Cross-matching large photometric catalogues for parameterization of single and binary stars

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Abstract

- We discuss the methods of reliable cross-matching of large photometric catalogues of various wavelengths (SDSS, GALEX, 2MASS, USNO-B1, etc) for the purpose of collection and use of multicolor (from UV to IR) photometry for cross-matched objects. We pay special attention to the performance issues and describe several approaches for the speed-up of the match, involving construction of various spatial indices, both planar and spherical. We discuss the means of dealing with ambiguous (multi-candidate) matches using a-priori information.

- Color-indices diagrams, constructed with the obtained photometry, are powerful tools for parameterization of stars. Particularly, detection of a composite flux in photometry can serve as an indication of a photometrically unresolved binarity and can contribute to the parameterization of the components of binary systems. Interstellar extinction value for cross-matched stars can also be calculated from the multicolor photometry.

Outline

- Ultraviolet region: reddening and parameterization of stars

- Cross-correlation of multiwavelength catalogues: reliable results

- Construction of UV color index diagrams: models – reddening – GALEX/SDSS observations

- Binaries recognition on color index diagrams

- Summary, future work

Reddening on color index diagrams

Extinction reddening
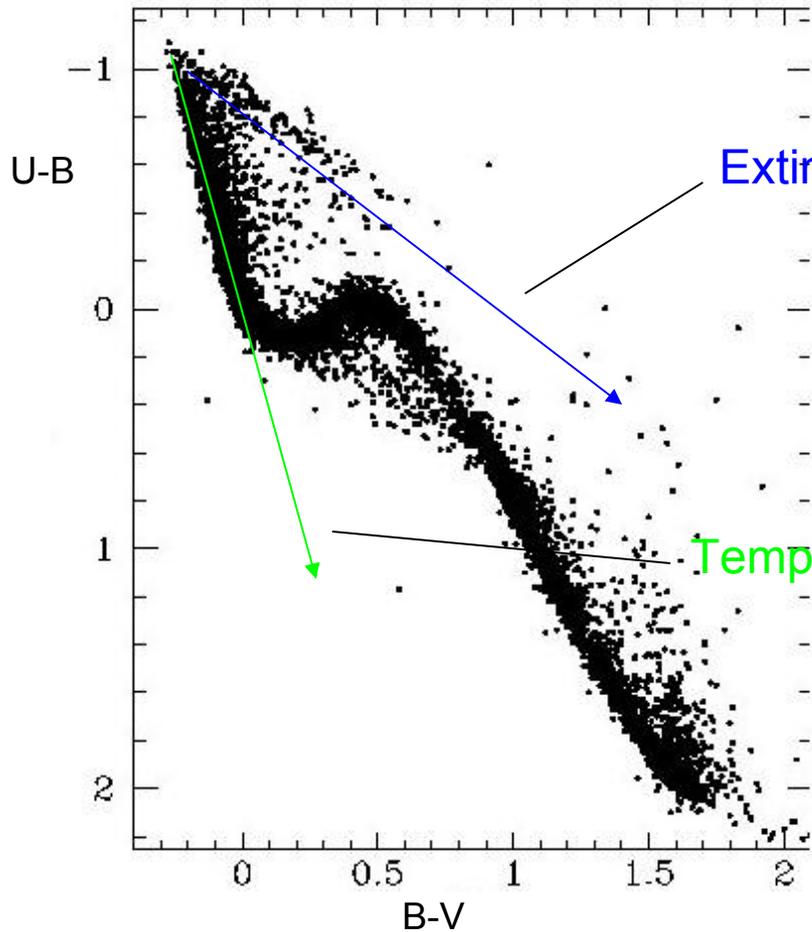
Temperature reddening
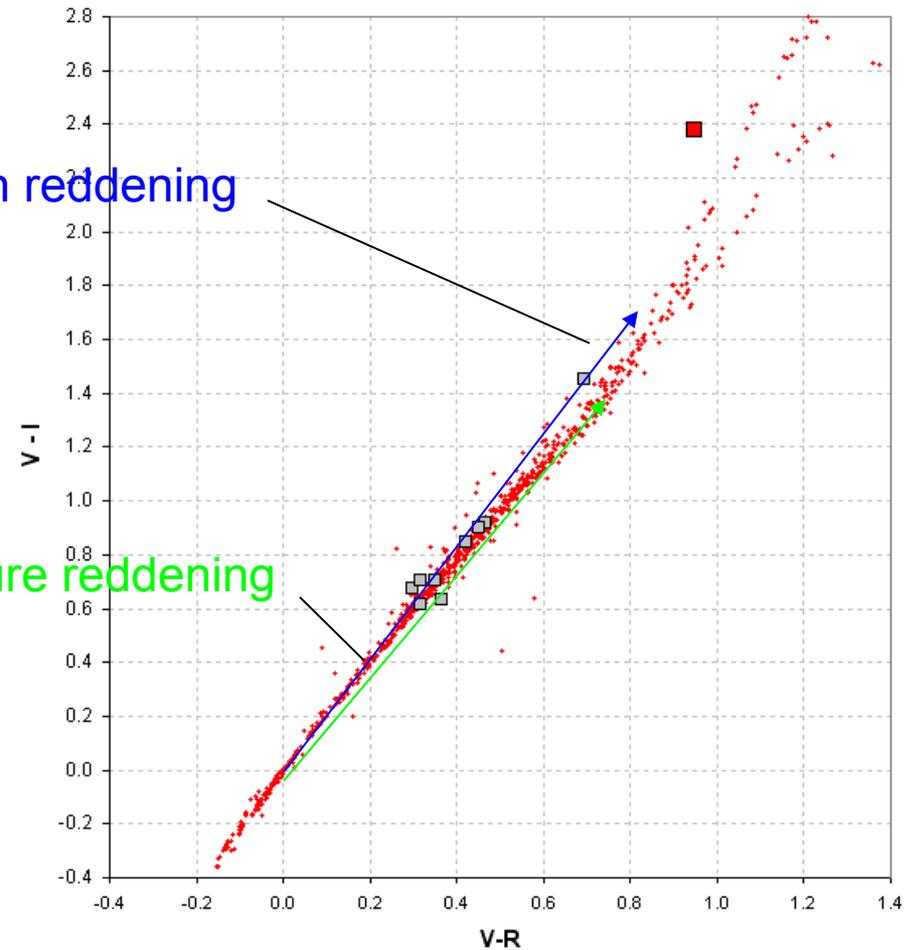
Extinction reddening and temperature reddening can be separated, when a significant deviation from monotonic function is observed

- in stellar spectrum, e.g.
  - Balmer jump area for B5-G0 stars
  - molecular bands in the spectrum of M stars
- in the Interstellar extinction law
  - extremely high extinction in a broad bump at about λ=2175 A

ADASS – 2010
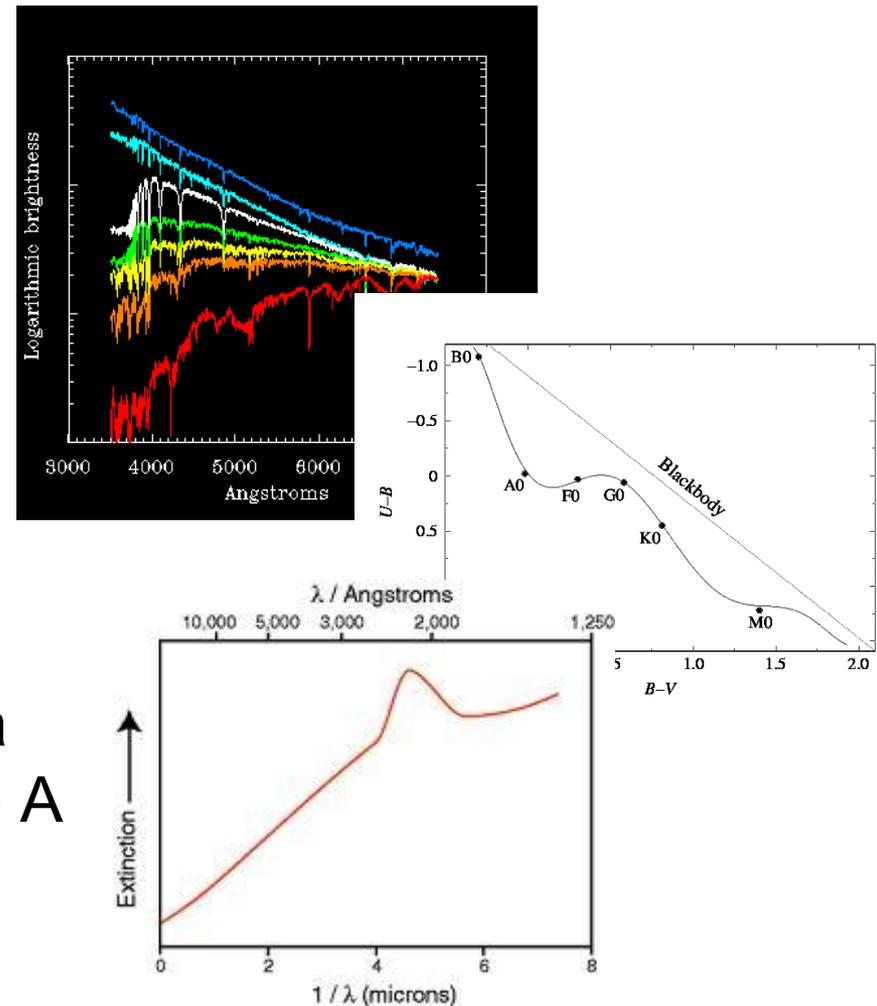
Cross-matching: general problem

- The aim is to reliably link the same object data in different catalogues
  - 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

No matches

Unambiguous match

Multiple matches

Multiple matches

Which one is correct?..
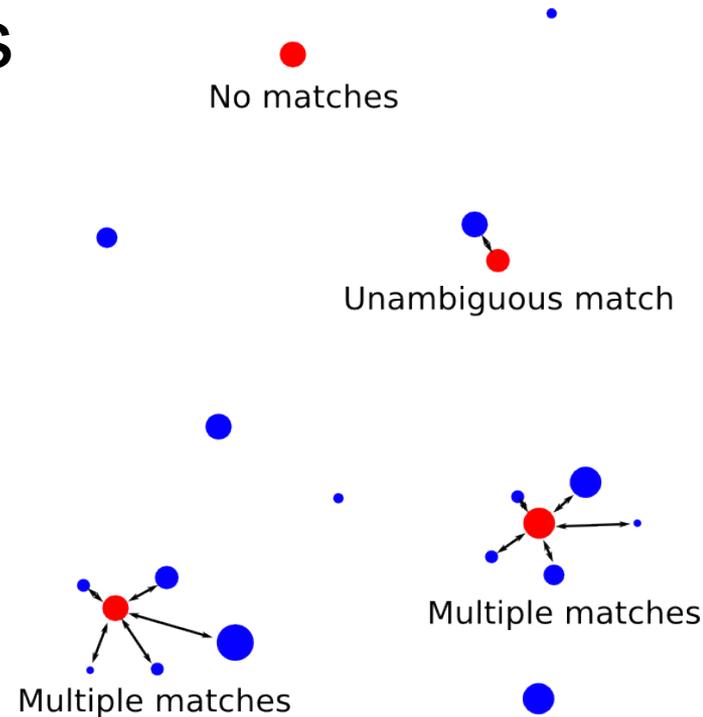
Cross-matching: finding reliable matches

- Positional match

  - all objects from one catalogue within given radius from each object of second catalogue

- Parametric filtering

  - nearby bands = nearby magnitudes

  - similar objects = similar colors

- Postfactum filtering

  - rejection of outliers after final spectral fitting

Cross-matching:
finding reliable matches

2MASS vs SDSS
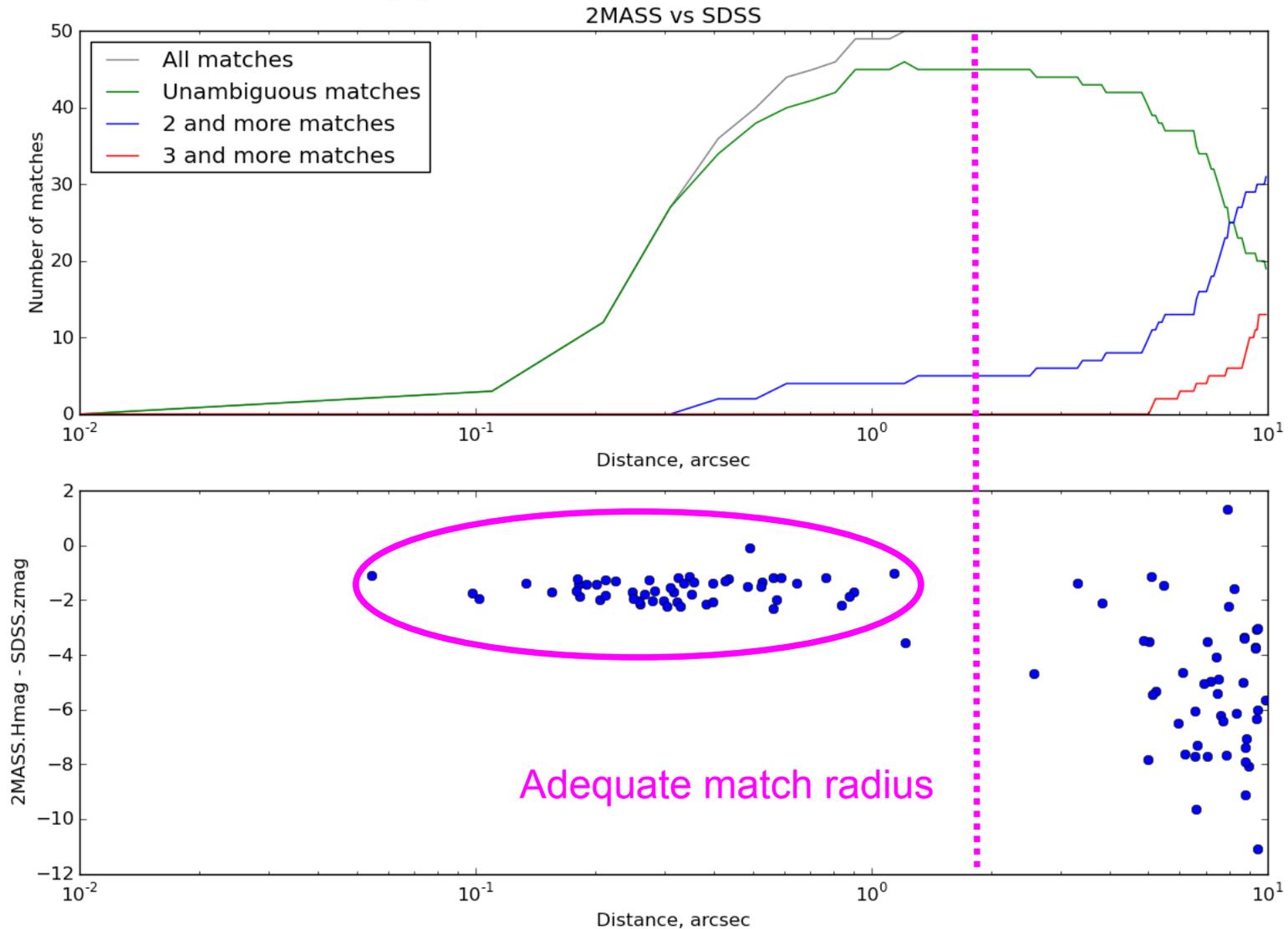
Cross-matching: technology

- Extraction of data for selected fields
  - VO, Registries, ConeSearch, VOTable
- Indexing to speed-up spatial queries
  - HTM — Hierarchical Triangular Mesh
- Matching and filtering
  - Python + ATPy + NumPy
- Visual checking
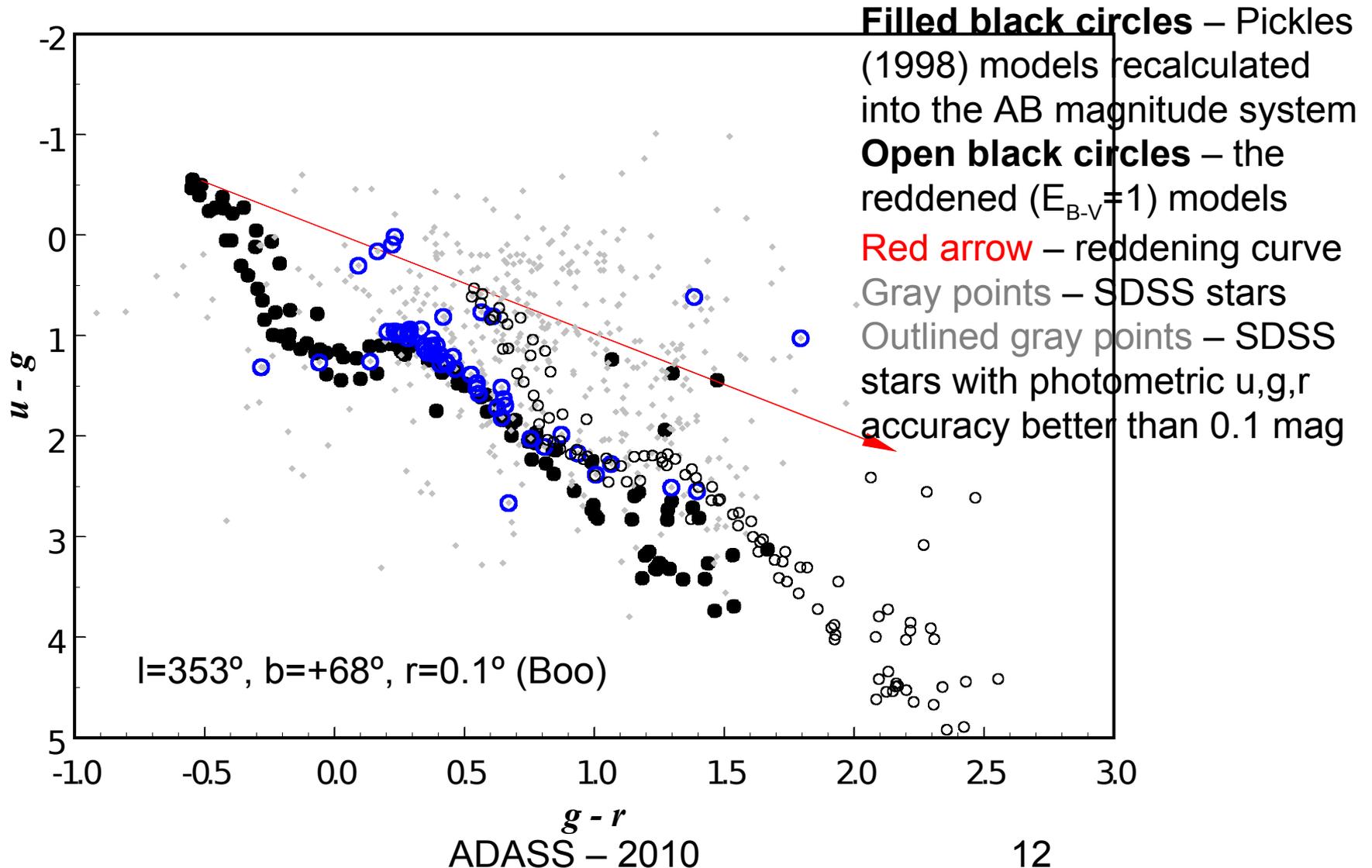 - Topcat, Python + MatplotLib

Modelling: choice of spectral library

- An analysis shows that Pickles A.J. (1998, Publ. Astron. Soc. Pac. 110, 863) is one of the best empirical libraries

- Drawbacks:
  - LC are from I to V (no WDs),
  - Spectral type serves as an input parameter (usage of continuous parameters – Teff, lg g, … – is more comfortable)
  - Early type stars (O-B3) remain reddened

Modelling: response curves and interstellar extinction law

- Response curves of UV photometry surveys
  - SDSS (Gunn J.E. et al. 1998, AJ 116, 3040)
  - GALEX (Morrissey P. et al. 2005, ApJ 619, L7)
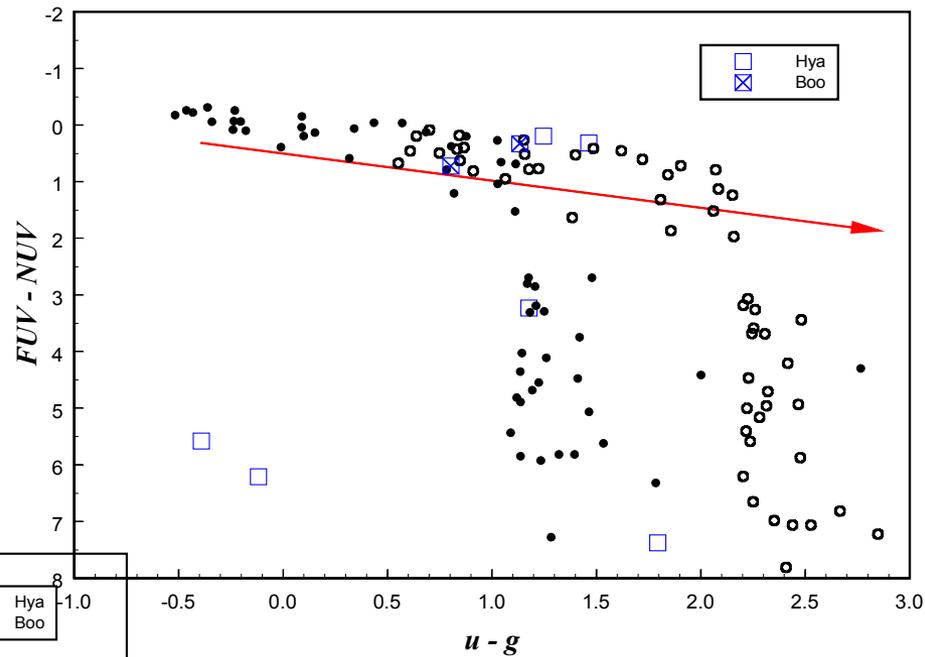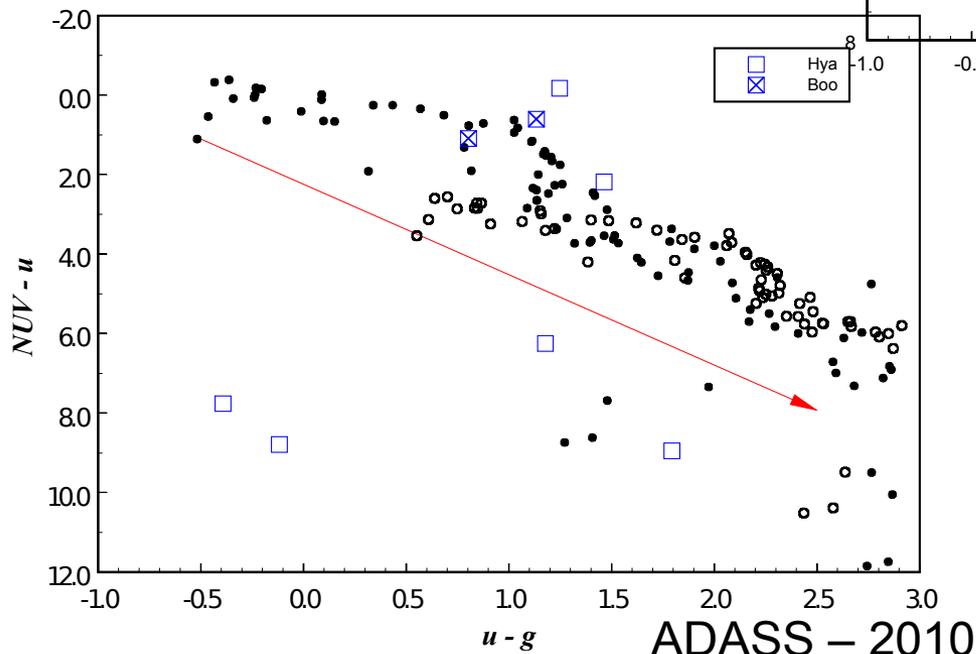- Fluks et al. (1994, AAS 105, 311) interstellar extinction law

SDSS: theory and observations

Filled black circles – Pickles (1998) models recalculated into the AB magnitude system
Open black circles – the reddened (E_{B-V}=1) models
Red arrow – reddening curve
Gray points – SDSS stars
Outlined gray points – SDSS stars with photometric u,g,r accuracy better than 0.1 mag

l=353º, b=+68º, r=0.1º (Boo)

GALEX/SDSS: theory and observations

l=353º, b=+68º, r=0.1º (Boo)
l=228º, b=+27º, r=0.1º (Hya)

Filled black circles – Pickles (1998) models recalculated into the AB magnitude system
Open black circles – the reddened ($E_{B-V}=1$) models
Red arrow – reddening curve
Blue squares – GALEX/SDSS stars

Possible reasons for disagreement of observational and simulated points:

- Observational error, misprint in catalogue or cross-matching error
- The star is a variable
- The star belongs to other LC
- Non-stellar nature of the object (galaxy, …)
- Non-standard interstellar extinction law in the area
- ...
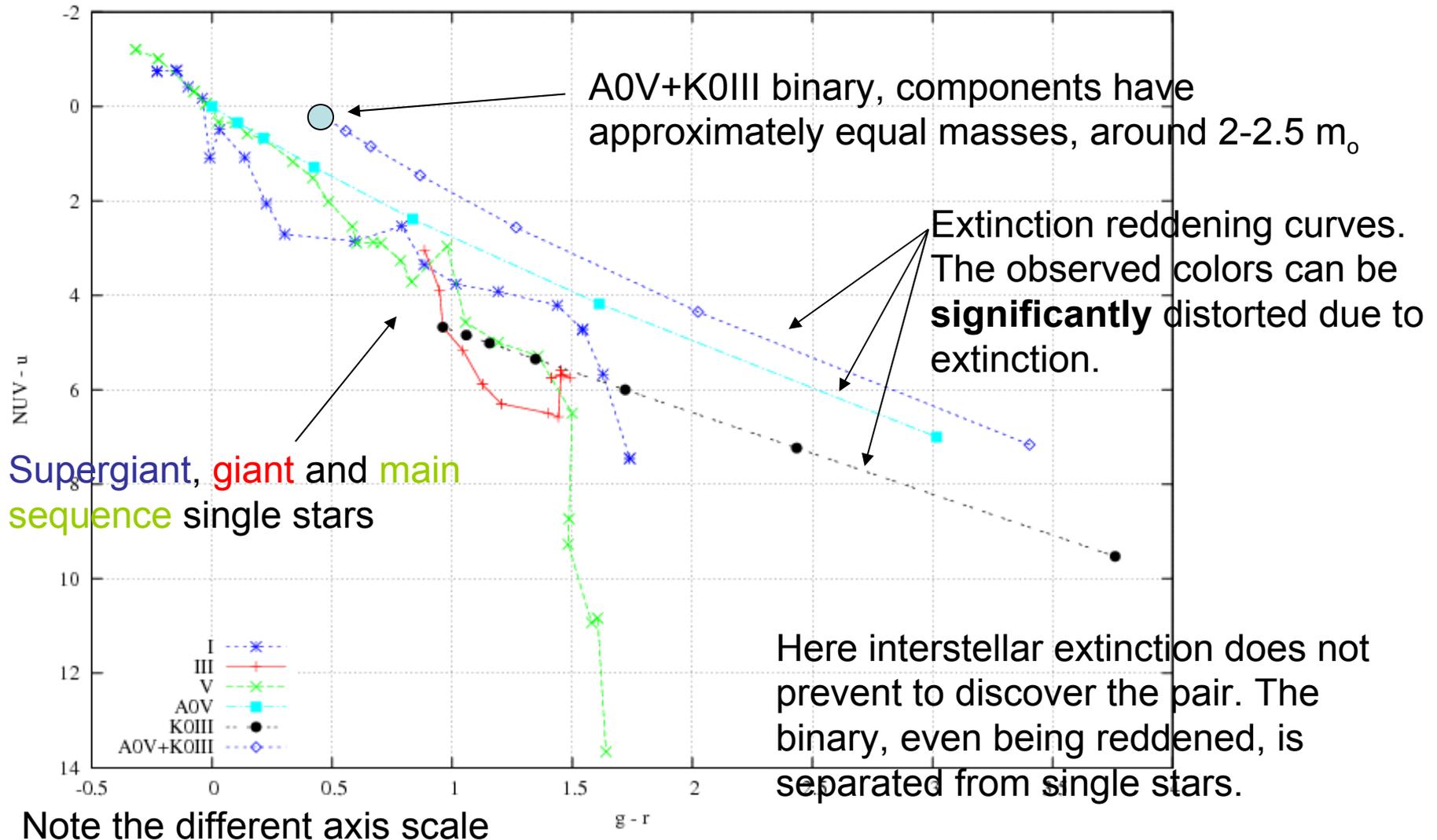- **The star is a photometrically unresolved binary**

Unresolved binaries simulation

- Some photometrically unresolved binaries exhibit colors different enough from ones of single stars.

- Such binaries can be separated from single stars in some color index diagrams.

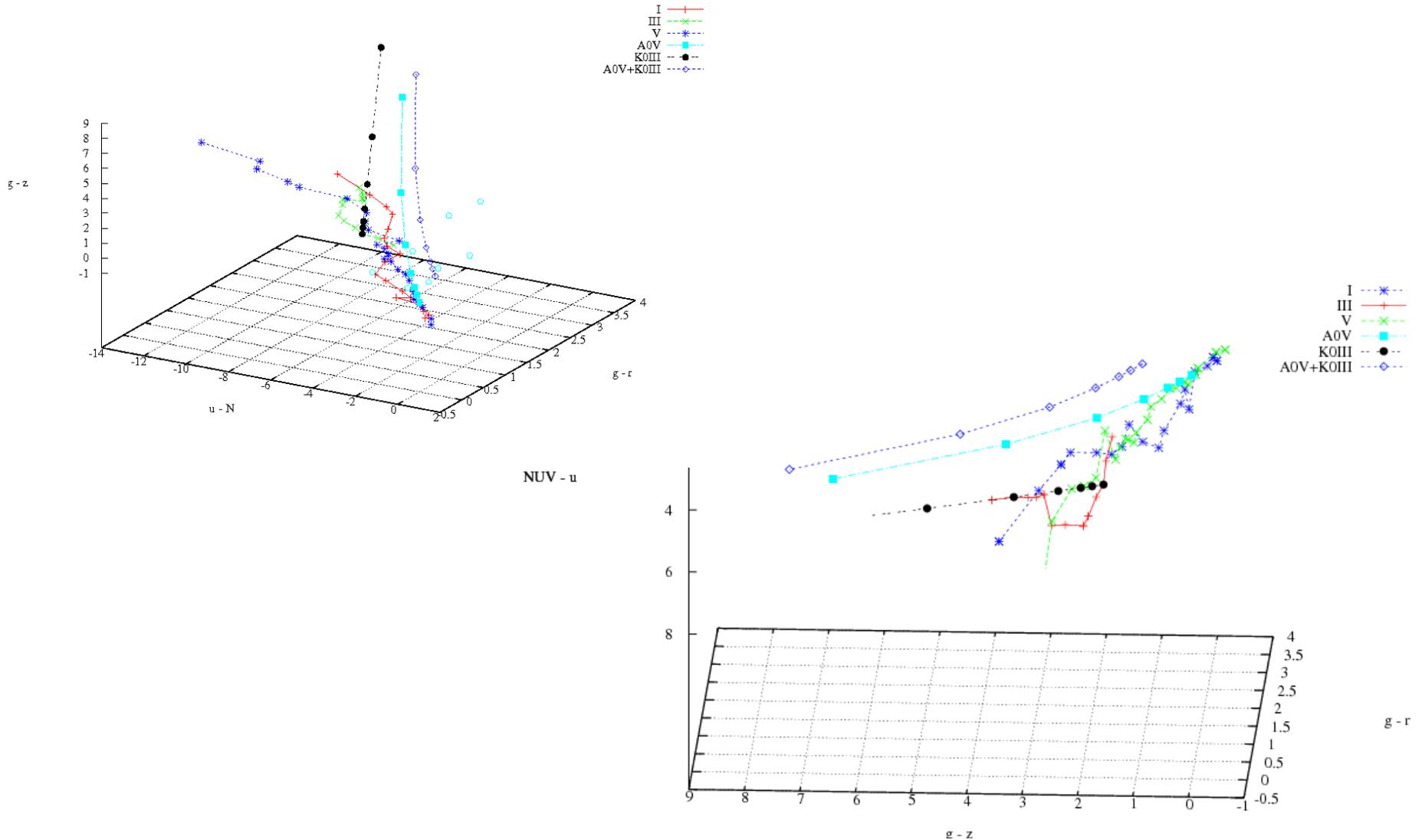- The goal is to specify those binaries and those color index diagrams.

The following pairs can be unfiled:

- Evolutionary meaningless pairs.

- Pairs with components of very different luminosity ($\Delta m > 3^m$).

- Pairs with components of similar temperature ($\Delta Sp < \frac{1}{2}$ Sp, it approximately gives $\Delta \log T_{eff} = 0.1$ for hot stars, and 0.02 for cool stars). *However, such pairs are recognizable on color-magnitude plots, as they have an increased luminosity for a given color.*

An example: GALEX/SDSS colors of A0V+K0III unresolved binary

A0V+K0III binary, components have approximately equal masses, around 2-2.5 m_o

Extinction reddening curves. The observed colors can be **significantly** distorted due to extinction.

Supergiant, giant and main sequence single stars

Here interstellar extinction does not prevent to discover the pair. The binary, even being reddened, is separated from single stars.

Note the different axis scale

A0V+K0III GALEX/SDSS photometry, three-color diagrams

Summary

- Method for reliable cross-matching of catalogues with different object densities is realized

- A tool for simulation of color index diagrams is constructed.

- It is shown that GALEX/SDSS photometry can be used for [*even reddened*] single-binary star separation and for parameterization of stars.

Future work

- Cross-matching of current surveys (GALEX, SDSS; together with UKIDSS, DENIS, 2MASS photometry) and use of coming data (Gaia, WSO-UV, Lira-B, Svecha).

- Parameterization of single and, when possible, binary stars.

- Determination of extinction value in a given area, and construction of a 3D galactic interstellar extinction map.

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If you have any questions, comments, or criticism, please, contact me here or at malkov@inasan.ru
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