INITIAL FORMATION AND GROWTH OF IMBHs AT HIGH REDSHIFTS

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A gravitational wave mission called the Laser Interferometer Space Antenna (LISA) was studied extensively by ESA and NASA between 1993 and 2011. A smaller version of this mission called evolved LISA (eLISA) will be proposed to ESA in 2014, hopefully with partial support from NASA. Probably the major scientific objective of these missions is the observation of gravitational waves from mergers of Intermediate Mass Black Holes (IMBHs: 100 to 10,000 solar masses) and more massive black holes (MBHs) at redshifts up to about z = 10. This would put valuable constraints on the formation and early growth of IMBHs and MBHs, and hopefully help to clarify the interaction between these processes and galaxy formation and evolution.

When a mission like eLISA flies, it hopefully will provide strong evidence on which ones of the 3 or more currently proposed explanations for IMBH and MBH formation at early times actually were important. However, much tighter constraints on the various possible explanations appear to be possible if mergers of roughly 10 solar mass black holes (BHs) with IMBHs at redshifts up to z = 10 can be observed with a second generation gravitational wave mission. We suggested a candidate for such a mission called the Advanced Laser Interferometer Antenna (ALIA) mission in 2005, and have just submitted a more detailed paper on it (with J. R. Gair) to Class. & Quantum Grav.

The rates for BH-IMBH mergers at early times are very uncertain, even if a particular mechanism for initial formation of the IMBH is assumed. Thus, it is possible that eLISA will see few mergers involving IMBHs at large redshifts, and mainly more massive MBH mergers. This could be because most MBHs form with masses higher than the IMBH range, which would fit in with the quasi-star formation mechanism. But it also could be because IMBHs in galaxy centers grow by accretion to above the IMBH mass range before galaxy mergers occur. Or, early galaxy mergers might not cause IMBHs in the 2 galaxies to sink to the center and to form binaries that would coalesce in substantially less than a Hubble time.

On the other hand, if even 3% of the mass growth of an IMBH to 10,000 solar masses was due to BH-IMBH mergers, this would give about 15 such events during the growth from 5,000 to 10,000 solar masses. Most such events appear likely to be observable by a mission like ALIA, even at z = 10. Thus a much more detailed record of the early history of IMBH and MBH growth appears to be observable with only fairly modest improvements in the sensitivity of a second generation mission. As an example, such a mission might involve an increase in the telescope diameter to 1 meter, an increase in the laser power to 30 W, a decrease in the distances between spacecraft to 0.5 million km, and a decrease in the spurious acceleration noise by a factor 10 at frequencies above 1 mHz. Depending on what is seen by eLISA, a second generation gravitational wave mission may well be highly desirable scientifically on a 20 to 30 year time frame.