Bursts from the Very Early Universe

with Joe Silk, Oxford

Our direct observation of the universe is almost always via the photon

(Exceptions: Cosmic rays, Solar neutrinos, SN 1987a neutrinos)

For the early universe only photons.

The earliest we can go with the photon is t=400 000 years (CMB). Before that photons cannot fly freely and are stopped.

We hope to see thermal relics from earlier....

But

What if there were bursts of weakly interacting particles?

They are plenty of bursts in the nearby universe, SN's, Gamma ray, Hi E photons...

Recall proposal to measure accelearation parameter q with neutrino burst

Different ν types with mass, time separated pulses, hopefully

Time Delay

$$\Delta t \approx \frac{z}{H}[1-\frac{3+q}{2}z+...]\frac{1}{2}[\frac{m_1^2}{P_1^2(now)}-\frac{m_2^2}{P_2^2(now)}]$$

Neutrinos and Beyond

With neutrinos can get to seconds/msecs, with WIMPs to $\sim 10^{-11} s$,....with gravitons to Planck time (10^{-43} s)

There are an enormous number of independent regions of spacetime on our past light cone–perhaps anything could have happened occassionally...

Could we potentially “see” the transplanckian epoch, the creation of “baby universes”, tunnelling between configurations of the “landscape”... If yes these happenings become more than merely metaphysical...

So let's try to consider phenomology of what bursts could look like to us

Bizarre Feature/Difficulty: "Events" that Last a long time

Red shift stretches all time scales

Great redshift:at T=1 MeV, $z \sim 10^{10}$

Amusing Thought: "1 msec burst" will last a year!

Maybe your detector is not drifting......

Important point:

Length of burst not expected to increase indefinitely with red shift.

Natural timescale for burst is Hubble parameter– shortening at early times.

One finds, after redshift to present,
$\tau_{burst} \sim 9 \times (10^9 sec)(t_{em}/s)^{1/2} s$

About a year at the QCD phase transition,
$10^{-12} s$ at the Planck time.

Flux dilution:

Number crossing unit area $\approx N \cdot \frac{1}{4\pi}(\frac{1}{3t_{now}})^2$

$\sim N \cdot 6 \times 10^{-59}/cm^2$

N=initial number of particles in burst

Interesting: stops decreasing at high z

"Distance" to BB is finite

Size/ Present Energy Flux

Seemingly biggest possible burst is energy contained in a casually connected region ("within the horizon") at the time of emission. Gets small at very early times.

$$E^{now}_{horizon}/cm^2 = 3 \times 10^3 (t_{em}/s)^{3/2} \text{ eV/cm}^2$$

Enormous number of causally independent regions—tends to compensate small energy and small burst probability.

$\mathcal{P}$ = probability of a burst per unit 4-volume at emission time t_{em}

Obtain

$$d\ (energy\ \ flux)_{now} = d\ (energy\ \ flux)_{cmb}\, \mathcal{P}\, \frac{1}{2}\, \frac{dt_{em}}{t_{em}}$$

Leads to "Olbers paradox"? With $\mathcal{P}$ constant $\sim -ln\, t_{em}$

Finally a curious new issue raised by all this....

Can there be an arbitrarily weakly interacting particle???

Why: It turns out, as would be expected, that a graviton, $\sigma \sim G^2 S^2$ can just reach us from the planck time $1/m_{pl} = \sqrt{G}$.

So if we want to see the transplanckian or quantum gravity epoch, let's just invent a particle more weakly interacting than the graviton.

That was easy.... BUT Wrong!!

In GR the "charge" is the energy. All particles are universally coupled to it–all particles have energy.

No particle can interact more weakly than the graviton!!

Hence cannot see the transplanckian or quantum gravity epoch.

(A possible way out suggested by V. Zakharov: A string could be more weakly interacting than its constituents. Maybe a kind of shielding a la antigravity is posssible.)

PETER!!

There's still an awful lot for us to think about.