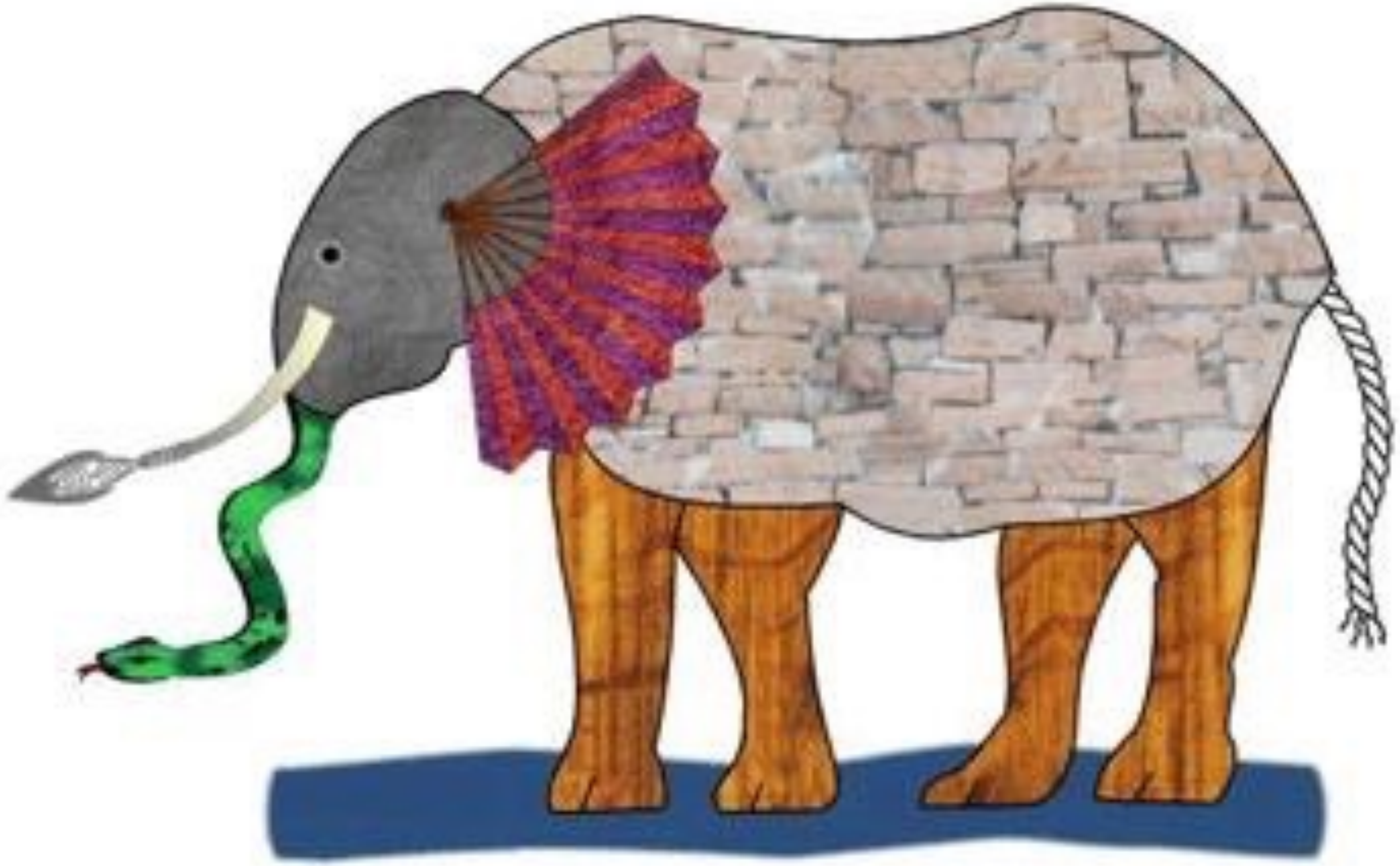
Абстракт

- В докладе описываются существующие и планируемые большие фотометрические обзоры и обсуждаются проблемы кросс-отождествления объектов в этих обзорах.
- Полученная в результате кросс-отождествления многоцветная фотометрия (дополняемая, при наличии, сведениями о тригонометрических параллаксах и спектральной классификации) используется для определения параметров звезд и межзвездного поглощения. Разработанная для этой цели методика апробирована на ряде высокоширотных (|b|>15d) направлений, и полученные результаты показали хорошее согласие с независимыми наблюдениями.

Multi – wavelength, multi – time scales, multi – flux level approaches

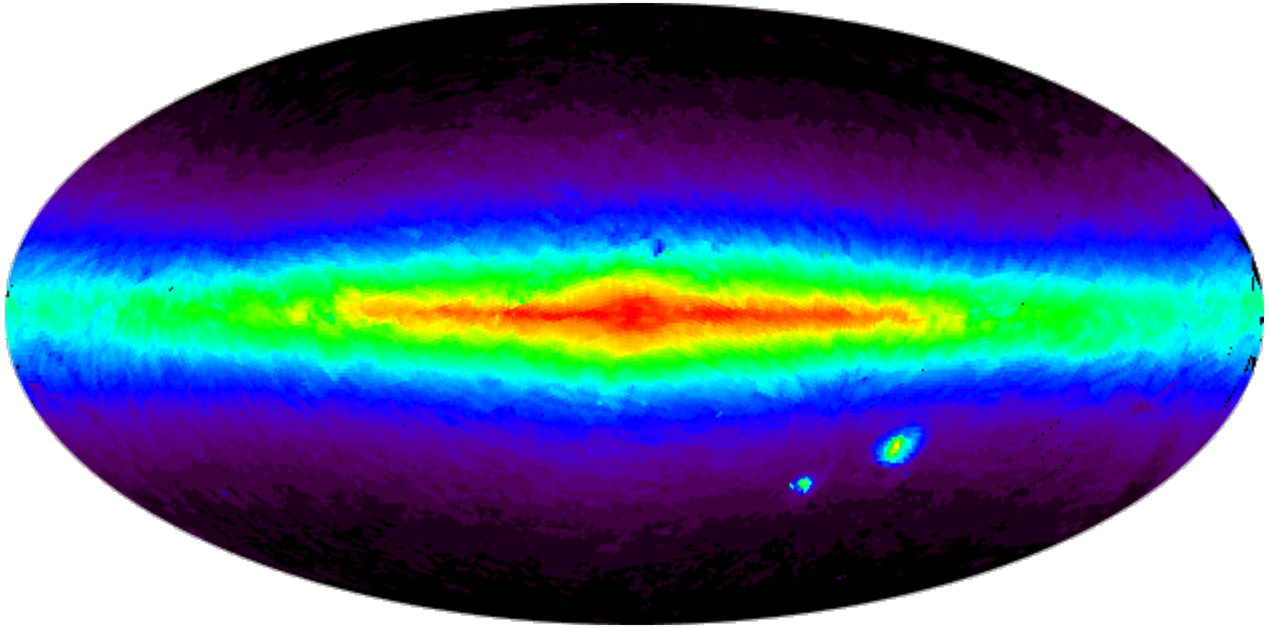
Multi – wavelength, multi – time scales, multi – flux level approaches



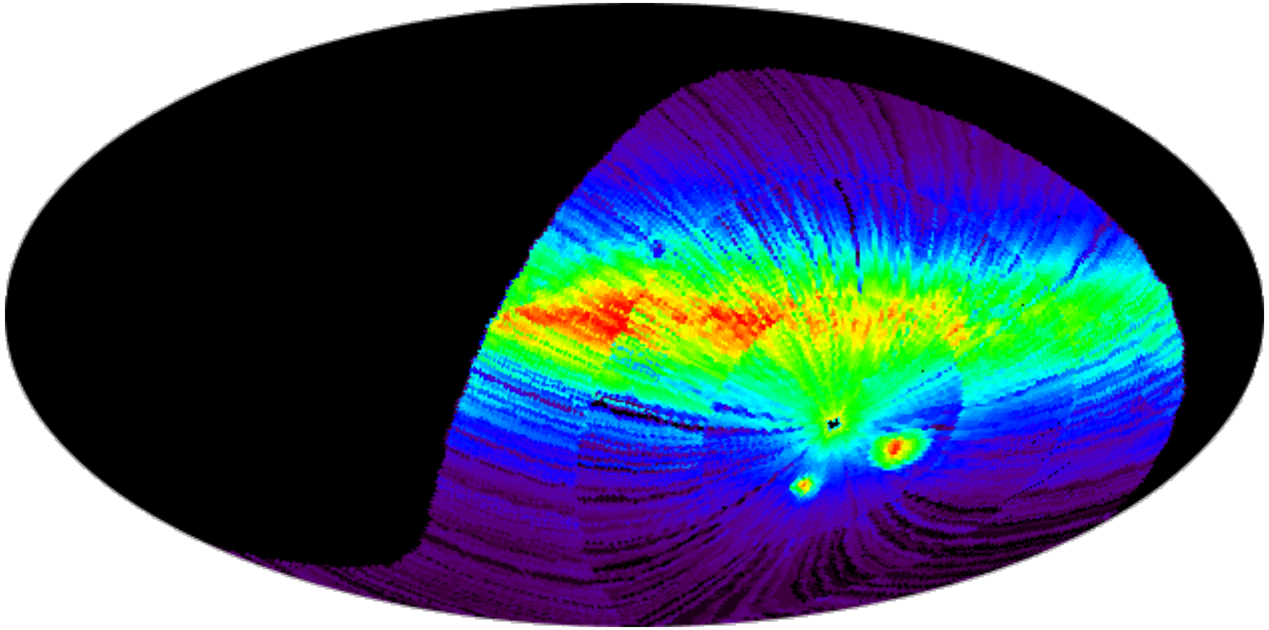
... should be accompanied by development of standards

Photometric surveys

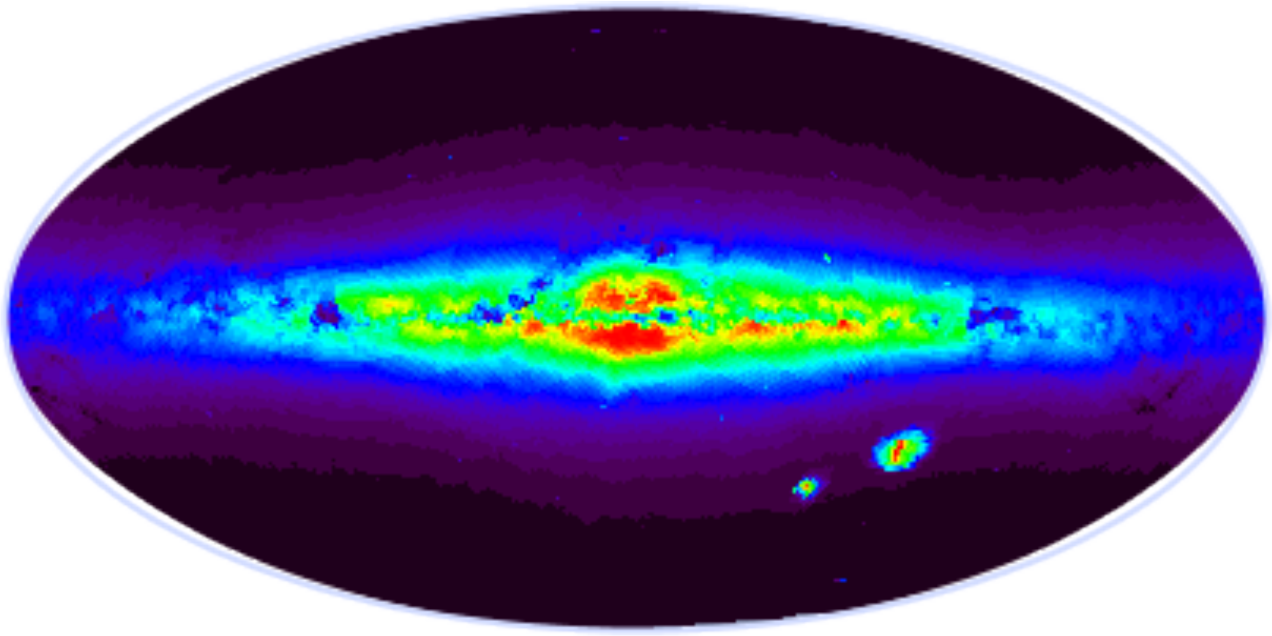
2MASS All-Sky Catalog of Point Sources (Cutri+ 2003)



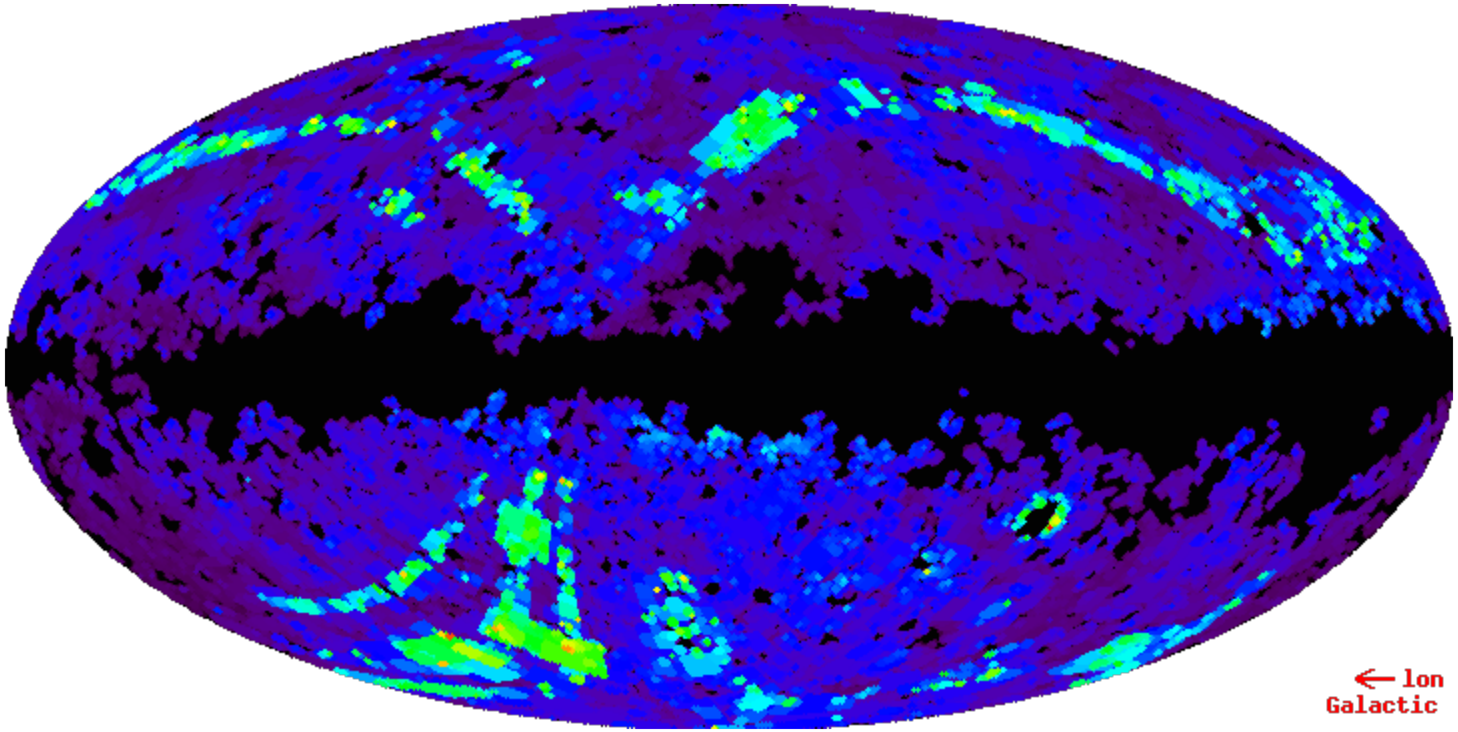
The DENIS database (DENIS Consortium, 2005)



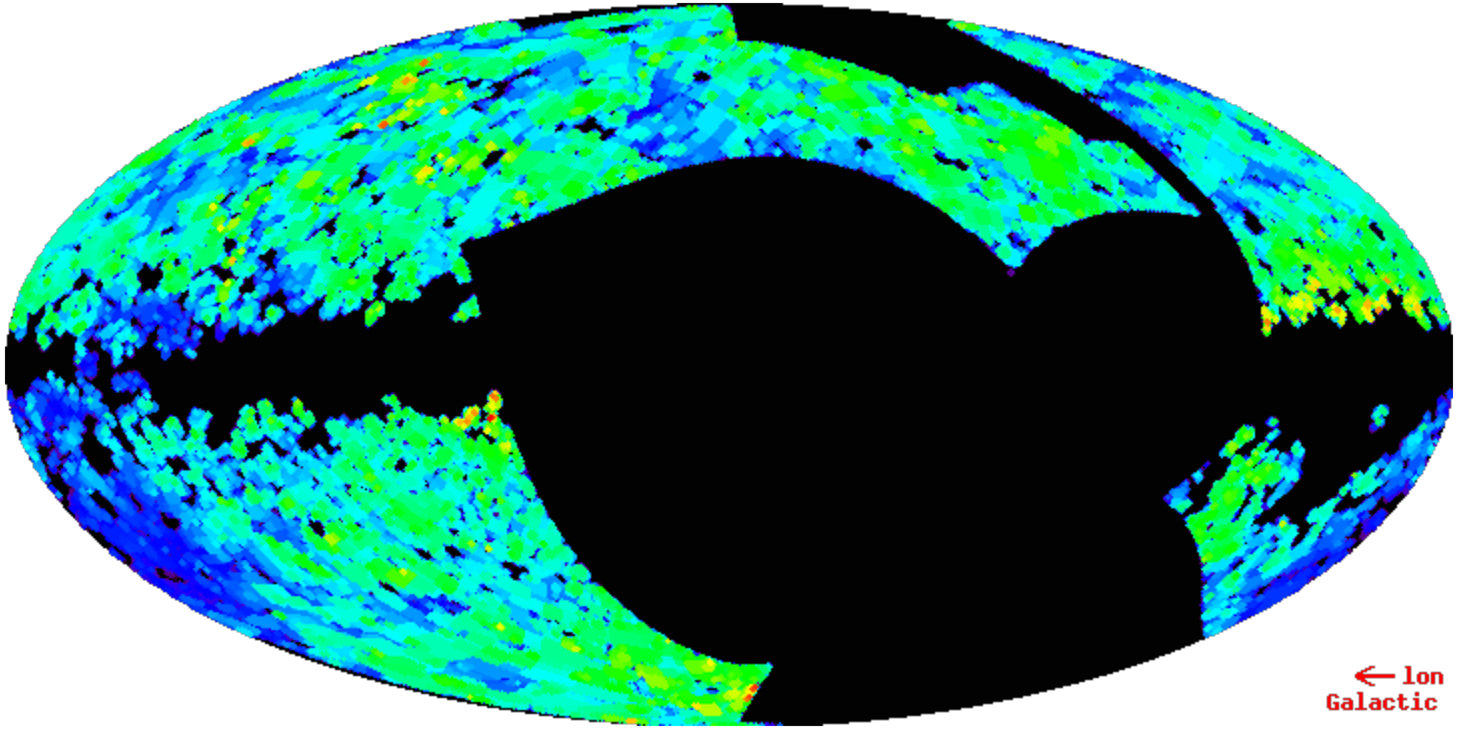
Gaia DR2 (Gaia Collaboration, 2018)



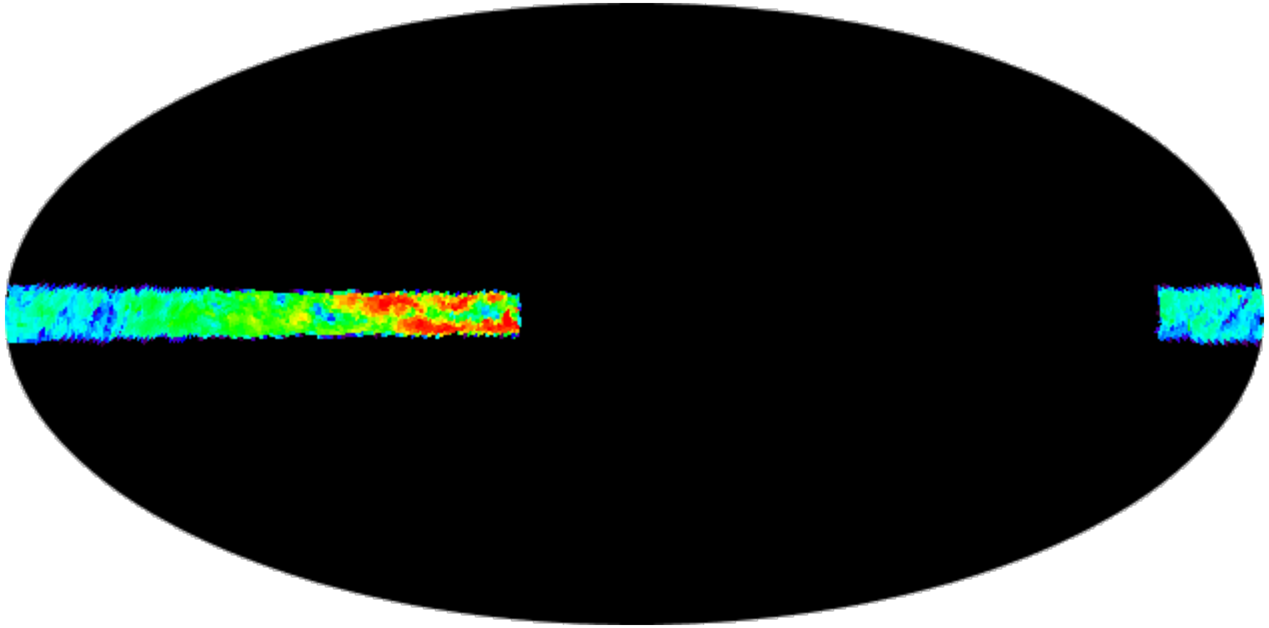
GALEX-DR5 (GR5) sources from AIS and MIS (Bianchi+ 2011)



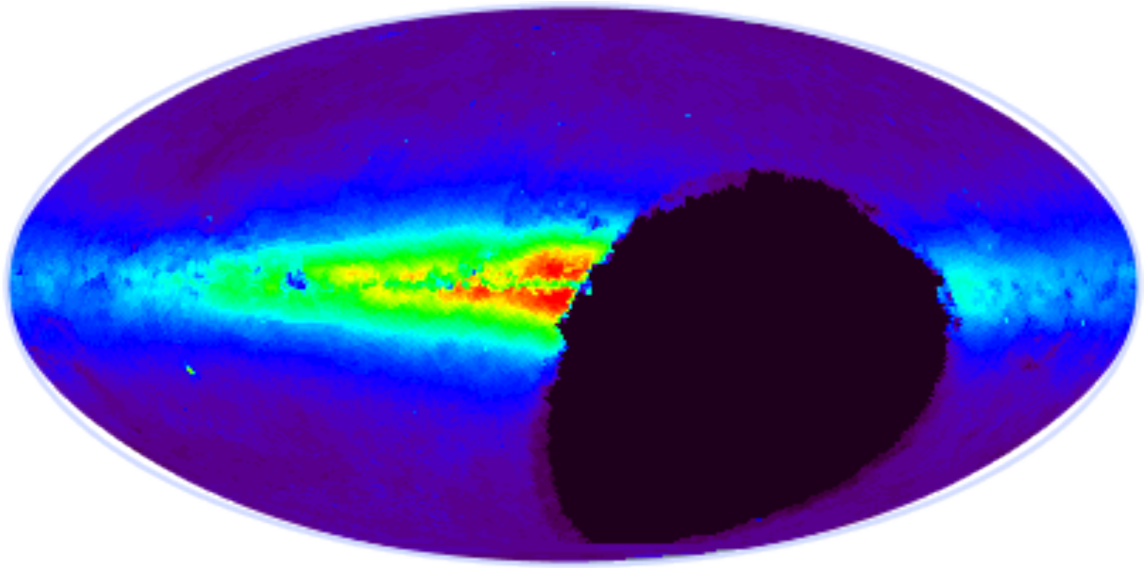
Revised catalog of GALEX UV sources (GUVcat_AIS GR6+7) (Bianchi+ 2017)



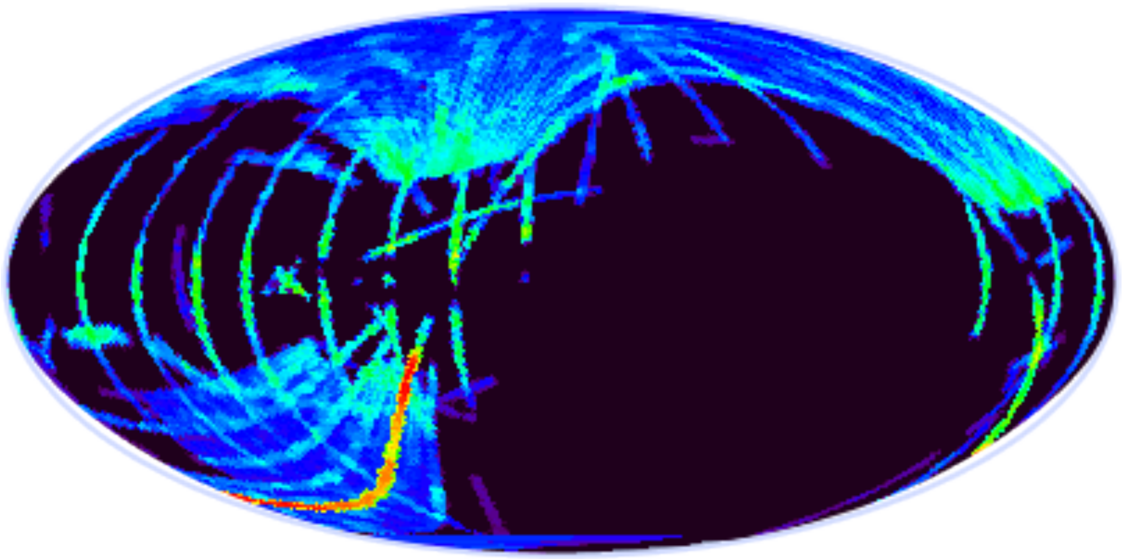
IPHAS DR2 Source Catalogue (Barentsen +, 2014)



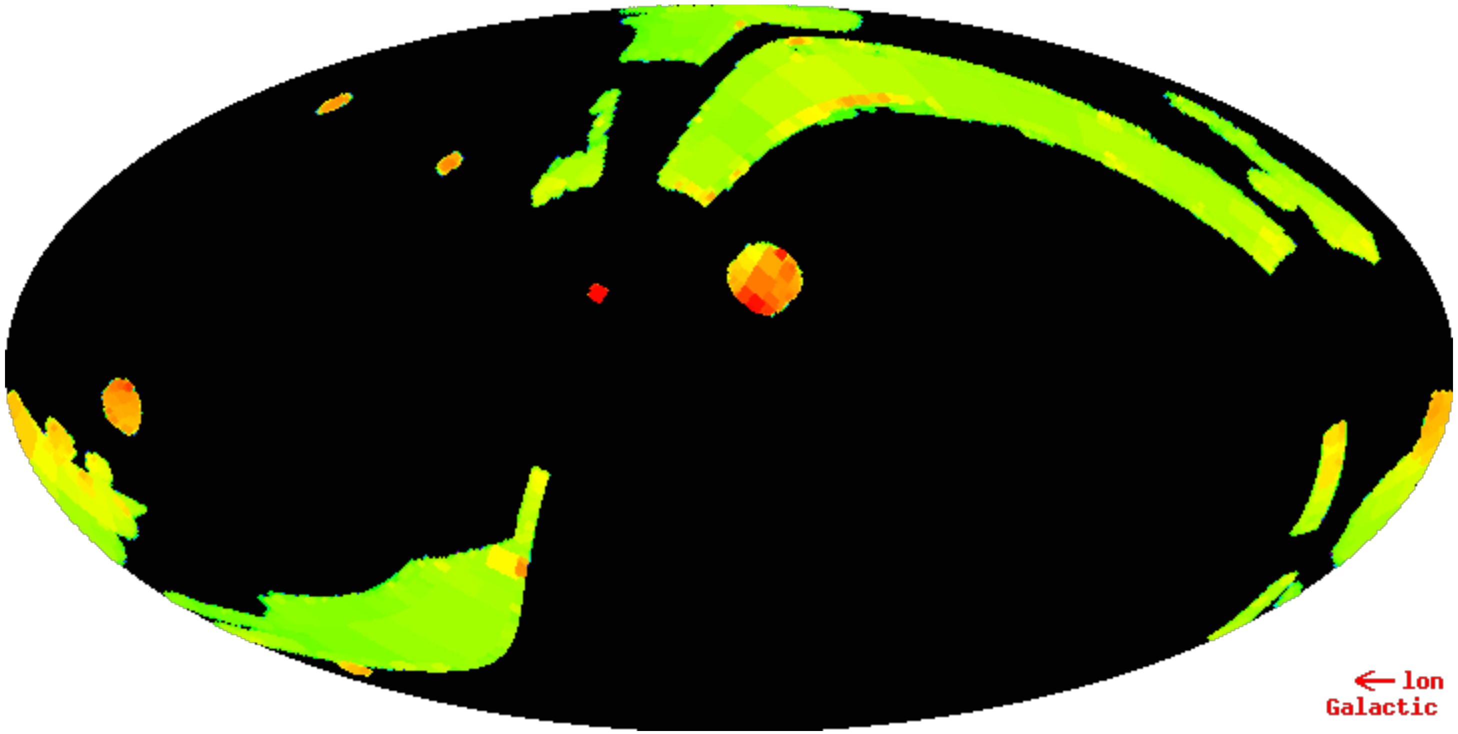
The Pan-STARRS release 1 (PS1) Survey - DR1 (Chambers+, 2016)



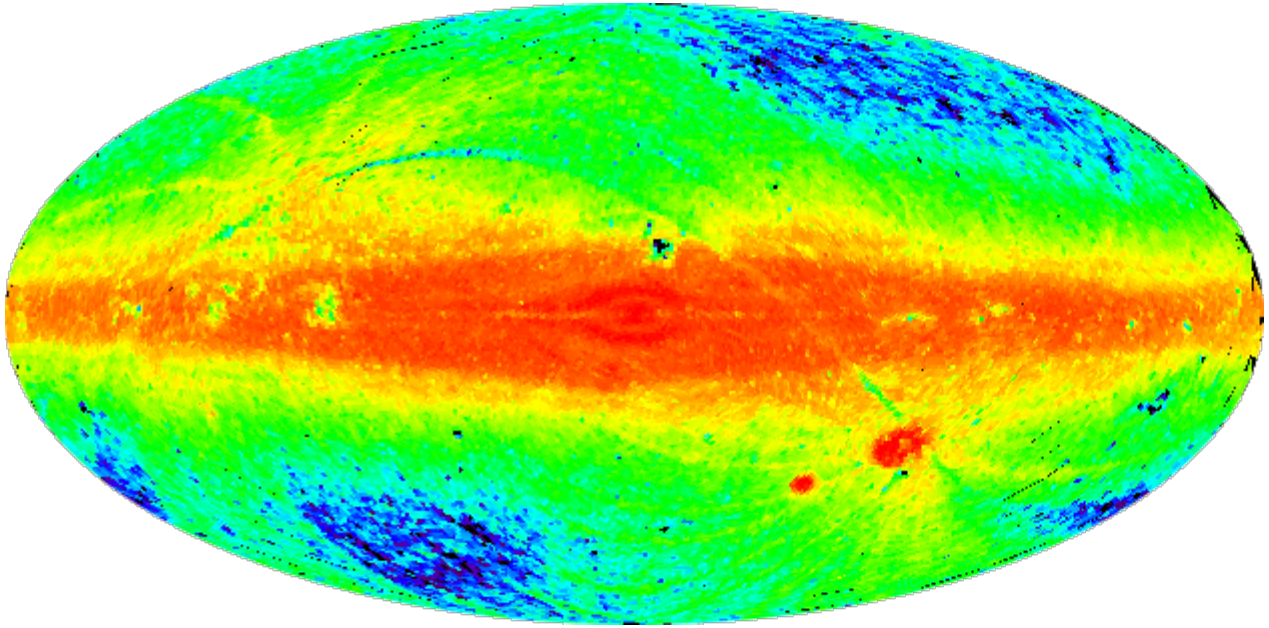
The SDSS Photometric Catalogue, Release 12 (Alam+, 2015)



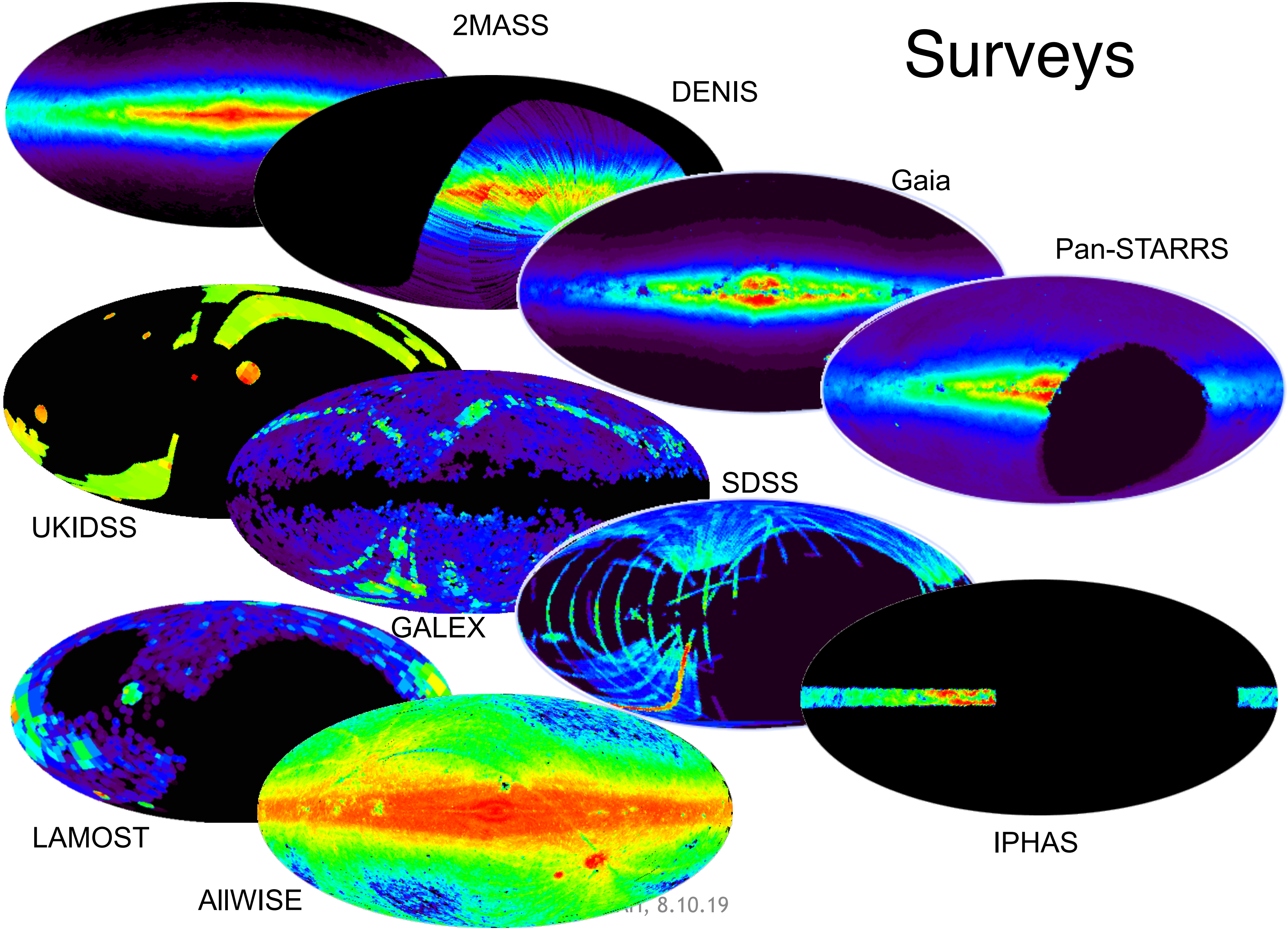
UKIDSS-DR9 LAS, GCS and DXS Surveys (Lawrence+ 2012)



AllWISE Data Release (Cutri+ 2013)



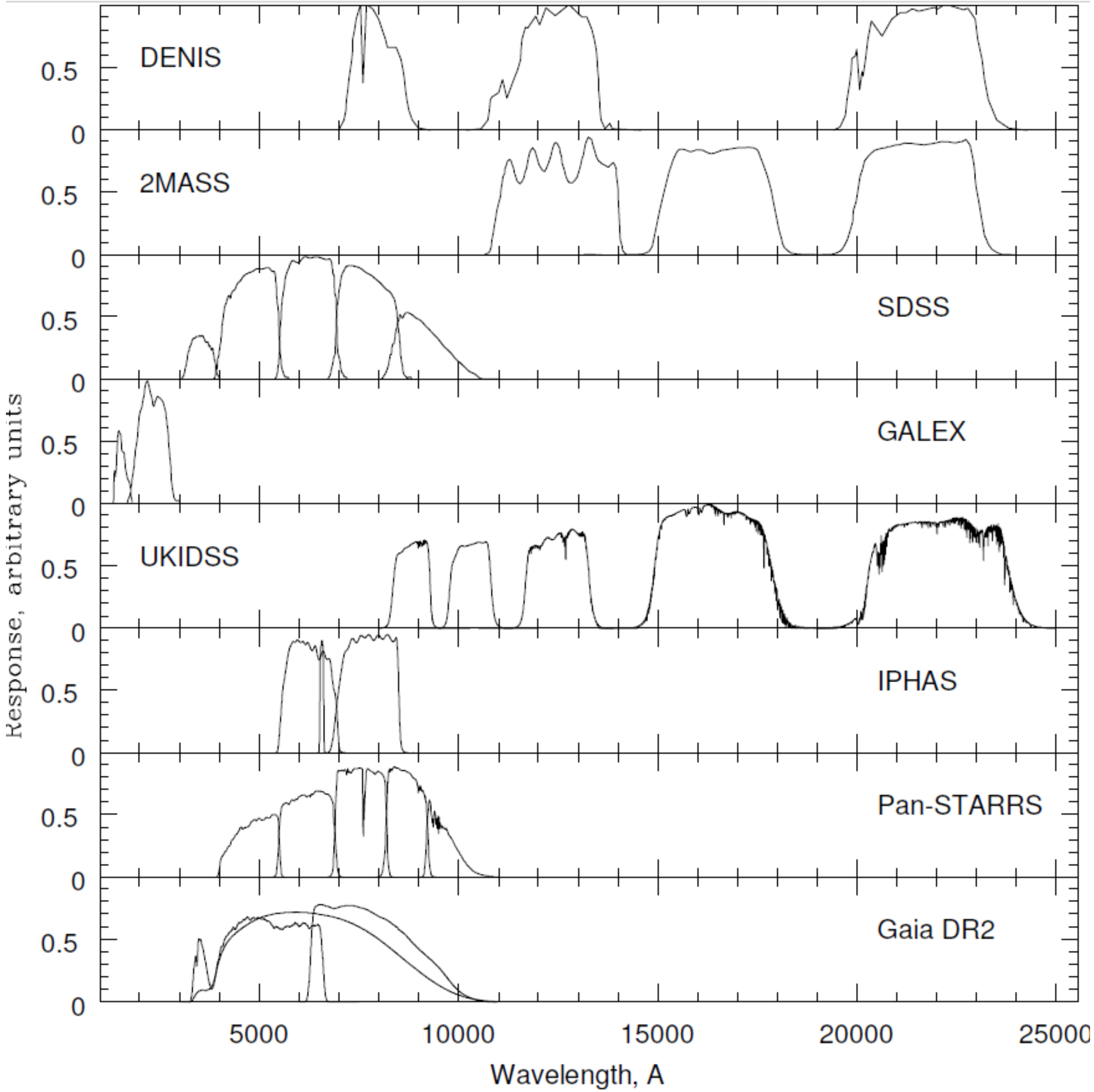
Surveys


2MASS
DENIS
Gaia
Pan-STARRS
UKIDSS
GALEX
SDSS
LAMOST
AllWISE
IPHAS

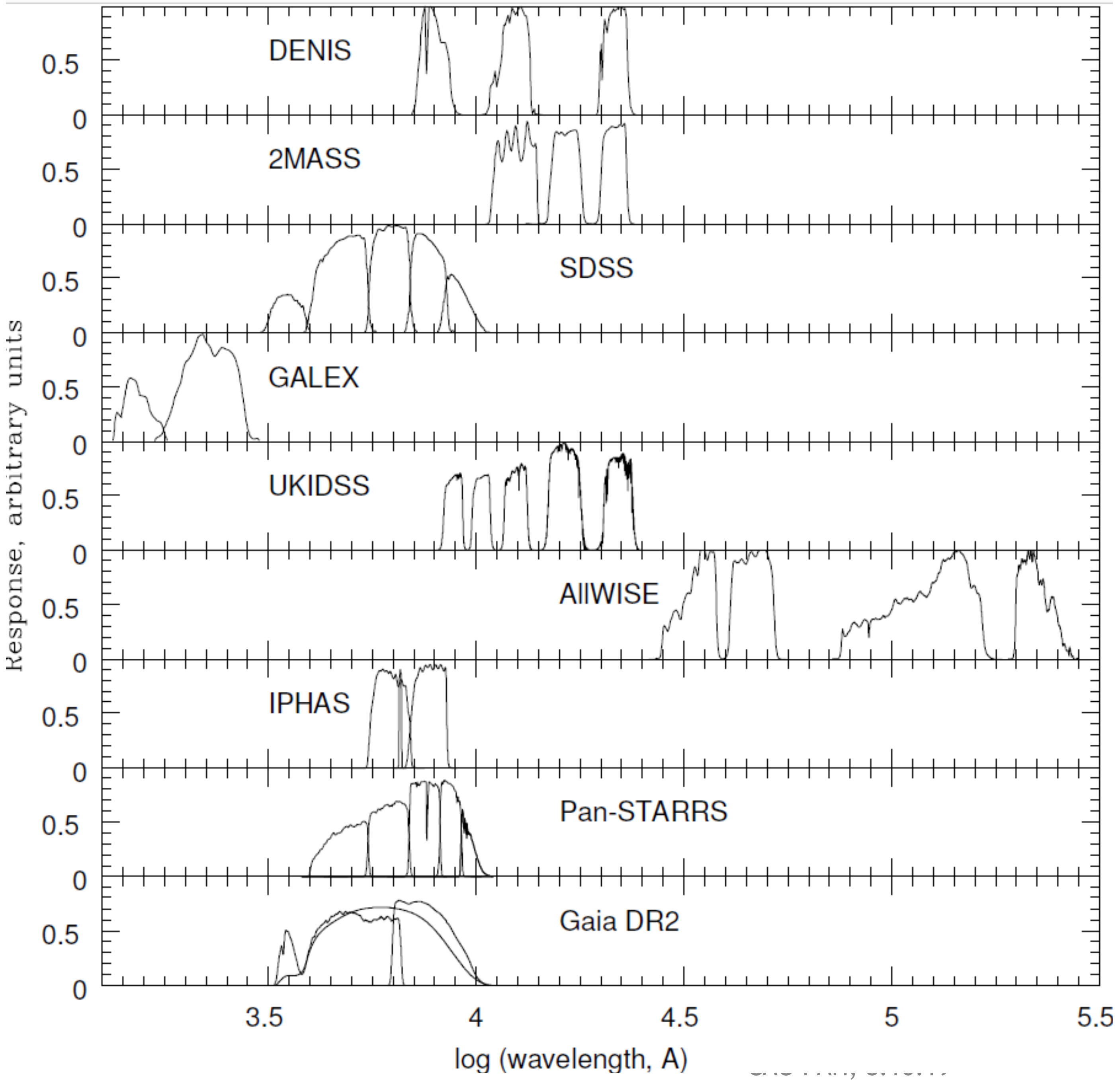
Large photometric surveys

Survey	N[a]	Sky coverage	Photometric bands	Limiting magnitude
DENIS	355	Southern hemisphere	Gunn-i, J, K_S	18.5, 16.5, 14.0
2MASS	471	All sky	J, H, K_S	15.8, 15.1, 14.3
SDSS 12	325	25%	u, g, r, i, z	g,r=22.2
GALEX DR5 (AIS+MIS)	78	90%	FUV, NUV	$\sim$25
UKIDSS DR9 LAS	83	15%	Z, Y, J, H, K	K=18.3
AllWISE	748	All sky	W1, W2, W3, W4	16.6, 16.0, 10.8, 6.7
IPHAS DR2	219	Northern Galactic plane	r, i, H_α	r=21-22
Pan-STARRS PS1 - DR1	1919	All sky but southern cap	g, r, i, z, y	i$\sim$20
GAIA DR2	1693	All sky	G, BP, RP	G=20

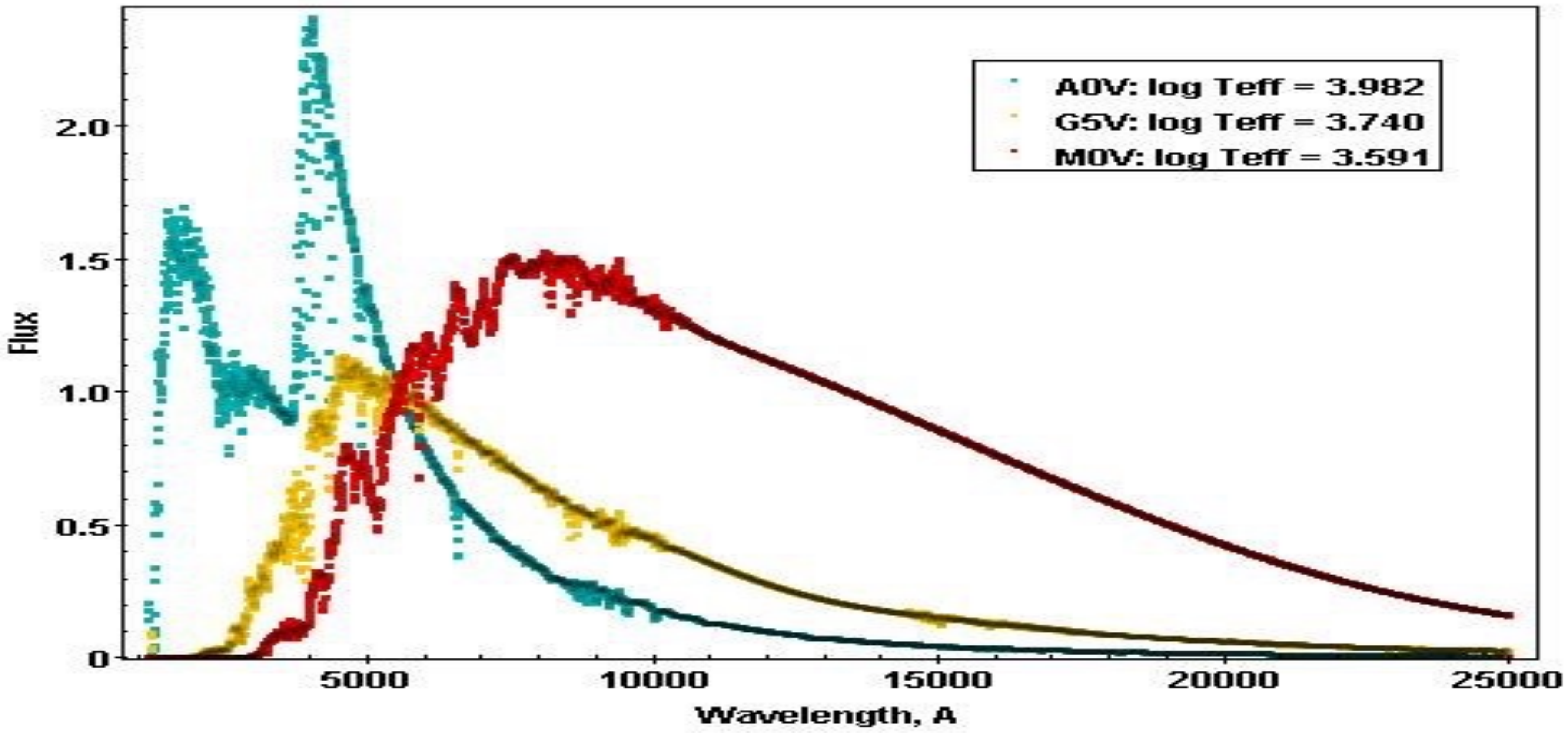
[a]N is number of objects, 10^6.

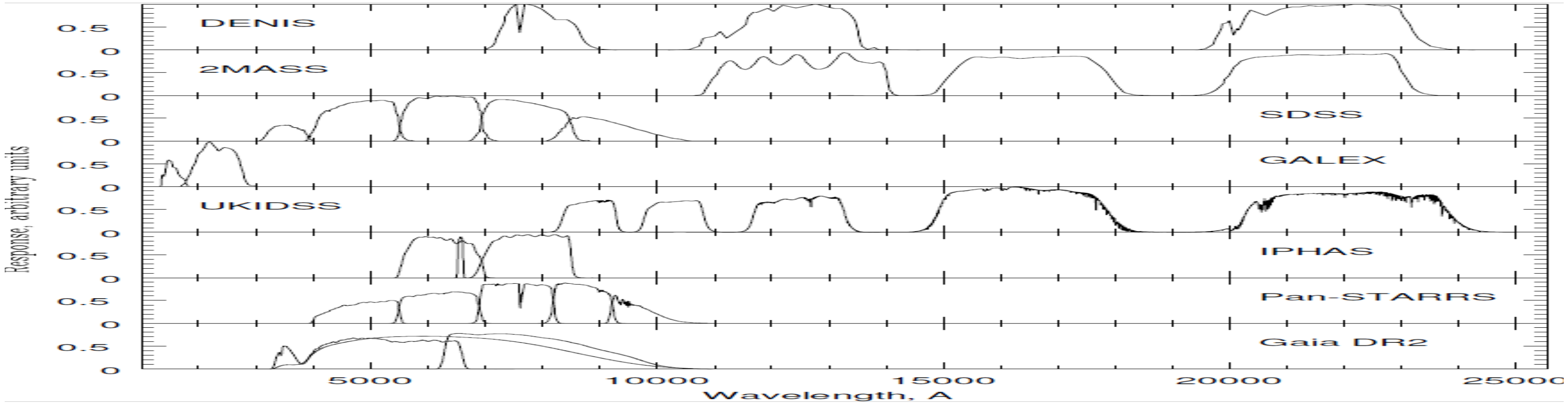


Response curves of the photometric surveys



Response curves of the photometric surveys


A0V: log Teff = 3.982
G5V: log Teff = 3.740
M0V: log Teff = 3.591
Flux
Wavelength, A


DENIS
2MASS
SDSS
GALEX
UKIDSS
IPHAS
Pan-STARRS
Gaia DR2
Response, arbitrary units
Wavelength, A

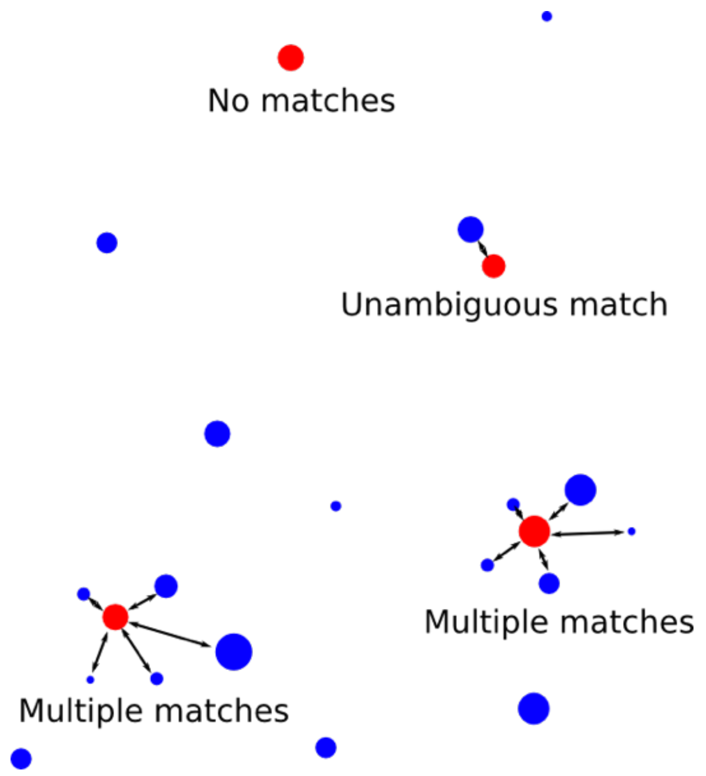
Multicolor photometry and parameterization of stars

- Cross-identification of stars in modern large photometric surveys
- Determination of spectral types and distances to stars in surveys, as well as interstellar extinction
- Incorporation of future multi-wavelength surveys

Cross-matching: a general problem

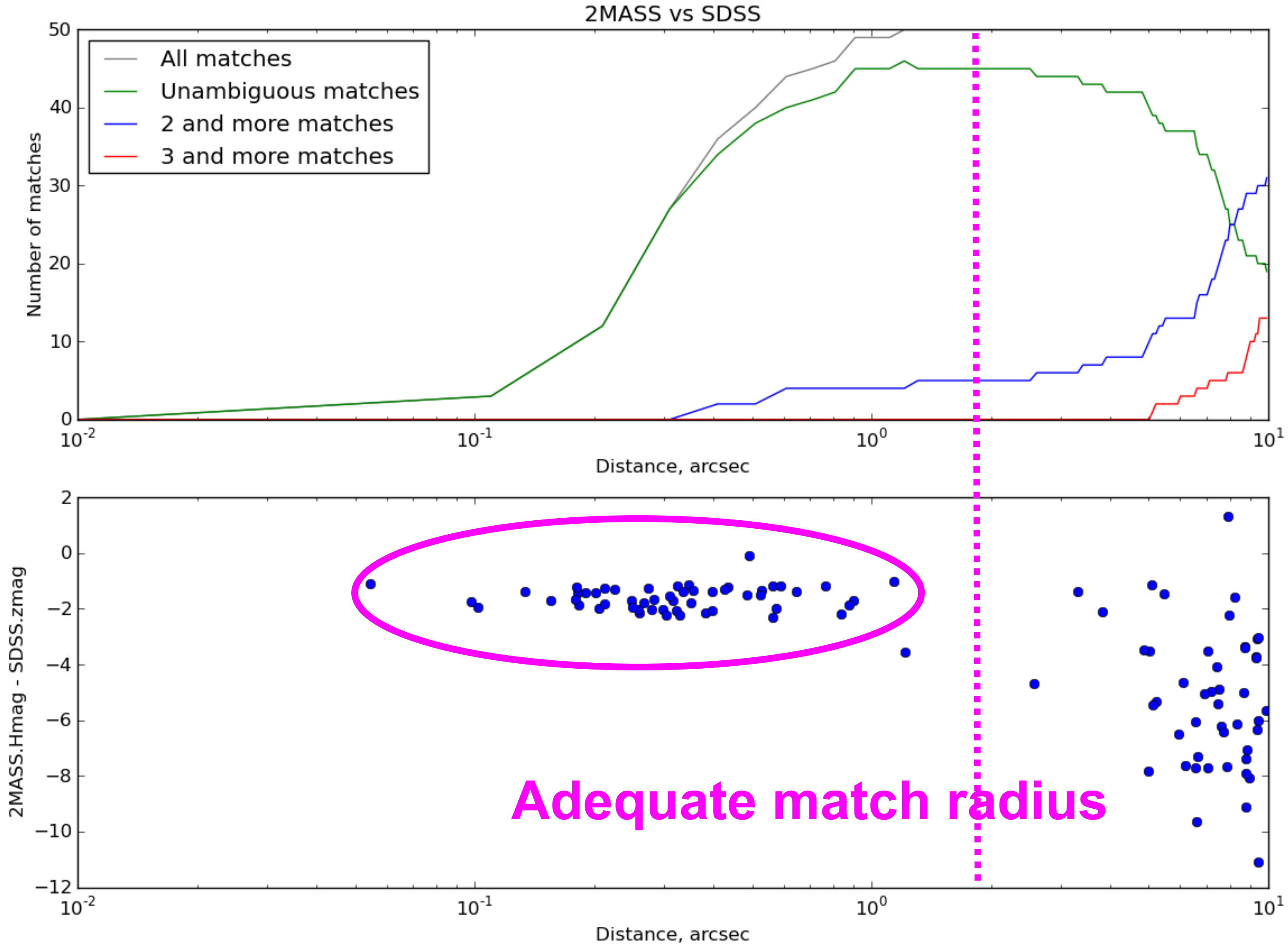
- The aim is to reliably link the same object data in different catalogues, having
  - different sky coverage
  - different detection limits
  - different object densities
    - 2MASS – 50 objects
    - SDSS – 133 objects
    - UKIDSS – 176 objects
    - GALEX – 342 objects

    in l,b,r=(210°,12°,0.1°) area



Which one is correct?..

Cross-matching: finding reliable matches



Parameterization procedure

- Varying
  - (i) spectral type of star, SpT,
  - (ii) its distance, d, and
  - (iii) interstellar extinction value (A_V),
- we simulate observational brightness, m, with distance modulus equations
  $m = M_i(SpT) + 5 \log d - 5 + A_i(A_V)$
  for every photometric band i, and, based on the quality of the simulation process, choose the most appropriate SpT-d-A_V set.
- Published calibration relation $M_i(SpT)$ and interstellar extinction law $A_i(A_V)$ were used for photometric bands, included in the original surveys.

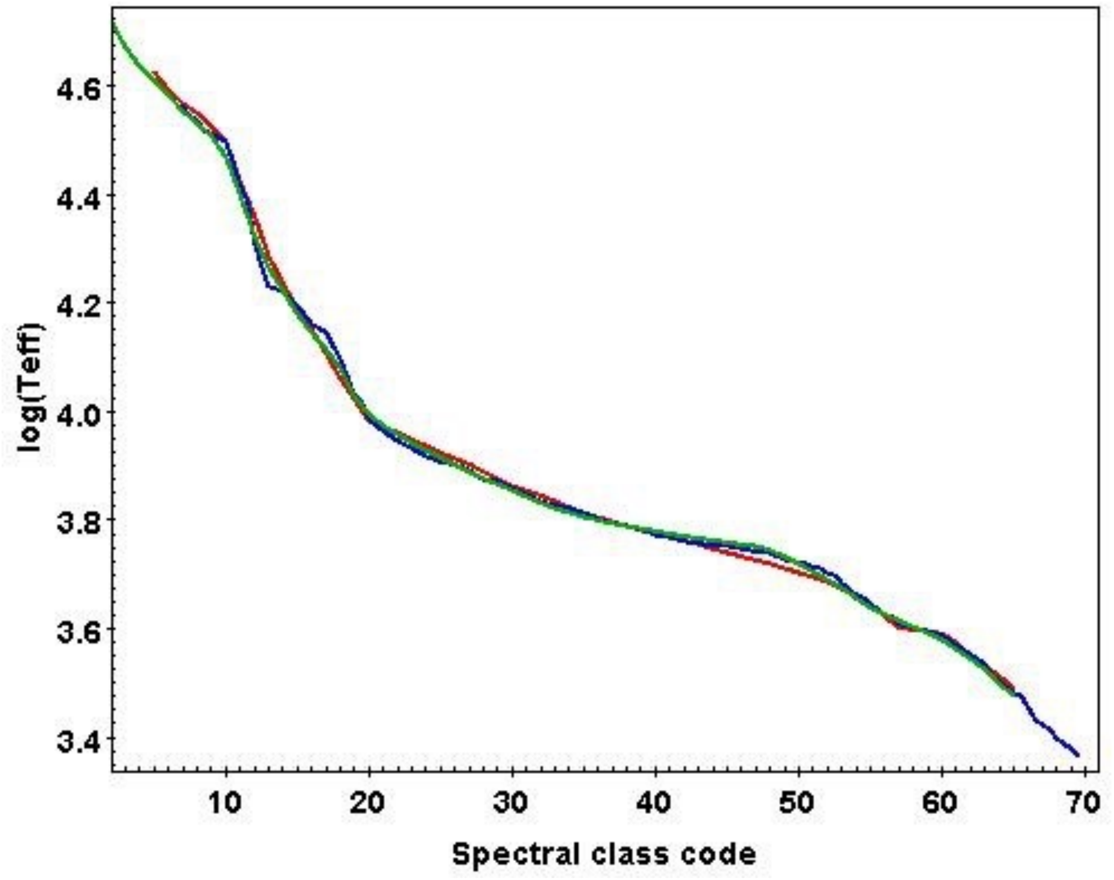
Parameterization procedure

- Objects in four selected areas in the sky were cross-matched with 2MASS, SDSS, GALEX, and UKIDSS surveys, and multi-wavelength photometric data were used to determine the parameters of stars.
- We have compared our results with LAMOST data and extinction values to distant SNs (based on IRAS and DIRBE microwave data), available in the literature. The comparison exhibits a good agreement.
- A comparison of our results with Gaia DR2 data also demonstrates a good agreement for stars as faint as $19^{m}.6$ g_{SDSS}, and shows that our method allows us to determine spectral type, distance and interstellar extinction of objects out to 4.5 kpc.

Statistical relations between stellar spectral and luminosity classes and stellar effective temperature and surface gravity

- To construct analytic (spectral class - atmospheric parameters) formula for **main sequence stars** we have used published relations (Straizys (1992), Pecaut & Mamajek (2013), Eker et al. (2018)) and made a polynomial approximation.
- To construct analytic (spectral class - atmospheric parameters) formula for **supergiant and giant stars** we have used data from the empirical stellar spectral atlases ELODIE (Prugniel et al. 2007), Indo-US (Valdes et al. 2004), MILES (Falcon-Barroso et al. 2011), and STELIB (Le Borgne et al. 2003), and made a polynomial approximation.

Main sequence stars. Spectral class - effective temperature relation. Spectral class is coded as follows: 3 for O3, ..., 10 for B0, ..., 60 for M0. Straizys (1992), Pecaut & Mamajek (2013), and Eker et al. (2018) data are represented by red, blue and green curves, respectively.



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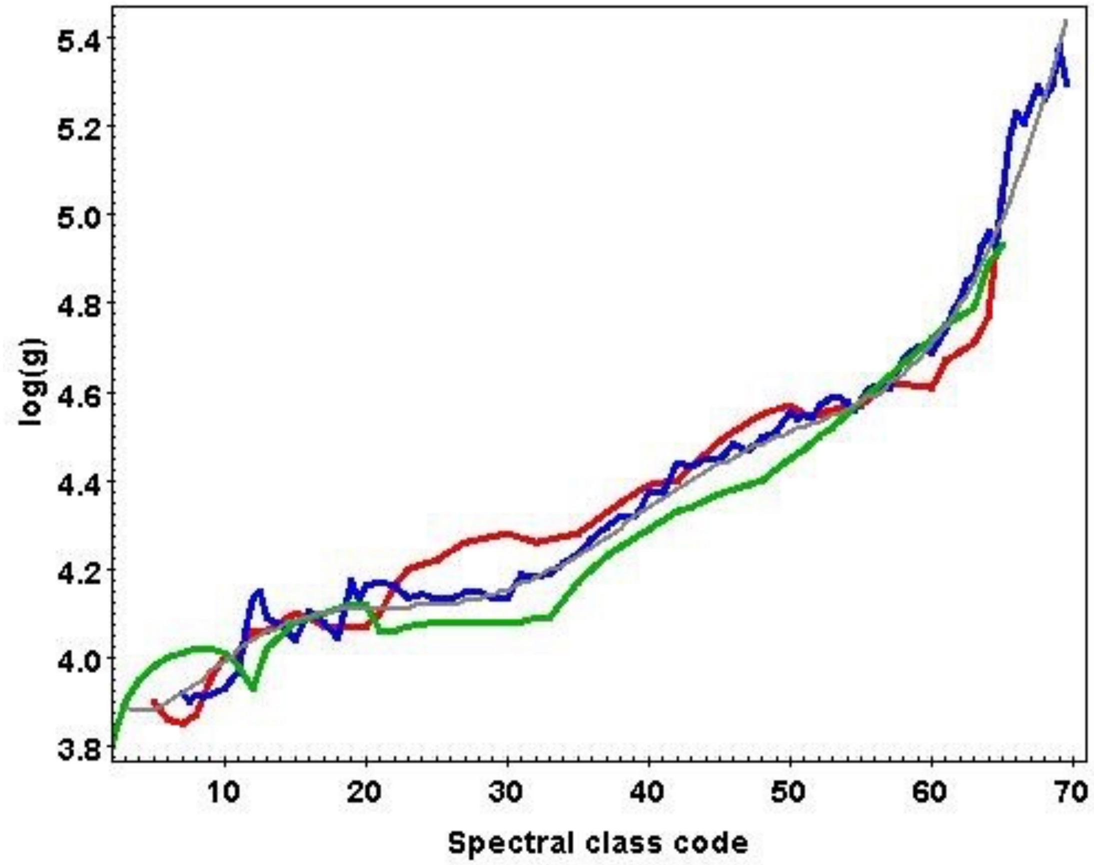
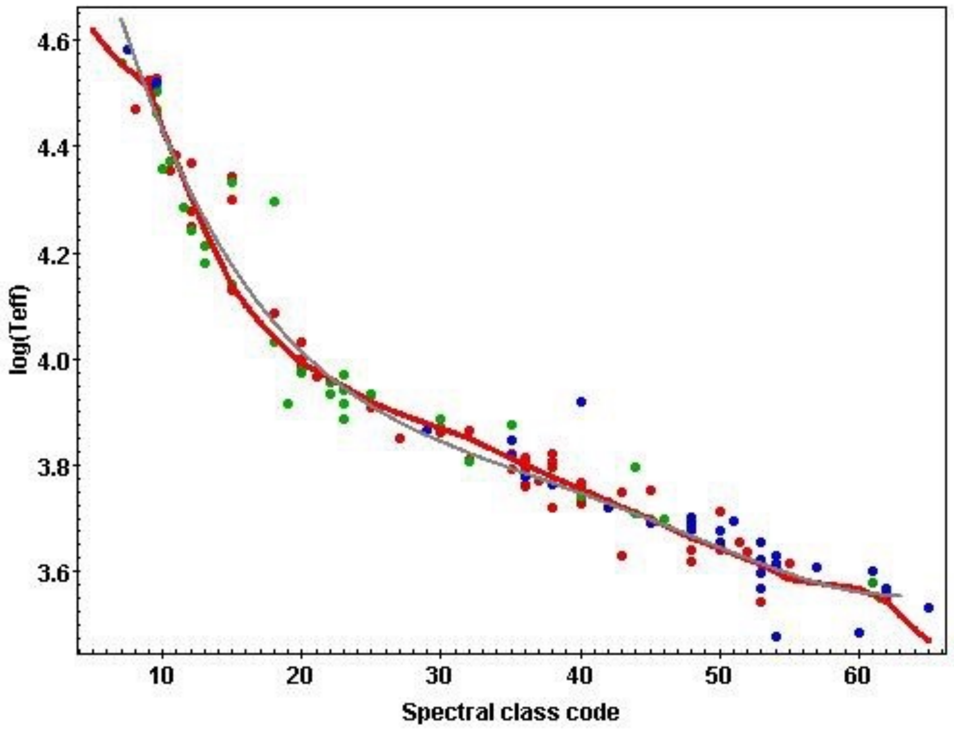
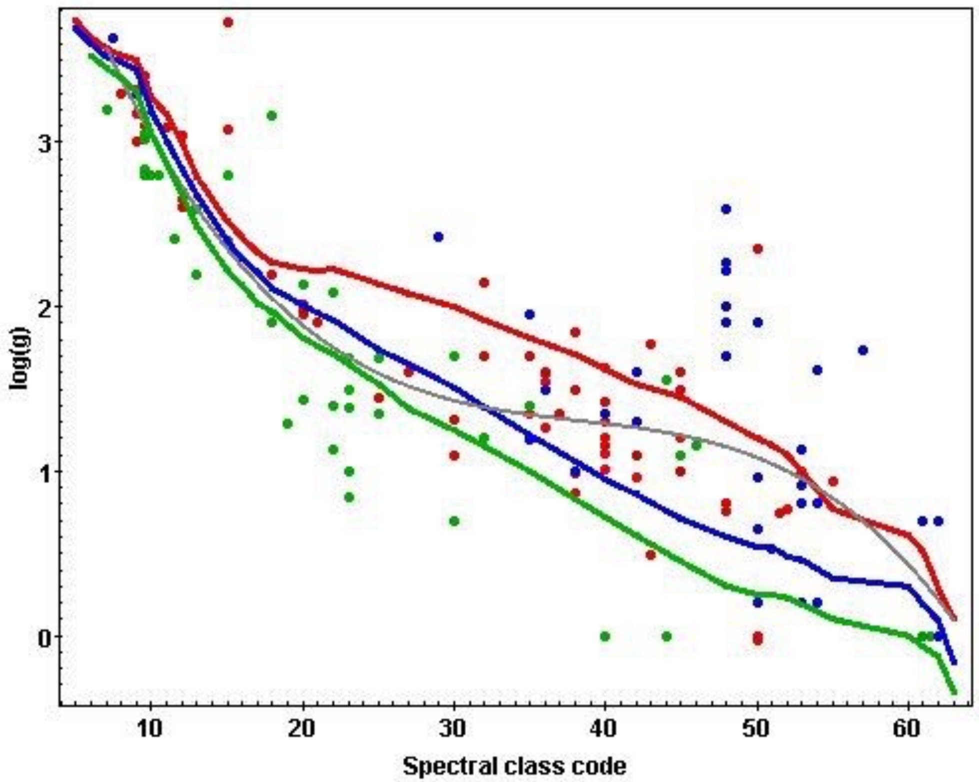


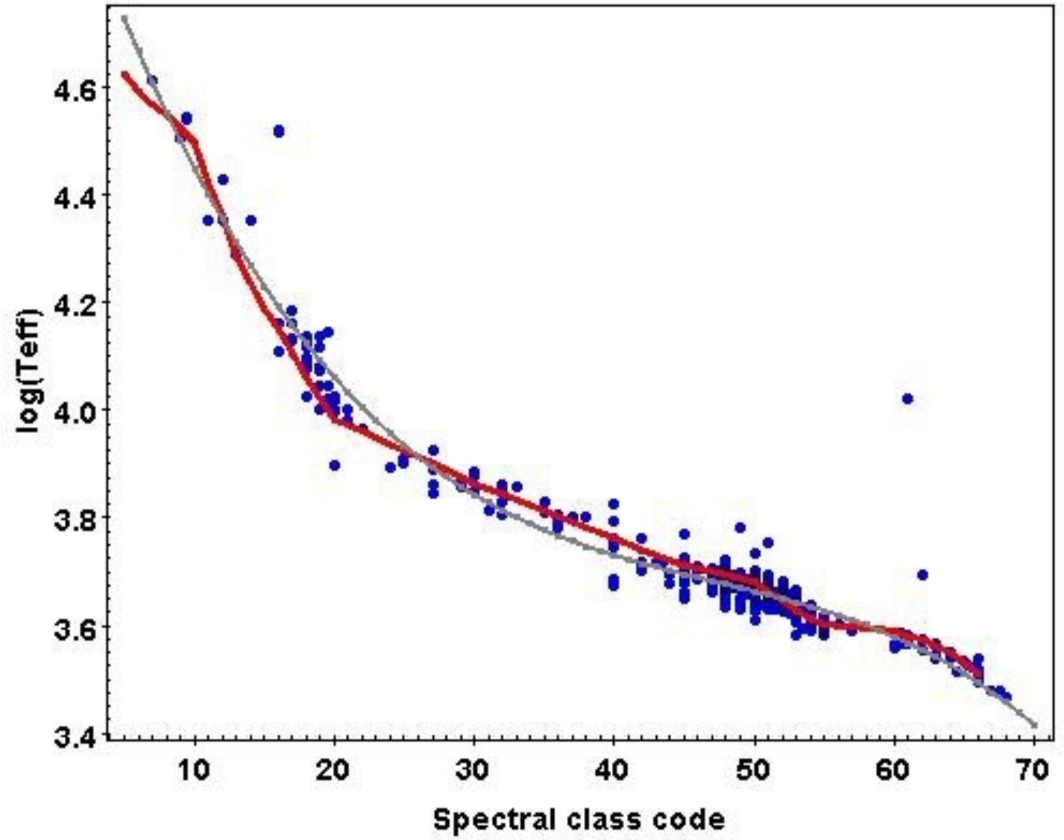
Supergiants. Spectral class - effective temperature relation.
Spectral class is coded as follows: 3 for O3, ..., 10 for B0, ..., 60 for M0.
Low (Ib), intermediate (Iab) and high (Ia) luminosity supergiants, selected from empirical stellar spectral atlases, are represented by red, blue and green dots, respectively. Gray curve is the (logTeff - spectral class) relation, approximated by polynom (see Table 1, Eq. (5)). Red curve represents Straizys (1992) (spectral class - logTeff) relation for supergiants.



Supergiants. Spectral class - surface gravity relation.
Spectral class is coded as follows: 3 for O3, ..., 10 for B0, ..., 60 for M0. Low (Ib), intermediate (Iab) and high (Ia) luminosity supergiants, selected from empirical stellar spectral atlases, are represented by red, blue and green dots, respectively. Gray curve is the (log g - spectral class) relation, approximated by polynom (see Table 1, Eq. (7)). Green, blue and red curves represent Straizys (1992) (spectral class - log g) relations for Ia, Iab and Ib supergiants, respectively.



Giants. Spectral class - effective temperature relation.
Spectral class is coded as follows: 3 for O3, ..., 10 for B0, ..., 60 for M0.
Dots represent giants, selected from empirical stellar spectral atlases.
Gray curve is the (logTeff - spectral class) relation, approximated by polynom (see Table 1, Eq. (9)). Red curve represents Straizys (1992) (spectral class - logTeff) relation for giants.



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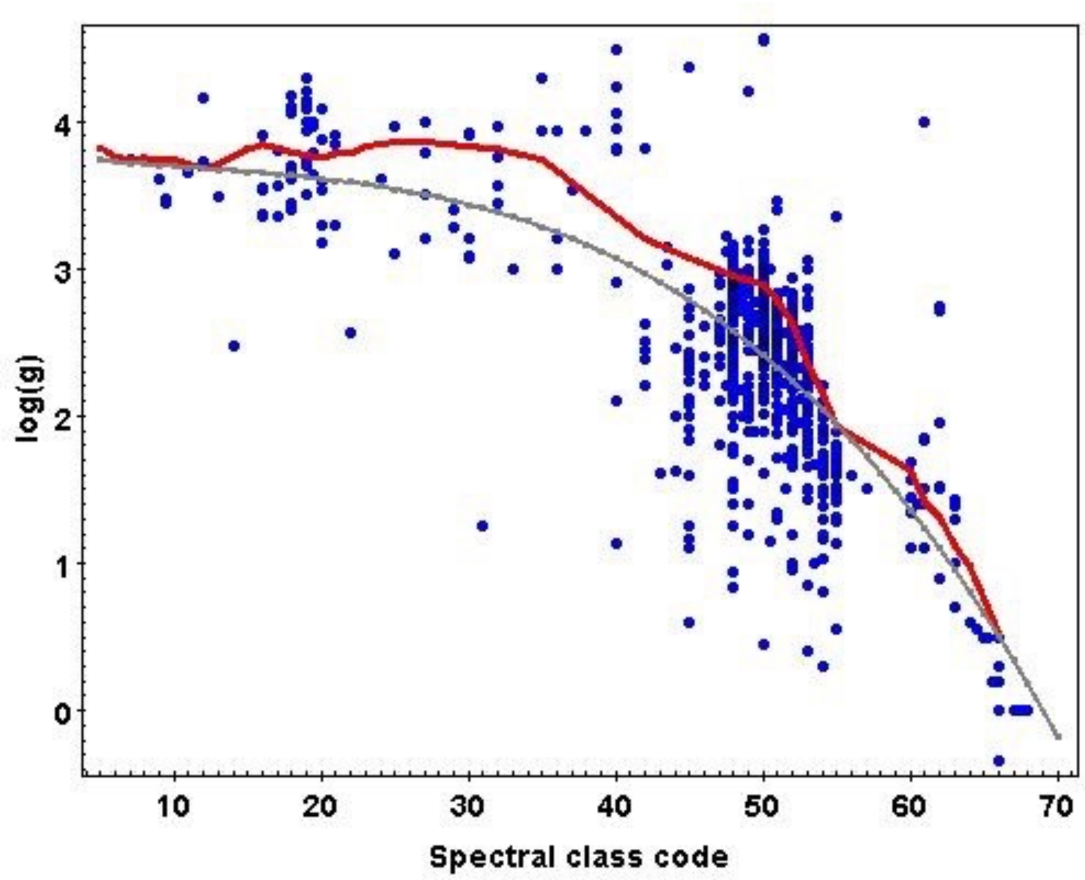
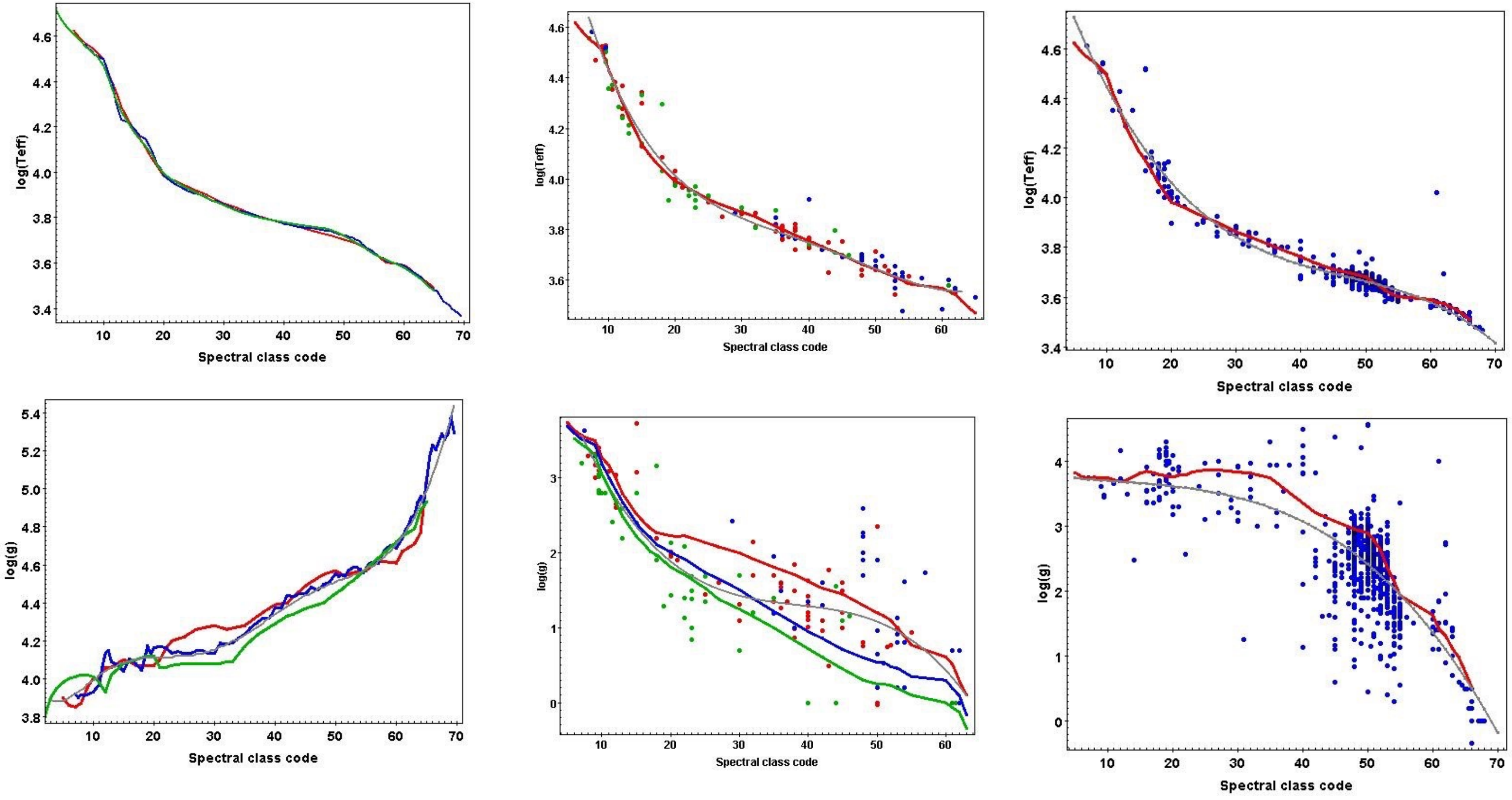
Dots represent giants, selected from empirical stellar spectral atlases.
Gray curve is the (log g - spectral class) relation, approximated by polynom (see Table 1, Eq. (11)).Red curve represents Straizys (1992) (spectral class - log g) relation for giants.



Spectral class - surface gravity – effective temperature relations for Main sequence, supergiant and giant stars



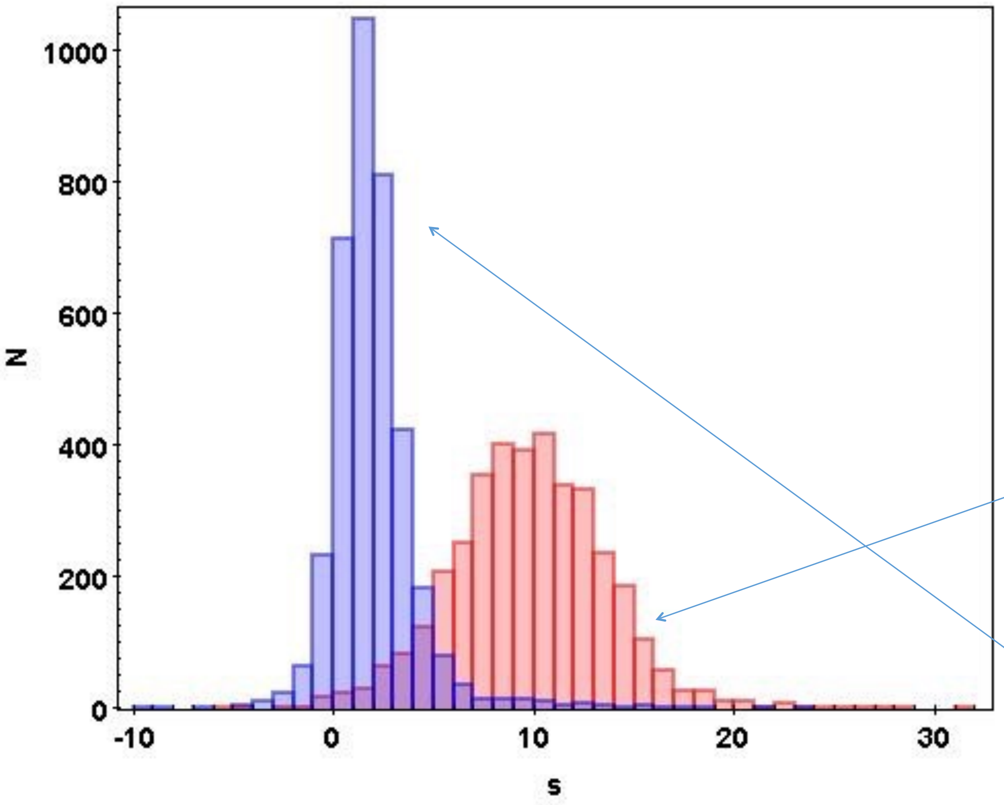
Spectral class – Teff – log g relations

Table 1. Spectral class — effective temperature — surface gravity relations

			std. dev.	valid for	Eq.
LC=V					
$\log T_{\rm eff}$	=	$4.80223 - 0.0465961S + 0.00157054S^2$	0.004	O3–O9	(1)
$\log T_{\rm eff}$	=	$5.30408 - 0.111312S + 0.00284209S^2 - 2.51285e^{-5}S^3$	0.011	B0–G7	
$\log T_{\rm eff}$	=	$3.25745 + 0.0285452S - 0.000388153S^2$	0.008	G8–M9	
S	=	$-77.4025 - 208.506T - 72.7616T^2$	0.36	$3.38 \le \log T_{\rm eff} < 3.75$	(2)
S	=	$13.0566 + 68.6827T + 404.486T^2 + 751.011T^3 + 497.913T^4$	0.75	$3.75 \le \log T_{\rm eff} < 4.10$	
S	=	$5.53554 - 34.2627T - 4.78570T^2 + 191.168T^3 + 317.065T^4$	0.34	$4.10 \le \log T_{\rm eff} \le 4.72$	
$\log g$	=	$4.23248 + 0.0194541S_1 + 0.000552749S_1^2 - 4.30515e^{-5}S_1^3 - 1.09920e^{-6}S_1^4 + 7.61843e^{-8}S_1^5 + 8.20985e^{-10}S_1^6 - 3.27874e^{-11}S_1^7$	0.055	O3–M9.5	(3)
S	=	$-0.117642 + 1.07059G + 192.069G^2 - 183.386G^3 + 49.7143G^4$	4.02	$3.8 \le \log g \le 5.3$	(4)
LC=I					
$\log T_{\rm eff}$	=	$5.37107 - 0.132197S + 0.00447197S^2 - 7.12416e^{-5}S^3 + 4.17523e^{-7}S^4$	0.049	O7–M3	(5)
S	=	$5.87386 - 49.0805T - 135.952T^2 - 119.090T^3 + 124.459T^4 + 108.708T^5$	3.14	$3.45 \le \log T_{\rm eff} < 4.60$	(6)
$\log g$	=	$5.26666 - 0.289286S + 0.00728099S^2 - 6.33673e^{-5}S^3$	0.485	O7–M3	(7)
S	=	$5.26199 - 10.2492G + 2.79561G^2 + 0.526251G^3$	9.74	$-0.2 \le \log g \le 3.8$	(8)
LC=III					
$\log T_{\rm eff}$	=	$5.07073 - 0.0757056S + 0.00147089S^2 - 1.03905e^{-5}S^3$	0.034	O5–M10	(9)
S	=	$8.49594 - 49.4053T - 191.524T^2 - 335.488T^3 - 144.781T^4$	2.59	$3.45 \le \log T_{\rm eff} < 4.65$	(10)
$\log g$	=	$3.79253 - 0.0136260S + 0.000562512S^2 - 1.68363e^{-5}S^3$	0.513	O5–M10	(11)
S	=	$33.3474 - 18.3022G - 5.33024G^2 - 0.667234G^3$	7.03	$-0.5 \le \log g \le 4.7$	(12)

S is spectral class code: 3 for O3, ..., 10 for B0, ..., 60 for M0.
$S_1 = S - 35$
$T = \log T_{\rm eff} - 4.6$
$G = \log g - 3.7$

Verification of our results for LAMOST data on giants



s is spectral class code difference

s_t is spectral class estimated from Teff (coded as follows: 3 for O3, ..., 10 for B0, ..., 60 for M0)

s_g is spectral class estimated from log g (ibid)

s_t-s_g

s(mean) = (s_t+s_g)/2

s(mean)-s(LAMOST)

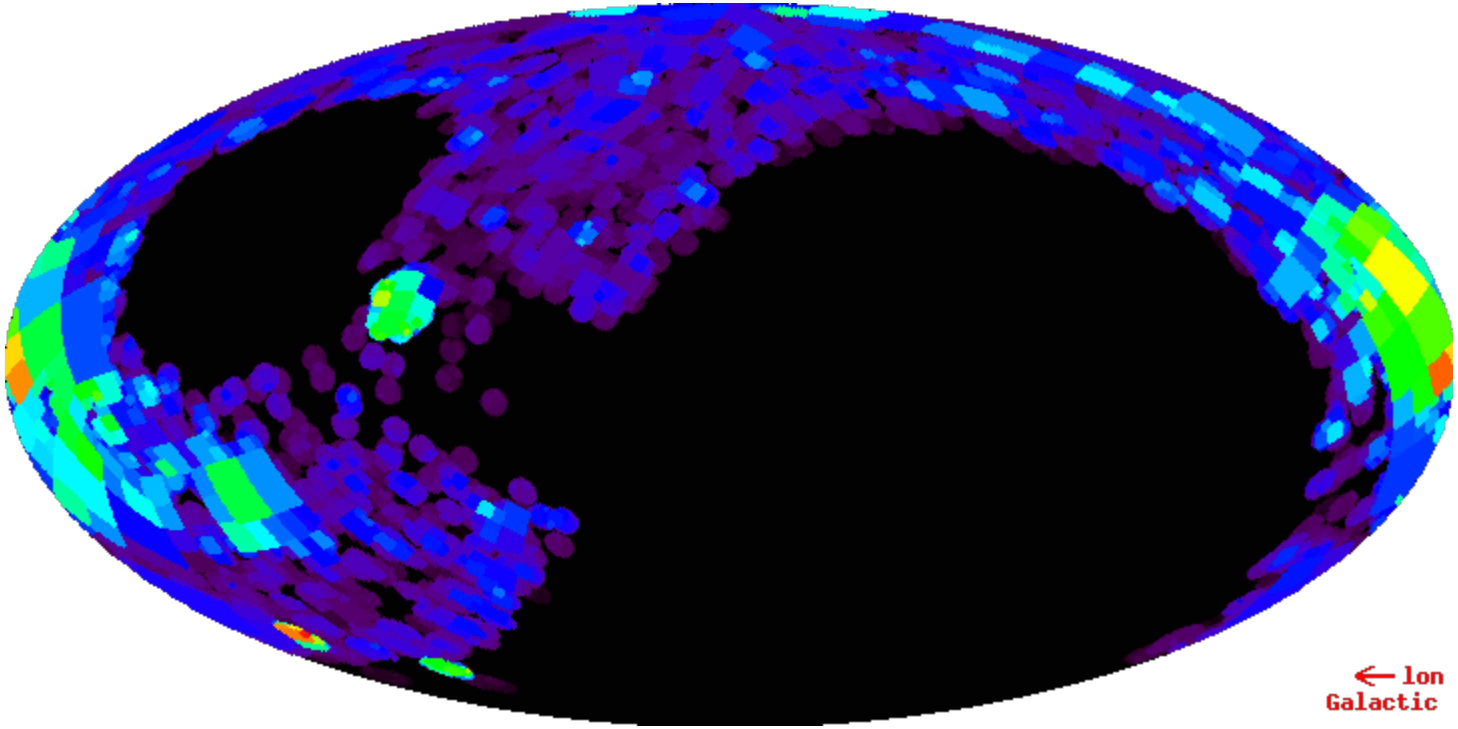
3716 giants

Coming photometric surveys

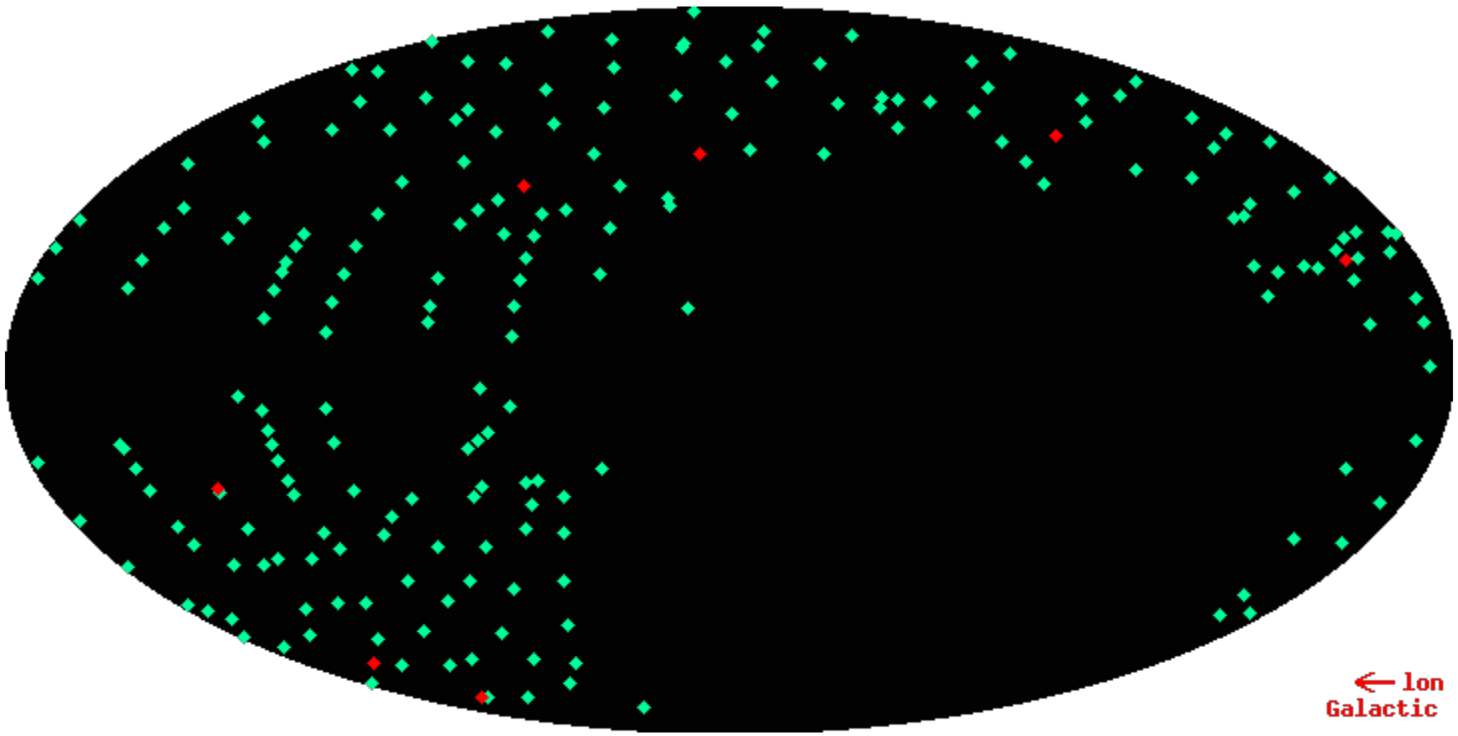
- LSST (2019ApJ...873..111I)
- Stellar Abundance and Galactic Evolution (SAGE, 2018RAA....18..147Z) project aims to study the stellar atmospheric parameters of 0.5 x 10^9 stars in the 12.000 deg^2 of the northern sky, with declination delta > -5, excluding the bright Galactic disk (|b|<10) and the sky area of 12 <R.A.<18 hr. The survey uses a self-designed SAGE photometric system, which is composed of eight photometric bands: Stromgren-u, SAGE-v, SDSS g,r,i, Halpha-wide, Halpha-narrow, and DDO-51.
- The UVIT instrument on-board the Indian space observatory ASTROSAT (2017AJ....154..128T)

Spectroscopic surves

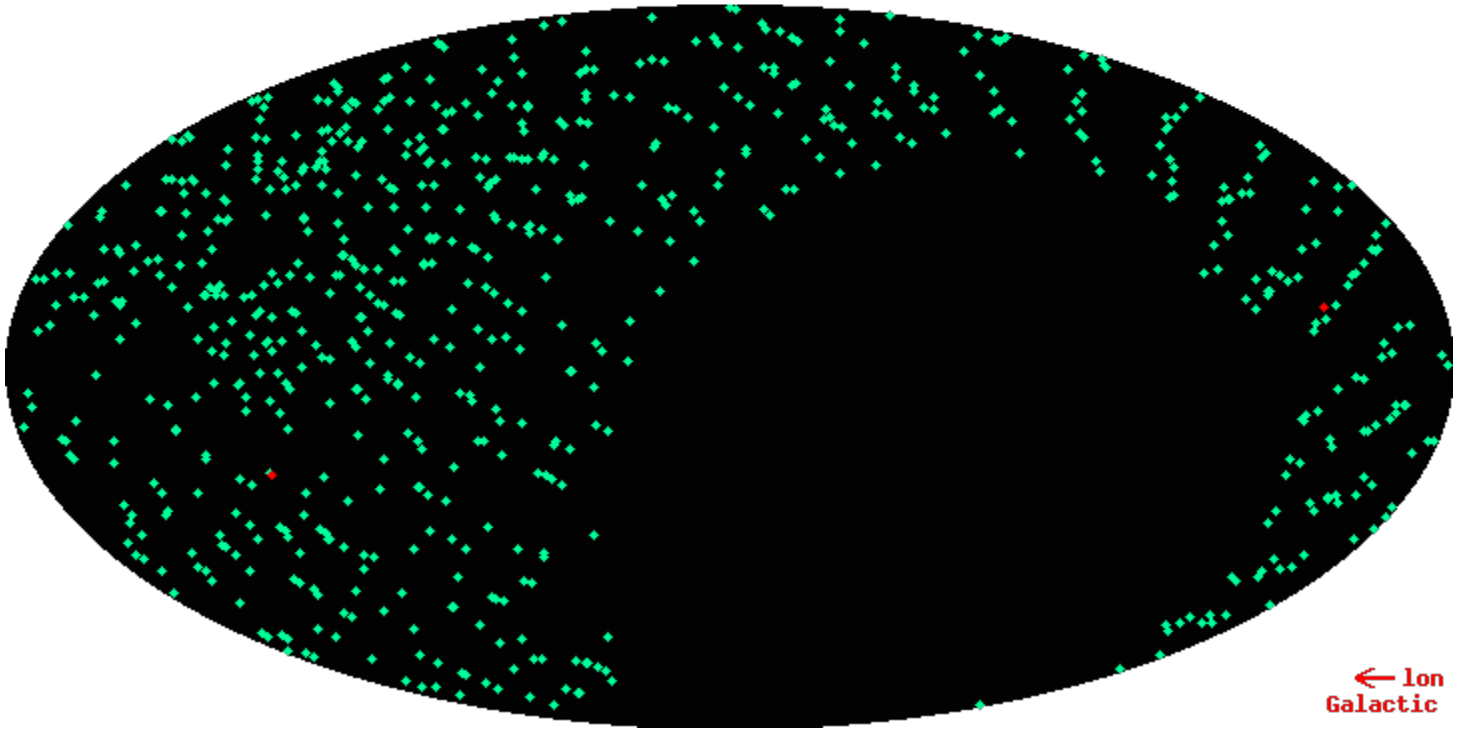
LAMOST DR4 catalogs (Luo+, 2018)



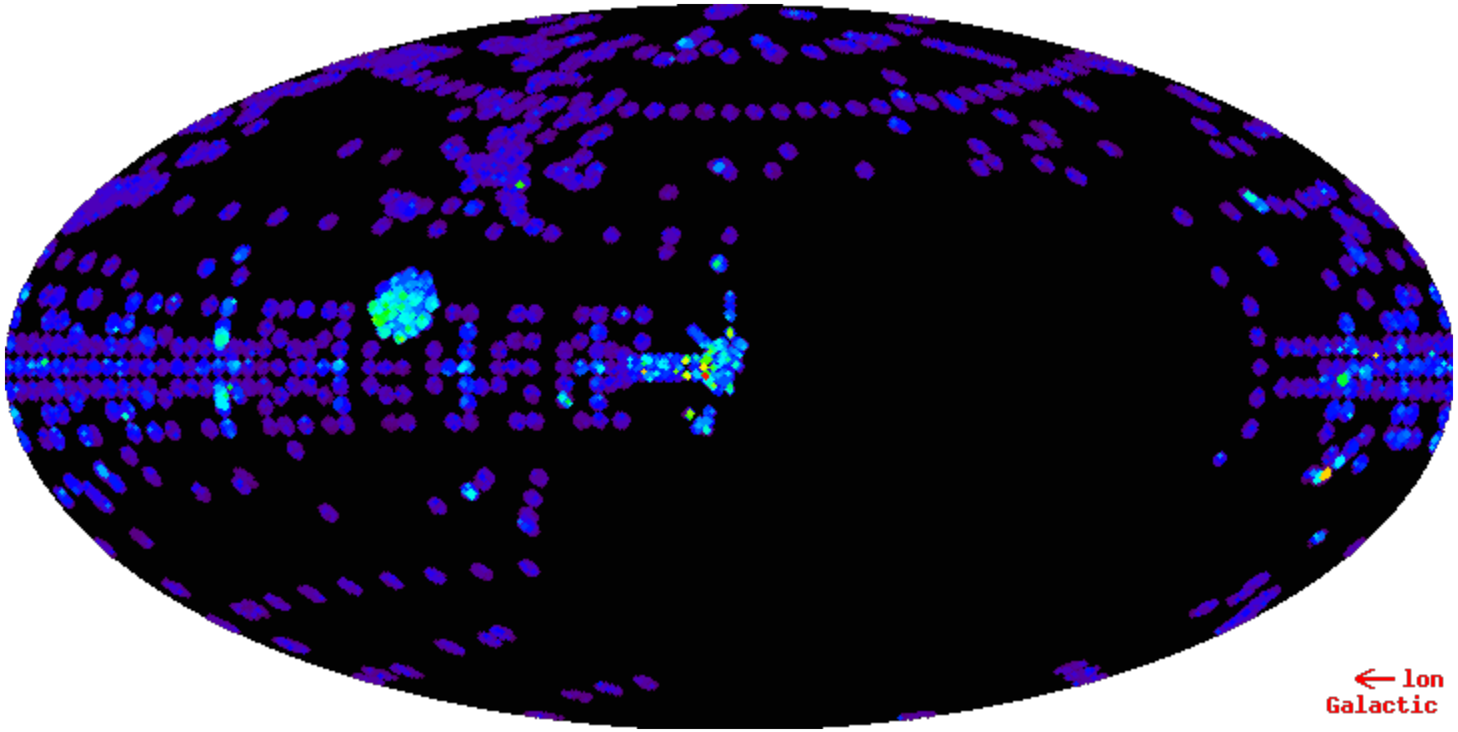
SEGUE plate pairs (Yanny+, 2009)



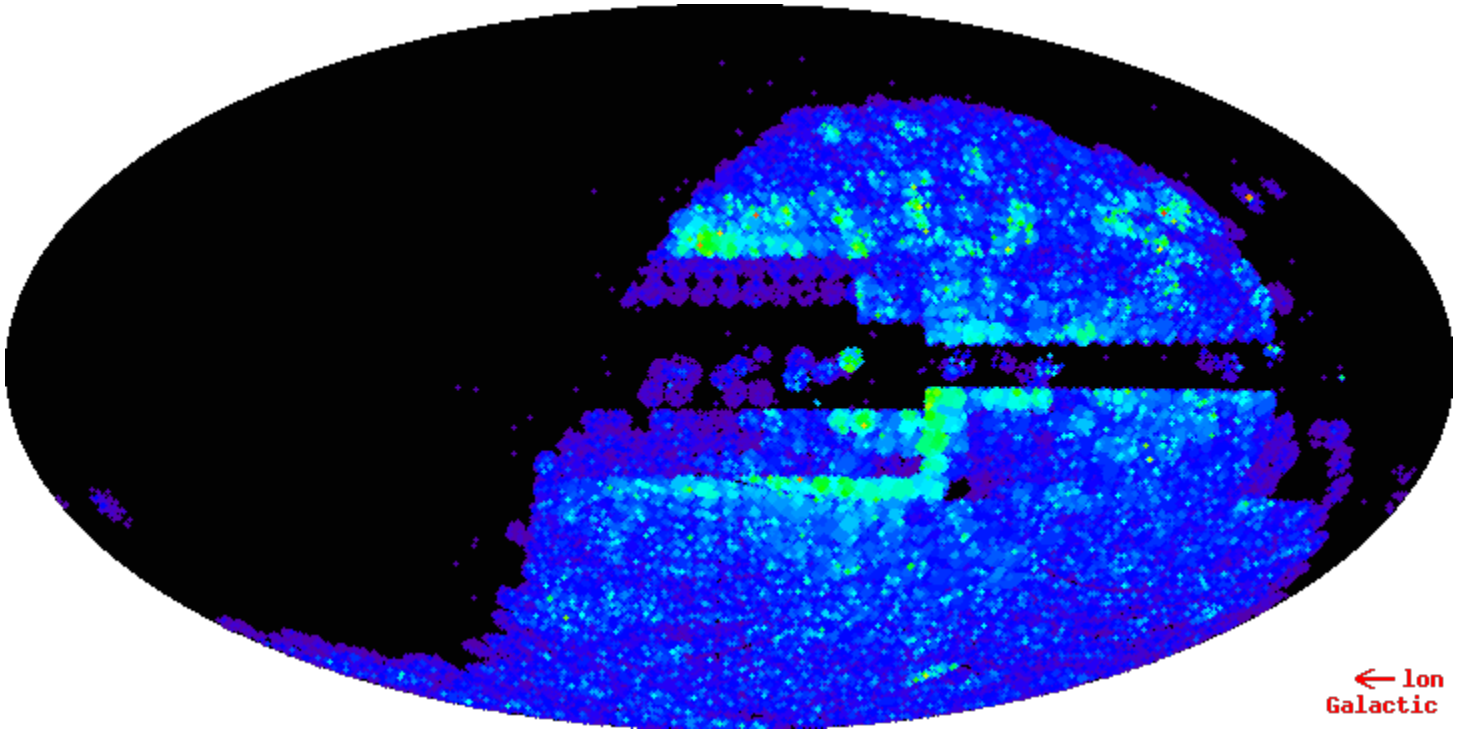
APOGEE giants (Feuillet+, 2016)



Outliers and similarity in APOGEE (Reis+, 2018)



RAVE 5 (Kunder+, 2017)

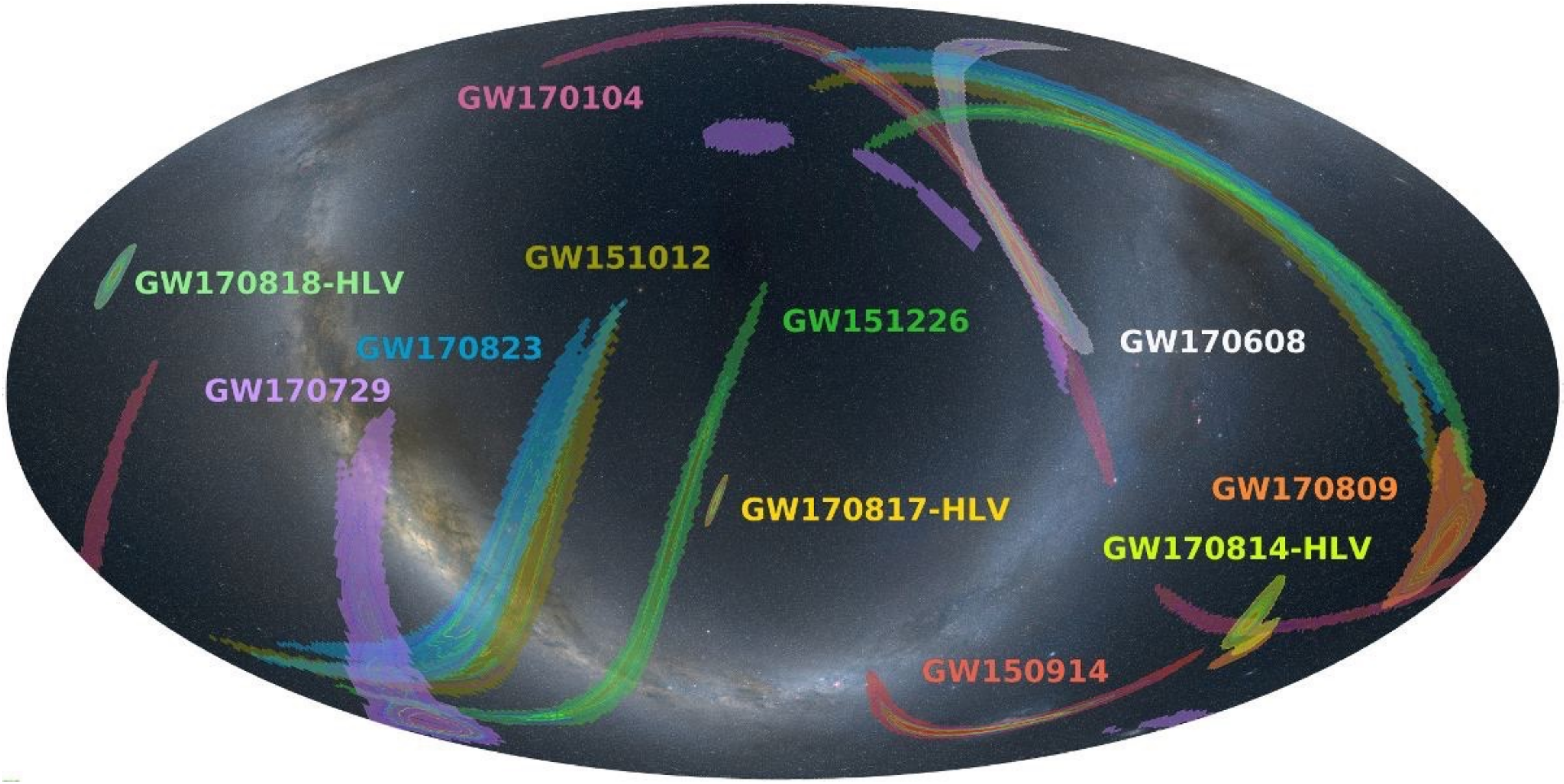


Coming spectroscopic surveys

- 4MOST {2019Msngr.175....3D}
- MOONS {2016ASPC..507..109C}
- WEAVE {2016sf2a.conf..271S}

Conclusions

- We have shown that multicolor photometric data from large modern surveys can be used for parameterization of stars closer than 4400 pc and brighter than $g_{SDSS} = 19.^{m}6$, including estimation of parallax and interstellar extinction value.
- We have approximated spectral class -- atmospheric parameters relations for main sequence, giant and supergiant stars, using both observational data and published calibration tables. We have verified the relations for giants with LAMOST spectral data, and the results of comparison of our estimations with observations had been quite satisfactory. The obtained results can be of use for an estimation of MK spectral class from effective temperature and surface gravity or vice versa. In particular, it could help to use spectral energy distributions from theoretical stellar atlases for given (Teff, log g) values, and assign the resulting values to corresponding spectral classes. That procedure is necessary, e.g., for estimation of absolute stellar magnitudes in one or the other photometric system used in modern sky surveys.


GW170104
GW151012
GW170818-HLV
GW151226
GW170823
GW170608
GW170729
GW170817-HLV
GW170809
GW170814-HLV
GW150914