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


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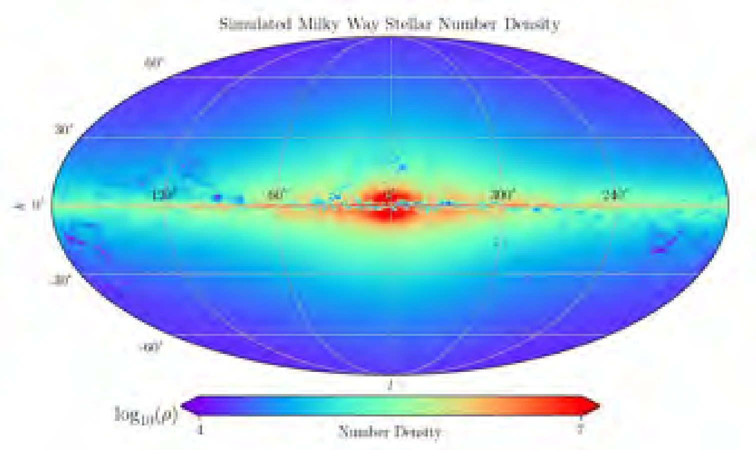
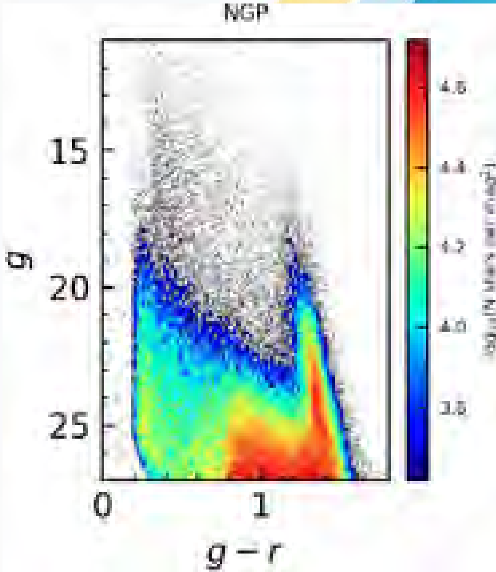


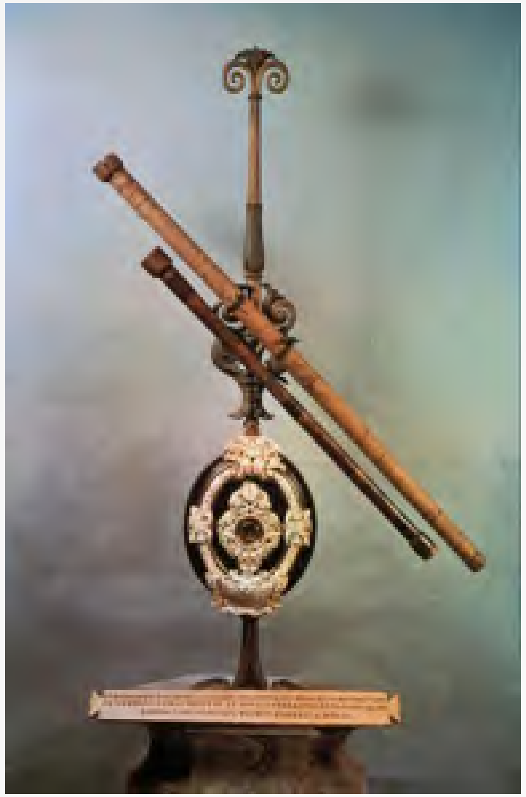
# **Outline** :

- 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

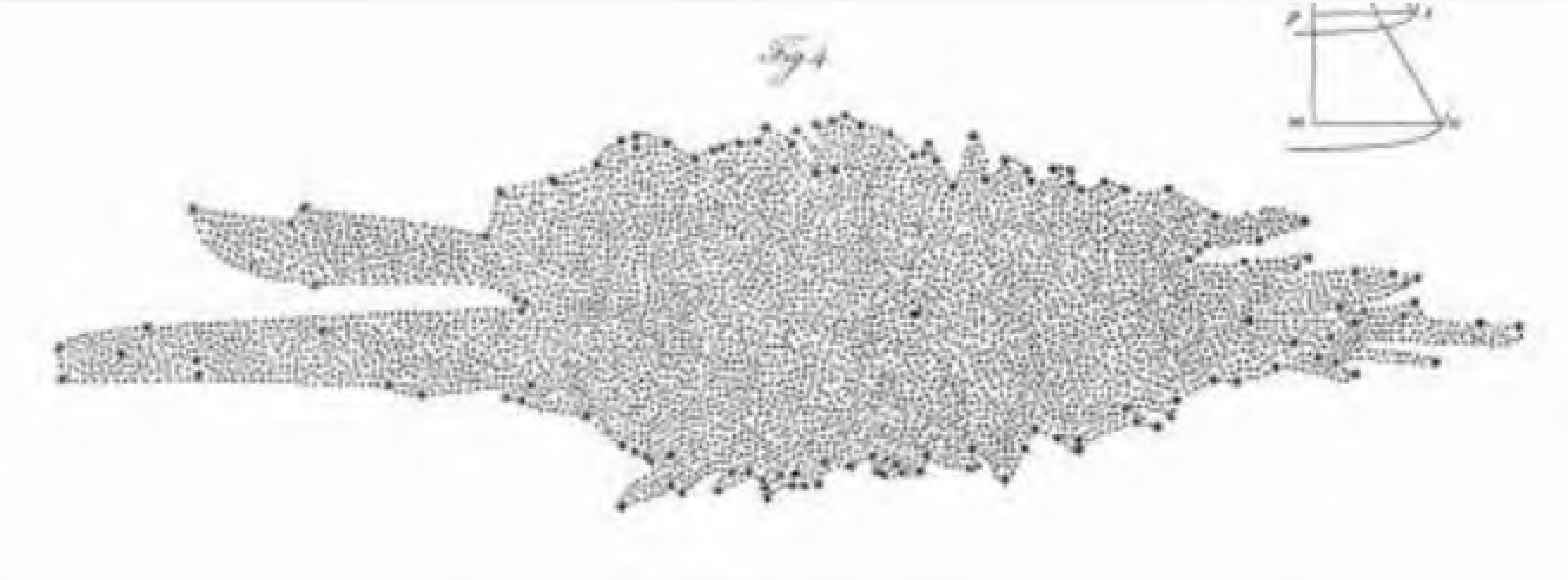
- 1750, Thomas Wright: Milky Way is a thin spherical shell of stars. The Sun is located inside the shell about midway between the inner and outer edges.

- 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

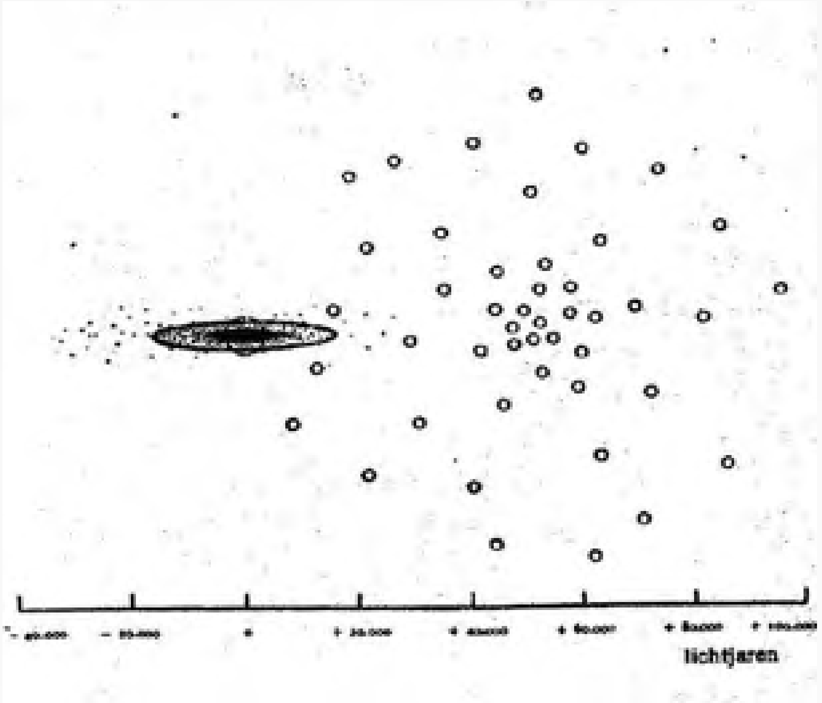


Shape of the MW by W. Herschel, 1785

# 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 (AP).—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

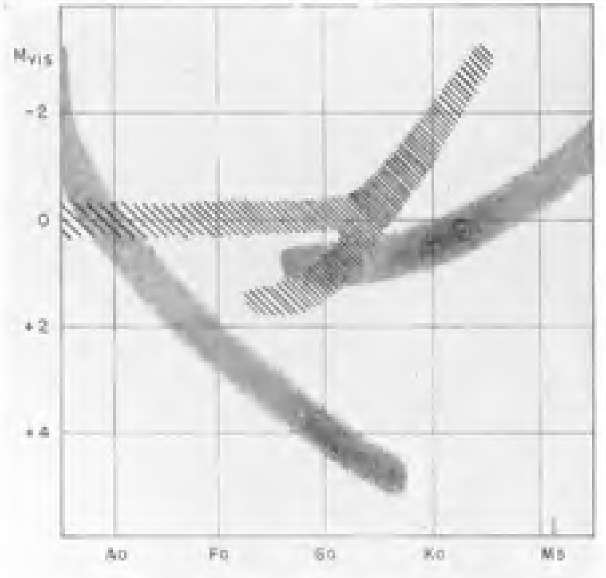



FIG. 1.—Shaded areas: ordinary H-R diagram (type I). Hatched area: H-R diagram of stars in globular clusters (type II).

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

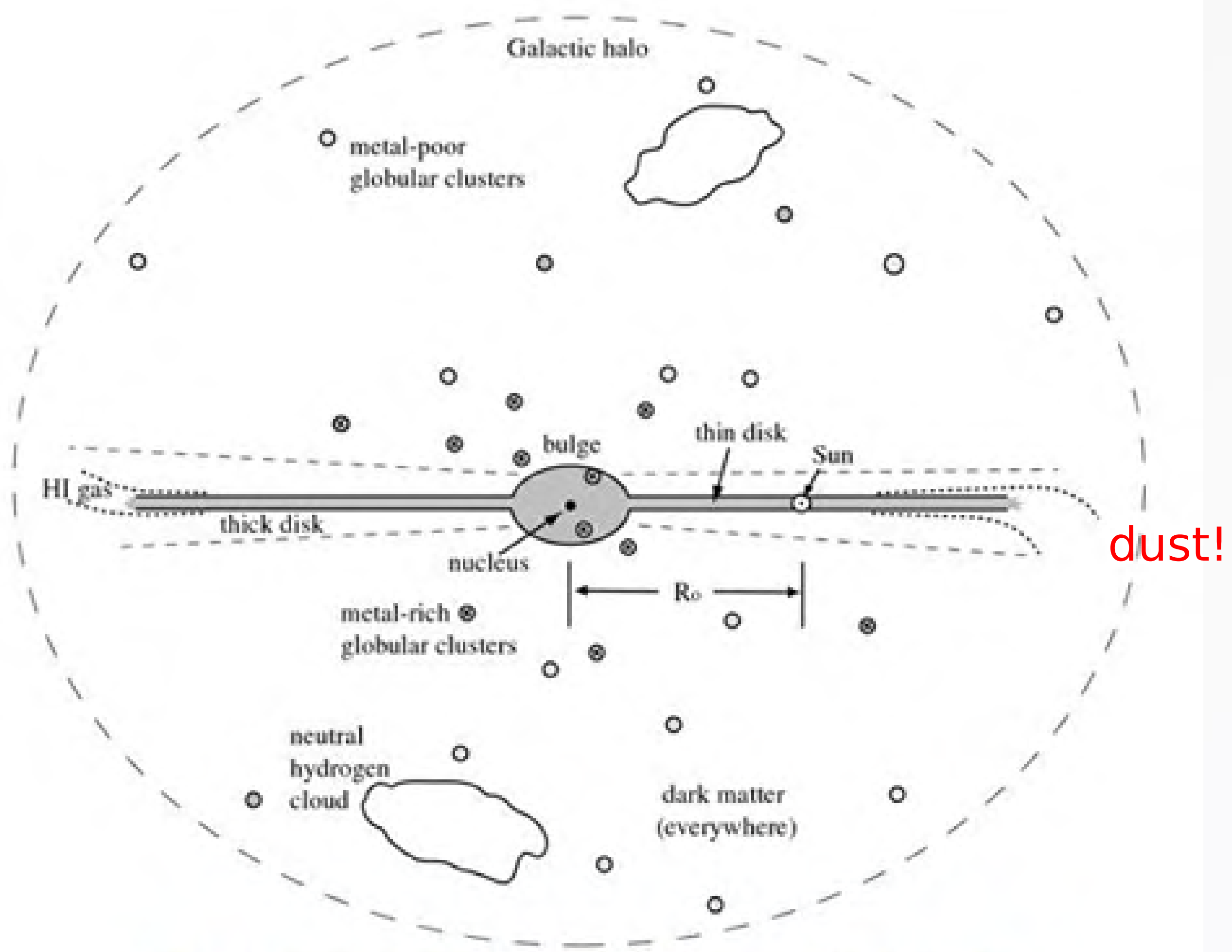
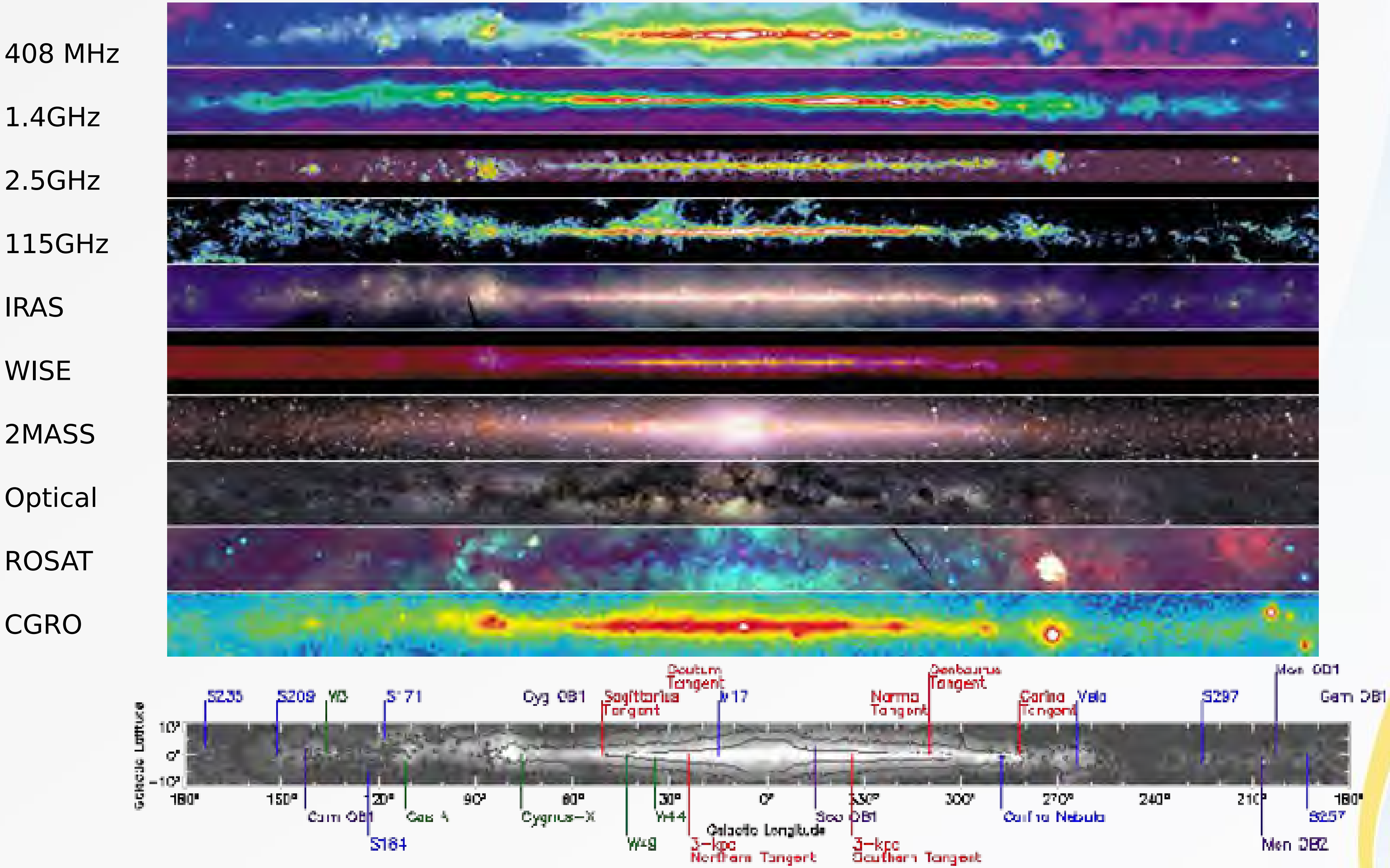


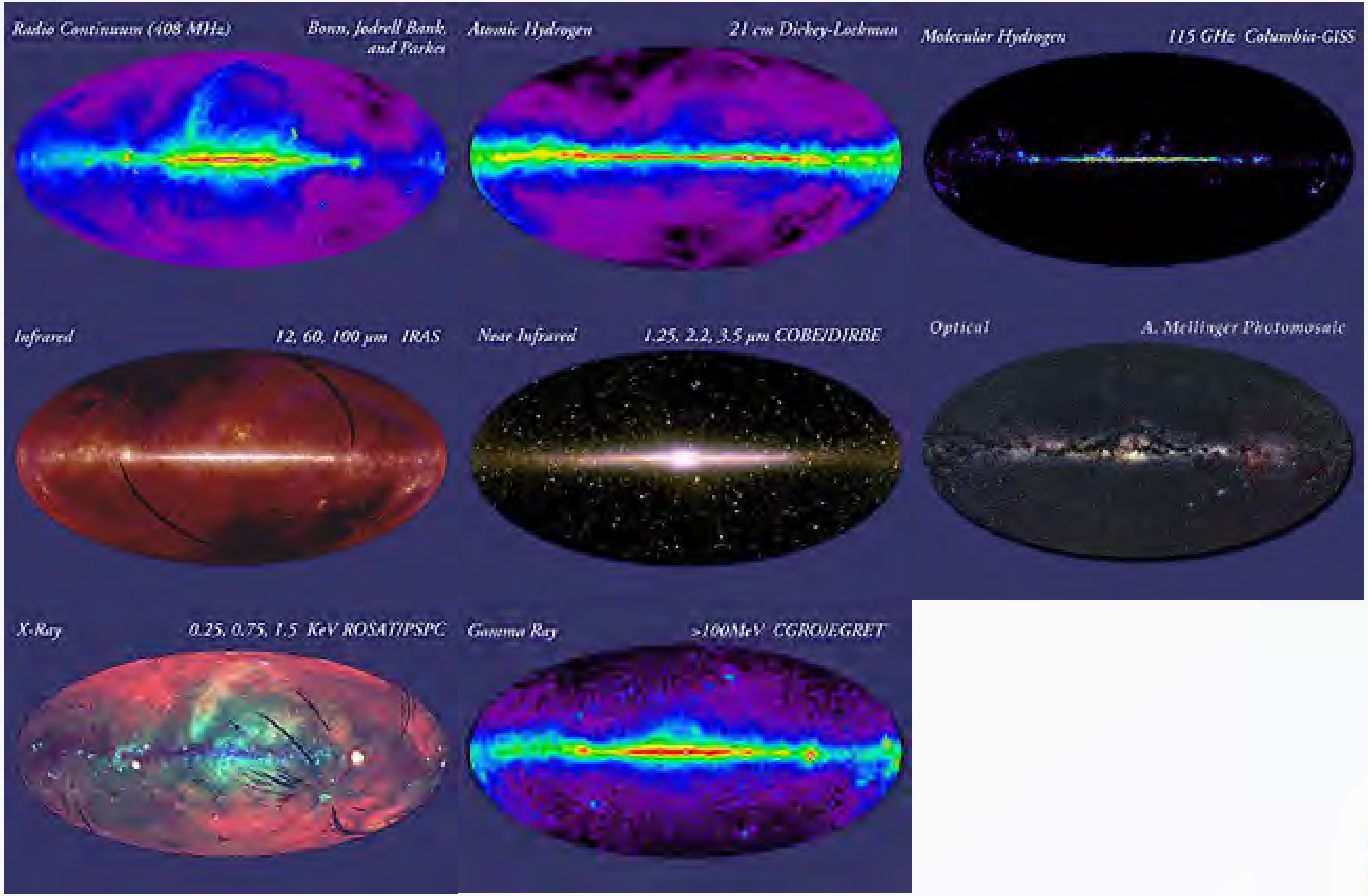

Fig 1.8 'Galaxies in the Universe' Sparke/Gallagher CUP 2007

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

Density profile Luminosity function

# Galactic components & luminosity functions

$\rho(\mathbf{r})$

$$\rho = \rho_{\mathrm{d}} + \rho_{\mathrm{h}} + \rho_{\mathrm{b}}$$

$$\rho_{\mathrm{disk}}(r) \propto \exp\left[-z/H(M) - (x - r_0)/h\right]$$

$$\rho_{\mathrm{spheroid}}(r) \propto (r/r_0)^{-7/8} \exp\left[-10.1(r/r_0)^{1/4}\right] ;$$

and

$$\rho_{\mathrm{massive\ halo}}(r) = \rho_H(r_0)[a^2 + r_0^2]/[a^2 + r^2]$$

May also be the potential

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

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

1. 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

**Table 3** Recent measurements of distance $R_0$ to the Galactic Center

| Label | Reference | Method | Location | T | $R_0$ (kpc) |
|---|---|---|---|---|---|
| Rd+09 | Reid et al. (2009b) | Trig. parallax of Sgr B | GC | d | 7.90 ± 0.75 |
| Mo+12 | Morris et al. (2012) | Orbit of S0-2 around Sgr A* | GC | d | 7.70 ± 0.40 |
| Gi+09 | Gillessen et al. (2009b) | Stellar orbits around Sgr A* | GC | d | 8.33 ± 0.35 |
| Ch+15 | Chatzopoulos et al. (2015) | NSC statistical parallax | GC | d | 8.27 ± 0.13 |
| Do+13 | Do et al. (2013) | NSC statistical parallax | GC | d | 8.92 ± 0.56 |
| BB15 | Bajkova & Bobylev (2015) | Trig. parallaxes of HMSFRs | DSN | m | 8.03 ± 0.32 |
| Rd+14 | Reid et al. (2014) | Trig. parallaxes of HMSFRs | DSN | m | 8.34 ± 0.19 |
| Ho+12 | Honma et al. (2012) | Trig. parallaxes of HMSFRs | DSN | m | 8.05 ± 0.45 |
| ZS13 | Zhu & Shen (2013) | Near-$R_0$ rotation young tracers | DSN | m | 8.08 ± 0.62 |
| Bo13 | Bobylev (2013) | Near-$R_0$ rotation SFR+Cepheids | DSN | m | 7.45 ± 0.66 |
| Sch12 | Schönrich (2012) | Near-$R_0$ rotation SEGUE stars | DSN | m | 8.27 ± 0.41 |
| Ku+15 | Küpper et al. (2015) | Tidal tails of Pal-5 | IH | m | 8.30 ± 0.35 |
| VH+09 | Vanhollebeke et al. (2009) | Bulge stellar population model | B | m | 8.70 ± 0.50 |
| Pi+15 | Pietrukowicz et al. (2015) | Bulge RR Lyrae stars | B | s | 8.27 ± 0.40 |
| De+13 | Dékány et al. (2013) | Bulge RR Lyrae stars | B | s | 8.33 ± 0.15 |
| Da09 | Dambis (2009) | Disk/halo RR Lyrae stars | DSN | s | 7.58 ± 0.57 |
| Ma+13 | Matsunaga et al. (2013) | Nuclear bulge T-II Cepheids | B | s | 7.50 ± 0.60 |
| Ma+11 | Matsunaga et al. (2011) | Nuclear bulge Cepheids | B | s | 7.90 ± 0.36 |
| Gr+08 | Groenewegen et al. (2008) | Bulge Cepheids | B | s | 7.98 ± 0.51 |
| Ma+09 | Matsunaga et al. (2009) | Bulge Miras | B | s | 8.24 ± 0.41 |
| GrB05 | Groenewegen & Blommaert (2005) | Bulge Miras | B | s | 8.60 ± 0.81 |
| FA14 | Francis & Anderson (2014) | Bulge red clump giants | B | s | 7.50 ± 0.30 |
| Ca+13 | Cao et al. (2013) | Bulge red clump giants | B | s | 8.20 ± 0.20 |
| Fr+11 | Fritz et al. (2011) | NSC red clump giants | GC | s | 7.94 ± 0.76 |
| FA14 | Francis & Anderson (2014) | All globular clusters | B, IH | s | 7.40 ± 0.28 |
| Bi+06 | Bica et al. (2006) | Halo globular clusters | IH | s | 7.10 ± 0.54 |

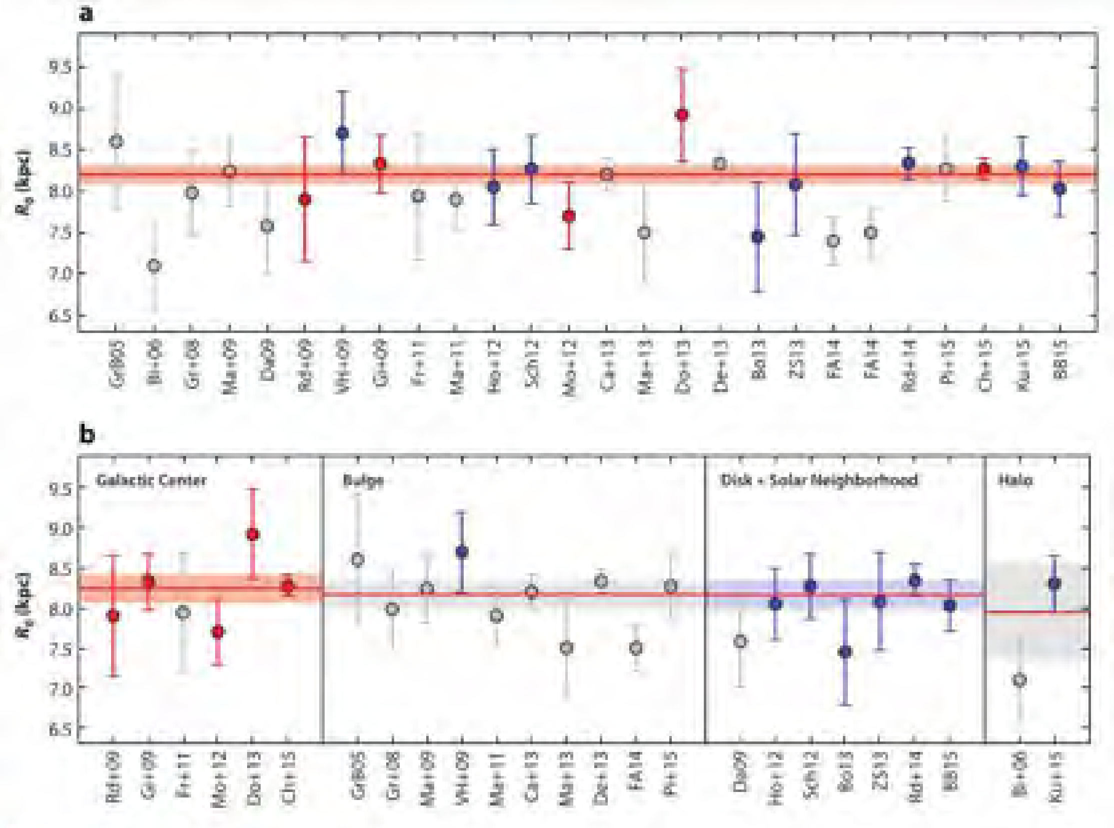



Figure 4

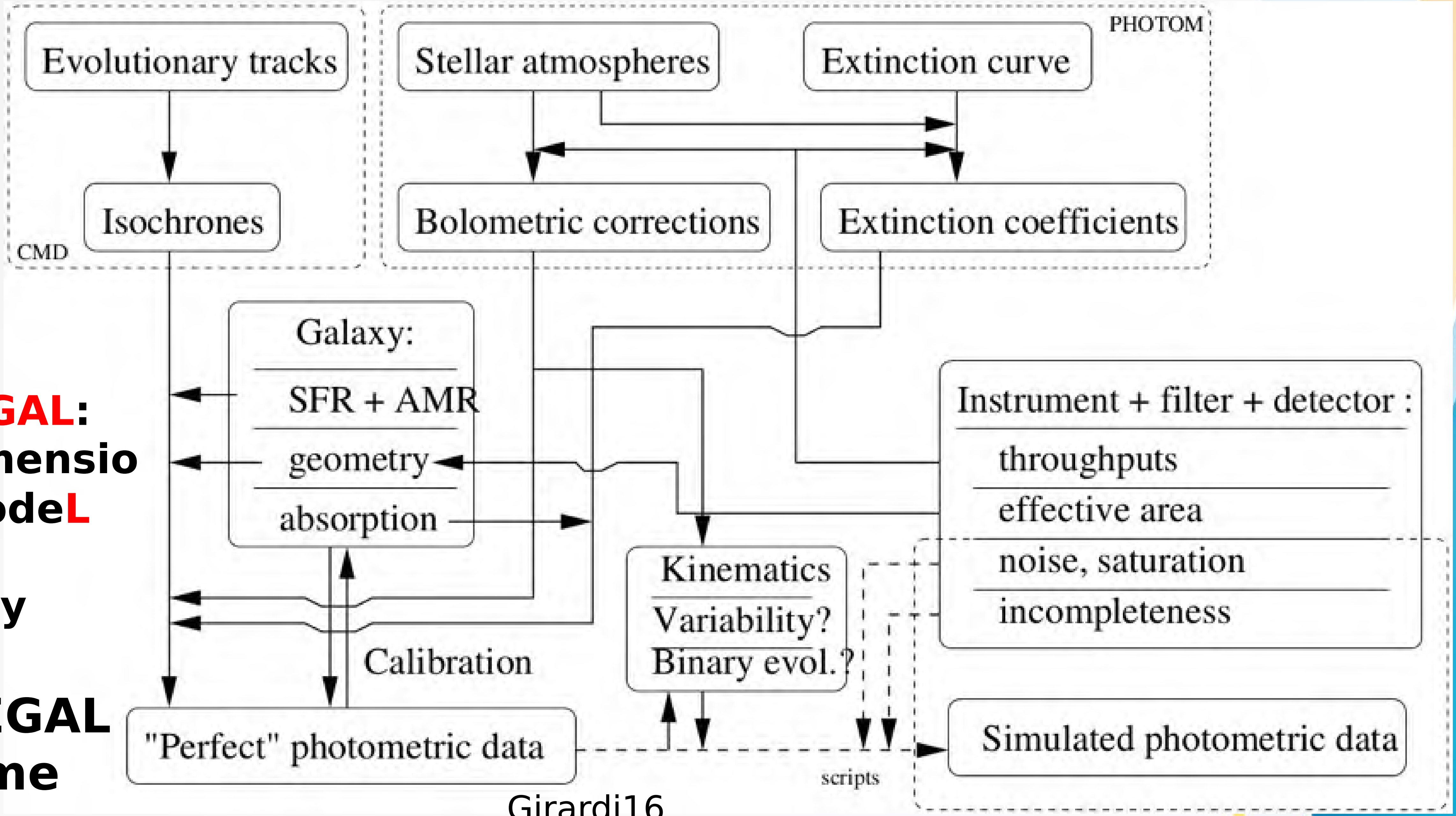
Recent measurements of $R_0$ from **Table 3**, using different methods. Red, blue, and gray points denote direct, model-based, and secondary estimates, respectively. (*a*) Time sequence for all, with our adopted best estimate, $R_0 = 8.2 \pm 0.1$ kpc. (*b*) Separate time sequences for determinations in the Galactic Center, bulge, disk and Solar Neighborhood, and inner halo (not using the FA14 globular cluster value that includes the inner metal-rich clusters). The horizontal lines show weighted mean values for the respective components, and colored bands show 1σ UUE (uncorrelated unbiased 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 | Kinematics | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| TRILEGAL (Girardi+05) | Triaixal | Exp.+ Sech^2 | Exp.+ Sech^2 | Power-law, axisymmetric | N | N | PARSEC | N | 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 shape | | | | Y | Gas | PEGASE (with Padova models as default) | Y | Y | S. Gao contributed |
| GalMod (Pasetto+18) | Spherical+density potential | Exp.+Sech^2 | | Solved from the potential | Y | Bar | PARSEC | Y | Y | |

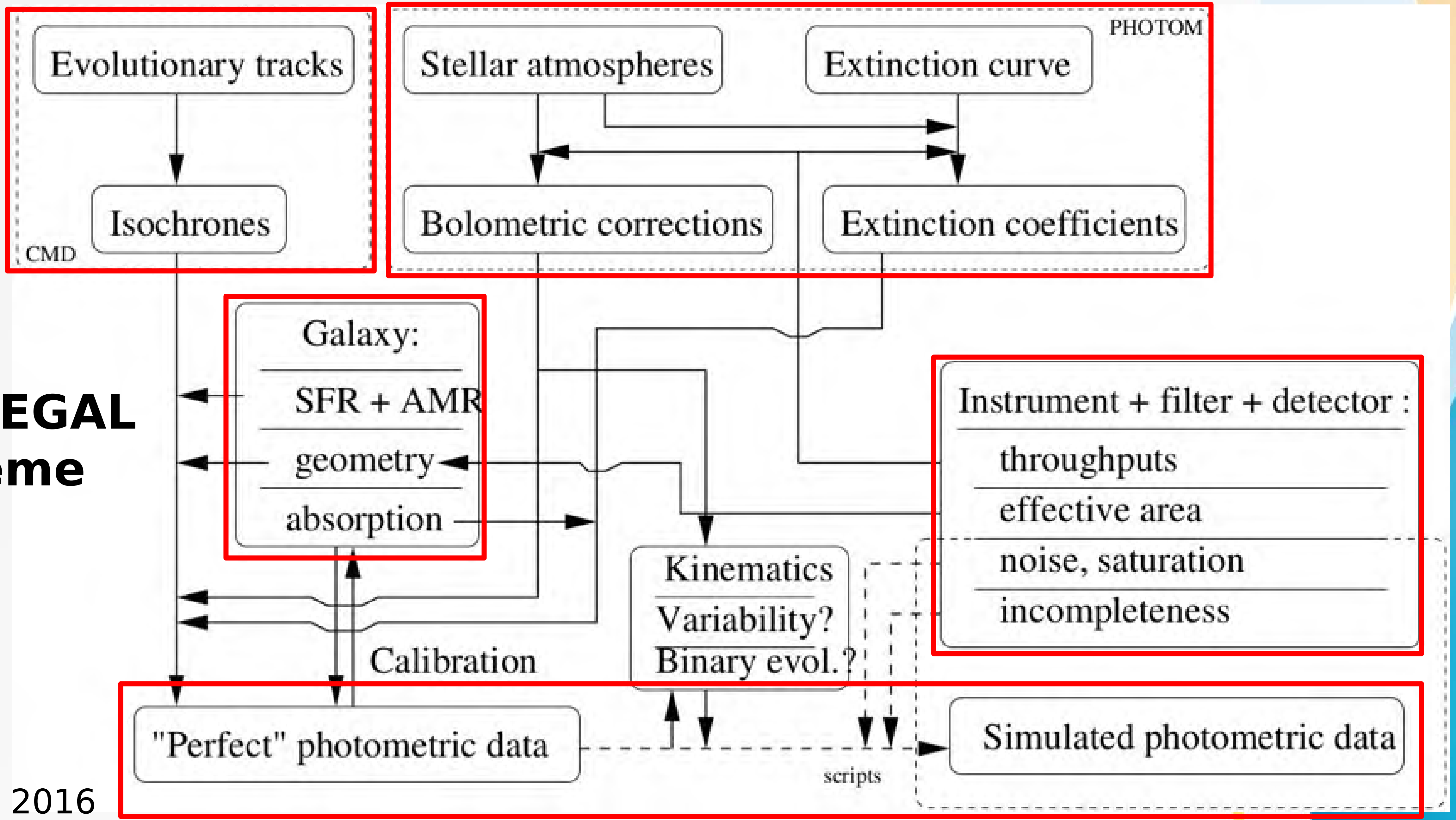
**TRILEGAL: TRIdimensional modeL of thE GALaxy**




# TRILEGAL scheme

Girardi16

# TRILEGAL scheme




Girardi, 2016

# TRILEGAL’s Galactic components

## Geometry:

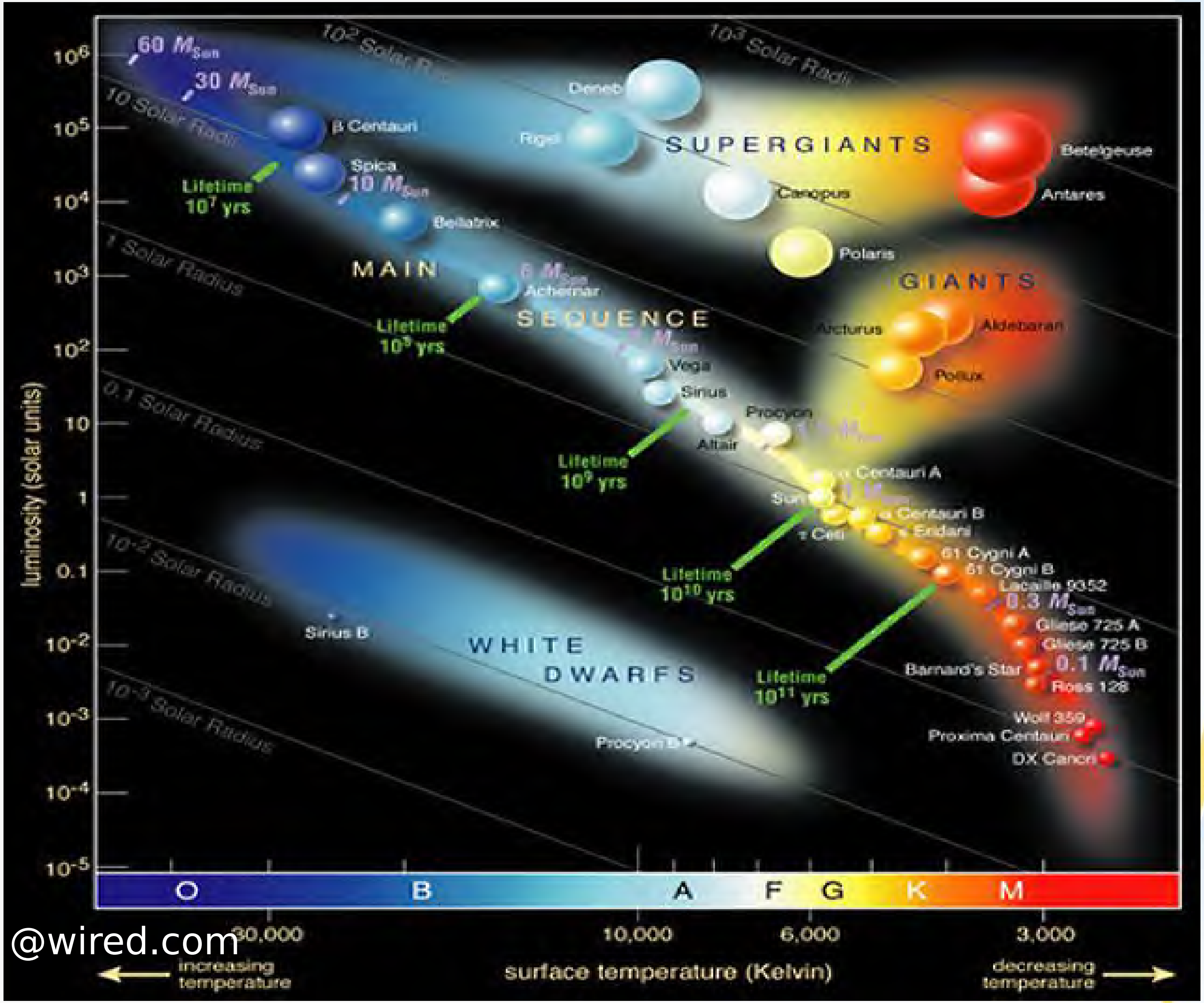
**Thin disk** exp. in R and sech² in z, scale height increasing with population age
**Thick disk** exp. in R and sech² in z, fixed scale height
**Halo** power-law oblate
**Bulge** triaxial cf. Binney+97
**Dust layer** exp. in z, extinction cf. SFD+98, SF+11, Abergel+14, Lallement+18, Green+19
**External objects** (e.g. SMC and LMC)

| Galactic component | Mass distribution | Constants | |
|---|---|---|---|
| Thin disk | $\rho_d = C_d \frac{\exp(-R/h_{Rd})}{\cosh^2(0.5z/h_{zd})}$ | $h_{Rd} = 2913.36$ pc | $z_0 = 94.69$ pc |
| | $h_{zd}(t) = z_0(1+t/t_0)^{5/3}$ | $t_0 = 5.55079 \cdot 10^9$ | $C_d = 0.14691\ M_\odot/\mathrm{pc}^3$ |
| Thick disk | $\rho_D = C_D \frac{\exp(-R/h_{RD})}{\cosh^2(0.5z/h_{zD})}$ | $h_{RD} = 2394.07$ pc | $h_{zD} = 800.0$ pc |
| | | $C_D = 0.00378\ M_\odot/\mathrm{pc}^3$ | |
| Bulge | $\rho_b = f_0 \frac{\exp(-a^2/a_m^2)}{(1+a/a_0)^{1.8}}$ | $f_0 = 406.0\ M_\odot/\mathrm{pc}^3$ | $a_m = 2500.0$ pc |
| | $a = \sqrt{x^2+(y/\eta)^2+(z/\zeta)^2}$ | $a_0 = 95.0$pc | $\eta = 0.68$ $\zeta = 0.31$ |
| Halo | $\rho_h = C_h \left(\frac{R_\odot}{\sqrt{R^2+(z/q)^2}}\right)^{2.75}$ | $q = 0.62$ pc | $C_h = 10^{-4}\ M_\odot/\mathrm{pc}^3$ |

## 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



luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^-2
10^-3
10^-4
10^-5
60 M_Sun
30 M_Sun
10 M_Sun
6 M_Sun
0.3 M_Sun
0.1 M_Sun
10^2 Solar Radii
10^3 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
10^-2 Solar Radius
10^-3 Solar Radius
β Centauri
Spica
Bellatrix
Achernar
Vega
Sirius
Procyon
Altair
Centauri A
Sun
Centauri B
τ Ceti
Eridani
61 Cygni A
61 Cygni B
Lacaille 9352
Gliese 725 A
Gliese 725 B
Barnard's Star
Ross 128
Wolf 359
Proxima Centauri
DX Cancri
Deneb
Rigel
Canopus
Polaris
Betelgeuse
Antares
Arcturus
Aldebaran
Pollux
Sirius B
Procyon B
SUPERGIANTS
GIANTS
MAIN
SEQUENCE
WHITE
DWARFS
Lifetime 10^7 yrs
Lifetime 10^9 yrs
Lifetime 10^10 yrs
Lifetime 10^11 yrs
O
B
A
F
G
K
M
30,000
10,000
6,000
3,000
increasing temperature
surface temperature (Kelvin)
decreasing temperature

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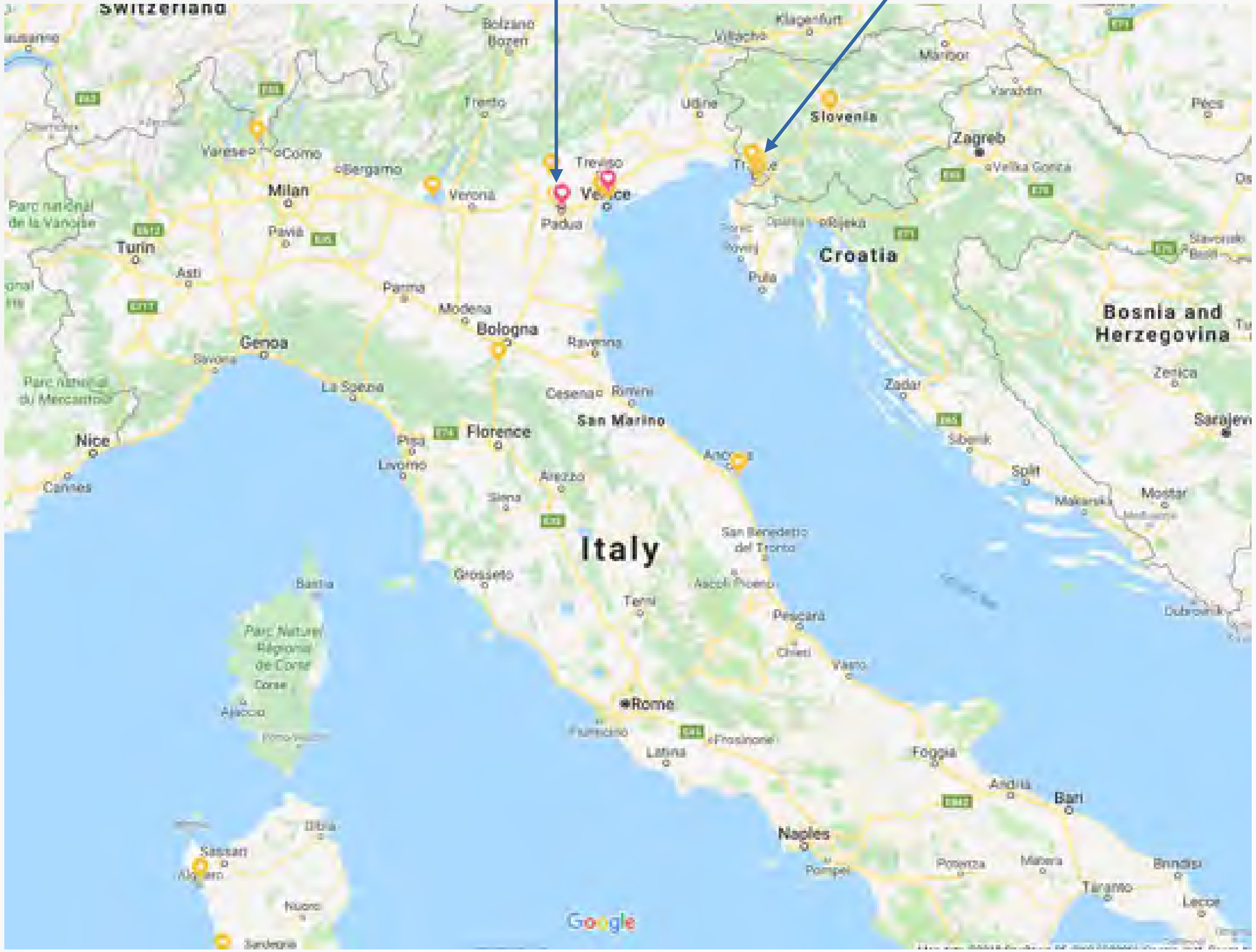
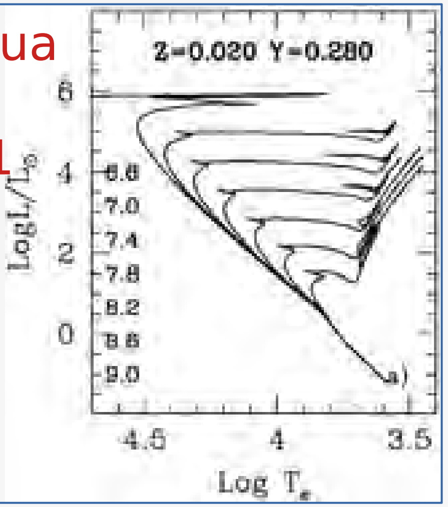
# PARSEC: PAdova and tRieste Stellar Evolutionary Code

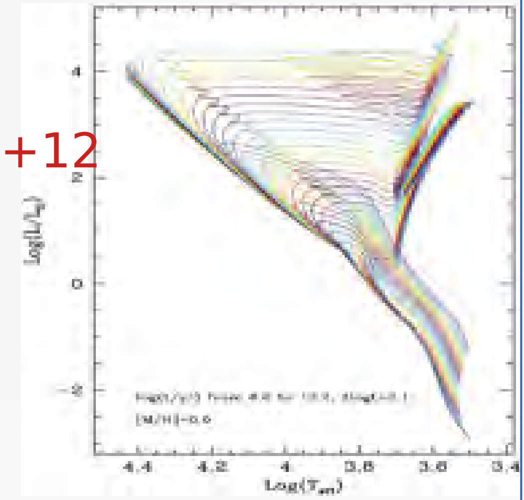


# PARSEC Tracks/Isochrones

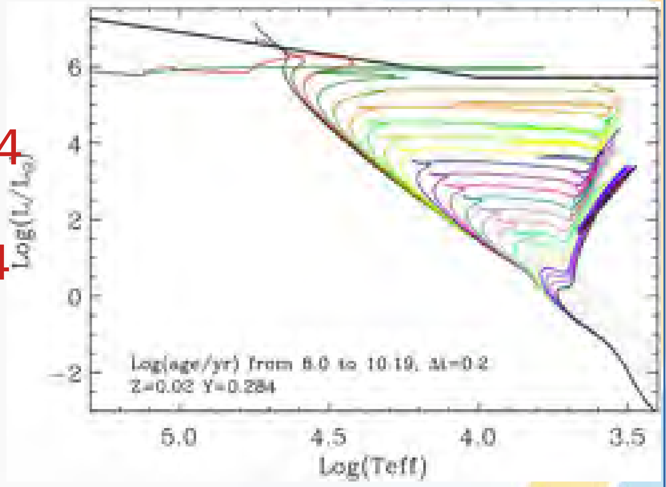
Padova/Padua models:
Bressan+81
…
Bertelli+94
Girardi+00
Marigo+08
Girardi+10



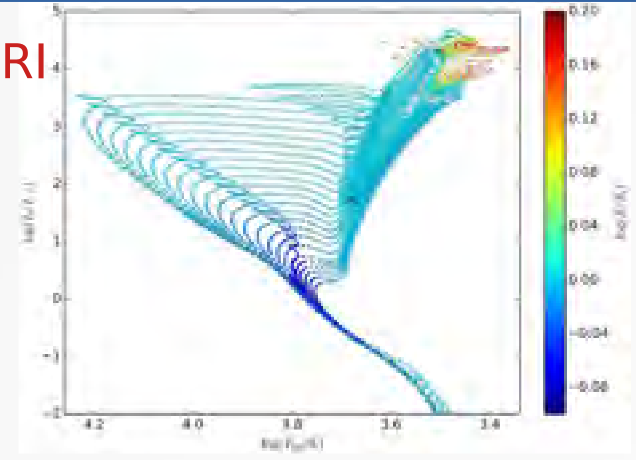

PARSEC models:
Bressan+12



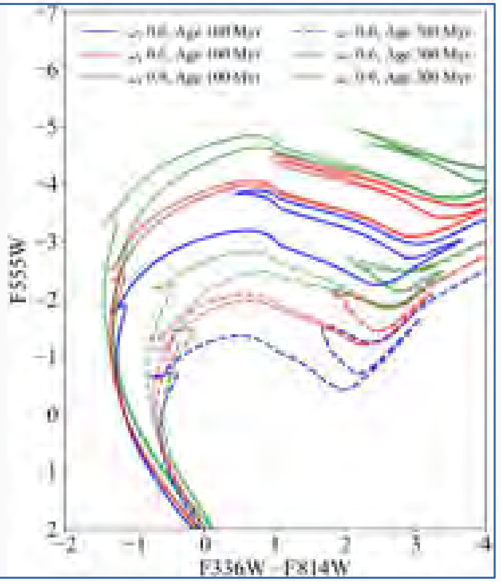
PARSEC models:
Chen+14
+15
Tang+14
+16
Fu+15
+18




PARSEC-COLIBRI models:
ERC/STARKEY
Marigo+17
Chen+18
Pastorelli+19
Pastorelli+20

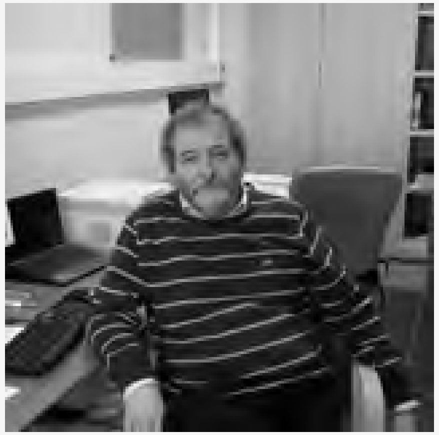


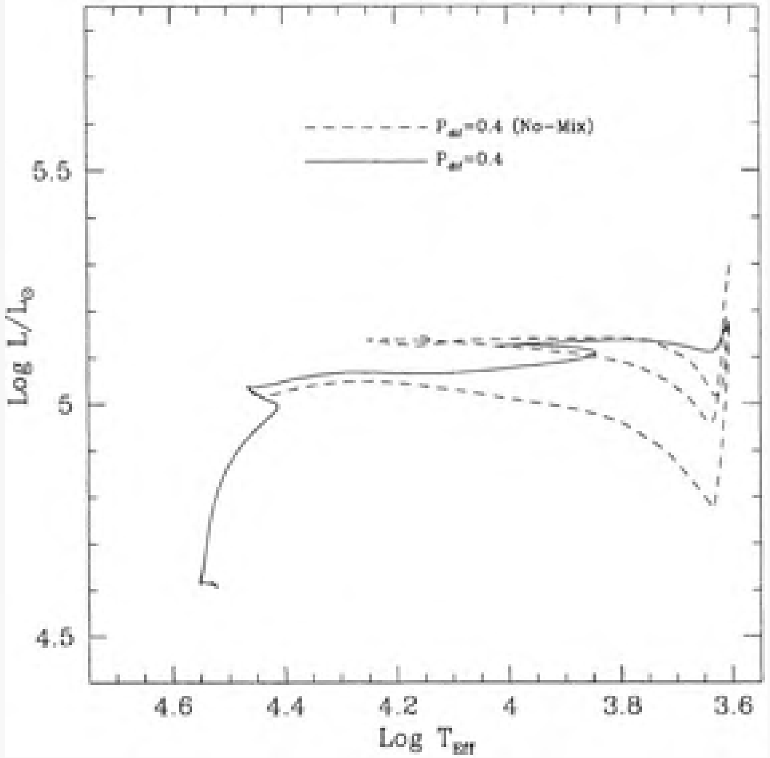
PARSEC models with rotation:
Costa+19
Costa+20

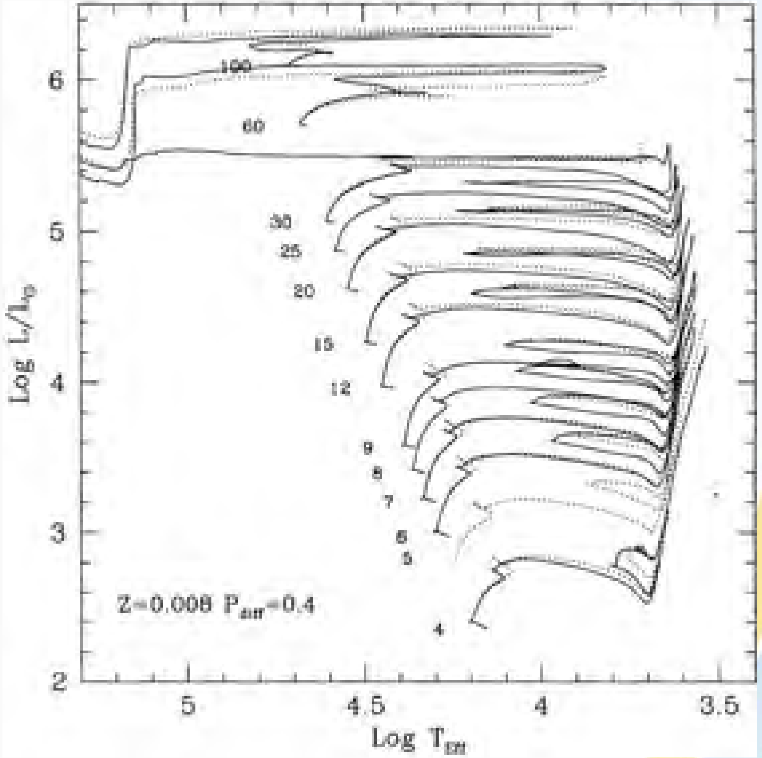



PARSEC-TRILEGAL models with interacting binaries, new WD & NS tracks: to do

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

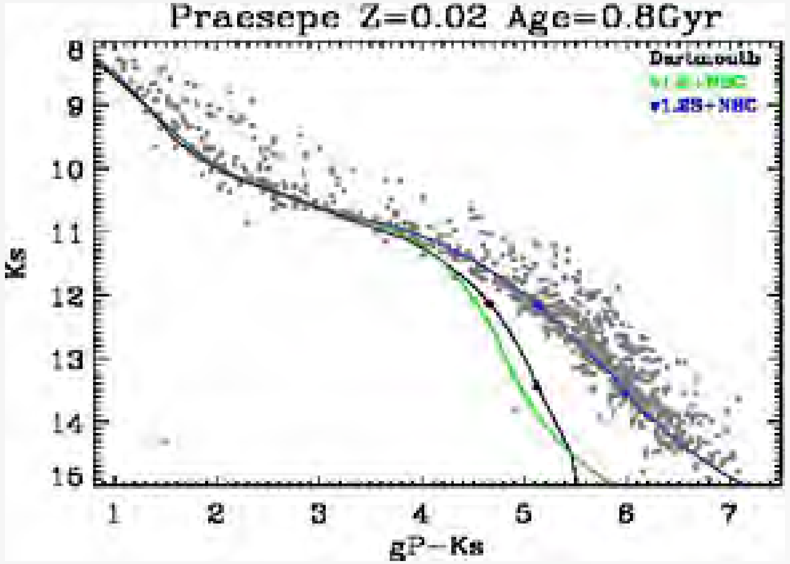


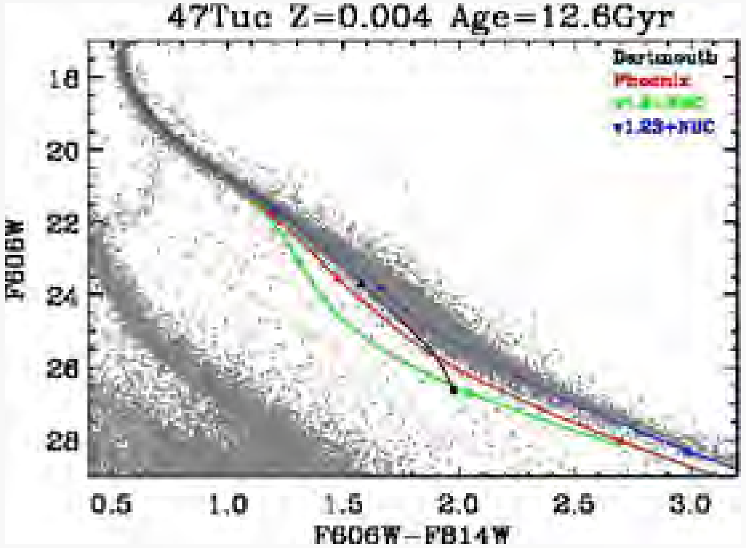


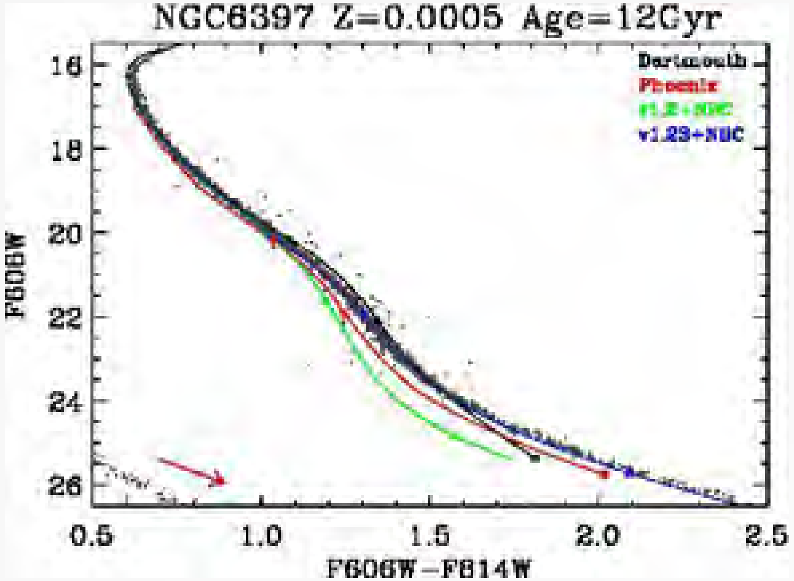



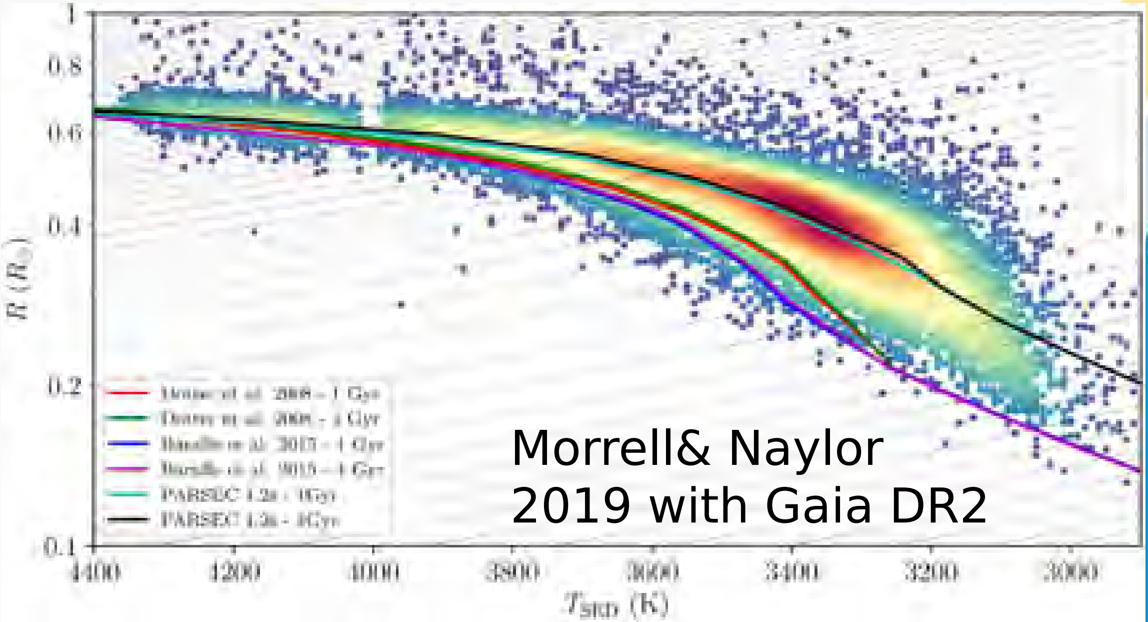

Stellar evolution with turbulent diffusion by Licai Deng, A&A, 1996, v.313, p.145-158 & p.159-179

# PARSEC very-low mass stars



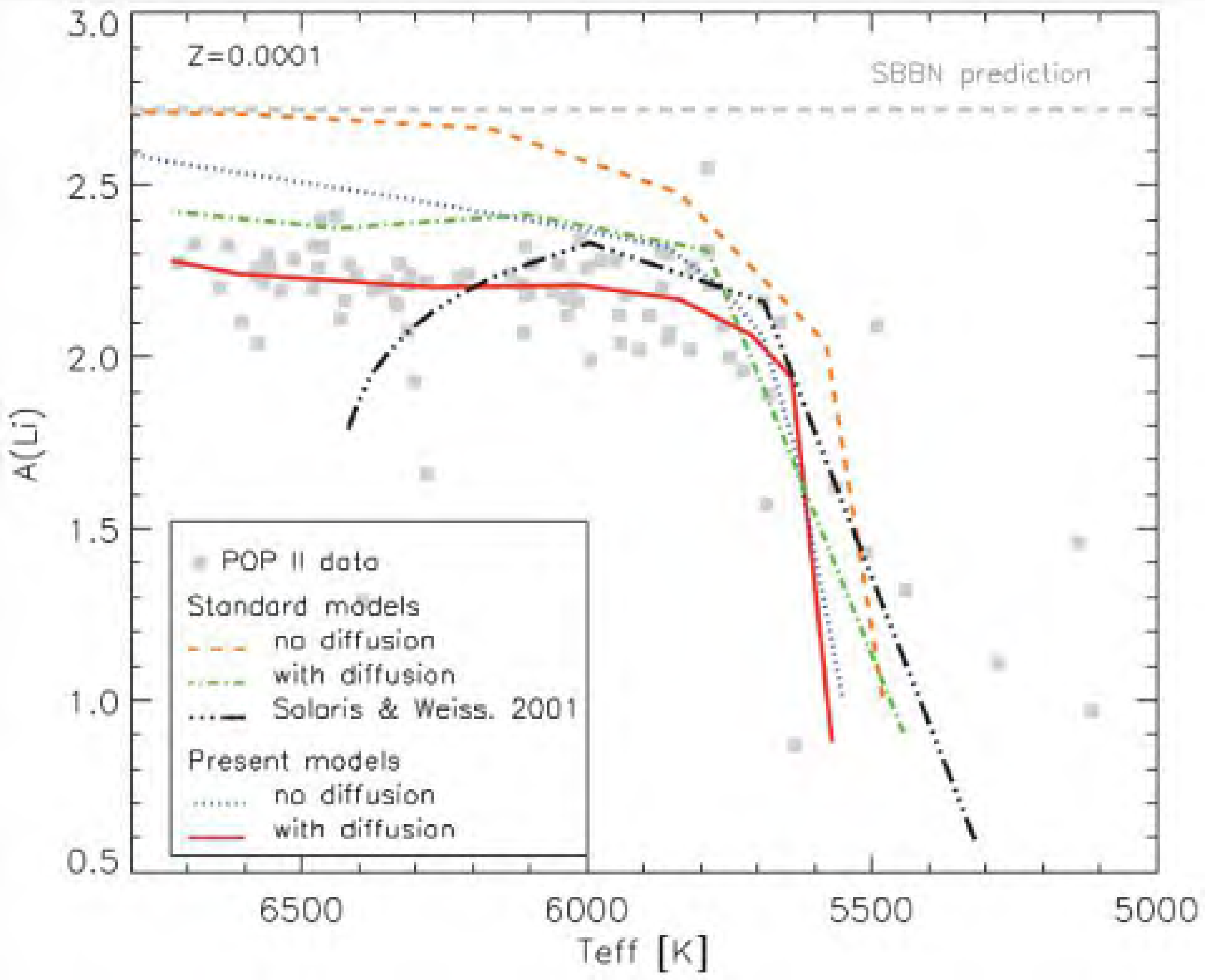




Morrell& Naylor 2019 with Gaia DR2

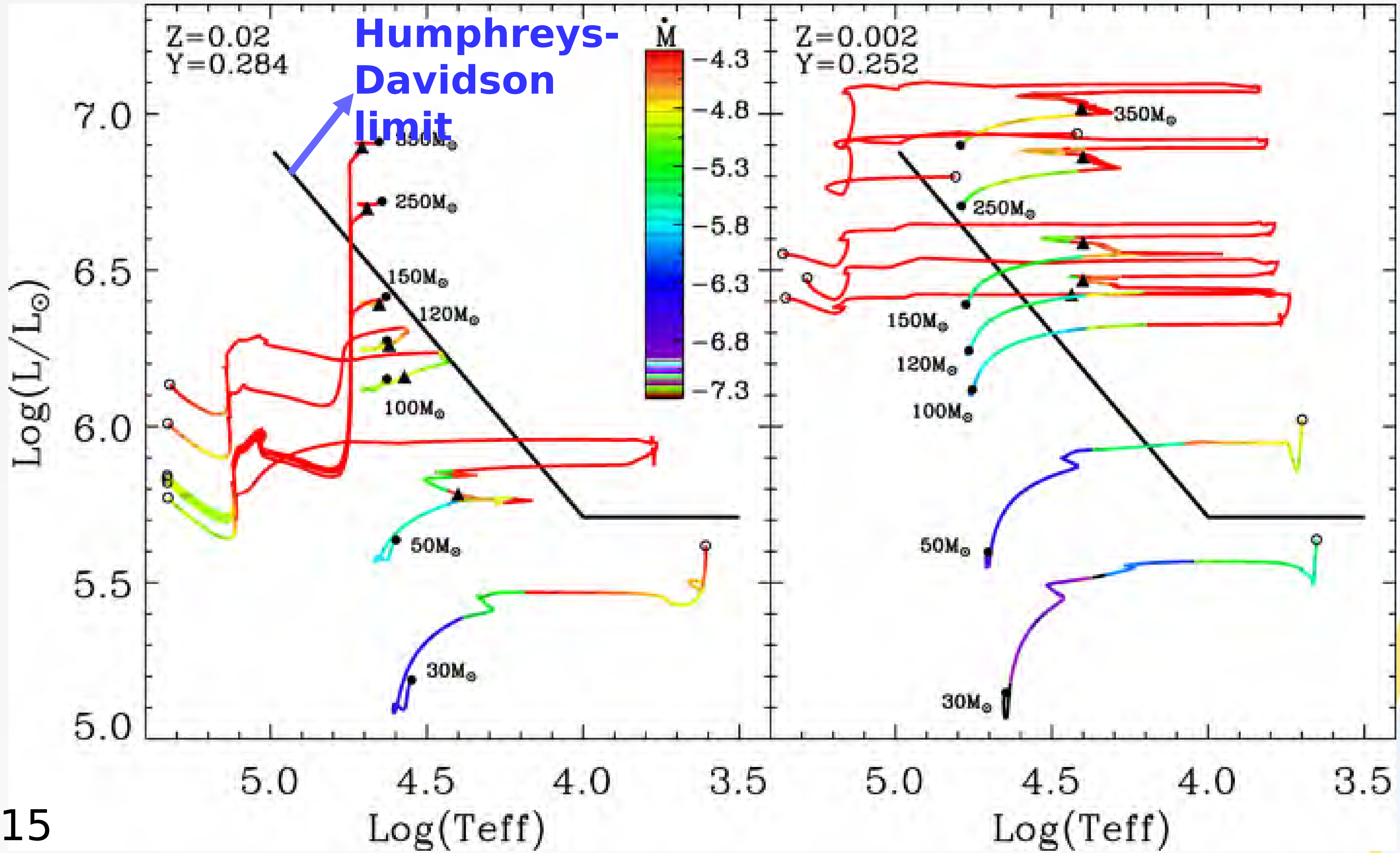
Chen+14

# PARSEC Pre-Main Sequence models



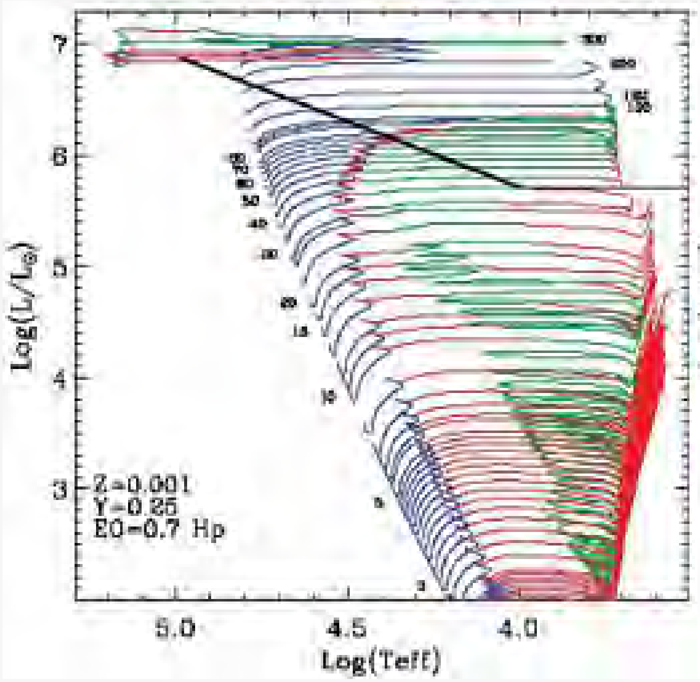

Fu+15: envelope OV  + residual accreting reproduces the Spite-plateau

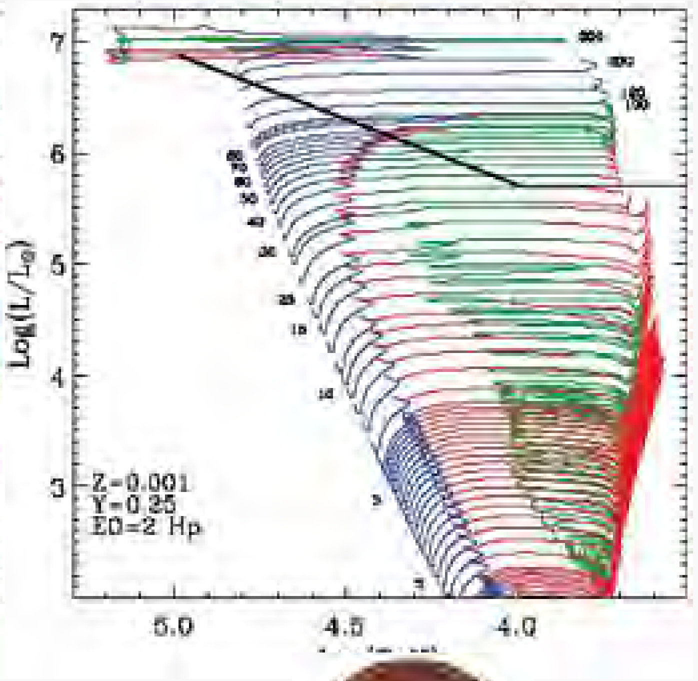
# PARSEC models for very-massive stars

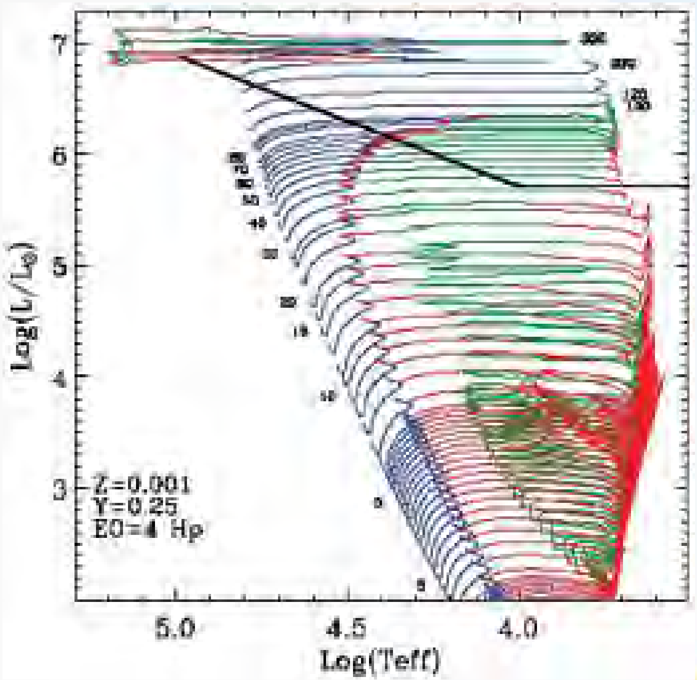


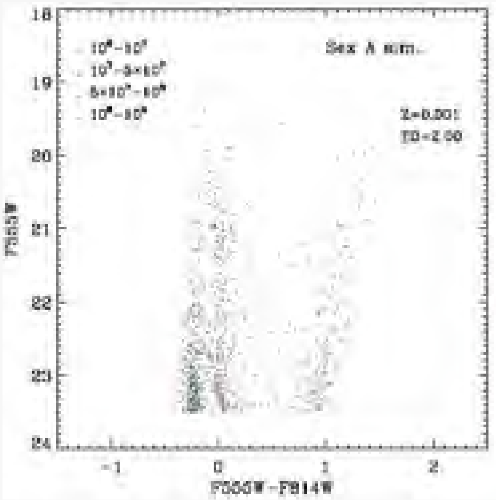

Chen+15

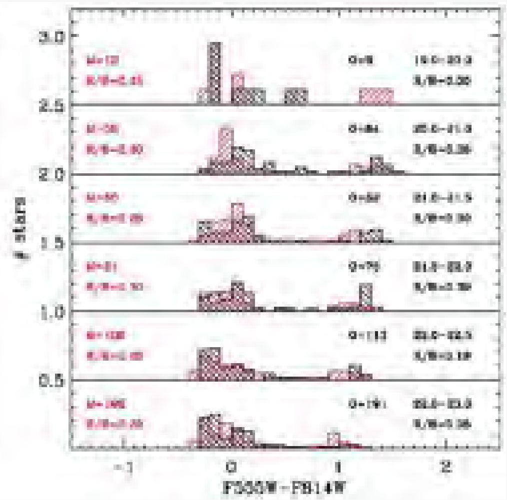
# PARSEC models for very-massive stars



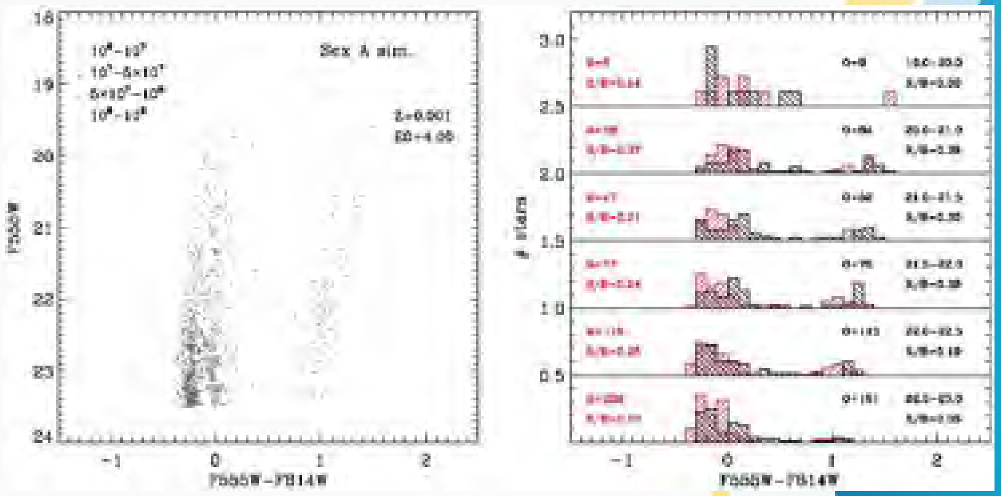



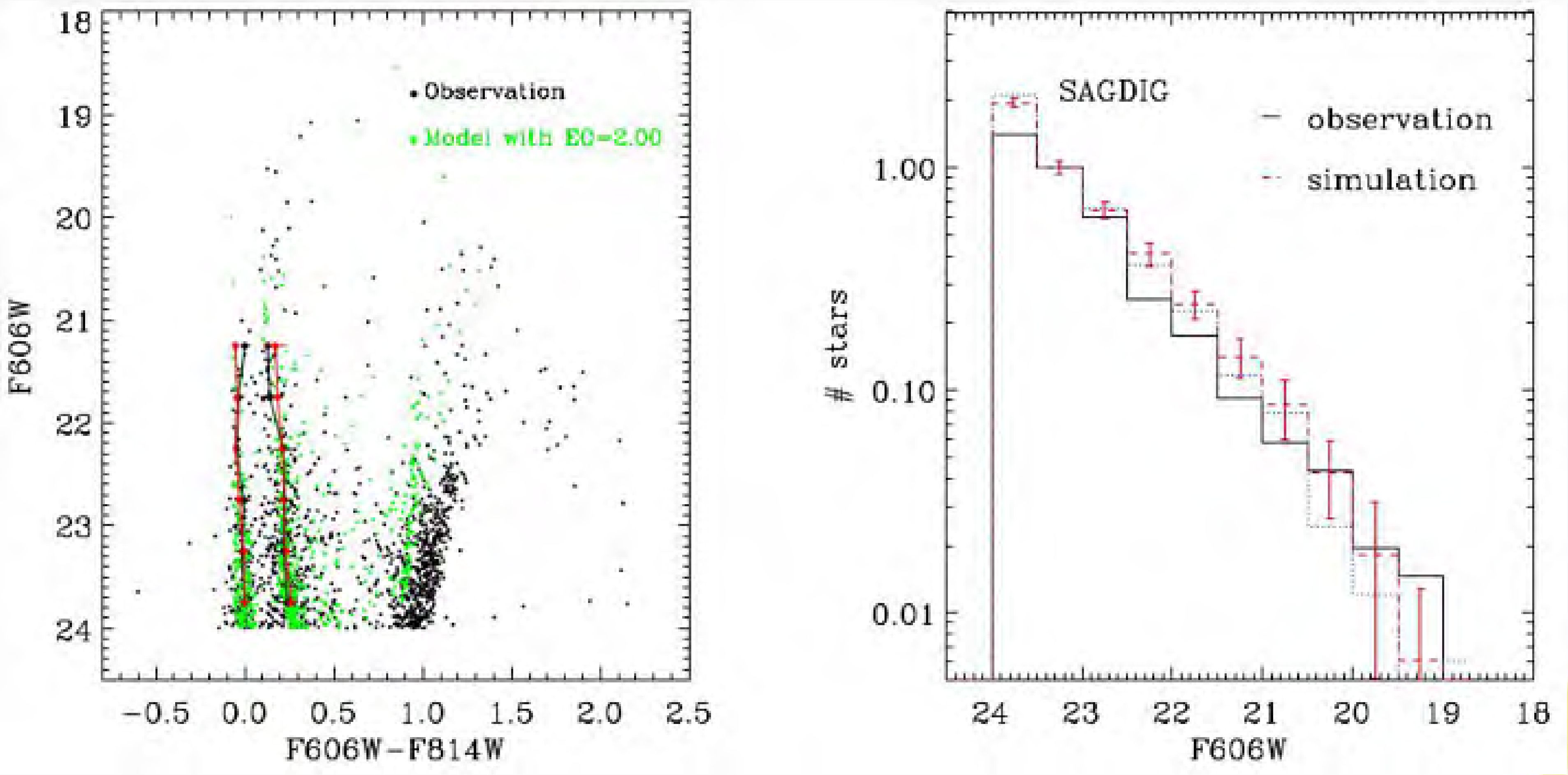



Tang+14: calibrating envelope overshooting

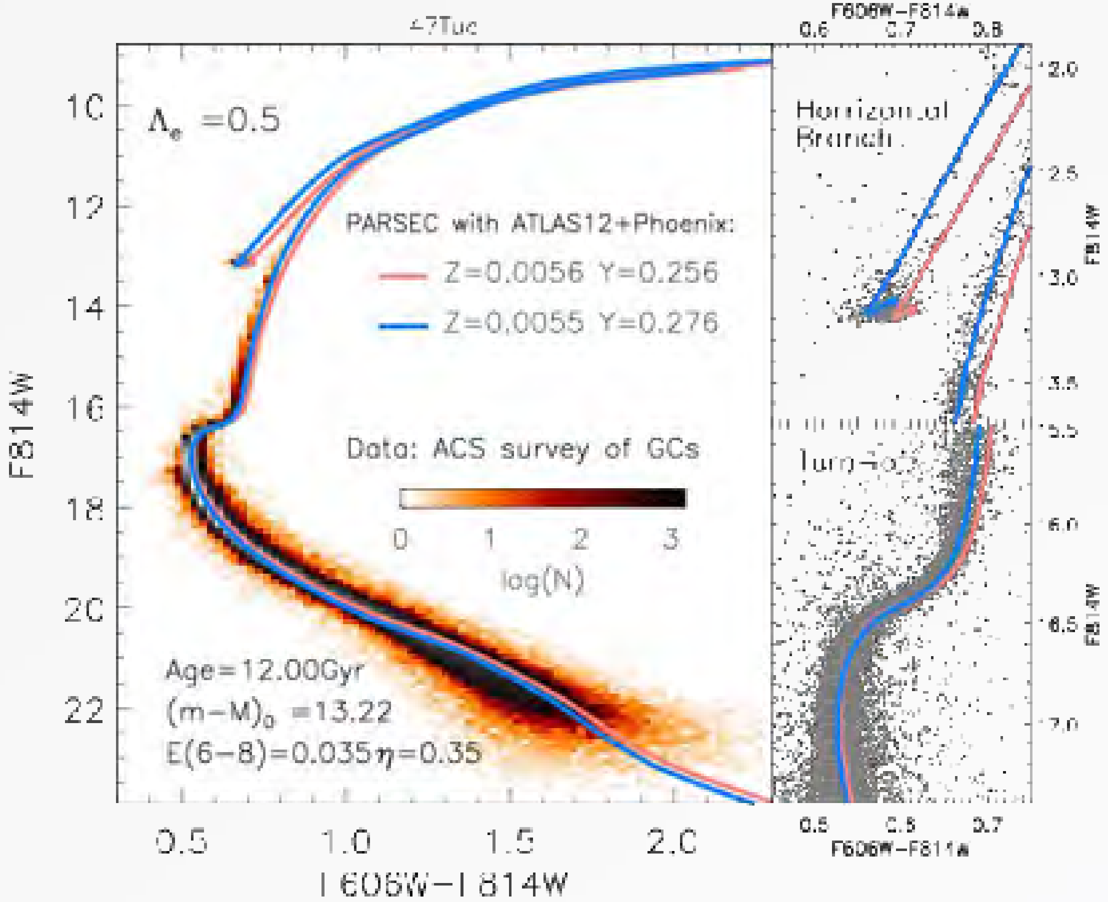


# PARSEC models for very-massive stars




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

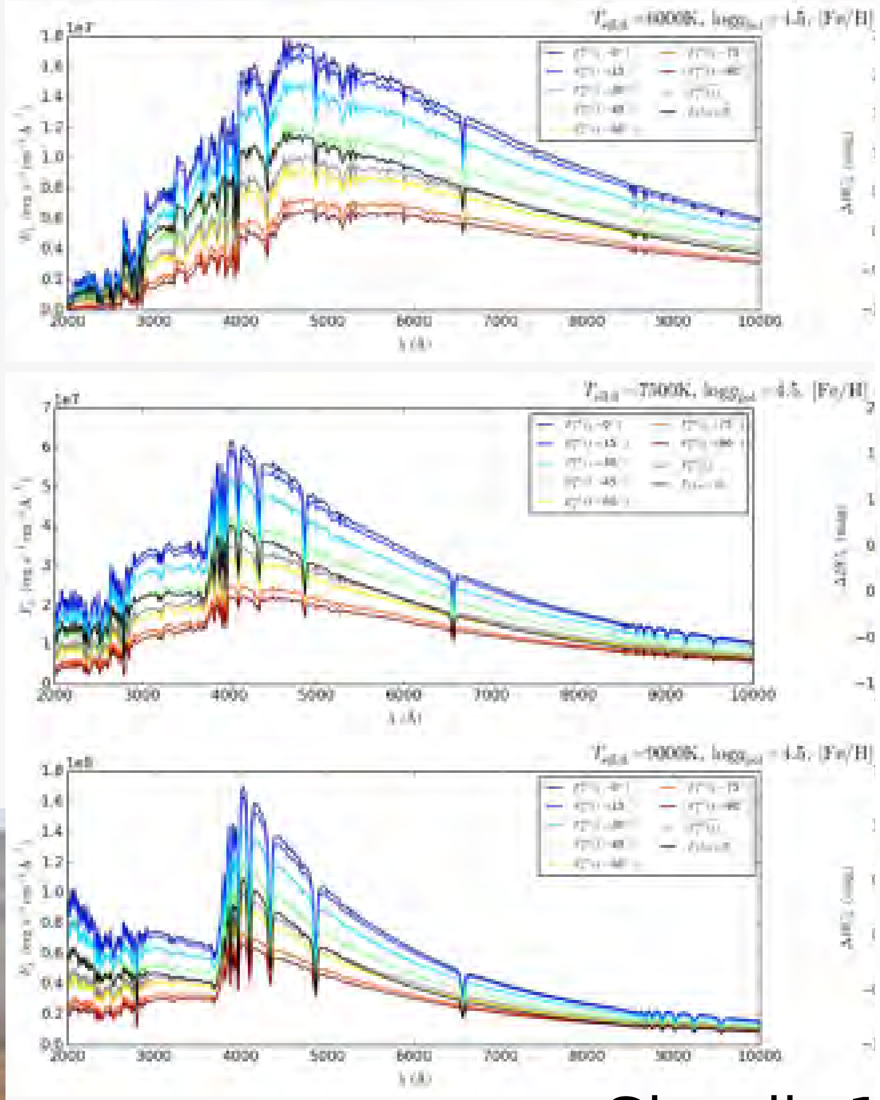
# PARSEC models with alpha-enhancement

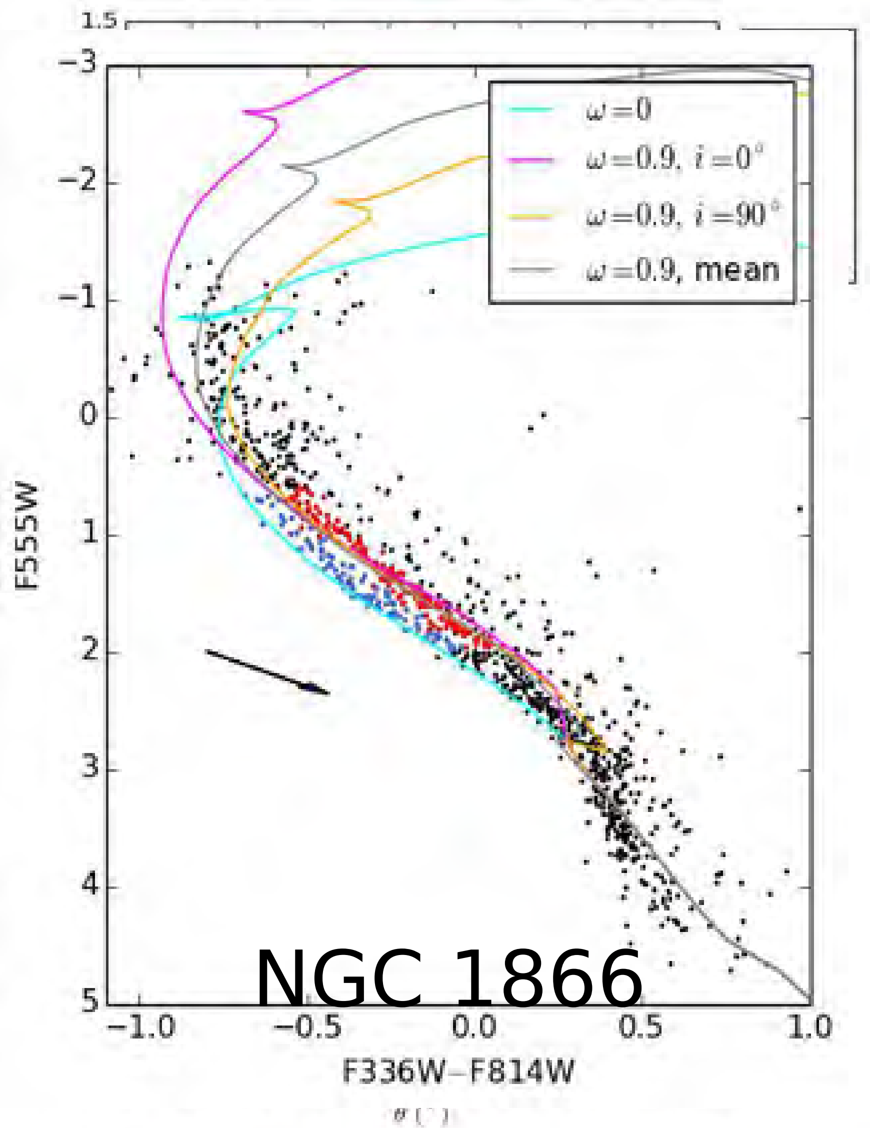


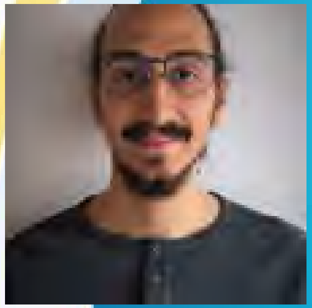

Fu+18: PARSEC alpha-enhanced model ftting to 47 Tuc

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

# PARSEC model of rotating stars

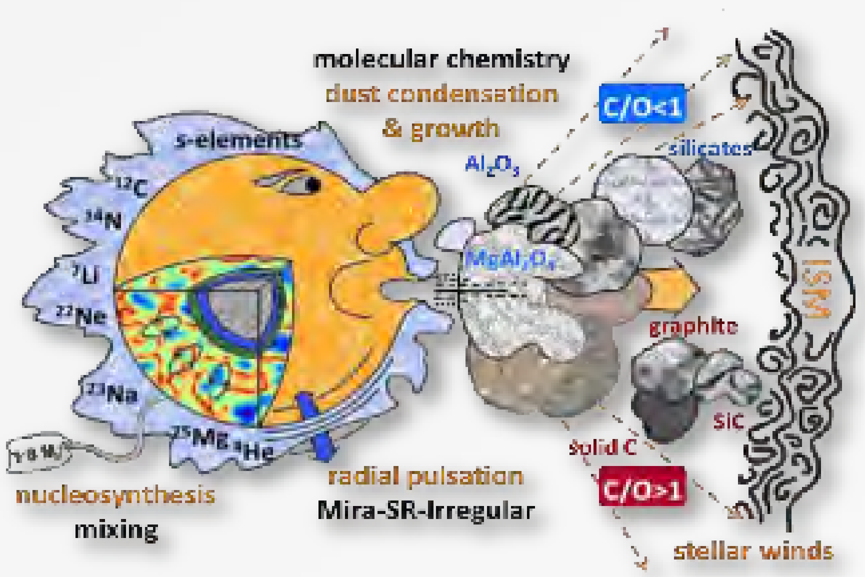


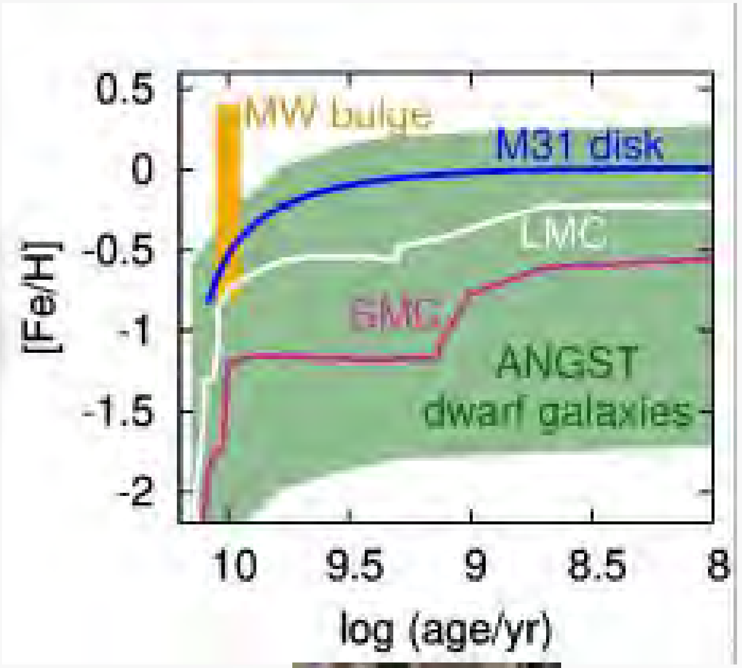


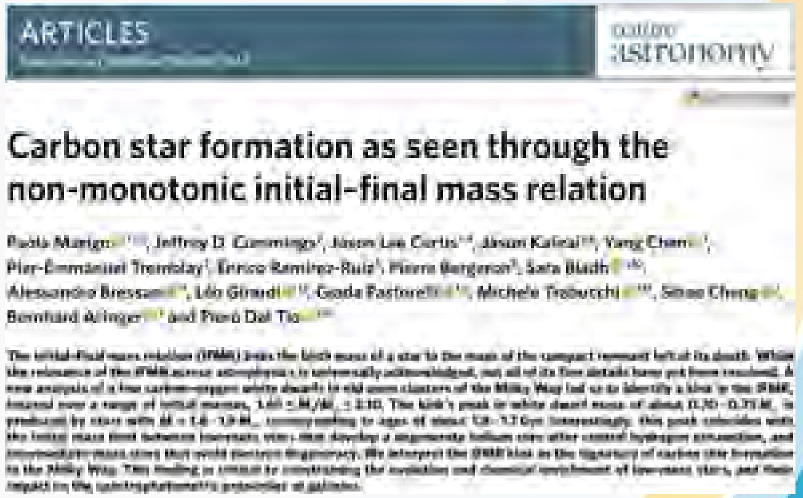



Girardi+19, Costa+19

# TP-AGB models: ERC project *STARKEY*

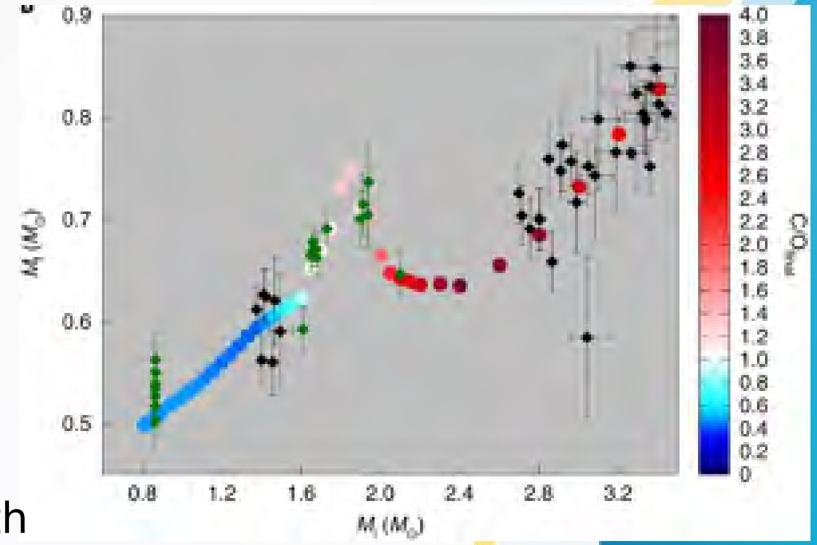


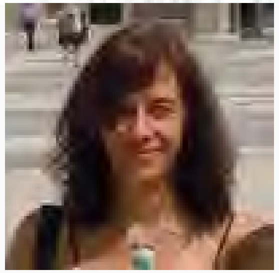


ARTICLES

nature astronomy

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

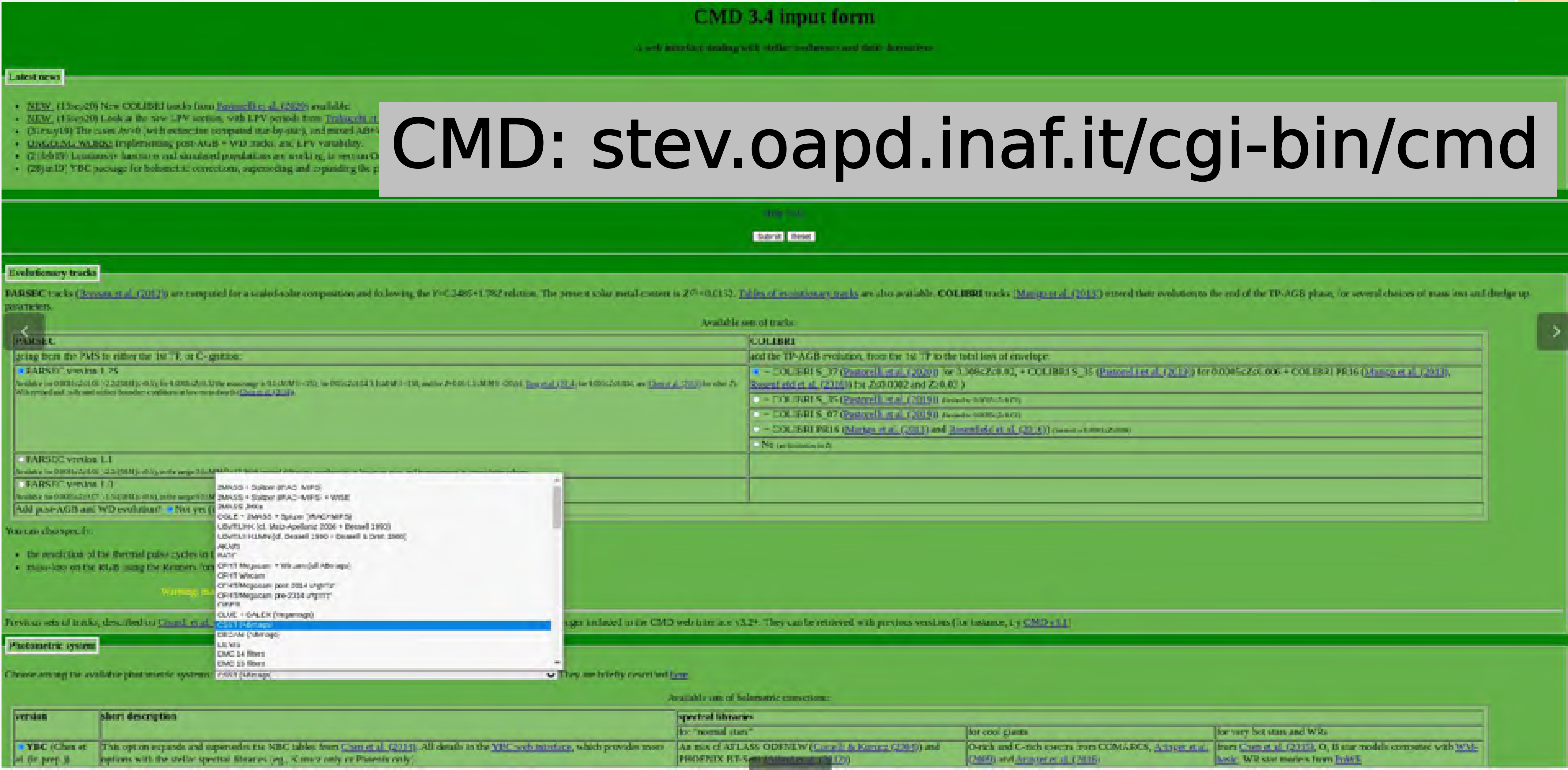



Starkey results: Pastorelli+19,+20, Chen+18, & in preps., Marigo+20



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

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



# Comparison of different stellar models

| Name | mass range | Z range | abundance | EOS | OP | NR | Rotation | stages | Else1 | BC | 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+McDonald | Ferguson05+ Freedman08 +OP+OPAL | JINA REACLIB | v/vcrit=0, 0.4 | Pre-MS to WD | Planets, Oscillations | ATLAS12+Grey | 16 |
| BastI (Cassisi, Teramo; Salaris, JMU) | 0.1-15(new) | 1E-5 to 0.05 | solar,a,CNO | FREEEOS | OPAL | NACRE | N | Pre-MS to AGB0/CB0 | WD, diff. Reimers etas | Vernazza+81 | 18 |
| DESP (Dotter, Dartmouth) | 0.1-4 | [Fe/H] from -2.5 to +0.5 | Solar,a | ideal gas+FREEEOS | OPAL + Ferguson05 | Adelberger+98 | N | Pre-MS to AGB0 | | | 08 |
| FRANEC (Chieffi & Limongi) | | | | | | | | | link | | |
| Genova (Meynet) | | | | | | | | | link | | |
| STERN (Brott) | | | | | | | | | link | | |
| STAREVOL (Decressin) | | | | | | | | | link | | |
| Yale-Yonsei-Potsdam (Demarque) | | | | | | | | | link | | |
| Pisa (Tognelli) | | | | | | | | | link | | |
| Victoria-Regina (VandenBerg) | | | | | | | | | link | | |
| Eggleton | | | | | | | | | link | | |
| CESAM (Morel & Lebreton) | | | | | | | | | link | | |

incomplete

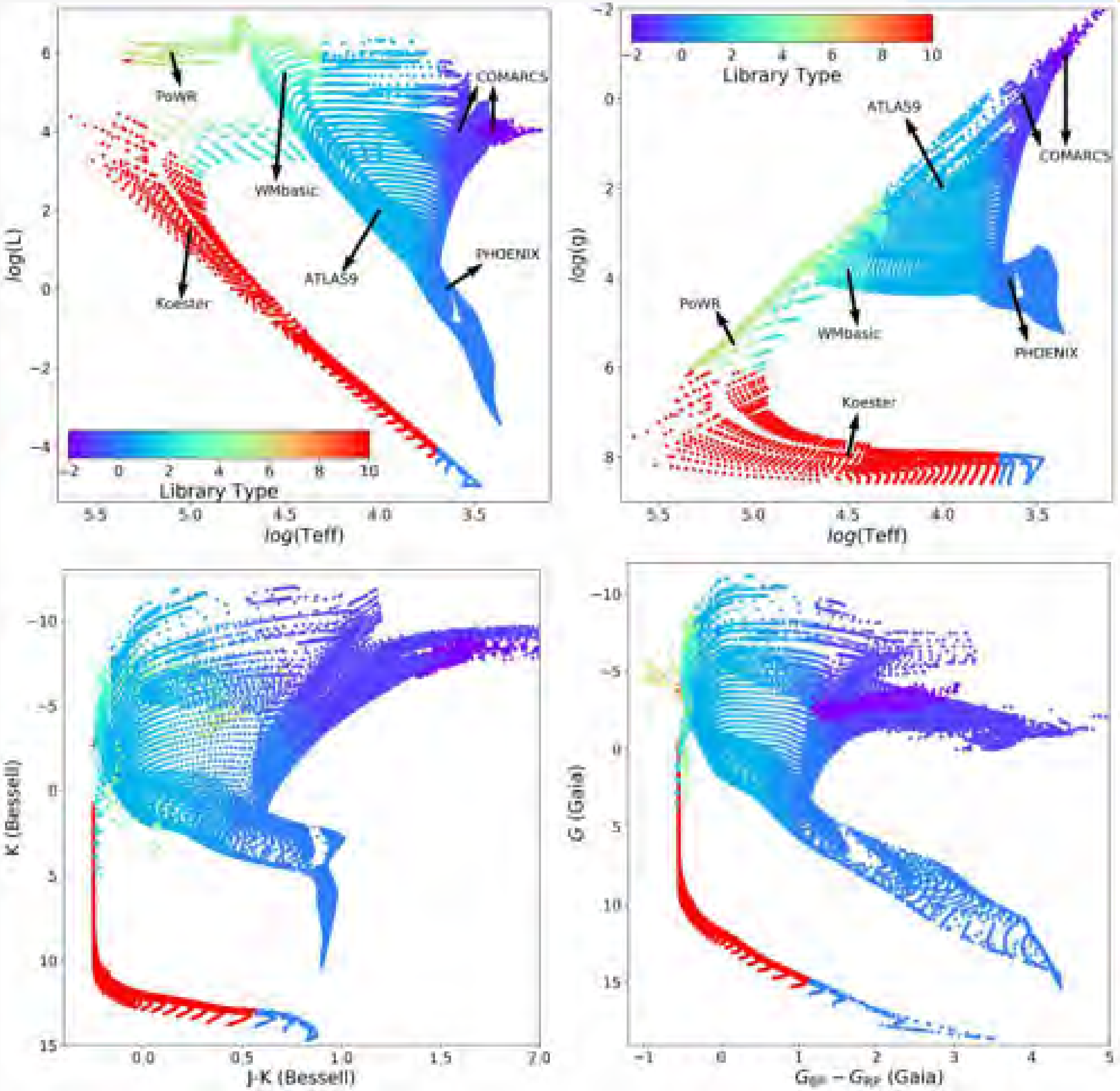
# TRILEGAL Bolometric corrections

**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



# TRILEGAL Bolometric corrections

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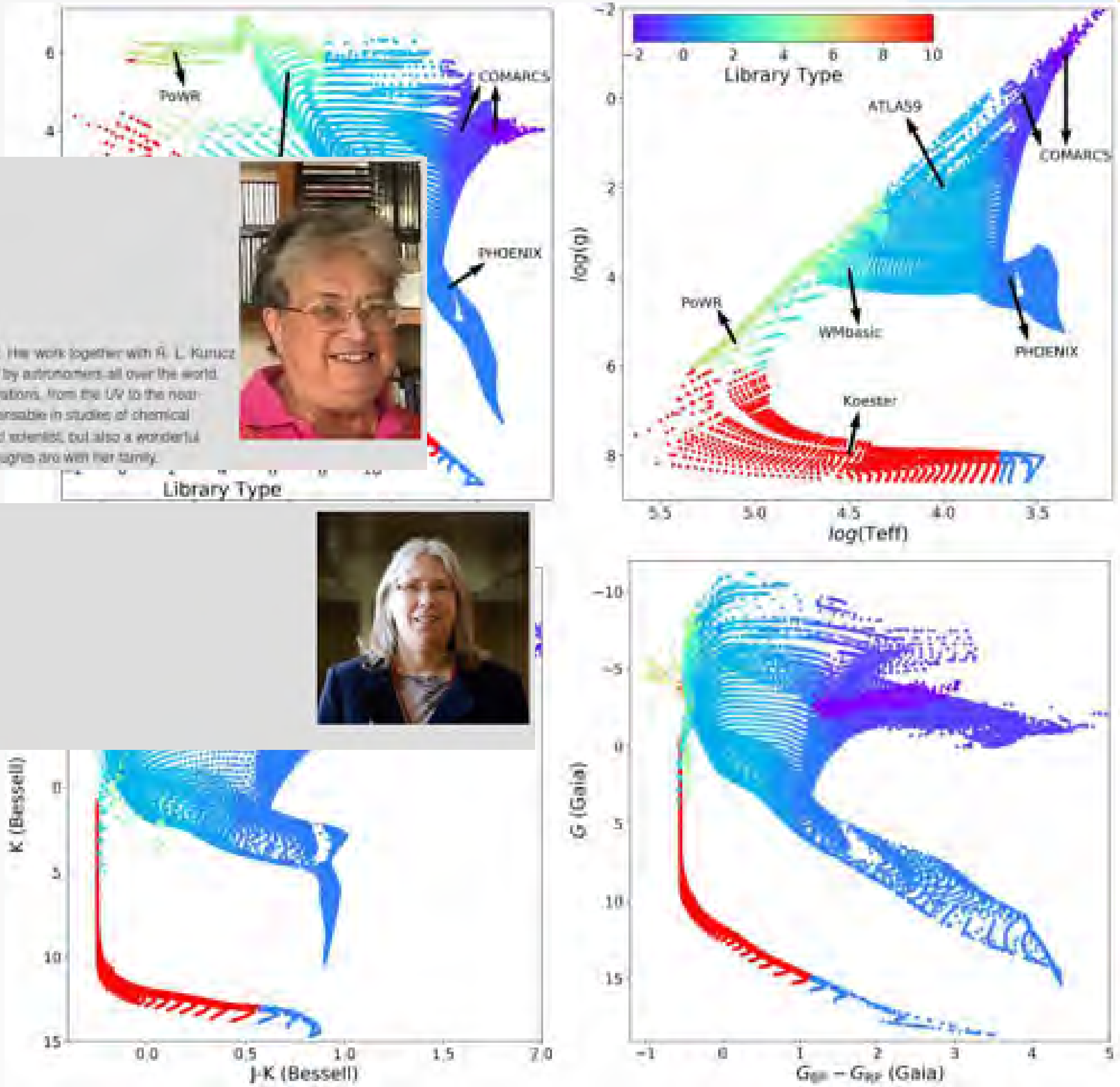



Fiorella Castelli

Italy

1943-2019

Obituary:

Fiorella Castelli passed away on 2019 July 26, at the age of 76. Her work together with R. L. Kurucz on ATLAS9 model atmospheres is well-known and widely used by astronomers all over the world. Fiorella's synthetic spectral libraries for multiwavelength observations, from the UV to the near-infrared, for different types of stars are also famous and indispensable in studies of chemical abundances. We are loosing not only an excellent highly valued scientist, but also a wonderful person always greatly helping colleagues in their work. Our thoughts are with her family.

France Allard

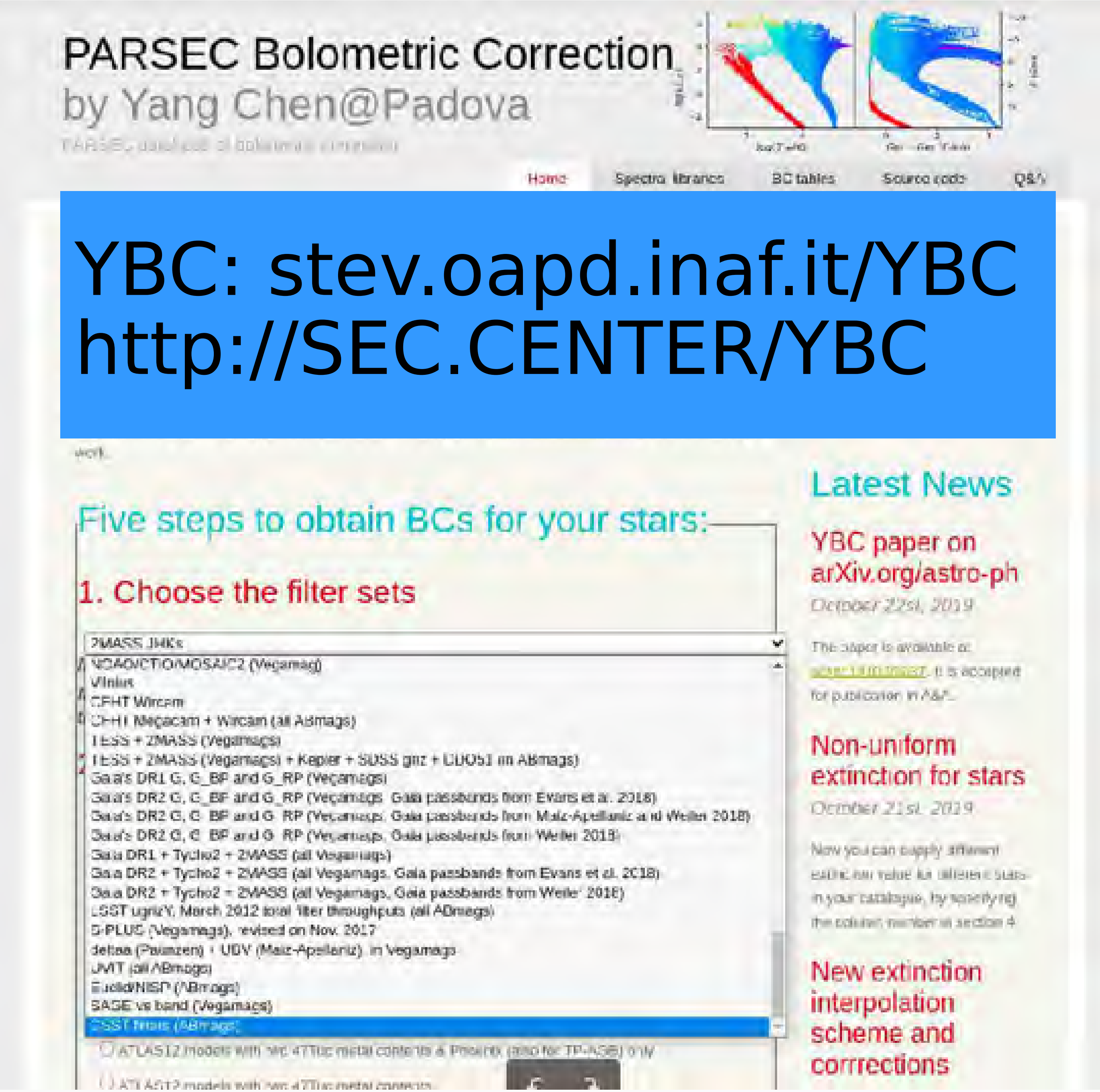
France

1963-2020

Obituary:

https://cral.univ-lyon1.fr/spip.php?article227&lang=en

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



# TRILEGAL output: synthetic stellar catalogues

**Stellar parameters**

LPVs periods

| Gc | mu0 | Av | comp | label | logAge | M_H | m_ini | Mass | logL | logTe | logg | McoreTP | Mloss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 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 |
| 1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | -0.25 | 0.33035 | 0.33 | -1.642 | 3.5203 | 4.632 | 0.0 | 2.43E-15 |
| 1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | -0.25 | 0.27569 | 0.275 | -1.764 | 3.5088 | 4.628 | 0.0 | 2.03E-15 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.2E-13 0 |

Surface composition

| C_O | tau1m | X | Y | Xc | Xn | Xo | Cexcess | Z | pmode | period0 | period1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.537 | 0.0 | 0.7348 | 0.2572 | 0.001418 | 3.872E-4 | 0.003518 | -1.0 | 0.008011 | -1 | 0.0 | 0.0 |
| 0.545 | 0.0 | 0.7273 | 0.2642 | 0.001539 | 4.15E-4 | 0.003764 | -1.0 | 0.008555 | -1 | 0.0 | 0.0 |
| 0.545 | 0.0 | 0.7273 | 0.2642 | 0.001539 | 4.15E-4 | 0.003764 | -1.0 | 0.008555 | -1 | 0.0 | 0.0 |
| | | ... | | | ... | | | ... | | | |
| 0.537 | 0.0 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | -1.0 | 0.008056 | -1 | 0.0 | 0.0 |

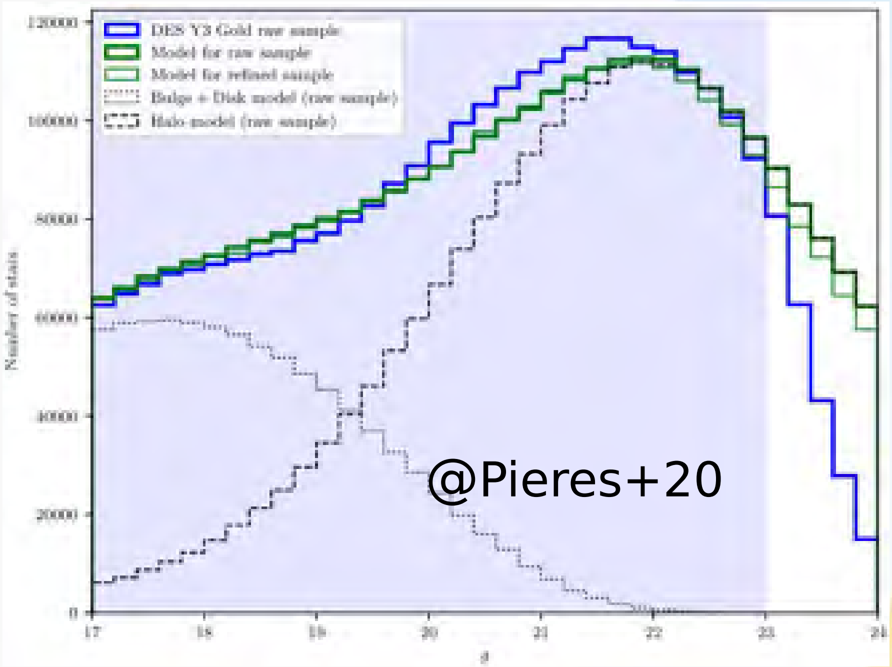
LSST + Gaia Photometry

Kinematics

| mbolmag | umag | gmag | rmag | imag | zmag | Ymag | Gmag | G_BPmag | G_RPmag | velU | velV | velW | Vrad | PMracosd | PMdec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14.731 | 16.758 | 15.561 | 15.315 | 15.261 | 15.244 | 15.219 | 15.243 | 15.503 | 14.875 | -48.7 | 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 | 19.444 | -35.8 | -26.6 | 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 | 19.79 | -35.8 | -26.6 | 0.8 | 38.7 | 0.82 | -2.36 |
| | | ... | | | ... | | | | ... | | | ... | | | |
| 13.581 | 15.467 | 14.35 | 13.983 | 13.863 | 13.816 | 13.793 | 13.941 | 14.257 | 13.474 | -37.7 | -15.6 | -2.9 | 29.8 | 2.95 | -3.99 |

Pastorelli+19

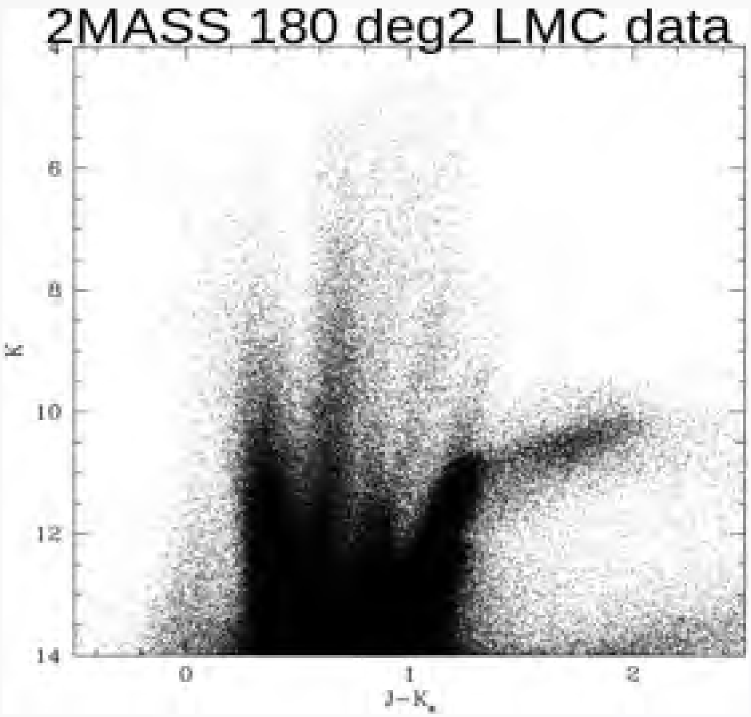
# TRILEGAL calibrations

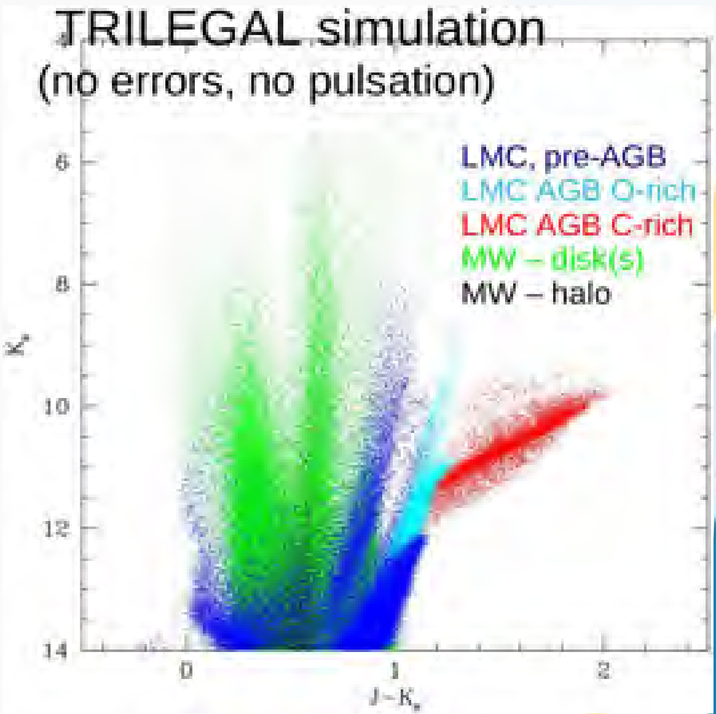



**Photometric surveys**:
Groenewegen+02: Halo+disk
Girardi+05: Halo+disc
Vanhollebeke+09: Bulge
Pieres+20: Discs+Halo
…

**Spectroscopic surveys**:
RAVE, SEGUE, etc.

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



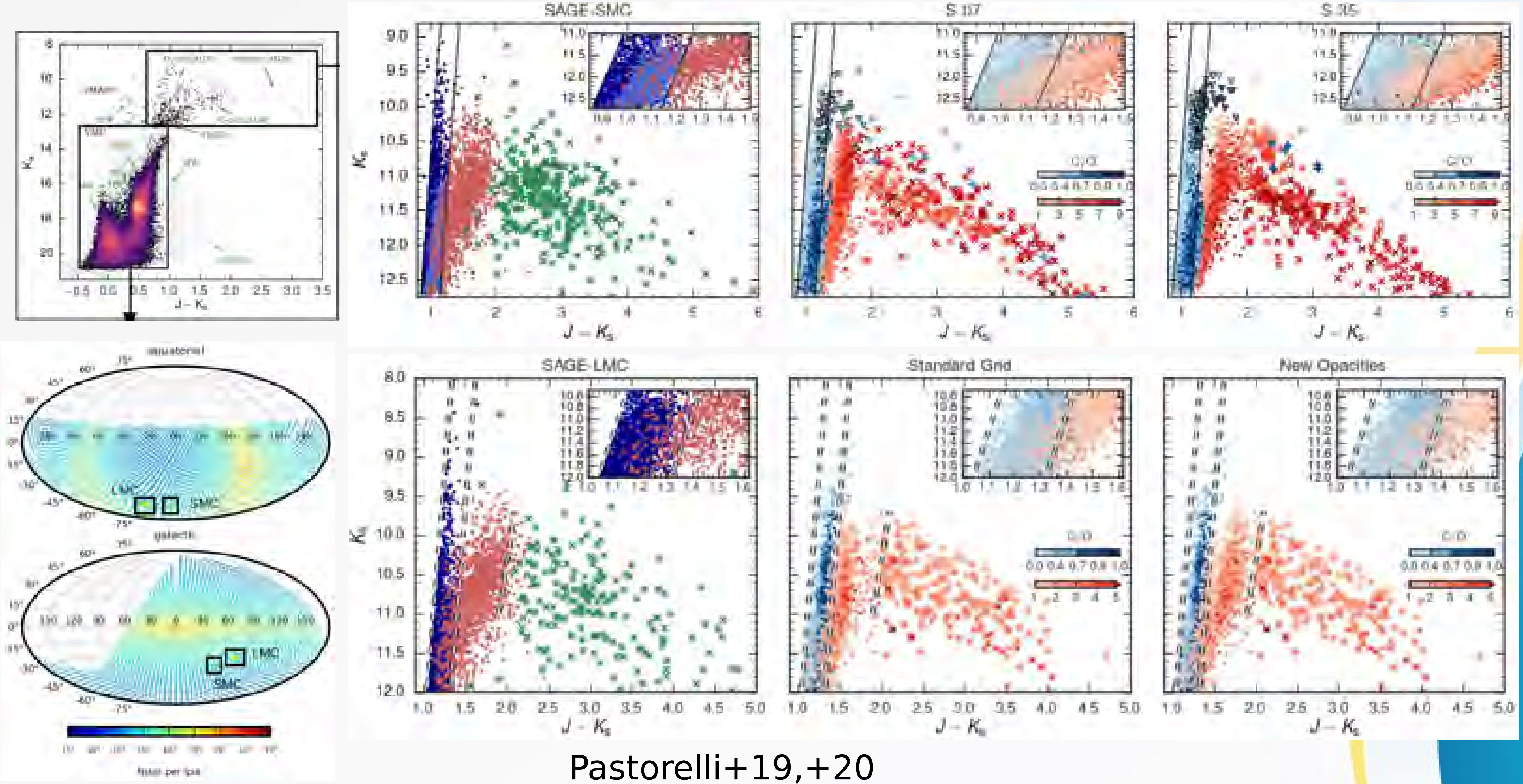

Girardi


stev.oapd.inaf.it/cgi-bin/trilegal

# TRILEGAL DEMO 1: LSST sky survey sim.

Blank intentionally

# TRILEGAL DEMO 2: SMC & LMC sim.

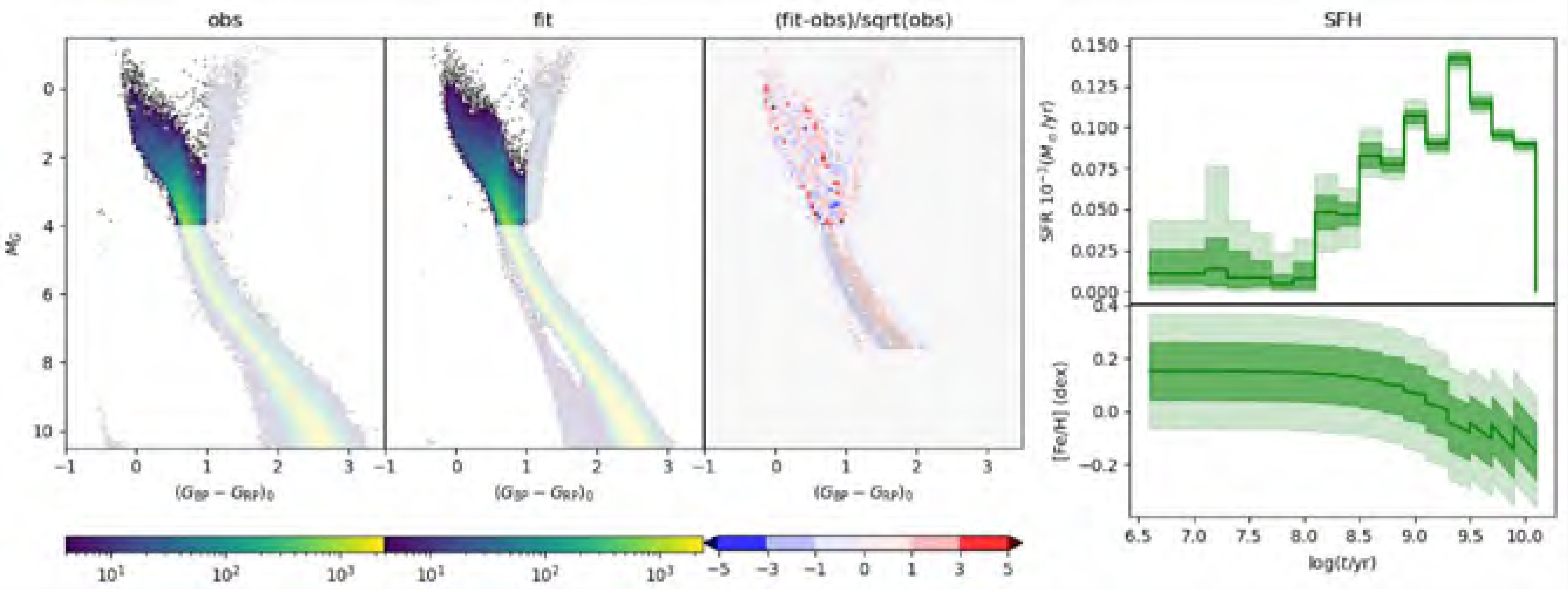



Pastorelli+19,+20

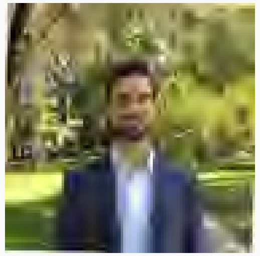
# TRILEGAL DEMO 3: M31 sim.

Blank intentionally

# TRILEGAL DEMO 4: Binaries



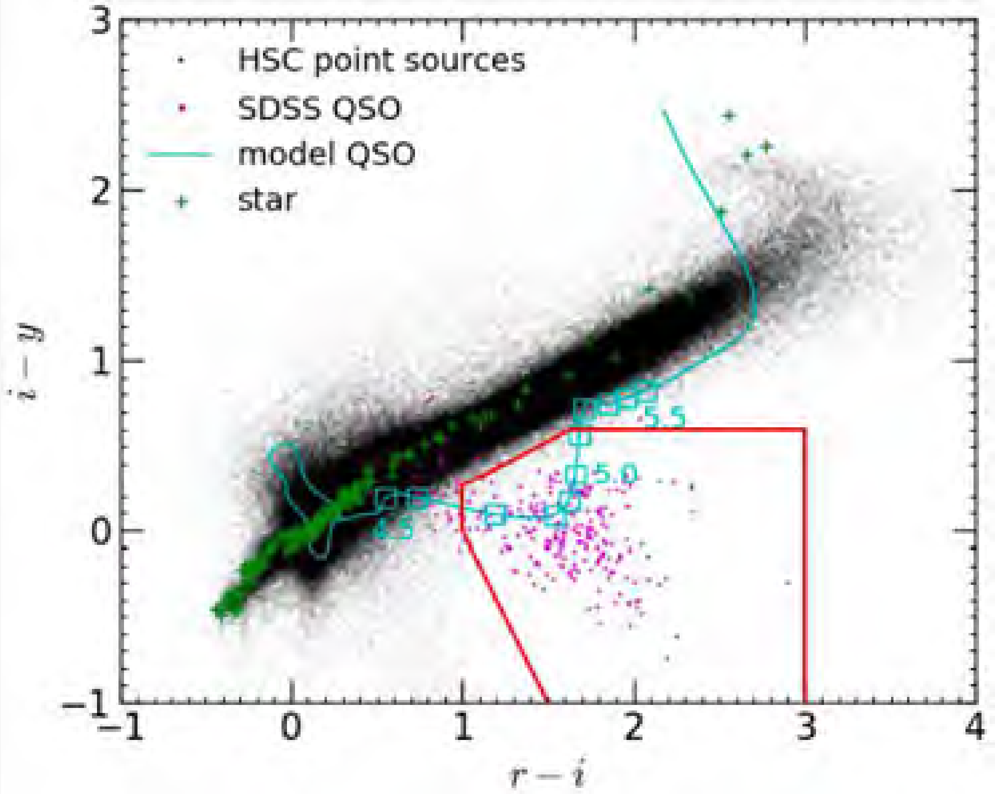

Dal Tio+19

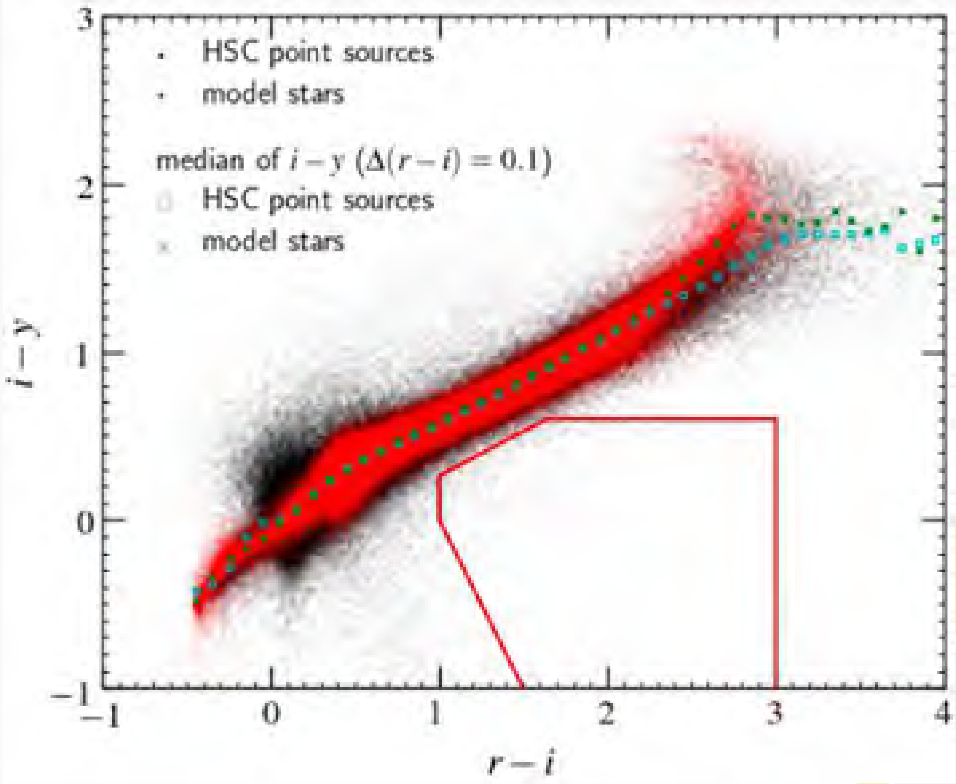


# TRILEGAL DEMO 5: Star Cluster sim.

Blank intentionally

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

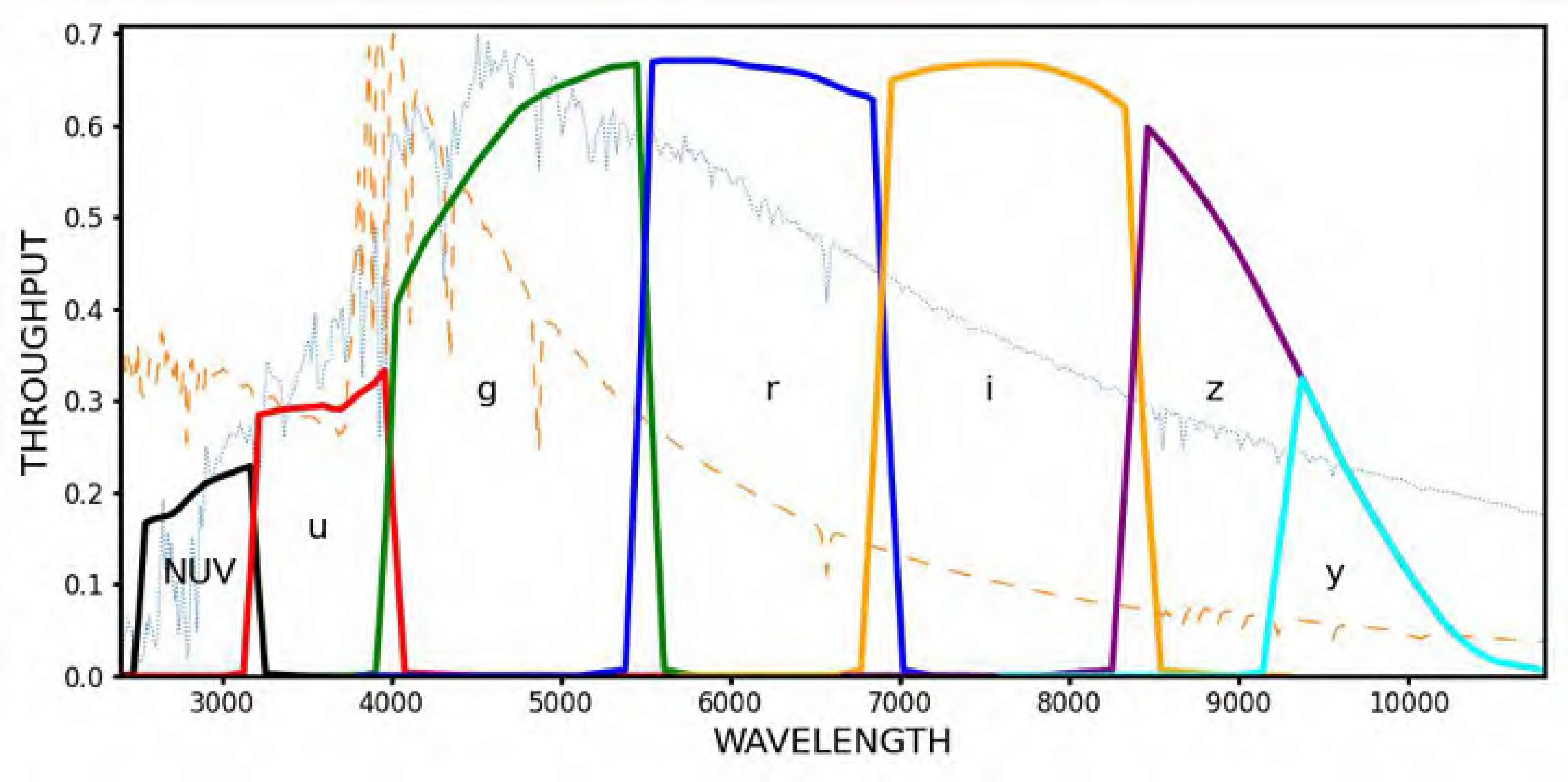



Niida+20: stellar contamination to the QSO sample

# 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

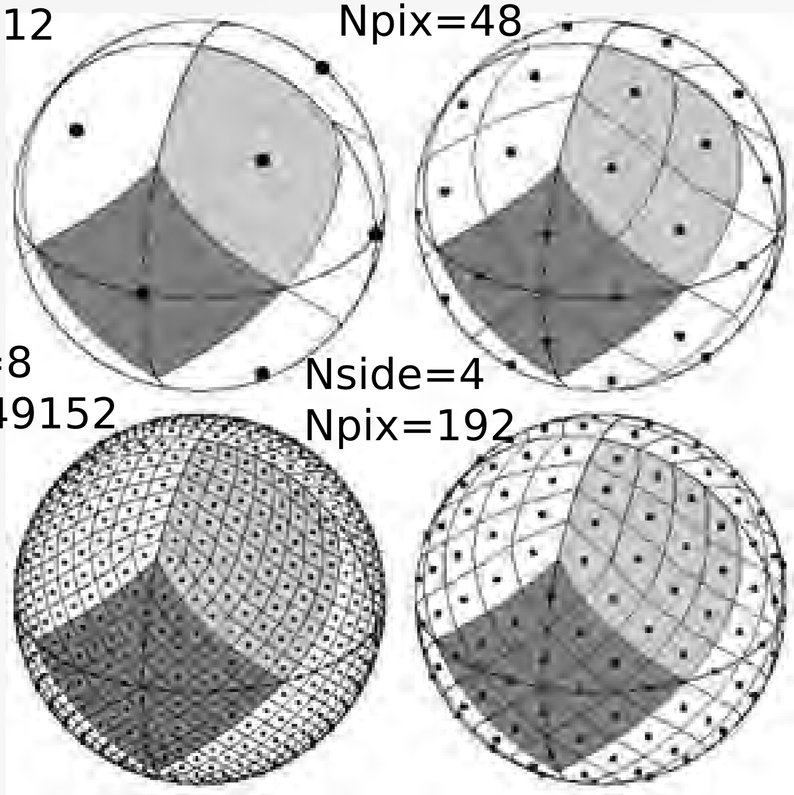
HEALPix nested subdivision scheme:

Nside=1
Npix=12

Nside=2
Npix=48

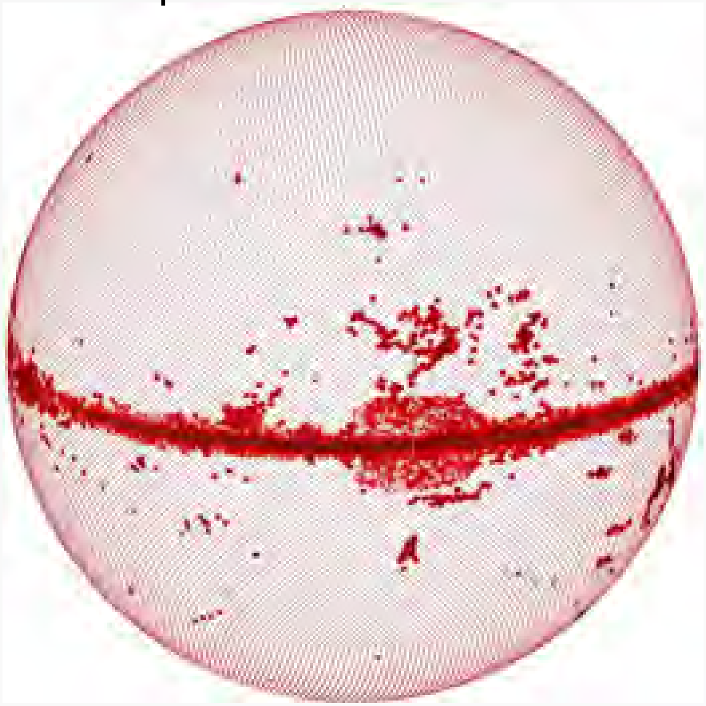
Nside=8
Npix=49152

Nside=4
Npix=192

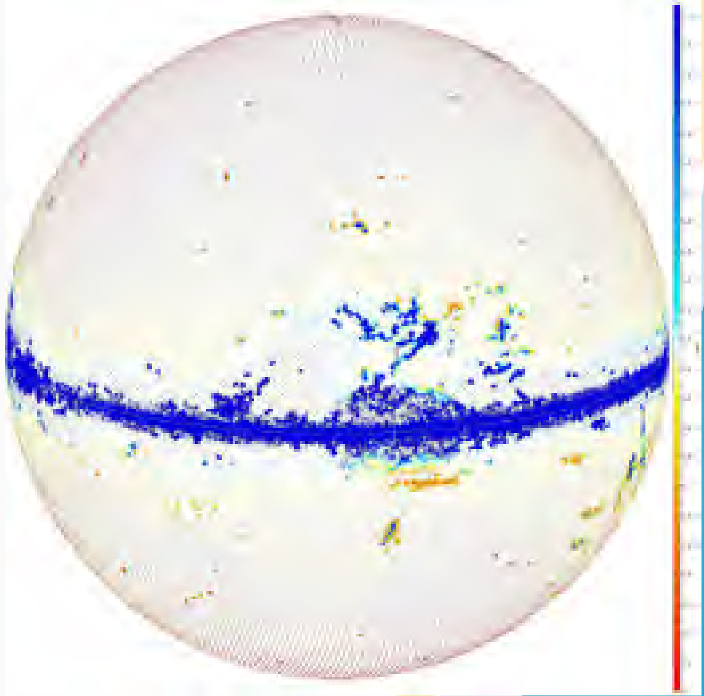


Gorski+05

Nside=64 to 2048 (1.72’)
Npix=596601



CSST sim. pixelization

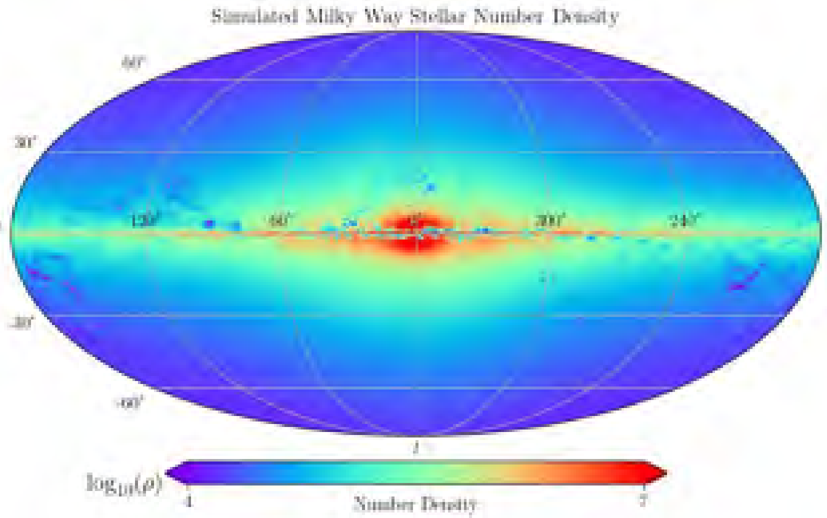


Dust map

# TRILEGAL simulation running

g<27.5
~1.5TB fits data
12.6 Bilion stars

Soon on the
NAOC VO



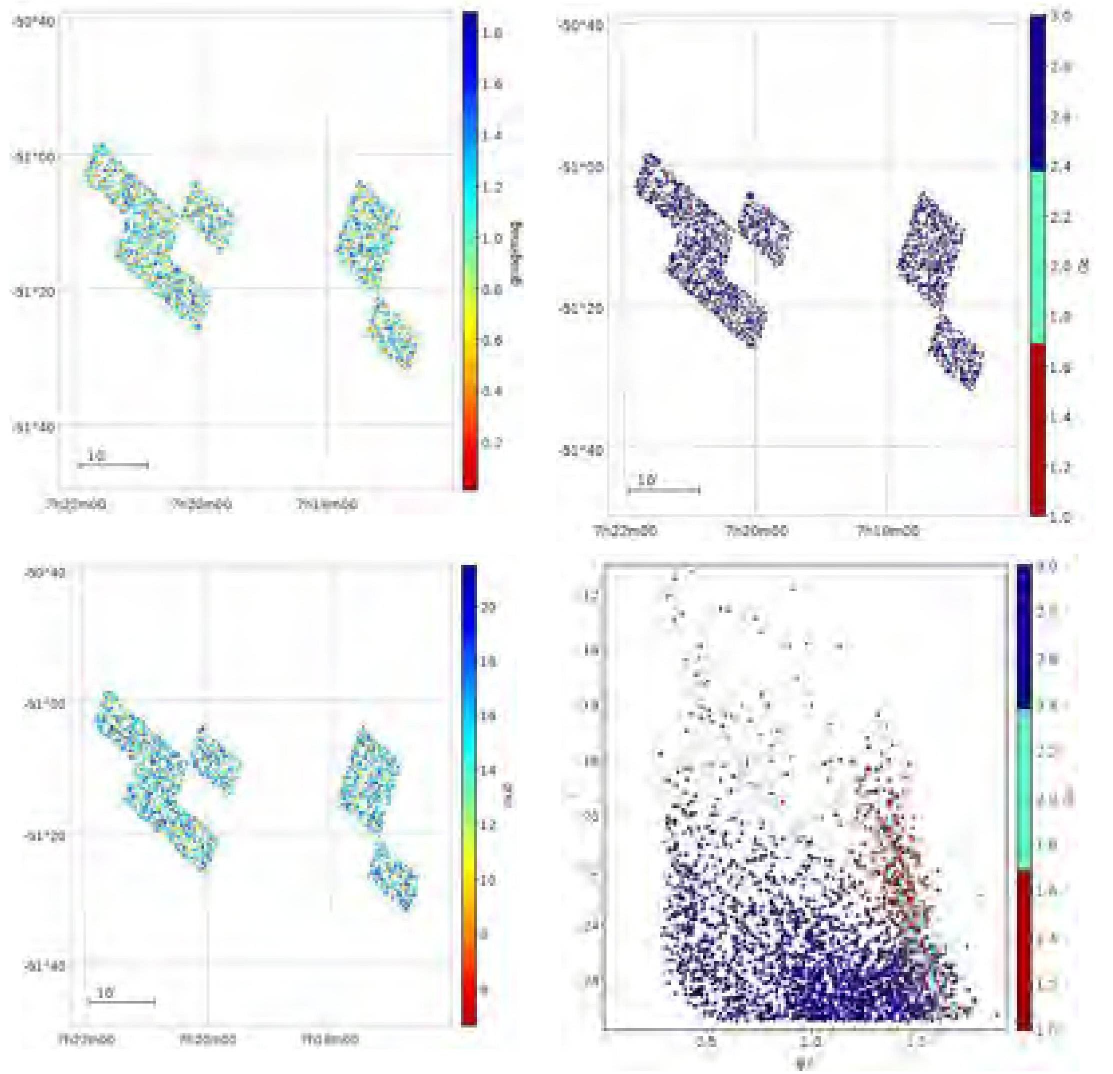



Table 1 Example of the mock catalogue

| Gc | logAge | M_H | m_ini | mu0 | Av | mratio | Mass | logL |
|---|---|---|---|---|---|---|---|---|
| 1 | 8.91 | -0.16514014 | 0.70204317569732 | 12.0 | 5.7288876 | 0.0 | 0.7020874 | -0.75758743 |
| 1 | 9.349999 | -0.206641 | 0.83383360445800 | 11.300001 | 5.6852345 | 0.0 | 0.83320236 | -0.35524124 |

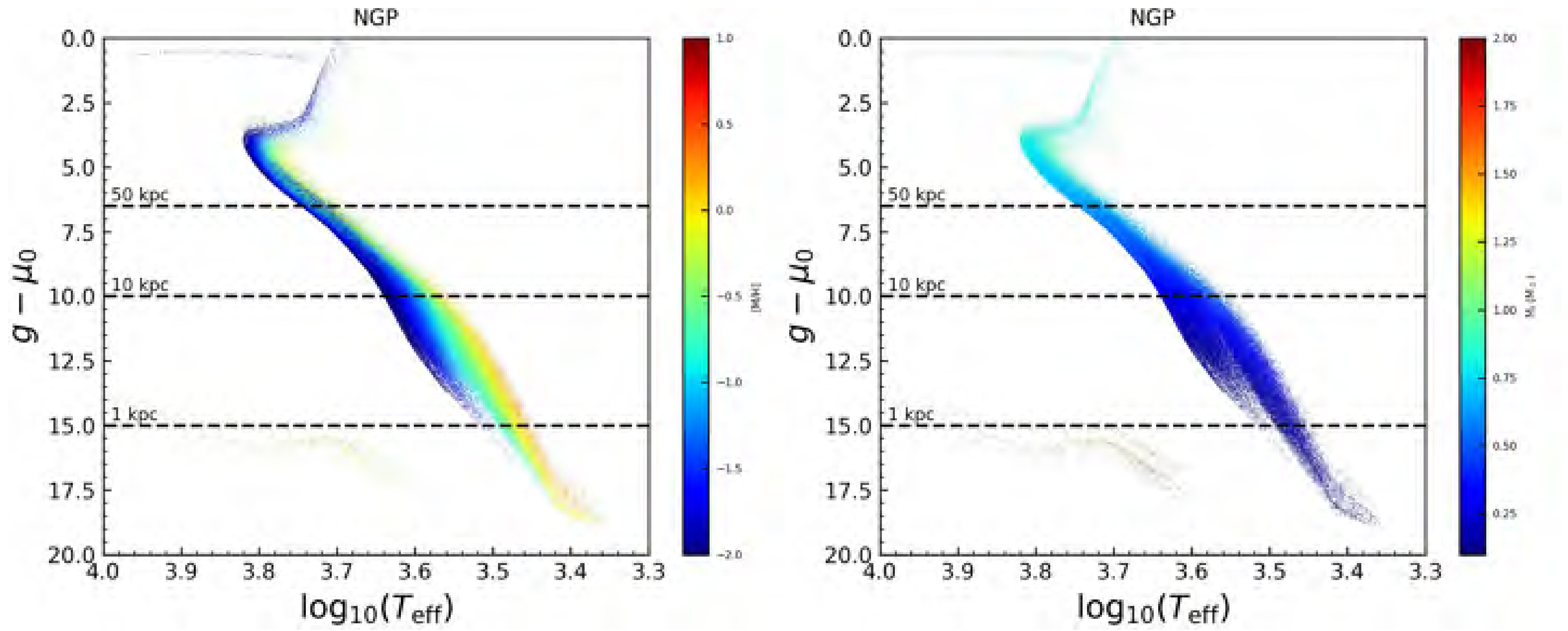
| logTe | logg | label | McoreTP | C_O | period0 | period1 | pmode | Mloss | tau1m |
|---|---|---|---|---|---|---|---|---|---|
| 3.6680293 | 4.6660957 | 0 | 0.0 | 0.544593 | 0.0 | 0.0 | -1 | -1.2162959E-14 | 0.0 |
| 3.7332726 | 4.590062 | 1 | 0.0 | 0.53722 | 0.0 | 0.0 | -1 | -3.0392355E-14 | 0.0 |

| X | Y | Xc | Xn | Xo | Cexcess | Z | mbolmag |
|---|---|---|---|---|---|---|---|
| 0.72519267 | 0.26460725 | 0.0018283299 | 4.935209E-4 | 0.0044763405 | -1.0 | 0.010200083 | 18.663969 |
| 0.73663384 | 0.25433245 | 0.0015997563 | 4.370039E-4 | 0.003970457 | -1.0 | 0.00903371 | 16.958103 |

| NUVmag | umag | gmag | rmag | imag | zmag | ymag | velU | velV |
|---|---|---|---|---|---|---|---|---|
| 34.179413 | 30.573284 | 26.087975 | 23.63411 | 22.122843 | 20.99646 | 20.66116 | -10.797998 | -27.755371 |
| 30.68219 | 27.577374 | 23.878262 | 21.74874 | 20.387028 | 19.353289 | 19.050008 | -12.106426 | -5.577133 |

| velW | Vrad | PMracos | PMdec | gall | galb |
|---|---|---|---|---|---|
| -11.022252 | 18.888453 | 0.17034815 | -2.7342863 | 206.94619730114937 | -16.770211787875738 |
| -10.877249 | 8.033565 | -1.1146122 | -1.9767536 | 206.93089798092842 | -16.785654244628205 |

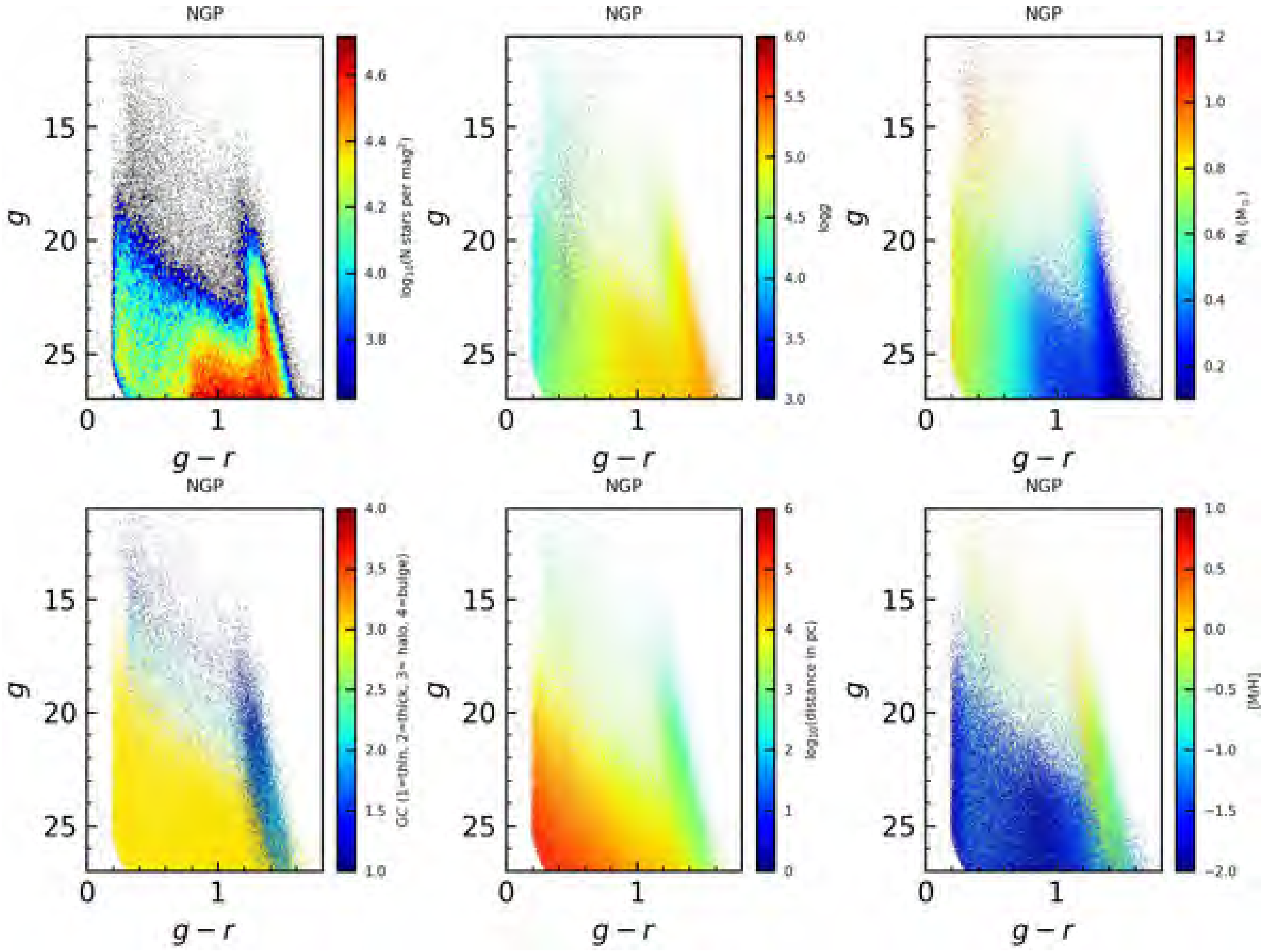
# TRILEGAL sim. of the north galactic pole



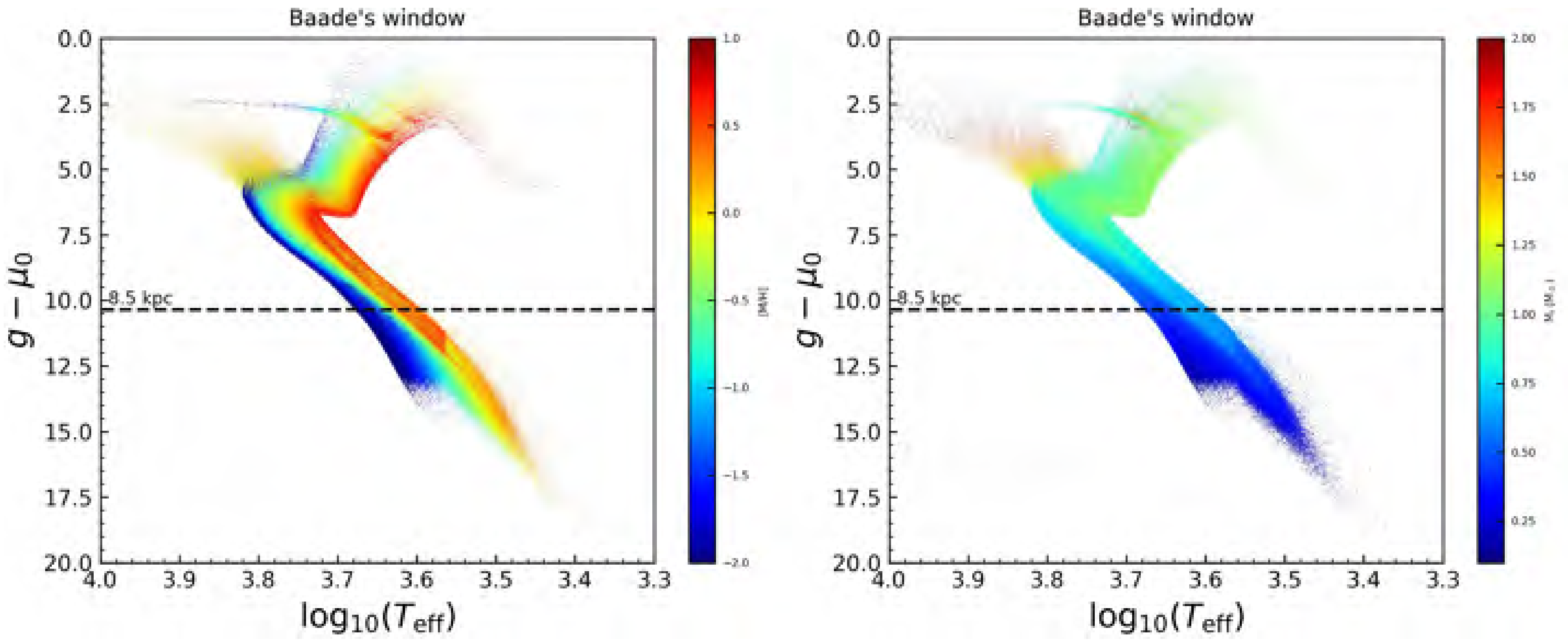

Absolute magnitude vs. effective temperature
CSST-OS will reach g~25.5 (or 26.5) mag. A star with M(g)~15 mag, will have g~25 mag at 1 kpc, being above CSST-OS limit.

# TRILEGAL sim. of the north galactic pole

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



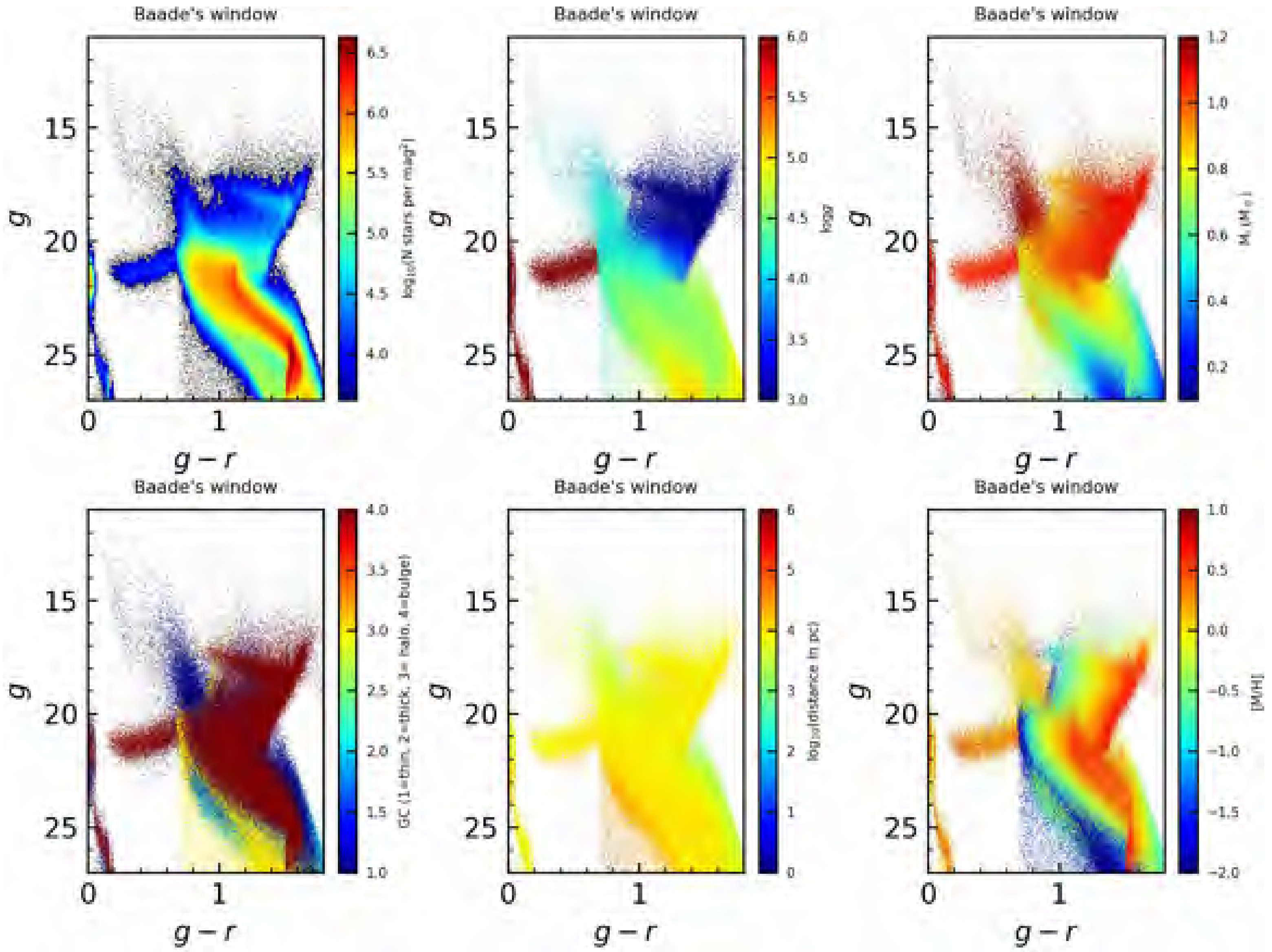
# TRILEGAL sim. of the Baade's window



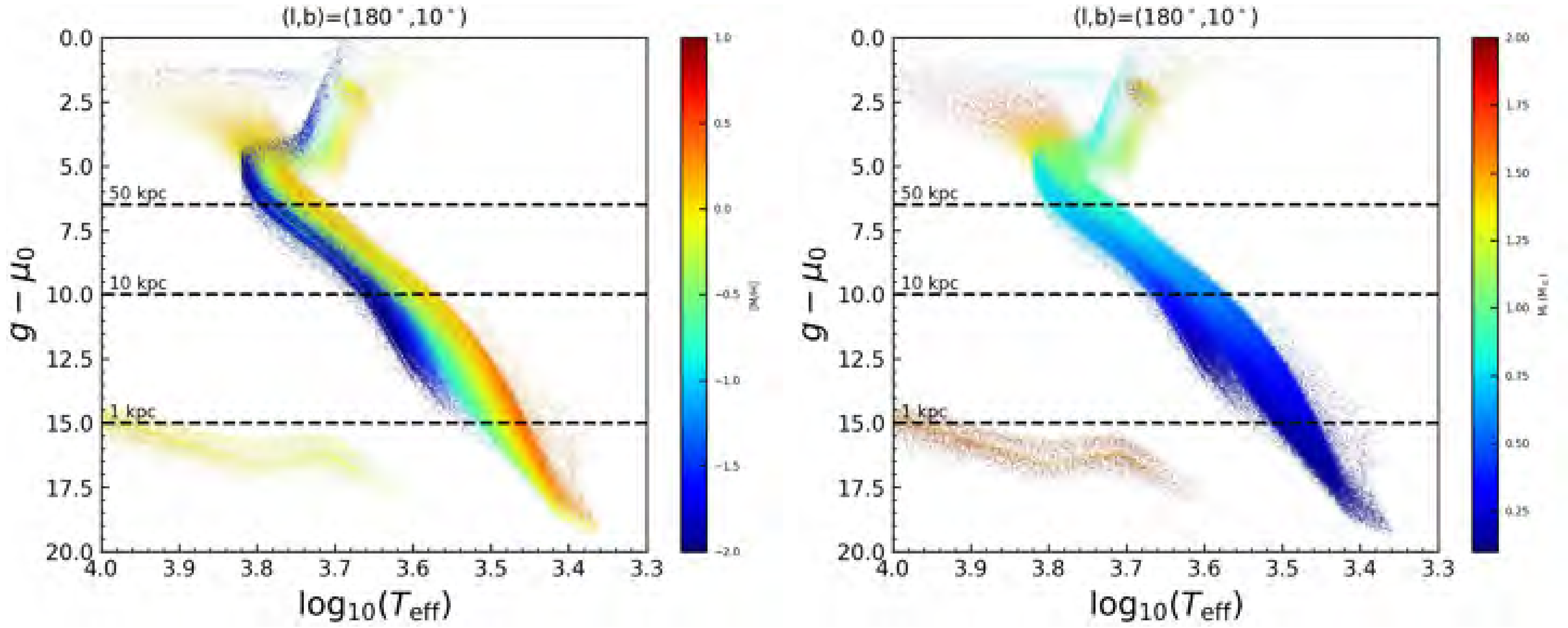

Absolute magnitude vs. effective temperature
CSST-OS will reach g~25.5 (or 26.5) mag. A star with M(g)~10.35 mag, will have g~25 mag at 8.5 kpc, being above CSST-OS limit.

# TRILEGAL sim. of the Baade's window

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



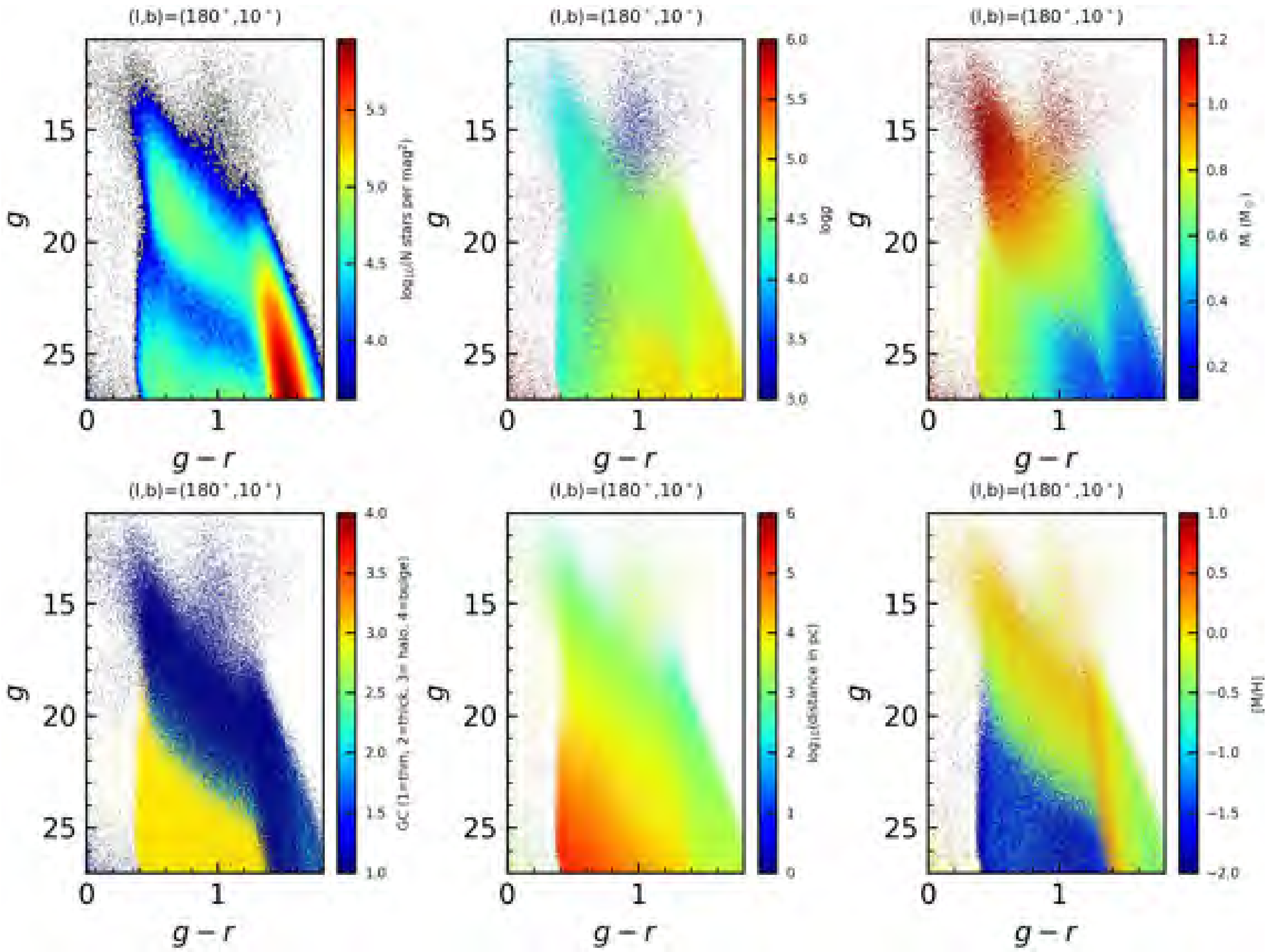
# TRILEGAL sim. of the anti-Gal. direction



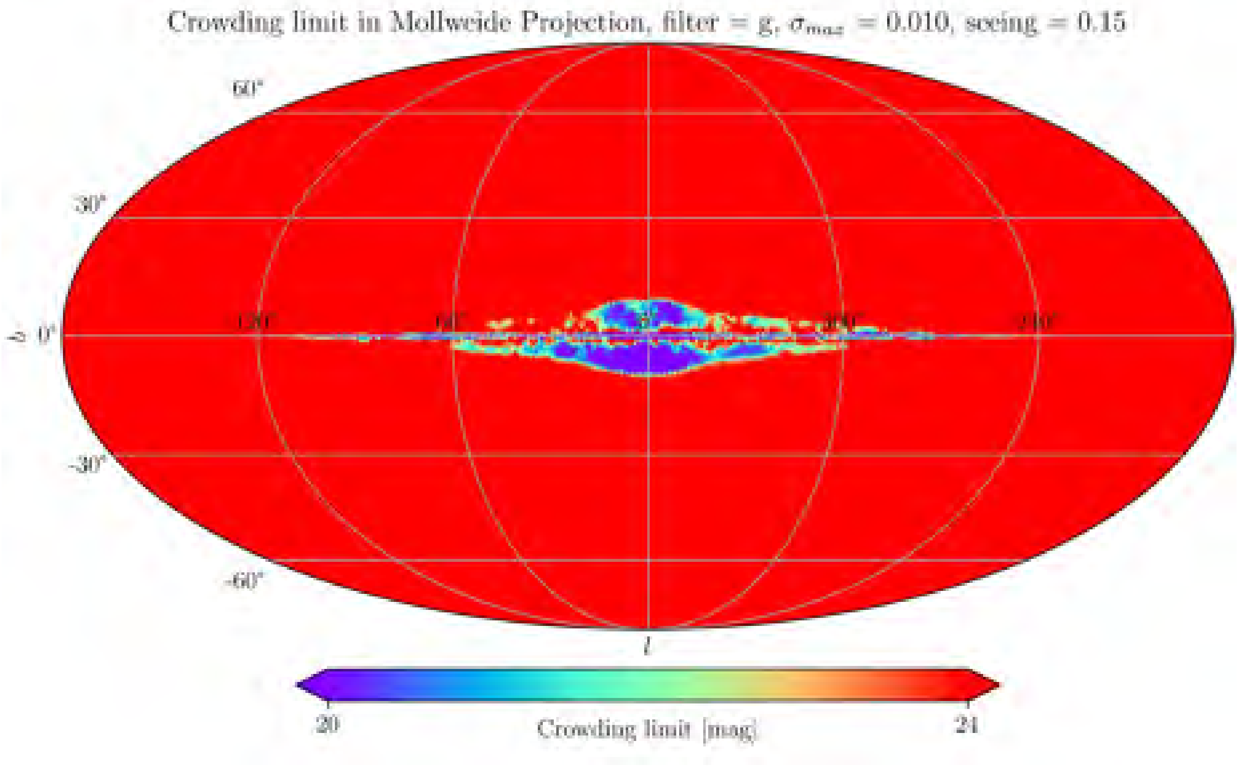

Absolute magnitude vs. effective temperature
CSST-OS will reach g~25.5 (or 26.5) mag. A star with M(g)~15 mag, will have g~25 mag at 1 kpc, being above CSST-OS limit.

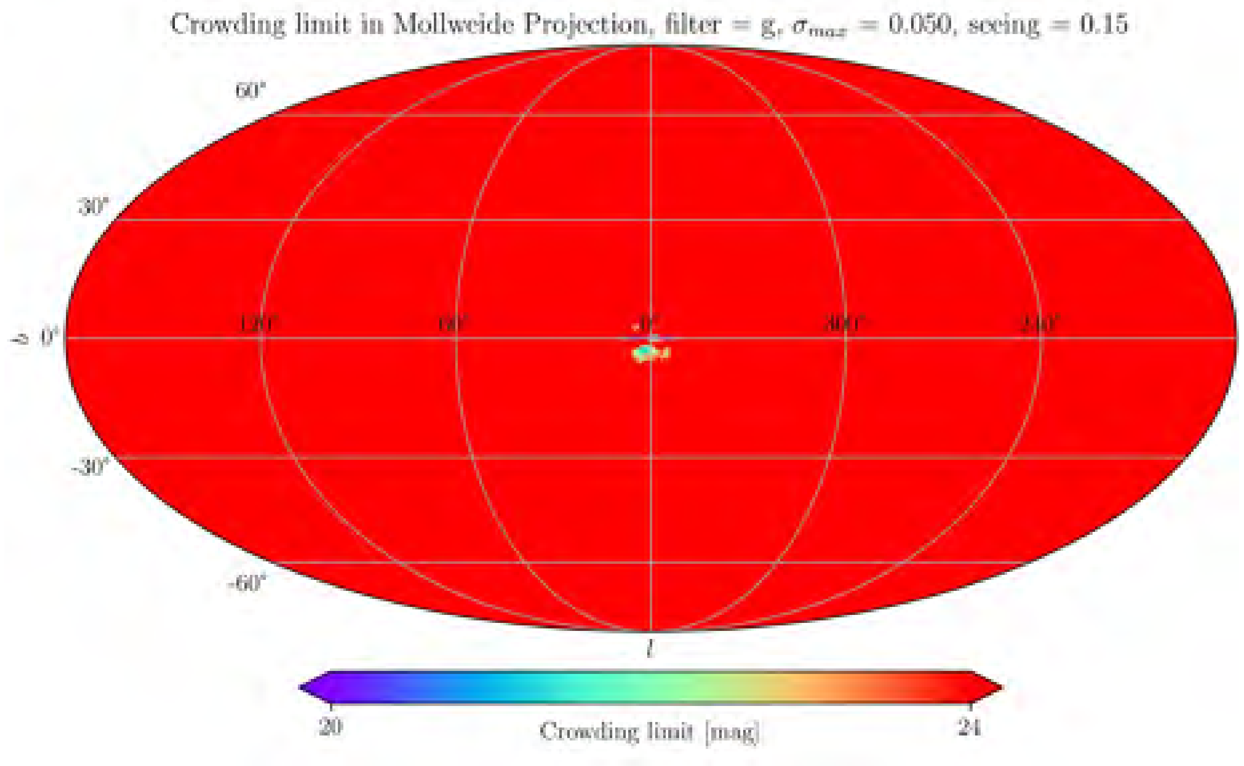
# TRILEGAL sim. of the anti-Gal. direction

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



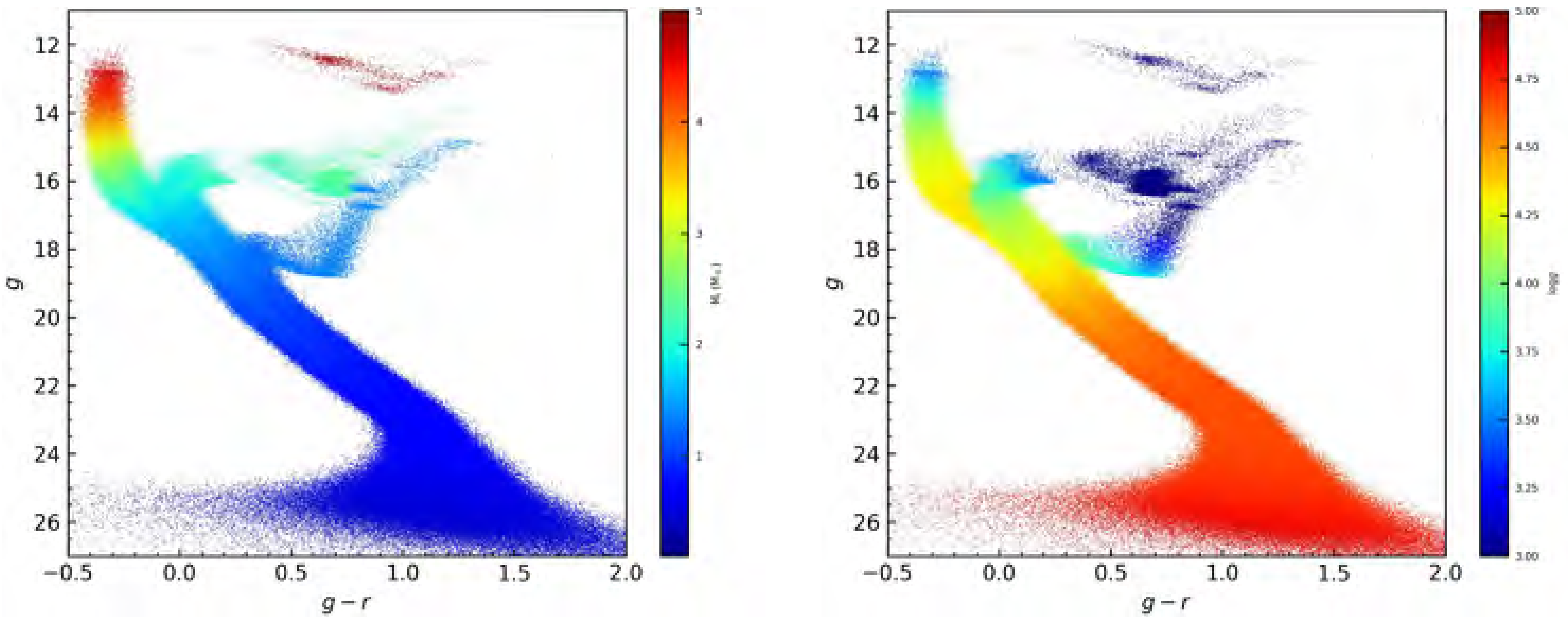
# TRILEGAL sim.: crowding limit analysis




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



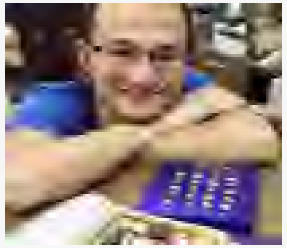

Simulated star clusters of 0.12, 1 and 4.5 Gyr with errors included.

# 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

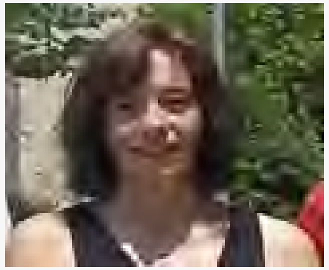
TRILEGAL:
Active coding people

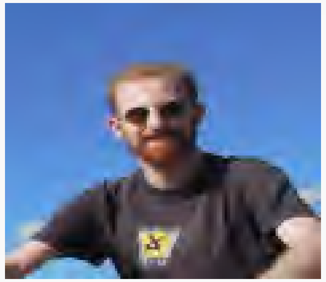

Léo Girardi


Yang Chen


Giada Pastorelli


Piero Dal Tio


Paola Marigo


Michele Trabucchi


Alessandro Mazzi

+

Collaborators: Bressan A., Xiaoting Fu, Costa G., etc.

+

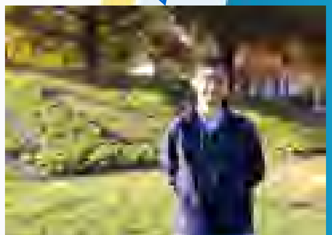
External collaborators: LSST, UW, STScI, SDSS, etc.

CSST MW TRILEGAL Sim.:

Initiates: Xiaoting Fu., Yang Chen, Chao Liu, etc.

+

TRILEGAL people



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谢谢！