Revised Yale Isochrones

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20세기에 수행된 이론천문학 분야의 중요한 업적 중 하나는 항성표면에서 방출되는 '빛'의 관측 자료를 바탕으로, 몇 가지 미분방정식과 물리학적 지식, 그리고 고속 컴퓨터를 이용하여 항성의 내부 구조와 진화에 대하여 비교적 자세한 이해를 할 수 있었다는 것이다. 이러한 항성진화모델을 Color-Magnitude Diagram(CMD)상에서 UBVRI 관측과 비교하는데 매우 유용한 자료가 바로 아래에 소개하는 Revised Yale Isochrones 이다.

잘 알려진 것과 같이 Isochrone 사용의 대표적인 예는 성단의 CMD와 비교하여, 성단의 나이를 결정하는 것이지만, 개개의 항성관측자료를 모델과 비교하여 여러 가지 유용한 결과를 얻는데도 사용되고 있다. 또한, 은하의 진화연구 및 관측우주론 연구의 중요한 도구가 되는 성단과 은하의 항성종족모델을 만들기 위한 기본적인 입력자료로도 사용된다.

Revised Yale Isochrones 자료는 현재 연세대 천문대의 SUN workstation 내에 저장되어 있으며, 다음의 절차를 따르면 누구나 ftp로 연결하여 화일의 이동이 가능하다:

(1) ftp to galaxy.yonsei.ac.kr (IP:165.132.28.11)
(2) login as "public" (passwd is "public")
(3) change directory to "RYI"

Isochrone 화일들은 화학 조성에 따라 구분되어 있다. 화일 이름의 처음 두 숫자는 금속함량(Z)을 의미하며, 세 번째 숫자는 헬륨함량(Y)을 의미한다. 예를 들면, ISO.123 화일은 Z=1×10**(-2), Y=0.30에 해당하며, ISO.432는 Z=4×10**(-3), Y=0.20에 해당한다. 좀 더 자세한 내용은 아래에 첨부하는 original document를 참조하기 바란다.

Overview

The revision of the original Yale isochrones and luminosity functions(Ciardullo and Demarque 1978) was motivated by the need for useful luminosity functions (LF's) and a better representation of the cooler parts of the color-magnitude (CM) diagram. In the process, many improvements and additions have been made to the isochrone tables as well, resulting in greater overall consistency and accuracy, plus a significantly better match to observations. We have compared the isochrones with recent CCD color magnitude diagrams of the globular clusters 47 Tuc, M4, M13, M15, NGC 6752, and M68, and with the old open clusters NGC 188, NGC 2420, M67, and the agreement is quite satisfactory.

The revised isochrones and LF's are based on the stellar evolution calculations of Mengel *et al.* (1979, hereafter MSDG) and Sweigart and Gross(1978, SG). We expect that they will be very useful, not least because these tables still comprise the most complete isochrone grid available in both age and composition. A comprehensive discussion of the new isochrones and LF's is contained in Green, Demarque, and King (1987, hereafter Paper I), with the details of the color calibrations given by Green *et al.* (1987, Paper II). The following is a brief summary of the most important changes.

The most obvious improvement in the new tables is the inclusion of UBVRI data as well as the theoretical quantities. For the first time, an attempt has been made to produce isochrones with magnitudes and colors that are empirically matched to a wide range of observational UBVRI data (paper II). In addition, the input data tracks have been carefully analyzed to get a more consistent set of equivalent evolutionary points (EEP's), making possible a more physically meaningful interpolation between the isochrones and better LF's. Nonlinear interpolation was used throughout the calculations, eliminating bumps and step functions in the LF's. A zero age main sequence (ZAMS) has been added to the ages for each composition.

To make the results directly comparable with observations, the isochrones were shifted in effective temperature to compensate for the fact that the original tracks were computed with a convective mixing length to pressure scale height of 1 instead of 1.5. Red giant branches (RGB's) have been interpolated wherever possible for the intermediate compositions Z = 0.0004, 0.004, and 0.04, which previously extended only up to the base of the RGB. The previous, large, nonphysical dip in the LF's on the lower giant branch has been eliminated by correctly joining the MSDG turnoff tracks to the corresponding SG giant branches (although a negligible glitch in log L and log Teff still remains). All LF's have now been normalized in precisely the same way, so that LF's for different compositions can be directly compared.

Finally, we have made available two Fortran programs, ISOTRP and LF, to facilitate working with the revised isochrones. They incorporate our experience of the best methods of interpolation, minimization of precision problems, and how to deal with compositions and ages that are not always complete. ISOTRP allows the user to interpolate for any helium abundance or metallicity in the range of the Yale isochrone tables. LF constructs customized differential luminosity functions for Mbol or a UBVRI magnitude, for any bin size, and for any initial mass function exponent.

Some constraints on usage

The revised isochrones use the same input mass tracks as the original Yale isochrones. The faint main sequences are extrapolated from Mbol of approximately 6.0 - 6.5 down to about 8.0, and cannot be meaningfully calculated fainter than that, due to a lack of lower mass input tracks (MSDG). The upper ZAMS (age = 0) artificially ends at the highest available MSDG mass track. Similarly, the isochrone calculations stop at the base of the red giant branch for the youngest ages, since the SG tracks do not include intermediate or high masses. None of the isochrones continue past the tip of the first giant branch.

The isochrones faithfully reflect the input mass tracks, with the one exception of the convective log Teff correction. Since this correction was made for the RGB as a whole and since theoretical temperatures at the tip of the RGB are quite sensitive to the model atmospheres used as boundary conditions (the SG tracks used only grey atmospheres), the calculated log Teff at the extreme tips of the RGB are not well determined. The discrepancies are minor for the metal poorest isochrones and worst for the most metal rich ones. A second consequence is that the isochrones do not include the effects of mass loss, either on the youngest upper main sequences or at the tips of the giant branches.

The tabulated observational quantities, V magnitude and UBVRI colors, were determined using empirical stellar data to calibrate Kurucz' (1979; plus private communication) and VandenBerg and Bell's (1985) model atmospheres, and to extend them to cooler temperatures. The observed stellar data points include the solar abundance ZAMS and several globular cluster giant branches, (-0.7 > [Fe/H] > -1.9), which were matched to isochrones of the appropriate compositions and ages. The observational isochrones should be reasonably good in the neighborhood of the fitted points, and somewhat less certain elsewhere.

The reference for The Revised Yale Isochrones and Luminosity Functions is: Green, E. M., Demarque, P., King, C. R. 1987, Yale University Transactions

The isochrone data files

Each file contains isochrones for a single composition. The first two numbers of the file extension indicate Z, and the third number indicates Y for that file. For example, ISO.123 contains data for Z = 1 x 10**(-2), Y = 0.30; ISO.432 pertains to Z = 4 x 10**(-3), Y = 0.20, etc. Zsun has been defined to be 0.02.

Each isochrone file has a ZAMS plus as many of the following ages as could be interpolated (or reasonably extrapolated) from the MSDG and SG mass tracks (units are 10**6 yrs) :
150, 200, 350, 500, 750, 1000, 1500, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000, 11000, 12000, 13000, 14000, 15000, 16000, 17000, 18000, 20000, 22000, 25000

The data files include the following compositions and ages :

Z	Y	MS-turnoff ages	Age range with Giant Branches
0.00001	0.10	0, 200 - 25000	none
	0.20	0, 200 - 25000	11000 - 25000
	0.30	0, 150 - 25000	6000 - 25000
	0.40	0, 150 - 18000	none
0.0001	0.10	0, 200 - 25000	none
	0.20	0, 200 - 25000	3000 - 25000
	0.30	0, 150 - 25000	6000 - 25000
	0.40	0, 200 - 18000	none
0.0004	0.20	0, 200 - 25000	3000 - 25000

	0.30	0, 150 - 25000	6000 - 20000
0.001	0.10	0, 200 - 25000	none
	0.20	0, 200 - 25000	6000 - 25000
	0.30	0, 150 - 25000	7000 - 25000
	0.40	0, 150 - 18000	none
0.004	0.20	0, 200 - 25000	3000 - 22000
	0.30	0, 150 - 17000	6000 - 17000
0.01	0.10	0, 200 - 25000	15000 - 25000
	0.20	0, 150 - 25000	750 - 25000
	0.30	0, 150 - 20000	500 - 20000
	0.40	0, 150 - 20000	3000 - 20000
0.04	0.20	0, 150 - 22000	3000 - 22000
	0.30	0, 150 - 25000	1500 - 25000
0.1	0.20	0, 150 - 22000	none
	0.30	0, 150 - 25000	none

Within each data file, every isochrone is preceded with a header line :

IGB, NPTS, ALPHA

format (I3, 8X, I3, F5.2)

where IGB = 0 indicates turnoff only, = -1 means RGB also

NPTS = number of points for this isochrone

ALPHA = effective convective mixing length to pressure scale height ratio; always = 1.50

The following quantities are listed for each of the following NPTS lines :
J, X, AGE, IY, IZ, MASS, LOG TEFF, LOG L, (DN(M), M=1,3), V, U-B, B-V, V-R, R-I

format (I3, A1, I6, I2, I4.4, F9.6, 2F10.7, 3E15.9E1, 5F7.3)

where J = equivalent evolutionary point (EEP) number

X = an * if this mass point was extrapolated (or if it was interpolated over a very large interval); a blank otherwise (See MSDG Table 1 for original mass data available)

AGE = the age in units of 10**6 years

IY = helium abundance Y*100

IZ = metal abundance Z*10**5 (except IZ=0000 for Z=0.00001 and IZ=9999 for Z=0.1)

MASS = mass in solar masses

LOG TEFF = Log Teff

LOG L = Log L, with L in solar luminosities

DN(M) = the number of stars between J and J+1, for three different MS initial mass functions, S = 1 + x = 0, 2.35, and 4.00, dN=const*M**(-S). The constant was chosen to normalize all dN to 1000 stars in the range 0.5 < M < 1.0 solar masses on the initial MS.

V, U-B, etc = UBVRI magnitude and colors; Johnson UBV and Cousins RI. (see paper II)