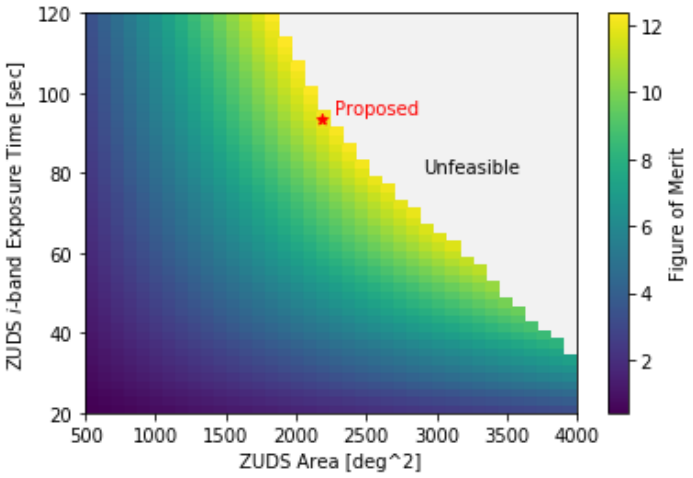
The ZTF Uniform-Depth Survey (ZUDS)[1]

Palomar winters are notorious for their long stretches of bad weather. While this can hinder ZTF science programs that require a stable cadence, it has little effect on projects that instead require deep observations over a longer time baseline. With this in mind, we propose for the period **Mid Oct 2019 - Mid Mar 2020**, to replace the high-cadence high-galactic latitude survey by the **ZTF Uniform-Depth Survey (ZUDS)**. The plan is as follows: monitoring of up to **45 ZTF fields in *g*, *r*, and *i* every clear night to a depth of >20.5 mag**. For *i*-band, this implies longer exposures. In order to *also* facilitate the search for fast transients and infant SNe, we propose to split the observations into 6 visits/night in **[g,r,i,i,g,r]** with exposure lengths **31, 31, 93 sec/visit in [g,r,i].** We plan to make use of the stacking pipeline (Goldstein et al. 2020, in prep) to reach **>21.5 mag on weekly stacks**, as well as the new *i*-band fringe corrections to improve the photometry (Medford et al. 2020, in prep)**.** For the stacked image depth we are assuming 50% losses due to weather and averaging over all lunations. We may reach >22 mag in stacks for optimal conditions. The stacked, cleaned ZUDS data products will be made available to the partnership at low latency, along with `Tractor` models of the images. The added volume is essential for studies of rare transients with (primarily) slow time evolution, e.g., TDEs, SLSNe, red/reddened transients and gravitationally lensed SNe (gLSNe). *For gLSNe, adding i-band is key to reach z ~ 1 magnified sources*. Moreover, the three filters would significantly enhance our ability to discriminate between e.g., faint high-*z* transients and AGNs, a severe limitation with efforts to find gLSNe with ZTF data today. This is particularly timely, as the gLSN team has secured LGS-AO follow-up time both at **Gemini-N and VLT**, and plans to submit comprehensive proposals to acquire **Keck and Palomar** follow-up time through Caltech and **Keck and Lick** time through UC. The redder/deeper 1-day cadence observations could also be very valuable for kilonova searches and reference building. We note that serendipitous discoveries (or upper limits on rates), independent of GW or sGRB triggers, could shed new light in the population properties of kilonovae and related phenomena.



Using the Monte Carlo simulations of the gLSN population (Goldstein et al. 2019), we calculated a Figure of Merit (FoM), defined as the number of gLSNe from ZUDS divided by the number from the g+r high-cadence + MSIP scheme. The figure above shows the FoM as a function of the survey area and *i*-band exposure time (assuming $t_g = t_r \mathrel{!}= t_i$). We optimized the FoM over the two parameters using the Nelder-Mead method, and found that the optimal survey

[1] "Zud" is a Mongolian term for a harsh winter. With our ZUDS survey, we hope to extract cutting-edge science from the traditionally harsh winter at Palomar.

(proposed here) would result in a **FoM of 12.4**, a dramatic improvement, resulting in **>10** gLSNe within detection reach in the 5 month survey, **including 3-5 lensed SNe Ia. Detecting multiple gLSNe would be a major breakthrough in time-domain cosmology.** For example, the resulting measurements of the Hubble constant based on time-delays could settle the question of whether new physics is needed to reconcile the tension between the local measurements of H_0 with the one based on CMB observations.

References

"Rates and Properties of Strongly Gravitationally Lensed Supernovae and their Host Galaxies in Time-Domain Imaging Surveys," D. A. Goldstein, P. E. Nugent, & A. Goobar, ApJS (2019), 243, 6

Appendix

Requested time:

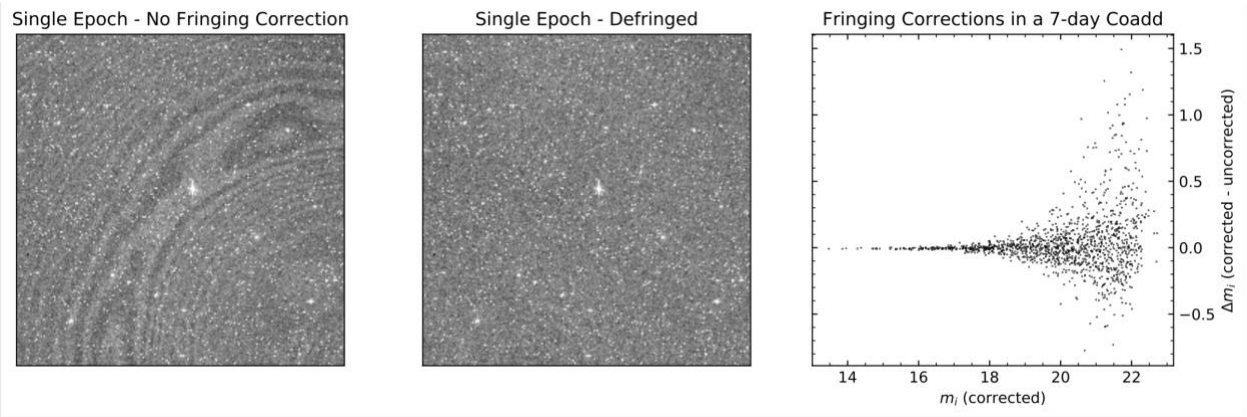
For each field we propose 4 x 31 s exposure and 2 x 93 second exposure; each has 10 seconds of overhead, totaling 0.10 hour/field. Considering the full 40% partnership allocation and the shortest (longest) clear night length, 4.3 (4.9) hs, we could potentially monitor between 43 and 49 fields/night. For the reported FoM we assumed 45 ZTF fields are monitored with 50% losses due to weather.

Field selection:

We select the ZTF fields observable for more than 2 hours per night for > 87% of the time during the winter months. Of the 48 fields selected, more than 20% are at declination that allows observability from Southern facilities, e.g. the VLT. However, only 10 of the chosen fields have references, hence, we will use the first week of operations to build references.

I-band fringe corrections:

While the limiting mag does not change much on individual images thanks to the de-fringing, the quality of the stacked images and the accuracy of the faint end photometry is much improved, as shown in the figure below.



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