Calibrating semi-analytic VT's to injections in O3a

Daniel Wysocki

July 7, 2020
LIGO-T2000432-v1

In the O2 populations paper, we took SNR-based VT grids in mass (m_1, m_2) and mass–aligned spin $(m_1, m_2, \chi_{1z}, \chi_{2z})$ space, and calibrated them against pipeline-based injection VT's in mass-space only, which are only usable when averaged over the entire parameter space. We assumed that the injection VT's had some underlying functional form, such that

$$VT_{\text{inj}}(m_1, m_2) = f(m_1, m_2)\, VT_{\text{grid}}(m_1, m_2), \tag{1}$$

where f is some unknown function. We took f to be a Kth order polynomial, $\sum_a^K \sum_b^K \lambda_{ab} m_1^a\, m_2^b$, such that

$$\langle VT_{\text{inj}}(m_1, m_2) \rangle = \sum_{a=0}^{K} \sum_{b=0}^{K} \lambda_{ab} \, \langle m_1^a\, m_2^b\, VT_{\text{grid}}(m_1, m_2) \rangle \tag{2}$$

allowing us to estimate the coefficients λ_{ab} via least squares approximation, by taking the averages over a number of different population models. Due to decisions made early on with the injection-based VT's, these population models all followed the Model A powerlaw from the O2 populations paper, with fixed $m_{\text{min}} = 5\, M_\odot$, $\beta_q = 0$, and variable α_m and m_{max} in order to cover a wide range of parameter space.

Now in O3a, we have injections in mass–aligned spin space, and want to perform calibration again. Extending the calibration naïvely to the 4D mass–aligned spin space will result in a very high order basis with K^4 terms. Not much sensitivity information is present in $(m_1, m_2, \chi_{1z}, \chi_{2z})$ that isn't present in $(m_1, m_2, \chi_{\text{eff}})$, so a simple dimensionality reduction can be made here, taking our calibrating function to be $\sum_a^K \sum_b^K \sum_c^K \lambda_{abc} m_1^a\, m_2^b\, \chi_{\text{eff}}^c$.

All that's left to be decided is a population model. It may first be wise to extend the mass calibration from Model A to Model B, still fixing m_{min} (but now lowered to our injection campaign's new minimum of $3\, M_\odot$), but allowing β_q to vary. For the spin d.o.f., the population models being used in our analysis are no longer viable, so instead we propose using a rescaled beta distribution in χ_{eff}, and varying $\mathbb{E}[\chi_{\text{eff}}]$ and $\text{Var}[\chi_{\text{eff}}]$, restricting them to values which produce non-singular distributions (i.e., $\alpha_{\chi_{\text{eff}}}, \beta_{\chi_{\text{eff}}} \geq 1$)