X-rays in the Prime of Life: The Story of Wolf 359

The star is X-ray bright and flares a lot!
This is detrimental to the formation of life.
But there is hope.

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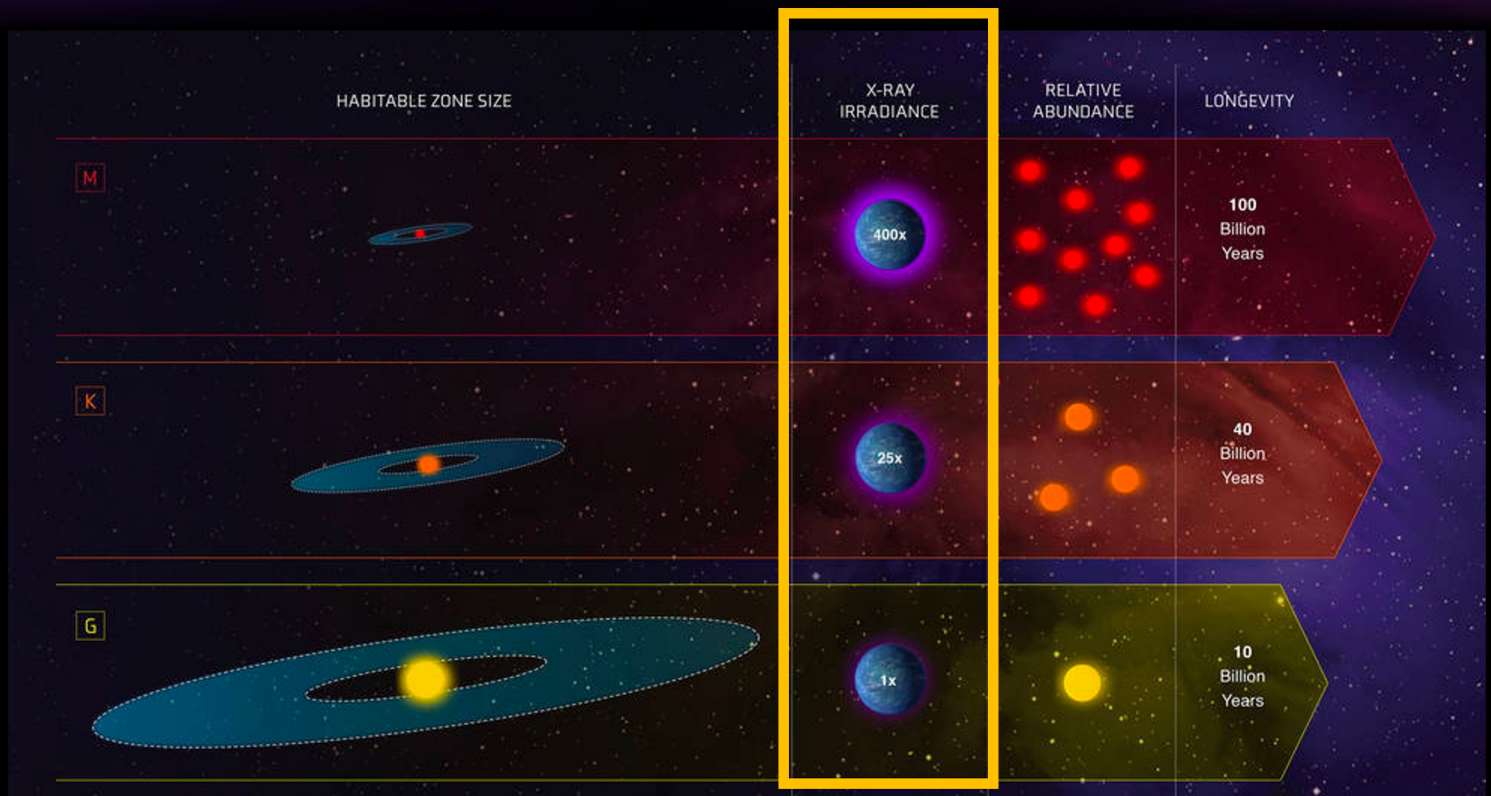
Why look for life around M stars?



NASA, ESA and Z. Levy

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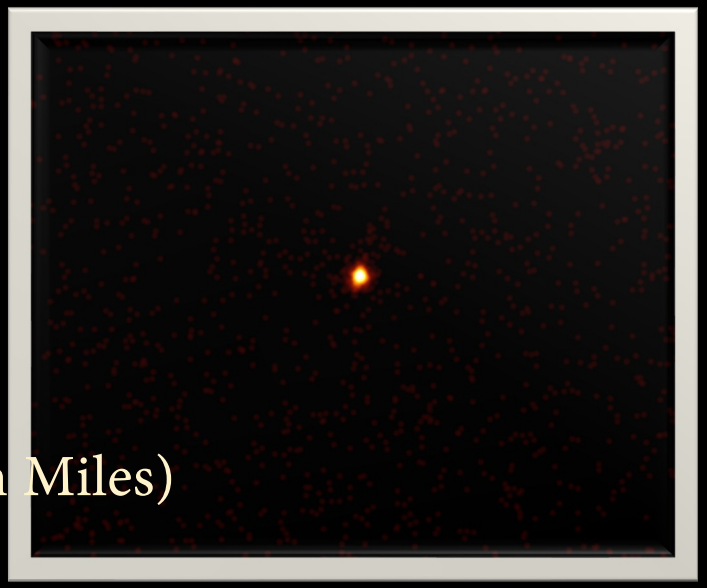
Wolf 359 Factoids



- Distance 2.4 pc (7.86 ly)
- M6V
- M= 0.11 $M_{\odot}$
- R=0.144 $R_{\odot}$ = 62,307 Miles
- L= 0.001 $L_{\odot}$
- HZ 0.024 AU- 0.052AU. (2.23 – 4.83 million Miles)
  - 2 putative planets on either side.
- 0.1-1.5 Gyr
- Will be the site of the Battle of the Borg in 2367.

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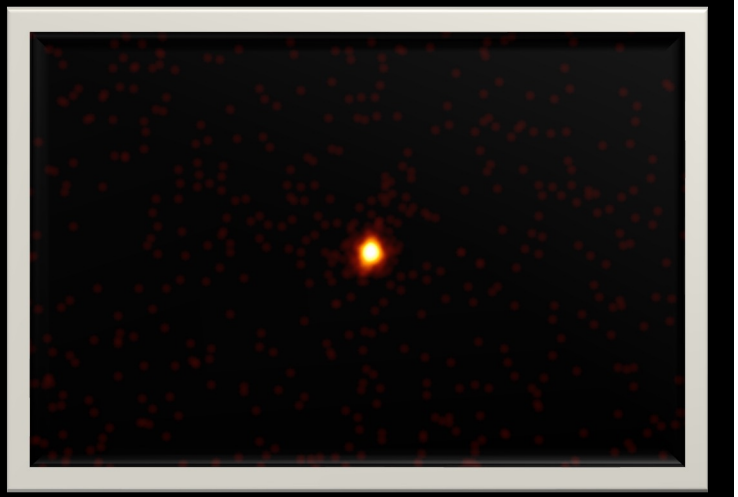
Wolf 359 Factoids



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➢ A planet with the stellar irradiance of Earth sees over 1000x the X-rays as the Earth

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Similar stars within 5 pc

- **Barnard's Star**
- **EV Lac**
- **Proxima Centauri**
- **BL Ceti** and **UV Ceti**

Wolf 359 Planetary Irradiation

Planet	Separation	Radius	Mass	Intensity (optical)	IXUV	Mass Loss	
	A.U.	Earths	Earths	Earth Units	Erg/sec (x 10^{20})	g/s (x10^{7})	Earth Units
c	0.018	2	3.8	3.09	128	108	6500
b	1.845	~3.1	~44	0.00029	0.0291	0.0033	0.39
Habitable Zone							
Inner	0.024	1.0	1.0	1.73	21.8	35.0	1738.95
Earth like	0.0315	1.0	1.0	1.00	12.6	20.3	1009.46
Middle	0.038	1.0	1.0	0.69	8.7	13.0	693.65
Outer- req. Green house	0.052	1.0	1.0	0.37	4.6	7.45	370.43

How worrying in this?

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Wolf 359: Can a Habitable Planet Survive?

At the outer edge of the habitable zone…

- 1 Earth atmosphere survives about 2 million years .
- We think stars like Wolf 359 remain active for ~4 Billion years.
- 1 Venus atmosphere survives about 200 million years .
- But what about the ocean?
- One ocean survives about 600 million years .
  - You need about 8 times the mass of ocean and atmosphere as the Earth, then you will have ~1 ocean mass left at around 4 billion years as the star settles down.

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Wolf 359 Flares

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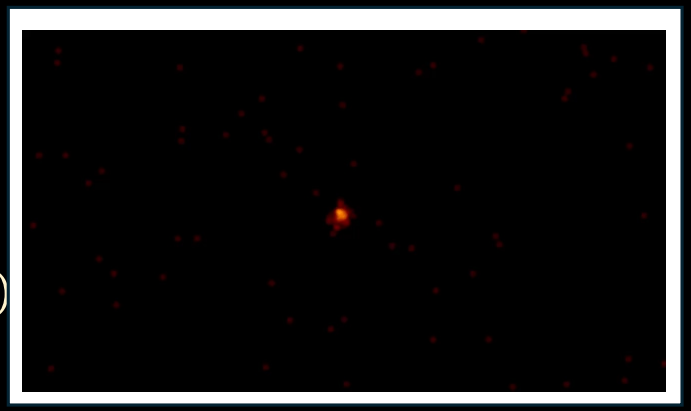
- Distance 2.4 pc (7.86 ly)
- M= 0.11 $M_{\odot}$
- R=0.144 $R_{\odot}$ = 62,307 Miles
- L= 0.001 $L_{\odot}$
- HZ 0.024 AU- 0.052AU. (2.23 – 4.83 million Miles)
- 0.1-1.5 Gyr → Known flare star
- L_X=1 $L_{X\odot}$



➢ A planet with the stellar irradiance of Earth sees over 1000x the X-rays as the Earth

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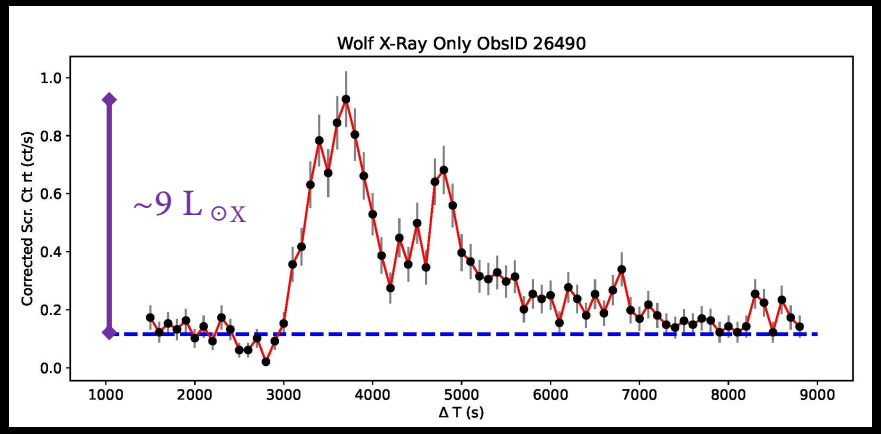
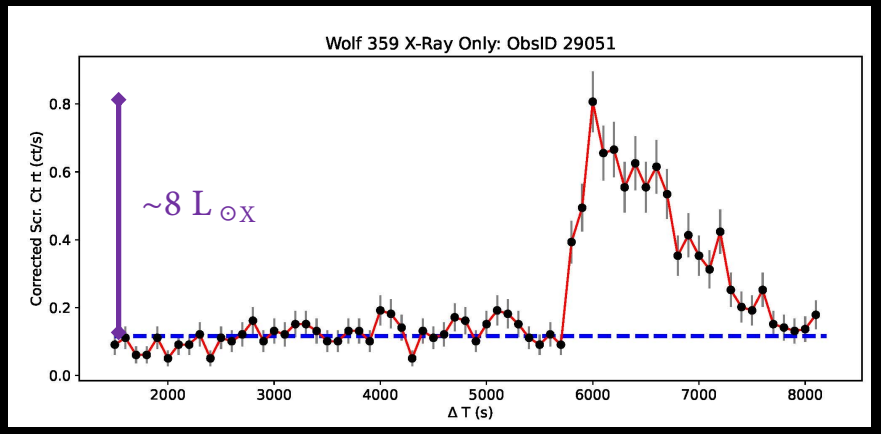
Wolf 359 Variability





2.2 hours

~2 hours

- A planet with the stellar irradiance of Earth sees over **10,000x** the X-rays as the Earth in these flares

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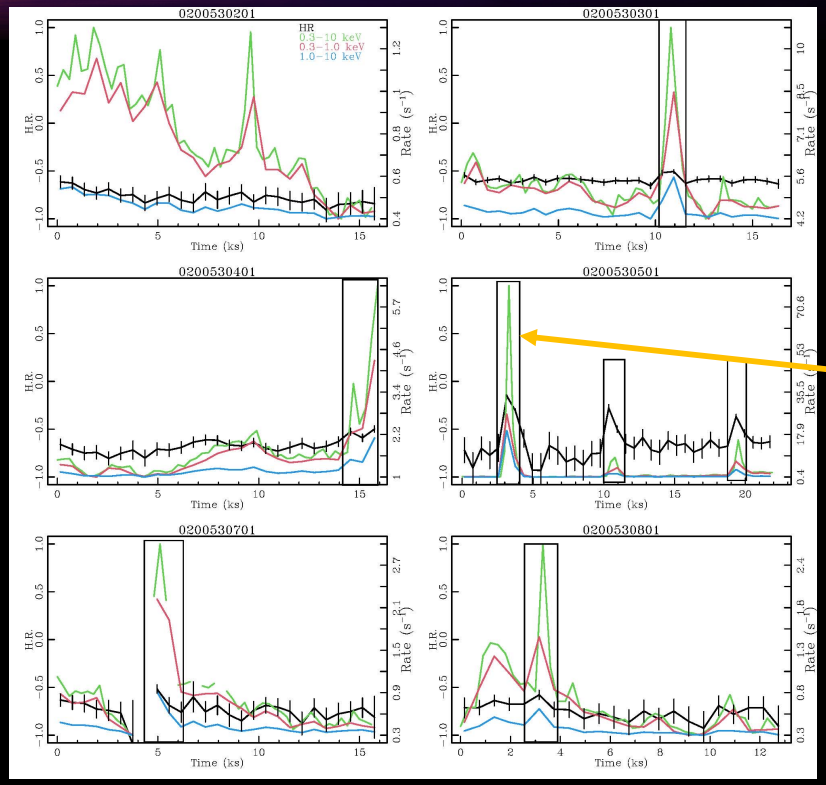
Wolf 359 Variability

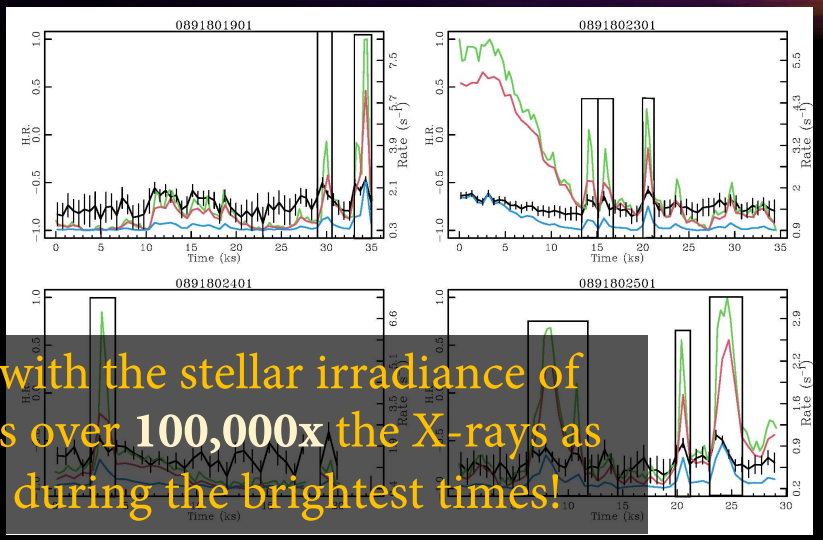
From XMM Archival Data



13 hours

14 hours

A planet with the stellar irradiance of Earth sees over **100,000x** the X-rays as the Earth during the brightest times!



15 hours

18 hours

16 Flares in ~60 hours

18 Flares in ~72 hours

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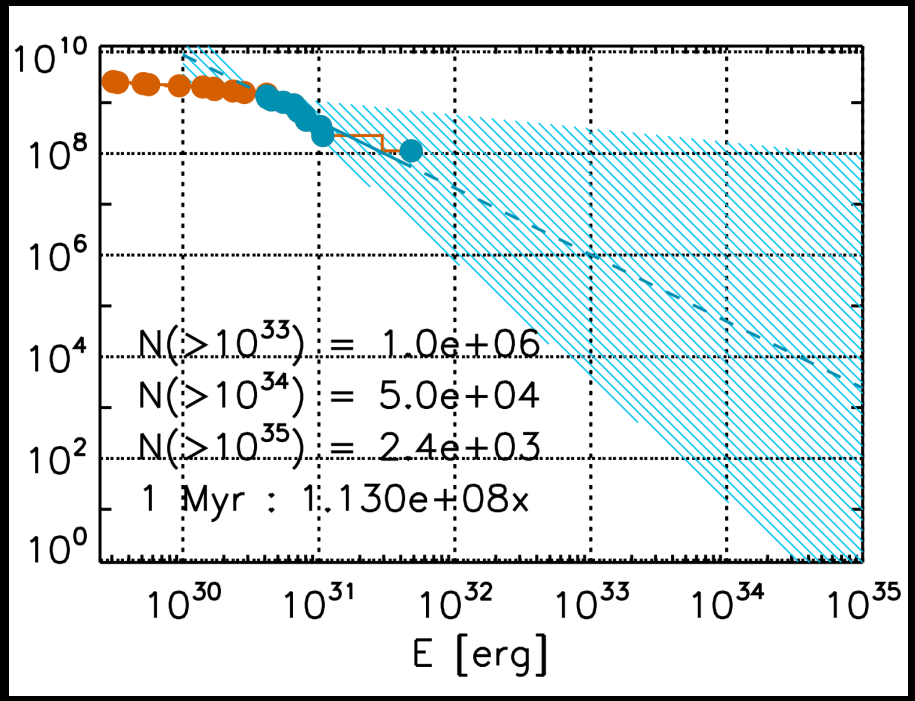
Do Flares Harm Habitability?



- We can extrapolate from the 3 days of data to try to understand things on a geological time scale.
- This is a small (25%) addition to the total mass of atmosphere/ocean needed.

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Can a Habitable Planet Survive around the Most Common stars in the Universe?

At the outer edge of the habitable zone…

- A greenhouse atmosphere survives about 200 million years .
- Stars like Wolf 359 remain active for ~4 Billion years.
- But what about the ocean?
  - You need about **10** times the mass of ocean and atmosphere as the Earth, then you will have ~1 ocean mass left at around 4 billion years as the star settles down…
- Can they support life?
  - Yes, if they are lucky.

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Wolf 359 Visualization