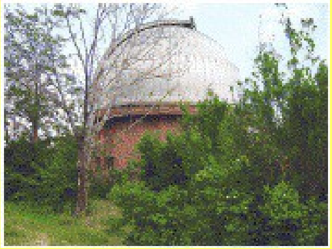

AGB stars
and the plate archives heritage

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AGB stars

The AGB stars, due to their large luminosity, can be traced up to the limit of our Milky Way halo and therefore serve as tracers of its gravitational field and dark matter distribution.

In this paper we report on an on-going survey program of AGB candidates in the northern hemisphere, aimed at obtaining a better spectral classification and exploring the possibilities of a classification from recent photometric infrared data from satellite surveys.

Candidate stars were taken from the "Revised and Updated Catalogue of FBS Late-Type Stars"(Gigoyan and Mickaelian, 2012).

AGB stars

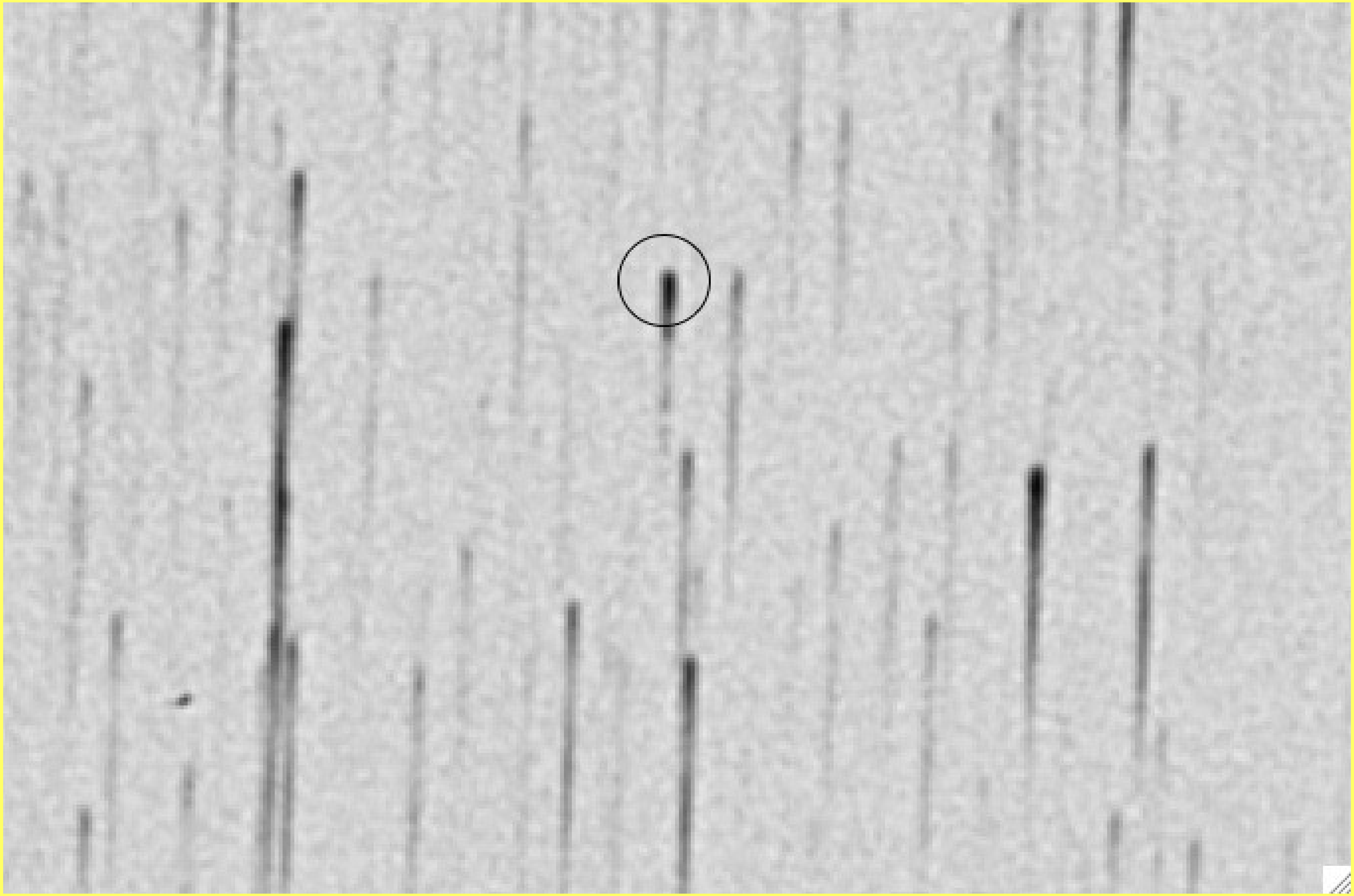
AGB stars are generally easily recognizable on objective prism plates.

The large Schmidt telescope of the Byurakan Observatory (102/132/213 cm) with the 1.5 degree prism and 103aF emulsion made a successful survey of the northern sky in the 1970's.

On these plates late type stars have a strong, nearly point-like, red emission while the blue part of the spectrum is very faint or even absent.

This allows to build sample of AGB stars candidates, and/or to check the nature of infrared (IR) objects detected by space-based IR instruments like WISE, IRAS, AKARI or of ground-based surveys like 2MASS.

2-D DFBS spectrum
FBS 2213+421

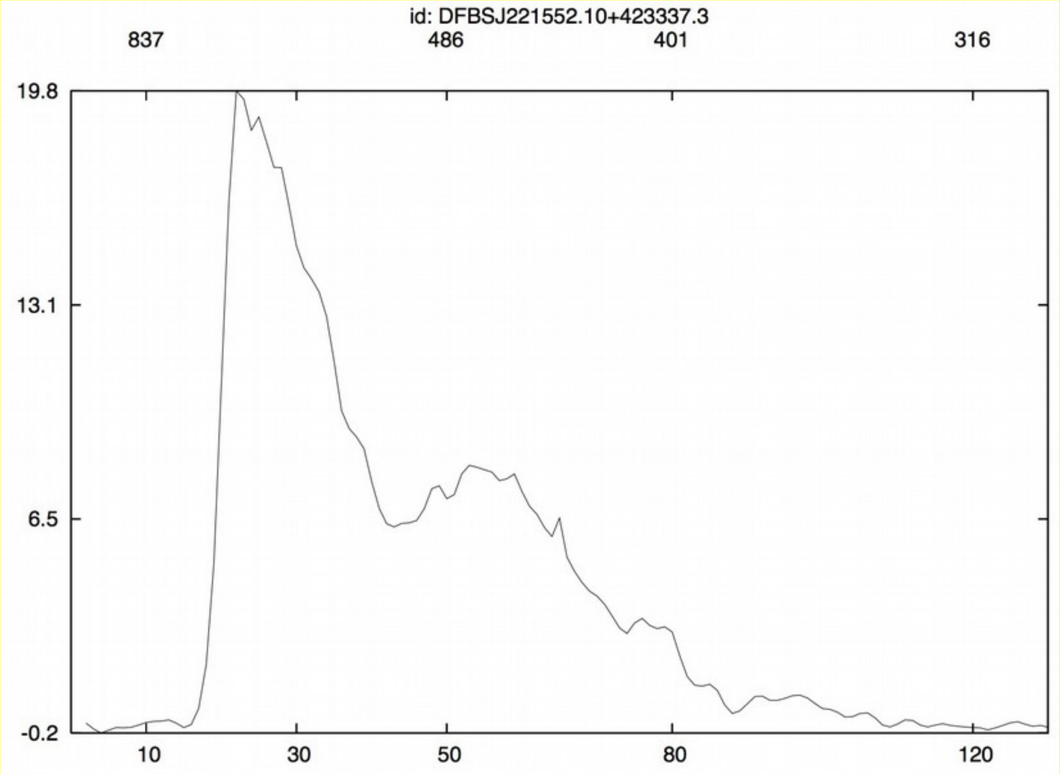


DFBS spectrum

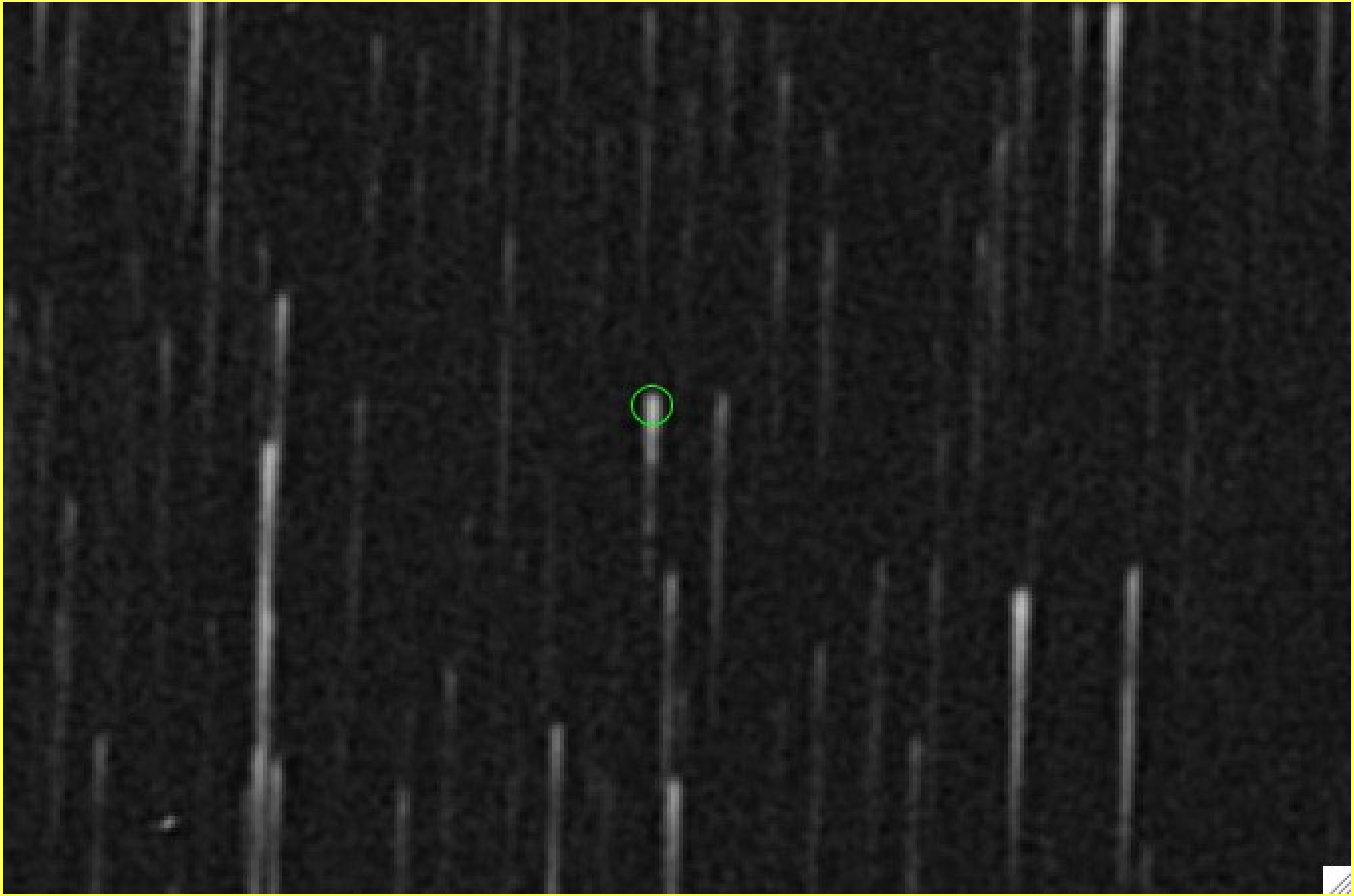
The Digitized First Byurakan Survey is available since 2007 on a server at La Sapienza University (http://byurakan.phys.uniroma1.it)
Both two-dimensional images and unidimensional extracted spectra can be retrieved.

Spectrum automatically extracted from the DFBS plate n. 0932, of the Carbon Star FBS2213+421.

Ordinate: arbitrary units above sky level;
Lower abscissa: pixels;
Upper abscissa: wavelength (nm).



2-D spectrum
FBS 2213+421



Slit spectroscopy

Each star in our sample has been spectroscopically classified using the BFOSC instrument at the Loiano 1.5m telescope
or the AFOSC instrument at the Asiago 1.8m telescope,

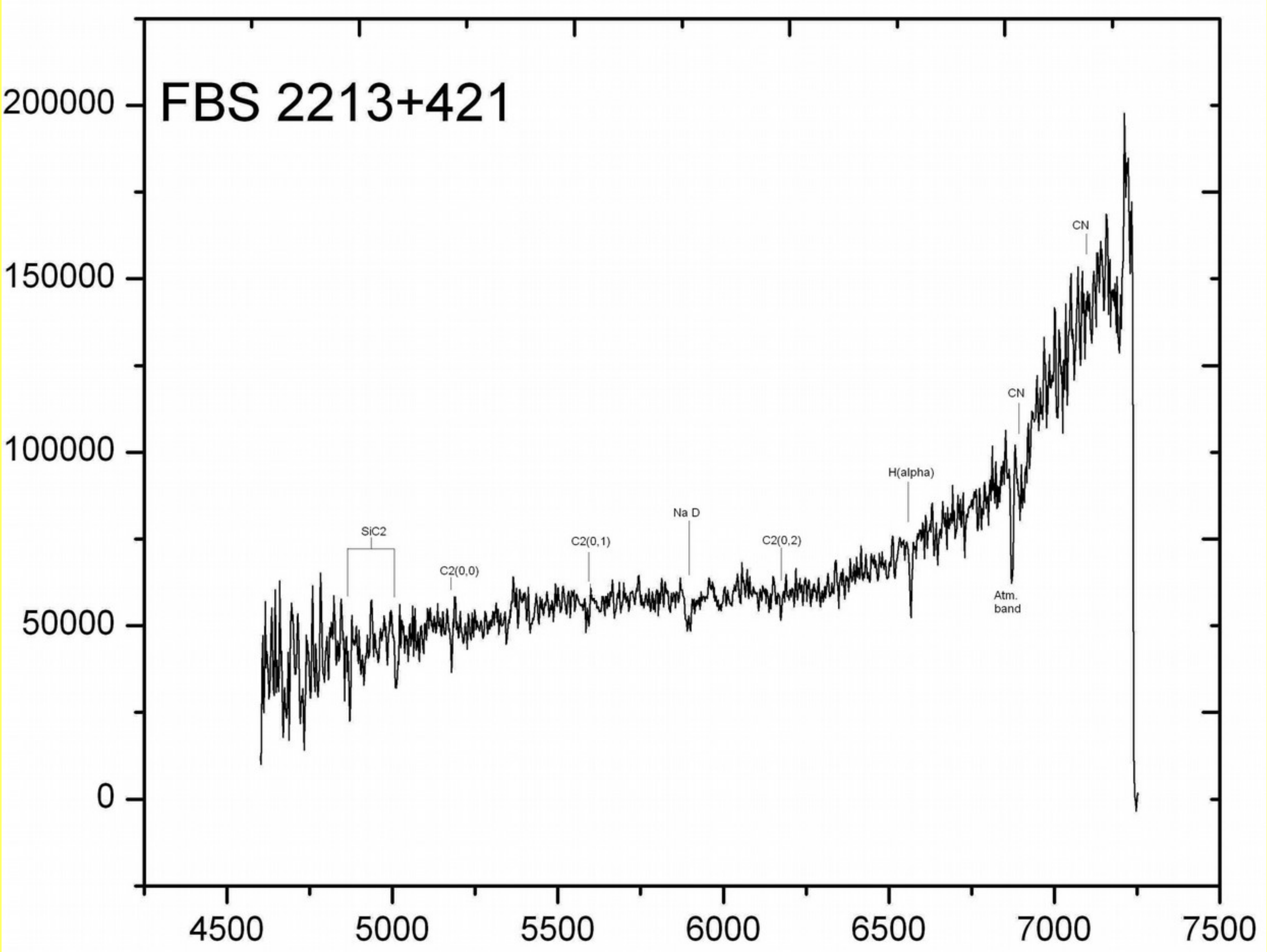
Spectral resolution was generally of 12 Angstrom, in many cases of 6 Angstrom.

The resolution was not enough to measure accurate radial velocities: a 3 meter class telescope would be necessary.

But enough to :
establish a firm spectral subtype.
discriminate giants from dwarfs.

Actually very few dwarfs were found.

Slit spectrum



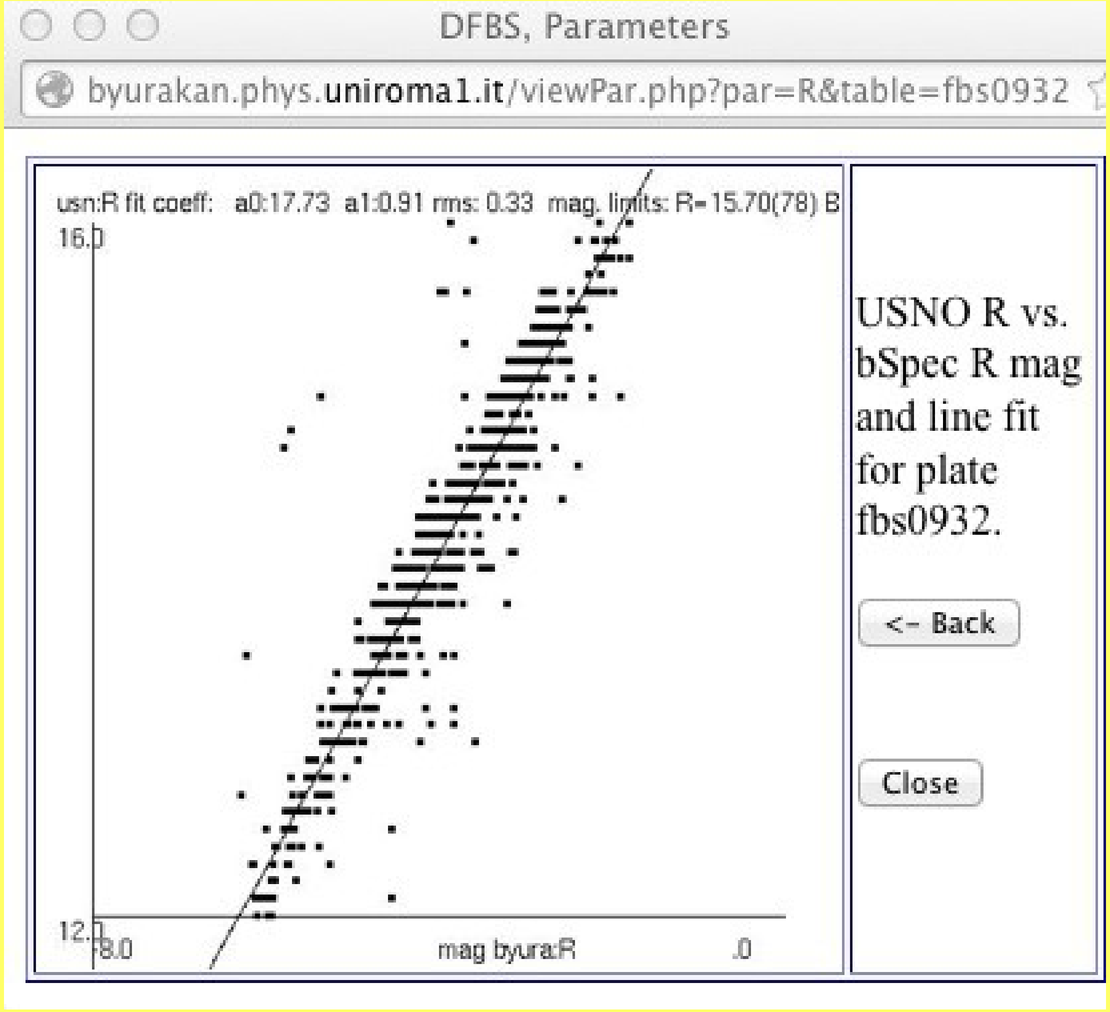
DFBS magnitudes

The DFBS provides also R and B magnitudes for the extracted spectra, computed as follows:

1) integration of the spectrum in proper wavelength intervals;

2) linear fit of the instrumental magnitudes with those from the USNO-A2 in the range 13-16

The plot refers to plate n.350: slope 0.91, rms 0.33 .

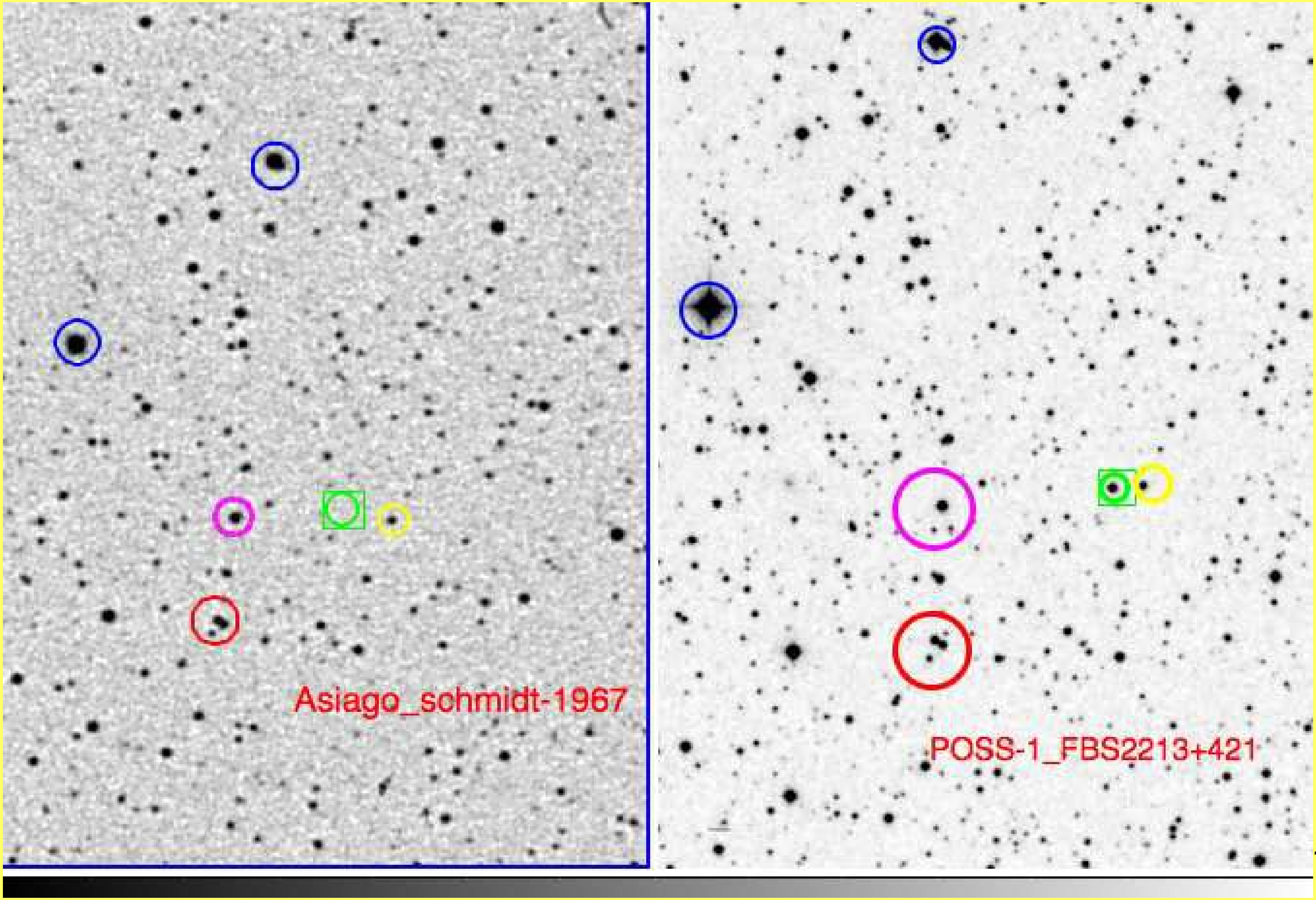


Variability

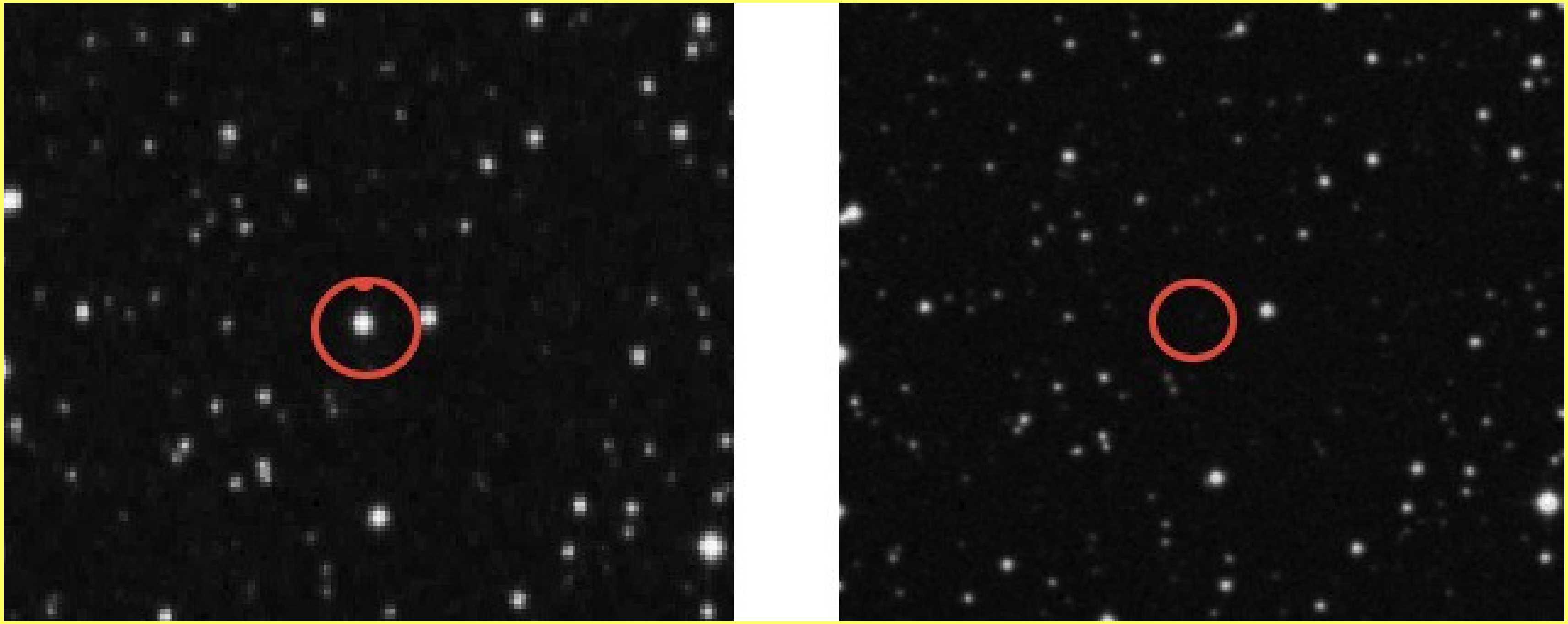
Among the stars of our sample, several are variable.
As an example FBS 2213+421 (V381 Lac) was:

- very bright at the epoch of POSS1 (1952);
- invisible in the Asiago plates in 1967;
- invisible in the red plates of POSS2 (1989);
- bright between 1999 and 2000, from NSVS;
- At the very limit of the SDSS in 2006.

Variability

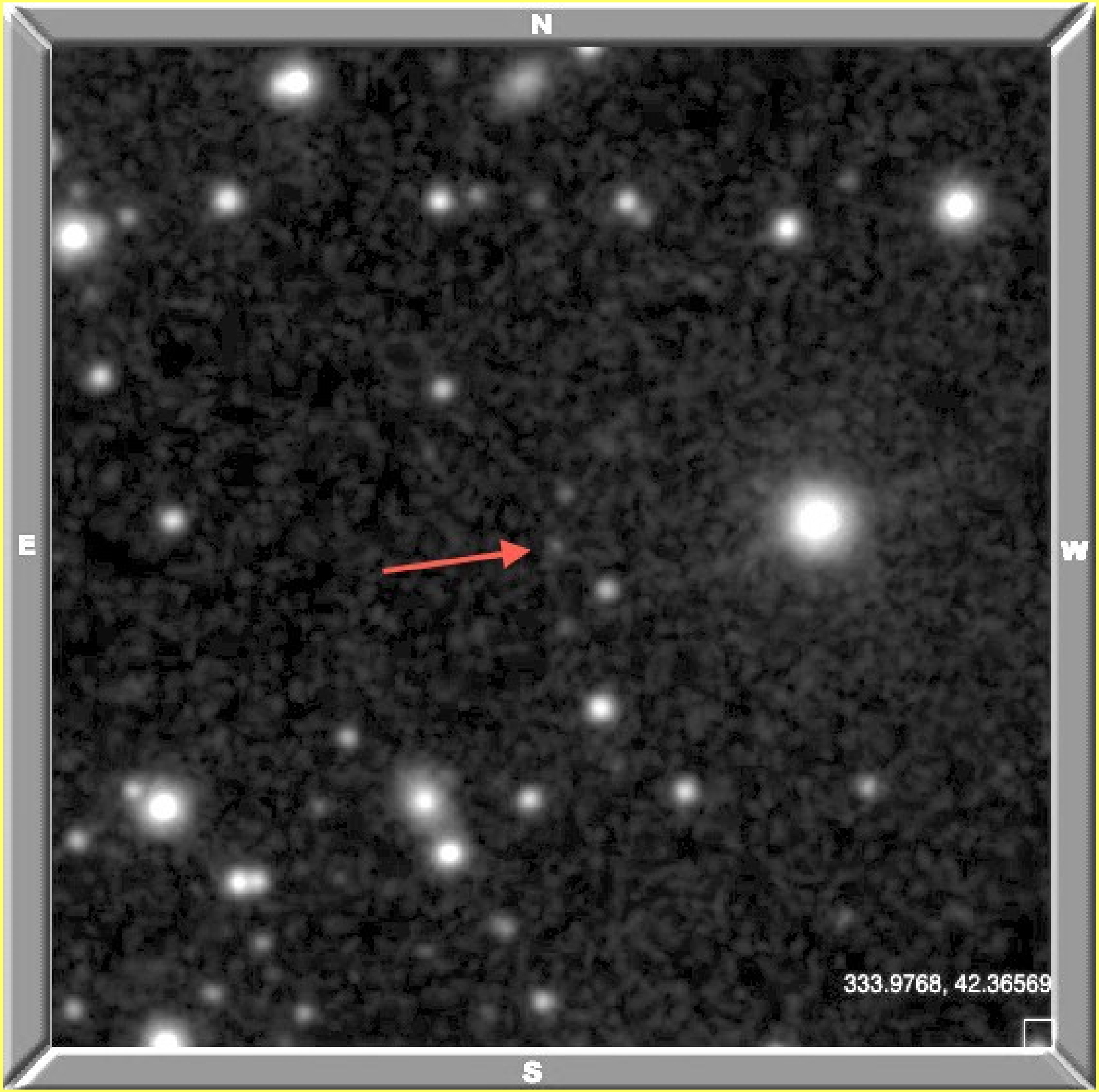


Variability



Blue POSS plates indicating strong variability of FBS2213+421: left 1952, right 1989.

Variability



SDSS image showing FBS2213+421 at the very survey limit in 2006.

2014-03-19

Variability

We started checking the variability of our stars using the USNO-B1 Catalog, based on the POSS I and POSS II surveys, in the B and R bands.

The photometric accuracy of this catalog is not high, especially for stars partially saturated: form our experience a difference of at least 0.5 magnitudes is required to be sure of the star variability.

A few other digitized plates taken with the Palomar 120/180/307 cm Schmidt, besides those used for the Digital Sky Survey, can be retrieved from the Space Telescope Science Institute website (http://archive.stsci.edu/cgi-bin/dss-plate-finder/).

Magnitude estimates

To derive magnitudes also from these plates, we re-made the aperture photometry of our stars with IRAF/apphot on all the POSS plates,

Nearby (radius 4 arcmin) reference stars taken from the GSC2.3.2 catalog;

For consistency, the same sequences were used also for the CCD photometry of our images from the Asiago and Loiano telescopes.

It is useful to have an estimate of the photometric reliability of the most used all sky catalogs.

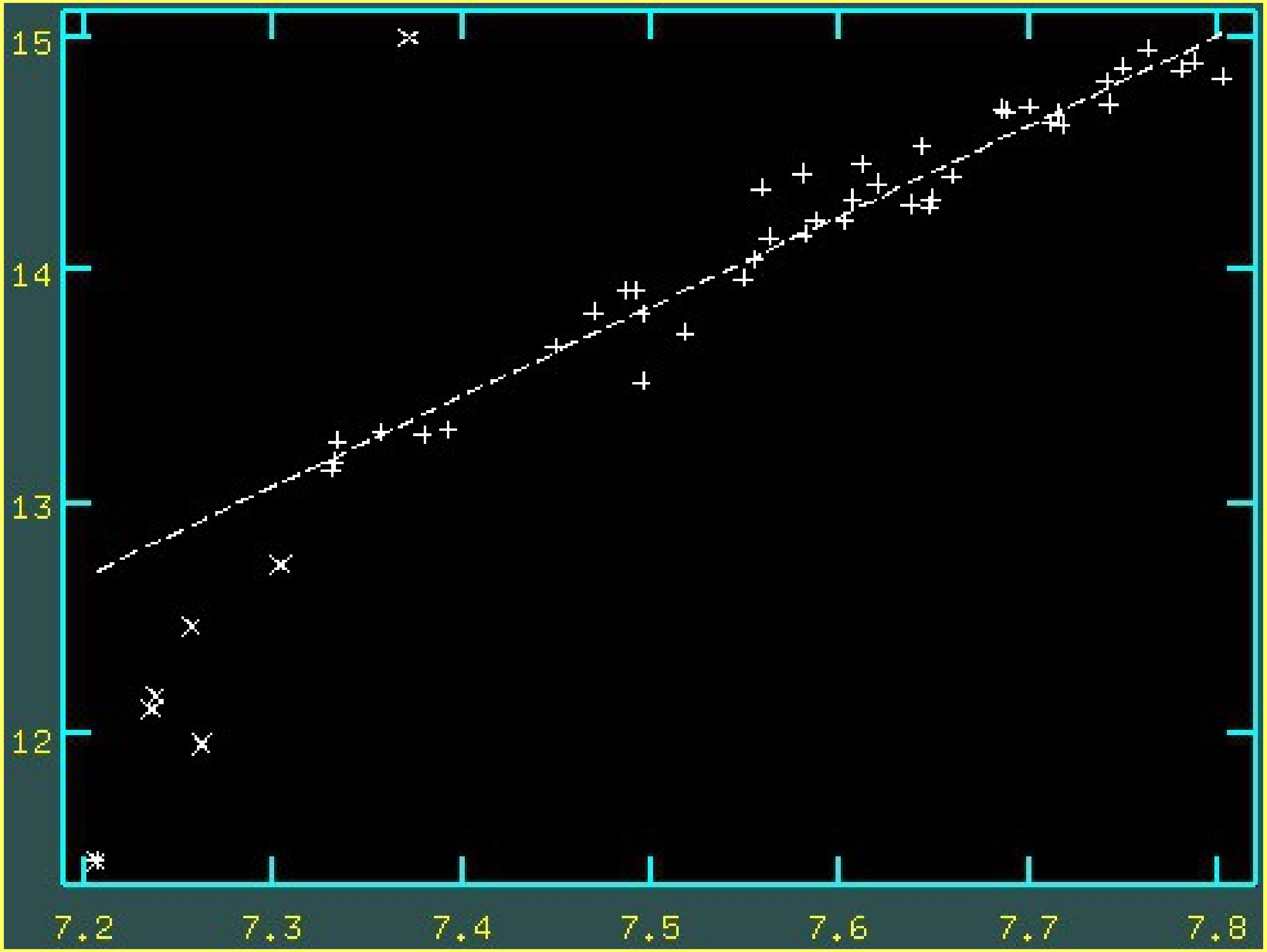
In our search we tested the USNO-A2, the USNO-B1 and the GSC2.3.2. The new APASS (UCAC 4) may become a valid alternative in the near future, given that it is not based on photographic photometry but is entirely based on CCD images.

Calibration

- The Data Numbers in the digitized POSS (or ESO-SRC) plates are like CCD counts for not-saturated stars.
- The response of photographic emulsion however is less linear than that of a CCD device.

- A calibration curve must therefore be computed for a given plate to derive magnitudes by simple fixed-radius aperture photometry.

- The calibration curve is nearly linear for stars fainter than about 13 mag, but the slope is rather different from 1.0



USNO-A2 GSC2.3.2

The photometric calibration of the catalogs based on DSS plates was made on a plate-by-plate basis.
Differences between catalogs are therefore expected to vary somehow from plate to plate. As an example we report here the relations between catalogs for the field of V 381 Lac.

USNO-A2 *vs* GSC2.3

R(A2)=B(GSC)*0.86+2.63 (rms=0.27)
B(A2)=B(GSC)*0.80+2.71 (rms=0.43).

The correlation is good, but the scatter is large.
for the R magnitudes there is a small deviation from a straight line for the bright (R<13) stars.

Using only GSC2 stars with R<15 the slopes become more near to the ideal value of 1.

R(A2)=R(GSC)*0.99+1.77 (rms=0.26)
B(A2)=B(GSC)*0.83+2.34 (rms=0.36)

USNO-A2 USNO-B1

At variance with the A2 catalog, the USNO-B1 catalog reports magnitudes for the two epochs of the Digital Sky Survey.

The comparison of GSC2.3 *vs* USNO-B1 is the following:

R1(usno)=R(gsc)*1.03-0.49 (rms=0.23)
R2(usno)=R(gsc)*1.02-0.12 (rms=0.27)
B1(usno)=B(gsc)*0.99+0.08 (rms=0.28)
B2(usno)=B(gsc)*0.96+0.94 (rms=0.42)

The slope is always very near to 1 but the scatter is again rather large.

Other archives

Further sources of photometric data are the recent sky surveys for NEO or GRB, the Catalina Sky Survey at Caltech (Drake et al. 2009; http://nesssi.cacr.caltech.edu/DataRelease/)

CSS data are given for the Johnson V filter.

the NSVS (Wozniack et al. 2004; http://skydot.lanl.gov/nsvs/nsvs.php).

The NSVS data were obtained with an unfiltered CCD, so that the quantum efficiency of the sensor makes the effective band comparable to the Johnson R, or better a mix of V and R colors, which is a function of the spectral type of the star.

NSVS calibration

To inter-calibrate the NSVS and our magnitudes we used the stars in our sample with a very stable NSVS light curve.

Actually a larger set of non variable stars in the M0-M8 spectral types range would be required to define a better color correction.

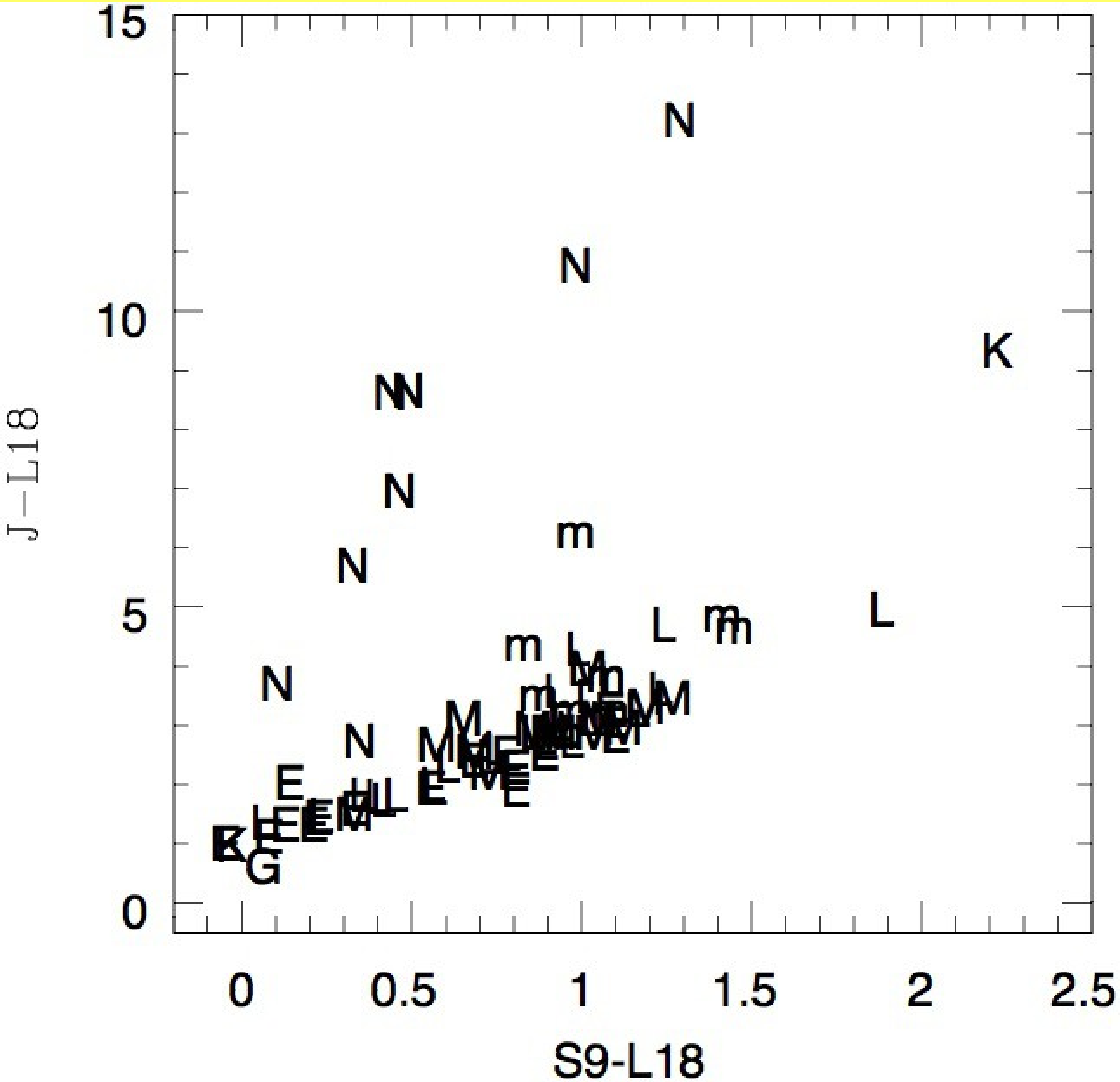
In fact, we verified that for M8 stars, which emit most the photons in the IR tail of the unfiltered detector, the ROTSE instrumental magnitudes are generally brighter than for M1 stars of similar R magnitude.

In any case, even with this caveat, our data have been useful to confirm the variability/stability of the stars of our sample.

Color selection

- As supplementary diagnostic for stellar classification we used IR photometry building color--color diagrams.
- We checked among the different color-color plots which can be made using the AKARI, WISE, 2MASS fluxes of our sample stars if there are good photometric discriminants between Carbon rich and Oxygen rich objects.
- Extensive work on these tools has been made by Ishihara et al. (2011) and Xun Tu \& Zhong-Xian Wang (2013).
- Here we present preliminary results using different color choices.

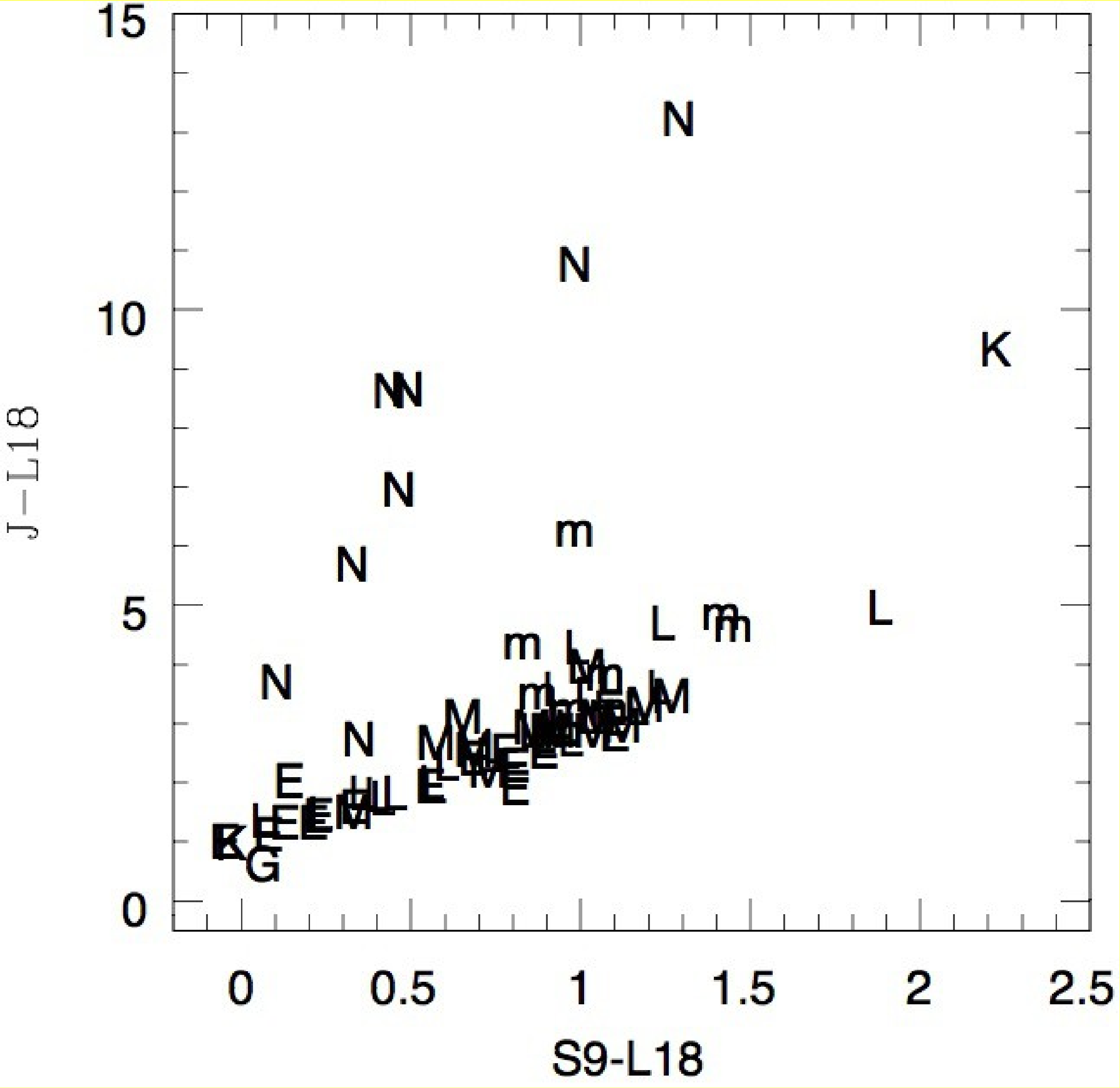
AKARI - J band colors



A very useful diagram,
Johnson's J band
vs
AKARI S9 and L18 bands

N=N-type
E=earlier than M5
L=M5 and later
m=Mira variables
C=CH-type
M=generic M-type
F and K= peculiar stars

AKARI - J band colors



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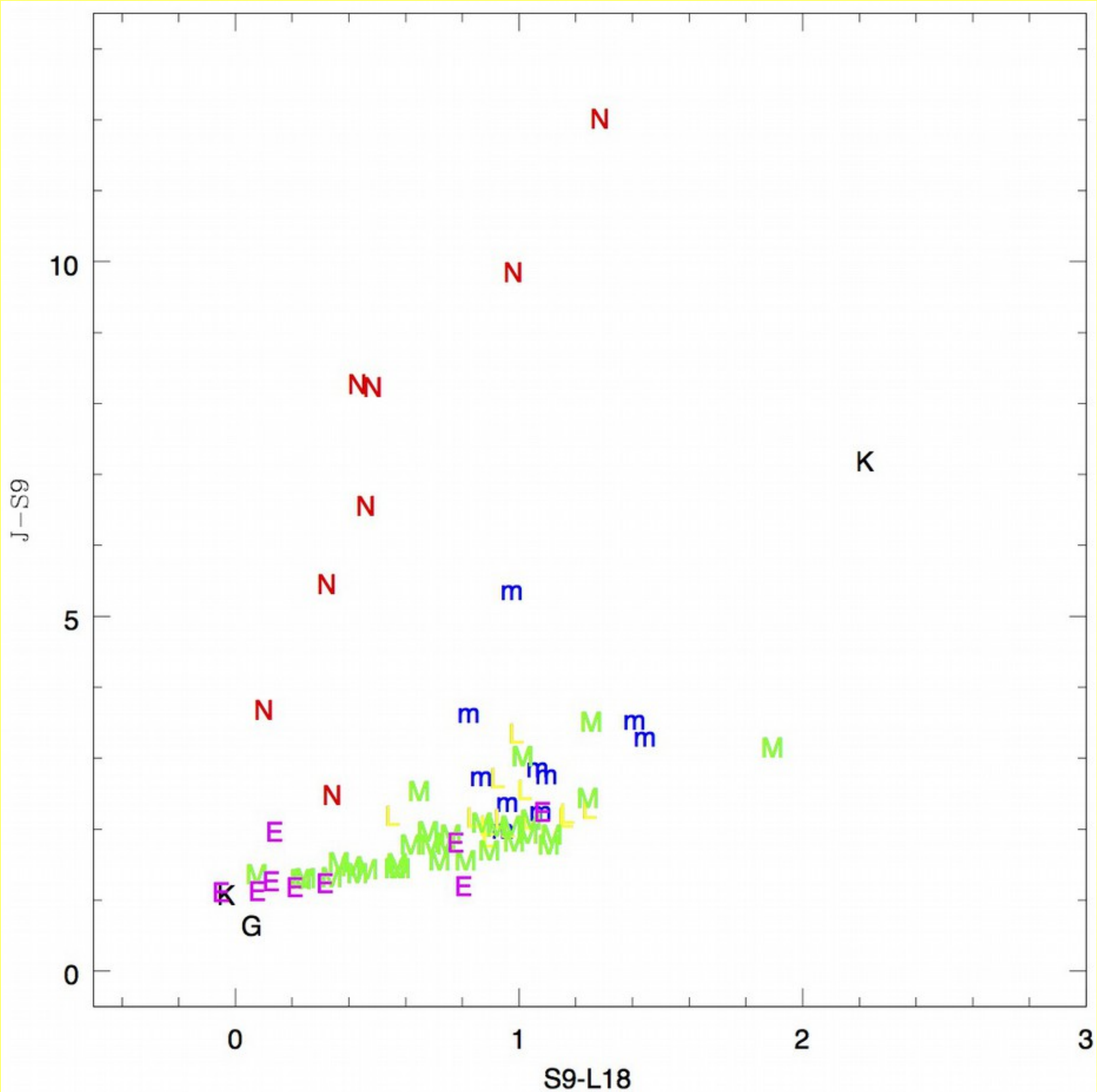
AKARI - J band colors

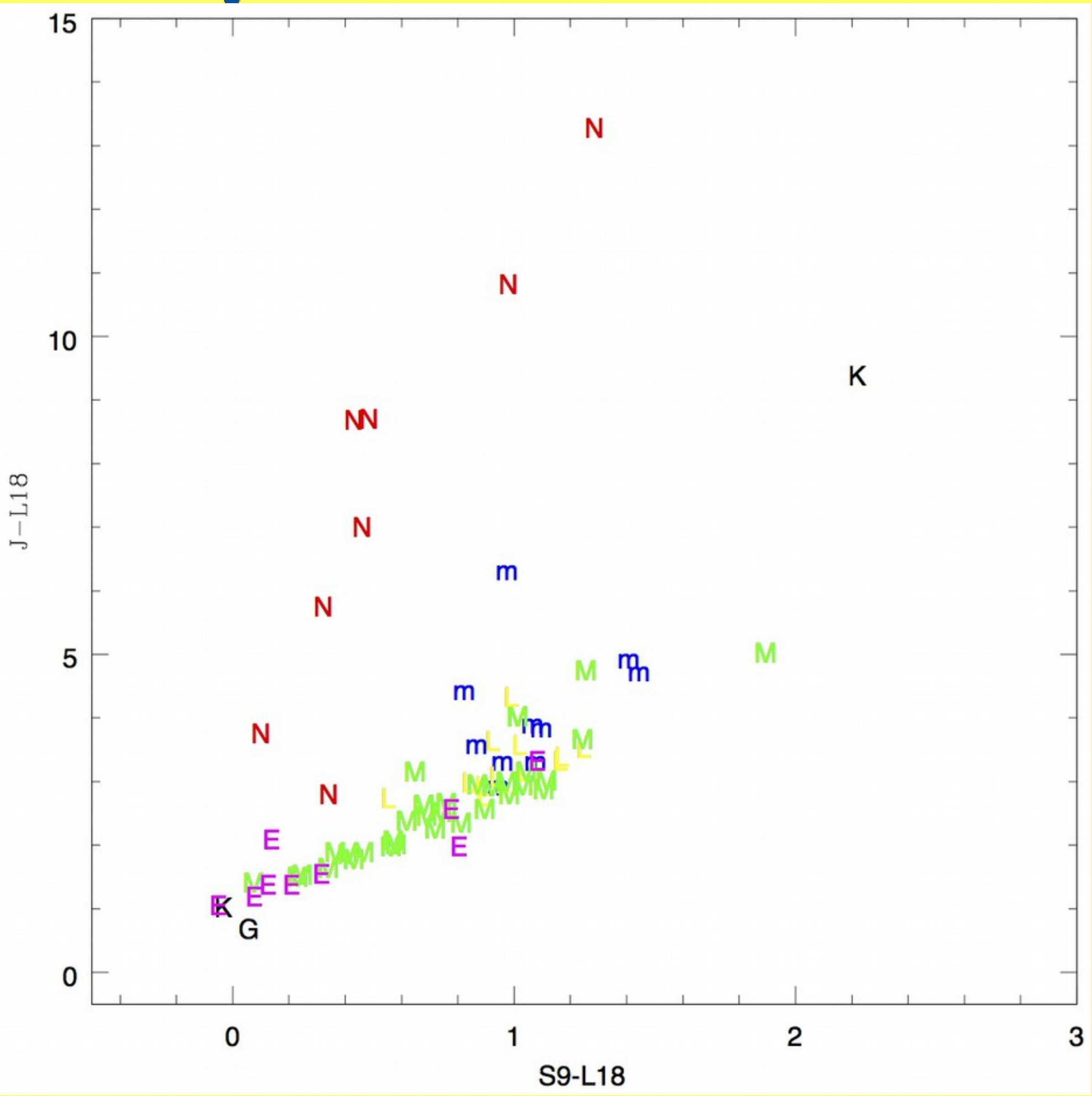


A very useful diagram,
Johnson's J band – AKARI S9
vs
AKARI S9-L18 bands

N=N-type
E=earlier than M5
L=M5 and later
m=Mira variables
C=CH-type
M=generic M-type
F and K= peculiar stars

N-type stars and Mira's are well discriminated.

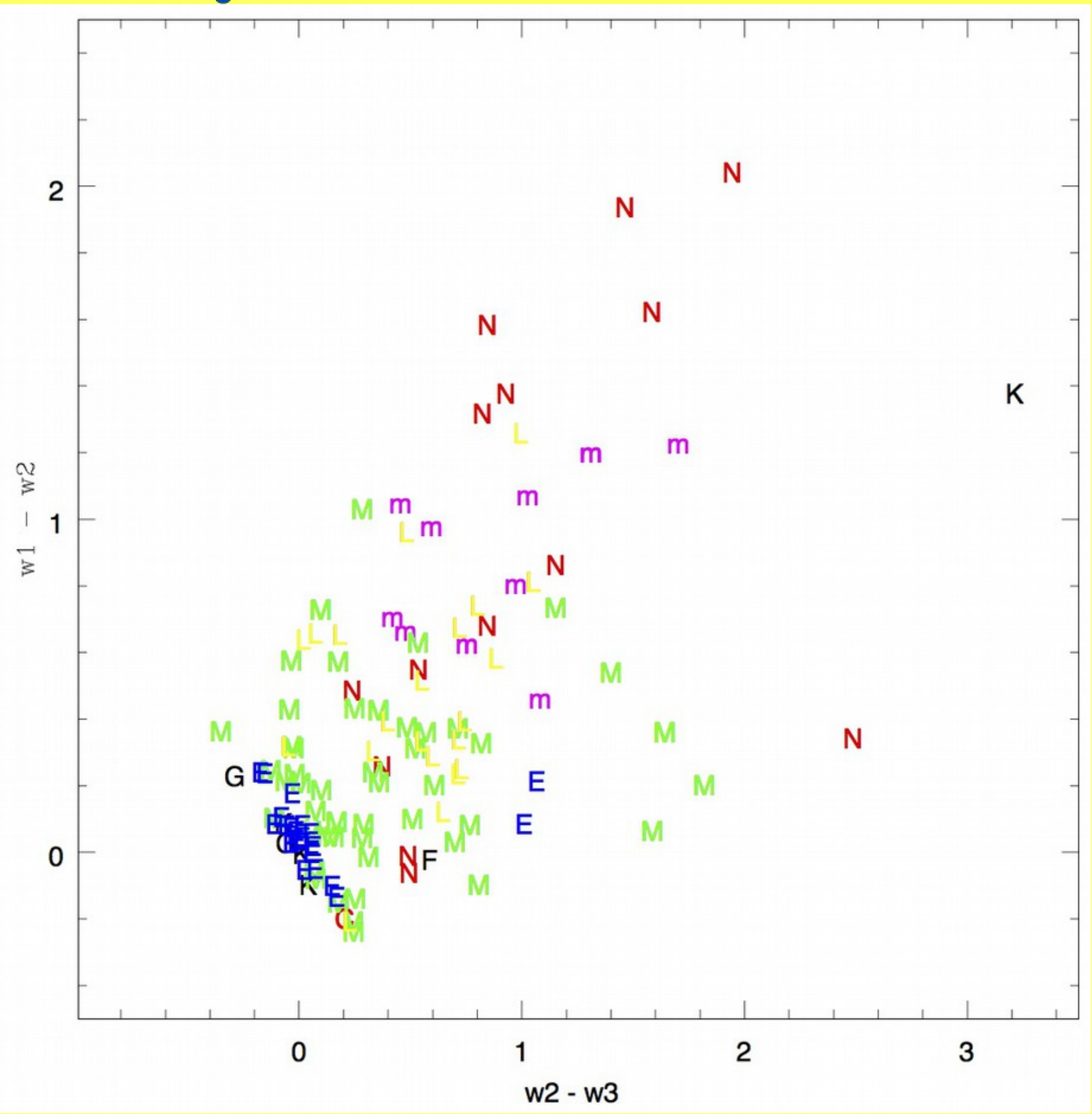
AKARI - J band colors



An even better diagram, Johnson's J band – AKARI L18 *vs* AKARI S9-L18 bands

N=N-type
E=earlier than M5
L=M5 and later
m=Mira variables
C=CH-type
M=generic M-type
F and K= peculiar stars

WISE-WISE colors

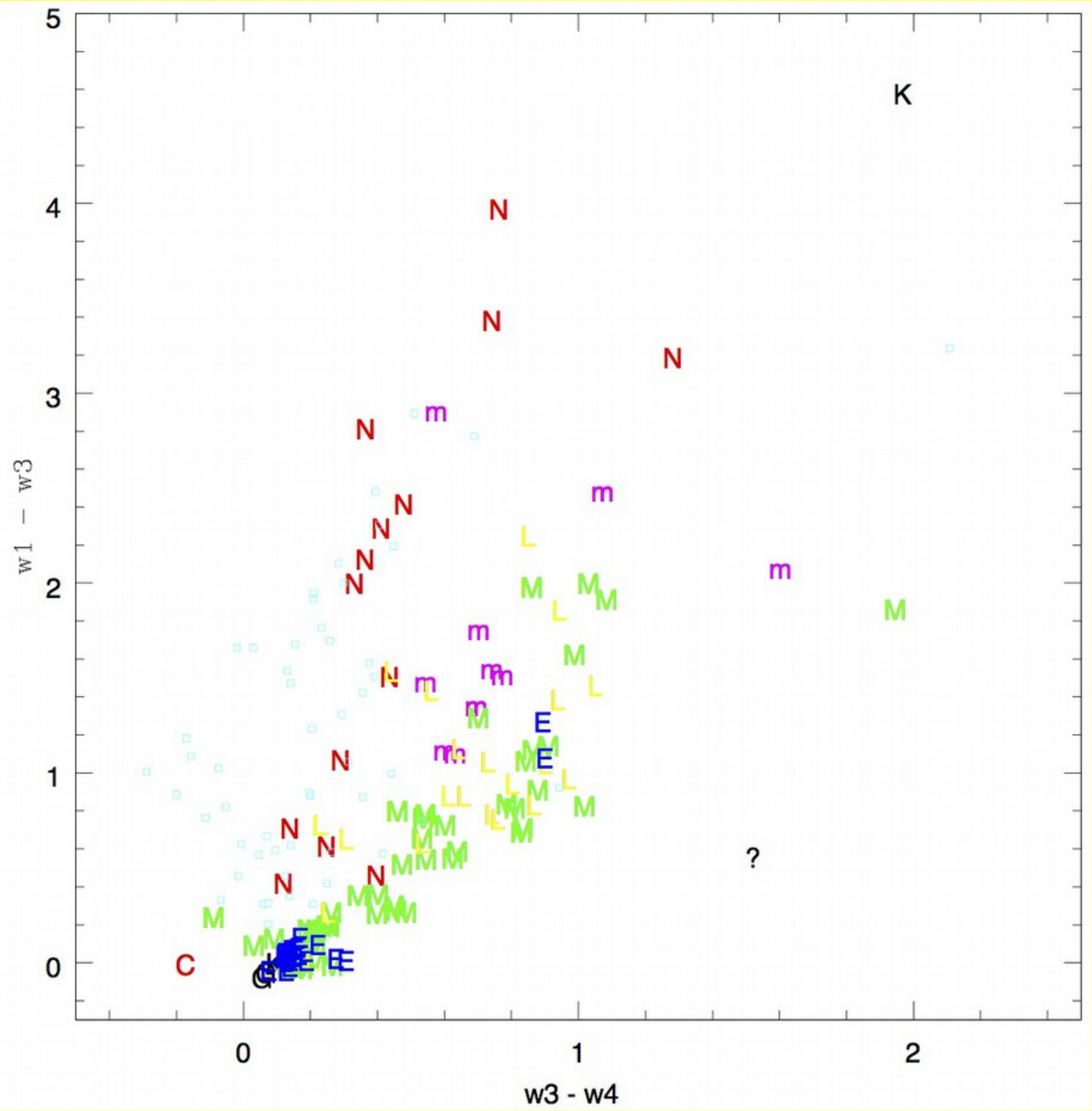


A very useful diagram,
WISE W1-W2
vs
WISE W2-W3 bands

N=N-type
E=earlier than M5
L=M5 and later
m=Mira variables
C=CH-type
M=generic M-type
F and K= peculiar stars

The lower envelope is the Main Sequence.
Mira stars are well grouped.

WISE colors



A still more useful diagram,
WISE w1-w3
vs
WISE w3-w4

N=N-type
E=earlier than M5
L=M5 and later
m=Mira variables
C=CH-type
M=generic M-type
F and K= peculiar stars

N-type Carbon stars are very well separated.
Pale blue dots are from a Mauron's sample of Carbon Stars.

IRAS colors

As a further check we looked also at the IRAS catalog to locate our sources in the classical [25]-[60] vs [12]-[25] color-color plot.

The agreement with the work by van der Veen and Habing (1988) was poorer than expected.

The most probable reason of some strong discrepancies might be the large uncertainties of the fluxes reported in the IRAS catalog for many of our stars, suggesting to use great caution in the application of this plot.

Conclusions

For the Observatories:

- plate archives provide unreplaceble information of the past history of astronomical objects;
- importance of the storage conditions : the material of the plate archives should be kept in good conditions to allow us to take advantage of the heritage of this important tool of the astronomical research.
- a web interface is necessary to allow an easy access to the archives;
- at least logbooks must be put on the web;
- a service of scan-on-request is a viable alternative to full scanning work if manpower is lacking.

For the astronomers:

- all the published archives must be consulted even for the study of a single object.
- Archive values cannot be taken nominally without consistency checks.