European X-ray Astronomy –from a faltering start to world leadership

Ken Pounds
University of Leicester

60 years ago…..

- early ‘pioneers’ from cosmic ray physics (eg JT)
- or solar astronomy (eg me)

- Sun the only known x-ray source in 1956 when I joined UCL Rocket Group - as yet with no rocket

- expectations higher for UV and Gamma-ray sources

  - one reason why ESRO was slow to respond

Wider context: Sputnik (1957): NASA (1958): CERN (1959)

1964 ESRO formed – with UK as largest funder

1968 ESRO-2, ESRO-1, HEOS-1 launched, but no x-ray mission planned

although ….

1962/3 first cosmic x-ray sources detected by Giacconi and Friedman

and Skylark observations from Woomera in 1967

1967 X-ray proposal to ESRO (COS-A) rejected due to impact on COS-B gamma-ray observatory

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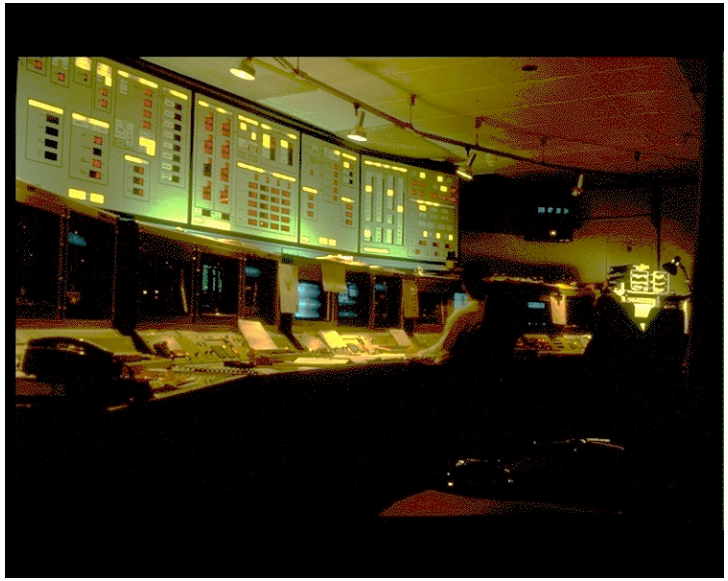
1969 Astro group recommends lunar occultation mission – with similar (source i.d.) objectives to COS A

1971 LPAC approval of HELOS for ESTEC study for start in 1975, and launch in 1979.

- Financial crisis led to further delay – with ESRO + ELDO >> ESA in 1975
- 1983 launch with modified payload but deep space orbit retained

EXOSAT (1983-86)

- first X-ray satellite in deep space orbit
  - real-time operations and continuous monitoring
  - first dedicated guest observer facility
- Over 1800 successful observations of galactic and extragalactic x-ray sources
- Strong user support form ESA with “science quality” data products and software tools available online
- A model later transferred to GSFC to become the foundation of NASA’s HEASARC
- Combination of MEDA and CMA detectors provided unique broad-spectrum X-ray spectra
- ‘Long looks’ in final months a great success



Low-frequency divergent X-ray variability in the Seyfert galaxy NGC4051

A. Lawrence*, M. G. Watson†, K. A. Pounds†
& M. Elvis‡

* School of Mathematical Sciences, Queen Mary College, Mile End Road, London E1 4NS, UK
† Department of Physics, University of Leciester, University Road, Leicester LE1 7RH, UK
‡ Center for Astrophysics, 60 Garden Street, Cambridge, Massachusetts 02138, USA

The X-ray emission from NGC4051, a nearby low luminosity Type 1 Seyfert galaxy, exhibits variations that are both rapid and apparently quasi-periodic[1,2]. Many Seyfert galaxies are variable[3] but our knowledge of the form of variability has not advanced substantially since early well-resolved observations[4] and attempts at statistical description[5]. Here we report an uninterrupted 62-h observation of NGC4051 with the EXOSAT observatory, giving an order of magnitude improvement in the quality of the time series, allowing comparison with X-ray binaries. The observed power spectral density is roughly proportional to $1/f$, similar to Cyg X-1, and characteristic of turbulent processes. No preferred timescale or luminosity gradient has been seen so far. If this behaviour holds generally for active galactic nuclei, quantities derived from short samples will be subject to selection effects.

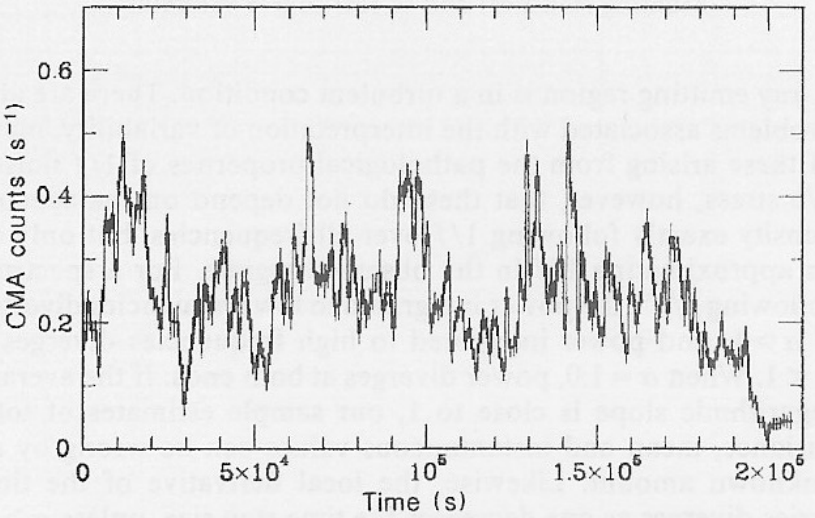


Fig. 1 X-ray light curve of NGC4051, commencing 1985 December 3 02:20 UT. Data presented here are from the EXOSAT[18] low-energy energy imaging system, the Channel Multiplier Array (CMA, ref. 19), using the thin Lexan filter, covering the energy range 0.05–2 keV. The source was also seen in the medium energy (ME, ref. 20) proportional counter array, showing variability closely similar to that seen here with the CMA. Bin size used is 1,000 s, error bars are $\pm\sigma$. Data were background-subtracted and exposure-corrected as in [2].

is smooth and divergent at low frequencies, following a form close to $1/f$, where f is frequency. The shape is not necessarily exactly $1/f$, but for our purposes the important factors are the low-frequency divergence, and the fact that no preferred timescale stands out. We also cannot reject the possibility of modest

EXOSAT Legacies

- EXOSAT Results Database: online data archive from 1989
- Strong user support and provided a model for future x-ray missions
- Deep space orbit adopted for Chandra and XMM-Newton

but perhaps even more important for the longer term…..

led to a strong European community of (relatively young) x-ray astronomers, including the EXOSAT operations team:

Lorella Angellini, Paul Barr, Lucio Chiappetti, Thierry Courvoisier, Paolo Giommi, Manfred Gottwald, Frank Haberl, Julian Osborne, Arvind Parmar, Andy Pollock, Luigi Stella, Gianpiero Tagliaferri, Michiel van der Klis and Nick White

contributing to the choice of XMM-Newton as a Cornerstone of Horizon 2000

XMM: A Long-Lived Orbiting X-Ray Multi-Mirror Observatory

J Bleeker , A Brinkman , J Culhane , L Koch-Miramond , K Pounds , H Schnopper , E Silver , G Spada , B Taylor , J Trümper

Physica Scripta, Volume 1984, T7

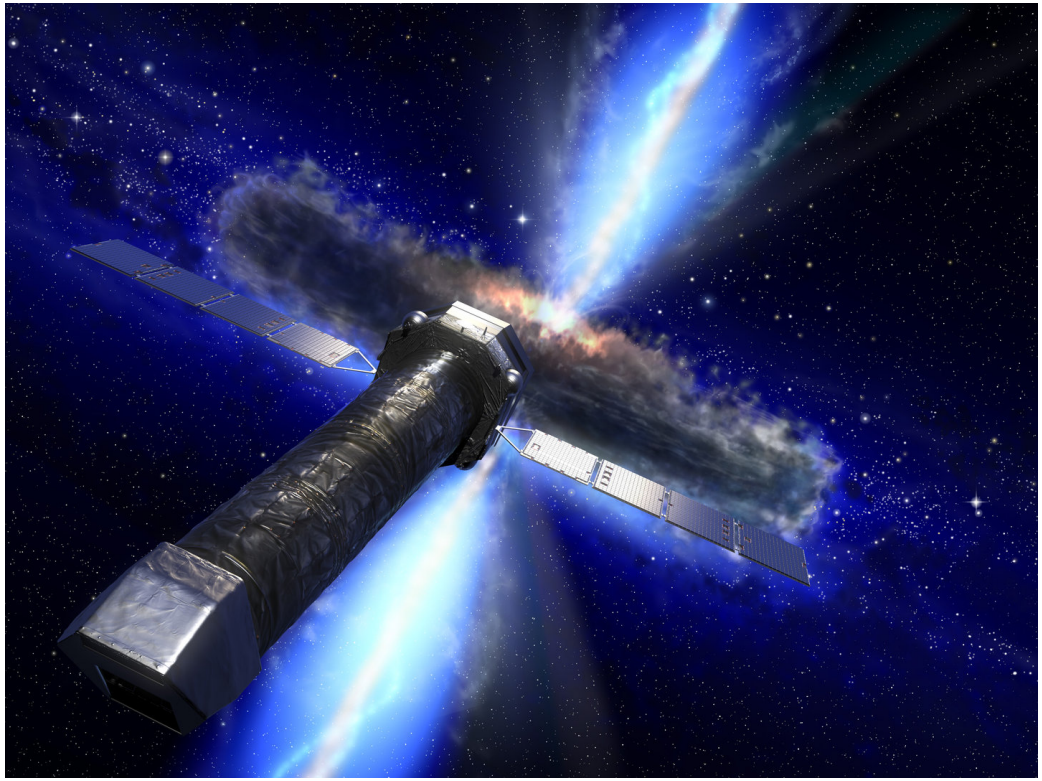
- XMM is a third generation X-ray astronomy mission in which the artificial boundary between astronomy and astrophysics disappears. This long lived orbiting observatory brings sensitivity improvements of > 10 over existing missions (EINSTEIN, EXOSAT, ROSAT). It will be capable of finding and studying in detail either the furthest quasars ……..

Now … in 2019…

Over 20 years of successful operation, XXM-Newton is building it's own legacy, having:

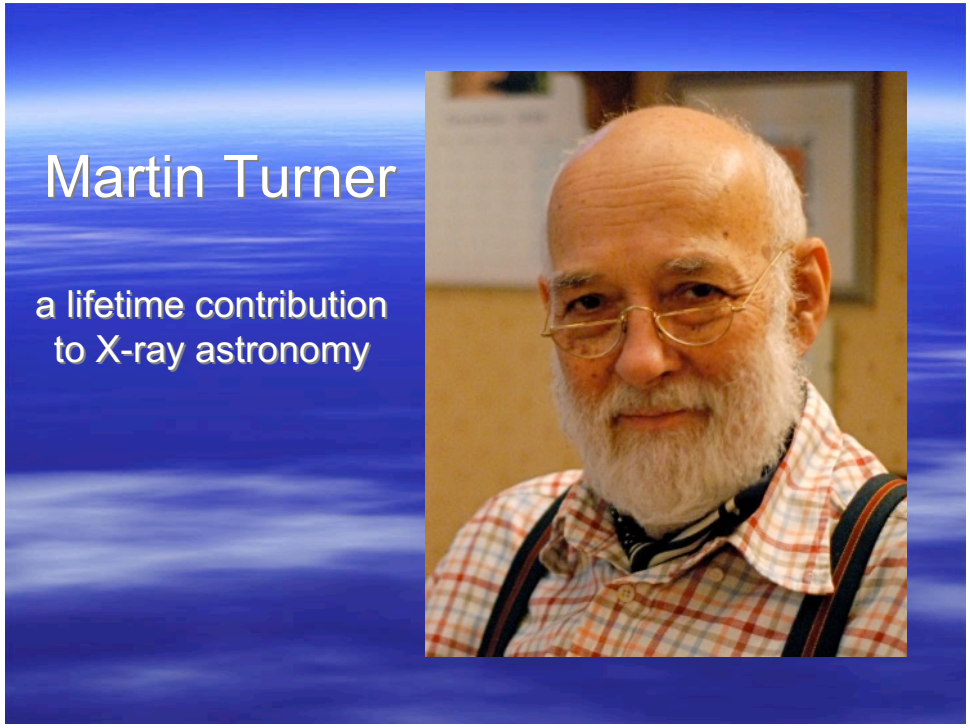
- (with Chandra) placed x-ray astronomy firmly on a par with ground-based astronomy
- further broadened and strengthened the international x-ray community (extending over 42 nations),
- yielded a high quality catalogue of more than half a million x-ray sources – a key component of the 'multi-messenger future of astronomy and cosmology

while further strengthening Europe's scientific, technological - and political – confidence to lead the first global XRA Observatory



Over to you ESA for X-ray mission no. 3 !

In celebrating the success of EXOSAT and XMM-Newton perhaps is also a good time to recall some heroic colleagues no longer with us. One such is Martin Turner:



P.I for :

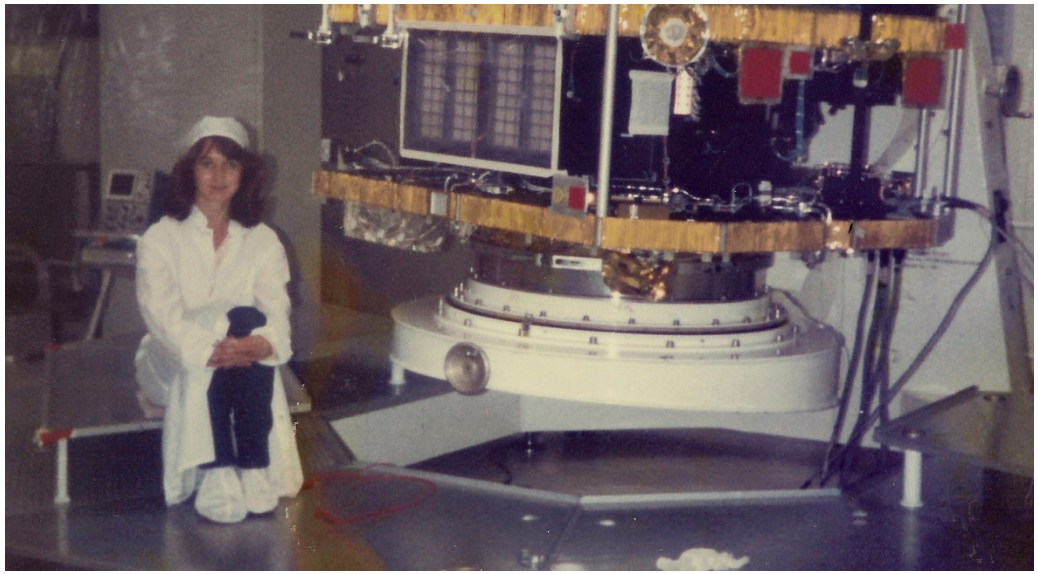
EXOSAT MEDA

GINGA LAC

XMM EPIC

with a final gift of data enabling me to have a busy post-retirement

EXOSAT (1983 - 1986) – a timely ESA mission



'long looks' in final months

a science bonus

ME instrument

- PCS with a total area of 1600 cm^2 and 45 arcmin FWHM f.o.v.
- offset capability of half array and Be body detectors to reduce deep space background

Pioneers on the shoulders of ….

COSPAR meeting at The Hague in March 1959

Fig. 4.1. Participants at the second COSPAR meeting at The Hague, March 1959. *(Front row left to right):* H. Massey, M. Roy, E.K. Federov, H. Kallman-Bijl (sec.), H.C. Van de Hulst, R.W. Porter, K. Maeda. *(Second row):* –, –, J. Bartels, D. Rose, H.E. Newell, A. Wexler, A.C.B. Lovell, F.A. Kitchen, A, Dollfus. *(Third row):* –, –, A.W. Frutkin, J. Kaplan, –, –, M. Nicolet, M. Florkin. H. Odishaw, M.O. Robins. *(Back row):* –, L.G.H. Huxley, –, F. Hewitt, –.

Die weiche Röntgenstrahlung der ungestörten Sonnenkorona

Von Gerhard Elwert

Aus dem Astronomischen Institut der Universität Tübingen

(Z. Naturforschg. 9a, 637—653 [1954]; eingegangen am 3. September 1953)

Mit der in einer früheren Arbeit abgeleiteten Ionisationsformel der Sonnenkorona werden für die Elemente großer kosmischer Häufigkeit Teilchendichten der Ionen in den in Betracht kommenden Ionisationsstufen ermittelt. Die bei den Photorekombinationen und bei frei-frei-Übergängen entstehende Ausstrahlung führt zu einem kontinuierlichen Emissionsspektrum, das in der Wellenlängenskala ein Maximum bei 30 bis 50 Å hat.

Größere Intensität liefert die Linienemission, deren Maximum bei etwas längeren Wellen liegt. Sie wird für die wesentlichen Übergänge diskutiert. Im Vergleich zu den Rekombinationen in höhere Schalen sind Elektronenstöße der wirksamere Anregungsmechanismus. Für die Berechnung der Wirkungsquerschnitte wird die Bornsche Stoßtheorie verwendet. Unter Berücksichtigung der Selbstabsorption werden Spektren der Strahlung der ungestörten Korona für verschiedene Temperaturen angegeben. Mit der berechneten Eigenstrahlung der Korona wird die Gültigkeit der verwendeten Ionisationsformel kontrolliert.

Auf die Bedeutung der Röntgenstrahlung für die Bildung der normalen ionosphärischen E-Schicht wird hingewiesen.

EXOSAT 1983-86 - a pioneering first European X-ray astronomy mission

- Deep space orbit
- Uniquely broad spectral cover
- Operated as a true international observatory

XMM-Newton 1999 -

highest photon grasp of any current x-ray observatory

- Best for timing
- And for spectroscopy
- Opening new fields of study, eg powerful AGN winds

COS-A/B >>> HELOS >>> EXOSAT

- COS A - modified Oda telescope proposal made in 1967/8 to obtain better source positions. Rejected by COS WG (probably correct decision) in favour of a gamma ray mission…

- COS B launched in August 1975 from WTR, cataloguing ~ 25 gamma ray sources

- Meanwhile support built up for a European x-ray mission T
- Connie Dilworth suggested lunar occultation with similar science aims
- Successful rocket expts by NRL (Crab) and Leicester (GX 3+1)

- HELOS chosen by new Astro advisory group and selected for study by LPAC and in 1973 for start in 1975 and launch in 1979

- EXOSAT launched from WTR on a USAF Delta in May 1983
- Highly eccentric orbit with 90.6 hour period – becoming the orbit of choice in XRA

A discouraging report from US colleagues as EXOSAT was being prepared for launch

THE ASTROPHYSICAL JOURNAL, 264:92–104, 1983 January 1

THE ABSENCE OF RAPID X-RAY VARIABILITY IN ACTIVE GALAXIES[1]

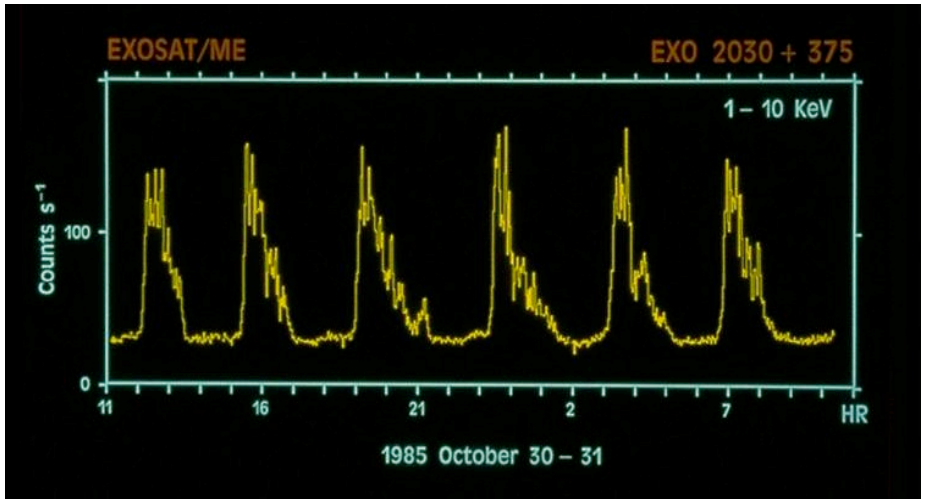
ALLYN F. TENNANT[2] AND R. F. MUSHOTZKY
Laboratory for High Energy Astrophysics, Goddard Space Flight Center
Received 1982 April 1; accepted 1982 June 30

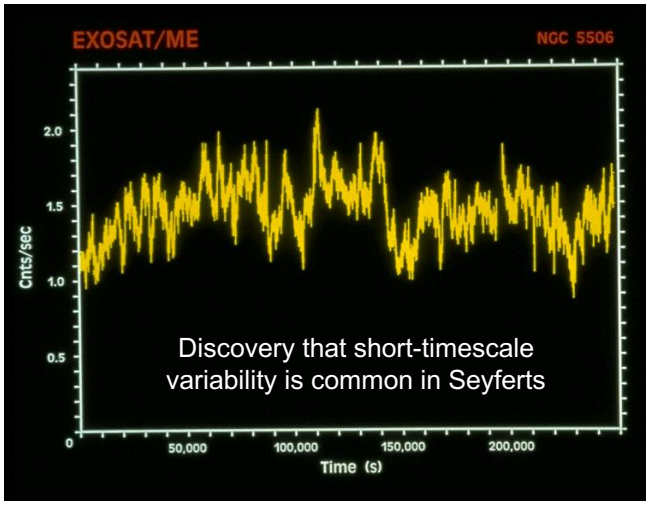
ABSTRACT

We have searched for variations on time scales ranging from minutes to several hours in the X-ray flux from 54 observations of 38 active galaxies. Our sample is composed mostly of Seyfert I galaxies but also includes radio galaxies, narrow emission-line galaxies, BL Lac objects, and 3C 273. Only NGC 6814 varied on time scales as short as 100 s. No other source was observed to vary with a time scale of less than 12 hr. We conclude that large-amplitude short-term variations are not a characteristic of the X-ray emission from active galaxies. Upper limits on σ_I/I ranged from 2% for Cen A, 5% for NGC 4151, to ~20% for sources giving 1 count s^{-1} in our detector. Three objects, NGC 3227, NGC 4151, and MCG 5-23-16, show variability consistent with a time scale of ~1 day.

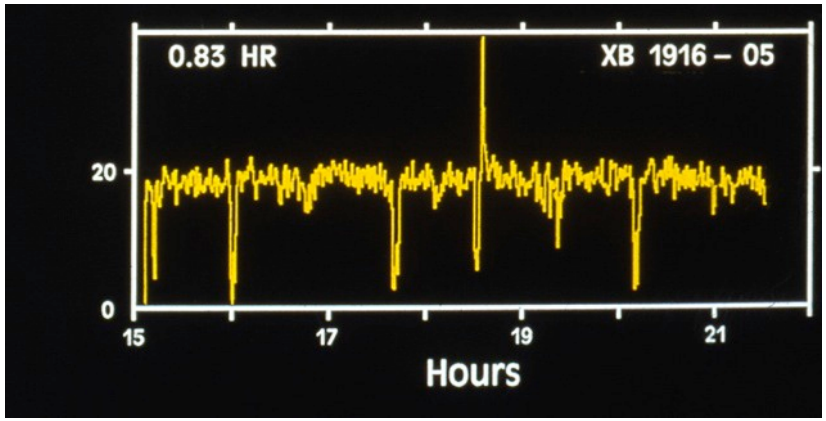
But Nature didn't let us down….

EXOSAT

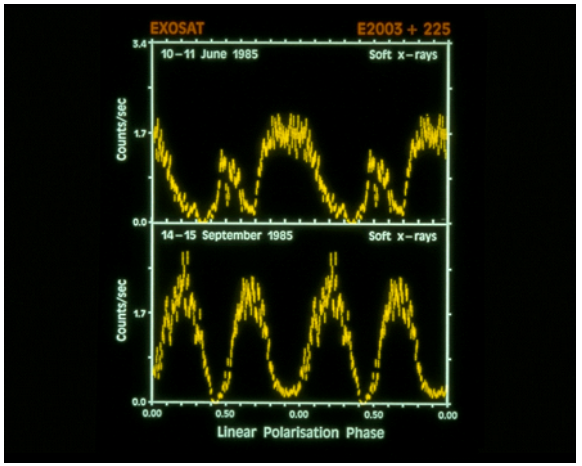




Long-term monitoring of Galactic and extragalactic sources with EXOSAT ME



"Dippers" - X-ray signature of LMXB at last



orbital/spin modulation of mCVs