What will Gaia do for the disk?

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Gaia in a nutshell

- high accuracy astrometry (parallaxes, proper motions)
- radial velocities, optical spectrophotometry
- 5D (some 6D) phase space survey
- all sky survey to G=20 (1 billion objects)
- formation, structure and evolution of the Galaxy
- ESA mission for launch in late 2011

Gaia capabilities

	Hipparcos	Gaia
Magnitude limit	12.4	G = 20.0
No. sources	120 000	1 000 000 000
quasars	0	1 million
galaxies	0	10 million
Astrometric accuracy	~ 1000 μas	12-25 μas at G=15
		100-300 μas at G=20
Photometry	2 bands	spectra 330-1000 nm
Radial velocities	none	1-10 km/s to G=17
Target selection	input catalogue	real-time onboard selection

How the accuracy varies

- astrometric errors dominated by photon statistics
  - parallax error: $\sigma(\varpi) \sim 1/\sqrt{\text{flux}} \sim$ distance, d for fixed M_V
  - fractional parallax error: $\sigma(\varpi)/\varpi \sim d^2$
  - fractional distance error: fde $\sim d^2$
  - transverse velocity accuracy: $\sigma(v) \sim d^2$
- Example accuracy
  - K giant at 6 kpc (G=15): fde = 2%, $\sigma(v)$ = 1 km/s
  - G dwarf at 2 kpc (G=16.5): fde = 8%, $\sigma(v)$ = 0.4 km/s

Distance statistics

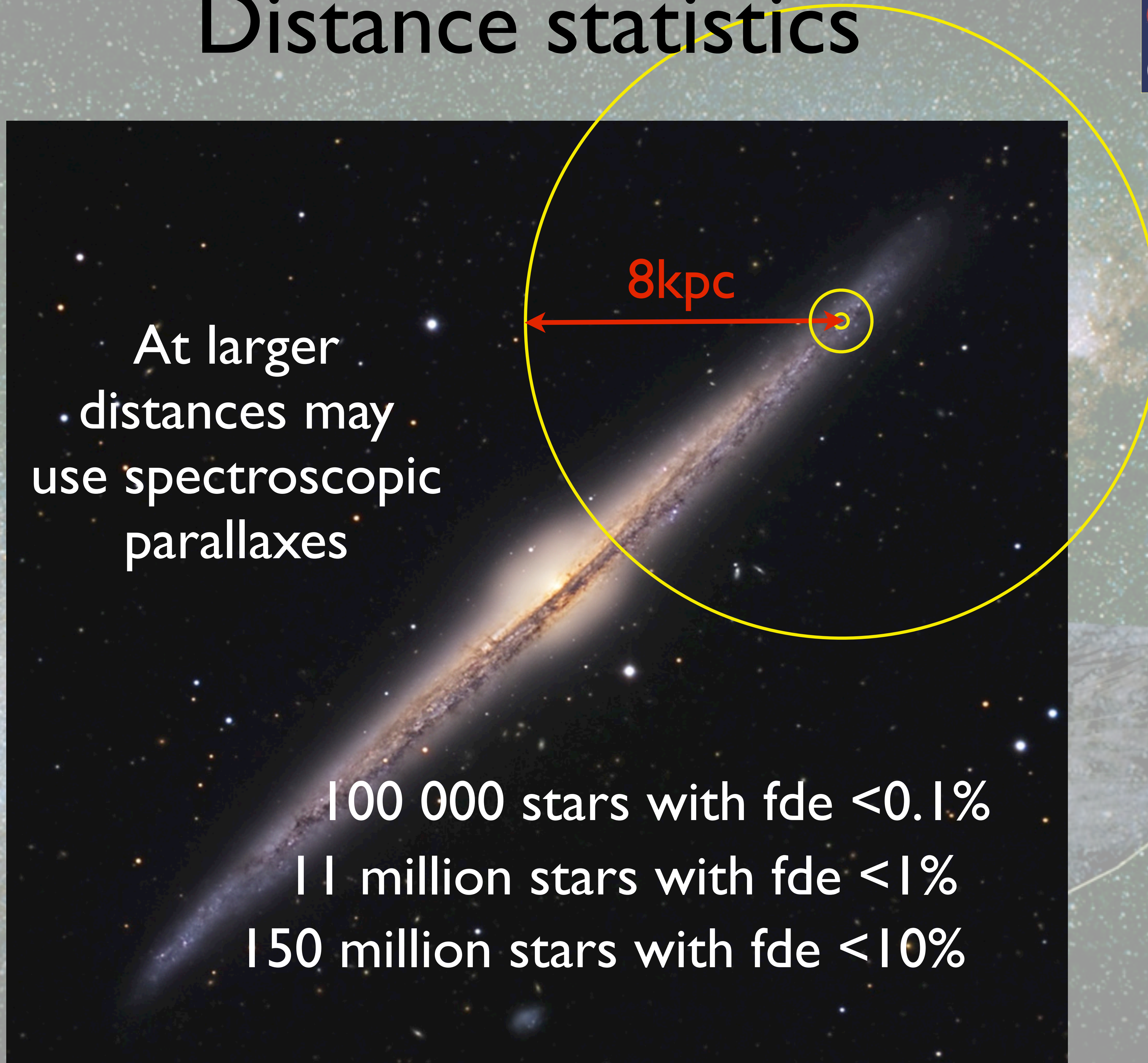
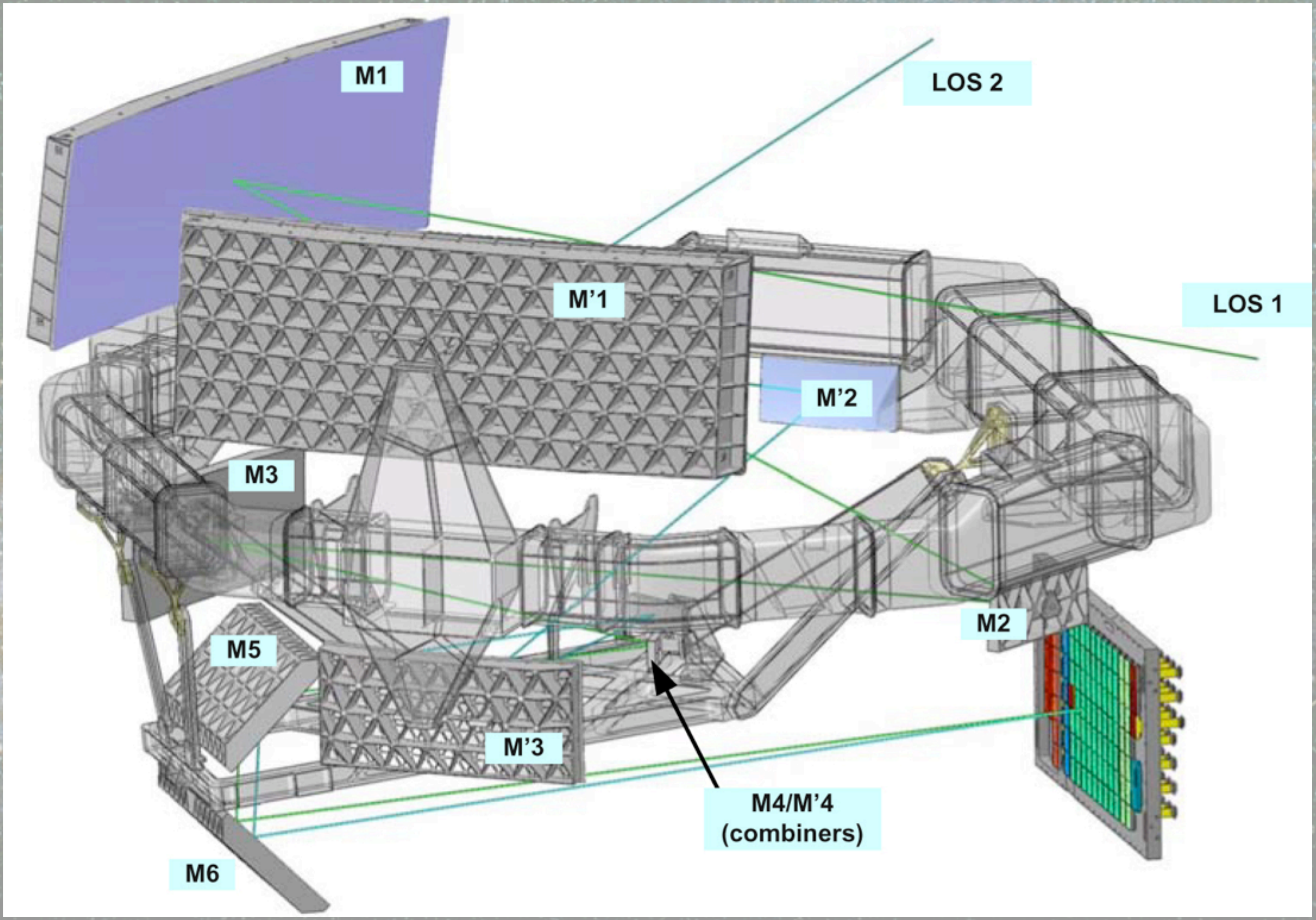


Image: NGC4565 from panther-observatory.com

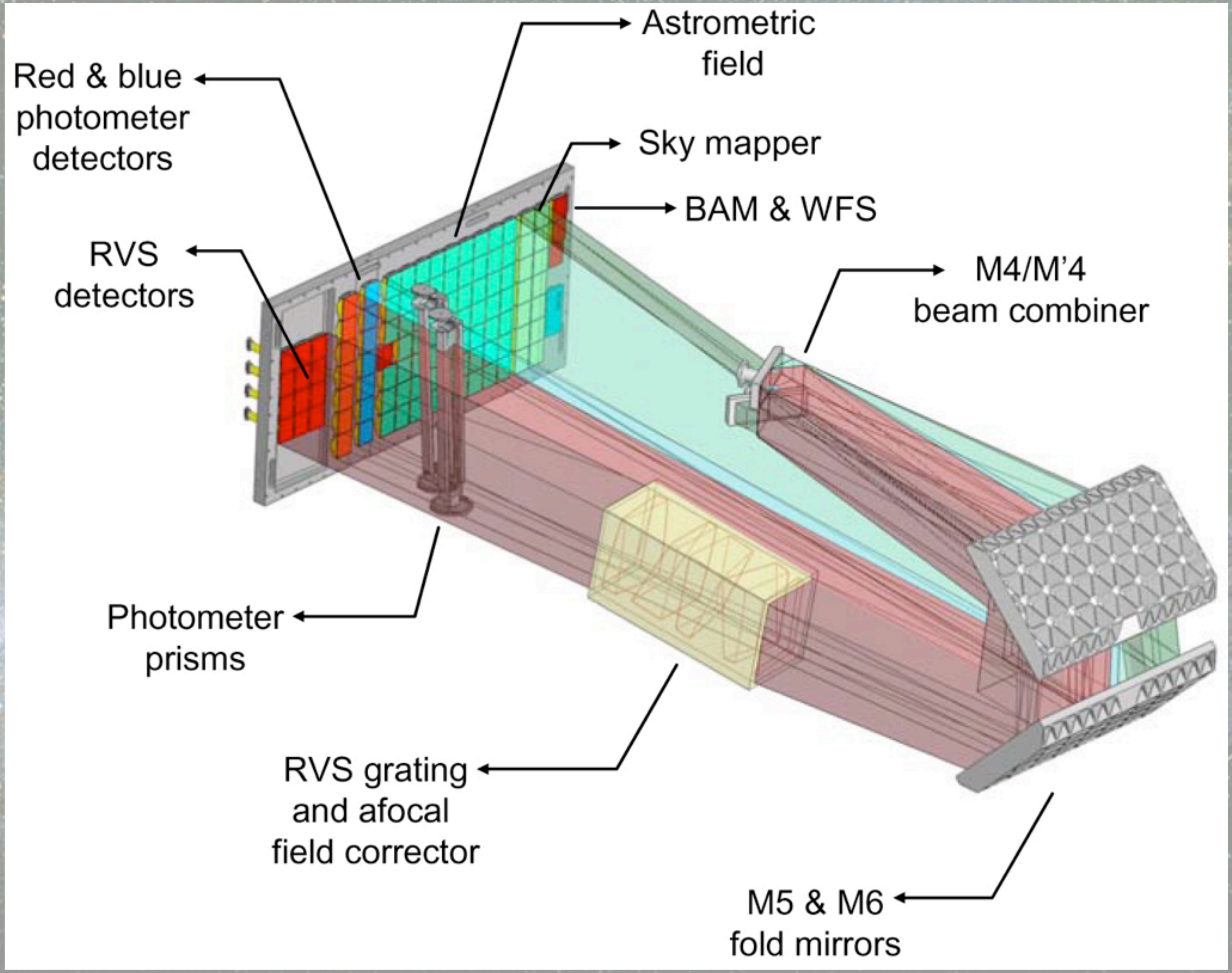
At larger distances may use spectroscopic parallaxes

100 000 stars with fde <0.1%
11 million stars with fde <1%
150 million stars with fde <10%

Payload overview

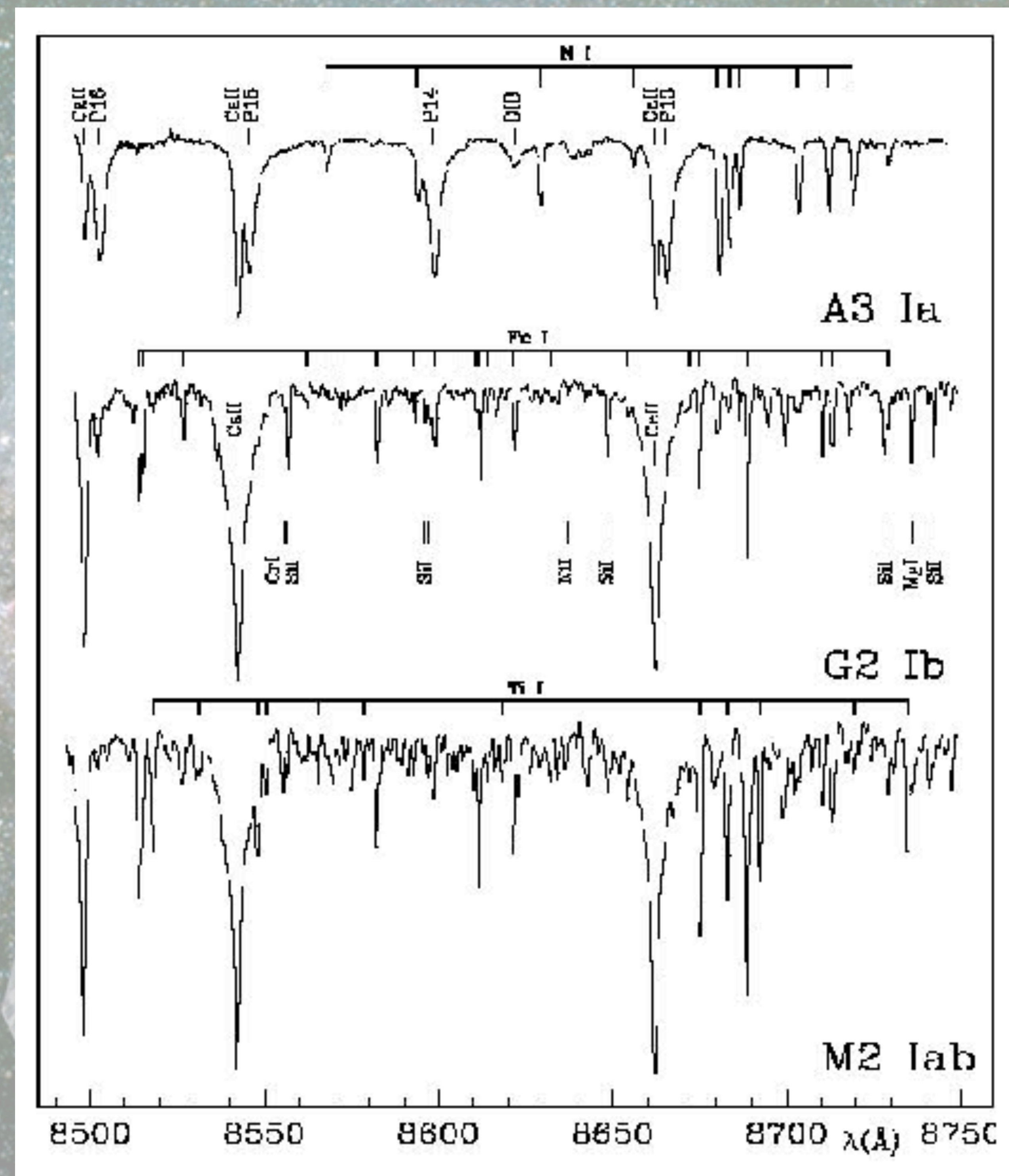


Instruments



Radial velocity spectrograph

- R=11 500
- CaII triplet (848-874 nm)
- more detailed APE for V < 14 (still millions of stars)



Spectrophotometry

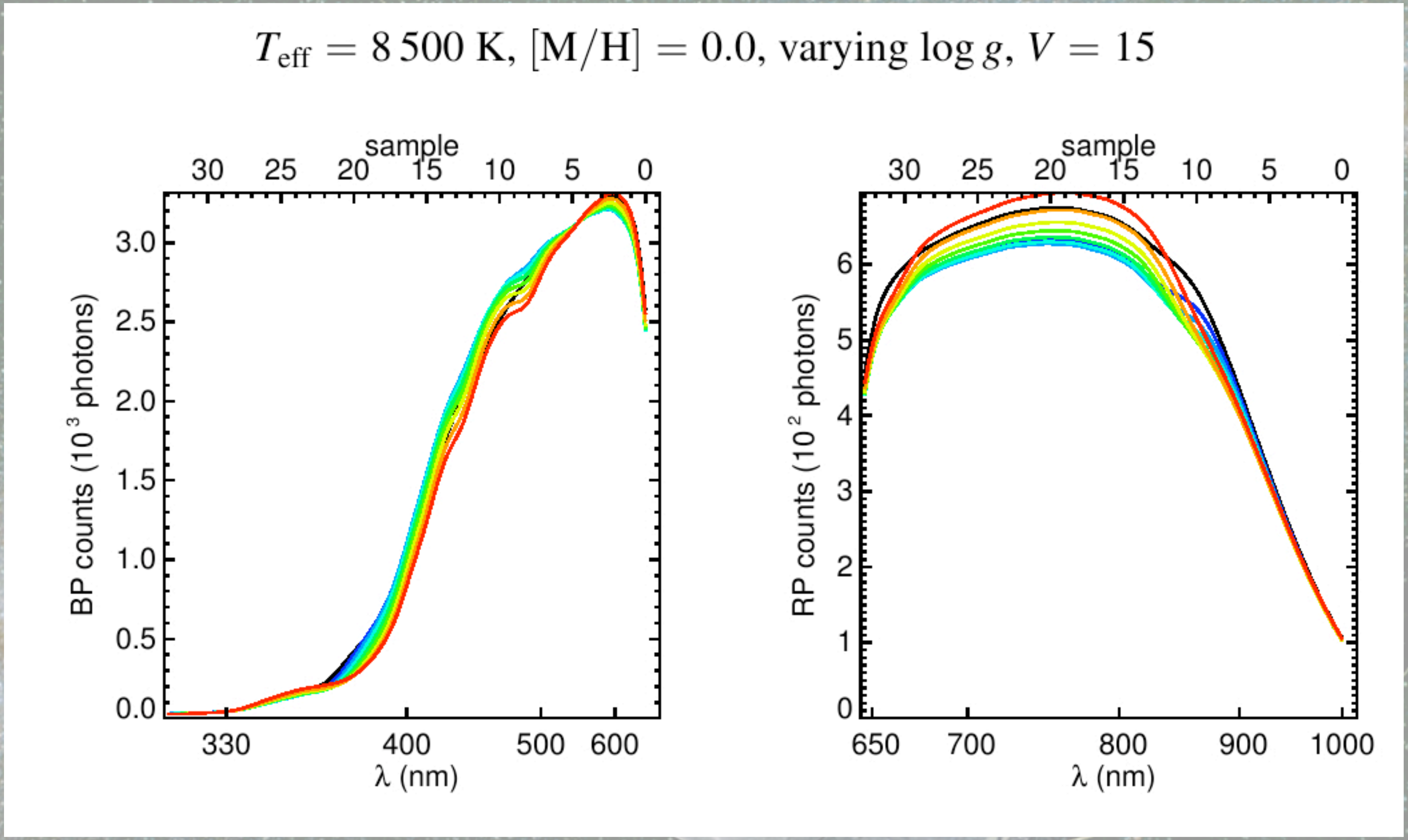


Figure: Anthony Brown

Dispersion: 7-15 nm/pixel (red), 4-32 nm/pixel (blue)

Stellar parameters

- Infer via pattern recognition (e.g. SVM)
- From BP/RP at G=15, RMS internal uncertainties:

Teff	1-5% for wide range of Teff
Av	0.05-0.1 mag for hot stars
[Fe/H]	<0.2 dex for cool stars (SpT>F) down to -2.0 dex
logg	0.1-0.4 dex, <0.1 dex for hot stars (SpT≤A)

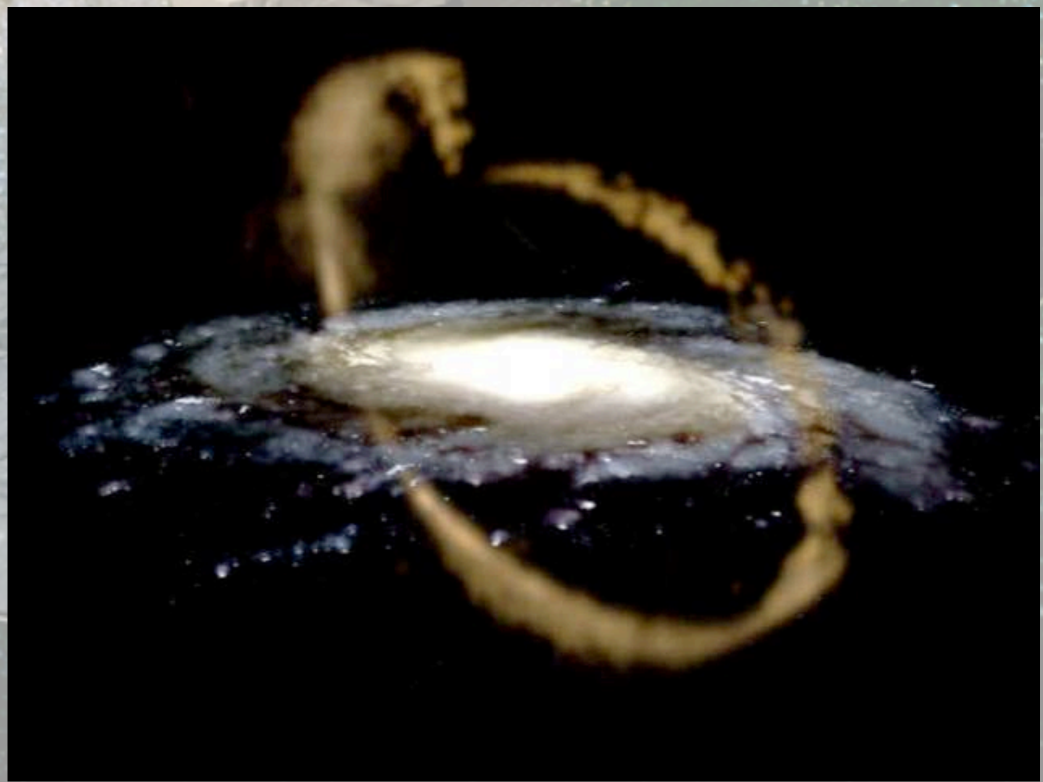
- calibration: input physics and synthetic spectra

Disk structure

- current uncertainties
  - thin disk scale height estimates: 200-330 pc
  - thin disk scale length estimates: 2-4 kpc
  - vertex deviation, vertical tilt not well known
  - velocity ellipsoids currently based on small samples
- Gaia will give
  - 3D spatial maps
  - transverse velocities accurate to <1 km/s for ~ 50 million stars out to a few kpc

Disk structure & formation

- search for merger debris (Monoceros, Sagittarius, ...)
  - substructure in phase space
- map dark matter distribution
  - compare luminous distribution with gravitational potential



Figures: HST; David Martinez-Delgado (MPIA) & Gabriel Perez (IAC)

Stellar clusters

- about 70 clusters and SFRs within 500 pc
  - *individual* distances to 0.5-1% at G=15 (K3 V)
  - *individual* transverse velocity accuracy to < 50 m/s at G=15
  - ages from MSTO fitting
  - examine mass segregation, cluster dispersion
  - saturation limit is G=6
- confirm new (refute old) clusters
- use as abundance tracers in disk out to tens of kpc

Spiral structure

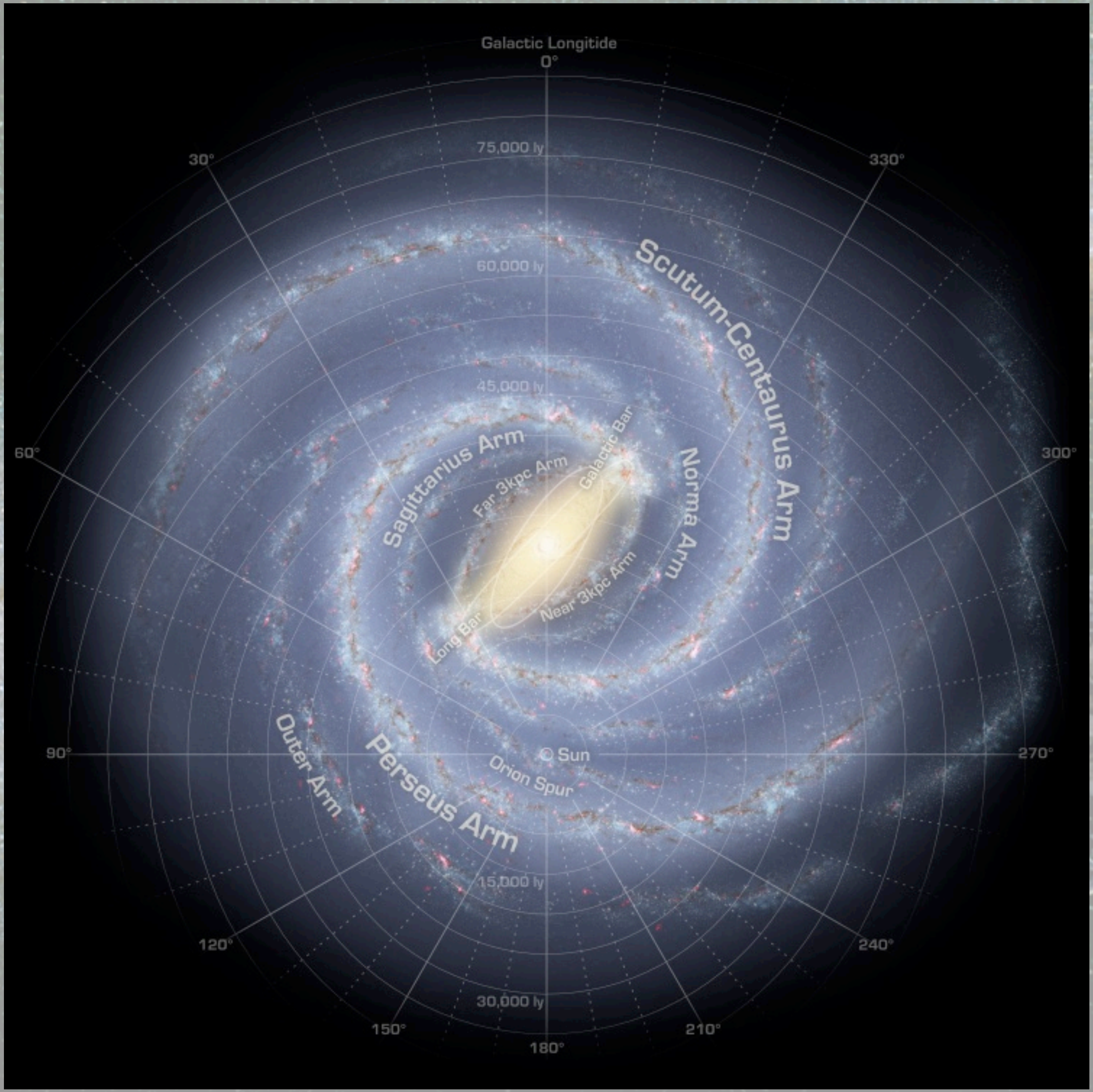


Image: R. Hurt, Spitzer Science Center (GLIMPSE survey)

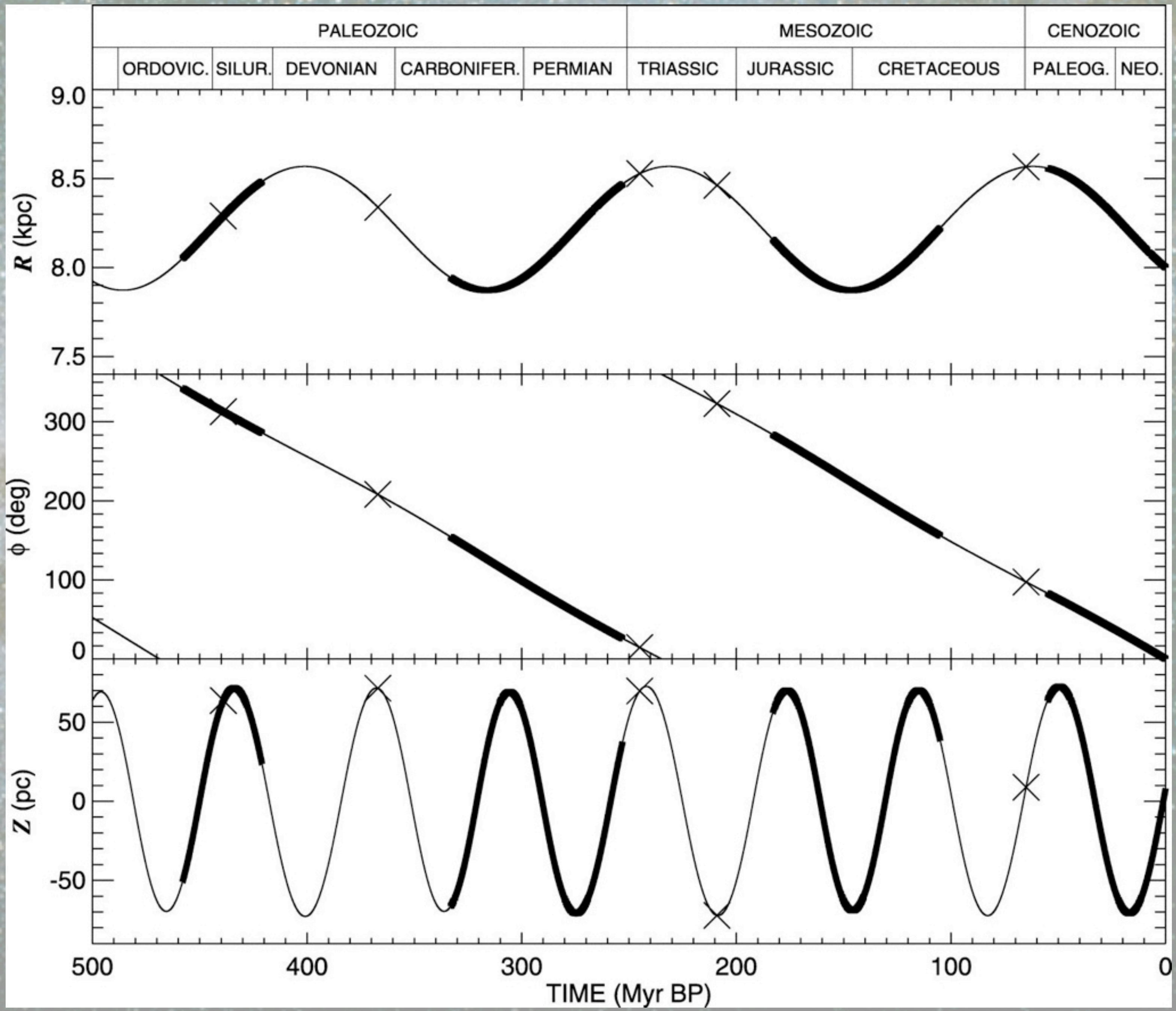
Spiral structure

- map local spiral structure in 3D
  - without assuming M-L relation or extinction
- 3D velocities without assuming rotation curve
- OB star with M_V = -2.5 at d=5kpc with 4 mags extinction (G=15)
  - fractional distance error of 13%
  - transverse velocity error of ~ 1km/s
  - radial velocity error of a few km/s
  - ~ 50 000 OB stars

Ice ages and mass extinctions

Passage of Sun through the Galaxy reconstructed from Hipparcos

thick portions: ice ages
crosses: major extinctions

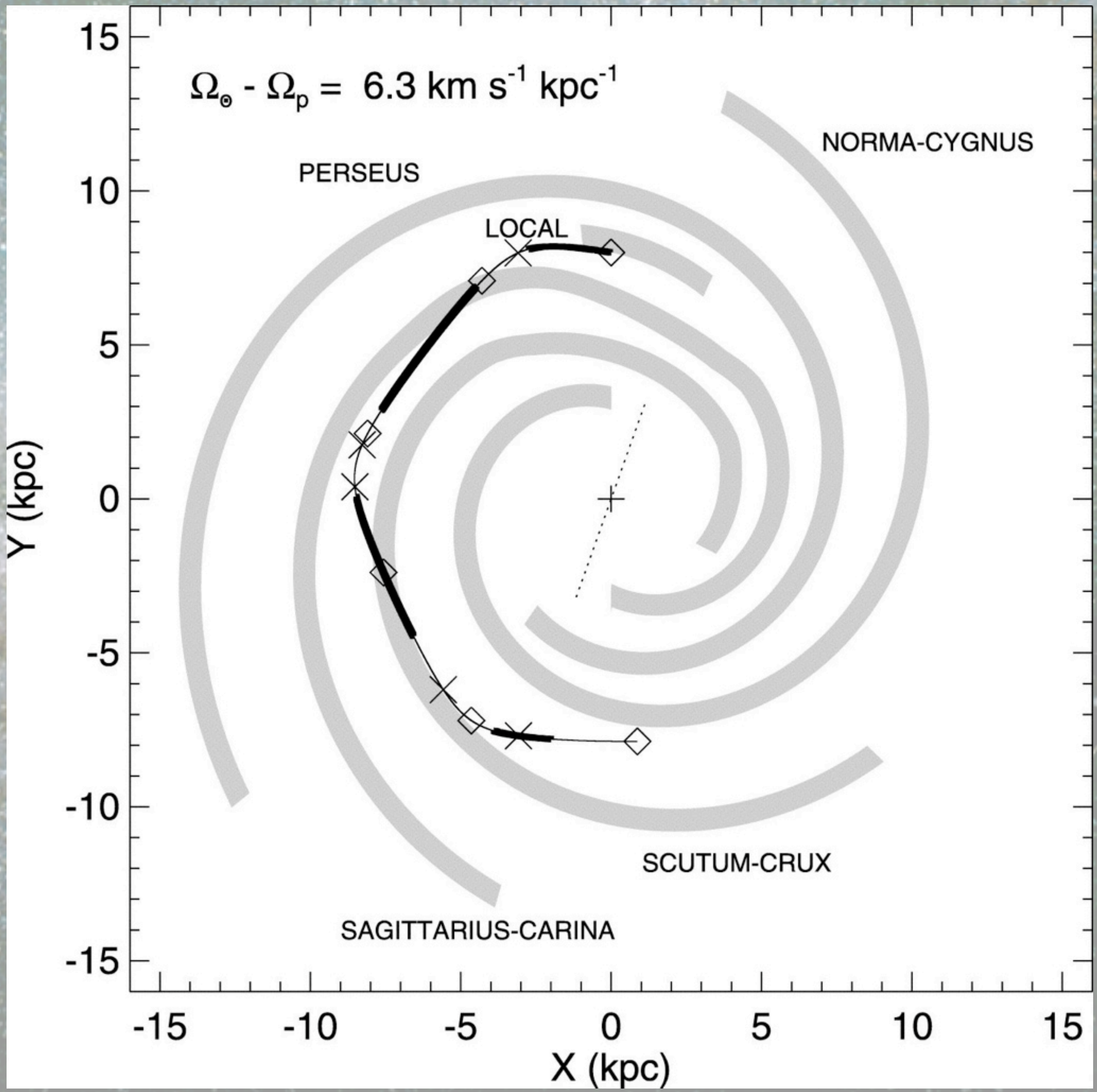


Gies & Helsel (2005)

Ice ages and mass extinctions

Passage of Sun through the spiral arms

thick portions: ice ages
crosses: major extinctions
diamonds: 100 Myr markers



Gies & Helsel (2005)

Mass-luminosity relation

M-L relation to be calibrated by Gaia across a wide range of masses with a large sample of binaries

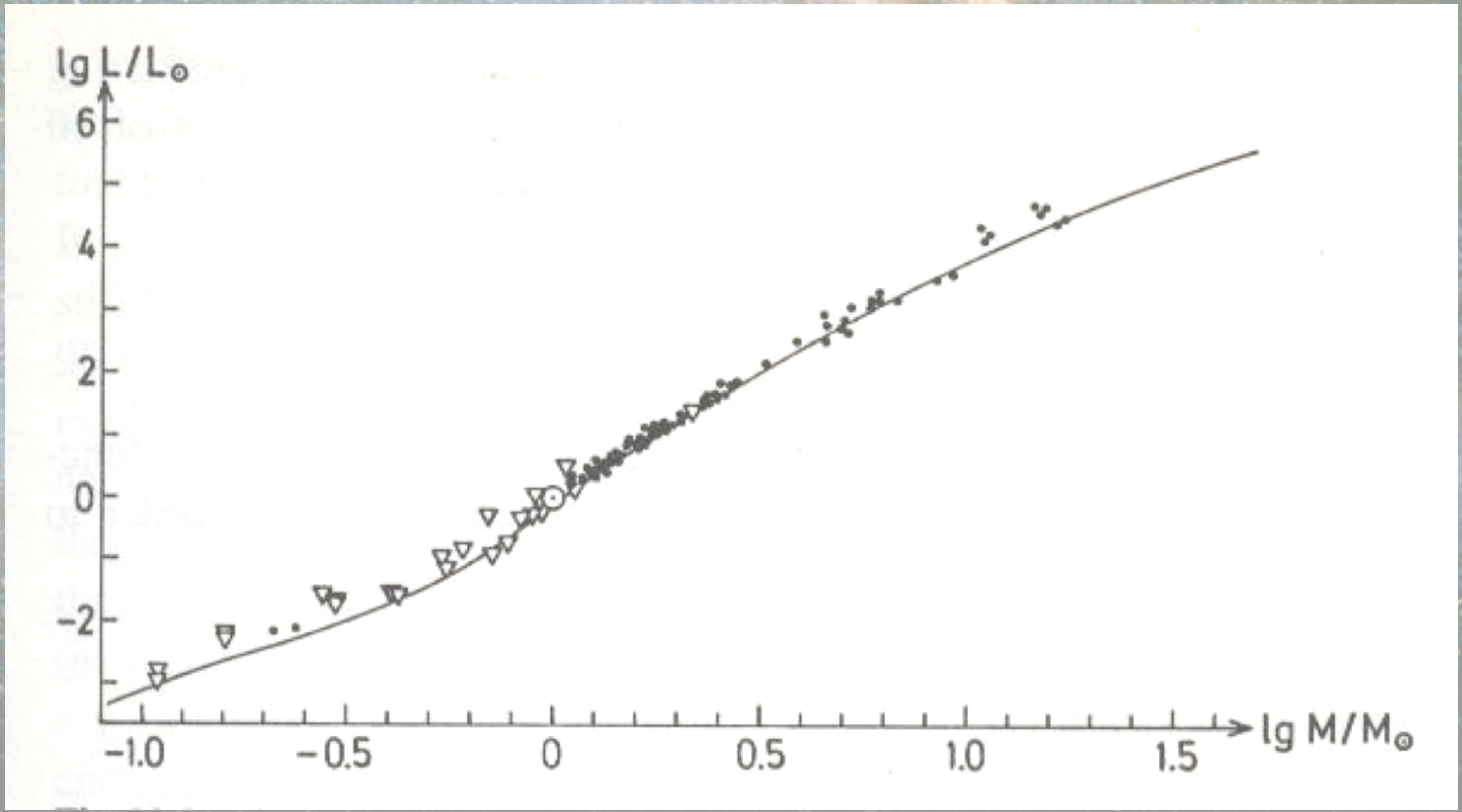


Figure: Kippenhahn & Weigert (1990)

Mass-Luminosity relation

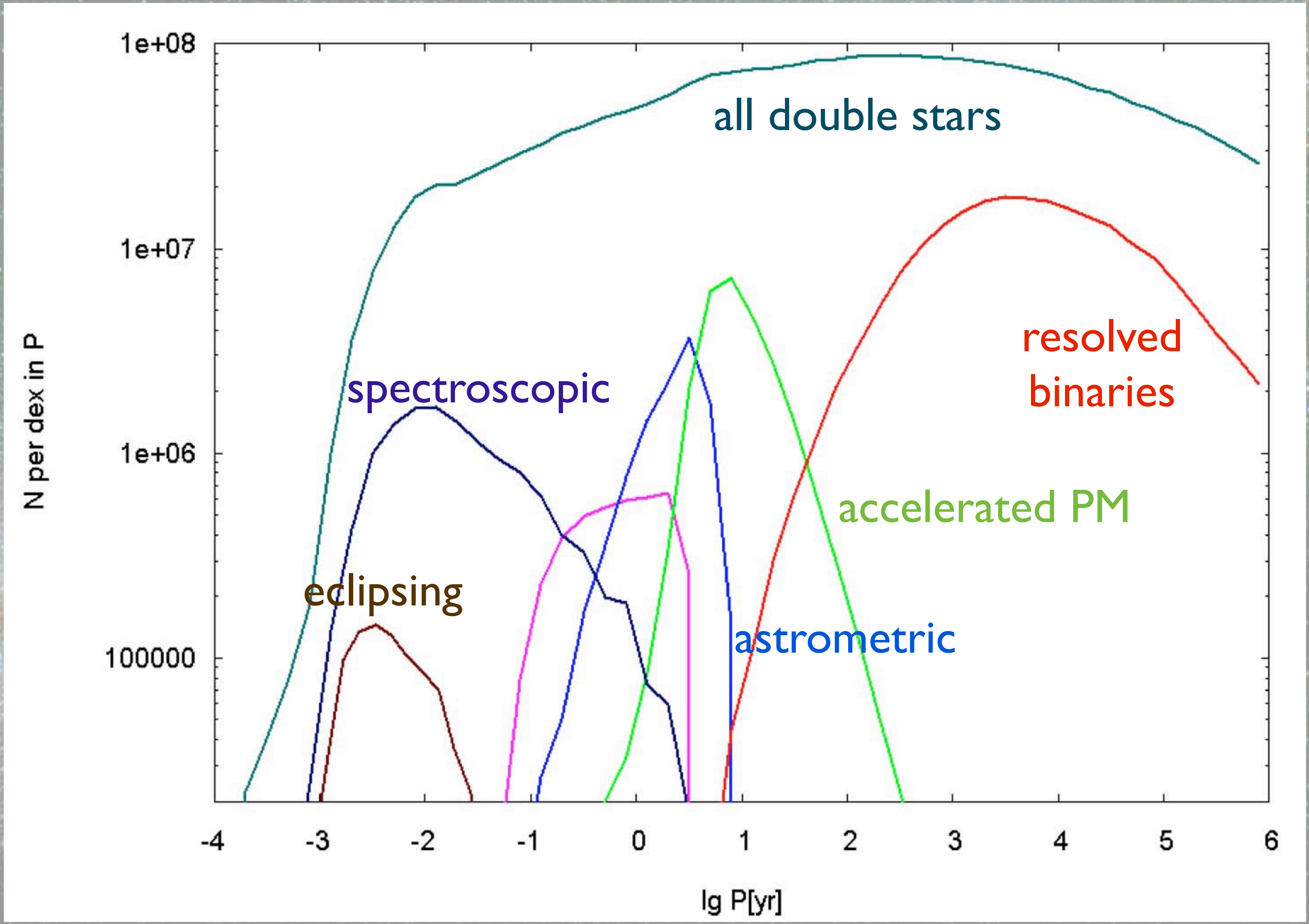


Figure: Arenou & Söderhjelm (2005)

Initial mass function

- LF ➠ (I)MF
  - universal?
  - metallicity dependent?
  - time variable?

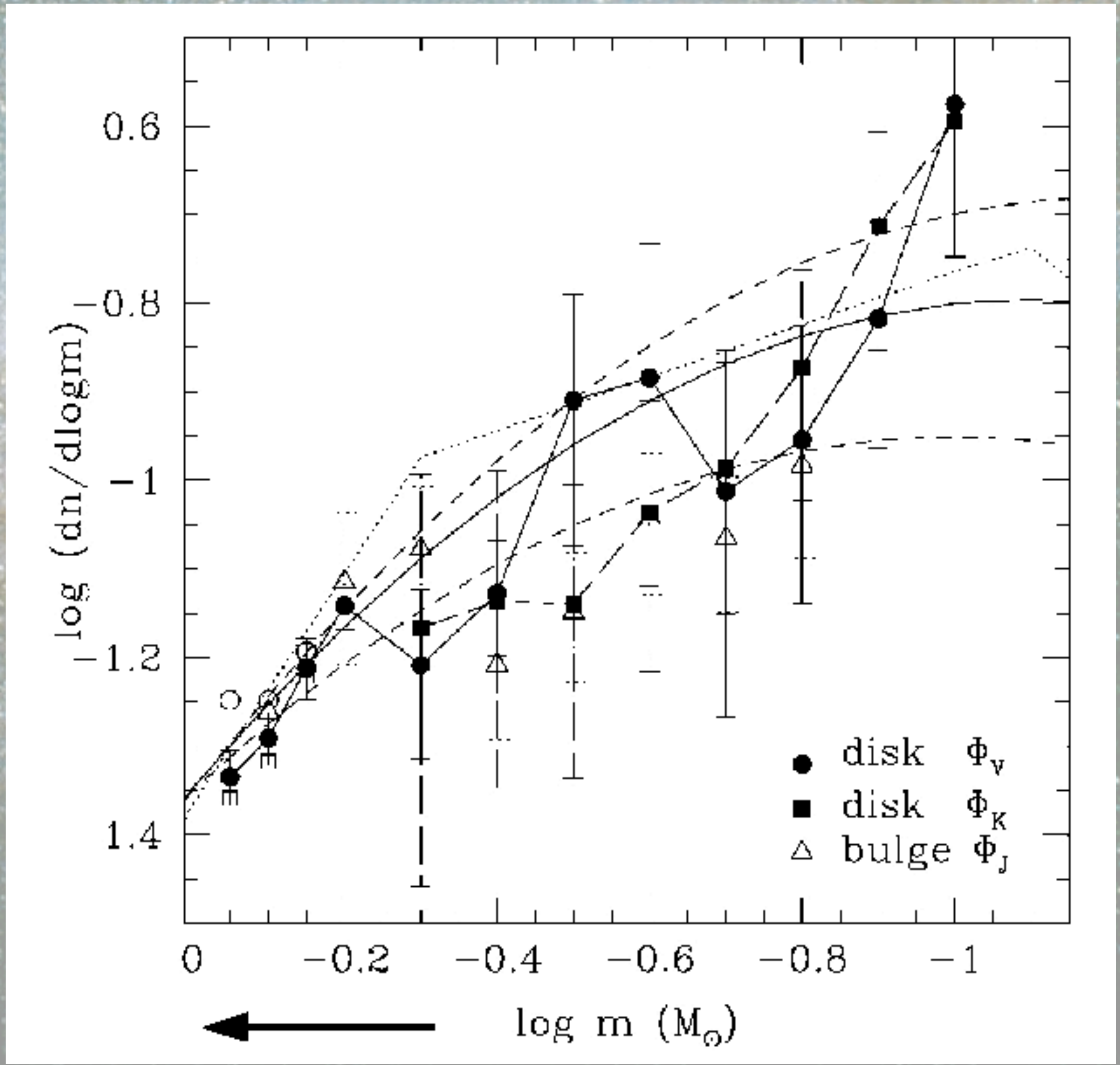


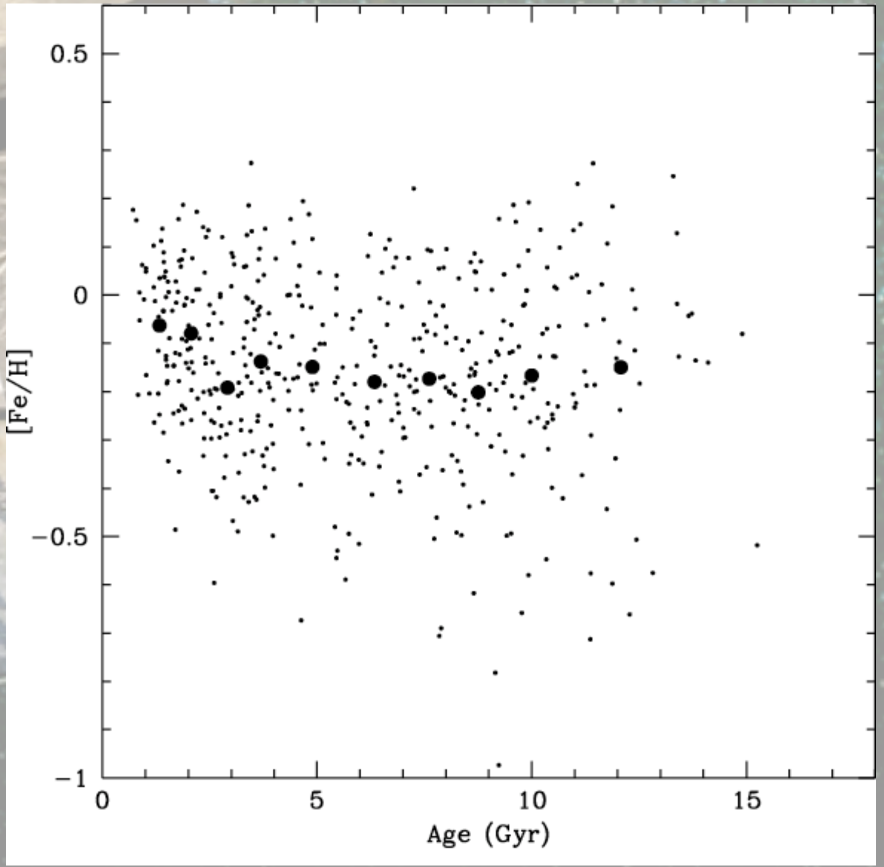
Figure: Chabrier et al. (2003)

solid line:
empirical log normal

dotted line:
four-component power law

age-velocity-metallicity relation

- velocity dispersion appears to increase with age
  - GMC scattering, spiral arm perturbation, dark matter, ...
- small decrease in mean metallicity with age, but a large scatter (Nordström et al. 2004)
- Gaia contribution
  - 2D or 3D velocities on a large sample
  - improve ages (stellar luminosities)
  - [Fe/H] for large sample



Summary

- strength is in accuracy *and* statistics
  - 150 million stars with fde < 10% out to 8kpc
  - fde of 1-2% at 1 kpc for G=15
- Gaia will have well-defined selection biases
- impact on many fields of Galactic structure; in the disk:
  - LF; M-L relation (binares); disk shape and structure; substructure (mergers); open clusters; spiral structure; ...
- `http://gaia.esa.int`