

The Digitized First Byurakan Survey - DFBS



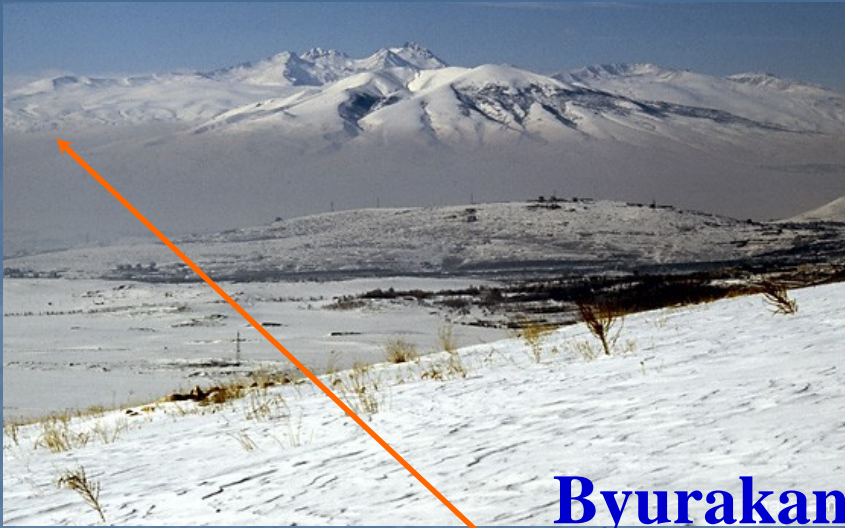
Areg M. Mickaelian
Byurakan Astrophysical Observatory (BAO), Armenia

13 June 2006
Observatoire de Strasbourg, France

Overview

- Armenia and Byurakan
- Objective prism surveys and SDSS
- The First Byurakan Survey (FBS)
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- FBS based projects
- The Digitized First Byurakan Survey (DFBS)
- Other digitization projects
- The Armenian Virtual Observatory (ArVO)
- First science with the DFBS

Armenia



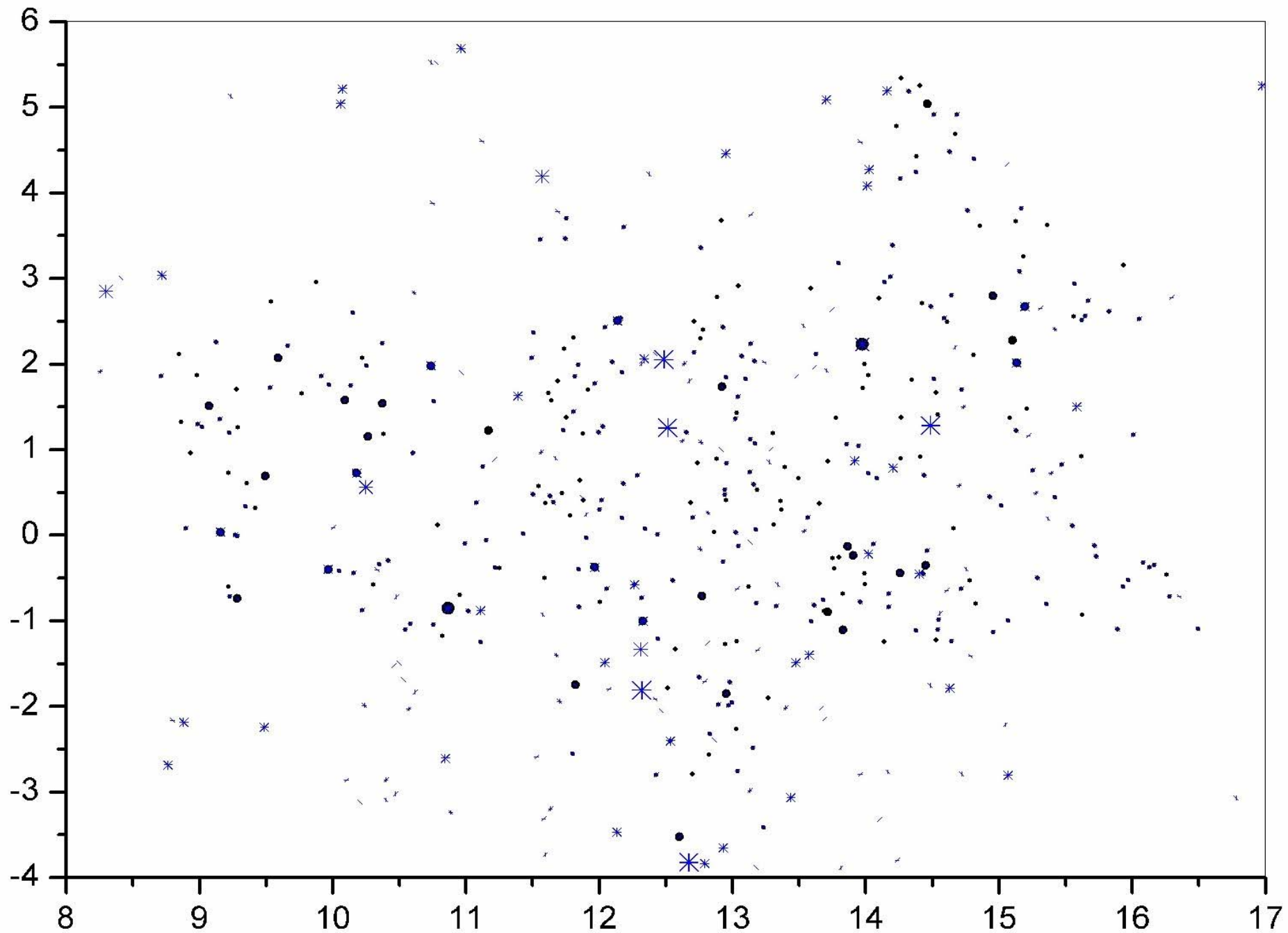
Byurakan



Southern slope of Mt. Aragatz,
near village Byurakan, 30km Northwest of Yerevan

Objective prism surveys and the SDSS

Survey	Years	Telescopes and equipment	Emulsions	D at Hy	Spectral range, A	Area covered	Vlim	Objects of interest
FBS	1965-1980	Byurakan 102/132 cm Schmidt, 1.5° prism	IIa-F	1800	3400-6900	$ b > 15^\circ$ $\delta > -15^\circ$ 17,000 deg ²	17.5	UVX galaxies (Markarian galaxies) FBS BSOs
SBS	1978-1991	Byurakan 102/132 cm Schmidt, 1.5°/3°/4° prisms	IIIa-J IIIa-J+GG495 IIIa-F+RG2 IV-N	1800 900 280 ■	3400-5300 4950-5400 6300-6950	$ b > 30^\circ$ $49^\circ < \delta < 61^\circ$ 965 deg ²	19	UVX galaxies, QSO/Sy, BCDG, hot stars
Case	1983-1995	Kitt Peak 61/91 cm Burrell Schmidt, 1.8° prism	IIIa-J	1350	3400-5300	$ b > 30^\circ$ $\delta > 30^\circ$	18	Blue stellar objects, UVX galaxies (CSO/CBS/CG)
HQS	1985-1997	Calar-Alto 80 cm Schmidt, 1.7° prism	IIIa-J	1390	3400-5300	$ b > 20^\circ$ $\delta > 0^\circ$ 12,000 deg ²	19	QSOs, Hamburg/RASS
HES	1990-1996	ESO 1m Schmidt, 4° prism	IIIa-J	280	3400-5300	$ b > 30^\circ$ $\delta < +2.5^\circ$ 9,000 deg ²	18	QSOs
SDSS	2000-	Apache Point 2.5m Ritchey-Chretien, Double MOS	CCD	res.: 2.5A	3800-9200	$ b > 30^\circ$ $\delta > 0^\circ$ 10,000 deg ²	21	100 million objects; 1 million galaxies, 100,000 QSOs



The First Byurakan Survey (FBS)

Authors:	<i>B.E.Markarian, V.A.Lipovetsky, J.A.Stepanian</i>
Years:	<i>1965-1980</i>
Instruments:	<i>102/132/213 cm Byurakan Schmidt telescope 1.5° objective prism (1800 Å/mm at Hγ)</i>
Emulsions:	<i>Kodak IIA-F, Ila-F, 103a-F, II-F</i>
Spectral range:	<i>3400-6900 Å with a sensitivity gap near 5300 Å</i>
Field:	<i>4.1° × 4.1° (plates: 16 × 16 cm)</i>
Scale:	<i>96.8 "/mm ■</i>
Region of sky:	<i>$\delta \geq -15^\circ$, $b > 15^\circ$</i>
Total area:	<i>17,056 sq. degree (1139 fields, more than 1874 plates)</i>
Limiting magn:	<i>17^m-17.5^m ($\leq 18.5^m$)</i>
Main goal:	<i>selection of UV-excess galaxies</i>
Selected objects:	<i>UV gal, Sy, QSO, BLL, LINER, SB, HII, radiogalaxies, etc.</i>
Number of objs:	<i>1515</i>
Publication:	<i>15 lists (1967-1981), 2 catalogs (Mazzarella & Balzano 1986, Markarian et al. 1989)</i>



The Byurakan Observatory 1m Schmidt telescope

FBS based projects

- Survey for UVX galaxies (Markarian survey)
- Second part of the FBS: blue stellar objects and late-type stars
- Byurakan-IRAS Galaxies (BIG) and Byurakan-IRAS Stars (BIS)

References:

Mazzarella J.M., Balzano V.A., A Catalogue of Markarian Galaxies // *Astrophys. J. Suppl. Series*, 1986, 62, 751.

Markarian B.E., Lipovetski V.A., Stepanian J.A., Erastova L.K., Shapovalova A.I. // *Commun. Special Astrophys. Obs.*, 1989, 62, 5.

Markarian B.E., Lipovetski V.A., Stepanian J.A., First Byurakan Survey (FBS), *Centre de Donnees Stellaires (CDS), Catalog VII/172, Strasbourg, 1997,*

<http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=VII/172/fbs>

Abrahamian H.V., Mickaelian A.M., Lipovetsky V.A., Stepanian J.A., First Byurakan Survey (FBS), 2nd Program, 1990-1996, *Centre de Donnees Stellaires (CDS), Catalog II/223, Strasbourg, 1999,*

<http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=II/223/fbs2>

BIG and BIS objects in *SIMBAD*; BIG objects in *NED*

The Markarian Survey



Main Features:

- First systematic objective-prism survey
- The largest objective-prism survey of the Northern sky
 -
- New method of search for AGNs
- 1515 UVX galaxies: 181 Seyferts, 17 LINERs, 13 QSOs, 3 BLLs, 95 Starburst, 26 HII galaxies
- Classification of Seyferts: Sy1 & Sy2 (Weedman & Khachikian)
- Definition of Starburst galaxies (Weedman)

Digitized
DFBS

First Byurakan Survey

Digitized First Byurakan Survey – DFBS

Byurakan Astrophysical Observatory (BAO), Armenia:

Mickaelian A.M., Sargsyan L.A., Erastova L.K.,
Gigoyan K.S., Mikayelyan G.A., Hovhannisyan L.R., Sinamian P.K.

Cornell University, Ithaca, NY, USA:

Houck J.R., Weedman D.W., Barry D., Brandl B.

Universita di Roma "La Sapienza", Italy:

Nesci R., Massaro E., Trevese D., Rossi C., Sclavi S., Gaudenzi S.

Hamburger Sternwarte (HS), Germany:

Hagen H.-J.

DFBS: *the project*

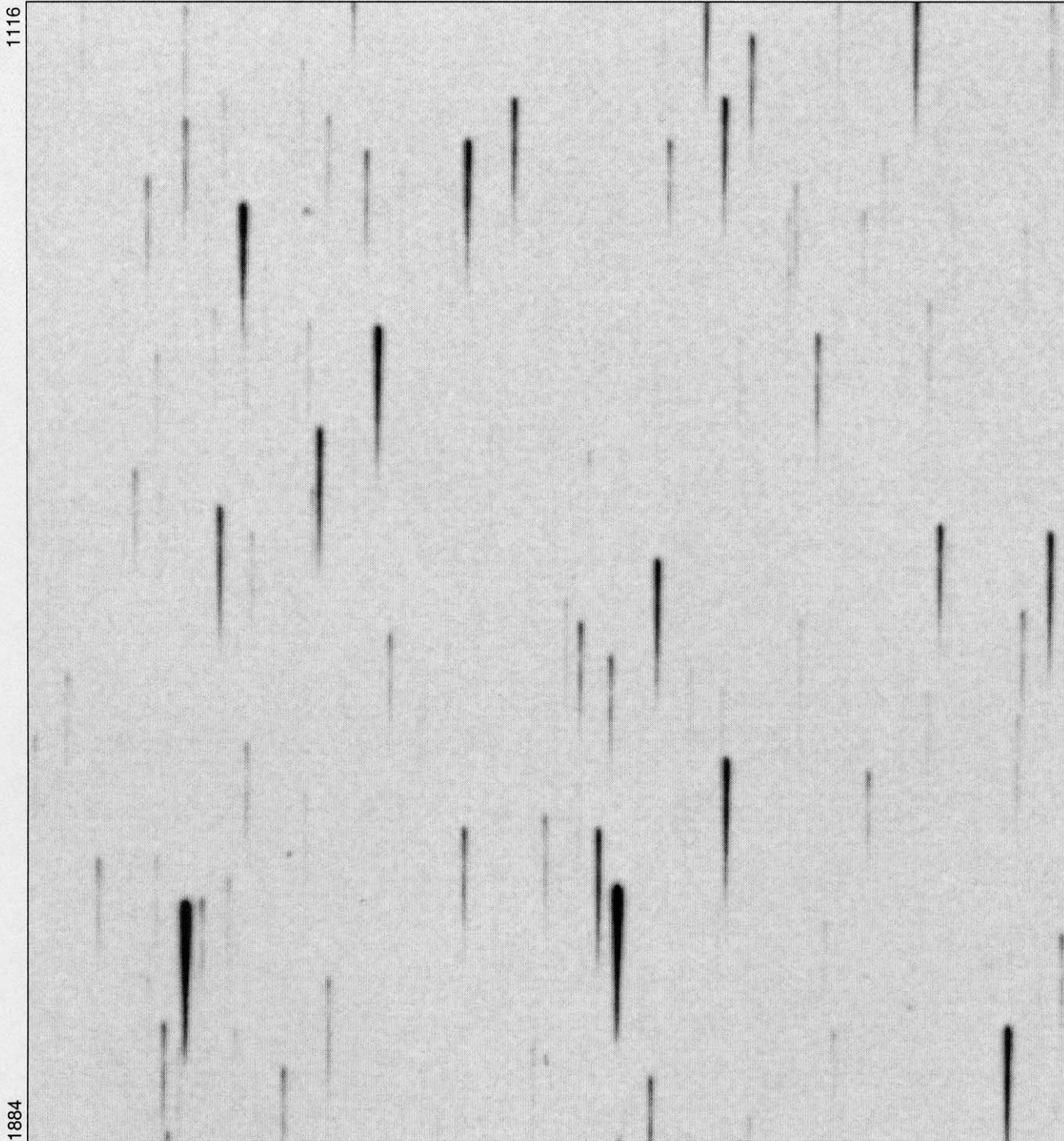
- *scanning*
- *astrometric solution*
- *extraction*
- *wavelength calibration*
- *density and flux calibration*
- *multiband (UBVR) photometry*
- *making up template spectra*
- *numerical classification*
- *DFBS catalog and database*
- *web page and user interface*

DFBS: *scanning*

Main parameters of the digitization:

- Epson Expression 1680 Pro scanner
- 1600 *dpi* resolution (pixel size 15.875μ or 1.542")
- transparency (positive) mode
- 16 bit dynamic range
- scanning direction: East-West (along R.A.)
- 9601×9601 pixels each plate
- program *scanfits* by *Stefano Mottola*, FITS images
- 180 MB file for each plate
- 107 *pix* × 5 *pix* spectra (spectra are 1700μ long)
- DN to I conversion: $I = (V - B) / (T - B)$ (*V-unexposed, B-black, T-given pixel*)
- scanning period: *June 2002 – December 2003*
- storing on CDs, DVDs, and on a server; whole DFBS on 85 DVDs
- results: 1874 plates (**1133** FBS fields = 17,056 deg²)

1116



1884

1156

1843

DFBS: *astrometric solution*

1. R. Nesci:

- the *Tycho* catalog as an input
- IRAF tasks of the *images.imcoords* package: *ccmap* and *ccsetwcs*
- ~20 bright stars for each plate for the first guess
- fainter stars from the *Tycho* catalog for second approximation
- the best accuracy (rms): 1.54" (1.0 *pix*) for R.A.
0.84" (0.6 *pix*) for DEC
- total time ~ 1 hour, done 30 plates

2. H. Hagen:

- the *GSC-2* (Guide Star Catalog)
- Programs under C: *preparefbs* (rotation and flipping), *fbsskytra* (coordinate conversion)
- up to 800 stars, using up to 7 approximations
- the best accuracy (rms): 0.87", typical accuracy ~1" rms
- total time ~ 5 minutes, done ~2000 plates

DFBS: *extraction of spectra*

SExtractor (Bertin et al): extraction of all spectra (objects) present in the plate

- centers of images are taken, not the real star positions
- defects and artifacts
- faint objects are being missed
- problems with superposed (blended) images

■
A *catalogue-driven procedure* by R.Nesci, written as an IRAF script, including two simple FORTRAN programs for format conversion and checks:

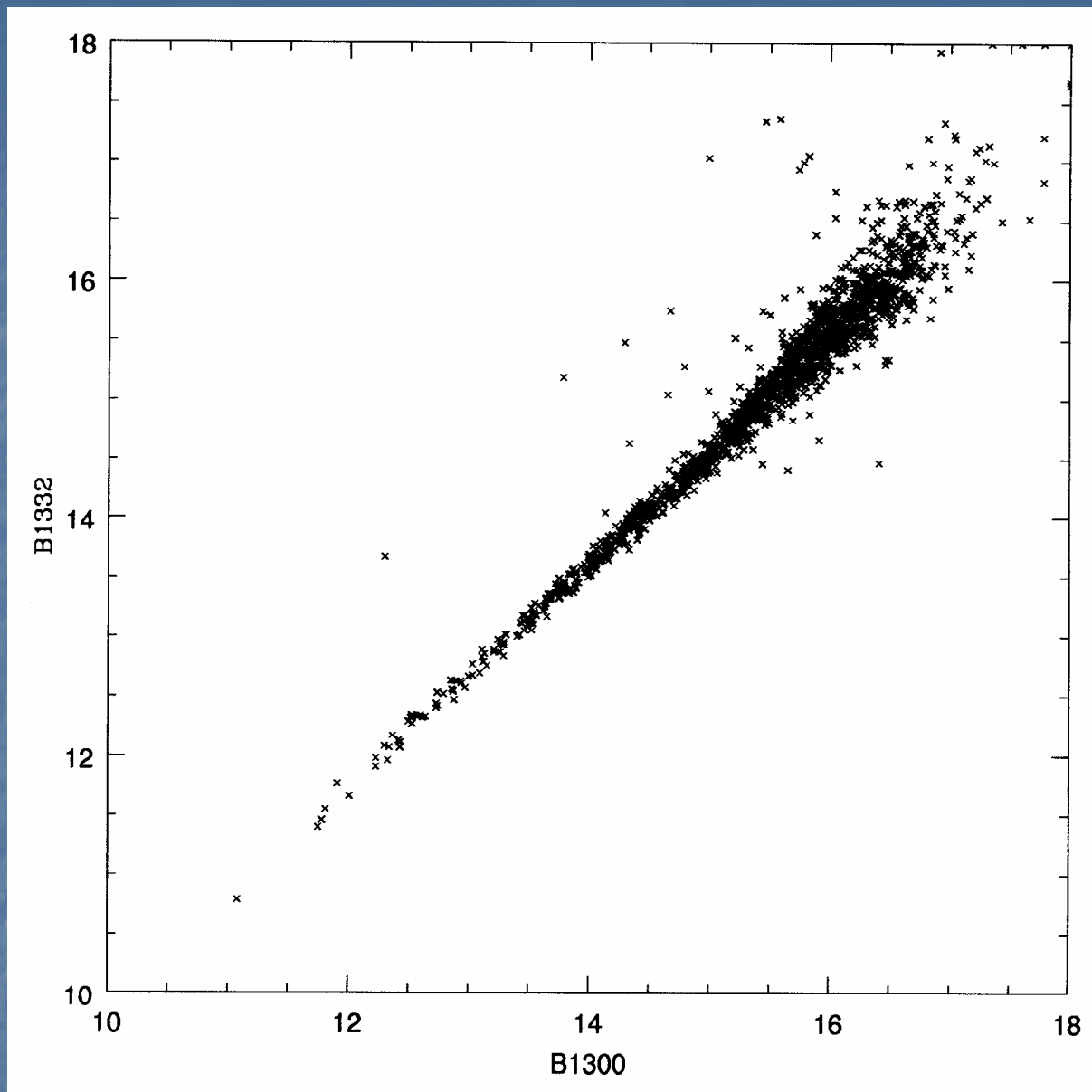
- the list of all objects present in USNO-A2 down to the plate limit and included in the sky area is converted into pixel coordinates with the IRAF task *cctran*
- an image section of 21x150 pixels including one well exposed star is selected and the spectrum is extracted with IRAF/*apall* in interactive mode (the typical FWHM of a spectrum is 5 pix and the length is 107 pix)
- all spectra of the list are extracted automatically by *apall*, assuming as sky value the mode of an area 21x150 pixel centered on each spectrum

DFBS: *wavelength calibration*

- ***Stars of intermediate brightness:*** a few dozens of WDs, subdwarfs, CVs, and QSOs from the available catalogs (to have broad Balmer and He lines)
- ***10 reference points:*** λ -start (3400Å), H ζ , H ϵ , H δ , H γ , HeII λ 4686, H β , sensitivity "gap" (5300Å), H α , and λ -end (6900Å)
- ***Dispersion curve and linearization:*** 33 Å/pix mean dispersion (22 Å/pix at the blue edge, 60 Å/pix at the red edge; 28.5 Å/pix near H γ)
- ***Spectral resolution:*** 1.5-2 times worse, as the photographic grains occupy 1.5-2 pixels (\sim 50 Å in average)

DFBS: *flux calibration & photometry*

- **Density calibration:** from the original data numbers (DN) according to formula: $D=(V-B)/(T-B)$
D is the (linear) density (units of transparency given by the scanner),
V is the average DN value for the unexposed plate,
B is the average DN value for the black corner,
T is the DN value for the given pixel. ■
- **Density-to-intensity calibration:** characteristic curve for each plate
- **Flux calibration:** accurate response curve for the F emulsion. The real spectral energy distribution (SED). Flux calibration using photometric standards in each FBS field. Estimated accuracy: 0.3^m
- **Multiband photometry:** UBVR, DSS O (4050A) & E (6450A) bands (to link with the MAPS and USNO database)

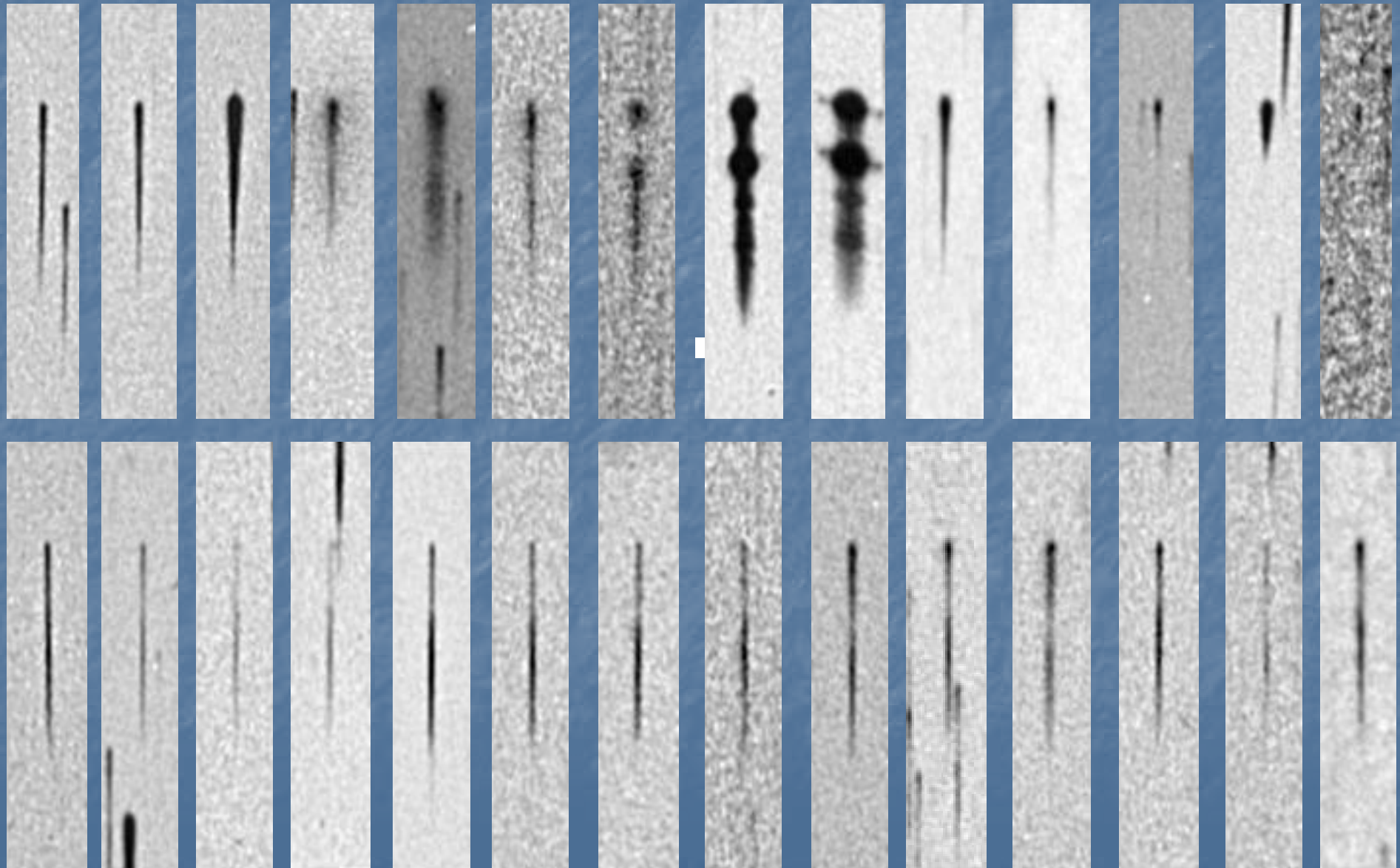


Photometric agreement between the two DFBS plates of the same field in B band ($\lambda=4500\text{\AA}$). Both DFBS plates contain objects up to 17.5^m ; rms is 0.12 for the B and 0.09 for the R instrumental mags

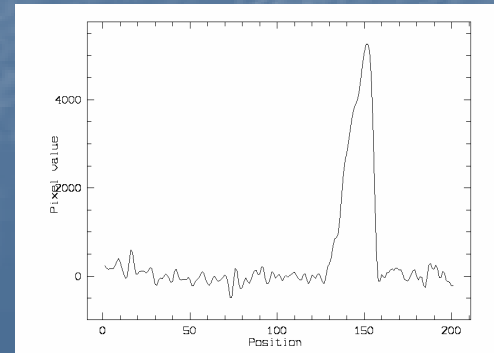
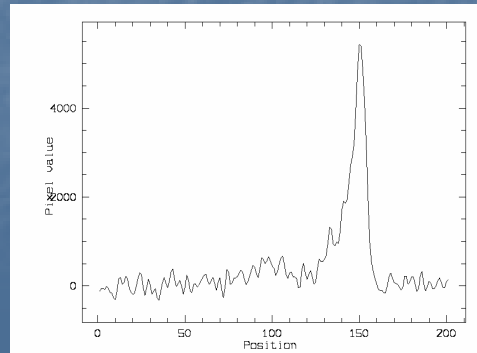
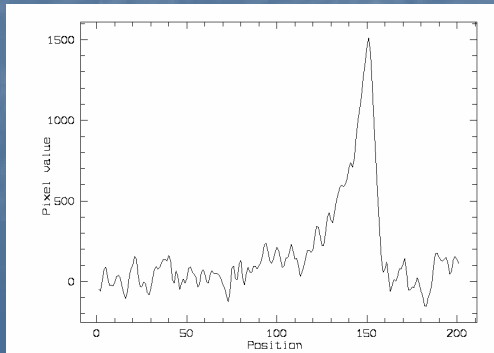
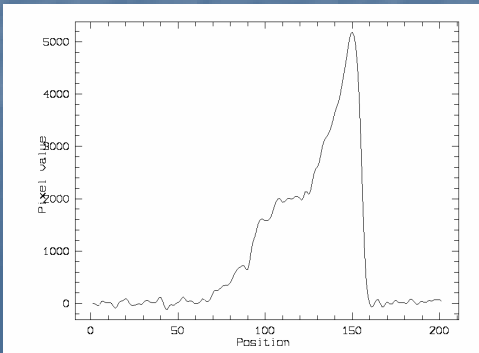
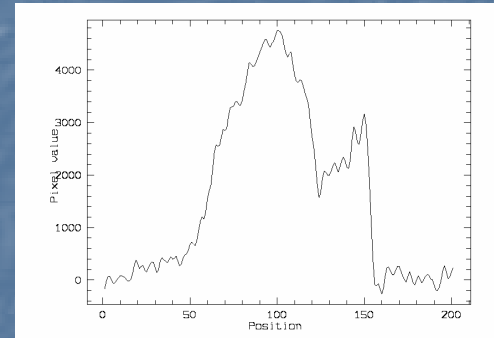
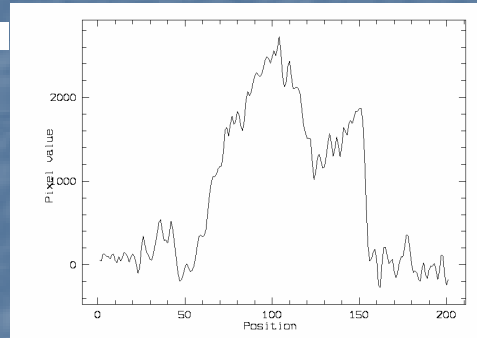
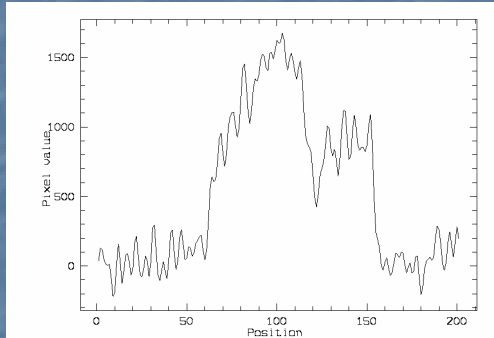
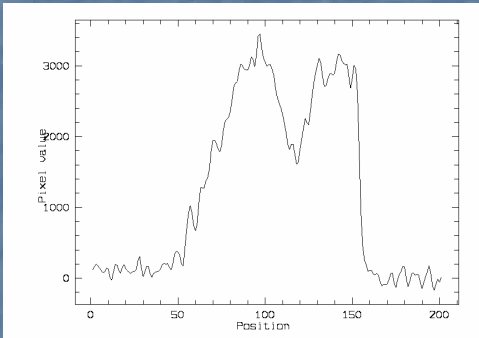
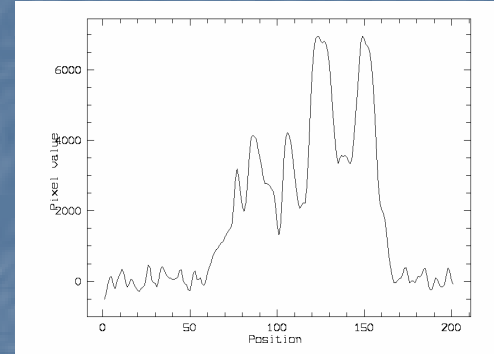
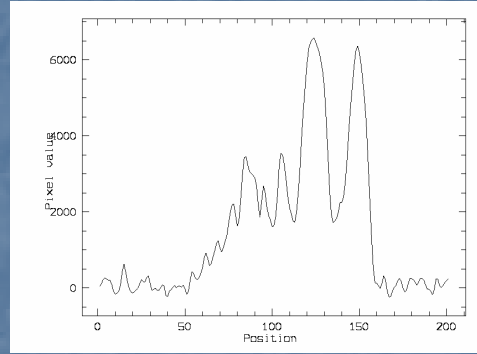
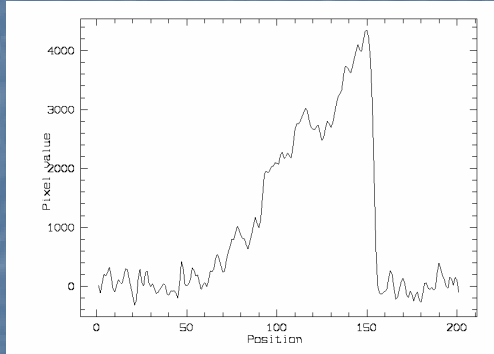
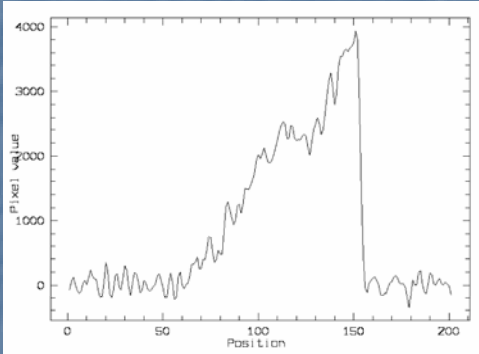
DFBS: *classification of spectra*

- ***Template spectra*** for different types of objects and search among the low-dispersion spectra: QSO, BLL, Sy, CV, WD, sd, M, C, etc. A few dozens of objects for each type and each 0.5^m magnitude
- ***Numerical classification*** scheme. Criteria worked out at FBS BSOs & IRAS programs. Based on the relation of magnitudes and widths of spectra (stellar/diffuse objects), SED (color), presence of broad lines. Link to general classification schemes by standard objects
- ***Modeling of spectra*** for known types of objects. SED, emulsion response curve, calibration, other effects?

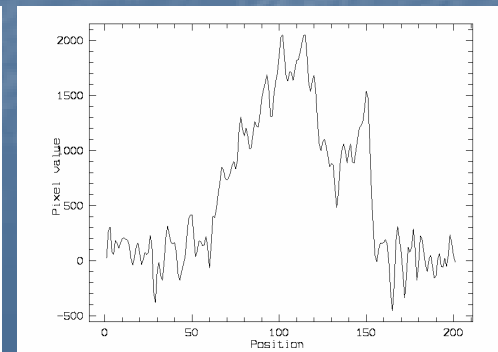
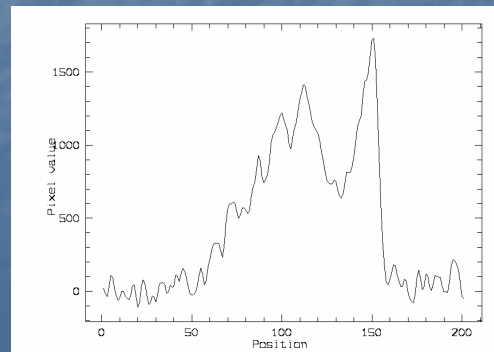
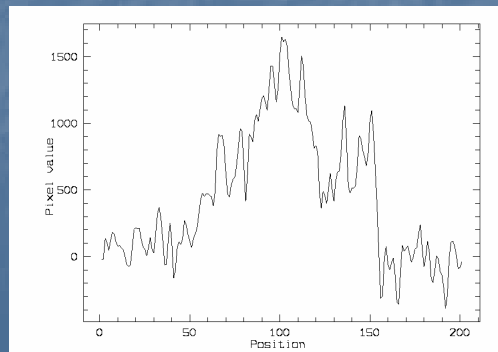
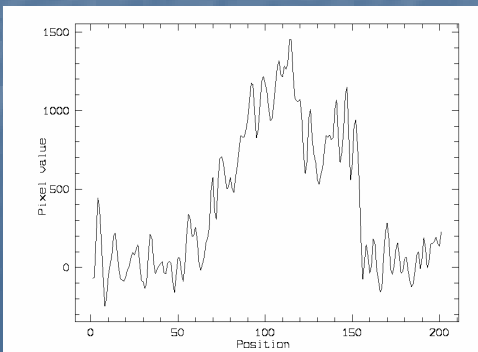
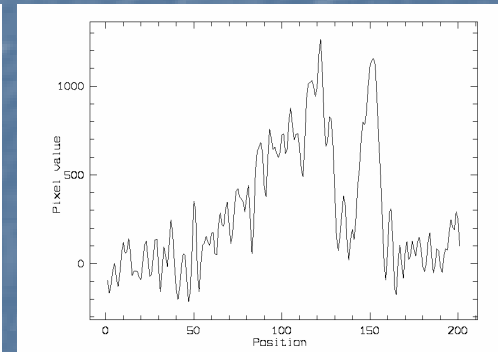
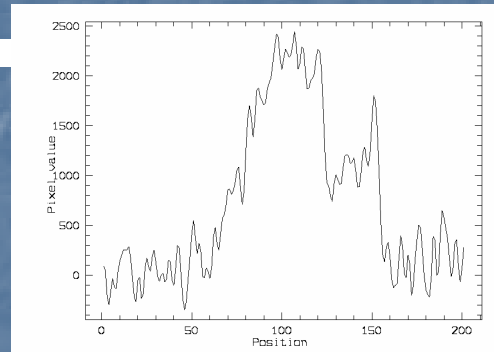
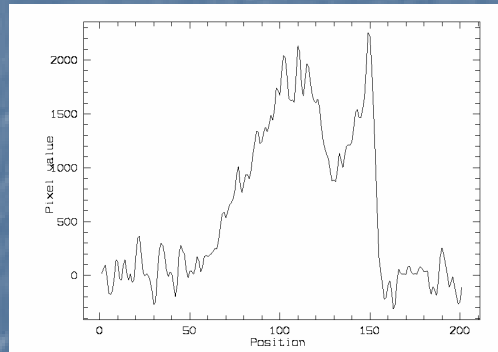
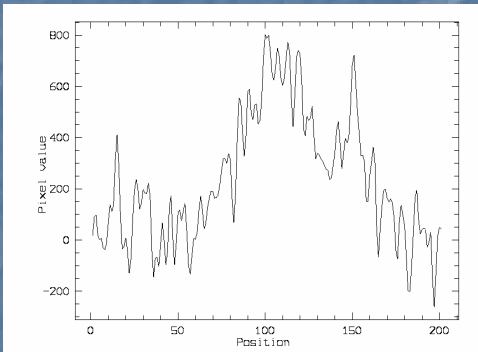
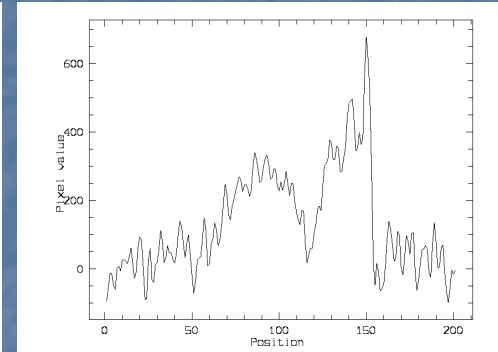
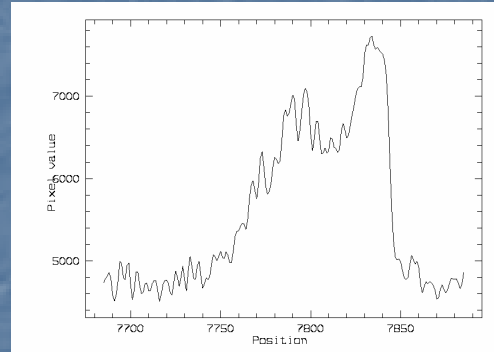
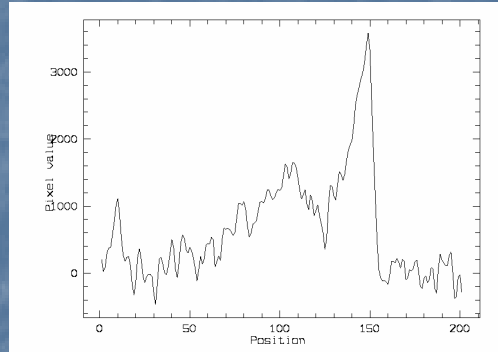
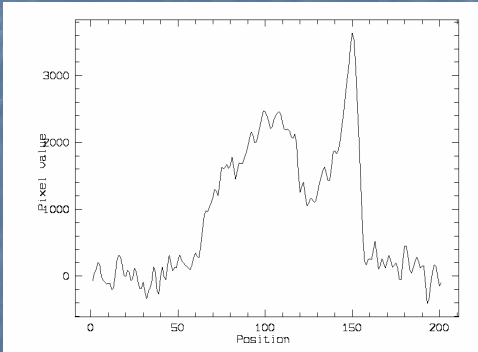
DFBS low-dispersion spectra



DFBS low-dispersion spectra



DFBS low-dispersion spectra



DFBS: *catalog and database*

- ***DFBS catalog:*** list of all FBS objects with positional, photometric and spectral information (some 40,000,000 spectra corresponding to 20,000,000 objects)
- ***DFBS database:*** all FBS plates, 2D and 1D spectra, and the DFBS catalog
- ***Available:*** at the end of 2006 on 100 DVDs and through Internet (DFBS web page, OBSPM server through CDS, etc.)

DFBS: *web page & user interface*

- ***FBS plate database:***

WFPDB: <http://draco.skyarchive.org/search>

CDS: <http://cdsweb.u-strasbg.fr/viz-bin/Cat?VI/116>

- ***DFBS web page:*** preliminary pages at <http://aras.am/dfbs.html> and

<http://astro1.phys.uniroma1.it/DFBS/fbs.html>

Main page in Byurakan with mirror sites in Cornell, Roma, OBSPM, and CDS

- ***User interface:*** access to database of 2D and 1D spectra, classification, using the DSS, MAPS, USNO, and other data, links to other databases, etc.

DFBS: usage of the database

- The needed region of the FBS plate with given sizes
- The corresponding region from DSS1 and DSS2bri
- 2D spectra of objects; comparison with templates
- Extracted 1D spectra of objects
- Wavelength and intensity calibration
- Numerical classification
- DFBS catalog data for objects: position, magnitude, colors, type
- Other available data from web:
SIMBAD/NED/MAPS/USNO-B1.0/catalogs
- Cross-matching and multiwavelength data

DFBS portal at Roma

<http://astrot1.phys.uniroma1.it/byurakan/index.php>

At present at construction stage and restricted for inner users only. However, a number of actions can be tested:

a) Sky coverage

b) Plate list

c) Explore: allows the display of a portion of plate around a given central RA, DEC position

d) Get image: allows users to select a portion of a plate in FITS format and all the spectra of this portion

e) Get spectra: allows downloading all the spectra in the database within a given distance from a selected central position

Other digitization projects:

Second Byurakan Survey (SBS)

- Authors:** *B.E.Markarian, J.A.Stepanian, L.K.Erastova, V.H.Chavushyan*
- Years:** *1978-1991*
- Instruments:** *102/132/213 cm Byurakan Schmidt, 1.5°, 3° & 4° prisms (1800 Å/mm, 900 Å/mm & 280 Å/mm at H γ)*
- Emulsions:** *Baked Kodak IIIa-J, IIIa-J+GG495, IIIa-F+RG2, IV-N*
- Spectral range:** *3400-5300 Å, 4950-5400 Å, 6300-6950 Å*
- Field:** *4.1° × 4.1° (plates: 16 × 16 cm)*
- Scale:** *96.8 "/mm*
- Region of sky:** *49° ≤ δ ≤ 61°, |b| > 30° (7^h 43^m ≤ α ≤ 17^h 15^m)*
- Total area:** *965 deg² (65 fields, 550 plates)*
- Limiting magn:** *18^m-20^m in V (completeness is ≤ 17.5^m)*
- Main goal:** *Extension of the FBS to fainter magnitude limits*
- Methods:** *UVX / emission lines / SED*
- Digitization:** *since 2003: 16 bit, 2400 dpi (10 μ pixel size); 180 SBS plates*

Armenian Virtual Observatory - ArVO





Armenian Virtual Observatory

ArVO creation and development:

DFBS (2002-2005), DSBS (2003-), other digitization projects (2004-)

ArVO project development: Armenian archives and telescope data, direct images and low-dispersion spectra cross-correlations, joint low-dispersion spectral database (DFBS/DSBS/HQS/HES/Case) (2002-)

ArVO logo and web page (since 15.07.2005): <http://www.aras.am/arvo.htm>

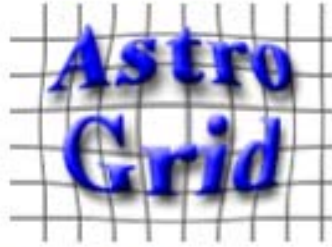
ArVO group at BAO (18.07.2005): funding needed !

ArVO authorized as official project in IVOA (ExecCom on 20.07.2005)

Agreement on ArVO development between BAO and IPIA (8.09.2005)

ArVO – VO France collaboration on the DFBS (April-July 2006)

VO meeting at JENAM-2007 in Yerevan (20-25 August 2005)



EUROVO





Armenian Virtual Observatory

ArVO objectives:

construction of a modern system for data archiving, extraction, acquisition, reduction, use and publication. ArVO is based on the Digitized First Byurakan Survey (DFBS) and is the Armenian contribution to the International Virtual Observatories Alliance (IVOA).

ArVO's main goal is to create an interoperability data system for Armenian astronomy based on the Armenian and world astronomy resources and according to IVOA standards.

ArVO includes also science development, as it is the actual goal of AVOs. Development of an automatic identification procedure for X-ray, IR and radio sources using the low-dispersion spectra and all other available databases; optical identification of ~100,000 X-ray, IR & radio sources; development of an automatic search procedure for modeled objects; automatic search for new bright AGN in DFBS/DSBS.



Armenian Virtual Observatory

Participating institutions and teams:

Byurakan Astrophysical Observatory (BAO)

PI: A.M. Mickaelian
Project scientist: T.Yu. Magakian
Team members: L.A. Sargsyan, L.K. Erastova,
P.K. Sinamian

Institute of Problems of Informatics and Automatization (IPIA)

Team leader: V. Sahakian

ArVO

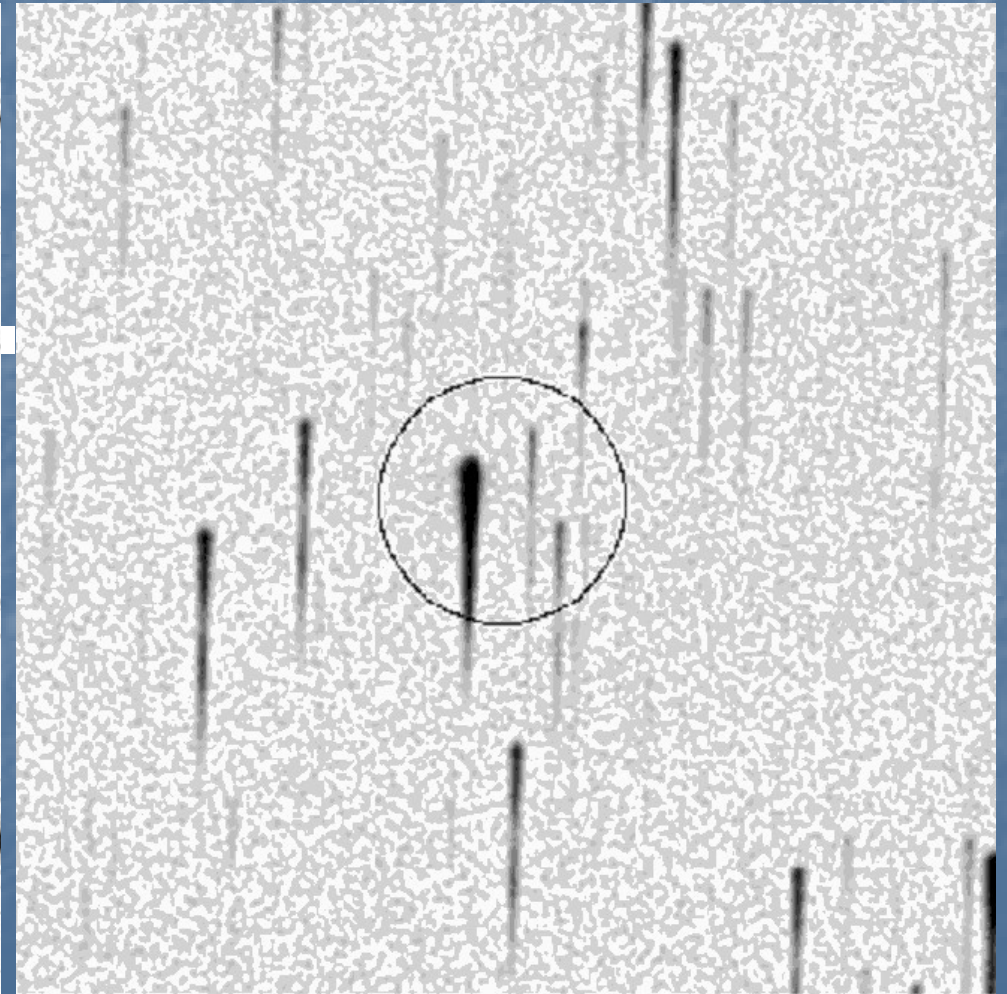
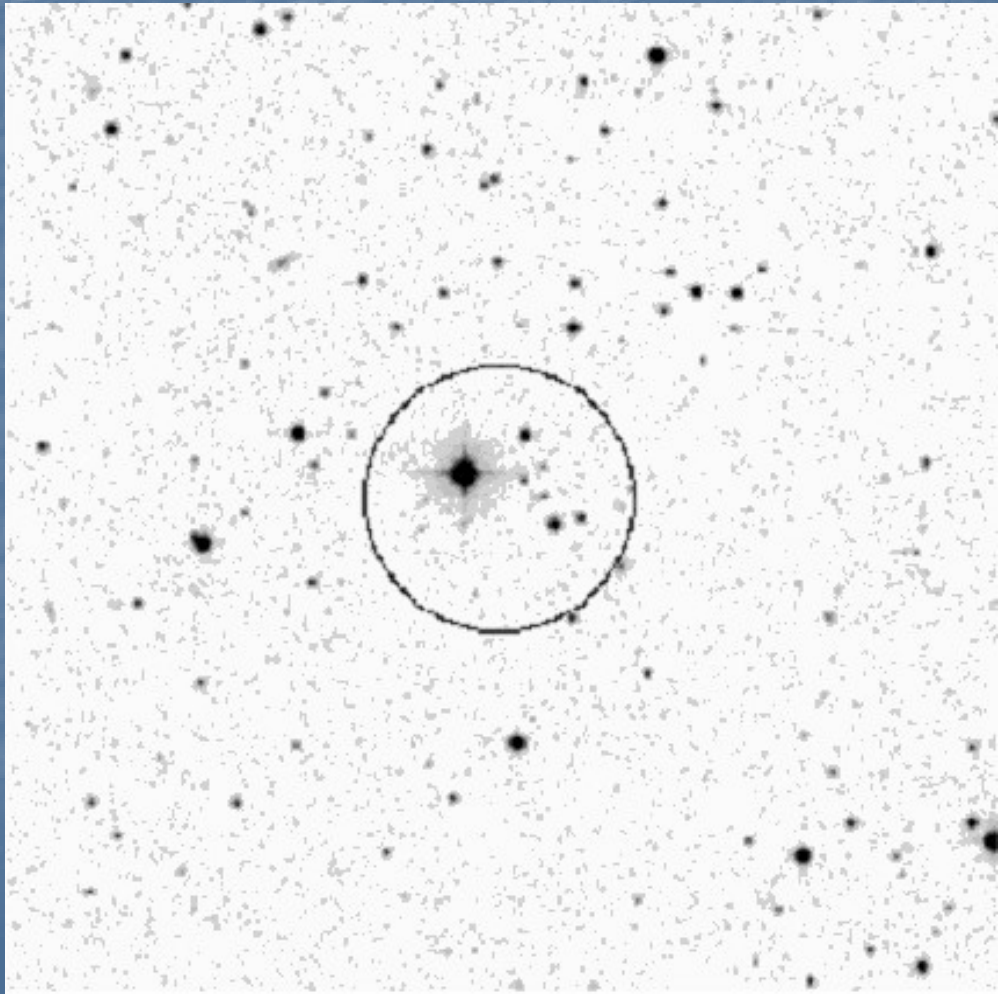
Armenian Virtual Observatory

ArVO current status

ArVO Organization and current tasks:

- Collection of information about all Armenian astronomical data resources (DFBS, DSBS, other Byurakan archives (~20,000 plates), 2.6m telescope observations), their classification and registration in the registries of other VO projects;
- Digitization of the Armenian astronomical plate archive and construction of an e-library, containing scans of plates;
- Online access for 2.6m observations (automatic 1-year delay access);
- preparing the Armenian metadata system;
- Mirroring of world principal databases;
- Construction of special collection of links to useful resources (Internet Resources in Astronomy) based on a multilevel classification scheme;
- Organization in the AVOs appropriate format (IVOA standards ADQL, VOTab, VOPlot, etc.);
- Free access for the astronomical community;
- Educational & public resources
- Integration in the international AVOs.

Optical identification of X-ray, IR and radio sources





First local trials

Multiwavelength search for blue objects:

- Region of the sky: $\delta \geq 61^\circ$, $|b| \geq 30^\circ$, 1500 deg²
- Blue objects from MAPS and USNO-B1.0
- Cross-correlation of catalogs:
MAPS/USNO/DFBS/ROSAT/IRAS/NVSS
- Classification of DFBS spectra

First science with the DFBS: Boötes region

J2000 central position: RA=14:32:05.71, DEC=+34:16:47.5, 3x3 degree
Only 12 QSOs/AGN known before (6+3+3; V=16.84-20.90) & 1 Mrk galaxy (#472)

73 unidentified sources (35 stars and 38 galaxies) (relatively bright objects)

DSS1 and DSS2 bri images: accurate positions,
extension, PM, color, variability

DFBS spectra: classification (+extension, PM, etc.);

DFBS plates:

Zone +31: plate# 219, 232, 593, 1204

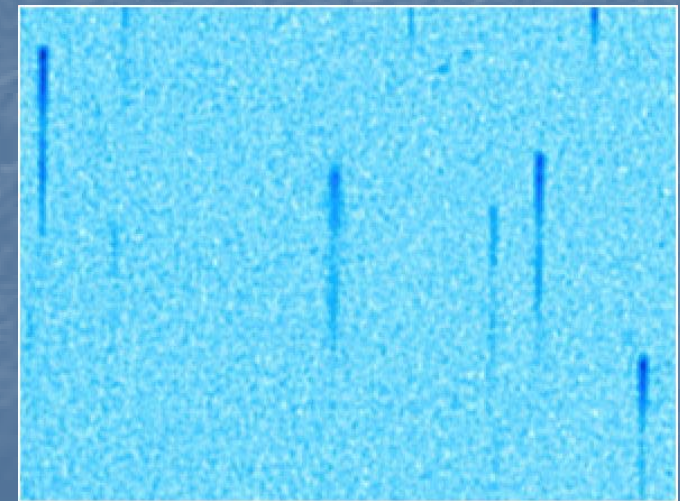
Zone +35: plate# 188, 210, 1230, 1272

MAPS & USNO-B1.0: accurate positions,
BRI magnitudes & colors, PM, variability

MW data: ROSAT-BSC, -FSC, 2MASS,
IRAS-PSC, -FSC, NVSS, FIRST

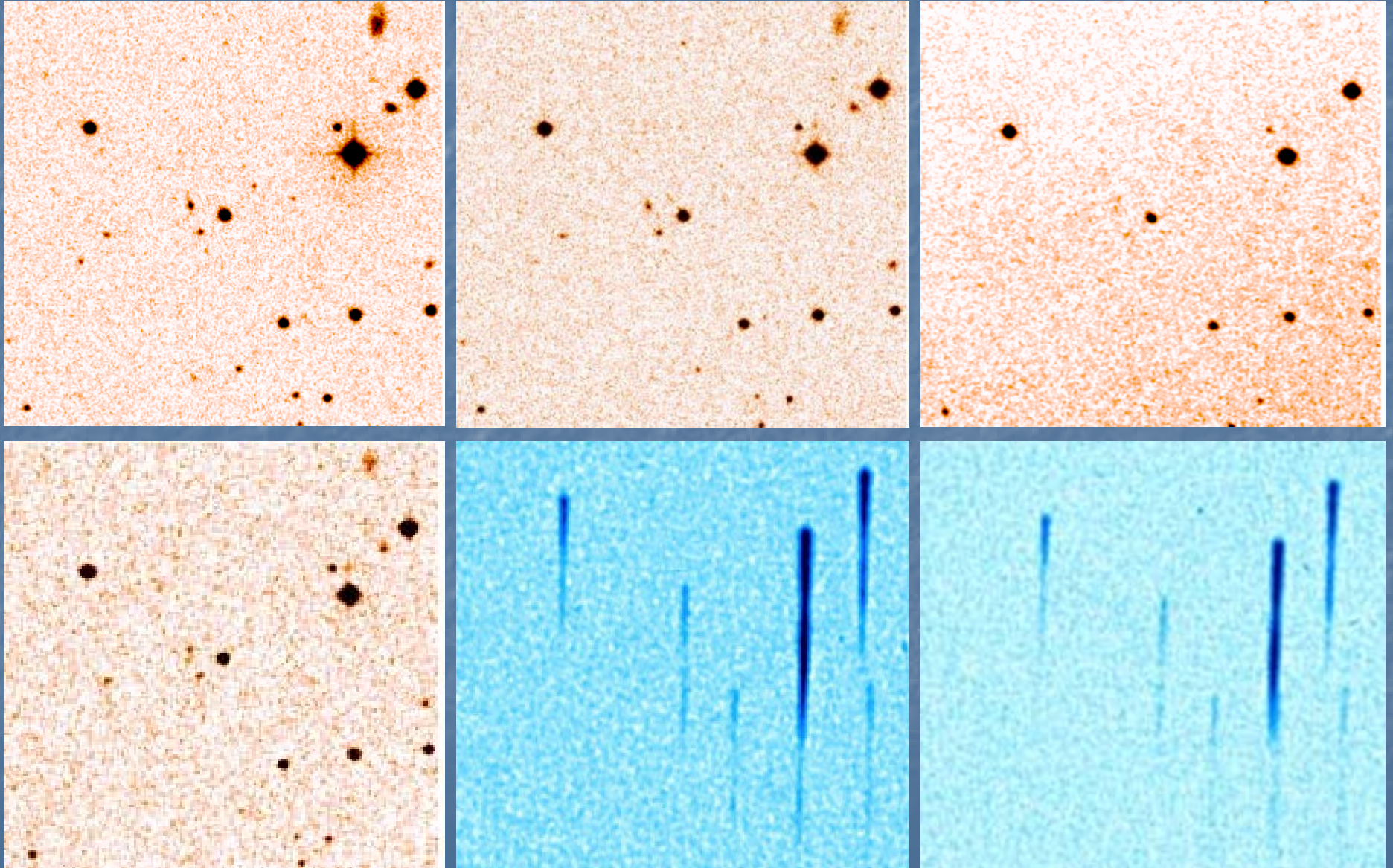
SIMBAD & NED data for known objects

VCV-11 data

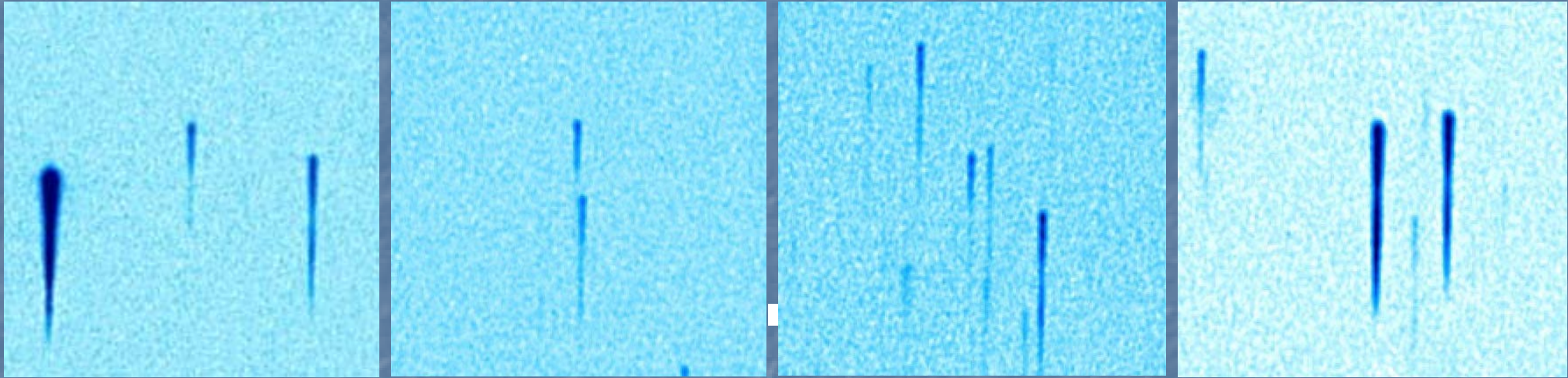


Mrk 472 spectrum in DFBS

DSS2bri, DSS1, and DFBS fields for 142626.17+351922.73



Boötes region results

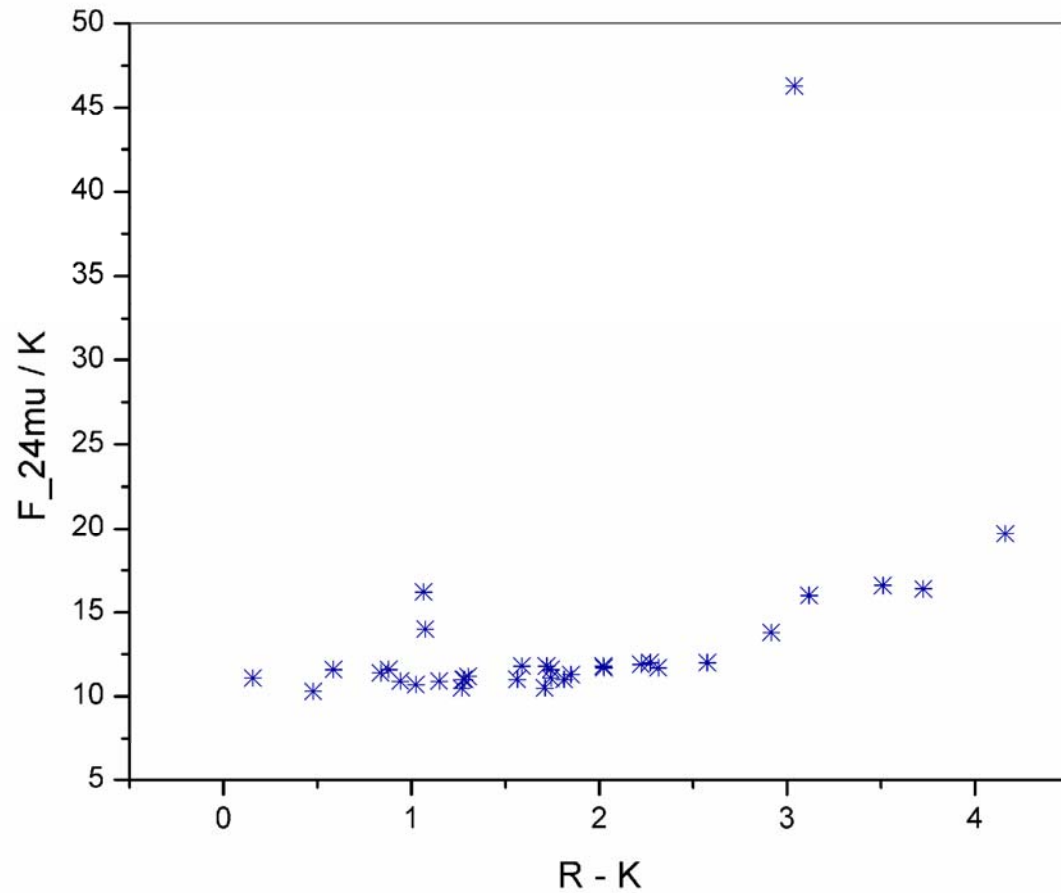


1 known QSO
22 known galaxies
28 known stars
4 X-ray sources
68 NIR sources
28 FIR sources
28 radio sources

22 new objects:

5 QSO candidates (2 radio sources)
10 galaxies (2 AGN:, 2 other blue galaxies, 6 int.
systems; 8 are radio sources)
7 stars (1 R, 1 K, 2 G, 3 FG-type)

8 other known stars did not have spectral classification,
we classify into: 1 A, 1 AF, 1 F, 1 FG, 3 G, 1 K-type



Plot of $F_{24\mu}/K$ vs. $R-K$ color for 34 stars. An R-type carbon star and two early type (A-F) stars are above the main sequence of objects

Summary

- **DFBS:** *available; ready at the end of 2005*
- **DSBS:** *started, ready at the end of 2006*
- **Other projects:** *FBS BSOs, Coma region plates*
- **ArVO:** *started; all Armenian astron. databases*
- **Joint low-dispersion spectral database:**
FBS + SBS + HQS + Case?
- **Science projects:** *automatic search for new interesting objects (AGN, etc.); optical identifications of radio/IR/X-ray sources using LDS*

Forthcoming meetings in Armenia in 2006-2008

- 26 Aug – 3 Sep 2006, Byurakan:
First Byurakan International Summer School
- 1-3 Sep 2006, Byurakan:
Byurakan Observatory 60th anniversary meeting
- 20-25 Aug 2007, Yerevan:
JENAM-2007 (6 mini-symposia)
- Sep 2008, Byurakan:
**V.A.Ambartsumian's 100th anniversary meeting
(IAU Symposium)**