The Earliest Habitable Planets - Constraints from Cosmic Rays

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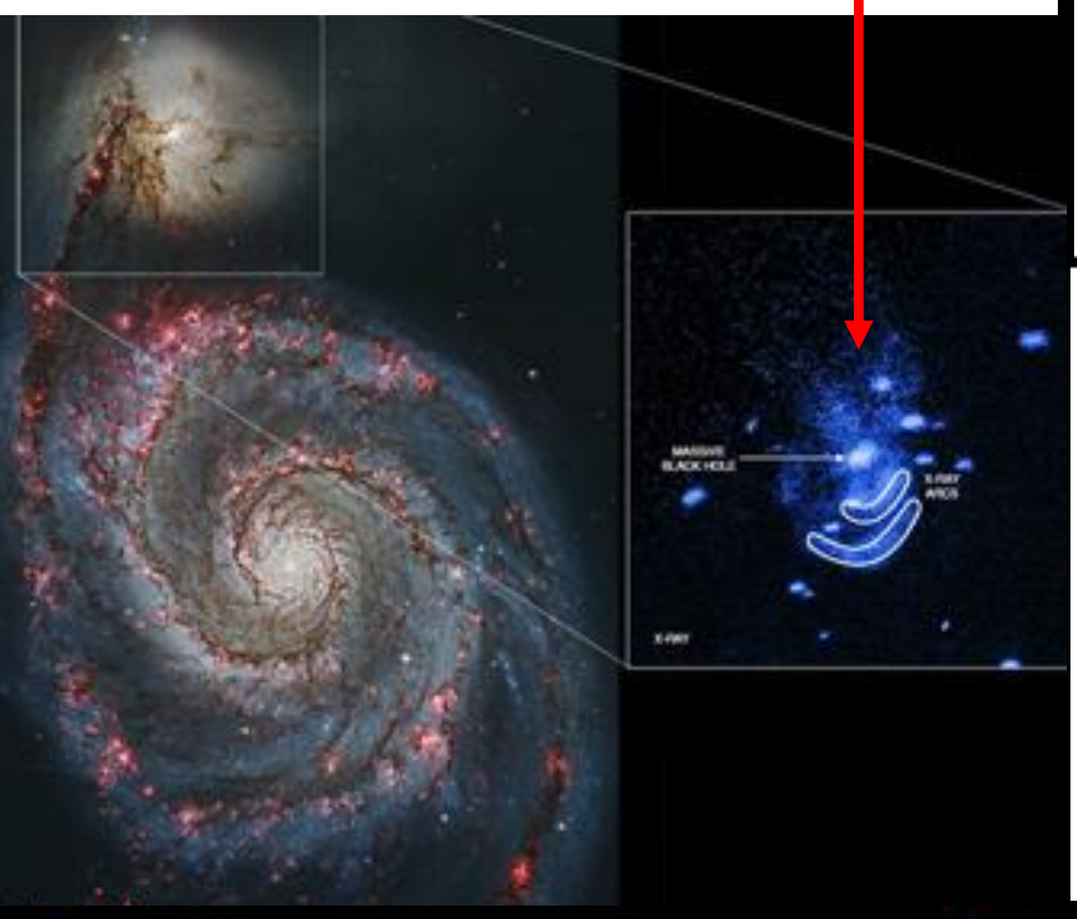
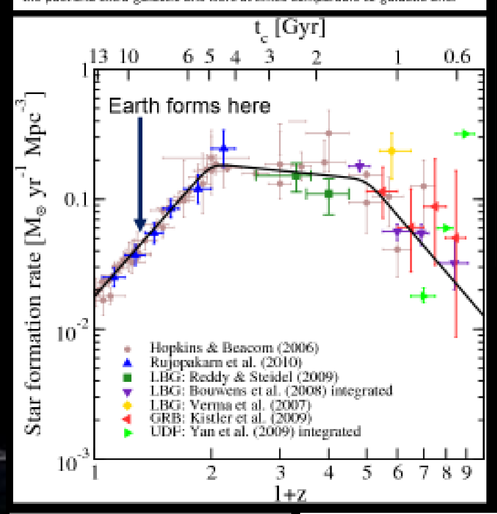
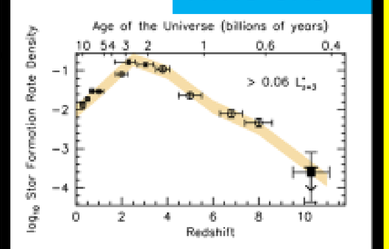
Galaxy Mergers amplify SN rate and SMH activity. The nearby galaxy M 51 has a merging companion NGC 5194. Chandra observations, below show huge particle ejection events from the supermassive black hole (Schlegel et al. 2016).



If star formation rate can be used to trace SN rate, then it likely tracks galactic CR levels over cosmic time. As the galactic SN-rate decreased, so did local threats such as sterilization from nearby SN and global threats due to the CR density of the galactic magnetosphere. However, the universe was smaller in the past and extra-galactic CRs were at times comparable to galactic CRs.



Cosmic Time CRs

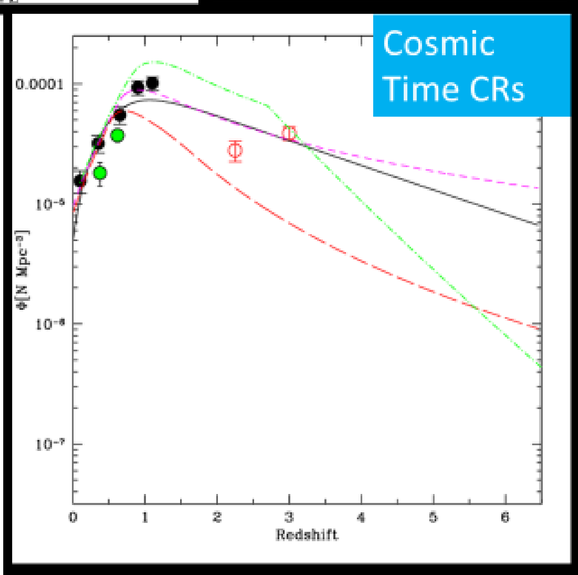


Consider the starburst galaxy M82, the local CRs in a starburst are quite high. Folding in what redshift means in terms of cosmic time, this implies that there may have been little chance for life to survive much earlier than Earth's starting epoch.

AGN activity was much greater in the past.

The AGN number density, as determined by recent X-ray surveys. The best fit results of the various determinations of the X--ray luminosity function from Aird et al (2010; black solid line), Ebrero et al. (2009; pink dashed curves), Silverman et al. (2008; red dashed curves) are reported in both panels. The green dot--dashed curves represent the expectations of the XRB synthesis model of Gilli et al. (2007).

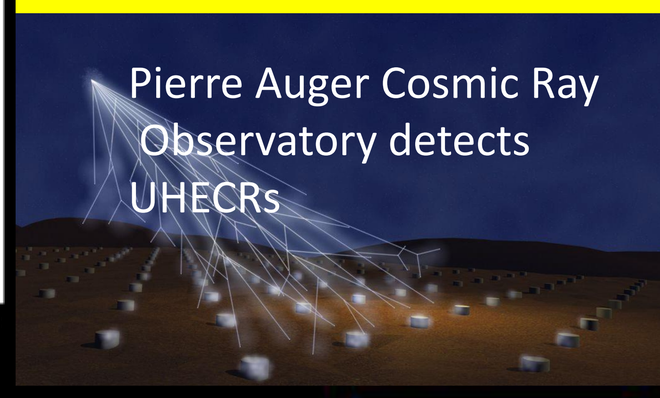
Cosmic Time CRs



AGN activity was more than an order of magnitude higher at z = 1 than today.

The density of both Galactic Cosmic Rays (GCRs) and Extragalactic CRs (ECRs) was dramatically higher in the past because:

1) The size of the universe was smaller in the past exposing planets to more direct Ultra High Energy CRs (UHECRs).
2) The star formation rate (SFR) and supernova rate were both higher in the past.
3) AGN activity was higher in the past, producing more ultra high energy CRs (UHECRs).



Milky Way Supermassive Black Hole

If we were to assume again, that it can go briefly to 10 x Eddington

it would put its CR-emission at the observed distance higher than the current Cen A, by a factor of $10^{7.6}$

So relative to current GCRs would be higher by $10^{5.6}$

Bad Neighbors

CHANDRA PRESENTS
ASTRONOMY FACT #1

There is a supermassive black hole in the center of our very own Milky Way Galaxy. It is called Sagittarius A* and it is 26,000 light years away from Earth.

Don't worry! Our solar system is safe.

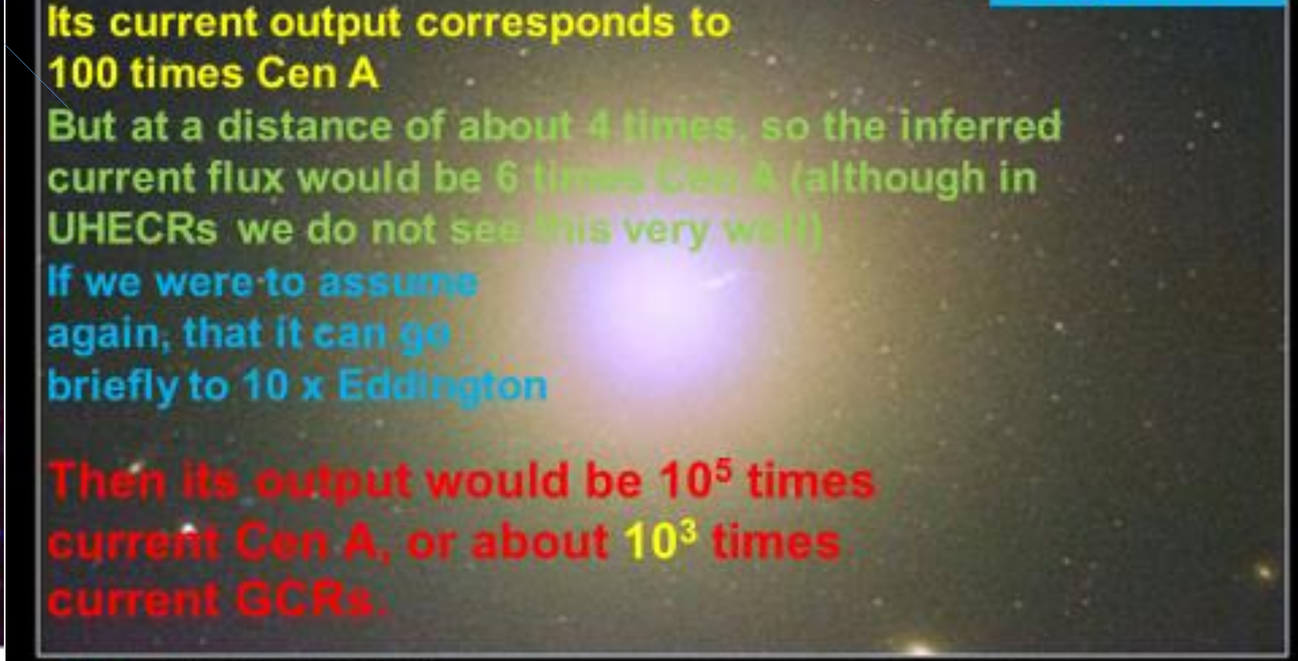
Safe for now! The Galactic Center BH is currently one of the least luminous supermassive black holes, this is probably a transient phase, the gas accretion and luminosity of Sgr A* may have been much higher in the recent past, from Greenland Ice core evidence.

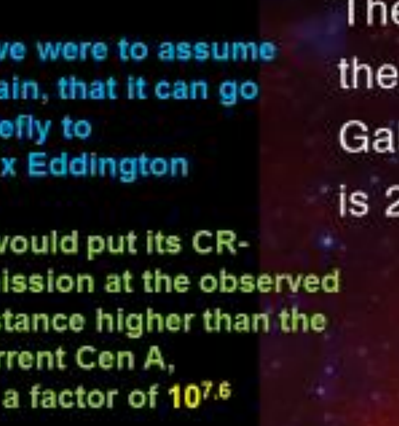
M87

Bad Neighbors

Its current output corresponds to 100 times Cen A
But at a distance of about 4 times, so the inferred current flux would be 6 times Cen A (although in UHECRs we do not see this very well)
If we were to assume again, that it can go briefly to 10 x Eddington

Then its output would be 10^5 times current Cen A, or about 10^3 times current GCRs.





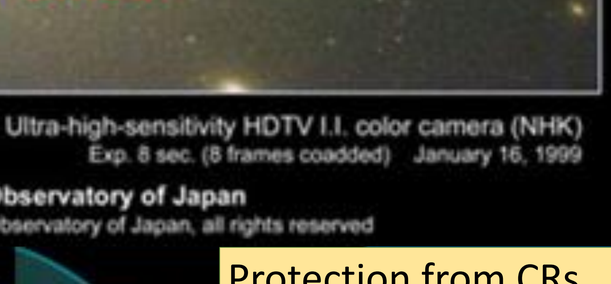
1) The size of the universe was smaller in the past exposing planets to more direct Ultra High Energy CRs (UHECRs).
2) The star formation rate (SFR) and supernova rate were both higher in the past
3) AGN activity was higher in the past.

The galactic magnetic field protects planets from ECRs.

The solar wind protects us from GCRs.

Earth's magnetic field protects us from solar wind.

A thick atmosphere is best protection against GCRs, but UHECRs even penetrate underground.



Protection from CRs likely has improved over the age of the universe:

1) Space has expanded
2) Increase in CNO abundance for atmospheres.
3) Decline of AGN activity