Stellar and Substellar Astrophysics with IRTF in the era of *Gaia*, LSST, and *TESS*

Andrew W. Mann
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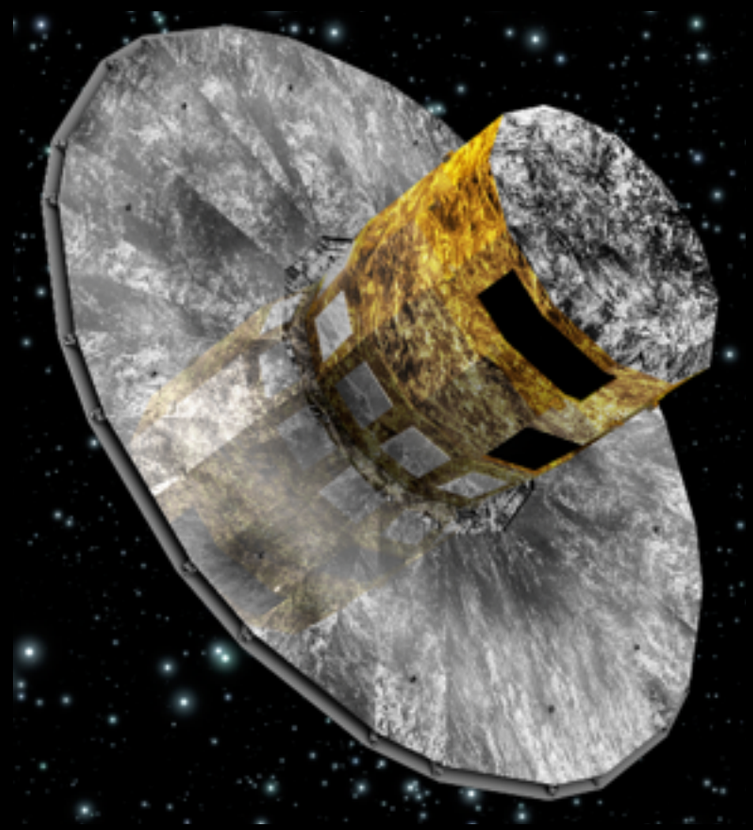
IRTF Future Directions Workshop
February 2018

image credit: Bill Keel

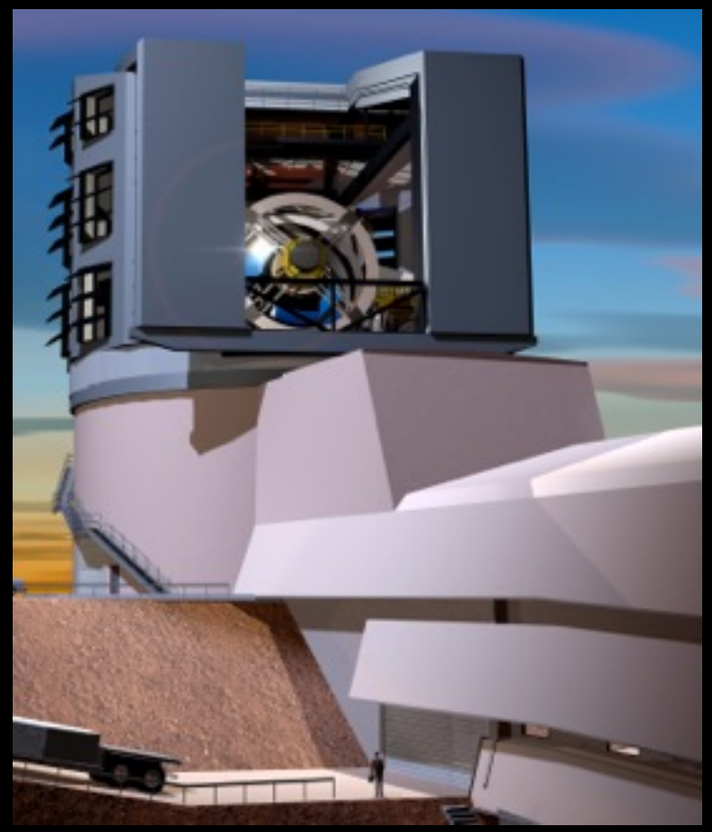
TESS



Gaia



LSST



Fundamental parameters of late-type stars and brown dwarfs

Mass

Radius

Luminosity

Metallicity

T_{eff}

Age

Fundamental relations, e.g., mass-luminosity EqW-metallicity luminosity-age color-teff

Empirical calibrators, e.g., eclipsing binaries

Fundamental parameters of late-type stars and brown dwarfs

Mass

Radius

Luminosity

Metallicity

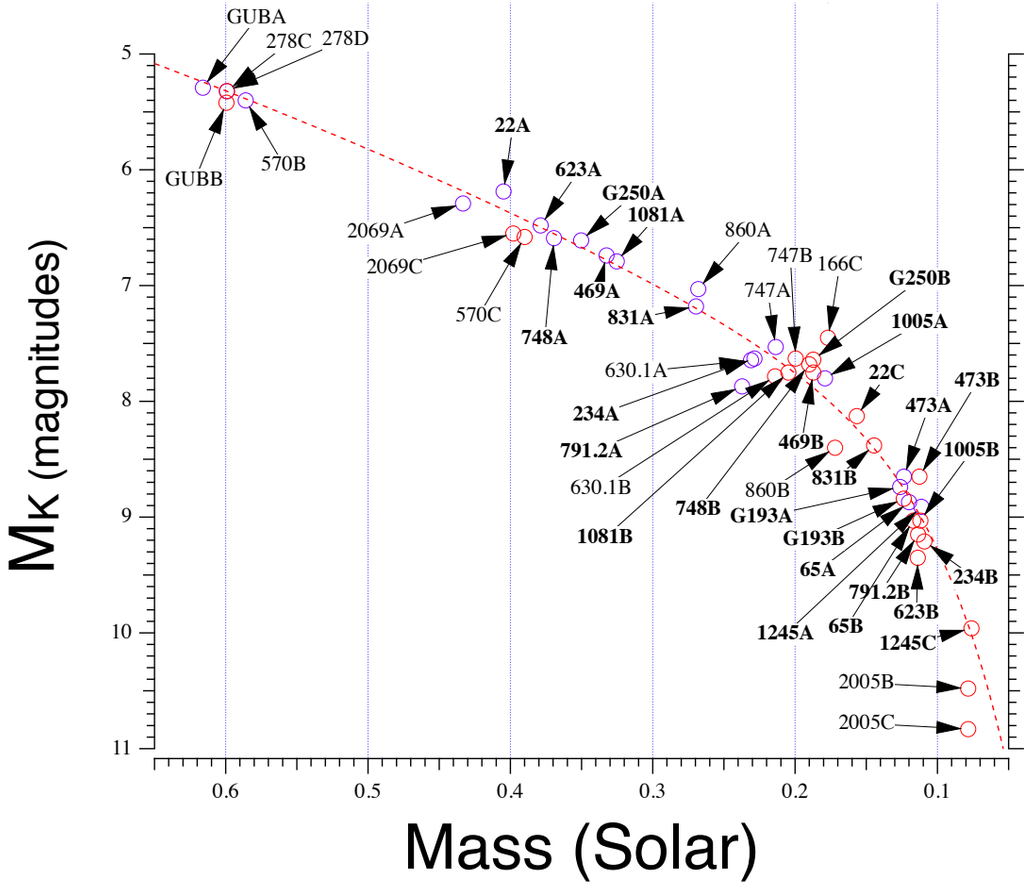
T_{eff}

Age

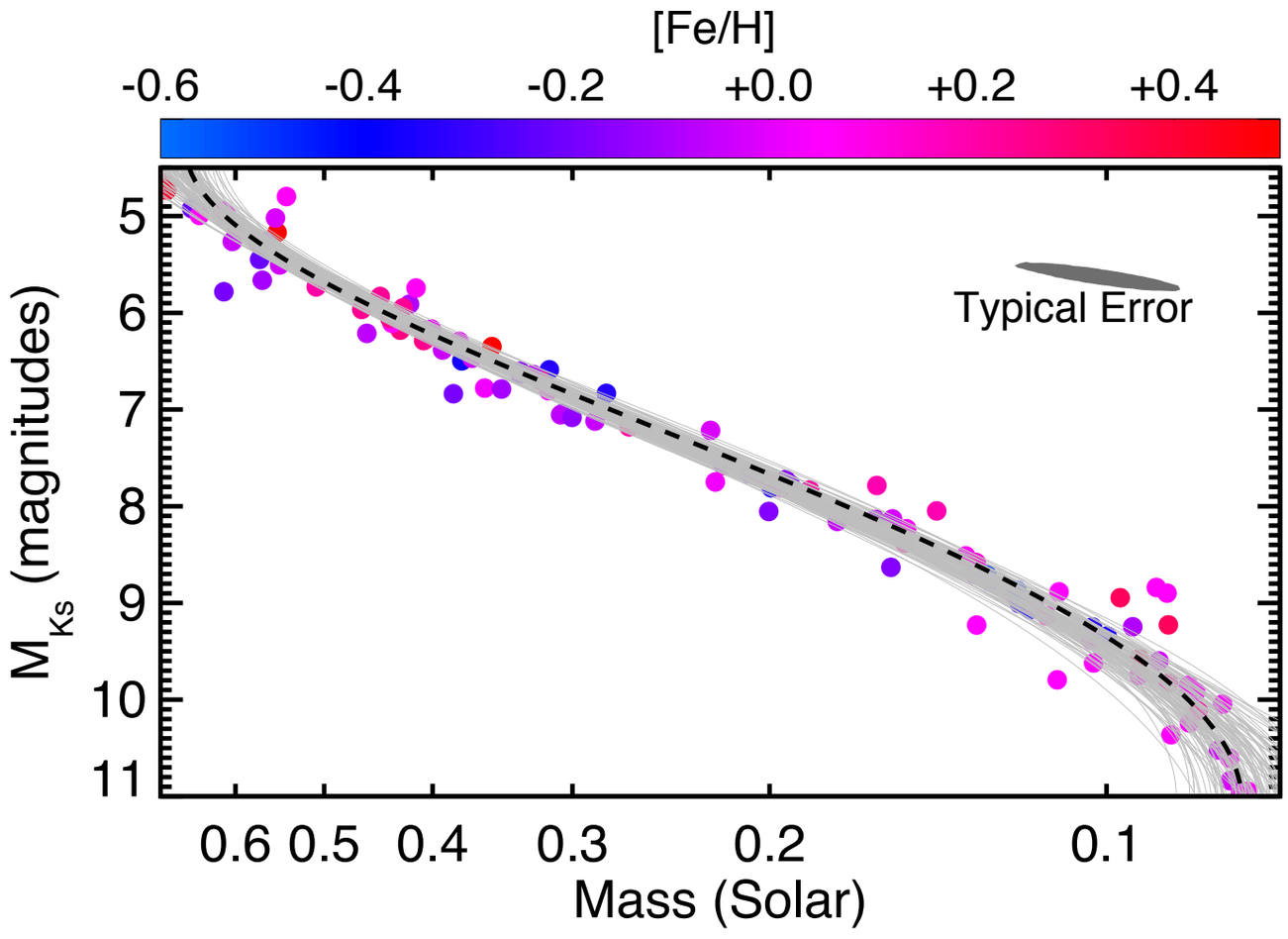
Fundamental relations, e.g., mass-luminosity

Empirical calibrators, e.g., astrometric binaries

The mass-luminosity relation

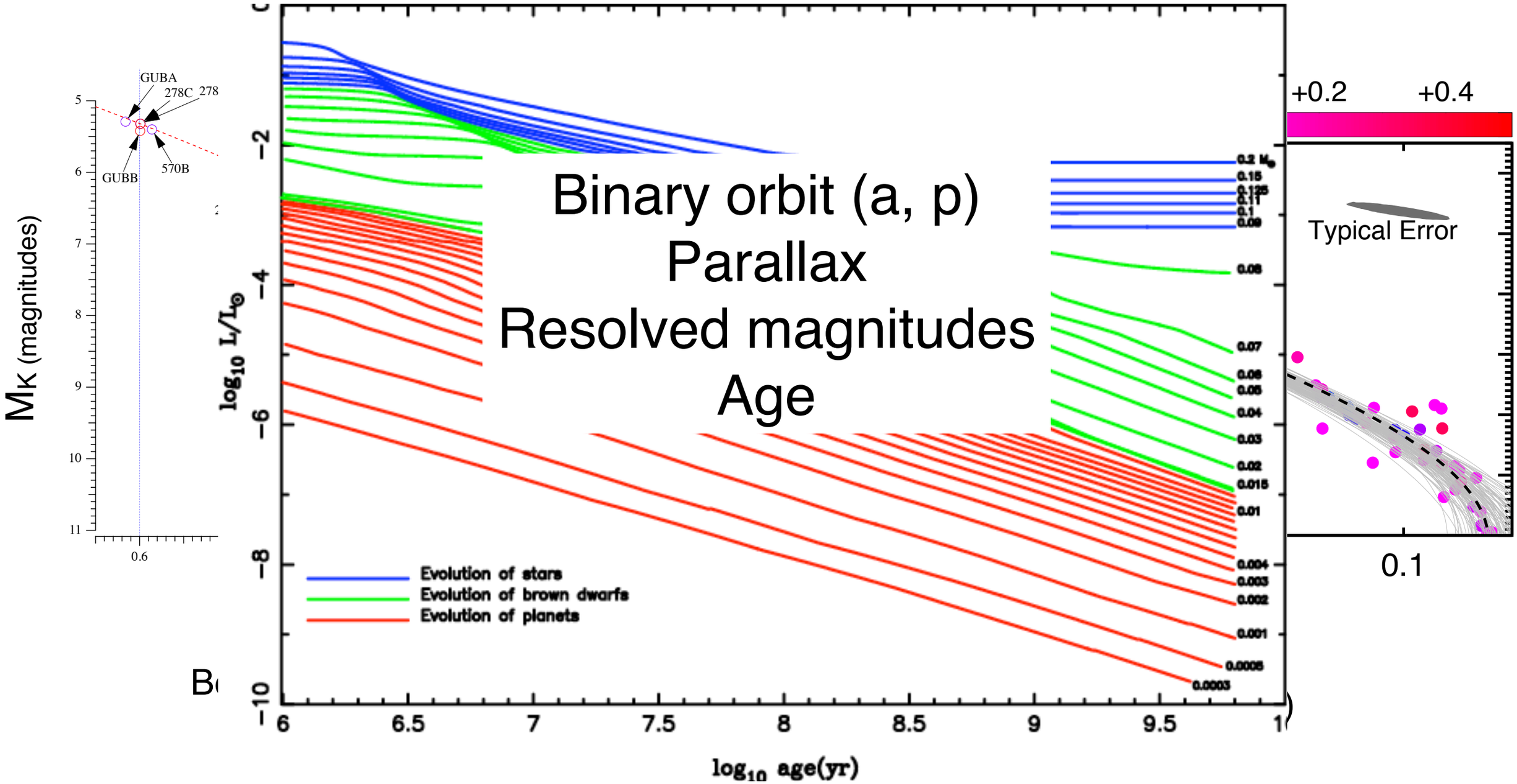


Benedict et al. (2016)



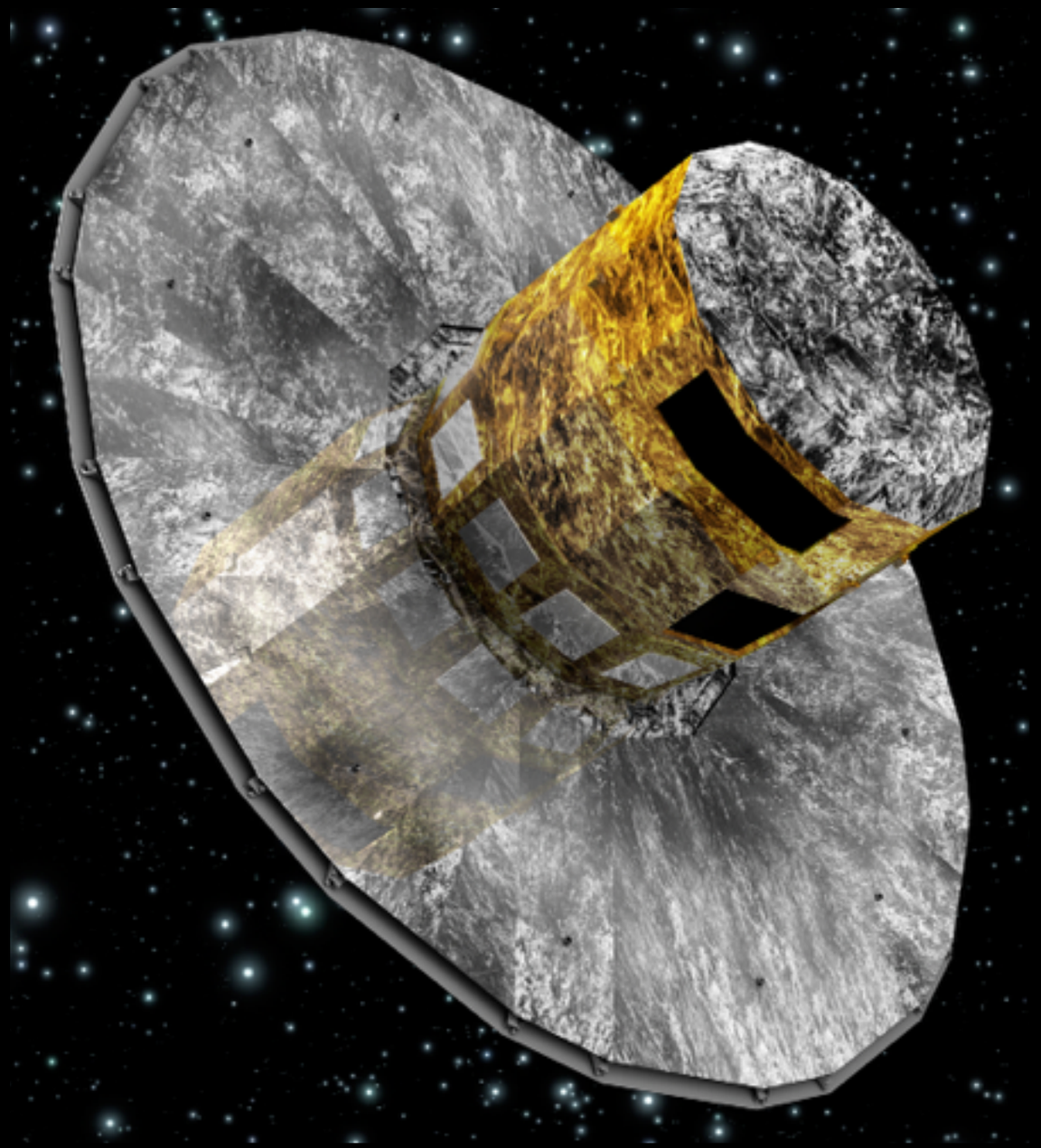
Mann et al. (in prep)

The mass-luminosity-age relation

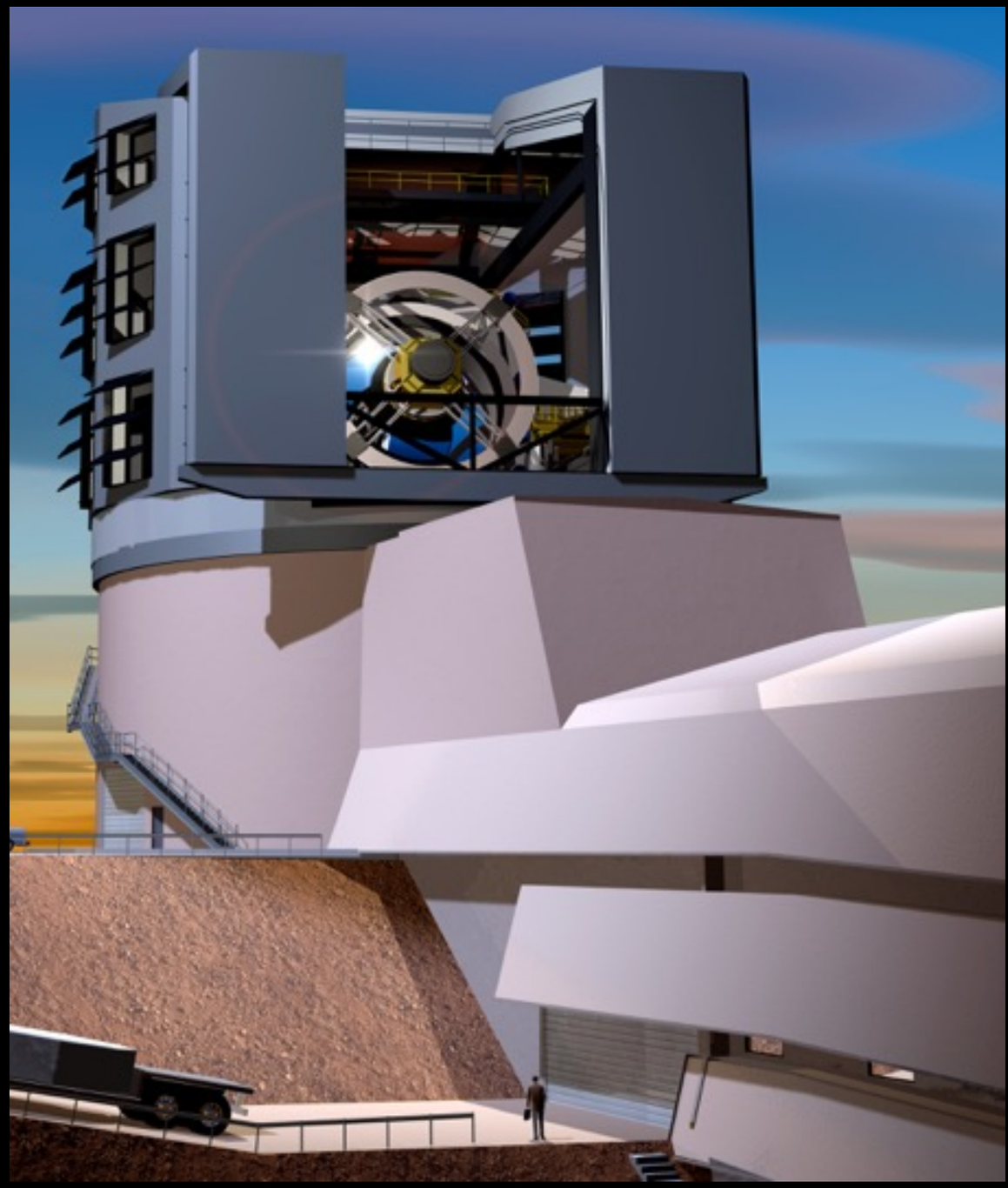


Burrows et al. (1997)

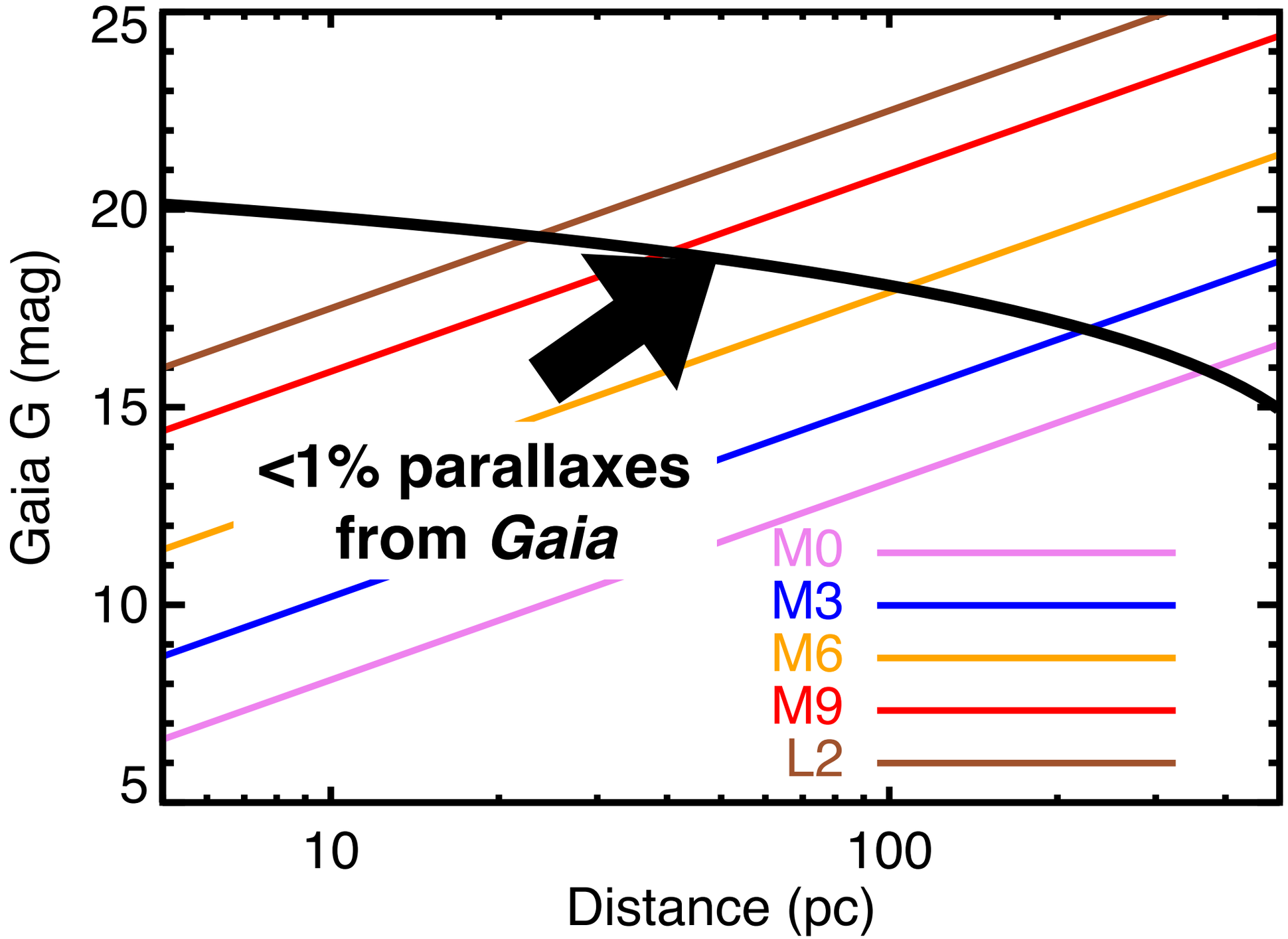
Gaia



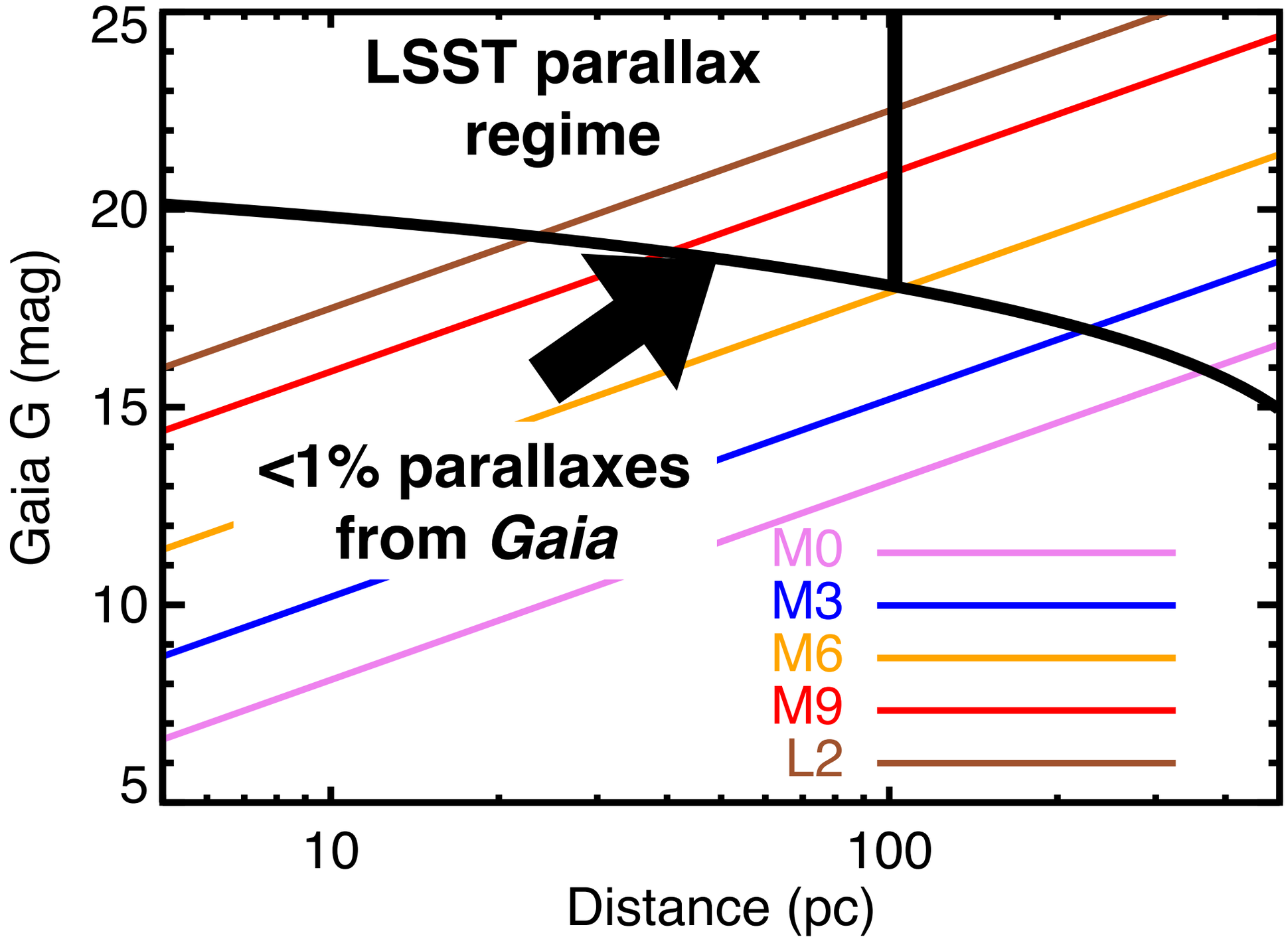
LSST



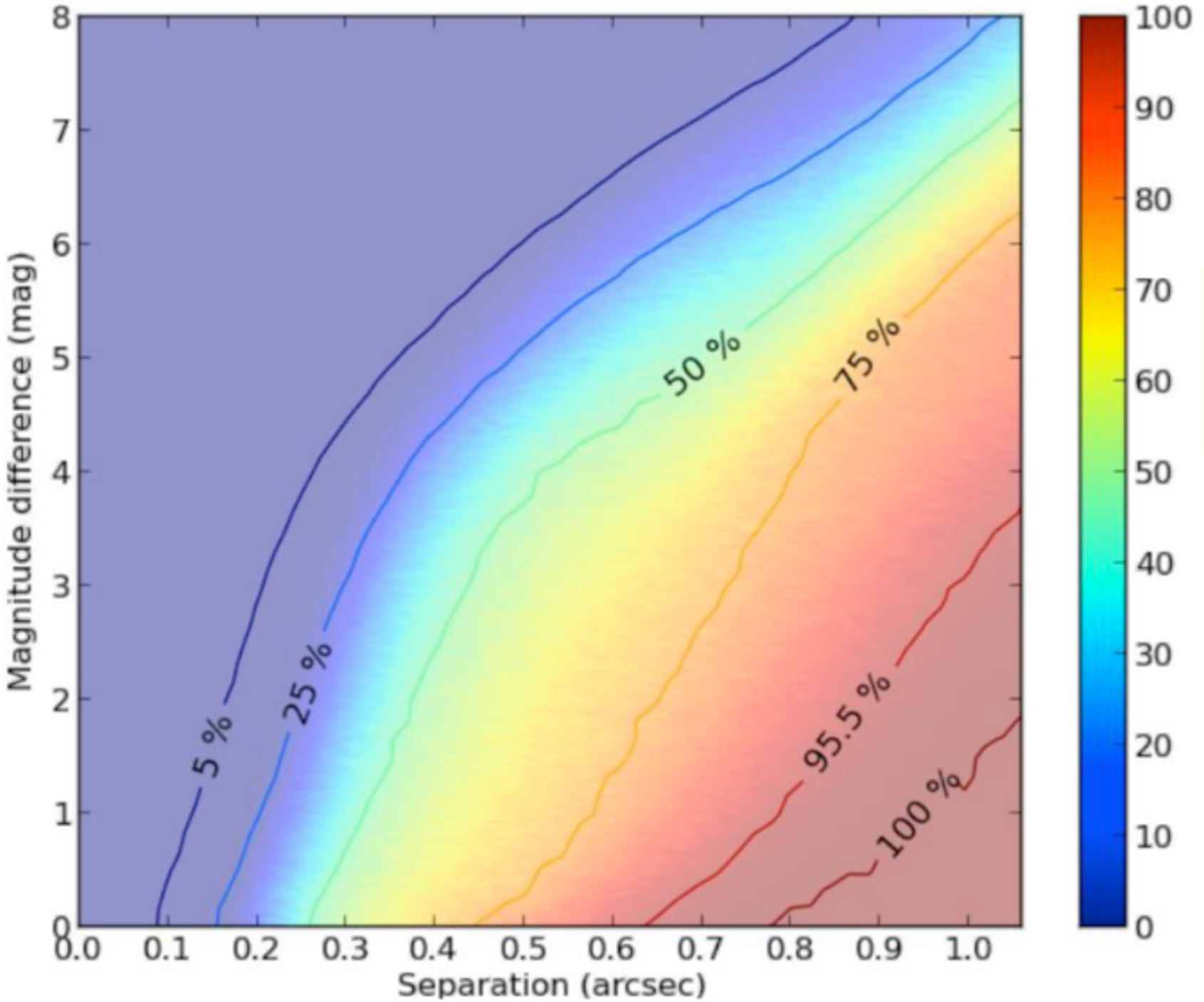
Parallaxes from *Gaia* and LSST



Parallaxes from *Gaia* and LSST

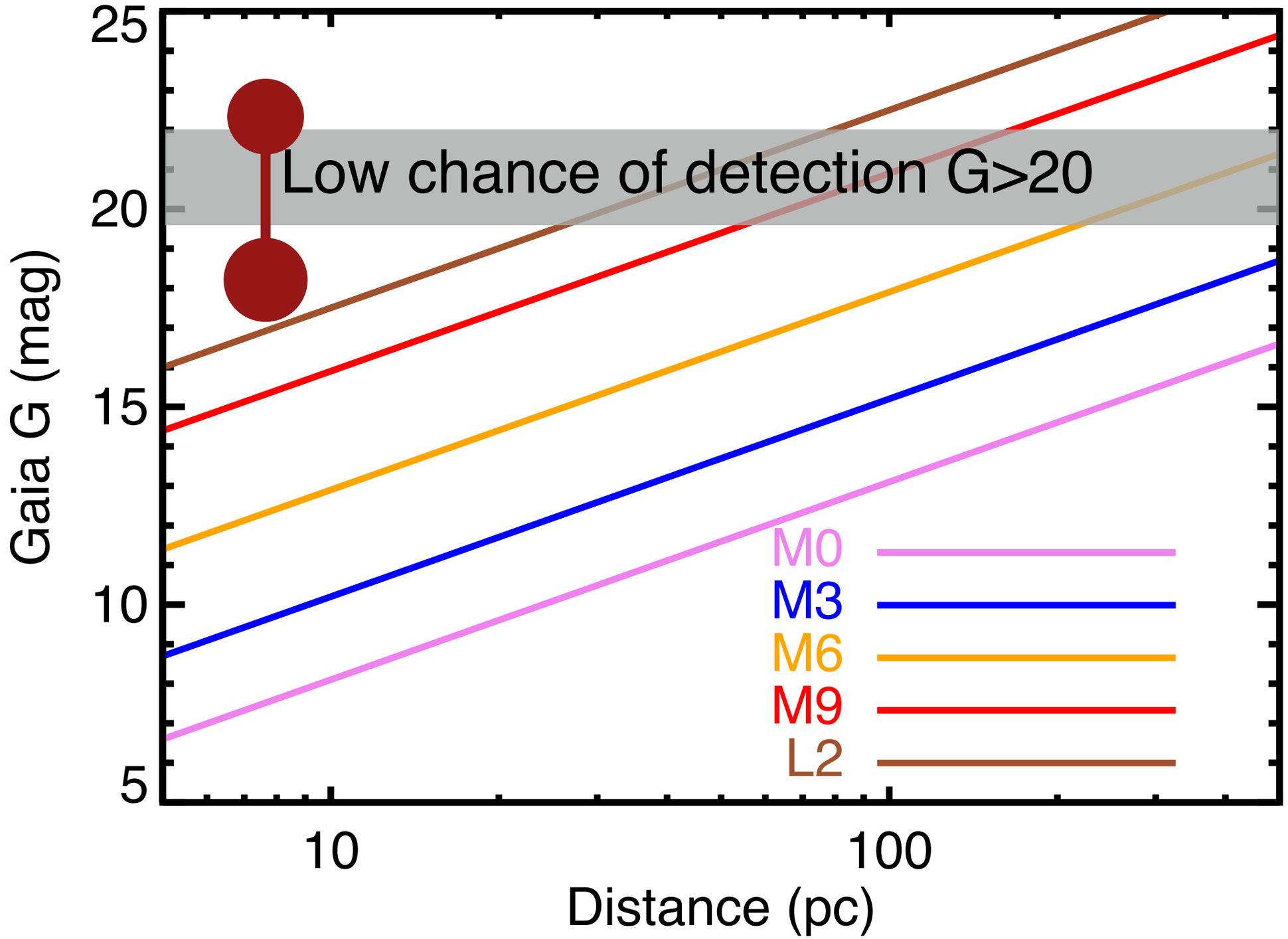


Gaia can resolve some binaries

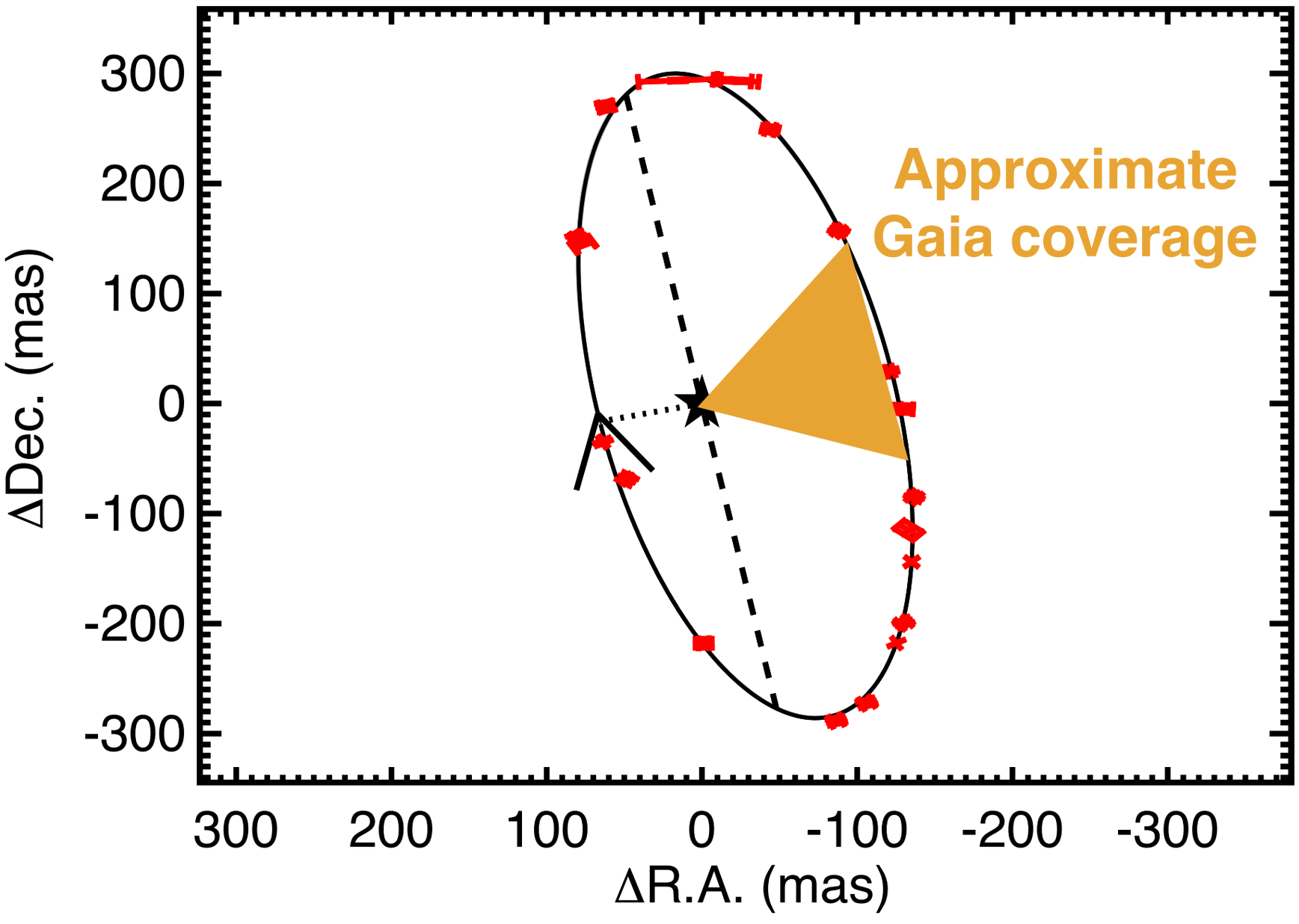


Courtesy Jos de Brujine

Gaia can't reach many brown dwarfs binaries

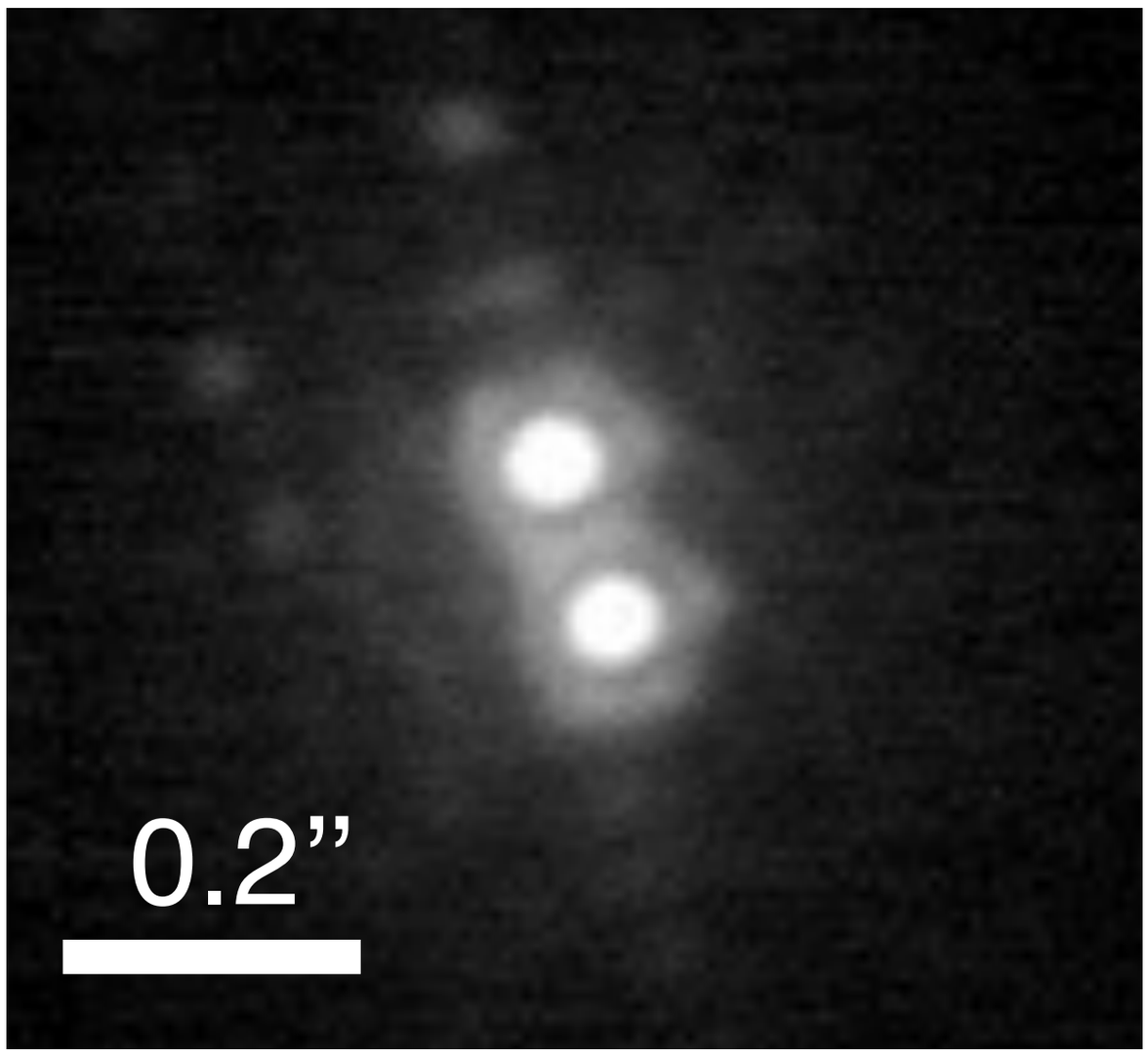


Many orbits require decades



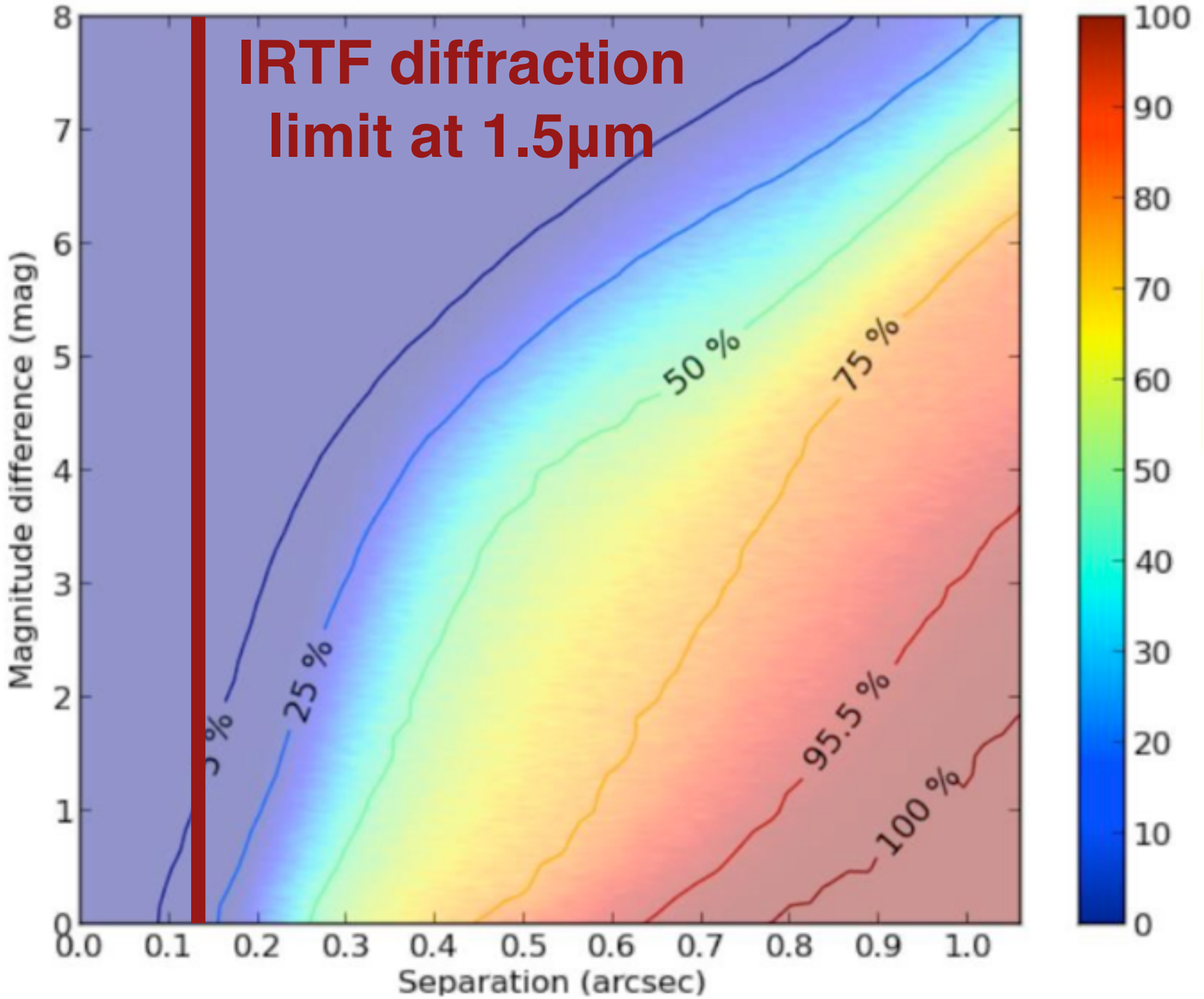
Excessive for larger AO systems

Keck/NIRC2



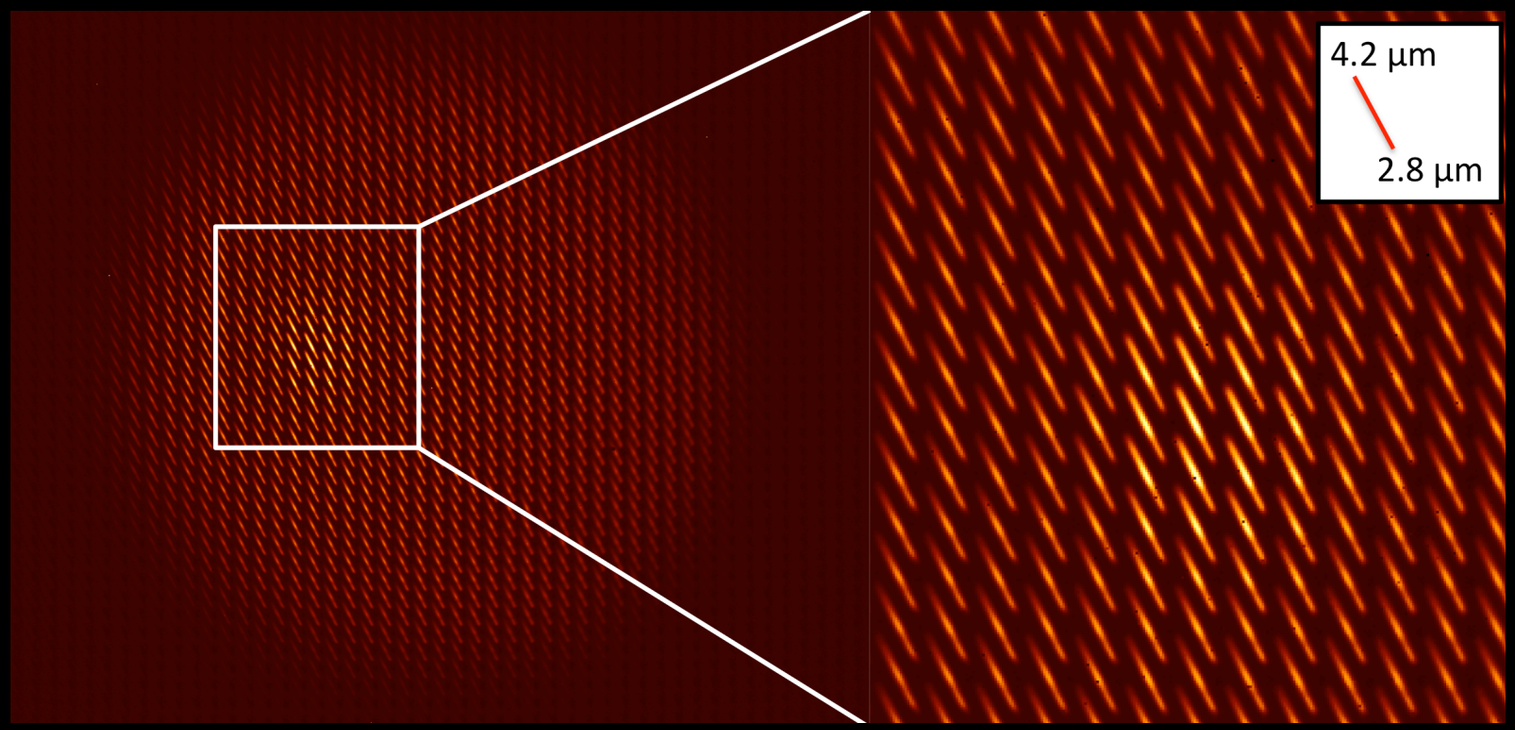
Nearby Associations	Approx Age (Myr)
AB Dor	150
Argus	60
BPMG	25
Carina	45
Columba	40
Eta Cha	10
Tuc-Hor	45
TWA	10
32 Ori	20
Hyades	650
Coma Ber	400

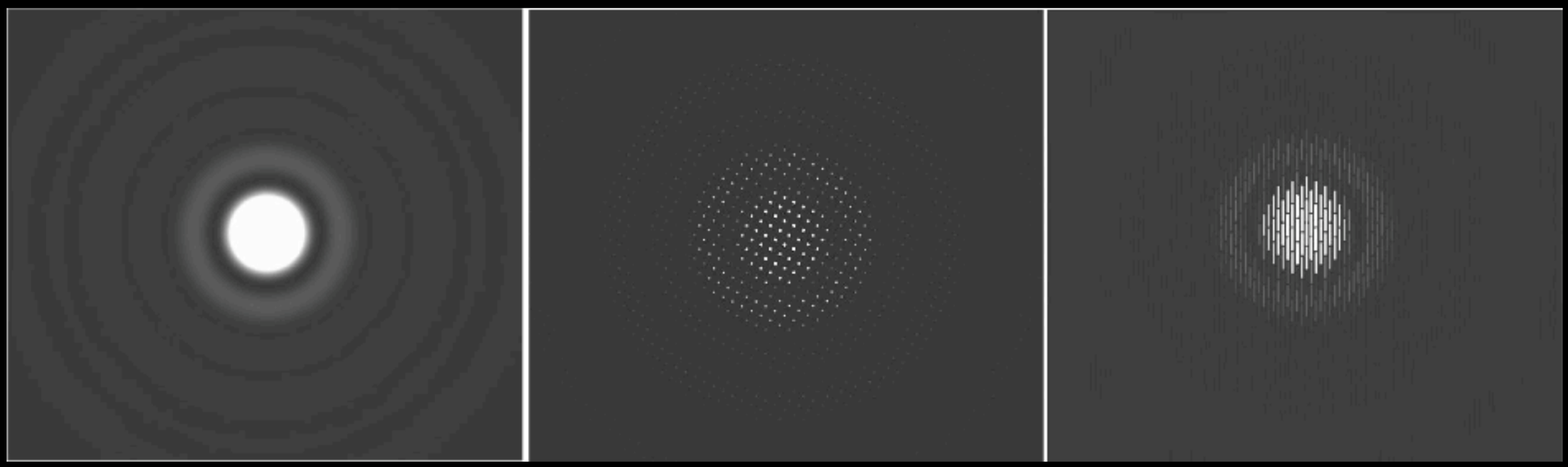
Binaries *Gaia* can find, IRTF can follow-up



Courtesy Jos de Brujine

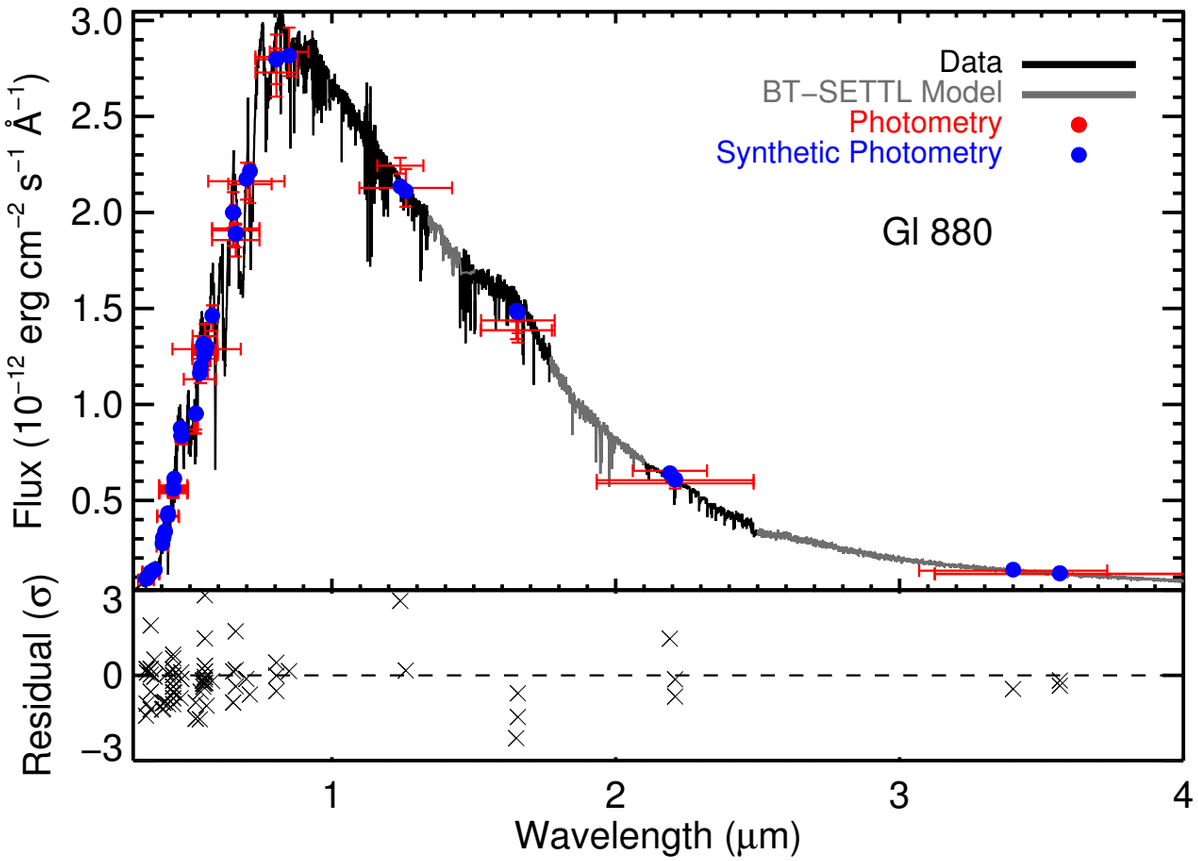
AO-assisted IFU;
e.g., LMIRcam + ALES

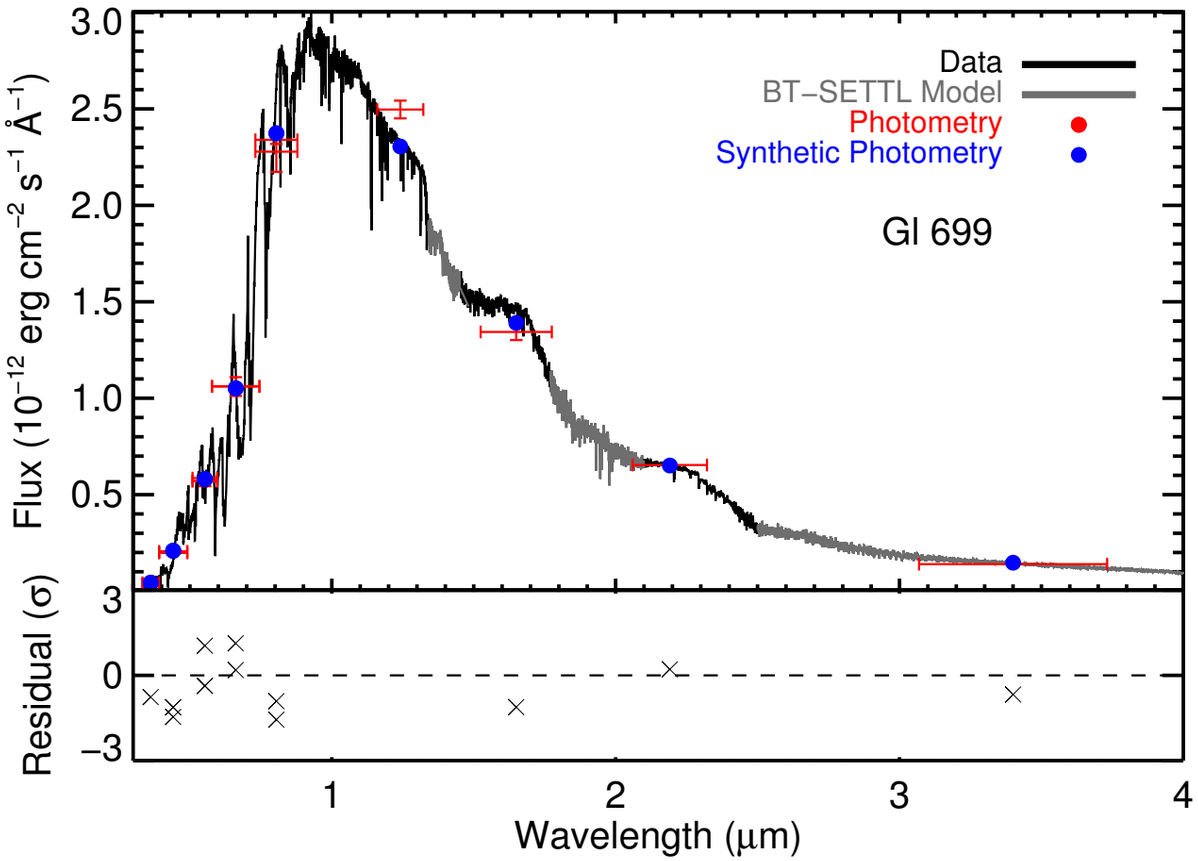




Skemer et al. (2015)

Resolved spectrophotometry for empirical luminosities





Mann et al. (2015)

Fundamental parameters of late-type stars and brown dwarfs

Mass

Radius

Luminosity

Metallicity

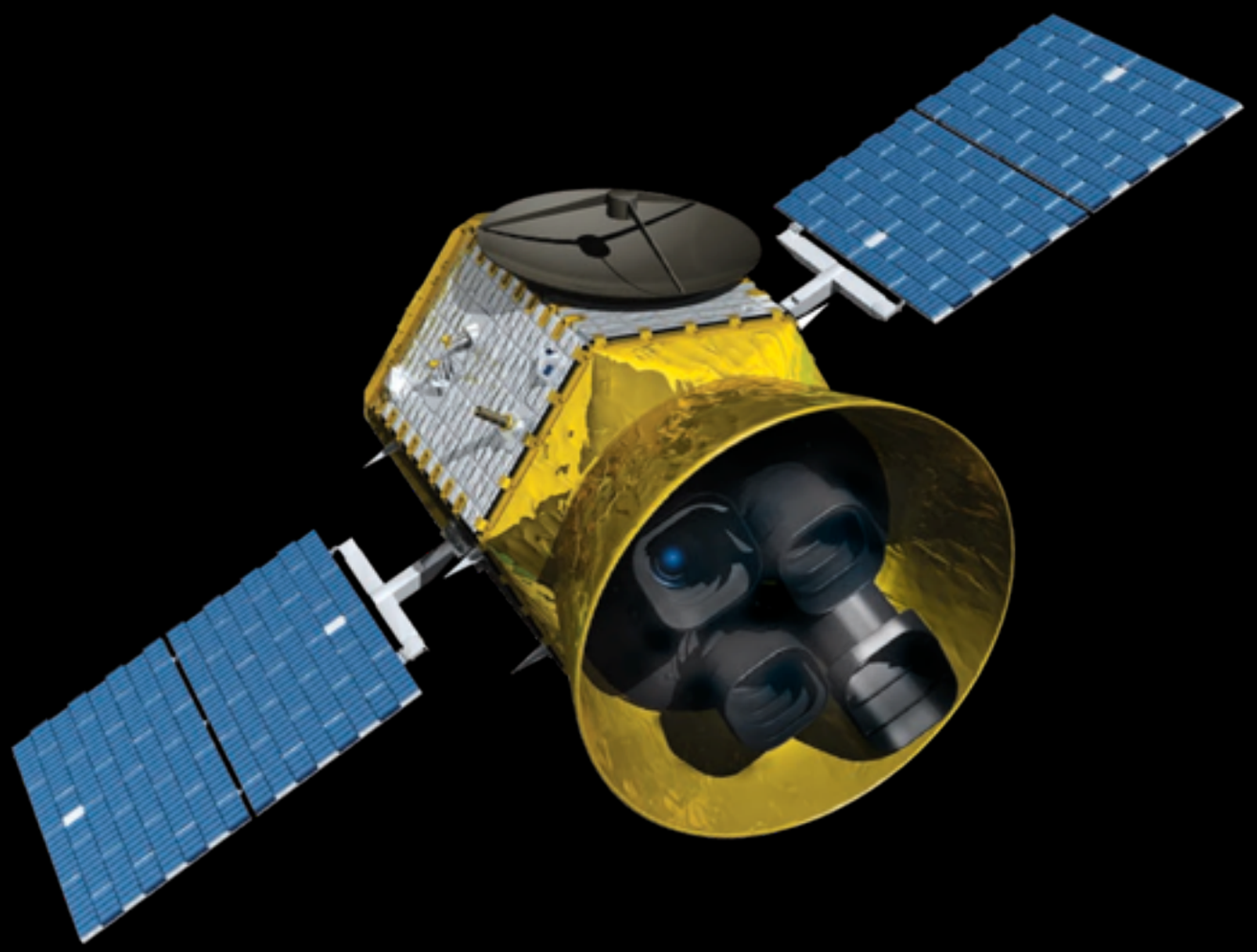
T_{eff}

Age

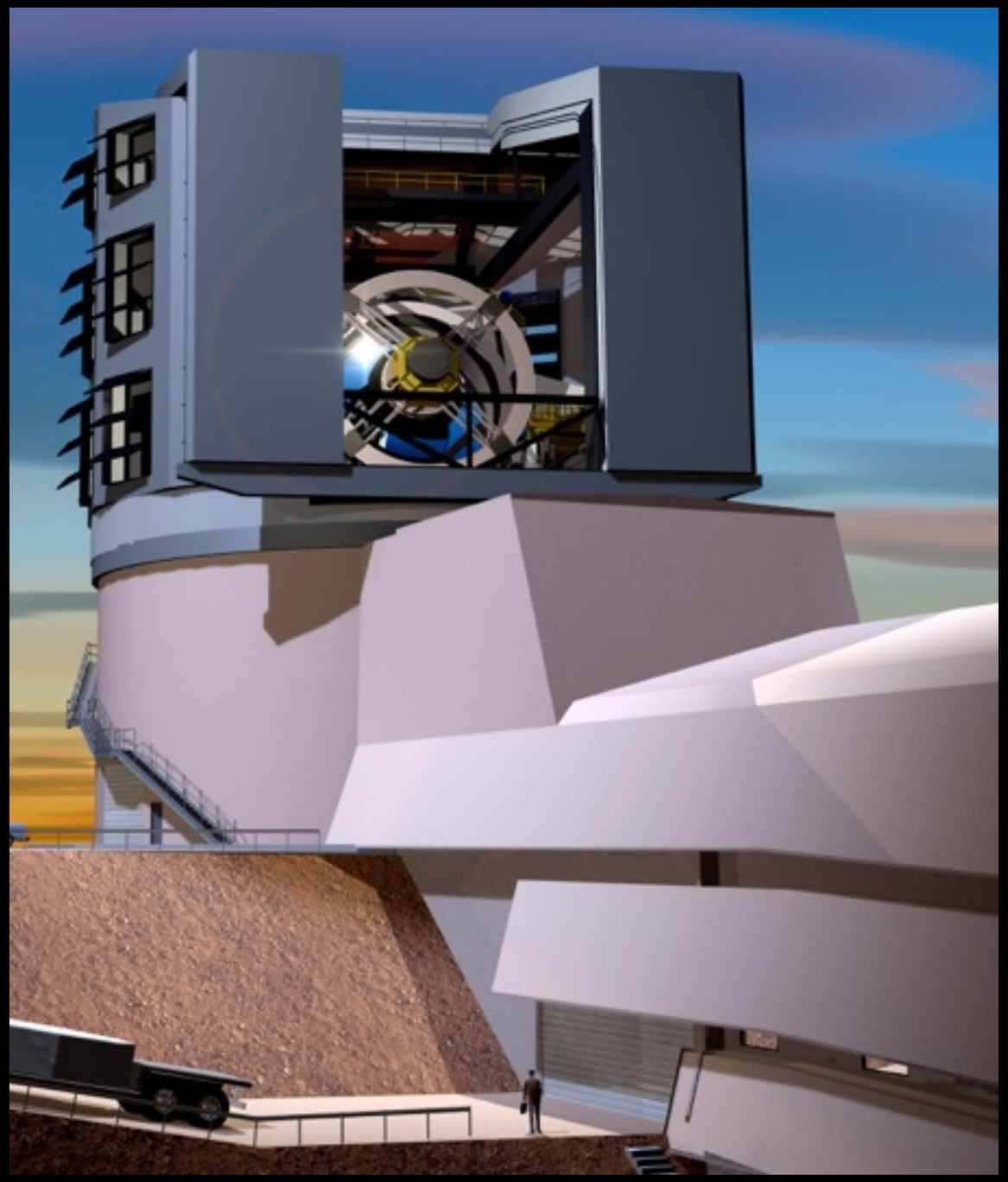
Fundamental relations, e.g., mass-luminosity EqW-metallicity luminosity-age color-teff

Empirical calibrators, e.g., clusters, YMGs

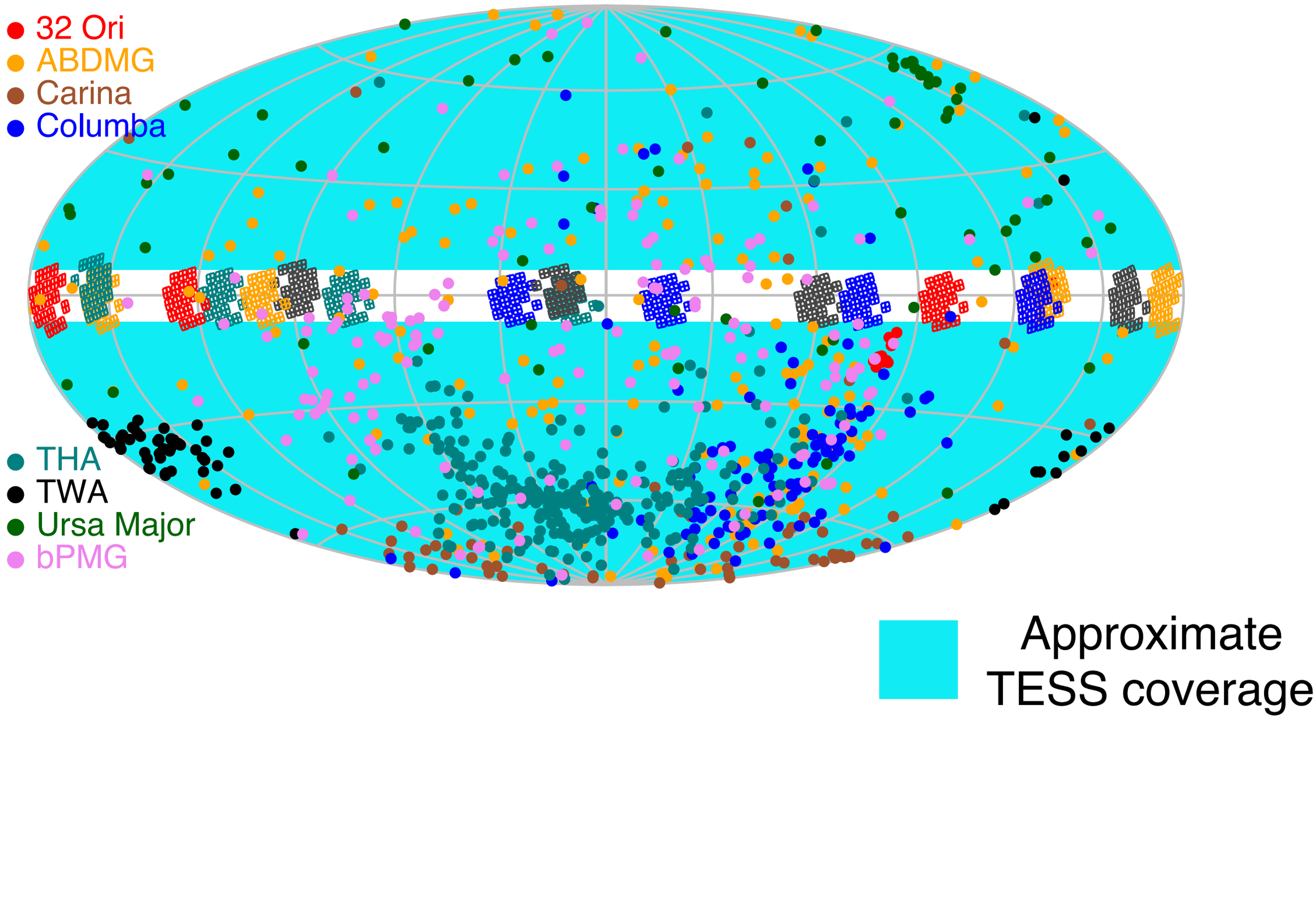
TESS



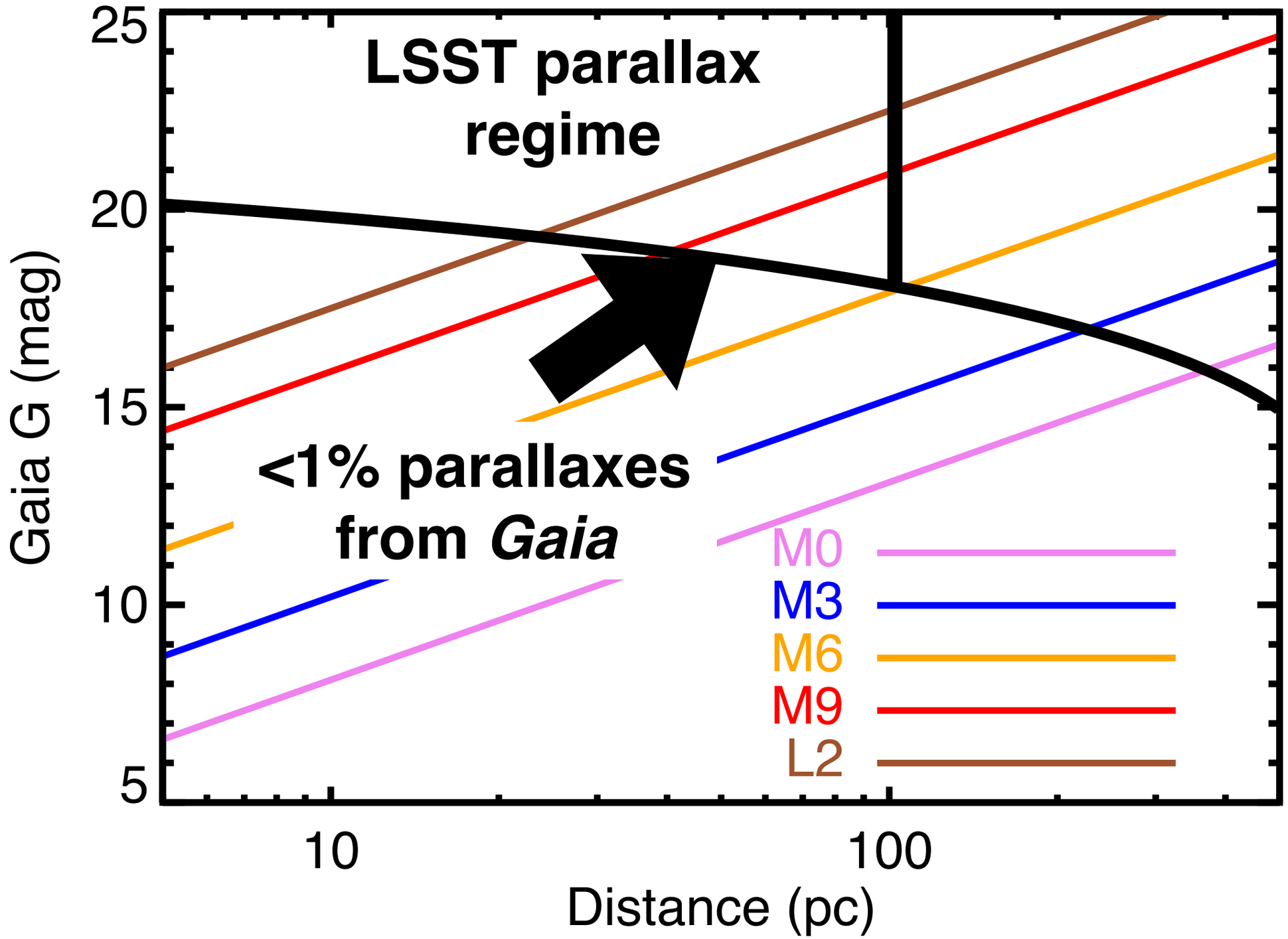
LSST



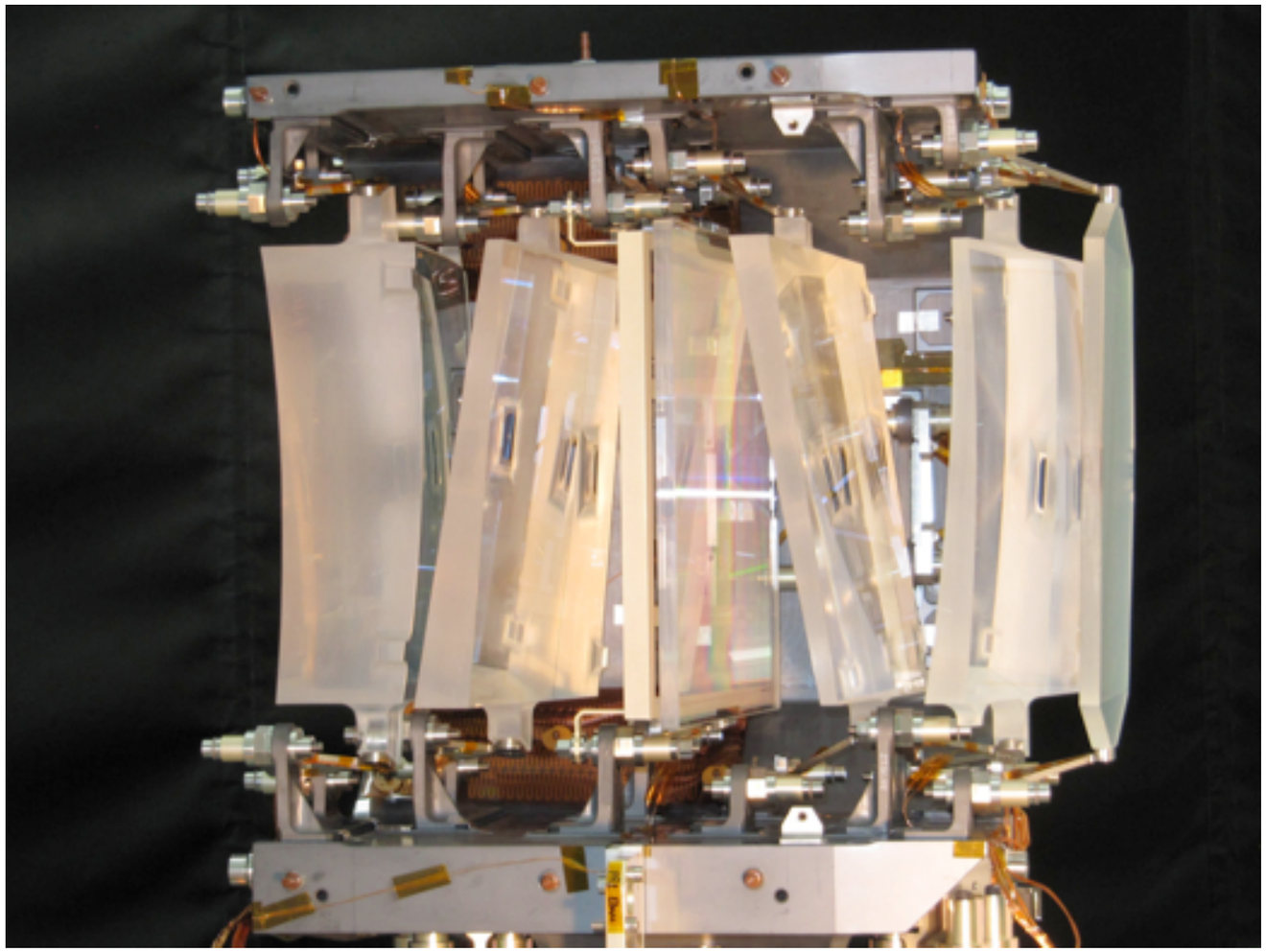
Members of nearby young moving groups



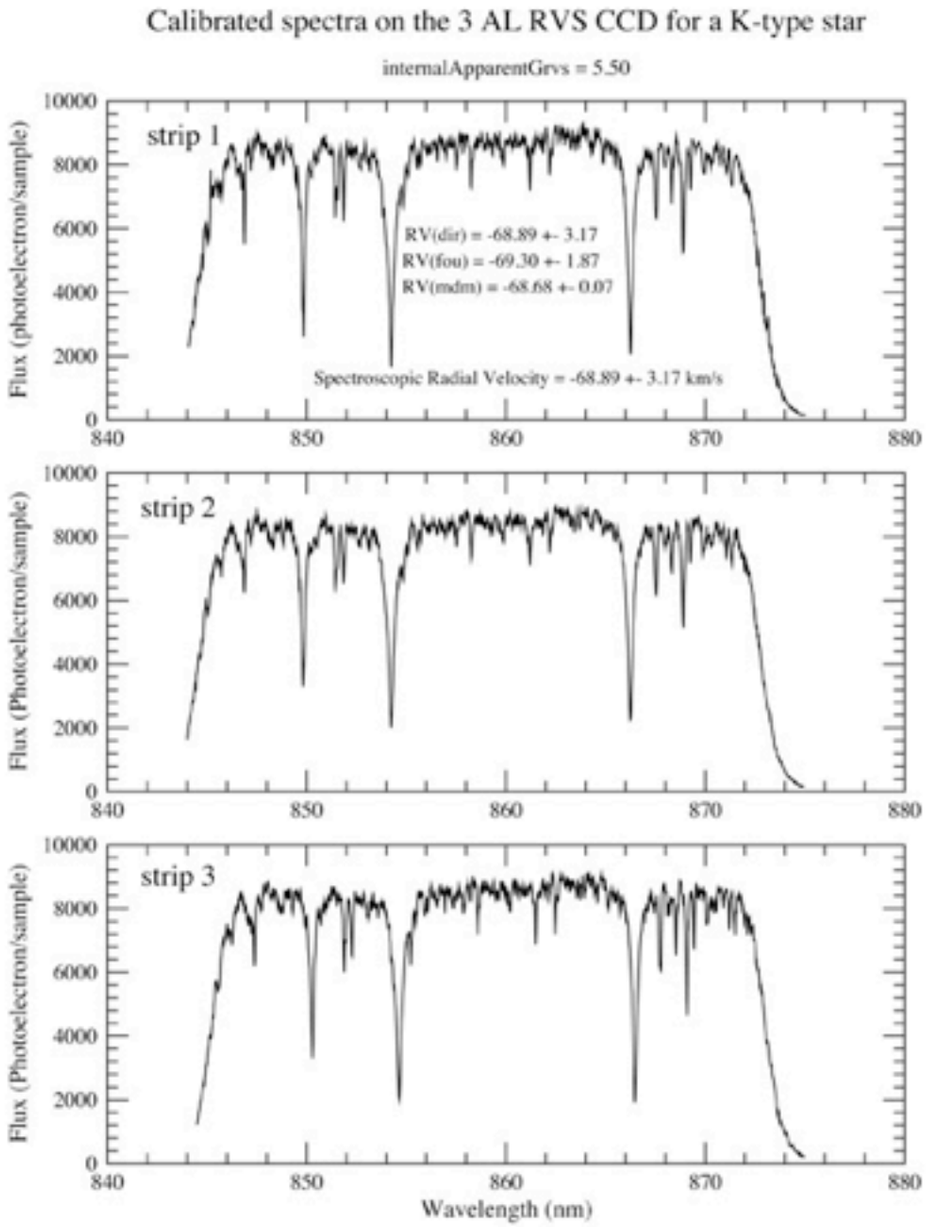
Parallaxes from *Gaia* and LSST



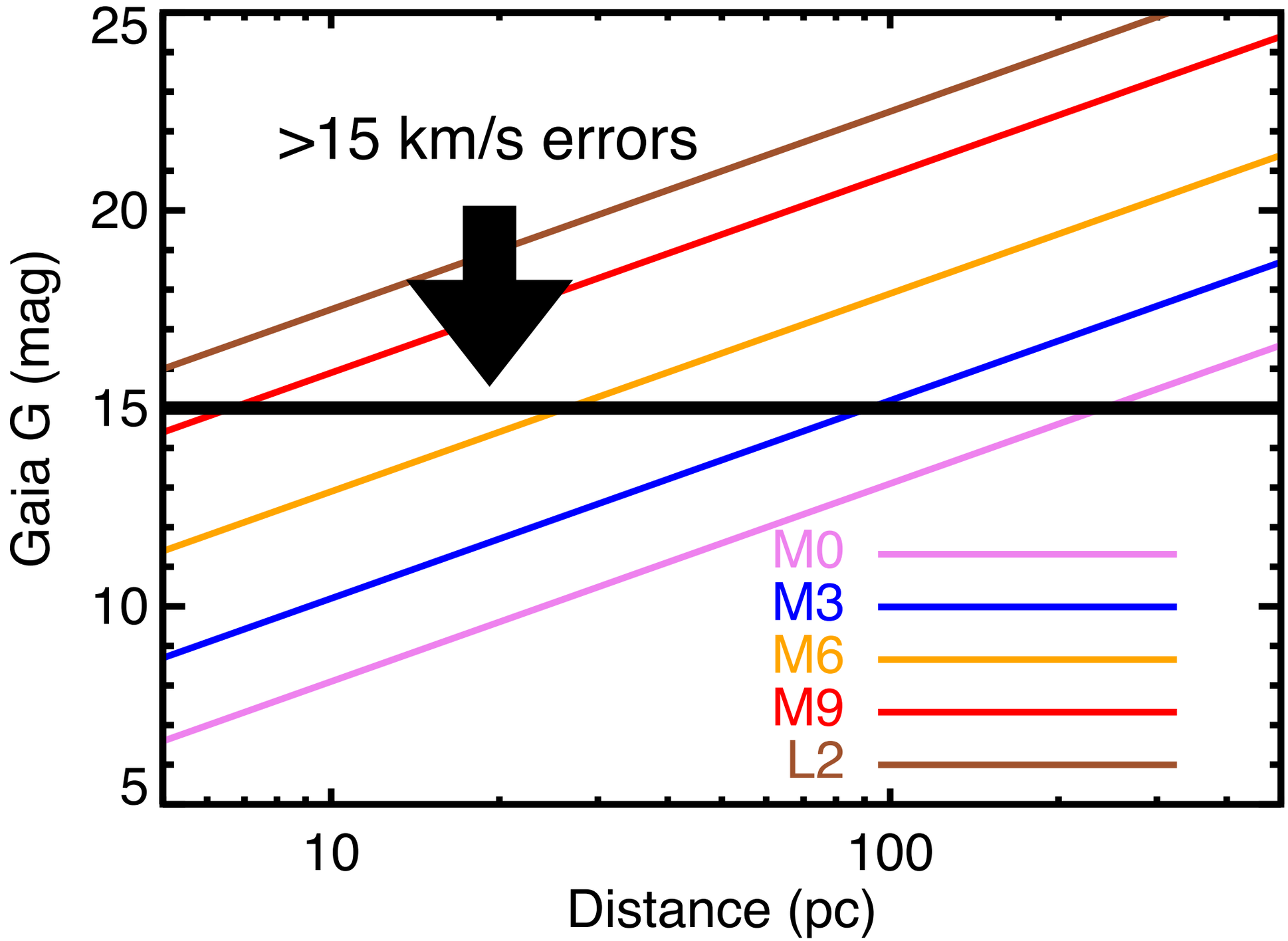
Gaia Radial Velocities



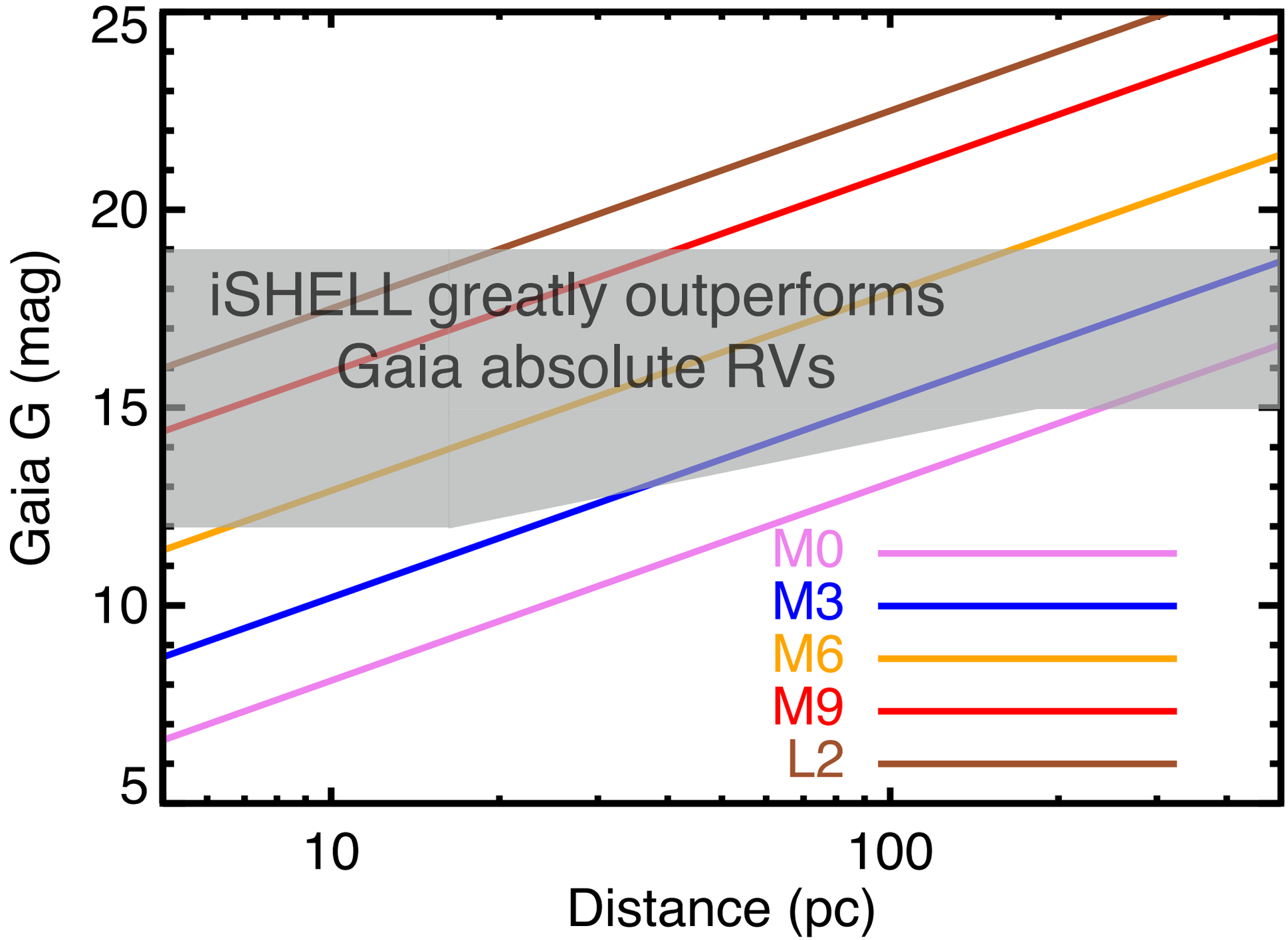
R ~ 11,500
845-872 nm



RVs from *Gaia*



RVs from ISHELL



Fundamental parameters of late-type stars and brown dwarfs

Mass

Radius

Luminosity

Metallicity

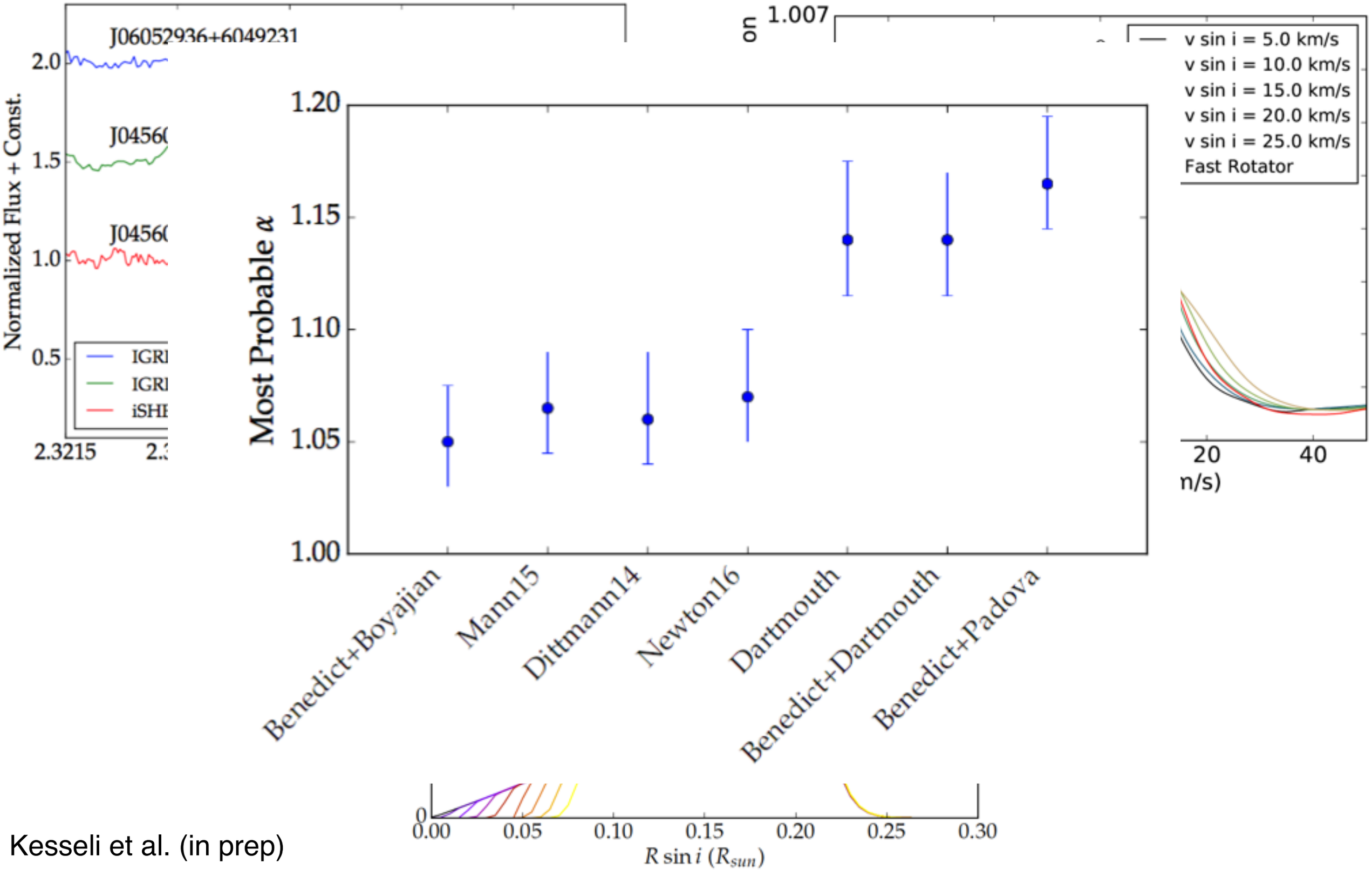
T_{eff}

Age

Fundamental relations, e.g., mass-luminosity

Empirical calibrators, e.g., astrometric binaries

Vsin(i) + P_{rot} -> Rsin(i)

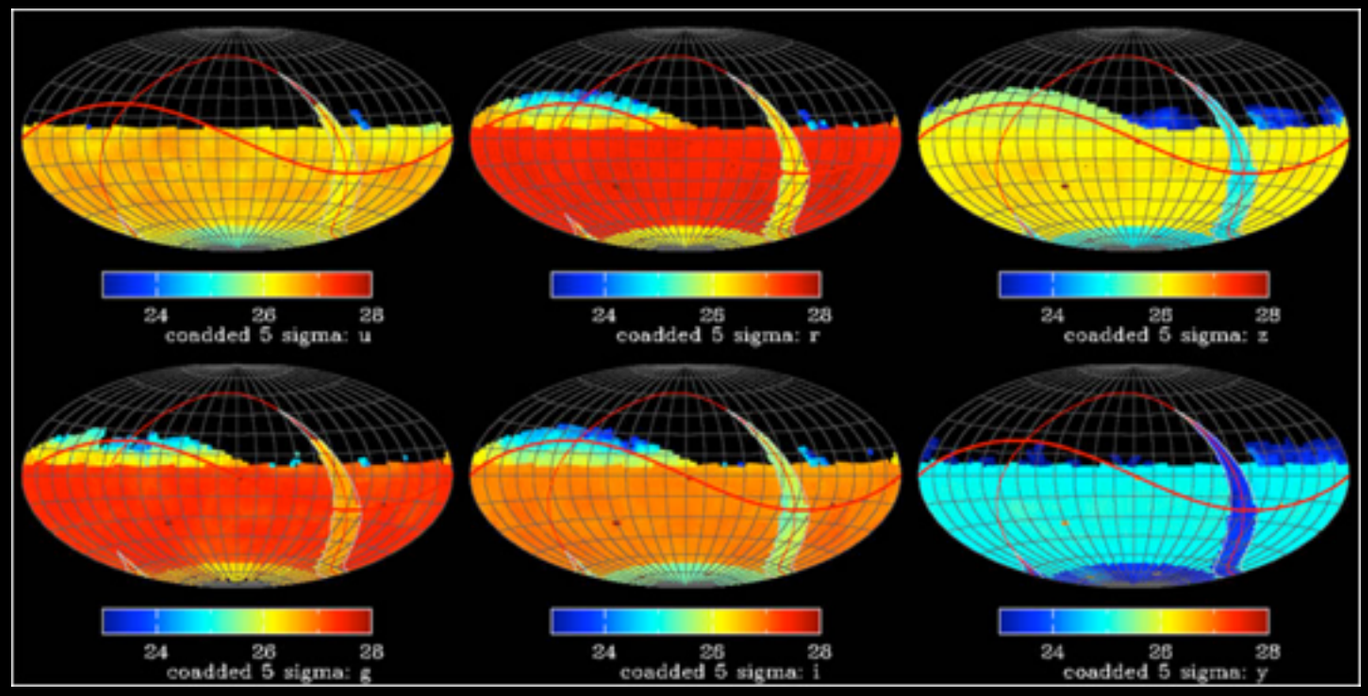


Kesseli et al. (in prep)

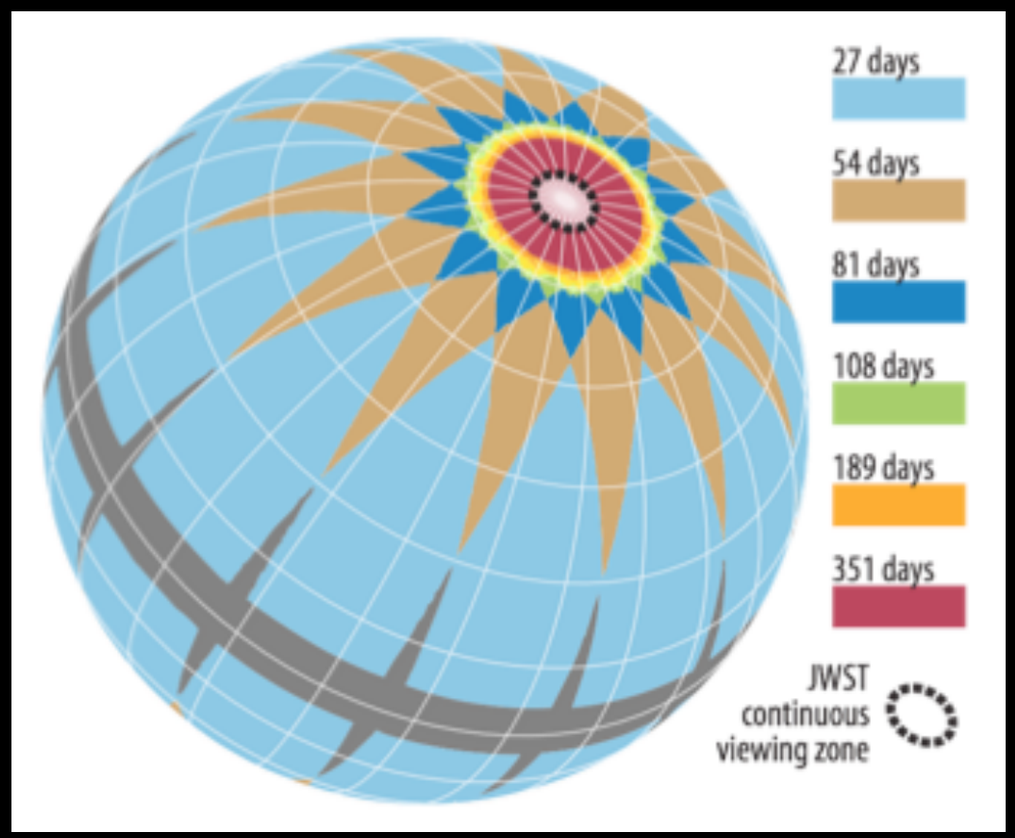
Fundamental parameters of late-type stars and brown dwarfs

Mass	Binary monitoring (RV, eclipses)
Radius	Metallicities for L dwarfs Vsin(i) + rotation -> Rsin(i) -> Radii
Luminosity	C/O and alpha for M dwarfs Precise bolometric fluxes
Metallicity	Empricial T_{eff} calibration from LBOI+SED Isotopic abundances for M dwarf ages
T_{eff}	Testing *Gaia* parallaxes through EBs Spot temperature modeling (2-T_{eff} fits)
Age	

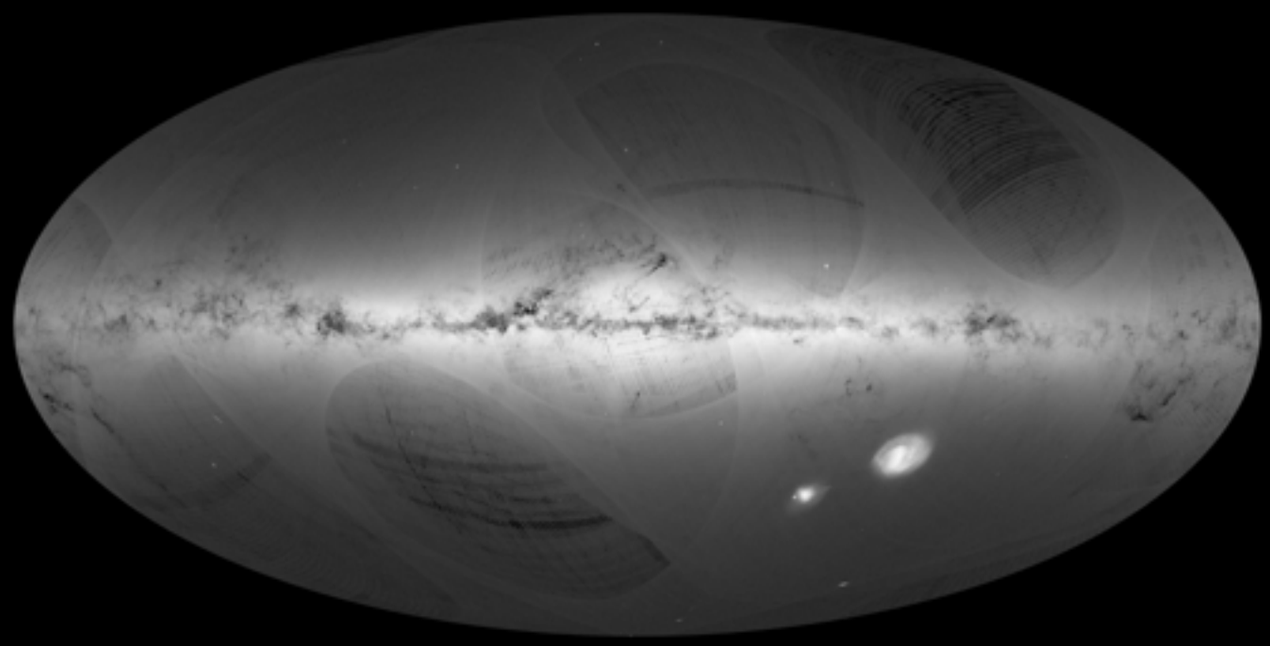
LSST



TESS



Gaia



Rapid follow-up, all-sky targets, time-sensitive phenomenon

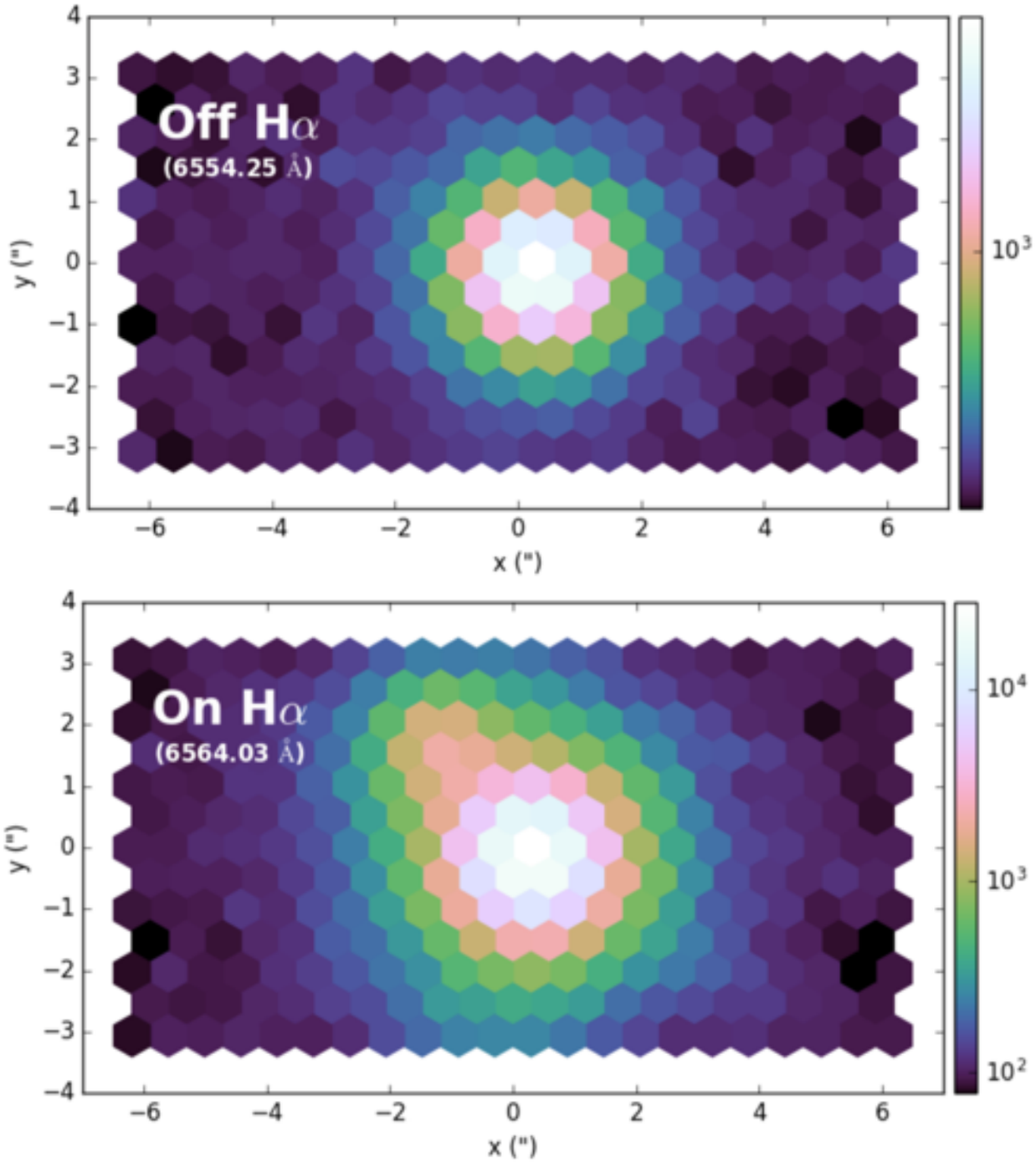
Likely an increase in:

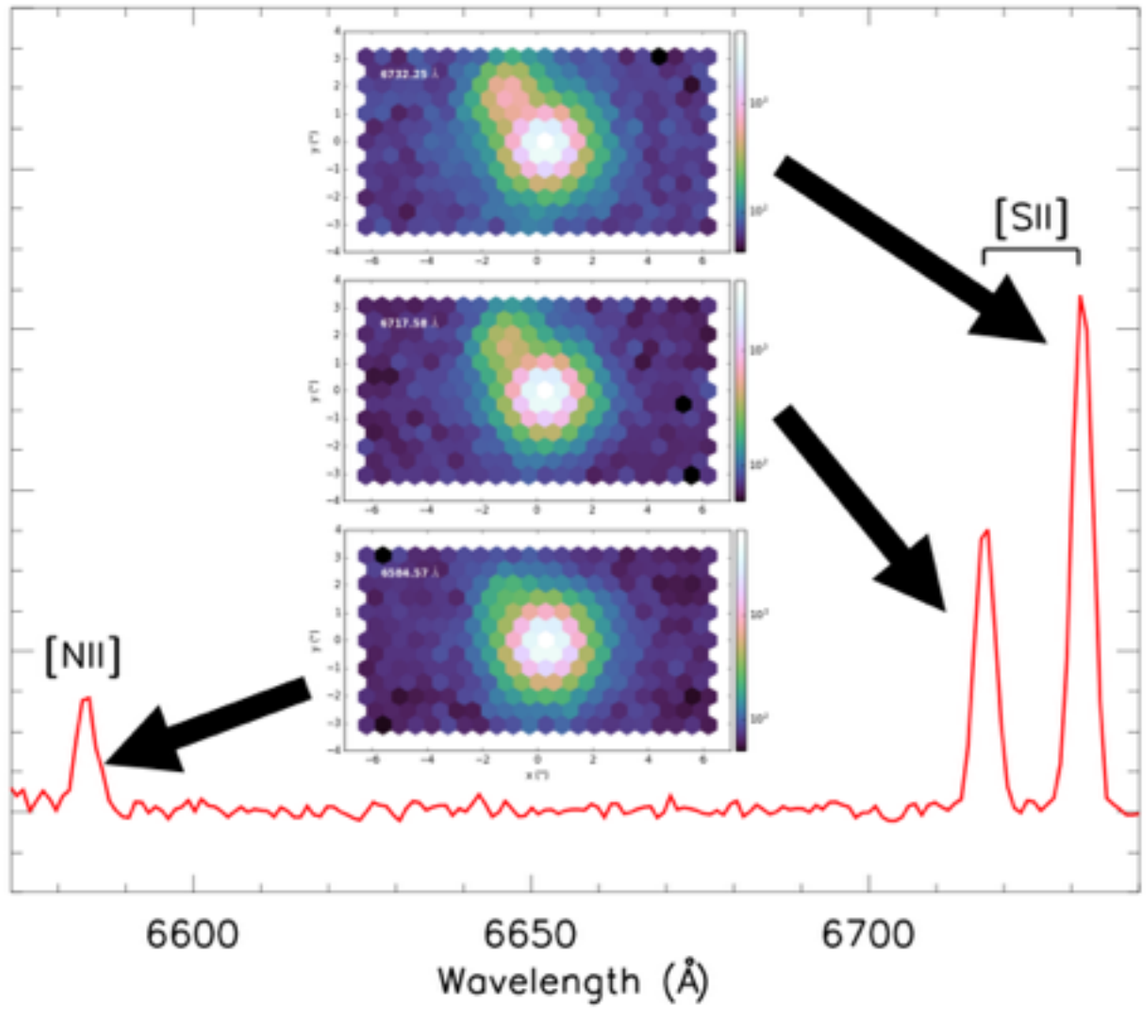
- TOO programs
- Programs requiring specific scheduling
- Time-domain programs
- Long-timescale projects

IRTF expanded support, e.g.,:

- Fast turnaround proposals
- Quicklook reduction tools (on-the-fly decisions)
- Options for queue observing modes
- Support for long-term (multi-year) proposals

Separating Binaries and Planets via Spectro-astrometry





LRS/HET; Optical IFU

Bowler, Liu, Kraus, & Mann (2014)
Ansdell, Gaidos, & Mann (2015)
Martinez, Kraus, & Mann (2018)

(1) SpT	(2) M_I mag	(3) $V-I$ mag	(4) M_V mag	(5) V mag @30 pc	(6) G mag @30 pc	(7) d pc	(8) σ_π/π %	(9) d pc	(10) σ_π/π %	(11) d pc	(12) σ_π/π %
						$G = 20.0$ mag $p_{\rm det} = 100\%$		$G = 20.5$ mag $p_{\rm det} = 80\%$		$G = 21.0$ mag $p_{\rm det} = 50\%$	
M5	12.00	4.00	16.00	18.39	15.95	194	6.45	244	12.73	308	29.16
M6	12.46	4.12	16.58	18.96	16.41	157	5.22	198	10.30	249	23.59
M7	12.92	4.23	17.15	19.54	16.86	127	4.23	160	8.33	201	19.10
M8	13.38	4.35	17.73	20.11	17.32	103	3.42	130	6.75	163	15.47
M9	13.83	4.47	18.30	20.69	17.78	83	2.77	105	5.47	132	12.54
L0	14.29	4.58	18.88	21.26	18.23	68	2.25	85	4.44	107	10.17
L1	14.75	4.70	19.45	21.84	18.69	55	1.83	69	3.60	87	8.26
L2	15.21	4.82	20.03	22.41	19.14	45	1.48	56	2.93	71	6.70
L3	15.67	4.93	20.60	22.99	19.59	36	1.20	46	2.38	57	5.45
L4	16.13	5.05	21.18	23.56	20.04	29	0.98	37	1.93	47	4.43
L5	16.58	5.17	21.75	24.14	20.49	24	0.80	30	1.57	38	3.60
L6	17.04	5.28	22.33	24.71	20.94	19	0.65	25	1.28	31	2.93
L7	17.50	5.40	22.90	25.29	21.38	16	0.53	20	1.04	25	2.38
L8	17.96	5.52	23.48	25.86	21.83	13	0.43	16	0.85	20	1.94
L9	18.42	5.63	24.05	26.44	22.28	11	0.35	13	0.69	17	1.58
T0	18.88	5.75	24.63	27.01	22.72	9	0.28	11	0.56	14	1.29
T1	19.33	5.87	25.20	27.59	23.17	7	0.23	9	0.46	11	1.05
T2	19.79	5.98	25.78	28.16	23.61	6	0.19	7	0.37	9	0.85
T3	20.25	6.10	26.35	28.74	24.06	5	0.15	6	0.30	7	0.70
T4	20.71	6.22	26.93	29.31	24.50	4	0.13	5	0.25	6	0.57
T5	21.17	6.33	27.50	29.89	24.95	3	0.10	4	0.20	5	0.46
T6	21.63	6.45	28.08	30.46	25.39	3	0.08	3	0.16	4	0.38
T7	22.08	6.57	28.65	31.04	25.84	2	0.07	3	0.13	3	0.31
T8	22.54	6.68	29.23	31.61	26.28	2	0.06	2	0.11	3	0.25
T9	23.00	6.80	29.80	32.19	26.73	1	0.05	2	0.09	2	0.20

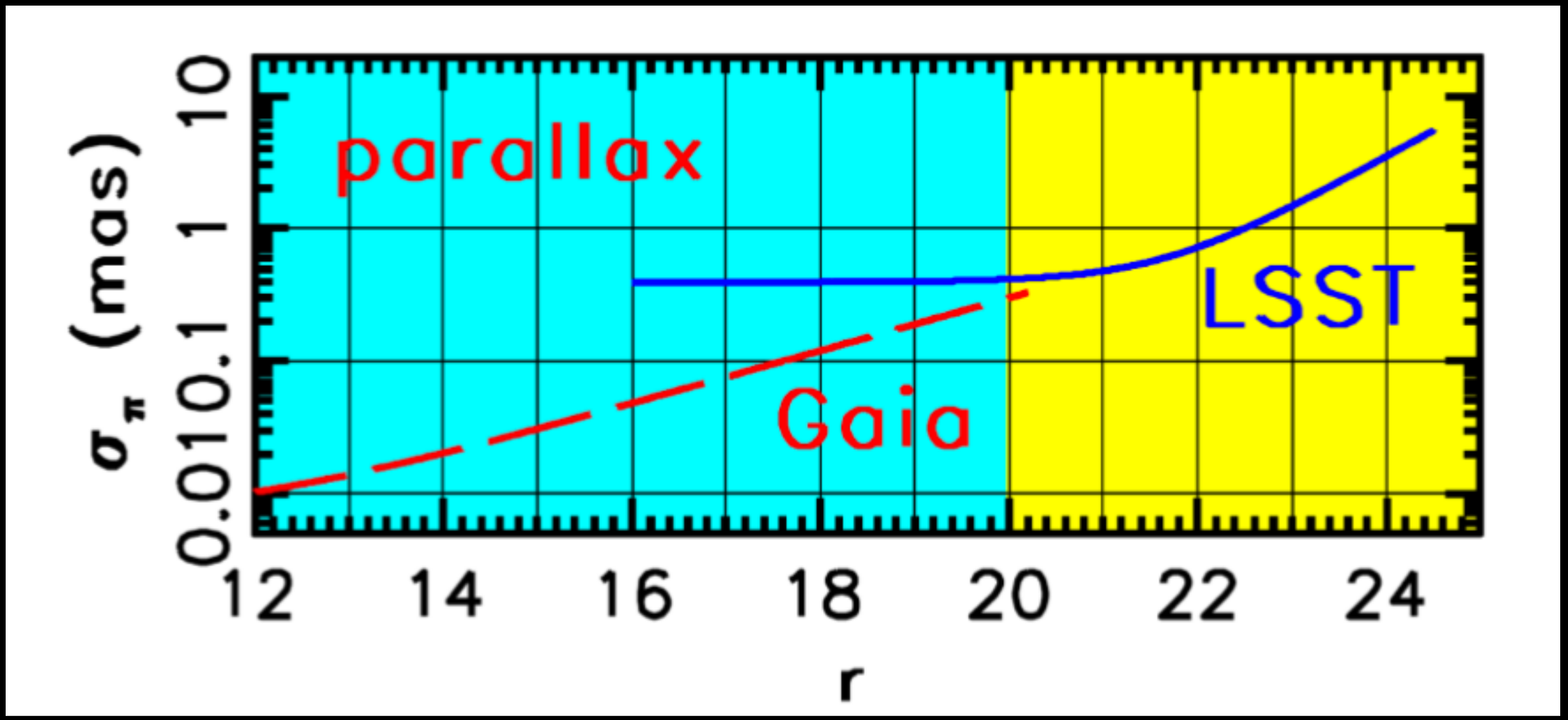

parallax
LSST
Gaia
σ_π (mas)
10
1
0.1
0.01
12
14
16
18
20
22
24
r

Table 1. Distance limits for L0 to T7 spectral types using Eq. 2. $D_{G<20.3}$ =distance limit assumming G <20.3 mags and $D_{G<20.7}$ for G <20.7 mags.

L SpT	$D_{G<20.3}$ (pc)	$D_{G<20.7}$ (pc)	T SpT	$D_{G<20.3}$ (pc)	$D_{G<20.7}$ (pc)
L0	69	82	T0	12	14
L1	55	67	T1	12	14
L2	45	54	T2	12	14
L3	36	44	T3	12	14
L4	29	35	T4	11	14
L5	24	29	T5	10	12
L6	19	23	T6	8	10
L7	16	19	T7	6	7
L8	13	15	T8	3	4
L9	10	12	T9	2	2