

## **TRILEGAL Milky Way Stellar Mock Catalogue** for the Chinese Station Space Telescope





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# **Outline** :

- Brief history of understanding the Milky way
- Introduction of TRILEGAL:
  - Galactic models
  - Stellar models
- TRILEGAL MW simulation for CSST
- Concluding remarks and prospects

## Brief history of understanding the Milky way

## History: Galileo's obs. of the MW

• In 1610, Galileo Galilei: MW is composed by countless stars





Two telescopes built by Galileo, Museo Galileo, Florence Image Source: www.mpg.de Galileo's original sketch of the three stars in Orion's belt and the Orion Nebula

# Hisotry: Kant's idea of MW

- 1750, Thomas Wright: Milky Way is a thin spherical shell of stars. The Sun is located inside the shell about midway between the inner and outer edges.
- In 1755, Immanuel Kant: MW is a large collection of stars gravitationally bound, rotating and flattened as a disk, with the Solar System embedded within the disk. Propsed "island universes" theory and sparked the "great debate".



Wright's original woodcut

# **History: Herschel's MW**

- In 1785, William Herschel: attempted to actually map out the shape of the Milky Way, based on the assumptions/neglections:
  - Stars uniformly distributed inside the MW boundary
  - Not realizing dust absorption



Shape of the MW by W. Herschel, 1785

# History: Kapteyn & Shapley's MW

- Jacobus Kapteyn (1901~1922): used photographic star counting, estimated distances statistically based on parallax & proper motions of nearby stars.
- Harlow Shapley (1915~1921): estimated globular cluster distances from RR Lyrae stars.



Oort's illustration of the discrepancy of the Kapteyn Universe and Shapley's system of globular clusters. From de Sitter's book 'Kosmos'.

# History: MW's position in the Universe by Hubble

 In 1923, Edwin Hubble: using Cepheids in M31, measured the distance M31 to be ~ 300 kpc (765 kpc nowadays' value), with the 100-inch Hooker telescope at Mount Wilson Observatory.

### ANOTHER UNIVERSE SEEN BY ASTRONOMER

Dr. Hubble Describes Mass of Celestial Bodies 700,000 Light Years Away.

CHICAGO, Jan. 21 (P).—For years astronomers have speculated as to whether various nebulous formations in the heavens belongs to this universe or were "island" universes of their own, immeasurable distances away.

From New York Times, 1923

# **History: MW Stellar populations**

- As early as 1926, Jan Oort has recognized two types of stellar populations.
- During 1944, Walter Baade, categorized groups of MW stars into
  - Population I: bluer stars associated with spiral arms
  - Population II: yellow stars dominated near the bulge and within GC



FIG. 1.—Shaded areas: ordinary H-R diagram (type I). Hatched area: H-R diagram of stars in globular clusters (type II).

Figure 1 represents schematically the H-R diagrams of the stars in the neighborhood of the sun (shaded) and of those in globular clusters (hatched). To conform with the usual

by Baade, 1944

## **History: modern view of the MW**



### Multiwavelength Milky Way



From https://asd.gsfc.nasa.gov/archive/mwmw/mmw\_images.html

### Multiwavelength Milky Way



From https://asd.gsfc.nasa.gov/archive/mwmw/mmw\_allsky.html

## Introduction of TRILEGAL

# **Star counting Galactic model**

Principle of star counting models based on

stellar population synthesis :

$$N(m_{\lambda}, \hat{\mathbf{r}}) \, \mathrm{d}m_{\lambda} = \mathrm{d}m_{\lambda} \int_{r=0}^{r=\infty} \rho(\mathbf{r}) \, \phi(M_{\lambda}, \mathbf{r}) \, r^2 \, \mathrm{d}\Omega \, \mathrm{d}r$$

$$M_{\lambda} = m_{\lambda} - 5\log r - A_{\lambda}(r) + 5$$

The goal of star counting models: to find the correct  $ho({f r})$  and  $\phi(M_\lambda,{f r})$ 

Density profile

Luminosity function

# Galactic components & luminosity functions

$$\rho(\mathbf{r}) \qquad \rho = \rho_{d} + \rho_{h} + \rho_{b}$$

$$\rho_{disk}(\mathbf{r}) \propto \exp[-z/H(M) - (x - r_{0})/h]$$

$$\rho_{sphereaul}(\mathbf{r}) \propto (\mathbf{r}/r_{0})^{-7/8} \exp[-10.1(\mathbf{r}/r_{0})^{1/4}]_{1}$$
and
$$\rho_{sphereaul}(\mathbf{r}) \propto (\mathbf{r}/r_{0})^{-7/8} \exp[-10.1(\mathbf{r}/r_{0})^{1/4}]_{1}$$

 $\rho_{\text{massive hato}}(r) = \rho_{\text{ff}}(r_0)[a^* + r_0^*]/[a^* + r_0^*]$ 

May also be the potential

 $\phi(M_{\lambda}, \mathbf{r})$ 

 $\phi(M_{\lambda}, \mathbf{r}) = \phi(M_{\lambda})$  for different components

 Empirical ones: derived from Solar Neighbourhood or globular clusters: Bahcall & Soneira 80-83, GALFAST (Juric+08)

2. Theoretical ones: Population synthesis star count models

Requires: IMF, SFH, age-metallicity relation (AMR), Stellar models

eg., Besançon (Robin+03), TRILEGAL (Girardi+05), Just-Jahreiss+08,

Galaxia (Sharma+11), GalMod(Pasetto+18), etc.

## Distance of Sun from the Galactic Center: as an example

Label	Reference	Method	Location	т	Ra (kpc)
Rd+09	Reid et al. (2009i)	Trig. parallas of Sgr B	GG	-d.	1.W0±0.15
Mo+12	Morris et al. (2012)	Orbit of \$0-2 around Sgr A*	GC	d	$2.70\pm0.40$
Gi+09	Gillessen et al. (2009h)	Stellar orbits around Sgr A*	GC	đ	- #33主化村
Ch+15	Charmpoulos et al. (2015)	NSC statistical parallas	GC.	-d	$\pm 8.27 \pm 0.13$
Do+13	Do et al. (2013)	NSC-statistical parallate	GC	đ	$8.92\pm0.56$
8815	Bajkova & Bobylev (2013)	Trig-parallases of HMSFRs	DSN	(1)	$11.03\pm0.51$
Rd+14	Reid et al. (2014)	Trip. parallaxes of HMSFRs	DSN	m	$-8.34\pm0.19$
Ho+12	Houma et al. (2012)	Trig. parallases of HMSFRs	DSN	115	$8.05\pm0.45$
Z\$13	Zhu & Shen (2013)	Near-Ra rotation young tracers	DSN	10	$8.08\pm0.62$
Boll3	Bobylev (2013)	Near-Ra rotation SFR+Capheids	DSN	01	$1.745\pm0.66$
Sch12	Schünrich (2012)	Near-Ro rotation SEGUE stans	DSN	тя	$4.27\pm0.41$
Ku+15	Kupper et al. (2015)	Tidal tails of Pal-5	01	105	$\pm 8,30 \pm 0.33$
VH+09	Vanhallebeke et al. (2009)	Bulge stellar population mudal	B	0.5	$1.8.20 \pm 0.50$
Pi+15	Pietrukowicz et al. (2015)	Bulge RR Lyrae stars	В	4	8.27±0.40
De+13	Dékiny et al. (2013)	Bulge RR Lyrae sour	R		#33±0.17
Da09	Dambis (2009)	Disk/halo RR Lyrac stars-	DSN	*	$7.58 \pm 0.67$
Ma+13.	Matsuniga et al. (2013)	Nuclear bulge T-II Cephyids	B	4 -	$7.30 \pm 0.60$
Ma+11	Massinaga er al. (2011)	Nuclear hulge Cepheids	n	4	$7.90 \pm 0.10$
Gr+08	Gröenewegen et al. (2008)	Bulge Cephends	8	1.4	$T298 \pm 0.91$
Ma+09	Marsunaga et al. (2009)	Bulge Mirae	8	1	824 + 0.47
GrB05	Groenewegen & Blommaert (2005)	Bulge Mirac	B	1.10.1	$8.60\pm0.81$
FA14	Francis & Anderson (2014)	Balge red clump guons-	8		$7.60 \pm 0.80$
Cat13	Cao et al. (2013)	Bulge red champ giants	8		8.20 ± 0.20
Fr+11	Fritz et al. (20(1)	NSC red clamp grans	GG	4	$2.94 \pm 0.76$
FA14	Francis & Anderson (2014)	All globular clusters	8,111	5	240±0.38
Bt+06	Bica et al. (2006).	Halo globular clusters	- 113	4	$7.30 \pm 0.54$

Table 3 Recent metagements of discourse H. to the Calactic Field



Recent measurements of  $R_1$  in Table 3, using different methods. Red, blue, and gray points denote direct, model-based, and secondary estimates, respectively. (a) Time sequence for all, with our adopted best estimate,  $R_0 = 8.2 \pm 0.1$  kpc. (b) Separate time sequences for determinations in the Galactic Center, bulge, disk and Solar Neighborhond, and inner halo (nor using the FA14 globular cluster value that includes the inner metal-rich clusters). The borizontal lines show weighted mean values for the respective components, and colored hands show 1 $\sigma$  UUE (incorrelated unbined standard errors).

From Bland-Hawthorn & Gerhard, 2016, ARAA

## **Comparison of different star counting MW models**

Model	Bulge	Thin disk	Thick disk	Halo	DM	Else	Stellar model	Dynamics	Kinem atics	Com ment
TRILEGAL (Girardi+05)	Triaixal	Exp.+ Sech^2	Exp.+ Sech^2	Power-law, axisymmetric	Ν	Ν	PARSEC	Ν	Y	
Besançon (Robin+03)	Exponential	Exponential	Exp.	Exp., spherical	Y	Warp, flare	Padova	Y	Y	
Galaxia (Sharma+11)		Similar	to Besançon			Accept N-body sim.	Padova	Self- consistent	Y	
J-J (Just & Jahreiß, 10)		Disc sha	pe		Y	Gas	PEGASE (with Padova models as default)	Y	Y	S. Gao contri buted
GalMod (Pasetto+18)	Spherical+density potential	Spherical+density Exp.+Sech^2 Solved from potential		Solved from the potential	Y	Bar	PARSEC	Y	Y	





# **TRILEGAL's Galactic components**

### **Geometry:**

**Thin disk** exp. in R and sech<sup>2</sup> in z, scale height increasing with population age **Thick disk** exp. in R and sech<sup>2</sup> in z, fixed scale height

Halo power-law oblate

Bulge triaxial cf. Binney+97

**Dust layer** exp. in z, extinction cf. SFD+98, SF+11, Abergel+14, Lallement+18, Green+19

External objects (e.g. SMC and LMC)

Galactic component	Mass distribution	Constants						
Thin disk	$\rho_{d} = C_{d} \frac{\exp(-R/h_{Rd})}{\cosh^{2}(0.5z/h_{rd})}$	$h_{Ed} = 2913.36 \text{ pc}$	$z_0 = 94.69 \text{ pc}$ $C_d = 0.14691 \ M_\odot/\text{pc}^3$					
	$h_{zd}(t) = z_0 (1 + t/t_0)^{5/3}$	$t_0 = 5.55079 \cdot 10^9$						
Thick disk	$\rho_{\rm D} = C_{\rm D}  \frac{\exp(-R/\hbar_{RD})}{\cosh^2(0.5z/\hbar_{zD})}$	$h_{RD} = 2394.07 \text{ pc}$ $C_D = 0.00378 M_{\odot}/\text{pc}^3$	$h_{zD} = 800.0 \text{ pc}$					
Bulge	$\rho_{\rm b} = f_0  \frac{\exp(-a^2/a_m^2)}{(1+a/a_0)^{1.8}}.$	$f_0 = 406.0 \ M_{\odot} / {\rm pc}^3$	$a_m = 2500.0 \text{ pc}$					
2101.1	$a=\sqrt{x^2+(y/\eta)^2+(z/\zeta)^2}$	$a_0 = 95.0  \mathrm{pc}$	$\eta=0.68\qquad \zeta=0.31$					
Halo	$p_{\rm h} = C_{\rm h} \left( \frac{R_{\odot}}{\sqrt{R^2 + (z/q)^2}} \right)^{2.75}$	$q = 0.62 \mathrm{pc}$	$C_{\rm h}=10^{-4}~M_\odot/{\rm pc}^3$					

### **Stellar populations:**

#### Each component has its own IMF, SFH, AMR

IMF Chabrier+03 by default, Kroupa, Salpeter, etc.
Binary fraction default 30% for mass ratio 0.7-1
Bulge age~10Gyr, AMR cf. Zoccali+03
Thick disk age~10Gyr, AMR cf. Boeche+13
Halo constant SFR over the last 12-13 Gyr, AMR cf. Henry & Worthey 99
Think disk constant SFR over the last 11 Gyr, AMR cf. Rocha-Pinto+00
External objects specific IMF, SFR and AMR

#### Check Girardi+05 for more details



## PARSEC: RAdova and tRieste Stellar Evolutionary Code



## **PARSEC Tracks/Isochrones**



## Padova models: diffusion mixing by Deng+96a,b









Stellar evolution with turbulent diffusion by Licai Deng, A&A, 1996, v.313, p.145-158 & p.159-179



## PARSEC Pre-Main Sequence models



Fu+15: envelope OV + residual accreting reproduces the Spite-plateau

## PARSEC models for very-massive stars



## PARSEC models for very-massive stars



## PARSEC models for very-massive stars



Tang+16: Contrary to what has been stated in the literature, we find that the Schwarzschild criterion, instead of the Ledoux criterion, favours the development of blue loops

## PARSEC models with alpha-enhancement



Fu+18: PARSEC alphaenhanced model ftting to 47 Tuc

Important for elliptical galaxies, dSph, GC, thick disk, bugle, halo, ...

## PARSEC model of rotating stars



## TP-AGB models: ERC project **STARKEY**



Starkey results: Pastorelli+19,+20, Chen+18, & in preps., Marigo+20

> Marigo+20 : reproduce the IFMR kink with COLIBRI TP-AGB model

Carbon star formation as seen through the non-monotonic initial-final mass relation

ARTICLES

Paola Marigo, 111, Jeffroy D. Commingo, Janon Lee Certis, 11, Januar Kalical, 11, Vang Chem, 1, Pler-Emmänisel Tremblay, Ernico Remirez-Ruiz, Pierre Gergeron, Sata Bladh, 140, Alessandro Bressan, 11, Léo Ginedi, 11, Goada Pastoretti, 11, Michele Trebucchi, 111, Smae Cheng, 11, Bernfuad Alimper, 11 and Piero Dal Tio, 111

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The territal-Final mass relation ((FMH)) prior the birth mass of a star to the mass of the compact resonance but at its about 10 Minutes are predicted in the territory of the first stars of the Film mass of the Film mass of the Compact resonance for at its death. When we are predicted of a loss start between engages which about a two film mass and the film Minutes for at the birth mass of the film mass of the film of the film mass of the film mass of the film mass of the film mass of the film of the film mass of the film mass



#### CMD 3.4 input form

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#### Latest news

- <u>NEW</u>, (136e, 20) New COLIBEI tools from <u>Boymelli r: al.</u> (2029) multiple:
- NEW, (150:520) Look a the new LPV section, with LPV periods from Trabacchi et
- (Stray19) The cases Av-0 (with extinction compand star by star), and mixed AB+1
- UNLER M. WERKE Implementing post-AUB + WD marks and EPV variability.
   (2) (46)(9) Leastness) has more and simulated populations are working, in section O.
- (28)in19; YBC package for bohometric connection, supersecting and expanding the p

## CMD: stev.oapd.inaf.it/cgi-bin/cmd

#### Subrit Reset

#### **Evelutionary trade**

FARSEC tacks (<u>Broadert of (2012)</u>) are tempoind for a scaled-solar composition and following the Y=C2485+1.782 relation. The present solar metal content is 2<sup>(5)</sup>=0.0152. <u>Tables of resistionary works</u> are also available. COLIBRI tracks (<u>Managort of (2012)</u>) entered that evolution to the end of the TP-AGB phase, for evenal choices of mass less and during upparameters.

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## Comparison of different stellar models

Name	mass range	Z range	abundance	EOS	ОР	NR	Rotation	stages	Else1	вс	UD
PARSEC (Bressan, SISSA)	0.1-350	5E4 to 0.07	solar,a	FREEEOS	OPAL+ÆSOP US	JINA REACLIB	0.002 to 0.02, omega=0 to 0.995, mi=1 to 5	Pre-MS to AGB0/CB0		Phoenix +Grey	19
MESA/ MIST (Paxton, UCSB)	0.1-300	[Fe/H] = -4 to 0.5	solar	OPAL+SCVH+Ma cDonald	Ferguson05+ Freedman08 +OP+OPAL	JINA REACLIB	v/vcrit=0, 0.4	Pre-MS to WD	Planets, Oscillations	ATLAS1 2+Grey	16
Bastl (Cassisi, Teramo; Salaris, JMU)	0.1-15(new)	1E-5 to 0.05	solar,a,CNO	FREEEOS	OPAL	NACRE	Ν	Pre-MS to AGB0/CB0	WD, diff. Reimers etas	Vernazz a+81	18
DESP (Dotter, Dartmouth)	0.1-4	[Fe/H] from -2.5 to +0.5	Solar,a	ideal gas+FREEEOS	OPAL + Ferguson05	Adelberger+9 8	Ν	Pre-MS to AGB0			08
FRANEC (Chieffi & Limongi)									link		
Genova (Meynet)									link		
STERN (Brott)									link		
STAREVOL (Decressin)									link		
Yale-Yonsei-Potsdam (Demarque)		in		nlata					link		
Pisa (Tognelli)			COM	piece					link		
Victoria-Regina (VandenBerg)									link		
Eggleton									link		
CESAM (Morel & Lebreton)									link		

# **TRILEGAL Bolometric**

## **Corrections YBC** (Chen+19)

Stellar spectral libraries: ATLAS PHOENIX COMARCS WM-basic PoWR Koester TLUSTY

#### Extinction:

. . .

Circumsterllar dust: Marigo+ Interstellar dust: CCM+O94, FM07, etc.

#### Supported photometric systems:

Basically all publicly available UV-Opt.-NIR-MIR systems





UV-Opt.-NIR-MIR systems

6 I 2 3 4 5 G<sub>60</sub> - G<sub>RP</sub> (Gaia)

1.5

K (Bessell)

7.0



TARSEC data fact of bolisment in mini-



YBC: stev.oapd.inaf.it/YBC http://SEC.CENTER/YBC

Home

work.

#### Five steps to obtain BCs for your stars:-

#### 1. Choose the filter sets

() ATT AST2 models with two aTT is metal contexts.

2MASS JHKs
VCAO/CTIO/MOSA/C2 (Vegamag)
Vinius
CEHT Wirkern
CHHI Meçacam + Wircam (all Alsmags)
LESS + ZMASS (Vegamacs)
(ESS + 2MASS (Vegamacs) + Kepler + SUSS gnz + UUO51 (in ABmags)
Galais DRLG, G. BP and G. RP (Vecamaga)
Salars DR2 G, G, EF and G, RP (Vecamags, Gala passbands from Evans et al. 2018)
Galar's DR2 G, G BP and G RP (Vecanage: Gala passbands from Malz-Apellaniz and Weller 2018)
Sala's DR2 C, C BP and O RP (Vecamags, Gala passbands from Weller 2018)
Sala DR1 + Tycho2 + 2WASS (all Vegamiags)
Gala DR2 + Tycho2 + 2WASS (all Vegamags, Gala passbands from Evans et al. 2018)
3a.a DR2 + Tycho2 + 2WASS (all Vegamags, Gaia passbands from Weller 2018)
LSST ugriz'(, March 2012 total filter throughputs (all ADmags)
S-PLUS (Vegamags), revised on Nov. 2017
deltaa (Paumzen) + UBV (Maiz-Apellaniz) in Vegamags
JVIT (all ABmaga)
EvelophisP (ABroas)
SASE vs band (Vegamacs)
TSST troos (ABryage)
CATLAST2 models with virt 4TTuc metal contents & Provintx (also for TP-ASE) only

#### Latest News

#### YBC paper on arXiv.org/astro-ph

Detplacer 22st, 2019

The steps is available at <u>
available to track</u>, it is accepted for publication in A&A.

#### Non-uniform extinction for stars

October 21st. 2019

New yourcan capply attention eather him value for unlines it stats in your catalogue, by schedying the column multiplier in section 4.

New extinction interpolation scheme and corrrections

# **TRILEGAL output: synthetic stellar catalogues**

Ste pa	ellar ram	eter	'S											LP\ per	/s Tiods	
		G	r muð	Av	comp	label	logAge	M_H	m.ini	Mass	logL	logTe	logg	Mco	neTP 1	Mloss
			11.75	0.684	0	1	8.55	-0.27	1.4118	1.412	0.716	3.8792	4.341		0.0 1.	52E-13
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1.1	14.731	16,758	15.561	15.315	15,261	15 244	15.219	15 243	15,503	14.87	5 -48.	T 1.8	-3.7	20.6	2.89	-1.53
	19.375	26,229	22.796	21.191	19,981	19:348	19,06	20.738	22.15	19.44	4 -55.	8 .25.6	0,8	38.7	0.82	-2.36
	19.679	26 822	23.289	21.66	20.344	19.666	19:361	21.121	22.628	197	9 -35.	8 26.6	0.8	38.7	0.82	-2.36
-	13.581	15.467	14.35	13.983	13.863	15 816	13.793	13.941	14:257	13.47	4 -37.	7 -15.6	-20	29.8	2.95	-199

Pastorelli+19

# **TRILEGAL** calibrations

Sec.

10

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#### **Photometric surveys:**

Groenewegen+02: Halo+disk Girardi+05: Halo+disc Vanhollebeke+09: Bulge Pieres+20: Discs+Halo

Spectroscopic surveys: RAVE, SEGUE, etc.

**Asteroseismic surveys:** CoRoT, Kepler, etc.



#### **TRILEGAL 1.6 input form**

Warning! (17mar13) We are forced to limit the maximum CPU time to 10 min. If this is too short, please split your simulation into smaller areas.

New version! (105ep12) v1.6 becomes the default. It's the result of correcting some bugs in the central disk densities (for thin and thick disks), and then recalibrating their parameters. A provisional description of these changes is in this career. Changes are not dramatic but are in the sense of improving agreeent with data. The previous version is still available in v1.5.

Help EAO Easers Prophy History
Submit Reset
Pointing parameters         Using Epoch 2000, decimal numbers:         • Galactic coordinates centered on I = 0   deg, b = 0   deg         • Equatorial coordinates centered on at = 0   b, b = 0   deg         • Equatorial coordinates centered on at = 0   b, b = 0   deg         • Total field area = 1   deg*(max=10 deg*)
Photometric system  Indexes convolues ar compared in in Casad in al. 2022.  Available (al. We deplace 2001 + Bensel 1990)  Limiting magnitude in a  B filter is set to a mag (max=32 mag) Distance modulus resolution of Galaxy components is al. mag (min=0.05 mag)
INF for single stars: [chare logicity] [se part] [ Turn binaries # on off Dinary fraction * 03 with mass ratios between (or and () Price binary components # as a single entry "separately Extinction
No dust extinction or  Exponential disk exp(-ipi/h <sub>x,down</sub> )*exp(-R/h <sub>x,down</sub> ) with scale bright h <sub>x,down</sub> * and scale length h <sub>x,down</sub> * account pc      Local calibration: disk(dt(0)* account mag)pc      Calibration at infinity: A <sub>1</sub> (a)* account mag      to dispension*(a mask the total extinction (max*0.3)
Solar position
This disc No this disc or
Along z: CExponential: $exp(\cdot z h_{r,d}) = Squared hyperbolic secant: sech(0.5ch_{r,d})$ with scale height $h_{r,d}$ increasing with age t cf. $h_{r,d} = x_0(1 + tv_0)^6$ $z_0 = [0.0001]$ pc, $t_0 = [0.5007000]$ [yr, $\alpha = [1.0006]$ ].
Along & Exponential disc: exp(-R/b <sub>R,d</sub> ) with scale length b <sub>R,d</sub> * <u>prints</u> pc, and inner/outer cutoffs at R* <u>6</u> pc and <u>inner</u> /outer cutoffs at R* <u>6</u> pc.
SFR and AMR gives by (2 sup UE) + following AME + a set (see paper) V with age(yr)=(0.7000)+1+(0.100)

## **TRILEGAL DEMO 1: LSST sky** survey sim.

# Blank intentionally

## **TRILEGAL DEMO 2: SMC & LMC sim.**



## TRILEGAL DEMO 3: M31 sim.

# Blank intentionally

## **TRILEGAL DEMO 4: Binaries**



Dal Tio+19



# **TRILEGAL DEMO 5: Star Cluster sim.**

# Blank intentionally

## **TRILEGAL DEMO 6: MW foreground** stars for high-z objects



Niida+20: stellar contamination to the QSO sample

## TRILEGAL MW simulation for CSST

## **CSST** filters



CSST filter transmission curves (from CSST group) SEDs: CK03 ATLAS9 models of Teff=6000K and 10000K (logg=4,[M/H]=0)

# **Skymap pixelization**

**HEALPix** nested subdivision scheme:



Nside=64 to 2048 (1.72') Npix=596601



CSST sim. pixelization

Dust map

Gorski+05

## **TRILEGAL** simulation running

Simulated Milky Way Stellar Number Density g<27.5  $\sim$ 1.5TB fits data 12.6 Bilion stars Soon on the 1 NAOC VO Number Density Example of the more rotalogue Table 1 M II Mass m ini log1 logAae mu0 Av mmbio. 12.00.16514014 0.70204317569732 5.7288876 0.0 0.7020574 0.75758743 -0.2066110.83383369445800 11.30000 5.6852345 0.0 0.83320236 -0.355241240.349990 logTe. long label MeoreTP CO period0 period1 pmode Mins mulm 0.544593 -1.21629594E-14 3.0080293 4.6600057 0.0 0.0 0.0 0.0 0 -1 3.7532720 1.590082 0.0 0.53722 0.0 0.0 -1 -3.0392355E-14 0.0  $\mathbf{x}$ Y. Xe Xn Xo Cexcess Z mbólinag 0.72519267 0.26460725 0.0044763405 0,010200083 0.0018283299 3.935209E-1 -1.018.063909 0.736633840.25433245 0.0015997563 4.370039E-4 0.003970457 -1.00.00903371 16.958103 NUVming velU velV umag cunic THIRD iming ZEILES. VHING. 31.179413 30.573284 26.087975 23.63411 22.122543 20.99646 20.66116 -10.707998-27.785371 20,387028 -12.10642630.68219 27.577374 23.878262 21.74874 19.353289 19.050098 -5.577133PMdee xalW Vrad PMracos. zall galb -16.770211787875738 -11.02225218,888453 0.17034815 -2.7342863 206.94619730114937 -10.877249-1.11461228.033585 -1.9767536206.93089798092842 -16.785654214628205



2.6 8

## **TRILEGAL sim. of the north galactic pole**



Absolute magnitude vs. effective temperature CSST-OS will reach g~25.5 (or 26.5) mag. A star with M(g)~15 mag, will have g~25 mag at 1 kpc, being above CSST-OS limit.

## **TRILEGAL sim. of the north galactic pole**



## TRILEGAL sim. of the Baade's window



Absolute magnitude vs. effective temperature CSST-OS will reach g~25.5 (or 26.5) mag. A star with M(g)~10.35 mag, will have g~25 mag at 8.5 kpc, being above CSST-OS limit.

## TRILEGAL sim. of the Baade's window





## TRILEGAL sim. of the anti-Gal. direction



Absolute magnitude vs. effective temperature CSST-OS will reach g~25.5 (or 26.5) mag. A star with M(g)~15 mag, will have g~25 mag at 1 kpc, being above CSST-OS limit.

## TRILEGAL sim. of the anti-Gal. direction

Color-magnitude diagram: g-r .vs. g



## **TRILEGAL sim.: crowding limit analysis**



CSST-OS: PSF FWHM~0.15 arcsec, photometric error ~ 0.2 mag at 25.5 mag, 0.01 mag at 29 mag.

## **TRILEGAL sim. of star clusters**



Simulated star clusters of 0.12, 1 and 4.5 Gyr with errors included.

# **Concluding remarks prospects**

- TRILEGAL is a powerful stellar population synthesis tool, can be used for broad applications, including for supporting the science of next generation telescopes
- We have generated a full sky MW mock stellar catalogue for CCST, and will do so for nearby galaxies. These catalouges will be publicly available
- We will refine PARSEC stellar models and TRILEGAL galactic models to provide better models

#### TRILEGAL: Active coding people





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External collaborators: LSST, UW, STScI, SDSS, etc.

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#### CSST MW TRILEGAL Sim.: Initiates: Xiaoting Fu., Yang Chen, Chao Liu, etc. + TRILEGAL people

