PUE'O-NUI Science Case : Observations of Pre-Main Sequence Binaries

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In this contribution, I explore the possible open issues that an instrument such as PUEO'NUI at CFHT could help solving in the study of pre-main sequence binary systems. PUE'O-NUI is a possible upgrade of the current adaptive optics system PUE'O at CFHT. The proposed instrument would provide high Strehl ratio images in the near-infrared (>90 %) and diffraction-limited images in the visible, down to R band at least. I only consider here young stars that are 10^7 yr-old at most and focus on H and K band observations, with a consideration of the benefits of observing at visible wavelengths.

The first point to have in mind regarding PUE'O-NUI is that its main advantage over the current PUE'O system is in the separation range 0.1"–1", where it will dramatically reduce the "speckle noise". Outside of this radius (on order of the seeing), the gain produced by the new system is negligible. One must therefore focus on this separation range to evaluate the scienfic gain of an instrument like PUE'O-NUI.

Systematic surveys for tight binary systems among young stars with PUE'O (and ADONIS on a similar-size telescope) has shown that tight stellar companions are very frequent among solar-type and lower mass objects. Indeed, based on the observed number of companions at separations >1" and the large range of flux ratios, one can expect many companions with large flux ratios $3 < \Delta K < 6$–8 mag) at separation as small as 0.1", where they are currently not detectable with PUE'O or other instruments. It is therefore worth investigating what kind of companions could be found with PUE'O-NUI and what open issue that would help solving.

From the current simulations, the objects for which PUE'O-NUI will provide a significant gain over PUE'O are relatively bright, typically $V < 12$. *With such a brightness criterion, only a handful – 20 or so – of young solar-*

type stars (T Tauri stars) are concerned. On the other hand, more massive objects are brighter and there are more than 100 stars that could be observed with PUE'O-NUI. They would be either Herbig AeBe stars (2–5 $M_\odot$) or OB stars ($> 5\,M_\odot$); their distance range from ~100 pc to ~2 kpc.

Regarding T Tauri stars, it is important to note that the vast majority of known binaries have moderate flux ratios ($\Delta K < 2$ mag), essentially because the mass-luminosity relation at such young ages is quite shallow. Even substellar objects are quite bright when they are only a few Myr old and they are in principle easily detectable at almost all separations >0.1" with PUE'O. In the visible, PUE'O-NUI would produce diffraction-limited images, which PUE'O cannot do at the moment. This could be scientifically useful, both in imaging (spectral energy distribution determination) and spectroscopic mode (spectral type, hence mass, could be derived) assuming that the latter be provided as a mode of PUE'O-NUI. However, with a ~0.06" resolution at I band and a moderate flux ratio (~40 %), such observations could also be conducted with HST, which offers a somewhat poorer resolution but a much better image quality. Overall, the gain of PUE'O-NUI over already existing instruments as far as observations of binary T Tauri stars is concerned is very limited.

While the mass-luminosity relation is relatively shallow below 1–2 $M_\odot$ at an age of a few Myr, it is very steep for more massive objects. With PUE'O, a 0.08 $M_\odot$ companion located 0.1–0.2" away from a 2 Myr-old star can be detected only if the latter is less massive than 1 $M_\odot$. With PUE'O-NUI, this would be possible at almost any separation >0.1" for primaries up to $\sim 15\,M_\odot$. This would represent a major improvement, in that it would allow *a complete census of stellar companions to massive stars.* There are a variety of questions that would be solved with such observations:

- Binary systems among solar-type objects show a relatively flat distribution of mass ratios. Is this also true for massive stars? If not, what is the physical difference in the formation process of low- and high-mass stars that is responsible for this difference?

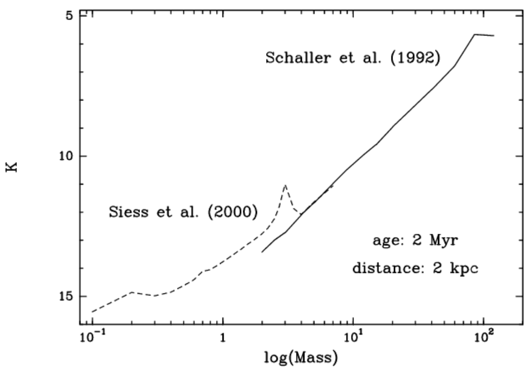
- Very few brown dwarf companions are known around low-mass stars. Do intermediate-mass stars have such companions? Brown dwarfs will be easily detectable with PUE'O-NUI around young 1–5 $M_\odot$ primaries.

- The dependence of the star formation process on environmental conditions is still strongly debated. The complete census of binary systems in both clustered and isolated populations of high-mass stars that PUE'O-NUI will enable would bring an importance piece of the puzzle.

- Visible imaging would provide complete spectral energy distribrutions for the low-mass companions of high-mass stars. From this, it would be possible to determine whether circumsecondary disks can survive in an environment that contains an OB star less than 1000 AU away. One could imagine that the high luminosity of the primary could photoevaporate such a disk long before planets can form, but no observations can currently quantify this phenomenon when stars are as close as a few hundred AUs. Photoevaporation is obviously an active mechanism in the Orion Trapezium but its potentially disruptive influence on planet formation still has to be quantified.

- A similar binary sensus among ZAMS and older high-mass stars could also be performed with PUE'O-NUI. The comparison of the overall binary properties of high-mass stars at various ages would help determining the origin of most field stars (clustered vs. isolated star formation) and the importance of dynamical interactions between stars in clusters.

In summary, *the most exciting scientific case for an instrument like PUE'O-NUI as far as young binary systems is concerned is the determination of all low-mass stellar and some substellar companions to high-mass (OBA) stars in various environments.* Such observations will provide extremely valuable information that will help improving our knowledge of the star formation process.



Mass-K magnitude relation for a 2 Myr stellar population, based on the evolutionary models of Siess et al. (2000, A&A, 358, 593) and Schaller et al. (1992, A&AS, 96, 269). Below $4\,M_{\odot}$, the population is still in the pre-main sequence contraction phase and is therefore more luminous than the main sequence models of Schaller et al.