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).

Pierre Auger Cosmic Ray Observatory detects UHECRs

The earliest habitable planets - constraints from cosmic rays

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).

Chandra presents: 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 10^4.

Don't worry! Our solar system is safe.

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

The earliest habitable planets - constraints from cosmic rays

Milky Way Supermassive Black Hole

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.

The Earliest Habitable Planets - Constraints from Cosmic Rays

If star formation rate can be used to trace SN rate, than it may track cosmic CR intensity over cosmic time. In the past, the size of the universe was smaller, planets were closer, and the rate of star formation was higher.

AGN activity was much greater in the past.

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

The Earliest Habitable Planets - Constraints from Cosmic Rays

M87

It's 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.

The Earliest Habitable Planets - Constraints from Cosmic Rays

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