

# The Legacy of EXOSAT

#### Arvind Parmar EXOSAT Duty Scientist

#### 25 May 2018

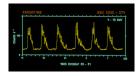
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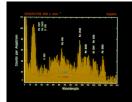
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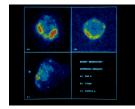
### **EXOSAT Data Products**

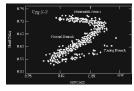
- Observatory's Automatic Analysis
- Observatory's Interactive Analysis
- Publications and the Scientific Legacy
- ESAC Science Archive











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#### EXOSAT – The "Raw" Data FOTs



On 6000 12" magnetic tapes, converted to Exabytes. Now part of the ESAC archive. Tapes were mailed to observers for them to decode with the help of the FOTH – Julian Sternberg

Target Name	RA	DEC	Obs. Start	Obs. End	FOT No. FOT ID Type	Exp.
CYGNUS X-1	23 21 00	+58 32 30	20-JUN-1983 20:22	23-JUN-1983 07:29	2 EE5226 L2	212872
CYGNUS X-1	23 21 00	+58 32 30	20-JUN-1983 20:22	23-JUN-1983 07:29	3 EE5231 GS	212872
CYGNUS X-1	23 21 00	+58 32 30	20-JUN-1983 20:22	23-JUN-1983 07:29	4 EE5223 L1	212872
CYGNUS X-1	23 21 00	+58 32 30	20-JUN-1983 20:23	23-JUN-1983 07:29	5 EE5228 ME	212760
N CYG X-1	23 21 00	+58 32 30	21-JUN-1983 14:00	22-JUN-1983 14:05	6 EE2856 ME	86728
CYG X-1	23 21 00	+58 32 30	21-JUN-1983 14:00	22-JUN-1983 14:09	7 EE1722 GS	86968
CYG X-1	19 56 17	+35 03 53	21-JUN-1983 20:00	22-JUN-1983 08:59	8 EE2383 L1	46792
CAS A	23 21 00	+58 32 30	23-JUN-1983 11:02	23-JUN-1983 23:58	9 EE3003 ME	46616
CAS A	23 21 00	+58 32 30	23-JUN-1983 11:02	23-JUN-1983 23:58	10 EE3016 ME	46616
CAS A	23 21 00	+58 32 30	23-JUN-1983 11:02	24-JUN-1983 18:39	11 EE5046 ME	113872

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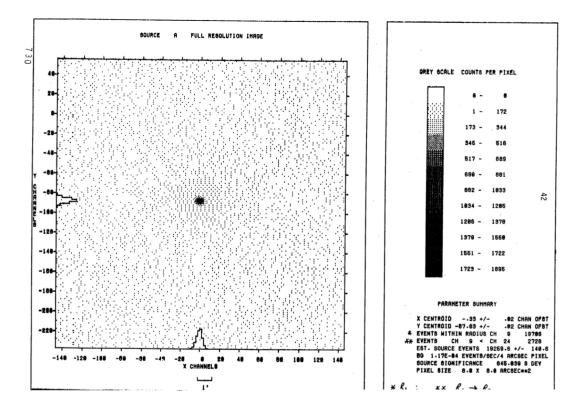
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## EXOSAT Science – The Automatic Analysis



- This produced pages of hard copy which was mailed to observers once the data had been processed in the SOC.
- It provided an overview of an observations, but did not normally provide "science ready" output.
- Limitations as it was too generic and did not have the latest calibration or background subtraction techniques etc



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- This ran on the Observatory's HP computers using the RTE operating system (16 bit) and was written in HP Fortran.
- It allowed visiting astronomers to obtain "science ready" products spectra, images and lightcurves for all three instruments.
- It was not made publicly available at the time, probably because it used the RTE operating system which was not popular (VAX VMS was the standard then) and was the initiative of some of the observatory astronomers.
- During post-operations in the late 1980's at ESTEC it was ported to HP-UX by Uwe Lammers and then to a more generic Unix and made available to users.
- With the end of post-operations, there was no more support available and the code was not updated to keep operational.

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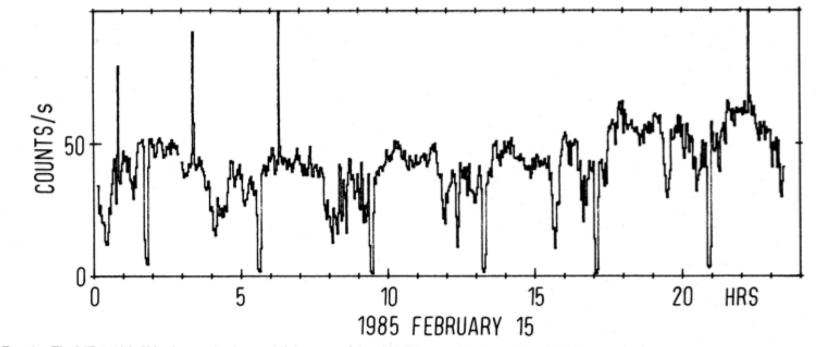


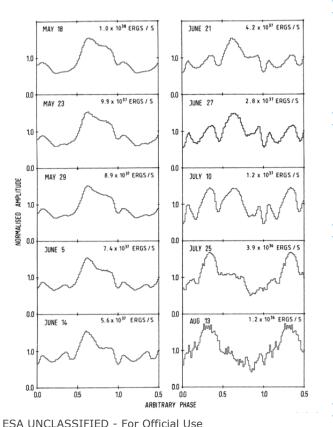
FIG. 1.—The ME 1–10 keV background subtracted light curve of the 1985 February 15 observation of EXO 0748-676 plotted with a time resolution of 125 s. Periodic eclipses, irregular intensity dips, and four X-ray bursts are visible.

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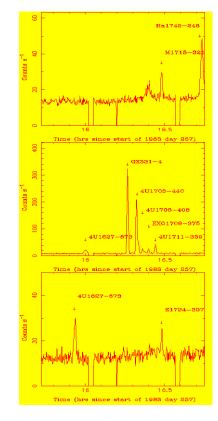
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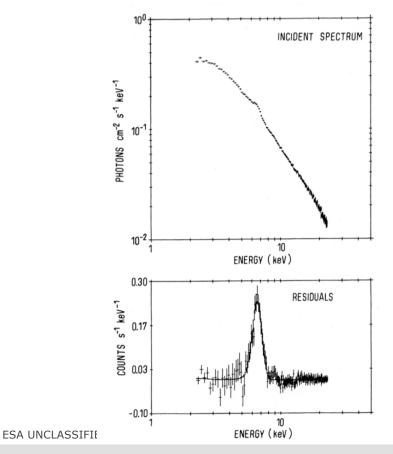
- A key to EXOSAT's success was its real-time nature and IA feedback into the flexible observing programme.
- The figure left shows the pulse profiles of a transient 42 sec pulsar discovered during a maneuver (the ME was kept on during slews).
- 10 observations of EXO2030+375 as its X-ray flux decayed by a factor of 100 with accompanying changes in the pulse profile which were modelled as a gradual change from fan-beam to pencil-beam dominated emission.

Not sure you could do this today!







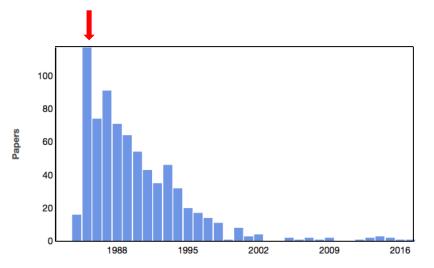


- No "standard" data formats or tools at the time.
- Nowadays 99% of users use a GSFC tool called XSPEC for spectral fitting.
- The EXOSAT observatory had its own spectral fitting program called ESPEC and own data file formats.
- It all worked! (But eventually all the files were converted to FITS to allow the use of "standard" astronomical software tools.
- Used to generate standard products for the eventual archive such as ME lightcurves with 30 sec time resolution, integrated spectra etc

### **EXOSAT Science - Publications**



There are 739 refereed papers that used EXOSAT data. You can find the list of papers under <u>https://www.cosmos.esa.int/web/guest/mission-publications</u>.



The peak year for publications was 1985 with 117 papers (16%) and the rate decreased pretty linearly until about 2000. 15 years of science exploitation!

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### **EXOSAT Science – Papers**



Country	First Authors	
GB	164	
IT	93	Excludes ESA authors
DE	85	
NL	65	
FR	20	
USA	97	

80% of the papers had first authors from today's ESA Member States. Science today is more cosmopolitan, with typically 50-60%.

65% of the publications were in three journals: ApJ, A&A and MNRAS ESA UNCLASSIFIED - For Official Use
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## EXOSAT Science – Who were the Culprits?



Author	Papers
N. White	61
M. Van der Klis	51
A. Parmar	49
J. Van Paradijs	41
L. Stella	40
P. Giommi	39
G. Tagliaferri	35
K. Mason	33
W. Lewin	28
G. Branduardi-Raymont	25

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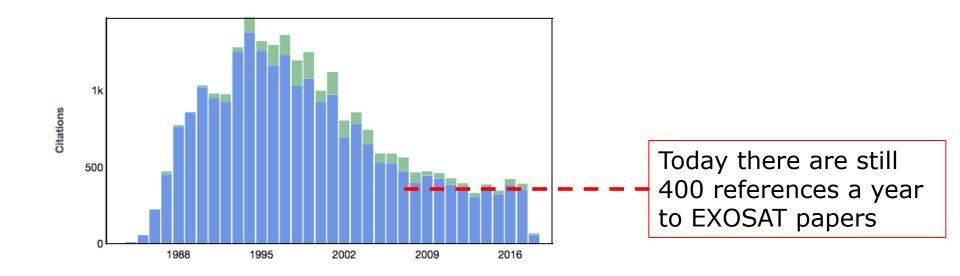
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#### The Science - Citations



The citations – references to the EXOSAT publications and perhaps a better measure of the "quality" of a paper – have continued for much longer:



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#### **EXOSAT Science - Citations**



- > There are 25,000 citations to the EXOSAT papers in the scientific literature.
- Only 10% of these are citations by the other EXOSAT papers ("self citations"), demonstrating the importance of EXOSAT to the rest of astronomy.
- > 500 of the 739 papers have at least 10 citations
- A remarkable 45 papers with at least 100 citations (normally taken as a measure of a very influential paper).

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### **EXOSAT – The Most Influential Papers**



1 🗌	1989A&A22579H <b>Two patterns of correlate</b> <b>binaries.</b> Hasinger, G.; van der Klis, M		cited: 722 d spectral behavio	aur in	i≣ Iow-m	Sass X-ray
2 🗌	1989MNRAS.240833T The EXOSAT spectral sur Turner, T. J.; Pounds, K. A.	1989/10 vey of AGN.	cited: 560		≣	
3 🗌	1989PASJ411N Accretion-powered X-ray Nagase, F.	1989 <b>pulsars.</b>	cited: 553		≡	
4 🗌	1993ApJ412479D A Catalog of Intracluster David, L. P.; Slyz, A.; Jones		cited: 496		≣	
5 🗌	1991MNRAS.252414E EXOSAT observations of Edge, A. C.; Stewart, G. C.	1991/10 clusters of galaxie	cited: 357 es - I. The X-ray d	∎ ata.	≣	

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**European Space Agency** 

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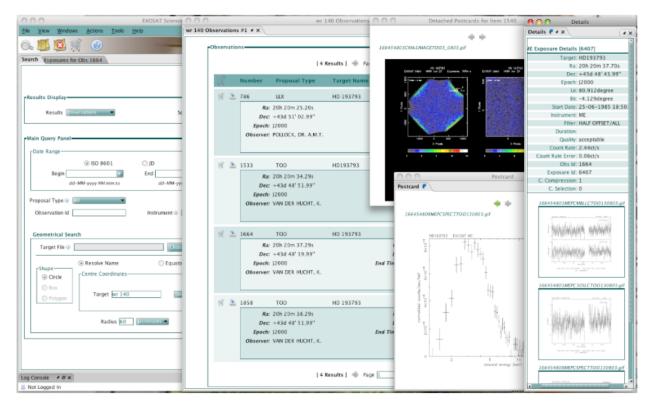


- There are 1100 unique author names for the EXOSAT publications – a crude measure of the size of the community using the mission (maybe 30% overestimate)
- EXOSAT helped ensure that the European high-energy community was ready, via Rosat and BeppoSAX, to scientifically exploit ESA's next X-ray observatory: XMM-Newton.
- By the time XMM-Newton had 5,000 papers, this community had grown to 12,000 unique names.

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### EXOSAT Science Archive at ESAC





#### Archive Scientist: Andy Pollock

Major Advantages: comprehensive, contains "science ready" products and its ease of use

Major Disadvantage: Contains "standard" products only – hence the need for the IA

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#### The Interactive Analysis - Today



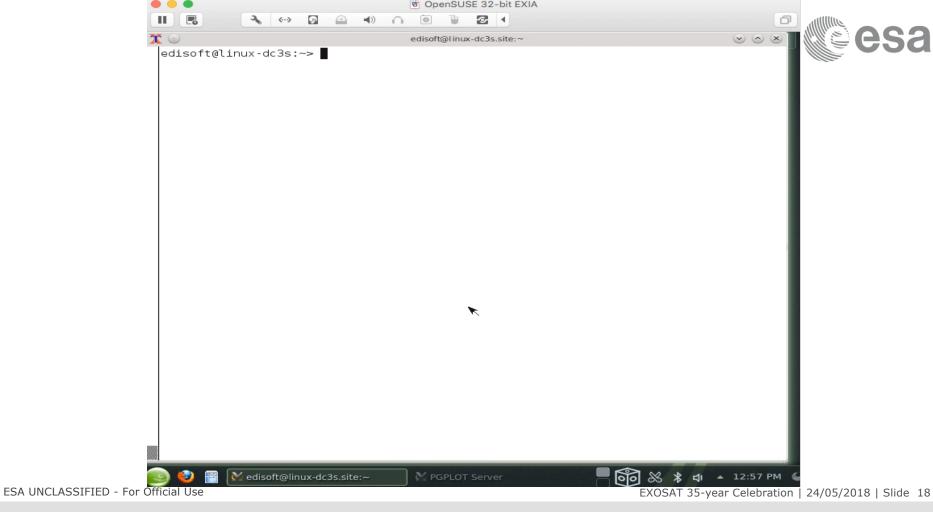
- In order to allow the scientific community to continue to exploit EXOSAT data fully, the IA has been "reborn" under a modern Unix operating system.
- Providing long-term data access is part of ESAC's core remit as ESA's science archive centre.
- With thanks to Aitor Ibarro at ESAC and Erik Kuulkers at ESTEC following on from Uwe Lammers and Tim Osterbroek.

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# Some Admin Stuff

#### Arvind Parmar EXOSAT Duty Scientist

#### 25 May 2018

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## Saturday Evening



- For those of you here on Saturday evening and would like to celebrate the anniversary of the launch together, Daniel de Pablo has reserved 20 places at a Tapas bar for 20:30.
- The bar is "El Anciano Rey de los Vinos", calle Bailén 19 and the booking is under "EXOSAT".
- The bar's website is http://elancianoreydelosvinos.es
- It is about 800 m from the hotel, walking along the front of the Royal Palace – PTO.

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## Saturday Evening





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