A Critical Review of Safety Papers Concerning Black Holes at the LHC

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By reviewing the different alternative categories of behavior outlined within physics papers for very small black holes that are thought could emerge from the LHC, I consider that in only the case of immediate decay or evaporation, has it been shown that there is sufficient basis for safety reassurance. But the basis of the methodology associated with the immediate decay model has strongly been questioned within physics papers. Another micro black hole behaviour analysis, being based on the recently peer reviewed minimum half mass theory for black holes of Vilkovisky (2006) - has not been seriously considered for potential dangers. The slower decay model is the basis of an argument by Plaga (2008) that there is an implied catastrophic danger in applying one of the modern theories (Randall/ Sundrum) that predicts micro black holes are likely. It is explained how counters to this argument by Mangano/ Giddings (2008), Stöcker et al. (2008) or Casadio et al. (2009) are based on misunderstandings; or disregard the implications of either the instantaneous 'Schwinger radiation' of black hole charge neutralization or of parameter values allowing for the slowest decay, even though both of the latter two are accepted in principle within the relevant pro safety papers themselves. It is concluded here that as a result, this argument for potential danger has not been invalidated. Finally, I argue that in the case of no decay, an argument of CERN's Mangano (2008/9) can be applied to that of Stöcker et al. (2008), to show that the astrophysical reassurance arguments are not reliable. I refer also to other relevant neglected arguments in this no decay context which have not been considered.

Recently, in reaction to concerns of black holes emerging from the LHC collider at CERN and a paper [1] suggesting a theoretical basis for a previously unconsidered risk, three papers [4], [5], [10] and a comment paper [11] argue that such danger could not occur. Here I will consider whether these papers suffer from neglects such that they fail to demonstrate the claimed safety.

Accepted - frequently production of LHC black holes could occur

I will first concentrate on what are accepted views within physics, if one of the recent 'TeV gravity' extra-dimensional* theories (1998/1999) is applicable for the micro scale of gravity:

'If the fundamental Planck scale is of the order of a TeV, as the case in some extra-dimensional scenarios, future hadron colliders such as the Large Hadron Collider will be black hole factories.' Giddings/ Thomas [2]

'If the scale of quantum gravity is near a TeV, the LHC will be producing one black hole (BH) about every second.' Dimopoulos/ Landsberg [3]

Also accepted, in CERN's LHC black hole risk paper [4], is that unlike any tiny black holes emerging from sufficiently high energy cosmic rays that strike the earth (or most astronomical objects), some proportion of such black holes produced at the LHC would be gravitationally captured by earth.

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* TeV: One trillion electron volts. An electron volt is the amount of energy involved in moving an electron through a potential barrier of 1 volt. 'TeV gravity' increases the amount of gravitational interaction - from this scale of energy for particle interaction - through the involvement of gravity within the extra dimension(s). Extradimensions: In the opinion of one of the theorists for 'TeV gravity'[20], extradimensions provide only an alternative, simpler means to explain theorized phenomena, hence non extra-dimensional theories could potentially explain those specific results presently predicted TeV gravity theories alone.

Four views within physics of LHC micro black hole behaviour

So, tiny 'micro' black holes could emerge. There are four views among physicists as to which of the following ways they would behave as black holes; whether they would decay extremely rapidly, much more slowly, be bounded in the extent of evaporation, or not evaporate at all. Firstly, the evaporation is expected to be so rapid that any consuming of matter at all would be very unlikely. In the second case, matter consuming 'accretion' can be allowed because the decay process slows considerably. Thirdly, if the evaporation is limited, it could only reach a minimum of around half the attained black hole mass. In the last case only matter absorption/ accretion - at some rate - would occur. In terms of physicists' discourse the following terms are used: immediate decay is described as the 'canonical' interpretation of Hawking evaporation/ radiation, slow decay involves the 'microcanonical' interpretation.

1. Immediate decay

I will consider here the main safety papers concerning black holes at LHC. 'Astrophysical Implications of hypothetical stable TeV-scale black holes' 2008, Mangano/Giddings [4] (Summary and Conclusion pp.50-53) and 'Exclusion of black hole disaster scenarios at the LHC' Stöcker et al 2008 [5]. Given the immediate decay considered, both utilise the 'canonical' interpretation of micro black hole Hawking evaporation/ radiation. The Stöcker et al paper [5] states this for their 'strong radiation' scenario.

Though an established approach, various criticisms of the applicability of this very rapid decay interpretation to black holes -and particularly micro black holes - have been made in the scientific literature. Prof Hawking, for example, has described [6] this approach as follows:

'..the standard statistical-mechanical canonical ensemble cannot be applied when gravitational interactions are important'.

Furthermore, Gingrich/ Martell [7] state:

'Modelling emissions with the [immediate decay] canonical ensemble from these [micro] types of black holes is inappropriate since a black hole in asymptotically flat spacetime cannot be in stable thermal equilibrium with its radiation.'

Also Hawking et al [8]:

'.. the attractive nature of gravity and the possibility of having a black hole cause the [immediate decay model] canonical ensemble to break down.'

2. Slower decay/ semi–stable micro black holes

In direct continuation from last quote [8]:

'One would expect that this problem could be overcome by the use of the microcanonical ensemble [slower/semi-stable micro black hole model] since this should still be well-defined.'

Further, according to Gibbons/Perry [9]:

'The use of the [slower/semi-stable micro black hole model] microcanonical ensemble is necessary because of the fact that self-gravitating systems can have negative specific heats (Lynden-Bell & Wood 1968; Hawking 1976).'

Yet CERN's black hole risk paper [4] completely neglects this slower decay/ semi-stable black hole (ie microcanonical) interpretation.

In isolation, slower decay black holes would eventually disappear. However, as shown by the peer reviewed 'Can black holes and naked singularities be detected in accelerators' 2002 by Casadio et al [10], and elsewhere, calculated results for decay rate with the 'canonical' rapid decay method differ very significantly from the slower decay alternative 'microcanonical' method for interpretation of micro black hole decay and radiation. For one relevant extra-dimensional theory - of Arkani-Hamed, Dvali, Dimopoulos ('ADD') - the micro black hole lifetime can be up to 10^-17seconds - still considerably longer than with the 'canonical' immediate decay calculation. For the other relevant extradimensional theory of Randall/ Sundrum, the paper estimates up to over 30 years for the smallest possible micro black hole from LHC.

'On the potential catastrophic risk from metastable quantum-black holes produced at particle colliders' 2008 [1] - by astrophysicist Rainer Plaga - applies this semi-stable black hole interpretation (produced after discussion with Casadio) to this Randall/ Sundrum theory. It argues that accretion can continue to dominate over any evaporation. This itself is already accepted by Stöcker et al in the 'weak radiation' scenario. However, by considering the inevitable black hole radiating aspect, Plaga goes on to argue that such black holes could reach masses such that the luminosity becomes dangerous. Plaga explained [1] this as:

'The mBHs in scenario 3 [addressed by his paper] emit Hawking radiation, .. the emitted power rises linearly with the mass. Might this radiation be more dangerous than the mechanical action of [radiation produced by] the accretion?'

'the radiation pressure of this Hawking radiation is intense enough to limit the amount of accreted matter to the same amount.'

'eventually catastrophic consequences due to global heating on an unprecedented scale and global earth quakes would seem certain.'

Within the earth, the micro black hole would only need to reach a level of mass many orders of magnitude below that of the whole earth, for such a catastrophe to occur. This paper then argues this to be feasible for the seriously and widely considered Randall/ Sundrum theory. It is further argued here, that similar implications for the relevant white dwarfs and neutron stars would, though, have undetectable consequences.

The paper 'Comments on claimed risk from metastable black holes' 2008 [11] by Mangano/ Giddings responds to Plaga's. But this fails to register the differing implications on luminosity shown by Casadio et al [10] from applying the microcanonical interpretation of Hawking radiation, so here, this incorrectly criticises [1]. This also incorrectly criticises Plaga by confusing the unattainability of a maximal accretion rate restriction ('Eddington limit') caused by the radiation from within the accretion process itself, with Plaga's consideration of an accretion rate restriction resulting from the micro black hole Hawking radiation.

'On the Possibility of Catastrophic Black Hole Growth in the Warped Brane-World Scenario at the LHC' 2009, by Casadio et al [12], considers specifically the slow decay scenario. When applying this microcanonical interpretation however, they neglect to make calculations using the parameter applied in the earlier peer reviewed [10] above (allowing over 30 year isolated duration). This is despite that the other parameter is still accepted in p.3 of the 2009 paper [12] as *'One possible choice is ..(16) [formula giving a parameter value]*'. Here it is also stated:

'In a previous publication {4} [[10] in this review], we showed that, using the metric of Ref. {8}, and depending upon the choice of parameter values, black hole lifetimes can be very long.'

The parameter formula given in Casadio et al 2002 [10] (at the bottom of p.3 in the arXiv version) is equivalent to equation (16) of [12]. This equation was the only one of [12]'s two formulae for this *particular* parameter value to be considered by [10] and giving the potentially very long duration. Infact, the very long duration calculation was the only given by [10] for the Randall/ Sundrum theory considered here.

The paper 'Exclusion of black hole disaster scenarios at the LHC' 2008 by Stöcker et al [5], here entirely relies on astrophysical considerations for reassurance. They consider two of the alternatives for decay. Within their 'weak radiation' or semi-stable black hole 'microcanonical' model however, they fail to incorporate the black hole charge neutralizing - 'Schwinger radiation'. Schwinger radiation would immediately neutralise any charge the black hole might have. Yet [5] does incorporate this Schwinger radiation in considering the alternative 'negligible radiation' scenario; though here Schwinger radiation is referred to as unlikely *because* Hawking radiation wouldn't occur in this scenario. This is stated also in CERN's paper [4], where again, no suggestion is made that Schwinger radiation should be unlikely where Hawking radiation does occur. So, by not applying Schwinger radiation for the Hawking radiating semi-stable black hole model, [5] implies that the earth or sun would electromagnetically stop such cosmic ray induced charged black holes, thus enabling any destructive consequences this may have - which are not observed. Yet if Schwinger neutralisation had been incorporated here, such stopping of micro black holes by the earth and ordinary stars could not occur.

Furthermore, this paper ([5]) fails to consider the increasing Hawking radiation aspect - so neglect Plaga's alternative cause for an 'Eddington limit', whereby the Hawking radiation from the micro black hole comes to restrict the accretion rate. Thereby the implication, outlined by Plaga, that no early white dwarf or neutron star collapse into cosmic ray induced micro black holes could occur - is ignored.

Nowhere has it been argued in opposition to Plaga - that indications from increased radiation caused by micro black holes' Hawking radiation within white dwarfs or neutron stars would be significant enough to be detectable. Moreover, for a sufficiently large composite black hole mass; micro black holes merging in white dwarf or neutron

star cores could, for wide parameter choices, be undetectably limited to a maximum of the conventional - four dimensionally determinable, luminosity.

By carefully confronting the various implications of such black holes - approaching and up to 30 years in isolated duration -as Plaga highlights; a proper, engaged consideration of this argument can be made.

3. Minimum limit of half the attained micro black hole mass

Gregor Vilkovisky has outlined in the peer reviewed 'Backreaction of the Hawking radiation' 2006 [13] a theoretical basis for black holes (in isolation) to only evaporate to a minimum of half the original mass:

'in the initial state all of the available energy is in the black hole, and in the final state exactly half.'

This then, is a further alternative consideration of how Hawking radiation would apply. Among the other mentioned papers here - this has only been referred to by CERN's LHC black hole risk paper [4]. However, no consideration is offered there as to the implications of danger from this. Yet, according to physicist Tony Rothman [14], Vilkovisky is 'a physicist of a similar calibre to Hawking'.

In considering the slower decay interpretation for this context, implications of this theory appears to allow continual accretion of micro black holes for broader parameter choices, perhaps alongside dangerous Hawking radiation; the latter would be to a lower extent than for semi-stable black holes.

4. No decay

If Hawking radiation were to not apply - considered possible in both CERN's black hole risk paper [4] and Stöcker et al's paper [5]- astrophysical data is again relied upon by both, for reassurance. This cosmic ray data relies upon the analogy of LHC collisions with astrophysical cosmic ray collisions upon the particular targets of white dwarfs and neutron stars, that could allegedly gravitationally capture black holes induced by such collisions. As the CERNs black hole risk paper [4] acknowledges, neutron stars are immunised enough by the strong magnetic fields that weaken cosmic rays, to prevent sufficiently probable black hole production. If neutron stars receive micro black holes already produced from cosmic rays; the argument of Prof Rössler [15] that their internal superfluid quantum coherence could prevent accretion, has not been countered in any safety paper. For acknowledged feasible parameters (p.26 Sect 4.4 of [4]) for the Randall/ Sundrum case - unutilised for accretion - accretion rates of any micro black holes within the candidate low magnetic field white dwarf could be slower than to enable their detectable early collapse from cosmic ray induced black holes. For this parameter, the continued accretion of earth would be a logical possibility. The full geological implications from many such micro black holes are not considered.

Otherwise, neglected arguments, though available through the literature, can be put forward concerning the decrease of white dwarf magnetic field strengths over time [16] (higher strength white dwarf magnetic fields can sufficiently weaken or deflect the LHC particle analogue of a cosmic ray) and the existence of extensive, fully concealing dust lanes, around inner galaxies- including ours, or of other dark nebulae (over 300 known) able to block cosmic ray paths from their sources. Such sources have been interpreted to number only a few hundred [17], or alternatively to reach us from predominantly one source - in the radio galaxy of Centaurus A [18].

Finally, in one of the two alternative methods of accretion calculation that is given in the 'negligible radiation' scenario of Stöcker et al, the relevance specifically of the strong nuclear force to early accretion is considered. As a result, it is considered possible that white dwarf accretion could be excluded (from p.12 of [5]). The relevant given parameter α, could have such a value that less than 1 in 10million of protons or neutrons would be accreted by a small micro black hole passing through them. This illustrates the uncertainties in this area, as here the argument of CERN's [4] differs. However, [4] does not explore the general implications of the strong nuclear force in relation to early accretion, whilst here it does make allowances for the electromagnetic force (for the electromagnetic capture radius 'R_{EM}'). Nevertheless, in Stöcker et al's [5], it is then argued that for such a parameter value of α in earth accretion, earth would be accreted in a period many times longer than the age of the universe. However, [5] admits that this alternative model lacks incorporation of the effect of the speed of a micro black hole passing through the proton or neutron. As argued in [19] of M Mangano, the amount of accretion of a proton or neutron, is in some way inversely related to the speed of the micro black holes passing through it. Thus, according to this basic alternative model (Stöcker et al [5]) of early accretion, but taking the argument of [19] into account, the rate of earth accretion for gravitationally captured LHC black holes would be significantly higher than given in this context of no white dwarf accretion. Furthermore, no lower bound above zero is given for this parameter α, so even neutron

star non-accretion from incoming black holes wouldn't be ruled out anyway; a similar argument implying micro black hole accretion within the earth would then apply.

Conclusion

I conclude that safety with black holes accepted as potentially emerging from the LHC has not been demonstrated. Moreover, a theoretical basis for catastrophe, within our lifetime, from available modern physics theory and with feasible parameters, has not been excluded. Any one scenario of danger: effects of dangerous levels of black hole radiation, hazardous geological consequences from non radiating black holes accreting in earth - even if slow, and potential implications from fully considering Vilkovisky's minimum attained black hole half mass model, should present sufficient cause for concern.

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