

A complex orchestration of VO tools in discovery of unknown sky objects

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IVOA Interoperability Meeting, Applications WG
Paris Observatory, Paris, France
14-th May 2019

Special Thanks to

- LAMOST people (Dongwei Fan, Yue Wu)
- China-VO (Chenzhou Cui)

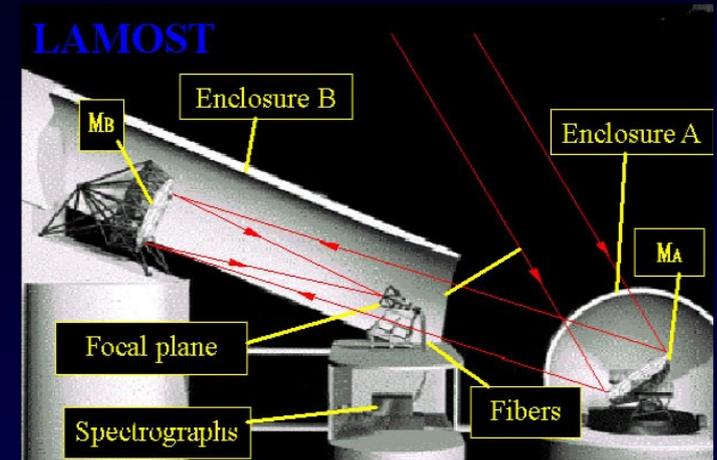
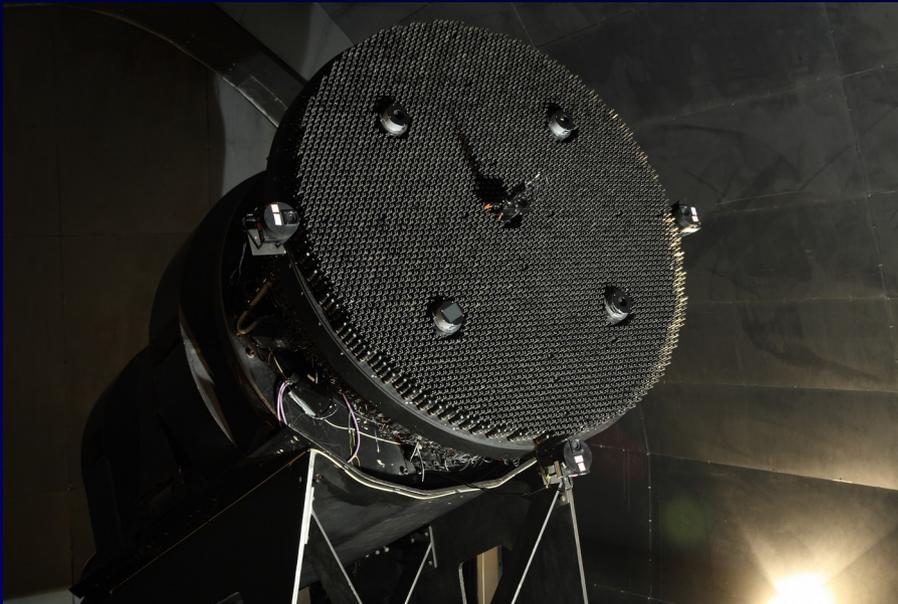
- Mark Taylor
- Margarida Castro Neves
- Pierre Fernique
- Markus Demleitner

Motivation

- Finding emission line stars in LAMOST DR1/2
- Using Machine Learning of spectra
- Method of Active Learning
- Verify results visually
- Select interesting cases, remove bad ones
- Get as much information as possible
- Discover yet unknown candidates

LAMOST (Guoshoujing)

Xinglong- China
4m mirror (30 deg meridian)
4000 fibers



Machine Learning - non VO

- Machine learning works only with ID of spectra
- Done in Jupyter notebook on cloud
- Just a short interval around H α (main feature)
- Result in simple CSV table
- For all candidates made plot in pdf -zoomed/full
 - + basic metadata - RA,DEC, Designation, Mag_r, class of emission

Results

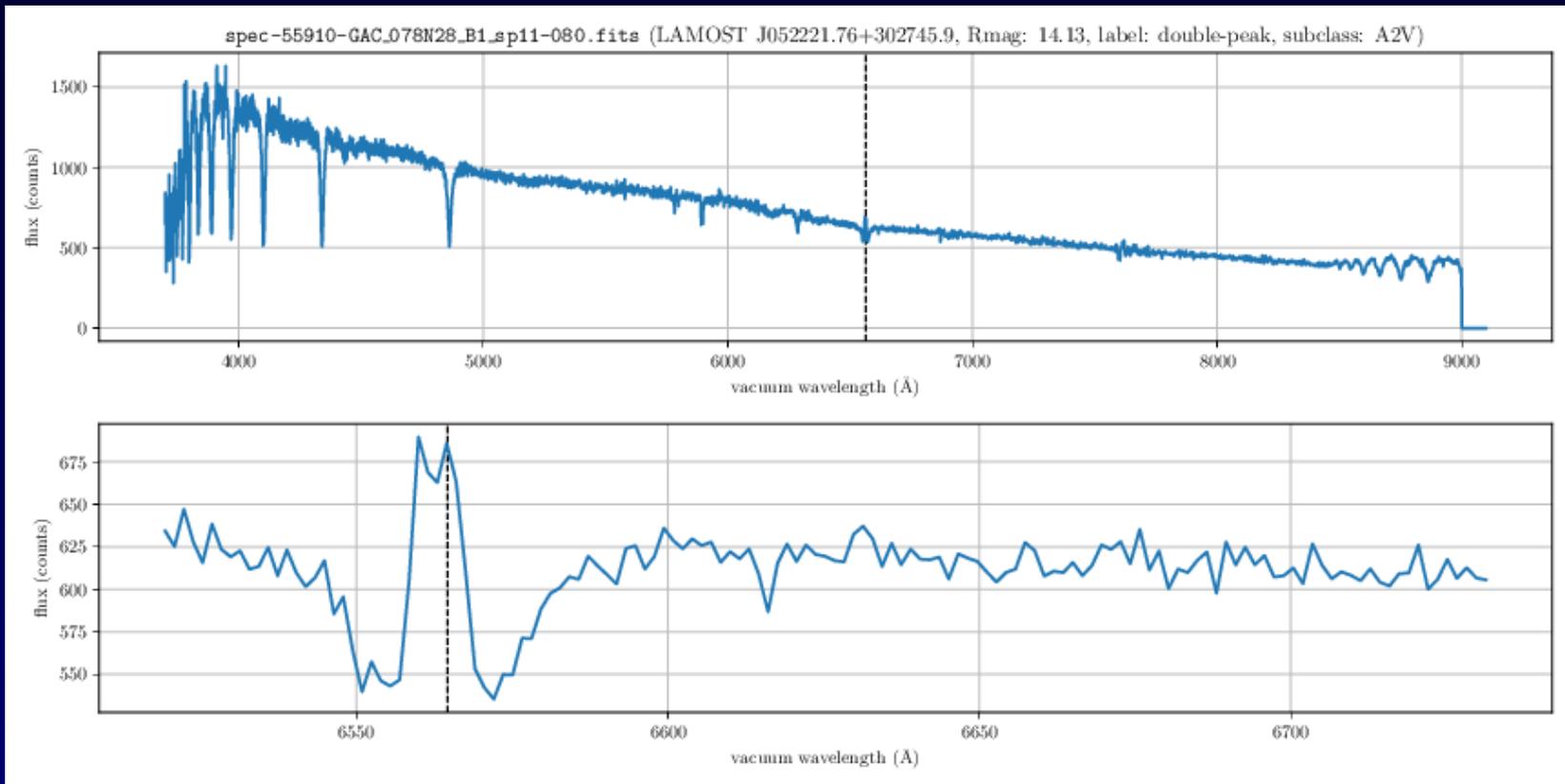
Number of SPECTRA (multiple exposures)

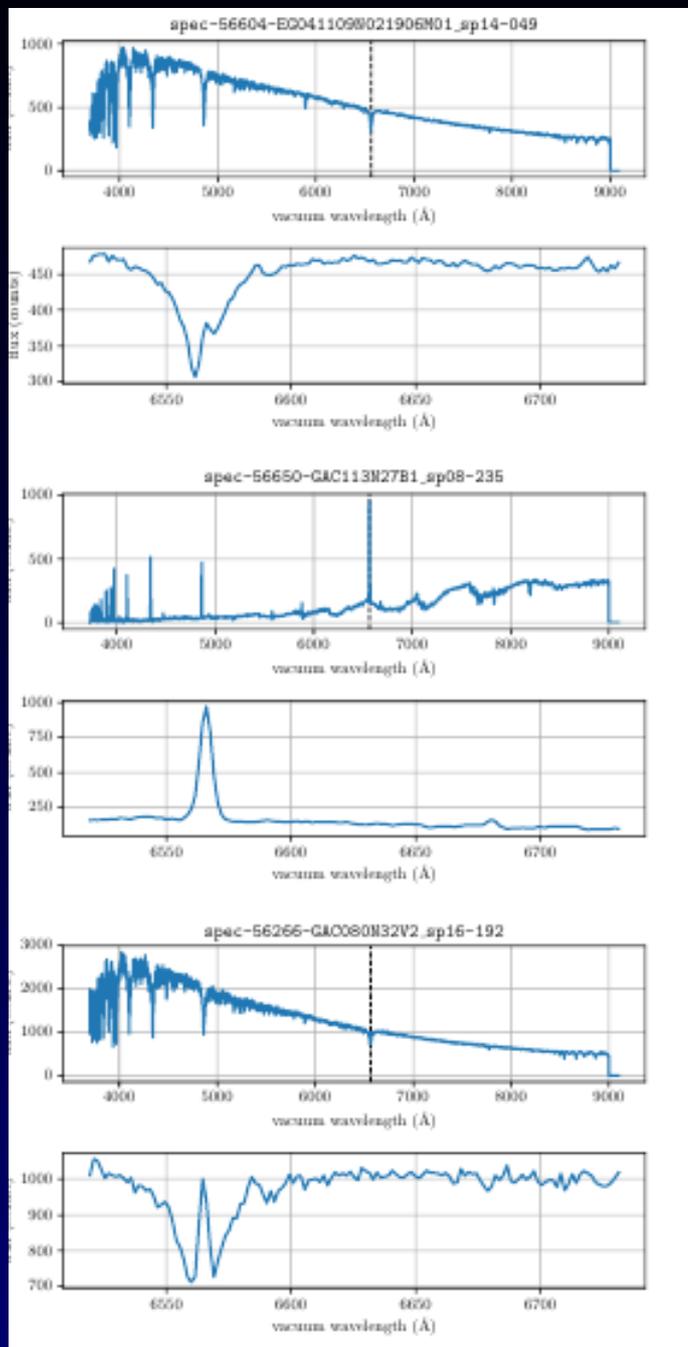
4379 candidates (from 4 mil)

58 bad – but still interesting – e.g. LAMOST HVS-1

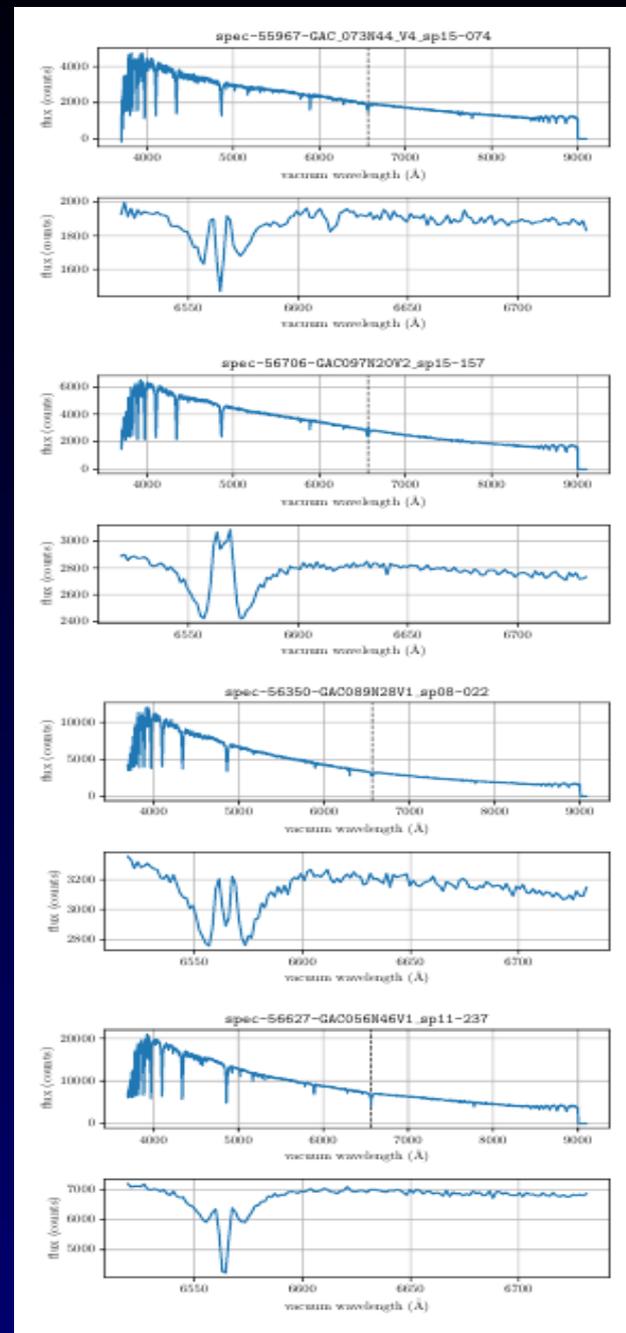
3731 single peak

648 double peak





Single peak



Double peak

DACHS - SSAP

LAMOST DR2 Spectra Web Interface - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Home - LAMOST | Google | Problem | Hou | Julian | A Beginner | active | Webmail | Ondřejov | LAMOST X

vos2.asu.cas.cz/lamost_dr2/q/web/form 80%

Most Visited Getting Started

LAMOST DR2 Spectra Web Interface

Help
Service info

Related
[LAMOST DR2 SSAP](#)

Metadata

Identifier
ivo://asu.cas.cz/lamost_dr2

Cite this
[Advice on citing this resource](#)

Description
LAMOST DR2 public web interface

Keywords
Optical spectroscopy

Creator


Created
2011-03-01T10:57:00

Data updated
2018-11-23

Reference URL
[Service info](#)

Try ADQL to query our data.

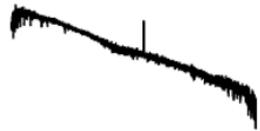
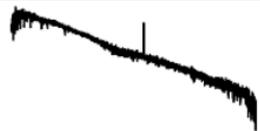
Parameters

- Location: BT CMI
- Search radius for Location: 5.0

Result

Matched: 42

Send via SAMP Quick Plot

Band start [Angstrom]	Band end [Angstrom]	Product key	Type	Object	Location [deg]	Aperture [deg]	Date Obs.
3699.99	9074.03	 spec-56316-GAC118N03V1_sp08-056.fits	image/fits	LAMOST J075703.80+025653.6	Position ICRS 119.2658400025 2.9482255019	0.000916667	2013-01-23T14:58:54Z
3699.99	9074.03	 spec-56316-GAC118N03V1_sp08-056.vot	application/x-votable+xml	LAMOST J075703.80+025653.6	Position ICRS 119.2658400025 2.9482255019	0.000916667	2013-01-23T14:58:54Z
3699.99	9074.03	 spec-56316-GAC118N03V1_sp08-079.fits	image/fits	LAMOST J075709.33+030041.9	Position ICRS 119.2889099991 3.0116545024	0.000916667	2013-01-23T14:58:54Z

07:07 cpu mem 8 days

TOPCAT - Column Magic

TOPCAT(2): Table Columns

Window Columns Display Help

Table Columns for 2: candidates_HOU2016.csv

Δ	Index	Visible	Name	\$ID	Class	Expression
0		<input type="checkbox"/>	Index	\$0	Long	
1	1	<input checked="" type="checkbox"/>	LAMOST_filename	\$1	String	
2	2	<input checked="" type="checkbox"/>	LAMOST_designation	\$2	String	
3	3	<input checked="" type="checkbox"/>	LAMOST_RA	\$3	Double	
4	4	<input checked="" type="checkbox"/>	LAMOST_DEC	\$4	Double	
5	5	<input checked="" type="checkbox"/>	LAMOST_subclass	\$5	String	
6	6	<input checked="" type="checkbox"/>	mag_r	\$6	Float	
7	7	<input checked="" type="checkbox"/>	class_by_ADL	\$7	String	
8	8	<input checked="" type="checkbox"/>	access_url	\$8	String	
9	9	<input checked="" type="checkbox"/>	accref	\$18	String	"http://vos2.asu.cas.cz/getproduct/lamost_dr2/data/fits/"+ matchGroup(LAMOST_filename, "spec.*(.*)_.*") + "/" + matchGroup(LAMOST_filename, "(.*)fits")...
10	10	<input checked="" type="checkbox"/>	SIMBAD_id	\$9	String	
11	11	<input checked="" type="checkbox"/>	SIMBAD_main_type	\$10	String	
12	12	<input checked="" type="checkbox"/>	SIMBAD_sp_type	\$11	String	
13	13	<input checked="" type="checkbox"/>	Hou_designation	\$12	String	
14	14	<input checked="" type="checkbox"/>	Hou_RA	\$13	Double	
15	15	<input checked="" type="checkbox"/>	Hou_DEC	\$14	Double	
16	16	<input checked="" type="checkbox"/>	Hou_Halpha_type	\$15	String	
17	17	<input checked="" type="checkbox"/>	Hou_obtype	\$16	String	
18	18	<input checked="" type="checkbox"/>	pdfname	\$17	String	"/home/skoda/LAMOST/KANDIDATI-11-2018/FINAL/"+ "previews/" + matchGroup(LAMOST_filename, "(.*)fits") + ".pdf"

TOPCAT(2): Table Browser

Window Rows Help

Table Browser for 2: candidates_HOU2016.csv

	LAMOST_filename	LAMOST_designation	LAMOST_RA	LAMOST_D...	SIMBAD_id	access_url	pdfname
1	-56296-GAC096N02V2_sp11-122.fits	LAMOST J062941.18+045323.9	97.42161	4.88998	TYC 141-2-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
2	-56296-GAC096N02V3_sp11-122.fits	LAMOST J062941.18+045323.9	97.42161	4.88998	TYC 141-2-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
3	-56296-GAC096N02V4_sp11-122.fits	LAMOST J062941.18+045323.9	97.42161	4.88998	TYC 141-2-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
4	-55930-B5593002_sp13-071.fits	LAMOST J030027.25+540007.2	45.1153	54.00142	EM* GGA 221	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
5	-55880-B8004_1_sp13-068.fits	LAMOST J030027.66+540005.1	45.11529	54.00142	EM* GGA 221	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
6	-55909-B90903_1_sp16-185.fits	LAMOST J033851.13+515341.2	54.71307	51.89479	TYC 3325-993-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
7	-55931-B5593103_sp16-185.fits	LAMOST J033851.13+515341.2	54.71307	51.89479	TYC 3325-993-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
8	-56640-GAC064N42V3_sp08-065.fits	LAMOST J042556.19+414907.7	66.48415	41.81883	TYC 2887-225-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
9	-55961-GAC 064N42_V1_sp08-065.fits	LAMOST J042556.19+414907.7	66.48415	41.81883	TYC 2887-225-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
10	-55961-GAC 064N42_V3_sp08-065.fits	LAMOST J042556.19+414907.7	66.48415	41.81883	TYC 2887-225-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
11	-55967-GAC 100N13_V4_sp05-019.fits	LAMOST J064405.81+114902.4	101.02421	11.81736	HD 262861	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
12	-55960-GAC 101N09_V2_sp11-001.fits	LAMOST J064405.81+114902.4	101.02421	11.81736	HD 262861	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
13	-55976-GAC 099N04_V1_sp14-068.fits	LAMOST J063209.83+050213.3	98.04098	5.03705	LS VI +05 8	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
14	-56296-GAC096N02V3_sp12-232.fits	LAMOST J063209.83+050213.3	98.04098	5.03705	LS VI +05 8	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
15	-56616-HD231029N411918V01_sp15-22...	LAMOST J230711.62+415504.7	346.79845	41.91799	TYC 3224-2282-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
16	-56571-HD231426N434153V01_sp02-13...	LAMOST J230711.62+415504.7	346.79845	41.91799	TYC 3224-2282-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
17	-56310-GAC105N24V2_sp07-010.fits	LAMOST J070639.51+222110.2	106.66464	22.35285	TYC 1357-740-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
18	-56688-GAC106N20V1_sp12-148.fits	LAMOST J070639.51+222110.2	106.66464	22.35285	TYC 1357-740-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
19	-55876-GAC 089N28_B1_sp04-028.fits	LAMOST J055517.56+292036.3	88.82317	29.34344	LAMOST J055517.56+292036.3	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
20	-55911-GAC 082N27_B1_sp12-053.fits	LAMOST J055517.56+292036.3	88.82317	29.34344	LAMOST J055517.56+292036.3	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
21	-56310-GAC105N24V2_sp05-070.fits	LAMOST J070010.15+231719.1	105.0423	23.28866	TYC 1895-1975-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1
22	-56651-GAC105N24V2_sp05-070.fits	LAMOST J070010.15+231719.1	105.0423	23.28866	TYC 1895-1975-1	http://vos2.asu.cas.cz/getproduct/lamost_dr2/...	/home/skoda/LAMOST/KANDIDATI-1

Total: 2,644 Visible: 2,644 Selected: 1

TOPCAT - SAMP

TOPCAT(2): Activation Actions

Window Actions Help

Activation Actions for 2: candidates_HOU2016.csv

Actions

- Use Sky Coordinates in
- Send Sky Coordinates
- Display image
- Display image region
- Load Table
- Plot Table
- Send FITS Image
- Send Spectrum
- Display Cutout Image
- Download URL
- View in Web Browser
- Execute code
- Run system command
- Send row index

Description
Executes a command in an Operating System shell

Configuration

Command:

Arg #1:

Arg #2:

Arg #3:

Arg #4:

Synchronous Capture Output

Status

Invoke now on row 11

Results

```
s
xpdf -remote my /home/skoda/LAMOST/KANDIDATI-11-2018/FINAL/previews/spec-55960-GAC_101N09_V2_s
xpdf -remote my /home/skoda/LAMOST/KANDIDATI-11-2018/FINAL/previews/spec-55909-B90903_1_sp16-16
xpdf -remote my /home/skoda/LAMOST/KANDIDATI-11-2018/FINAL/previews/spec-56688-GAC106N20V1_sp1
xpdf -remote my /home/skoda/LAMOST/KANDIDATI-11-2018/FINAL/previews/spec-55967-GAC_100N13_V4_s
```

TOPCAT(2): Activation Actions

Window Actions Help

Activation Actions for 2: candidates_HOU2016.csv

Actions

- Use Sky Coordinates in
- Send Sky Coordinates
- Display image
- Display image region
- Load Table
- Plot Table
- Send FITS Image
- Send Spectrum
- Display Cutout Image
- Download URL
- View in Web Browser
- Execute code
- Run system command
- Send row index

Description
Send the content of a file or URL column as a Spectrum to an external application using SAMP

Configuration

Spectrum Location:

Spectrum Viewer:

Status

Invoke now on row 18

Results

Seq	Row	Status	Message
2	18	FAIL	Error response from splat: Spectrum load failed
3	11	FAIL	Synchronous call timeout
4	18	OK	Successfully sent to splat

Aladin- HIPS

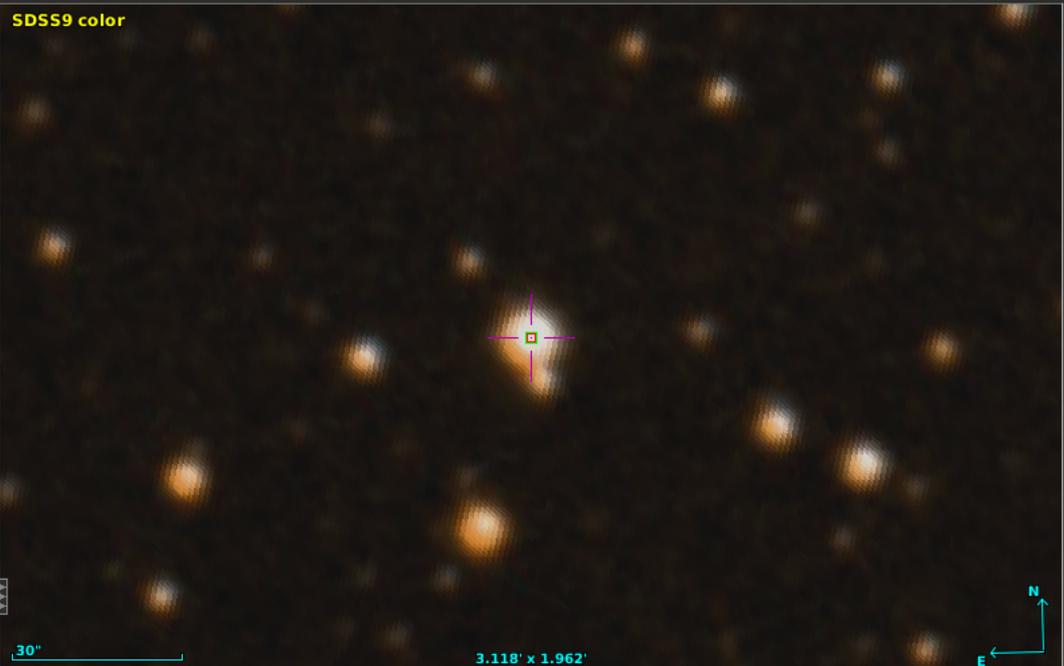
Aladin v10.1 *** BETA VERSION (based on v10.117) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Command 05:03:57.48 +44:17:43.4 Frame ICRS Projection Aitoff

DSS SDSS ZMASS WISE GALEX PLANCK AKARI XMM Fermi Simbad NED +

SDSS9 color



Imagine your eye looking through a stack of planes (below). Each plane contains its own data set: image, catalog, graphical overlays... You see the combination of them in the main panel. For accessing to other data, use the discovery tree in the left panel, or clic & drag your own local files.

- select
- pan
- dist
- phot
- draw
- tag
- moc
- spect
- filter
- cross
- x-y
- rgb
- assoc
- epoch
- size
- dens.
- opac.
- zoom
- pixel
- prop
- del

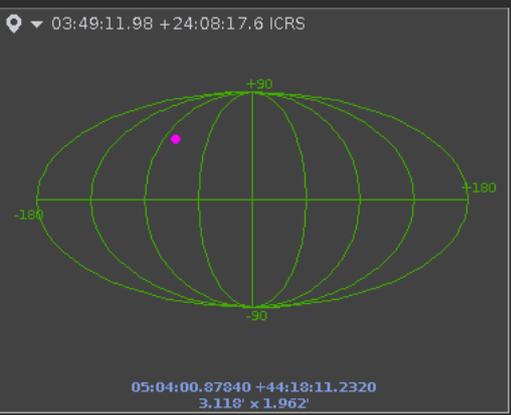
CDS / Simbad
CDS / P / SDSS9 / color
CDS / P / DSS2 / color

epoch -
size -
dens. -
opac. -
zoom -

grid study wink north hdr multiview match Search

main_id	nbref	ra_sesa	dec_sesa	main_type	other_ty...	radvel
EM* VES 867	6	05 04 00.88182	+44 18 11.2916	Em*	Em* *	IR

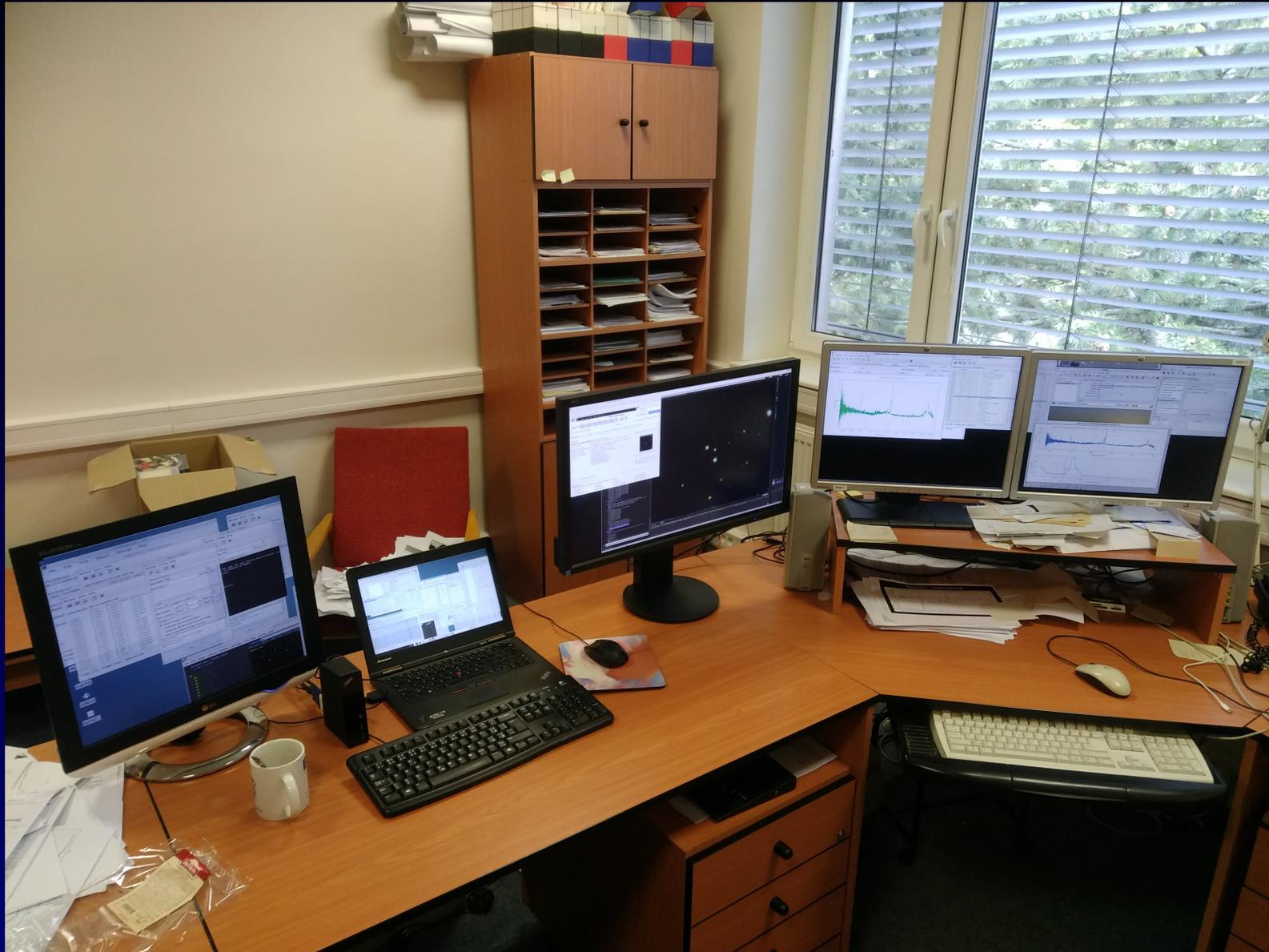
03:49:11.98 +24:08:17.6 ICRS

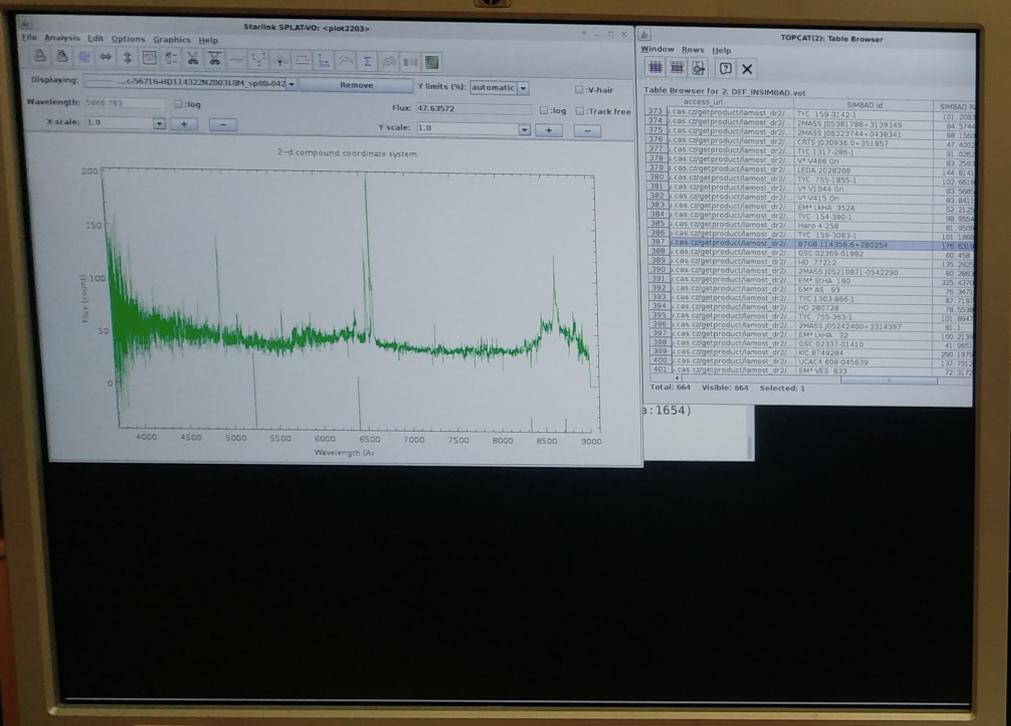


05:04:00.87840 +44:18:11.2320
3.118' x 1.962'

(c) 2018 Université de Strasbourg/CNRS - developed by CDS, distributed under GPLv3 1 sel / 4370 src 429Mb

Analysis



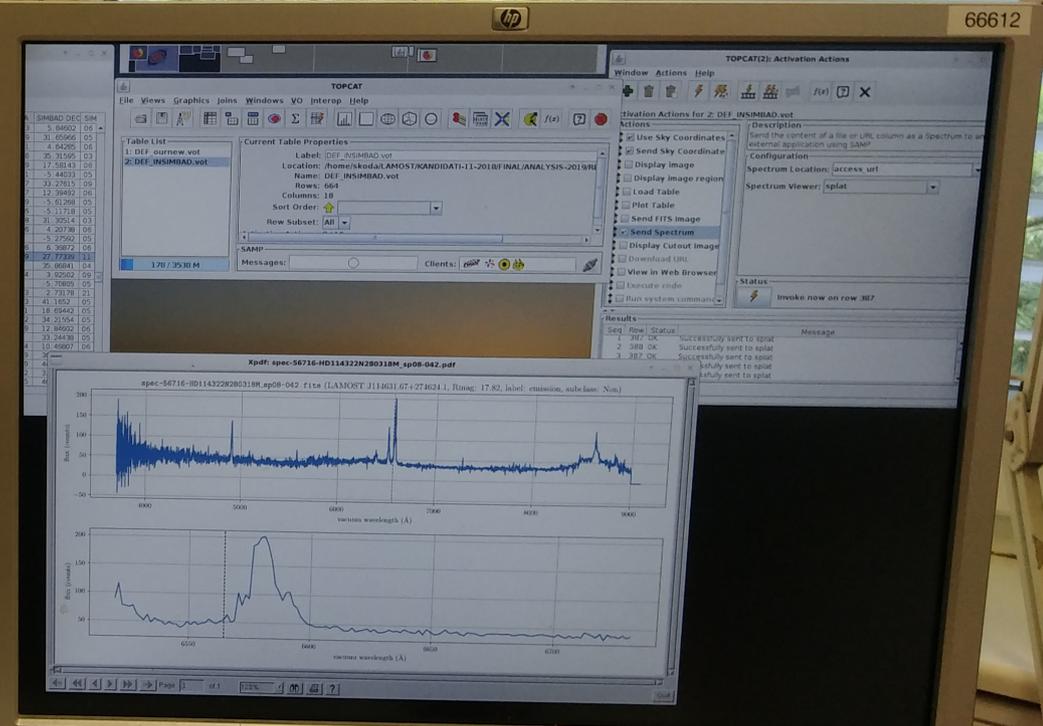


TOPCAT(2): Table Browser

Table browser for 2: DEF_INSIMBAD.vot

access_url	SIMBAD ID	SIMBAD R
373 cas.cageproduct/famost-dr2 TYC 15231421 101.2708		
374 cas.cageproduct/famost-dr2 2MAS5 J05301789+3139349 184.5164		
375 cas.cageproduct/famost-dr2 2MAS5 J0532744+0438341 88.1568		
376 cas.cageproduct/famost-dr2 CR3 0205395.0+203857 47.4058		
377 cas.cageproduct/famost-dr2 TYC 13172851 91.2505		
378 cas.cageproduct/famost-dr2 VV 4465.00 144.814		
379 cas.cageproduct/famost-dr2 LEDA 2028208 83.2795		
380 cas.cageproduct/famost-dr2 TYC 7551855-1 102.6016		
381 cas.cageproduct/famost-dr2 VV 21444.00 93.5688		
382 cas.cageproduct/famost-dr2 VV 0415.00 83.8413		
383 cas.cageproduct/famost-dr2 EM 1484.332A 98.8054		
384 cas.cageproduct/famost-dr2 TYC 15439051 52.2125		
385 cas.cageproduct/famost-dr2 NAME 429 81.9059		
386 cas.cageproduct/famost-dr2 TYC 15930831 101.1868		
387 cas.cageproduct/famost-dr2 8706 114356.6+28234 176.8318		
388 cas.cageproduct/famost-dr2 GSC 023650192 65.458		
389 cas.cageproduct/famost-dr2 HD 77210 135.2025		
390 cas.cageproduct/famost-dr2 2MAS5 J052108710542290 82.2665		
391 cas.cageproduct/famost-dr2 EM 504A_190 395.4379		
392 cas.cageproduct/famost-dr2 EM 5A_191 76.3473		
393 cas.cageproduct/famost-dr2 TYC 13038661 87.7139		
394 cas.cageproduct/famost-dr2 HD 280728 78.5038		
395 cas.cageproduct/famost-dr2 TYC 12539331 101.8645		
396 cas.cageproduct/famost-dr2 2MAS5 J05242800+3314397 81.11		
397 cas.cageproduct/famost-dr2 EM 1484_32 102.2728		
398 cas.cageproduct/famost-dr2 GSC 0233701410 401.5915		
399 cas.cageproduct/famost-dr2 IC 84498A 117.7614		
400 cas.cageproduct/famost-dr2 UCAC4 608-045639 117.7614		
401 cas.cageproduct/famost-dr2 EM VES 833 72.3125		

Total: 664 Visible: 664 Selected: 1



Handwritten notes and papers on the desk, including a document titled "MILAN FALGOUTER" and various scribbles and text.

6740800110710

Results

New objects – 664 in SIMBAD (Be, CV, Seyfert Gal...)

1013 (948 objects) NEW , NOT known

Visual check , XMATCH in VO, DSS2 , SDSS in Aladin

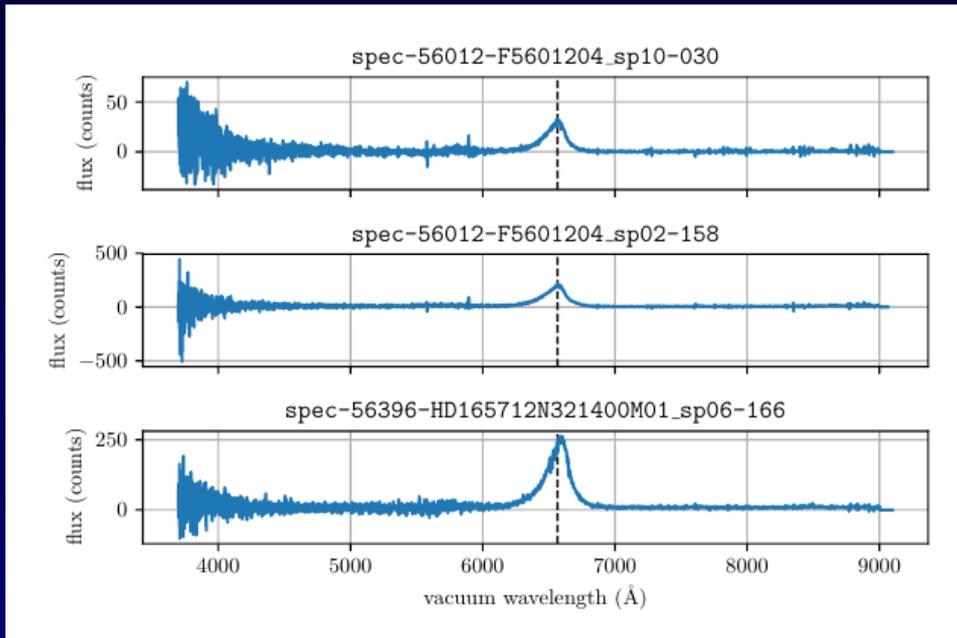
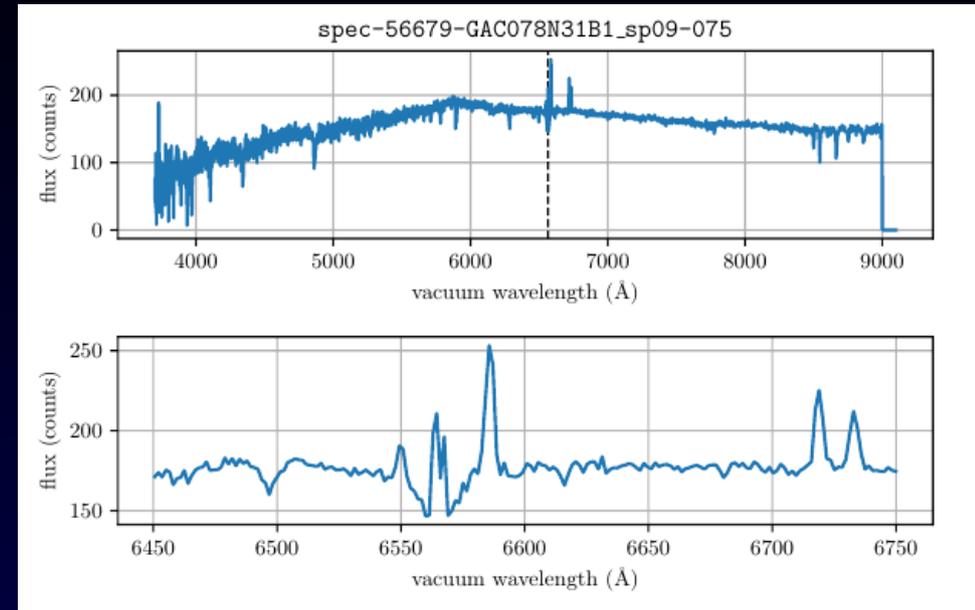
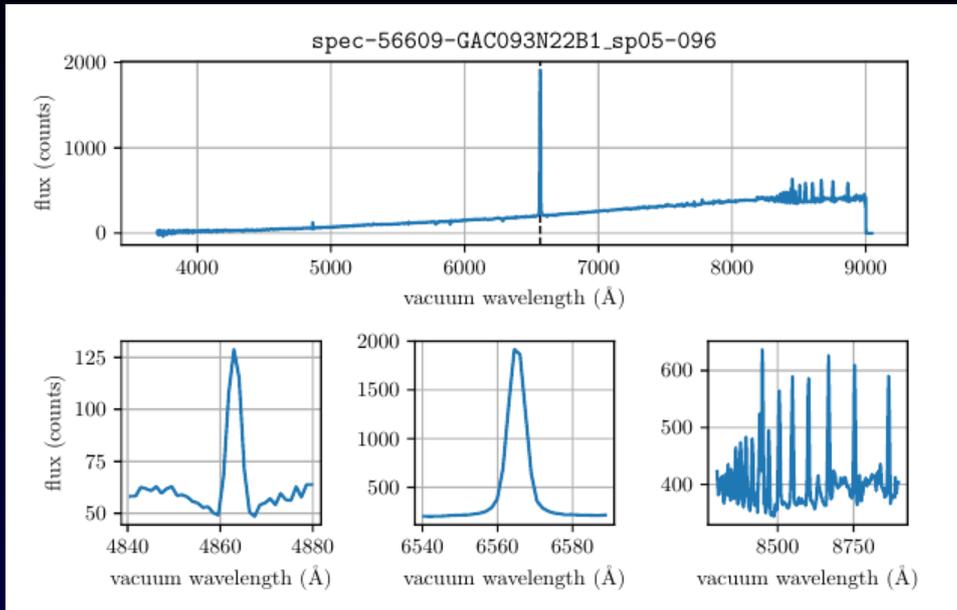
Most are correct - ? physical origin (YSO, CV, M, Novae)

Unreliable classification from LAMOST 1D pipeline (F, A/B)

A lot of new Be stars

Many SUPRISES !!!

Results - Interesting



Supernovae ???

In DSS2 /SDSS there are galaxies in 10arcsec around

Comparison with Other Method

RAA 2016 Vol. 16 No. 9, 138 (12pp) doi: 10.1088/1674-4527/16/9/138
<http://www.raa-journal.org> <http://iopscience.iop.org/raa>

*Research in
Astronomy and
Astrophysics*

A catalog of early-type emission-line stars and H α line profiles from LAMOST DR2

Wen Hou^{1,2}, A-Li Luo^{1,2}, Jing-Yao Hu¹, Hai-Feng Yang^{1,2,3}, Chang-De Du^{1,2}, Chao Liu¹, Chien-De Lee⁴, Chien-Cheng Lin⁵, Yue-Fei Wang⁶, Yong Zhang⁶, Zi-Huang Cao¹ and Yong-Hui Hou⁶

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³ School of Computer Science and Technology, Taiyuan University of Science and Technology, Taiyuan 030024, China

⁴ Institute of Astronomy, National Central University, Jhongli

⁵ Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai 200030, China

⁶ Nanjing Institute of Astronomical Optics & Technology, National Astronomical Observatories, Chinese Academy of Sciences, Nanjing 210042, China

$$\sum_{i=-5}^5 f_{\text{obs}}[n_0 + i] / 11 > f_{\text{conti}}[n_0],$$

$$\sum_{i=-1}^1 f[n_0 + i] / 3 > \sum_{i=-2}^2 f[n_0 + i] / 5$$

and

$$\max \left(f_{\text{obs}}[n_0 - 1 : n_0 + 1] \right) \geq \max \left(f_{\text{obs}}[n_0 - 2 : n_0 + 2] \right)$$

Integral pixel statistics on different intervals around H α

Hou (2016) DR2 - catalog of 11205 emission stars
we have 2644 of them - but 11k not well justified !
(VO xmatch, SPLAT visualization)

Confusion in Unique Identification

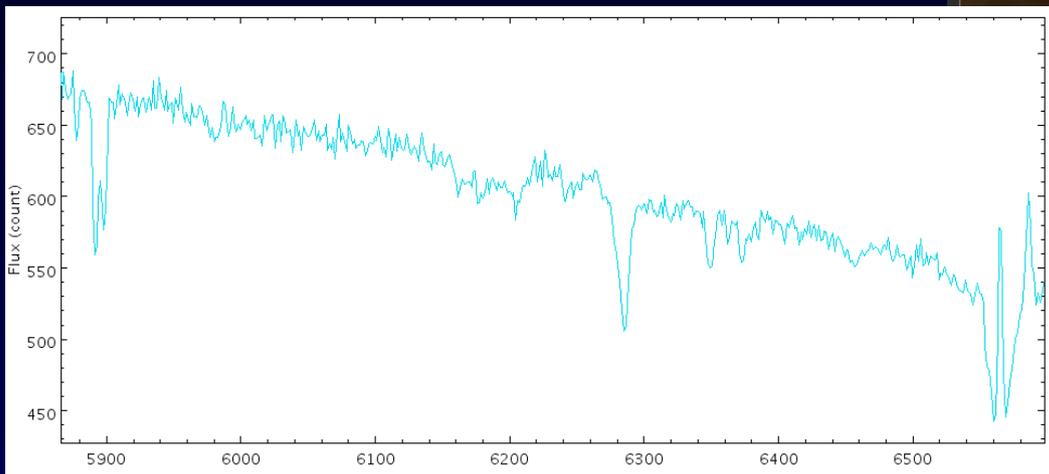
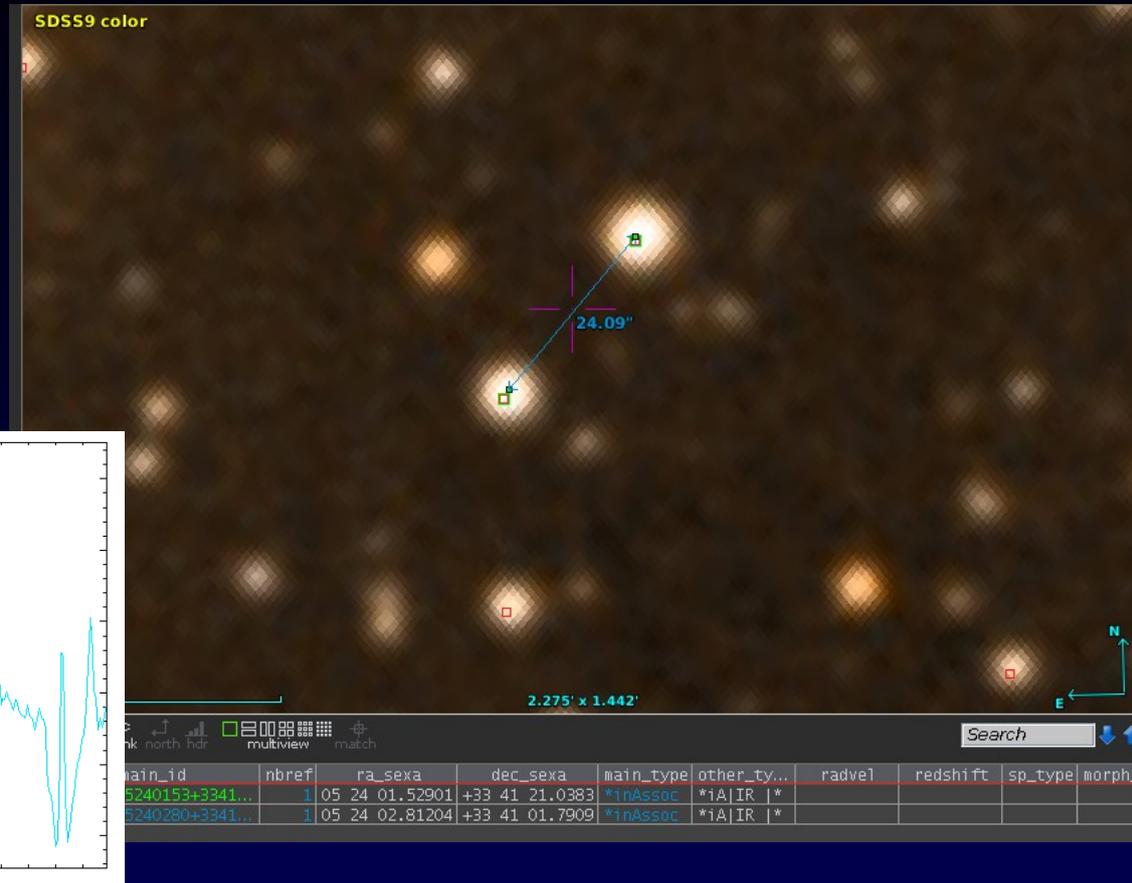
2 stars that are 24 arcsec apart

LAMOST J052402.81+334101.7

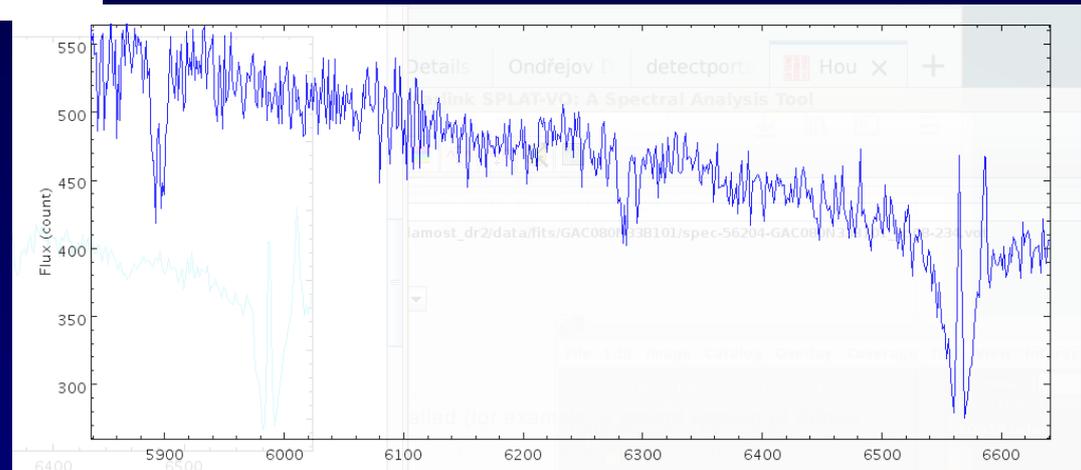
LAMOST J052401.53+334120.9

2MASS J05240280+3341017

2MASS J05240153+3341210



Is it the fiber light leakage ???
OR Nebula lines ??



Confusion in Unique Identification

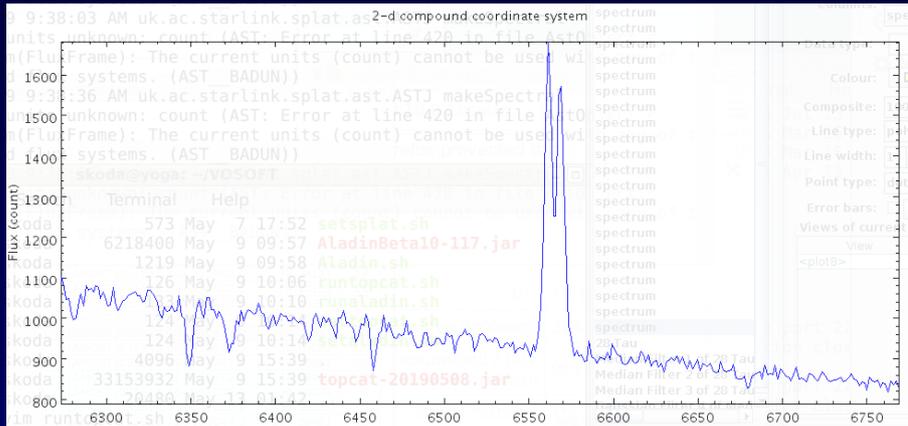
LAMOST J034912.80+240820.0

is Pleione (5mag) 22 arcsec apart

Basic data :

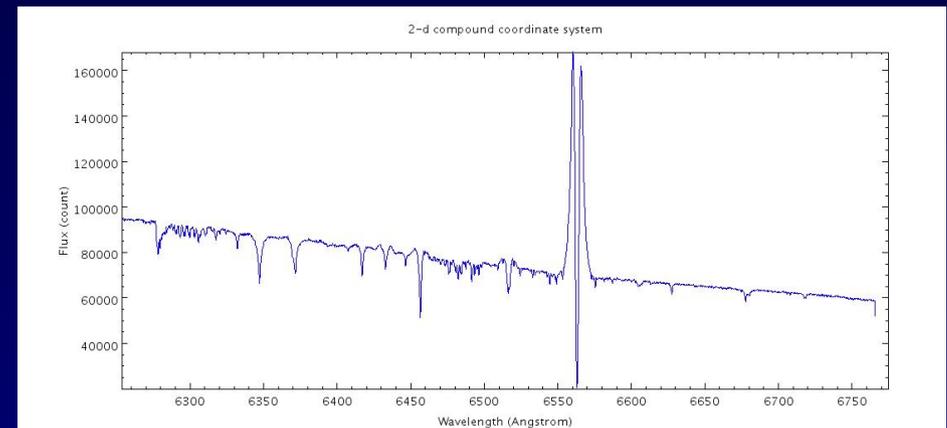
LAMOST J034912.80+240820.0 -- Peculiar Star

Other object types: **Pe*** (Ref)
ICRS coord. (*ep=J2000*) : **03 49 12.800 +24 08 20.04** (Optical) [] D **2015MNRAS.449.1401H**
FK4 coord. (*ep=B1950 eq=1950*) : 03 46 14.053 +23 59 13.23 []
Gal coord. (*ep=J2000*) : 166.959918 -23.163713 []
Spectral type: **A1mF1 D 2015MNRAS.449.1401H**

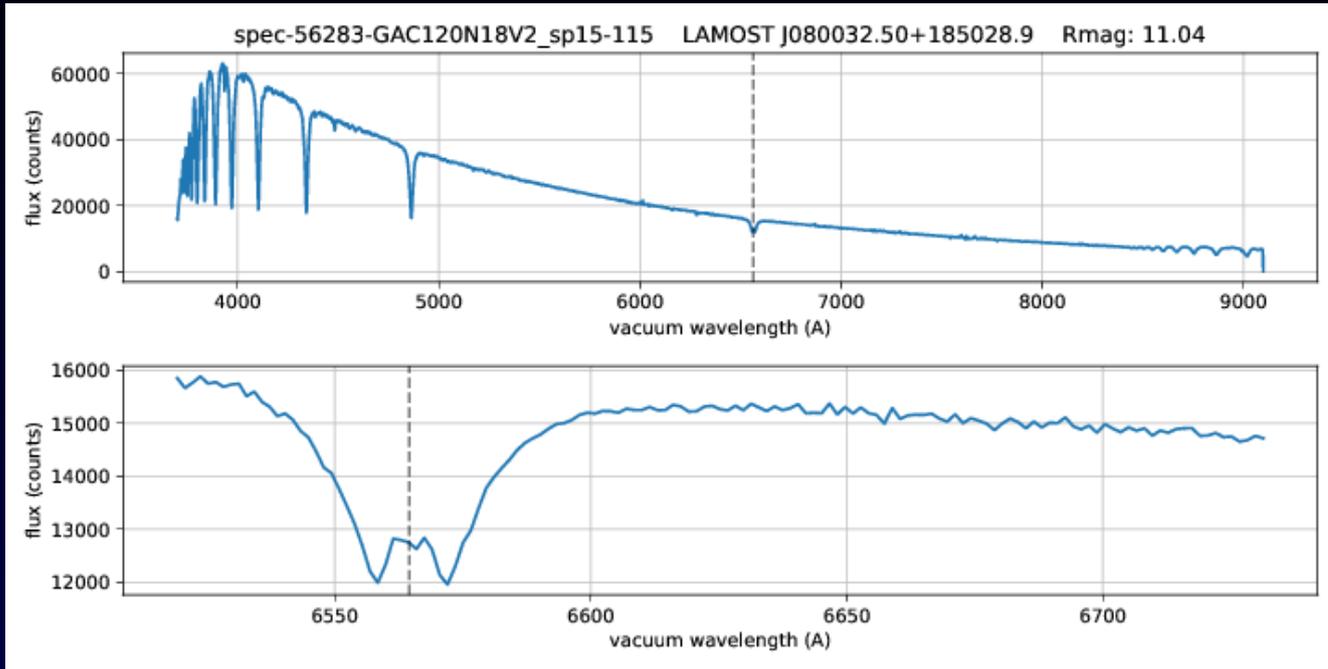


LAMOST MJD 56295

Ondrejev at MJD 56153



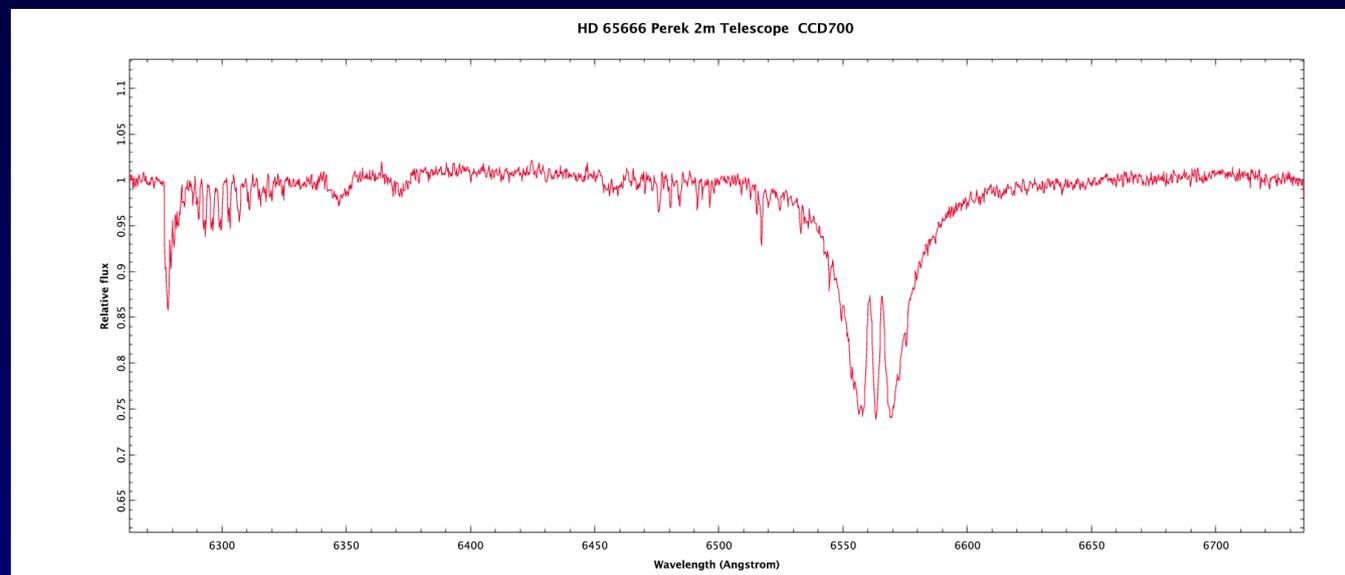
Results - Unknown Bright Be star



LAMOST

6.5 arcsec distant star 7 mag

CCD700 OND



Conclusions

- Making the ML experiment based on VO technology
 - Powerful tools to visualize
 - Flexible table handling
 - Massive Cross-matching (CDS Xmatch)
 - Multi – dimensional view of the same object
 - HIPS crucial
 - Interfacing with custom workflows !
 - Interactive slideshow
 - Outlier/interesting object
 - detailed analysis – metadata, other data

DEMO