TP-AGB Stars to Date High-Redshift Galaxies with the Spitzer Space Telescope

Claudia Maraston

Max Planck Institut für Extraterrestrische Physik, Giessenbachstr. 1,
85748 Garching bei München, Germany

Abstract. We present new stellar population models that include the contribution of the Thermally Pulsing Asymptotic Giant Branch (TP-AGB) phase also in the synthetic spectral energy distribution (SED). The TP-AGB phase is essential for a correct modeling of intermediate-age ($0.2 \lesssim t/\mathrm{Gyr} \lesssim 1 \div 2$) stellar populations, because it provides $\sim$ 40 % of the bolometric contribution, and up to $\sim$ 80 % of that in the K-band. These models are obtained by coupling the energetic of the TP-AGB phase as calibrated with data of Magellanic Clouds star clusters ([9]), with empirical spectra of TP-AGB stars ([3]). Now that the Spitzer Space Telescope (SST) allows the sigth of the rest-frame IR at high redshifts, these models provide the opportunity to use the TP-AGB phase as an age indicator also for high-redshift stellar populations. Here we focus on redshift ~ 3 and provide predictions of the colours of various galaxy models as will be measured by means of the IRAC imaging instrument on board the SST. We find a sizable magnitude difference between TP-AGB-dominated high-redshift stellar populations and those being older or younger. The first releases of GOODS data should allow a check of these predictions.

1 The Dating of Galaxies and the TP-AGB Phase

The epoch(s) of galaxy formation is constrained by dating the stellar populations at zero as well as at high redshift, because the timescales of stellar evolution are independent of cosmological models. Such a constraint provides an important check of current models of hierarchical galaxy formation, in the framework of which the assembly of massive galaxies appears to occur over a rather extended redshift range, with a substantial amount of star formation at redshift lower than 1 (see reviews by S. White and R. Sommerville, *this volume*). Such prediction appears to be at odd with the old average age, and the small spread in ages, derived for local massive ellipticals (Es) using optical absorption features and chemical evolution arguments (Thomas, Maraston, Bender, *this volume*; see also G. Gavazzi, *this volume*; [8]). Also, the finding of galaxies already massive at high redshifts (see contributions by A. Cimatti; R. Genzel, *this volume*; [16]) is difficult to accommodate in such models. On the other hand, there are also galaxies whose average ages appear to be rather young and could indeed be consistent with small formation redshifts ($z \lesssim 1$), like the so-called k+a galaxies ([13]), or lenticulars and some low-mass Es in the field (see Thomas, Maraston, Bender, *this volume*).

However, the dating of unresolved stellar populations by means of spectro-photometric indicators in the optical is limited by the well-known *age/metallicity*

ESO Symposia: Multiwavelength Mapping of Galaxy Evolution and Formation, pp. 290–295, 2005.

degeneracy ([4], [17], [11]), i.e. the phenomenon that a low metallicity can mimick a low age, and vice versa. When a stellar population ages above 1÷2 Gyr, the Red Giant Branch and the Main Sequence share almost equally the energy production (see e.g. Figure 3 in [9]), and their contributions evolve very smoothly with age. At the same time there are no other stellar phases of short duration and relevant energetics that become important and could be used as age indicators. Therefore, at old ages the age/metallicity degeneracy works at its best in confusing the age determination. To trace back the beginning of the formation of a stellar system it would be ideal to recognize it before it becomes a few Gyr old.

A clear signpost of intermediate age ($t \sim 1$ Gyr) stellar populations are Thermally-Pulsing Asymptotic Giant Branch stars (TP-AGB; [15], [9]). According to stellar evolution, the TP-AGB stellar phase, the brightest and the coolest on the HR diagram, becomes fully developed in stars with degenerate carbon-oxygen cores. The onset of such event in the life of a stellar population has been called the AGB-*phase transition* ([15]). The observational evidence of the onset of the TP-AGB is a sizable jump in the V−K colour that increases from $\sim$ 1.4 to $\sim$ 3.2, as observed among the Magellanic Clouds globular clusters (see Section 2). The narrow interval in evolutionary mass ($1.5 - 3\ M_{\odot}$) constrains the whole duration of the TP-AGB dominance to be $\sim$ 1 Gyr ([9]). Therefore, picking up the TP-AGB is a powerful way of dating a stellar population, and this technique has been applied with success to local stellar populations ([12]).

How can we extend this approach of age dating to $z > 0$?

An early suggestion in this direction is due to [14], who indicated that the AGB phase transition potentially is an effective tool to date the high redshift formation of Es. Two factors has hampered the exploitation of this idea until now. First, the rest-frame IR at redshift $2 \div 3$ is sampled by the observed frame around $8 - 10\ \mu$m. This window is only now available thanks to the advent of the S(pitzer)S(pace)T(elescope). Second, synthetic spectral energy distributions (SEDs) including the TP-AGB phase are clearly required, but usually evolutionary population synthesis models include only the early part of the AGB phase (so-called the Early-AGB), thereby missing the TP-AGB that is the one energetically important (see Section 2).

In this contribution we introduce model SEDs that include the TP-AGB phase (Section 3) and show the substantial effect on the integrated SEDs of intermediate-age stellar populations. In Section 4 we construct diagnostic colour-colour diagrams for the imaging instrument IRAC on board the SST for the illustrative redshift of 3. We further discuss the use of these models at every redshift.

2 TP-AGB in SSP Models: State of the Art

The TP-AGB is a critical stellar phase to be accounted for in a Stellar Population (SP) model, because its energetic and duration are affected by mass-loss and nuclear burning in the envelope, both phenomena requiring parametrizations to be calibrated with data ([7]). However, the TP-AGB phase is the dominant phase