Method of reducing the prior on time delay

The compilation of simulated ZTF-1a gLSNe systems has a wide range of time delay, from a few days to a tens of days. To accommodate all these time delays we had to consider a wide prior on the time delay in our resolving method; $0 \leq dt \leq 75$. This wide prior on dt causes many problems in the fittings including

- difficulty in convergence,
- degeneracies in solution,
- completely missing the region of the correct solution (correct peak in probability space),
- finding an incorrect solution,

etc.

However, we have seen that for relatively small time delays, $dt \lesssim 25$, the combined light curve has one single peak, whereas for larger time delays, $dt \gtrsim 30$ the combined light curves show two separate peaks (one for each of the images). We wish to utilize this information to shorten the prior on dt (and on μ also in some cases) before the fit starts. The algorithm is described below.

1. We first smooth the combined light curve. I tested a few smoothing methods including the widely used Savitzky–Golay smoothing. But, I prefer the smoothing method proposed by Arman (for example see [**?**]) because we have many freedoms in this method. We use a smoothing scale of 10 days. This would eliminate any spike occurring due to noise.

2. Next we find peaks in the smoothed (combined) light curves. While searching for peaks we set (i) a minimum height of the peaks relative to the tallest peak, (ii) minimum width and (iii) minimum separation between peaks.

3. Then we count the number of peaks.

   - If we have 1 peak: We are sure that time delay is not very high: we set the prior $0 \leq dt \leq 30$. Also we use the wide prior range (as before) on the relative amplitude: $0.25 \leq \mu \leq 4.0$.
   - If we have 2 peaks: We are sure that the system has high time delay. Moreover we can crudly estimate the time delay which would be roughly the difference in the peak positions in time, say Δt. Also we can have some idea about the relative magnification which would roughly be the ratio of the two peak heights (can be an overestimation though), say r. We then use the following priors: $(\Delta t - 15) \leq dt \leq (\Delta t + 15)$ and $r/2 \leq \mu \leq 1.5r$.
   - If we have. more than 2 peaks: We know there are 2 images and we already use this information in the fittings. So in this case we consider the 2 most prominent peaks and follow the treatment for 2-peak systems described above (we have various checks here).
   - In some rare cases with moderate time delay, we may have 1 wide peak instead of 2 peaks. So we also keep track of the width of the peak in 1 peak systems. If the peak width is found to be very large, we shift the prior range on time delay according to the width.

- We follow the above steps for green and red bands separately. If the conclusions are consistent only then we use this stricter priors, otherwise we proceed with the wider priors as before.

4. We tested this algorithm for reducing the prior on time delay on the 33 systems from the ZTF-1a simulations. We got correct results in all the cases.

5. In all cases the prior range on the time delay would be just 30 days instead of 75 days used in the earlier studies.

References

[1] D. A. Goldstein, P. E. Nugent and A. Goobar, Astrophys. J. Suppl. **243** (2019) no.1, 6 doi:10.3847/1538-4365/ab1fe0 [arXiv:1809.10147 [astro-ph.GA]].

[2] A. Shafieloo, JCAP **08** (2012), 002 doi:10.1088/1475-7516/2012/08/002 [arXiv:1204.1109 [astro-ph.CO]].