The sustainability of life in X-ray irradiated planetary atmospheres

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XMM-Newton : The Next Decade

ESAC 4-6 June 2007

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The search for exoplanets in HZs

- First exoplanet discovered in 1995
- Current exoplanet catalogue totaled 241 (last Friday)
  - Giant planets in the majority
  - 2004 : 14 M_{Earth} 0.1 AU from μ Ara
  - 2005 : 7 M_{Earth} 0.02 AU from M-dwarf Gliese 876
  - 5% of stars [15% at high metallicity]
- Habitable Zones (HZs)
  - liquid water at the surface of an Earth-like planet
  - not too hot, not too cold
  - Solar-like F,G,K stars
  - many more low-mass M stars
- Planetary conditions for development of life
  - atmosphere
  - magnetosphere
  - Gyears
  - High-energy radiation environment : XUV
  - High-energy particle environment : CME (Coronal Mass Ejection)

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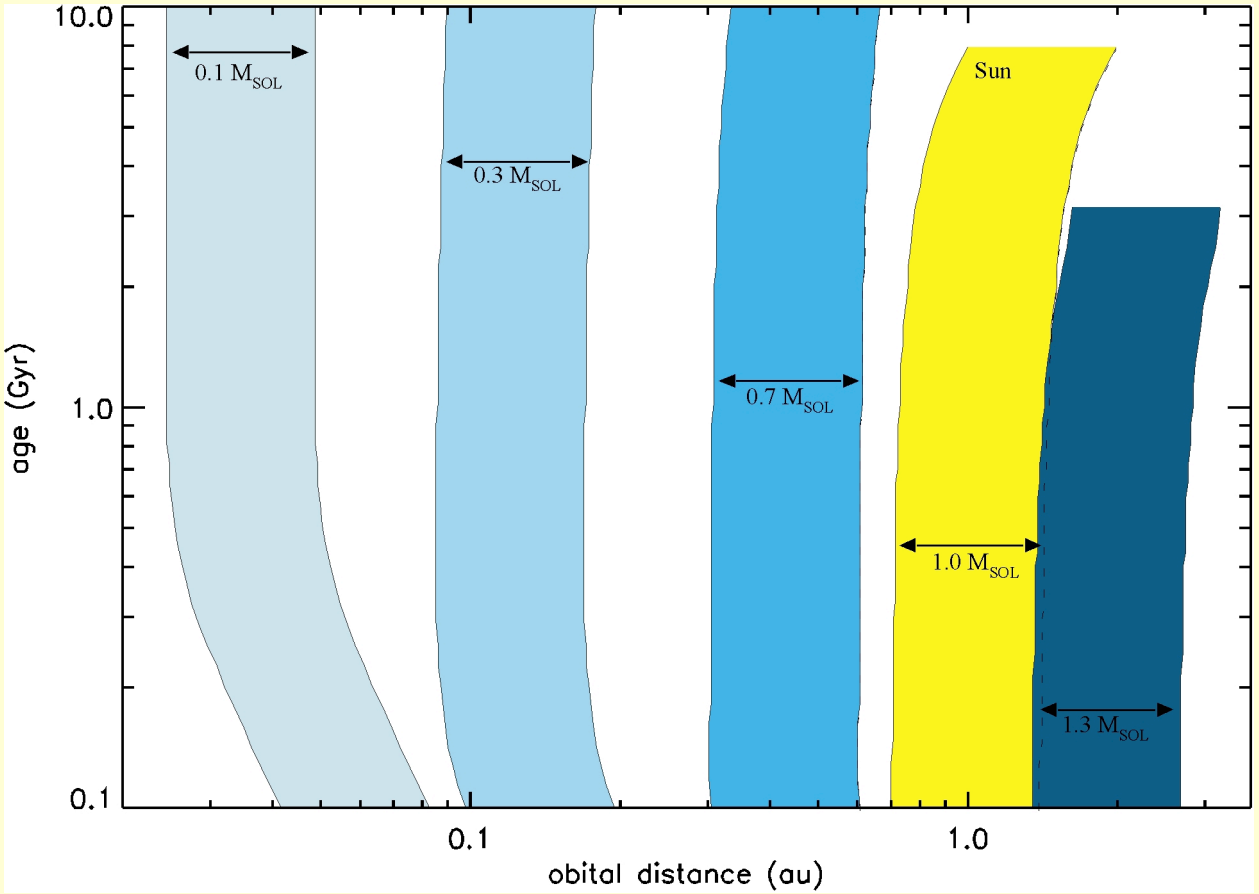
HZ boundaries around main-sequence stars



Khodachenko+10 2007, ASTROBIOLOGY, 7(1), 167

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Relevance of XUV for life on exoplanets in HZs

- Protoplanetary discs survive hostile PMS XUV
  - 10^8 large X-ray flares (Feigelson 2007)
- XUV heating causes atmospheric expansion (e.g. Cecchi-Pestellini+ 2006)
  - atmospheric erosion
- XUV at the planet surface (Sagan 1957 *et seq.*)
  - promote complex molecule formation
  - DNA mutations

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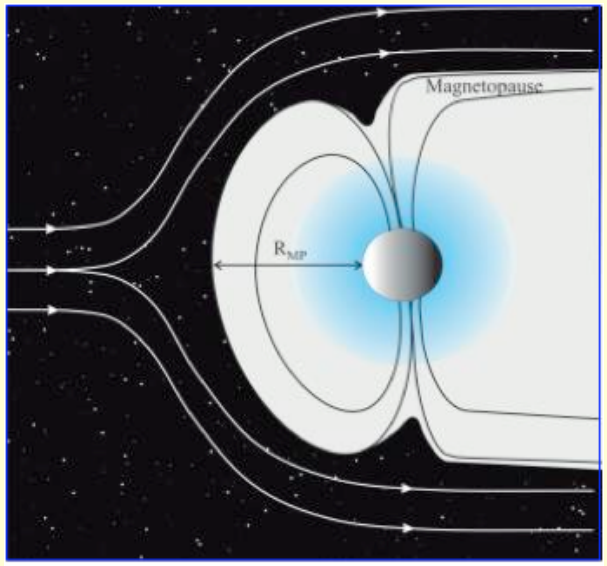
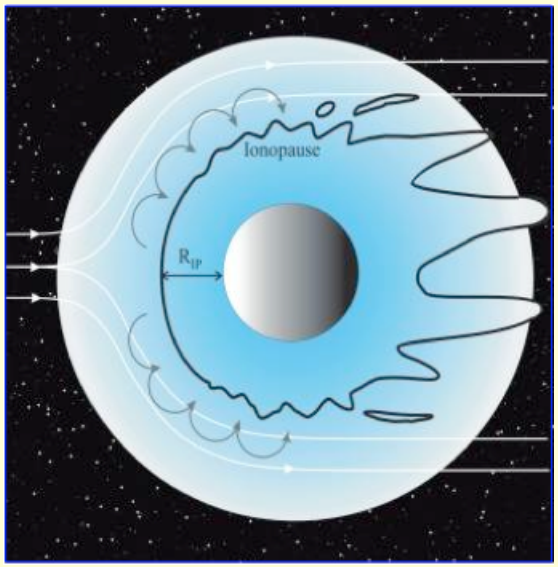
Relevance of magnetospheres for life on exoplanets

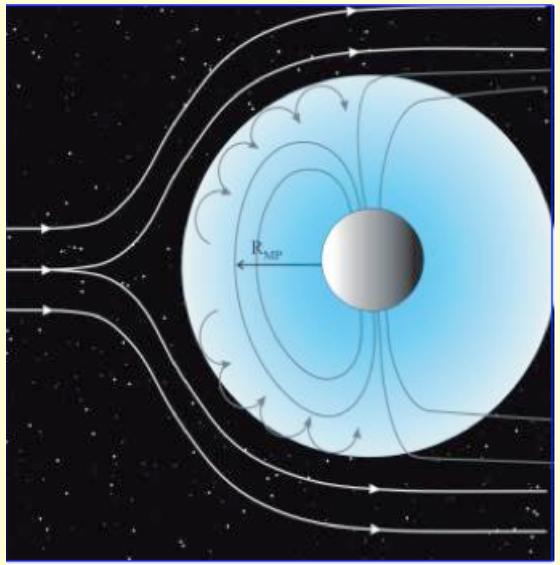
Earth-like (B≠0)



Mars or Venus-like (B~0)



XUV heating



Lammer+10 2007, ASTROBIOLOGY, 7(1), 185

"A weakly magnetized exoplanet at 0.2 AU exposed to more than about 50 $XUV_{\odot}$ for 1 Gyr is in real danger of being stripped of its whole atmosphere."

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Relevance of CME for life on exoplanets in HZs

- magnetospheric protection
  - atmospheric erosion
  - CME reaching the planet surface
  - tidally-locked planets have weaker fields
- CME at the planet surface
  - break up big molecules
  - DNA mutations

- XMM and Chandra get switched off during big solar flares

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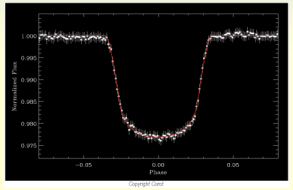
Search for exoplanets in HZs around (nearby) stars



- COROT (CNES)
  - launched 2006-12-27
  - first planetary transit
  - Earth-like planets more-or-less certain
- Kepler (NASA) 2008
- Darwin (ESA) (2015)
  - sample of 604 F,G,K stars within 25pc
  - (M stars)
- Requirements for the development of life
  - liquid water
  - atmosphere
  - 1 Gyr
  - magnetosphere
  - enough XUV
    - ⇒ quiescent X-ray flux
    - EM(T) for synthetic EUV spectrum
    - XUV(StellarAge)
  - quiet enough CME
    - ⇒ flaring X-ray flux

What do we know about the X-rays from these ?

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X-rays from nearby stars

(50 $XUV_{\odot}$)

Object	Distance (parsecs)	X-ray flux ($erg/s/cm^2$)	X-ray Luminosity (erg/s)	Other Name or Comment
Sun at Solar Minimum	0.00002	0.1	3×10^{26}	Peres et al. (2000, ApJ, 528, 537)
Sun at Solar Maximum	0.00002	2	5×10^{27}	Peres et al. (2000, ApJ, 528, 537)
Very Large Solar Flare	0.00002	7	2×10^{28}	Peres et al. (2000, ApJ, 528, 537)
II Peg®	42.	6×10^{-9}	1×10^{33}	RS CVn Binary
HR 1099®	29.	4×10^{-9}	4×10^{32}	RS CVn Binary
AB Dor®	10.	4×10^{-9}	1×10^{32}	Active Young Star
Algol®	28.	3×10^{-9}	3×10^{32}	Algol Binary
Capella	13.	1×10^{-10}	2×10^{30}	Wide Pair of Normal Stars

NASA HEASARC 2007-05-06

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X-rays from nearby F,G,K stars

- The ROSAT survey of nearby stars (NEXXUS@uni-hamburg.de)
  - Schmitt & Liefke 2004, A&A, 417, 651
  - mostly RASS 500s snapshots, A ~ 100cm^2
    - 100% completeness
      - F&G stars < 14 pc
      - K stars < 12 pc
      - M stars < 6 pc
    - 33% completeness
      - 1252 stars < 25 pc
  - quiescent ? flaring ? T ?
- XMM-Newton on the 604 Darwin F,G,K stars
  - 33 stars in normal observations
  - 7 stars in the Slew Survey
- Chandra
  - no better

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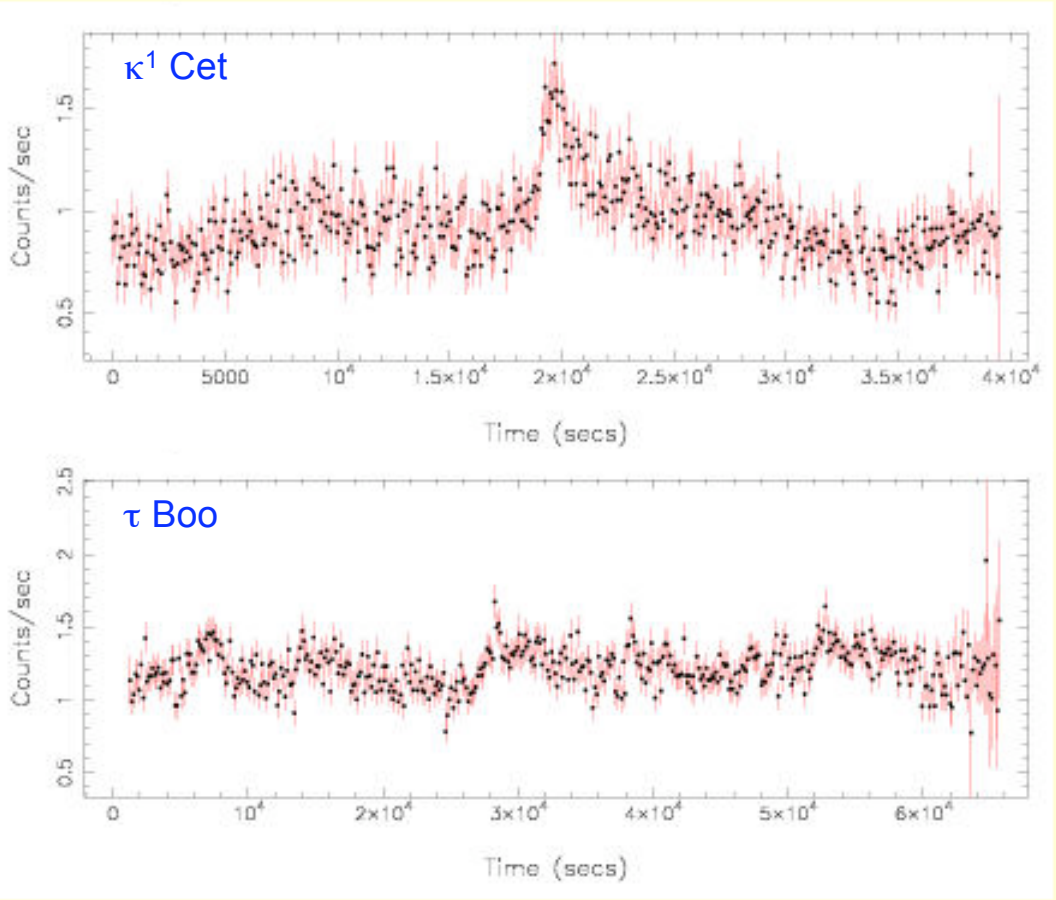
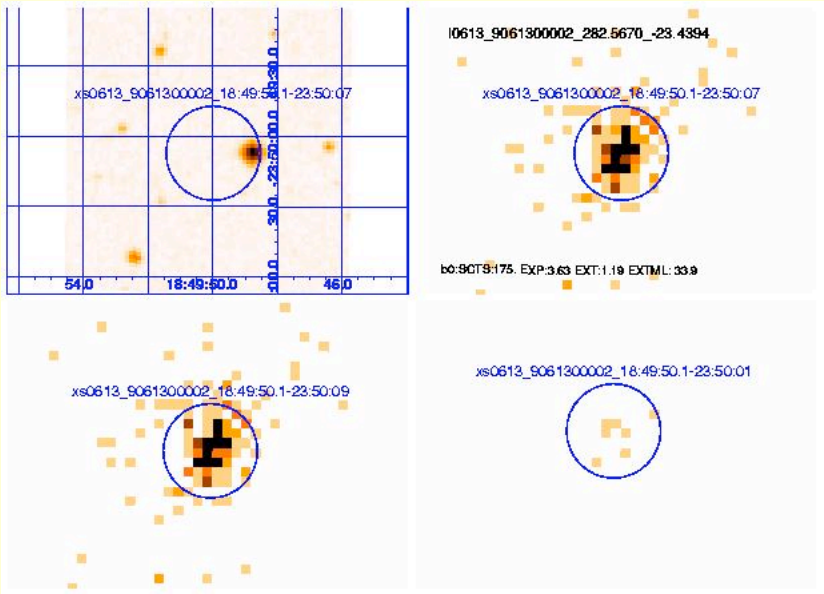
Darwin FGK-star EPIC X-ray data



XSA 2XMMp catalogue

Ross154 (23 cts/s ! - also Chandra)



XSA Slew Survey Catalogue

X-irradiated planetary atmospheres

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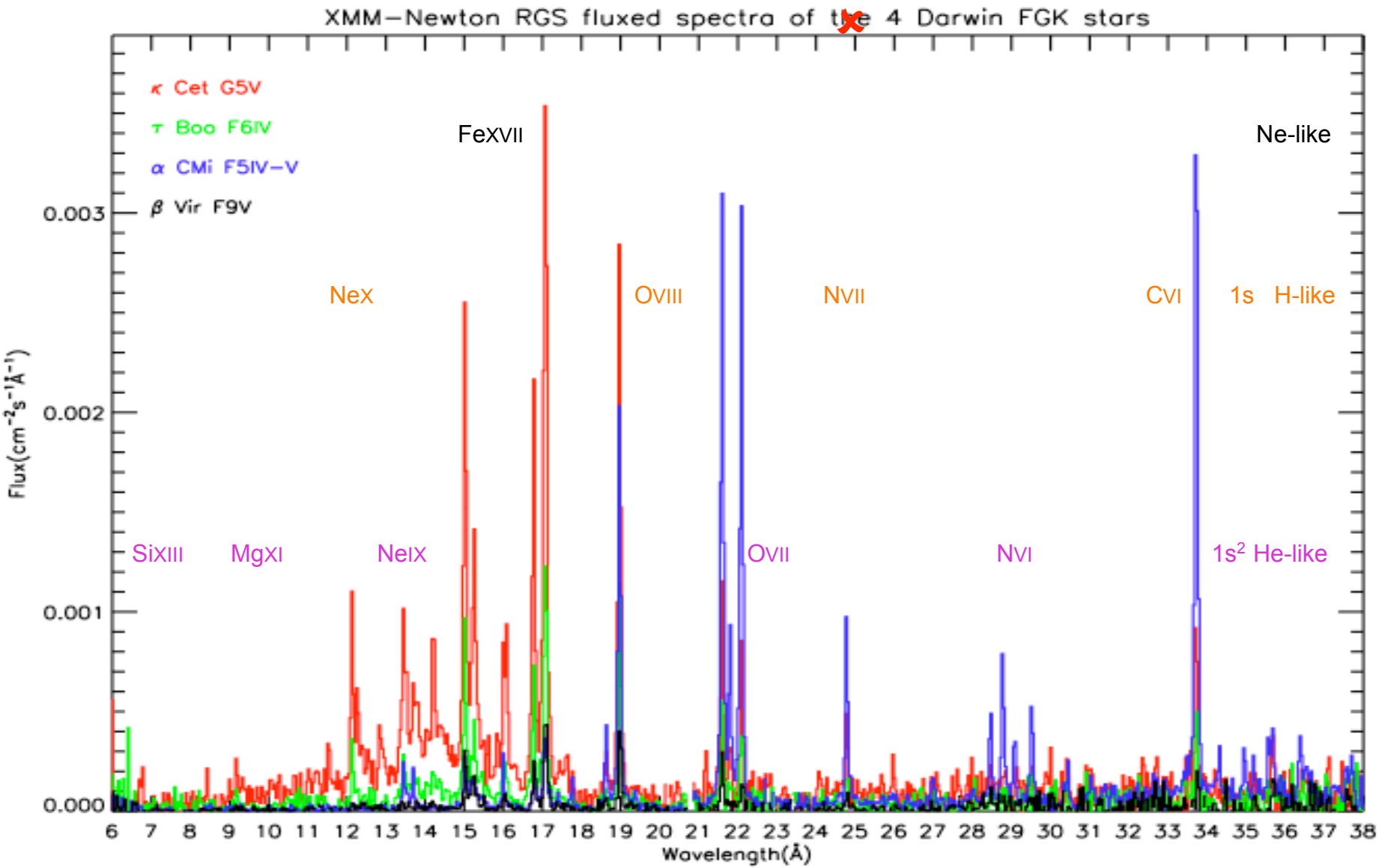
Darwin FGK-star RGS X-ray spectra



X-irradiated planetary atmospheres

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What XMM could do for HZs in the next decade

- Long exposures of stars with (Earth-like) planets confirmed by any means
  - e.g. Gliese 581 or a COROT discovery
- Snapshots of complete nearby stellar samples
  - e.g. extend ROSAT work to Darwin's 25pc
  - faint stars are important
- Define the high-energy environment in HZs
  - required to assess the viability of life
  - XUV(F_X)
  - ~CME(ΔF_X)
  - T($F_X(\lambda)$)
- Serious HZ physics has started
  - Now is the right time - things have changed since XMM launch
  - ASTROBIOLOGY 2007 special issue
  - Public Impact
  - if {!XMM} {?}

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