### Data challenges of the Virtual Observatory in Time Domain Astronomy

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The study of variability of astronomical objects over different time-scales

• A hot topic but a new field?

The study of variability of astronomical objects over different time-scales

• The Great Debate of 1920 on the Scale of the Universe (Curtis, Shapley)



• Observations of Cepheids showed the Universe is composed of many galaxies like our own.

The first standard candles

period-luminosity relation

### Leavitt law

Thanks to Leavitt law and the discovery of Cepheids in Andromeda

Pickering 1912

The study of variability of astronomical objects over different time-scales

• The Great Debate of 1998 on the Nature of the Universe (Peebles, Turner)



 Observations of SNe Ia first direct evidence of the cosmic acceleration

### **Standard candles**

### luminosity – decay time relation

Riess et al. 1998; Perlmutter et al. 1999

- What type of variable phenomena?
  - Periodic: binary orbits of stars/extrasolar planets, stellar rotation, stellar pulsation...
  - Transient: supernovae, gamma-ray bursts, novae, X-ray bursts, transits, gravitational microlensing, flares, tidal disruption events...
  - Stochastic: accretion in CVs, X-ray binaries,...





The study of variability of astronomical objects over different time-scales

What time-scales are we talking about?



The study of variability of astronomical objects over different time-scales

What time-scales are we talking about?



- What time-scales are we talking about?
  - Characterisation and classification of sources on the basis of their variability
  - Multi-wavelength approach is (sometimes) needed



The study of variability of astronomical objects over different time-scales

- What time-scales are we talking about?
  - Multi-messenger approach is (sometimes) needed



### **GW170817**

LIGO and Virgo make first detection of gravitational waves produced by colliding neutron stars

Discovery marks first cosmic event observed in both gravitational waves and light.

For the first time, scientists have directly detected gravitational waves — ripples in space-time — in addition to light from the spectacular collision of two neutron stars.

The discovery was made using the U.S.-based Laser Interferometer Gravitational-Wave Observatory (LIGO); the Europe-based Virgo detector; and some 70 ground- and space-based observatories.

THE ASTROPHYSICAL JOURNAL LETTERS, 848:L12 (59pp), 2017 October 20





Abbott et al.



X-shooter spectra in the kilonova in NGC 4993 over 12 days. Image credit: ESO/Pian et al./Smartt & ePESSTO.

- Characterisation & classification of sources on the basis of their variability
- Multi-wavelength / messenger approach is (sometimes) needed
- Follow-up observations and reaction time for that can be crucial
- Visualisation & navigation thought the data
- Analysis of variance of phenomena
- Coordination is crucial transmission of information



**TD Astronomy Challenges?** 

### **TD Astronomy DATA Challenges**

**TD Astronomy Virtual Observatory DATA Challenges** 

### What is the VO?

• Astronomical datasets, tools, services should work seamlessly together

### What is the IVOA?

- An organisation that debates and agrees the technical standards that are needed to make the VO possible
- A focal point for VO aspirations, a framework for discussing and sharing VO ideas and technology
- Promoting and publicising the VO

### Who is the IVOA?

- 6 Working Groups, 7 Interest Groups
  - There is a Time Domain Interest Group
  - Completely open to participation

### How to join the IVOA?

- 2 interoperability meetings per year
- Next meeting in Paris
- Register to email lists for discussion of topics

### http://ivoa.net/

### Who is the VO?

- VO is integrated in many Astronomy data centres and archives
  - Often behind the scenes...
  - Huge benefits from shared software components
  - VO enables many scientific capabilities, just not possible otherwise
    - All sky astronomy



### Who is the VO for?

- Research astronomers
- Data Centres and Archives
- Software developers
- Educators

. . .

### Idea of the VO?

- In a seamless way for the user:
  - Data discovery & access
  - Visualisation & analysis
  - Through Services & tools
- Research astronomers Time Domain Astronomers

### Does the VO meet Time Domain Astronomers needs?



**TD Astronomy Challenges?** 

**TD Astronomy DATA Challenges** 

### **TD Astronomy Virtual Observatory DATA Challenges**

What is available through the VO?

- Characterisation & classification of sources on the basis of their variability
- Multi-wavelength / messenger approach is (sometimes) needed
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- Characterisation & classification of sources on the basis of their variability
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- Follow-up observations and reaction time for that can be crucial
- Visualisation & navigation thought the data
- Analysis of variance of phenomena
- Coordination & transmission of information
- Characterisation & classification
  - Big Data
  - Heterogenous Data
  - Classical techniques
  - ➡ AI, ML, DL techniques
    - BoF on Monday & Session 7 & 8 on Tuesday
    - IVOA Knowledge Discovery Interest Group (K.L. Polsterer & M. Graham)

- Characterisation and classification of sources on the basis of their variability
- Multi-wavelength/messenger approach is (sometimes) needed
- Follow-up observations and reaction time for that can be crucial
- Visualisation & navigation thought the data
- Analysis of variance of phenomena
- Coordination & transmission of information
- Multi-wavelength/messenger
- Combining data in a coherent way from different missions covering different wavelengths
  - Big Data
  - Heterogenous Data
  - Source identification
  - Cross-matching techniques

# Minimum information about objects



#### Object Name

M81

▶ Se

Go

#### Results for object MESSIER 081 (M81)

ntifications

Overview Cross-IDs (65) Coordinates	s (47) Redshifts	(29) Distances (1	.01) Classificat	ions (117)	Notes (48)	Diameters (8)
Photometry & SED (246) Spectra (44)	Images (179)	References (2373)	External Links			
(10 <sup>3</sup> ) 10 <sup>3</sup> 10 <sup>-6</sup> 10 <sup>-15</sup> 10 <sup>-6</sup> 10 <sup>-15</sup> 10 <sup>-6</sup>		POSS-II F (N Search image Image Credit: Cal	orth), AAO-SES/S{ 25 litech or AAO/ROE	ERC-ER (Sou	th), Red image	

#### Selected data and derived quantities for MESSIER 081<sup>+</sup>. More information in the tabs above.

MESSIER 081; NGC 3031; UGC 0531	8; CGCG 333-007; CGCG 0	951.4+6918			
<b>Coordinates for Preferred Positio</b>	n				
Equatorial (J2000)					Galactic
RA, Dec	RA, Dec [Deg]	Unc Semi-major,minor ["]	Unc PA [deg]	Reference	Lon, Lat [deg]
09h55m33.1730s, +69d03m55.061s	148.888221, 69.065295	1.57E-03, 3.50E-04	90	1995AJ110880J	142.091841,
Preferred Redshift & Derived Qua	ntities [H <sub>0</sub> = 73 km/sec	/Mpc], Ωmatter = 0.27, Ωvacuum	= 0.73]		Redshift-ind
z (Helio)	V (Helio) [km/s]	Reference	V (CMB) [km/s]	Hubble Distance (CMB) [Mpc]	# Measureme
-0.00011 +/- 0.00001	-33.876552 +/- 3.897302	1991RC3.9.C0000d	48 +/- 7	0.66 +/- 0.11	101
Classifications					
Object Type	Morphology	Reference	Activity Type	Reference	Other
G	SA(s)ab	1991RC3.9.C0000d	Flat-Spectrum Radio Source,	2007ApJS17161H	SA(s)ab;LINE
Quick-look Angular & Physical Di	ameters			Foreground Galactic Extinc	tion (2011Ap
Passband	Diameter ["]	Reference	Diameter [kpc]	A <sub>λ</sub> [mag] V	A <sub>λ</sub> [mag] K
RC3 D_0 (blue)	1652.50	1991RC3.9.C0000d	29.43	0.220	0.024
Quick-look Photometry & Lumino	sities (brightest flux in e	each spectral region)			
Spectral region	Band	Apparent mag or flux	Reference	Absolute Mag or vLv [W]	$vL_v$ [L $_{\odot}(bol)$ ]
X-Ray	2-10 keV (BeppoSAX)	3.10E-11 +/- 0.40E-11 erg/cm^2^/s	2007A&A472705V	5.01E+33 +/- 6.59E+32 [W]	1.30E+07 +/-
UV	3320 A (OAO)	8.95 +/- 0.08 mag	1982ApJ2561C	-18.85 +/- 0.10 [mag]	1.34E+09 +/-
Visible	v	8.73 Jy	2007ApJ655863D	7.68E+36 [W]	2.00E+10
Near-IR	H_tot (2MASS LGA)	4.090 +/- 0.018 mag	2003AJ125525J	-23.71 +/- 0.07 [mag]	1.81E+10 +/-
Far-IR	FIR (IRAS)	3.65E-12 W m^-2^	1988ApJS6891R	5.86E+35 [W]	1.52E+09
Radio	57.5 MHz	2.4 +/- 0.6 Jy	1990ApJ35230I	2.23E+29 +/- 5.60E+28 [W]	5.80E+02 +/-
*Derived quantities are based on the median redshift-indepen	ndent distance when available, otherwise the	preferred redshift is used with the selected cosmological param	eters (which can be changed in search options).		



#### Basic data :

#### HD 165688 -- Wolf-Rayet Star

Other object types: \* (Ref,HD,...), WR\* (NR,WR), IR (2MASS,SSTGLMC), Em\* (Hen), V\* (Ref), X (2XMM) ICRS coord. (ep=J2000) : 18 07 56.9612003141 -19 23 56.866361615 (Optical) [ 0.0479 0.0406 90 ] A 2018vCat.1345....0G FK5 coord. (ep=J2000 eq=2000) : 18 07 56.9612003141 -19 23 56.866361615 ( 0.0479 0.0406 90 1 FK4 coord. (ep=B1950 eq=1950) ; 18 04 59.6493172659 -19 24 25.088719244 [ 4.5003 3.9502 90 ] Gal coord. (ep=J2000) : 010.8000508777768 +00.3944248835444 [ 0.0479 0.0406 90 ] 0.787 -1.732 [0.090 0.079 90] A 2018yCat.1345....0G Proper motions mas/yr : Parallaxes (mas): 0.6036 [0.0425] A 2018yCat.1345....0G WN5-6b C 1996MNRAS.281..1638 Spectral type: Fluxes (8) : II 10.46 [~] C 2002vCat.2237....0D B 10.31 [~] C 2002yCat.2237....0D V 9.87 [~] C 2002yCat.2237....0D R 9.85 [0.02] D 2012yCat.1322....0Z G 9.2064 [0.0006] C 2018yCat.1345....0G T 7 118 (0 018) C 2003#Cat 2246 0C H 6.716 [0.027] C 2003yCat.2246....OC K 6.223 [0.024] C 2003yCat.2246....0C







#### Identifiers (22) :

An access of full data is available using the icon Vizier near the identifier of the catalogue

ID 165688	Hen 3-1594	MR 83	UCAC4 354-117192
ALS 4678 🕮	HIC 88828	PPM 718808 🕮	WR 110
BD-19 4854 🕮	HIP 88828 🕮	SETGLMC G010.8000+00.3943	2XMM J180756.9-192356
CPD-19 6469	JP11 2931	TYC 6259-2666-1	Gaia DR2 4095125220807894400
GEN# +1.00165688	LS 4678	UBV 15399	
GSC 06259-02666	2MASS J18075695-1923568	UCAC2 24414003	

References (137 between 1850 and 2019) (Total 137) Similad bibliographic survey began in 1850 for stars (at least bright stars) and in 1983 for all other objects (outside the solar system). Sim Follow new references on this object

- Reference summaries :
- from: 1850 to: \$currentYea

Display or select by : (not exhaustive, explanation here) In table Title/Abstract/Keyword Score

#### **Collections of Measurements**

distance: 2 PM: 3 PLX: 3 MX: 5

display selected measurements display all measurements clear

## Collect and combine data



Different methods to access data on different astronomical archives

homogenize — e.g. cone-search

## Cross-matching

- Positional cross-correlation of sources in 2 tables (VizieR tables, simbad, user uploaded lists)
- Result in different formats (VOTable, CSV or ASCII)
- Programatic access too (http API)
- New developments for a multi-catalogue cross-match

Then, choose cross-match meth Electric click on Design the X M	oos-match. od and sky area in options.				
Finally, click on Begin the X-Ma	ten to taunen the computation.				торсат
Choose tables to cross-match					🖫 🗃 💿 Σ 🐺 🗊 🗖 🌐 🛱 🖨 🗽 🔀 🧭 1/2
e.g. VII/260/dr7qso, or select in	list e.g. VII/233/xsc, or se	elect in list		Table List	Current Table Properties
VILLER SIMBAD My store	VILIER			1: anonymous1541509785	507. Label: anonymous1541509785078.xml
Show options					Location: /Users/angm/Downloads/anonymous1541509785078.xml
					Name: anonymous1541509785078.xml
Begin the X-Match					Rows: 128
					Columns: 12
					Sort Order: 1
Visualize and manage your cros	s-match jobs				Row Subset: All
					Activation Actions: 0 / 0
List of X-match jobs					
List of X-match jobs Table 1 Table 2	Options	Begin Status	Actions		CAMD

# Cross-matching

### Performance, radius 5"

Table 1	Table 2	Computation time	Result generation	Result size	Total time
SDSS DR9 469M rows	<b>2MASS</b> 470M rows	3 min	7 min	19 GB	10 min
<b>2MASS</b> 470M	<b>GAIA-DR1</b> 1.1 billion	16 min	65 min	193 GB	81 min
<b>Tycho-2</b> <i>2M</i>	SIMBAD 8M	6 sec	25 sec	1 GB	35 sec
List of 40k positions	SIMBAD 8M	1 second	4 seconds	10 MB	5 sec

Add the time as a possible information to cross-matches?

- Characterisation and classification of sources on the basis of their variability
- Multi-wavelength/messenger approach is (sometimes) needed
- Follow-up observations & reaction time for that can be crucial
- Visualisation & navigation thought the data
- Analysis of variance of phenomena
- Coordination & transmission of information
- Follow-up observations & reaction time
- Coordination of observations
  - Where & when?
  - Multi-national collaborations
  - Planning observations
  - Transmission of events

## Planning observations: visibility services

+ES+ Southern Observatory	ESO — Rearthing New Heights in Astronomy	XMM-NEWTON MULTI-TARGET VISIBILITY CHECKER	ISAAC	NEWTON GROUP OF TELESCOPES
¥	━ ▮ ⊇ 羊 〓 ▮ ■ ■ ■ ■ ■ ■ ● ₩ ※ 🕺 😐	YOU CAN LOOKUP SIMBAD OR NED AGAIN, OR RUN THE VISIBILITY CHECKER USING THE RESULTS RETURNED BELOW	About ING	▼ Astronomy ▼ Developments ▼ Public Information ▼ Search:
Dublio Science	Hundred Contract Ritellion Contract	Target Name M31 (eg: Abel 170)	Home > Astron	nomy > Object Visibility
Public Science	User Pontal Contact She Map Search Contact Sh	SIMBAD Lookup NED Lookup		
Science Users Information	g wal boo weadyes > doering ind and denies > deeloanse > doerineng	Prese note: there is a du second timeout shows on neur not negotine.		Object Visibility – STARALT
Observing Facilities	Object Observability		Staralt is a pro altitude against	ogram that shows the observability of objects in various ways: either you can plot it time for a particular night ( <b>Starait</b> ), or plot the path of your objects across the sky for out ( <b>Starzet</b> ), or club how altitude changes over a vear ( <b>Starohs</b> ) or cet a table with
Observing with ESO Telescopes	See also: Opert Cosevability - Armasses - Lany Armana: - Sny Calendar The two investee when two weather takes have in a site of the original state and obtaining period. Times are given for the local time, including daylight saving times when applicable	SIMBAD LOOKUP RESULTS:	the best observat the bottom of	ving date for each object (Starmult). For further information, click on the "help" button of the page.
Policies and Procedures	In the provides operation of a second or and operation of the press of	If you are happy with these results, complete the "Visibility Details" and Submit	212	ANTON SERVICE ADDING
Telescope Time Allocation	Delet site, object coolunates and observing period, and press compare.	TARGET DETAILS	Mode	Staralt V
Phase 2 Preparation		Target Name [M31 Target name or identifier for output (eg. Abell 1750) RA (00.42.44.330 Decimal degrees or HH MM:SS.S (eg. 13.39.52.5)	Night	12 October  2017 or date when the local night starts. Staralt, Startrack only.
Phase 3 Duble Survey	Site: Paranal Observatory (VLT)	Dec +41:16.07.50 Decimal degrees or DD/MM:SS S (eg: -01.50.27.0)		La Silla Observatory (Chile)
Observing Tools and Services	Pates (yyyy mm dd): From: 2017 10 20 To: 2017 11 15	VISIBILITY DETAILS	Observatory	Longitude(°East) Latitude(°) Altitude(metres) UTC offset(hours) Ex: 289.2767 -30.2283 2725 -4
ESO ETC's	Object Coordinates (J2000)	Select either Revolution Range @First Revolution 3369 default is A017 revolution range: 3369 to 3551		
Instrumental Characteristics Archives and Catalogues	RA: 05 23 34.5 Dec: -69 45 22	Last Revolution (3551		Formats can be any of these: name hh mm ss ±dd mm ss
27 Calendars and Calculators	compute	Date Range D From Date 01 May 2018 default is A017 range: 01 May 2018 - 30 Apr 2019 To Date 30 Apr 2019		name hh:mm:ss ±dd:mm:ss name ddd.ddd dd.ddd name must be a sincle word with no dots, avoid using single numbers. Every entry
Weather Images Astroclimatology	Cluster resulted to resilter of lots Terretenson Datmith College (dr. TerretensonRetermith et)	Minimum visibility 5000 (minimum time the bin must be visible. Defsult is 5000 s)		must be in the same format, do not use different formats with different entries. We recommend a maximum of 100 targets per submission.
Meteo Information	20/Udit pluvided by cutilities of dutili fillutatenees, parendoni opergeovinis, intrateneergoerendosisoon	Submit	Coordinates	50.0 -70.2
Visiting Astronomers		YAM-NEWTON A017 TARGET VISIBILITY CHECKER	Altitudes, La	/ Silla Observatory 289,2700E -29,2567N, 2347 m above sea level
Science Software Data Handling and Products		AMMENTED ON AUT TANGET TOULETT CHECKER	עז Moon (dashed):	S.set Twill S.nse r→2 <sup>th</sup> / <sup>2</sup>
Science Archive Facility		VIEWING CONSTRAINTS FOR XXMM-NEWTON	Coordinates: 8 <sup>h</sup> 4 <sup>m</sup> +18°15	1 Object 50.00° -70.20°
Science Activities		Visible comers Bin Size Solar Append Min Earth Arge	Quarter: 4	
See also <u>Object Observability</u> - <u>A</u> i	imasses - Daily Almanac - Ephemendes	All four 2' x 2' 70'- 110' 42'	Numbers below cu	70°
Observability for 05	23 34.5 -69 45 22 The USO Slav Calendan Teal	SEARCH CRITERIA FOR ALL TARGETS	are Moon distance (in degrees) at th corresponding	e 60°
P1 Observatory (ULT)	The ESO Sky Calendar 1001	Ibit         Start Only         End Only         <	times.	5
Paranal Observatory (VL1)			4	
RA & dec: 5 23 34.5, -6	69 45 22, epoch 2000.0	Targets that are only visible for a small fraction of an onlyt are only visible at the start or end of a revolution (see columns Visibility StartEnd Place) and therefore have a higher likelihood for increased hashgoound radiation.	2417	
Site long⪫: +4 41 36.8 (n.m	a.s) West, -24 37 30 North.	HEARCH RESULTS PER TARGET		100
Shown: local eve. date, moon pn (2) natural center of night, ar	.ase, hr ang and sec.z at (1) eve. twilight, and (3) morning twilight, then comes number of	Target Name RA Dec M31 10.6647 41.2667		30"
nighttime hours during which ob Night (and twilight) is defined	jget is at sec.z Less than 3, 2, and 1.5. ad by sun altitude < −18.0 degrees.	Rev.         Vis. Start         Vis. Window         Vis. End         Rounded Vis. (s)         Visibility         Visibility         Start Aspect         Meas Astronomical           (tytys-em-dd httmm)         Duation (s)         (tytys-em-dd httmm)         Rounded Vis. (s)         Start Phase         End Phase         Angle(')         Position Angle(')		209 100-
Date (eve) moon eve	cent morn night hrs@sec.z:	338/         2014/d6/2012/58         27036         2014/06/28 10/29         26000         0.76         0.92         71.3         74.2           3386         2014/d6/20 12/40         78126         2014/d6/20 11/21         78000         0.47         0.92         72.8         72.8		
HA sec.z 2017 Nov 3 F -6 52 3.1	HA sec.z HA sec.z <3 <2 <1.5 -2 45 1.6 +1 21 1.5 8.0 6.0 3.3	398         2016-07-01         12-42         78063         2016-07-02         75000         0.47         0.92         /4-2         /1.3           3400         2016-07-02         2016-07-02         0.92         0.47         0.92         7.5         70.6		
2017 Nov 17 N -5 44 2.4	-1 49 1.5 42 07 1.5 7.8 6.7 3.8	3401         2016-07-05 12:29         77054         2016-07-06 10:06         75000         0.47         0.92         77.3         69.5           3402         2016-07-07 12:22         777.15         2016-07-06 19:58         75000         0.47         0.92         78.8         66.5		0° 1 E
SkyCalc provided by courtesy of	i John Thorstensen Dartmouth College John Thorstenson@dartmouth.edu	3403         2016-071-06         78002         2016-071-10         75000         0.47         0.93         80.4         67.4           3404         2016-071-11         2016-071-12         2016-071-12         75000         0.47         0.93         80.4         66.3		19 20 21 22 23 24 1 2 3 4 5 6 Mean Solar Zone Time, starting night 12 10 2017
any care provided by councey or a	John The School Databased Concerc.	A 101 00 4 0 4 0 4 0 4 0 4 0 4 0 4 0 4 0		Processed: 2017/10/12 at 10:21:34 UT, lease Newton Group of Telescopes, La Palma,

Different services have different inputs / outputs Facilitate the work by having same inputs / outputs

### Planning observations: coordination of observations



#### Schedule for revolution 1872

(this list is also available in csv-format, click here to download)

Rev	Start time (UTC)	End time (UTC)	Exp. time (s)	Target	Ra (J2000)	Dec (J2000)	Pattern	PI	Proposal	Observation	Note
1872	2017-10-10 13:29:15	2017-10-10 17:10:51	12600	Gal. Bulge region	17:45:36.00	-28:56:00.0	HEX	Erik Kuulkers	<u>1420001</u>	1420001 / 0022	Publ
1872	2017-10-10 17:13:34	2017-10-11 07:55:55	50000	Galactic Center	17:52:11.21	-25:21:49.7	5x5 Seq	Joern Wilms	<u>1420009</u>	1420009 / 0011	
1872	2017-10-11 08:16:46	2017-10-11 11:58:32	12600	Galaxy (I=0, b=0)	17:42:23.76	-29:38:02.4	<u>HEX</u>	Rashid Sunyaev	<u>1420021</u>	1420021 / 0039	
1872	2017-10-11 12:26:36	2017-10-11 12:56:36	1800	Galaxy (I=0, b=-30)	20:02:16.80	-41:20:31.2	HEX	Rashid Sunyaev	<u>1420021</u>	1420021 / 0038	
1872	2017-10-11 13:27:21	2017-10-11 14:29:17	3600	Galaxy (I=0, b=-30)	19:59:40.80	-41:05:16.8	<u>HEX</u>	Rashid Sunyaev	<u>1420021</u>	1420021 / 0040	
1872	2017-10-11 15:00:12	2017-10-11 17:38:07	9000	Galaxy (I=0, b=-30)	19:59:40.80	-41:05:16.8	HEX	Rashid Sunyaev	<u>1420021</u>	1420021 / 0040	
1872	2017-10-11 18:41:00	2017-10-12 08:01:56	45000	GRS 1915+105	19:15:11.79	+10:56:45.7	5x5 Seq	Jerome Rodriguez	<u>1420029</u>	1420029 / 0008	
1872	2017-10-12 09:06:18	2017-10-12 12:47:54	12600	Galaxy (I=0, b=0)	17:50:46.80	-28:55:30.0	<u>HEX</u>	Rashid Sunyaev	<u>1420021</u>	1420021 / 0041	
1872	2017-10-12 13:16:06	2017-10-12 14:49:58	5400	Galaxy (I=0, b=-30)	20:07:12.96	-40:00:10.8	HEX	Rashid Sunyaev	<u>1420021</u>	1420021 / 0042	



#### XMM-NEWTON SHORT-TERM SCHEDULE

The Short-term Schedule gives an overview of scheduled observations covering the time range from the past week until the up

Background: The planning and scheduling procedure is described in Sect. 8.2 of the Policies and Procedures. In addition, the process of scheduling XMM-N characterizer is described in A crited into the scheduling of an XMM Number scheduling.

Description: Each rew lists the revolution number (REV#), Observation identifier (OsaID), target name, pointing coordinates plus position angle (PA), start and stop times, prime instrument, accumulated exposure times (in kiloseconds) for each instrument (without overhead), and name of the Principal investigator (PI). The start and stop times in the start is not stort meet to be instrument. Expectially for effect to the instrument activities required to perform the observation. The exposure times are accumulated over all exposures times in the starts instrument. Expectially for the start to the instrument. Expectially for the start of the start Off, the observation can be solid in shorter exposures with different filterimode. EPIC exposure times in brackets indicate that one or all exposures use the closed filter. Det an be seen when clicking on the ObsID The row marked in blue indicates the target that is scheduled for the time of the last table update. The creation date is given at the top of the table.

Caveats: The scheduling of an XMM-Newton revolution may have to be revised (see Sects, 8.2, 8.3, and 5.2.2 of the Policies and Procedures). Continger solar flaring activity may impact at different levels the scheduled programme. The Observation Log Boweer can be checked to see what was actually don

Update frequency: Every 8 hours or when the schedule is updated (new revolution planned or any existing updated). The latest available version can be view the browser buffer from the contents of any previous sessions.

Last updated on: 2017-10-10 12:42:00 UT (Current Rev = 326)

Revn #	Obs Id.	Target Name	RA hh:mm:ss	DEC dd:mm:ss	PA ddd.dd	UTC Obs Start yyyy-mm- dd hh:mm:ss	UTC Obs End yyyy-mm- dd hh:mm:ss	Prime Instr.	PN Dur Ks	MOS1 Dur. Ks	MOS2 Dur. Ks	RGS1 Dur. Ks	RGS2 Dur. Ks	OM Dur. Ks	PI
3276	0805150401	ESO 018-G009	08:24:07	-77:46:57	88.63	2017-10-29 19:34:26	2017-10-30 00:54:26	EPIC	16.7	18.1	18.1	18.2	18.2	18.0	Peter Boorman
3276	0801870801	HD 81809	09:27:46	-06:04:17	92.00	2017-10-29 15:00:13	2017-10-29 18:20:13	EPIC	9.5	10.9	10.9	11.0	11.0	10.8	Fabio Favata
3276	0561381201	zeta Puppis	08:03:40	-40:00:36	112.00	2017-10-29 01:21:41	2017-10-29 14:08:21	RGS	44.5	44.9	44.9	45.0	45.0	37.3	Fred Janse XMM- Newton Mit
3276	0803950401	SDSS 102714.77+35431	10:27:14	+35:43:17	119.93	2017-10-28 15:44:35	2017-10-28 23:31:15	EPIC	25.5	26.9	26.9	27.0	27.0	26.8	Guido Risaliti
3276	0803240201	J072637.95+394558.0	07:26:37	+39:45:58	91.37	2017-10-28 11:02:32	2017-10-28 14:55:52	EPIC	11.5	12.9	12.9	13.0	13.0	12.9	Nathan Secrest
3275	0801990201	0457-6739	04:57:33	-67:39:06	136.67	2017-10-27 12:22:47	2017-10-28 01:07:47	EPIC	43.4	44.8	44.8	44.9	44.9	43.7	Patrick Kavanagh
3275	0801990401	0449-6903	04:49:34	-69:03:34	138.62	2017-10-26 23:32:47	2017-10-27	EPIC	42.5	43.9	43.9	44.0	44.0	42.8	Patrick Kavanagh
3275	0803952601	SDSS	08:26:19	+31:48:48	101.78	2017-10-26	2017-10-26	EPIC	36.0	37.4	37.4	37.5	37.5	37.3	Guido



#### Observing schedules

#### Short Range Observatory Schedule Download

This is the confirmed schedule of NuSTAR observations. This sequence of observations has been uploaded to the spacecraft and will execute is to contain the second The times reported here are the start and end of the on-target period (days of year UTC). The estimated exposure time takes into account Earth occutation and the SAA passage time where detector background is increased. The end time of the observation is the start of the slew to the next target. These examines the VSTAA R-Flown Timeline (LTP) for the log of past observations.

obs start	obs end	sequenceID	Name	J2000 RA	J2000 Dec	Exp	Notes
2017:281:19:05:02	2017:283:00:30:00	90201021006	Kepler	262.671620	-21.491957	60.6	DDT
2017:283:01:11:23	2017:283:02:40:00	90311211001	Sol_17282_AR2683_POS11	195.15715	-6.38520	3.4	ToO
2017:283:02:40:32	2017:283:04:20:00	90311212001	Sol_17282_AR2683_POS12	195.21879	-6.41062	3.4	ToO
2017:283:04:20:32	2017:283:05:50:00	90311213001	Sol_17282_AR2683_POS13	195.28046	-6.43604	3.4	ToO
2017:283:06:55:11	2017:284:09:20:00	60376001002	2MASXJ19301380p3410495	292.557500	34.180500	55.3	Extragalactic Legacy Survey
2017:284:09:45:09	2017:284:20:35:00	60360008002	SDSSJ152132d21p391206d9	230.3874232	39.2007671	22.0	Extragalactic Legacy Survey
2017:284:21:10:03	2017:285:21:00:00	90301320002	NGC_6440	267.218083	-20.358944	49.5	ToO
2017:285:21:20:06	2017:286:08:20:00	30302020004	GRS_1915p105	288.79813	10.94578	21.9	(2/4) coordinated with XMM and VLT
2017:286:08:35:06	2017:286:19:30:00	60160701002	2MASXJ18560128p1538059	284.00210000	15.63200000	23.3	BAT AGN
2017:286:20:05:11	2017:287:15:05:00	60376007002	UGC06728	176.316800	79.681500	61.4	Extragalactic Legacy Survey
2017:287:15:50:11	2017:288:03:20:00	60368001002	NGC_1144	43.80083	-0.18361	22.0	
2017:288:04:05:09	2017:288:23:00:00	60301004002	ESO_103m35	279.58458	-65.4275	50.3	
2017:288:23:30:08	2017:290:05:45:00	30301026002	AX_J1841d0m0536	280.25179	-5.59625	59.7	phase constrained
2017:290:06:00:04	2017:290:17:00:00	60160670002	2E1739d1m1210	265.47600000	-12.19700000	23.5	BAT AGN
2017:290:17:15:01	2017:291:04:20:00	30363001002	GX_3p1	266.98333	-26.56361	21.8	

Long Range Observatory Schedule Download

This is the latest NuSTAR long-term schedule. Observations have been sorted into one-week intervals, taking into account Sun, Moon, required exposure time, and other constraints. So the date is the Monday of the week in which the observation is scheduled to begin E.g. An observation with a date 2017-12-18 in this table is scheduled to have the observation starting sometime between 2017-12-18

0000Z and 2017-12-25 0000Z. Currently the schedule is driven by the large number of observations coordinated with other observatories and the need to complete the NuSTAR

Currently the schedule is driven by the large number of observations coordinated with other observationes and the neet to complete the hub / a Guest Observer programs. The exposure goal for targets allotted within one week may appear to fill more then the available NuSTAR exposure time in that week (average is 330 ks per week) but many observations start in one week and complete in the following week.

Targets of opportunity and any instrument or spacecraft anomalies may also cause the observing times of targets to shift. This long-term schedule is our present estimate of the future order of observations. Please be aware of the uncertaintie

ToO = Target of Opportunity DDT = Directors Discretionary Time N03 = NuSTAR GO cycle-3 115 = INTEGRAL GO cycle-15 X16 = XMM-Newton GO cycle-16 C18 = Chandra GO cycle-18 ELS/GLS = Extragalactic/Galactic legacy surveys

#### 09-Oct-2017 18:48:29 --- Preliminary EST Observing Timeline Report for SMS: 172888A4 ---SMS Start: 2017.288:22:10:00 (15-OcT-2017 22:10:00), End: 2017.296:00:00:00 (23-OCT-2017 00:00:00) Page

	Scheduling Unit		Principal			Science			Spectral	Exposure			
I	Begin UT End UT	SU Id	Investigat	Exp #	Target	Instrume	Mode	Apertures	Elements	Time(sec)	0B	AL	EX
I	2017.288 23:00:00 23:35:0	1483521	Lockwood	Z1-001	DARK	STIS/MA2	TIME-7	F28X50LP	NIRVIS	1300.00	21	01	01
	2017.288 23:14:45 06:30:5	1476735	Sing	35-001	WASP-69	COS/NUV	ACQ/SE	PSA	G230L	12.00	35	01	01
I	2017.288 23:14:45 06:30:5	1476735	Sing	35-002	WASP-69	COS/NUV	ACQ/PE	PSA	G230L	12.00	35	02	01
	2017.288 23:14:45 06:30:5	1476735	Sing	35-003	WASP-69	COS/NUV	ACQ/PE	PSA	G230L	12.00	35	03	01
I	2017.288 23:14:45 06:30:5	1476735	Sing	35-004	WASP-69	COS/FUV	TIME-7	PSA	G130M	1917.00	35	05	01
I	2017.288 23:14:45 06:30:5	1476735	Sing	35-005	WASP-69	COS/FUV	TIME-7	PSA	G130M	2706.00	35	07	01
I	2017.288 23:14:45 06:30:5	1476735	Sing	35-006	WASP-69	COS/FUV	TIME-7	PSA	G130M	2706.00	35	09	01
I	2017.288 23:14:45 06:30:5	1476735	Sing	35-007	WASP-69	COS/FUV	TIME-7	PSA	G130M	2706.00	35	08	01
	2017.288 23:14:45 06:30:5	1476735	Sing	35-008	WASP-69	COS/FUV	TIME-7	PSA	G130M	2706.00	35	0D	01
I	2017.289 00:00:00 00:28:33	14819JF	Riley	JF-001	DARK	STIS/CCD	ACCUM	F28X50LP	MIRVIS	1100.00	JF	01	01
I	2017.289 00:00:00 00:28:3	14819JF	Riley	JF-002	DARK	STIS/CCD	ACCUM	F28X50LP	MIRVIS	60.00	JF	01	02
	2017.289 00:00:00 00:28:33	14819JF	Riley	JF-003	DARK	STIS/CCD	ACCUM	F28X50LP	MIRVIS	60.00	JF	01	03
I	2017.289 00:00:00 00:46:10	145333B	Bourque	3B-001	DARK-NM	WFC3/UVI	ACCUM	UVIS	F373N	900.00	38	01	01
I	2017.289 00:00:00 00:46:10	145333B	Bourque	3B-001	DARK-NM	WFC3/UVI	ACCUM	UVIS	F373N	900.00	38	02	01
	2017.289 00:39:46 01:08:10	14819JG	Riley	JG-001	DARK	STIS/CCD	ACCUM	F28X50LP	MIRVIS	1100.00	JC	01	01
I	2017.289 00:39:46 01:08:10	14819JG	Riley	JG-002	DARK	STIS/CCD	ACCUM	F28X50LP	MIRVIS	60.00	JC	01	02
I	2017.289 00:39:46 01:08:10	14819JC	Riley	JC-003	DARK	STIS/CCD	ACCUM	F28X50LP	MIRVIS	60.00	30	01	03
	2017.289 00:46:10 01:32:20	145333C	Bourque	3C-001	DARK-NM	WFC3/UVI	ACCUM	UVIS	P467M	900.00	3C	01	01
I	2017.289 00:46:10 01:32:20	145333C	Bourque	3C-001	DARK-NH	WFC3/UVI	ACCUR	UVIS	F467M	900.00	3C	02	01
I	2017.289 01:27:12 01:56:24	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUM	F28X50LP	MIRVIS	0.00	90	01	01
	2017.289 01:27:12 01:56:2	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUM	F28X50LP	MIRVIS	0.00	90	01	02
I	2017.289 01:27:12 01:56:2-	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUM	F28X50LP	MIRVIS	0.00	90	01	03
I	2017.289 01:27:12 01:56:24	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUN	F28X50LP	MIRVIS	0.00	90	01	04
	2017.289 01:27:12 01:56:2	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUN	F28X50LP	NIRVIS	0.00	90	01	05
I	2017.289 01:27:12 01:56:2	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUM	F28X50LP	MIRVIS	0.00	90	01	06
I	2017.289 01:27:12 01:56:2	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUN	F28X50LP	NIRVIS	0.00	90	01	07
	2017.289 01:27:12 01:56:24	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUN	F28X50LP	MIRVIS	0.00	90	01	08
I	2017.289 01:27:12 01:56:2	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUN	F28X50LP	NIRVIS	0.00	90	01	09
I	2017.289 01127112 0115612	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUN	F28X50LP	MIRVIS	0.00	90	01	OA .
I	2017.209 01127112 0115612	1482190	Riley	90-001	BIAS	STIS/CCD	ACCUR	F28X50LP	MIRVIS	0.00	90	01	0.0
	2017.289 01127112 0115612	1462190	Riley	90-001	BIAS	STIB/CCD	ACCOR	FZGASULP	MIRVID	0.00	90		
	2017.209 01.27.12 01.90.2	1402190	Dilley	90-001	DING	0710/000	ACCOR.	PROADULE	MINUTO	0.00	90		00
1	2017.289 01:27:12 01:56:2	1482190	Piley	90-001	BTAG	9719/CCD	ACCUM	F288501.P	MTPUTC	0.00	911	01	0F
I	2017 200 01.27.12 01.56.2	1492190	Bilow	90-002	BIAG	0710/000	ACCUM	20X5010	MTDUTO	0.00	90		20
I	2017 289 01:27:12 01:56:2	1482190	Biley	90-002	BTAG	9719/000	ACCUM	F288501.0	NTRUTS	0.00	911	01	011
	2017 289 01.40.00 02.09.2	1451920	Colinowski	F0-001	BTAG	NCS /WEC	ACCENT	VEC	PE02N	0.00	20		61
I	10171107 01140100 0110711	1431010	0011004941	10-001	0100	ACO/ HEC	80000	NI C	TEEON	0100		· ·	**
I	2017-289 01-40-00 02-09-2	1451820	Colizovski	F0=002	DARK	MCS/WPC	ACCUM	NEC	P502N	1000.50	FO	01	02
									T660N				
I	2017.289 02:09:22 02:38:5	1451821	Golizowski	F1-001	DARK	MCS/WFC	ACCUM	WEC	P502N	0.50	<b>P1</b>	01	01
1									F660N	0150		- *	
1	2017.289 02:09:22 02:38:5	1451881	Colizovski	F1=002	DARK	MCS/WPC	ACCUM	NEC	P502N	1000.50	<b>P1</b>	01	02
1									F660N				
1													

Oct-2017 18:48:29 --- Preliminary EST Observing Timeline Report for SMS: 172888A4 ---SMS Start: 2017.288:22:10:00 (15-OCT-2017 22:10:00), End: 2017.296:00:00:00 (23-OCT-2017 00:00:00) Page 2

	Scheduling Unit	an 14	Principal	Pero d	Taxaat	Science	Mode	heartures	Spectral	Exposure	0.0		
	begin of the of	30 10	Investigat	www.	rarget	110 CL 0200		Whercares	0.400001150	symptone)	00	~	
													-
2017.289	02:38:56 03:08:18	1451852	Colimowski	F2-001	BIAS	ACS/WFC	ACCUM	WPC	P502N	0.00	22	01	. e
									F660N				
2017,289	02:38:56 03:08:18	14518F2	Golizowski	F2-002	DARK	ACS/WFC	ACCUN	WEC	F502N	1000.50	F2	01	. e
									F660N				
2017 200	03-10-31 03-40-05	1461092	Colimouski	F2 001	DARK	NOR (WEG	A CONTRACT OF	VEC	PEOPH	0.50			
	03110131 03140103		GOTTENDERY'	1 3-001	Lines.	ACO/ NEC	Marchine and	Re C	TECON	0.00			
									10003				
2017.289	03:10:31 03:40:05	1451873	Golimowski	¥3-002	DARK	ACS/WFC	ACCUN	WPC	F502N	1000.50	1.3	01	
									F660N				
2017.289	03:46:00 04:48:35	1483522	Lockwood	22-001	DARK	STIS/MA2	TIME-7	F28X50LP	MIRVIS	1300.00	22	01	. 0
2017.289	03:49:34 05:01:49	1454639	Shanahan	39-001	TUNCSTEN	WFC3/UVI	ACCUN	UVIS1-M512-S	F645N	60.00	39	01	. 0
2017,289	03:49:34 05:01:49	1454639	Shanahan	39-002	TUNCSTEN	WFC3/UVI	ACCUN	UVIS	F814W	2.00	39	01	. e
2017 209	03.49.34 05.01.49	1454639	Chanaban	29-003	71100.07720	MECO/INT	ACCUM	INTO	T430W	360.00	30	01	
2017 200	03.49.34 05.01.49	1454630	Chanahan	20-004	100000100	NECO/UNIT	ACCENT	INITE	PADEM	360.00	20		
1011.100	and a strained	- Callenna	Anananan		- manatika		BLANK.	livia	/ water		- 44		-
D. shale													

### What object has been (or will be) observed when and in which wavelength?

### The study of variability of astronomical objects over different time-scales

- Characterisation and classification of sources on the basis of their variability
- Multi-wavelength/messenger approach is (sometimes) needed
- Follow-up observations & reaction time for that can be crucial
- Visualisation & navigation thought the data
- Analysis of variance of phenomena
- Coordination & transmission of information

### Visualisation & navigation

- sequences of images, spectra, photometry, positions, ... and all interoperable
- tools

### The study of variability of astronomical objects over different time-scales

- Characterisation and classification of sources on the basis of their variability
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### • Analysis of variance

- period search methods
- phase folding, binning, fitting...

### Visualisation of the object/area of interest (Desktop / web)



### **Aladin Lite implementations**



MON Interactive Detection Skymap

### GW170814 interactive skymap



Detection	Sky localisation	Label	Pop-up info
GW170817 - H1 only			•
GW170B17 - L1/H1 only	~		
<u>GW170817 - L1/H1/V1</u>			
GW170B17 - Refined skymap			
GW170817 - (GRB170817A) Initial Fermi GBM localization	×	8	
GW170817 - (GRB170817A) Final Fermi GBM localization		2	
GW170B17 - SSS17a/AT2017gfo Transient sky position			
<u>GW170814 - H1/L1</u>			
<u>GW170B14 - H1/L1/V1</u>			
GW170B14 - Refined skymap			
GW170608 - Refined LIGO localization	•	•	
GW170104 - Refined LIGO localization			
GW151226 - Refined LIGO localization			

#### Background

If you want to see the extension of these sky regions through the constellations you can select an artis background image \_Constellations.

You can also select various background images at different wavelengths, combining the electromagnet data with the gravitational-wave information: 
 Mellinger (default) 
 WISE 2MASS DSS color 
 XMM Fermi



#### ESO Archive Science Portal

- ESA Sky allows for discovery and access of data observed by ESA space missions
- ALMA Science Archive
- GW170814 interactive skymap displays the localisation on the sky of the gravitational wave event jointly
- detected by LIGO and Virgo observatories, and announced in September 2017.
- HEASARC Xamin system for discovery and data retrieval
- · Skymap Viewer shows probability contours for gravitational wave events from LIGO/Virgo
- JVO Portal v2
- · Gamma Sky, a portal to gamma-ray sky (developed by C. Deil and A. Voruganti)
- · SETI uses Aladin Lite to display targets currently observed (development by J. Richards)
- J-PLUS DR1, a portal to access data of the First Data Release of the Javalambre-Photometric Local Universe Survey (J-PLUS)
- CEFCA images navigator and images tours
- ARCHES Walker, an Outreach tool showcasing astronomical objects in different wavelengths (ARCHES project)
- MOPRA Radio Telescope Pointing and Status
- JUDO2 (JAXA Universe Data Oriented)
- Akari explore tool
- CASSIS atlas of Spitzer Infrared Spectra
- GLIMPSE 360
- CADE (Centre d'Analyse de Données Etendues) uses Aladin Lite to provide previews of the HEALPix maps they publish (Example for CGPS data)
- · ADS All-Sky Survey makes use of Aladin Lite to display heatmaps of SIMBAD objects cited in the literature

### Hierarchical visualisation of images and catalogues

- HiPS Hierarchical approach to data
- The more we zoom the more detail we get



Something similar for *time* and treat light-curves in a lite way? Hierarchical approach to light-curves?

### Visualisation of photometric data: photometric viewer







2MASS	AAO	AKARI	Astrosat	BOK	CAHA	CFHT	COBE	CTIO	DENIS	Euclid	GAIA	GALEX	GCPD	Gemir
Generic	Geneva	GTC	Herschel	Hipparcos	HST	IAC80	ING	INT	IRAS	ISO	IUE	JWST	Keck	Keple
KPNO	LasCumbres	LaSilla	LBT	LCO	LICK	Liverpool	LSST	McD	Misc	МКО	MMT	MSX	NIRT	NOAO
NOT	OAF	OAJ	OSN	P200	Palomar	PAN-STARRS	Paranal	SAO	Scorpio	SkyMapper	SLOAN	SOFIA	Special	Spitze
STELLA	Subaru	Swift	TCS	TD1	TESS	OLL	TNG	TNO	ТҮСНО	UKIRT	VATT	WFIRST	WHT	WISE
WIYN														



Mouse position: Wavelength : 1.46e+1 µm Frequency : 2.05e+4 GHz Energy : 8.49e-2 eV Flux density or F(v) : 2.13e+0 Jy VF(v) : 4.38e-13 W.m<sup>-2</sup> F(\lambda) : 3.00e-11 erg.s<sup>-1</sup>.cm<sup>-2</sup>.µm<sup>-1</sup>



SLOAN filters:

Filter ID	λ <sub>mean</sub>	λ <sub>eff</sub>	λ <sub>min</sub>	λ <sub>max</sub>	W <sub>eff</sub>	ZP (Jy)	Obs. Facility	Instrument	Description
SLOAN/SDSS.u	3561.8	3594.9	3048	4028	558.4	1568.5	SLOAN		SDSS u
SLOAN/SDSS.g	4718.9	4640.4	3783	5549	1158.4	3965.9	SLOAN		SDSS g
SLOAN/SDSS.r	6185.2	6122.3	5415	6989	1111.2	3162.0	SLOAN		SDSS r
SLOAN/SDSS.i	7499.7	7439.5	6689	8389	1044.6	2602.0	SLOAN		SDSS i
SLOAN/SDSS.z	8961.5	8897.1	7960	10833	1124.6	2244.7	SLOAN		SDSS z

Filter Plots



Implement something similar for time — A time (series) viewer Need to annotate time properly

# Time Series visualisation tools

	Select a collection MAST Observations by Object Name of About Collections	r RA/Dec Y BD+19 706			Search 💩			Login	anonymous			
						Timeseries Vie	ewer		×			
	岌 Upload Target List 🛛 📥 My	Dow	nload Bas	sket: 0 files	User Manua	Configuration		«	3.96004	· · ·	Legend	
Home Page 🖌	MAST: BD+19 706 🛞				Time			3.87391 -			EVEREST_210780956_C04_Raw EVEREST_210780956_C04_Corrected	
554 Total Rows NGC 1555, radius: 0.20000° 📾 🔀 🔛 🔝 🗱 🦉							70.878					
Filters	<b>«</b>		💷 List View 📃 Album View									
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	(000)		6	<b>**</b>	PS1				0.000	44.176 28.351 42.527 56.702 70.878		
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	(165 of 165		0	<b>D</b>	DC 1	CDC1	DC1					
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PS1	(25 of 25		10	<b>***</b>	PS1	GPC1	PS1	z	+			
Chaur 2 Mars	·		11	<b>P</b>	PS1	GPC1	PS1	g				
iavascript: void(0)												

# Time Series visualisation tool - Firefly



# □ Time Series view (Aladin)



- For all catalogues available through Aladin + users
- Measurements as a function of time
- Simultaneously visualize the catalogue positions in the sky
- Background image can be any available through Aladin + users

# □ Time Series view (Aladin)



<sup>(</sup>c) 2018 Université de Strasbourg/CNRS - developed by CDS, distributed under GPLv3

0 sel / 3375 src 4 views 455Mb 📡

- Characterisation and classification of sources on the basis of their variability
- Multi-wavelength/messenger approach is (sometimes) needed
- Follow-up observations & reaction time for that can be crucial
- Visualisation & navigation
- Analysis of variance of phenomena
- Coordination & transmission of information
- Coordination & transmission
  - collect what was observed, when, in which wavelength
  - alerts, emails, webpages, references,...
- Communication and sharing in time domain multi-messenger astronomy is needed
  - If this is a must then lets get together and do it together as a community
  - This is exactly the vision of the VO (my point of view)

### What are the Time Domain challenges in the VO

- Display measurements as a function of time
- Simultaneously visualize single-epoch images
- Combine it with other data (description of time)
- Find the period of variability
- Combine spatial and temporal coverages
- Coordination and transmission of information
- ➡ The principle of the VO and the IVOA is to help the user to share information
- Using standards is very helpful and it works (all astronomers use it even if they don't know it!)
- It is not one tool to govern them all
- ➡ We work in international collaborations and everyone can join

# Useful links

- IVOA: <u>http://ivoa.net/</u>
- Time Domain Interest Group: <u>http://wiki.ivoa.net/twiki/bin/view/IVOA/IvoaVOEvent</u>
- List of available VO applications and VO-compliant Tools & Services for astronomers: <u>http://ivoa.net/astronomers/applications.html</u>
- IRSA Time Series viewer <u>https://irsa.ipac.caltech.edu/irsaviewer/timeseries</u>
- More tutorials on VO services & tools:

http://www.euro-vo.org/?q=science/scientific-tutorials