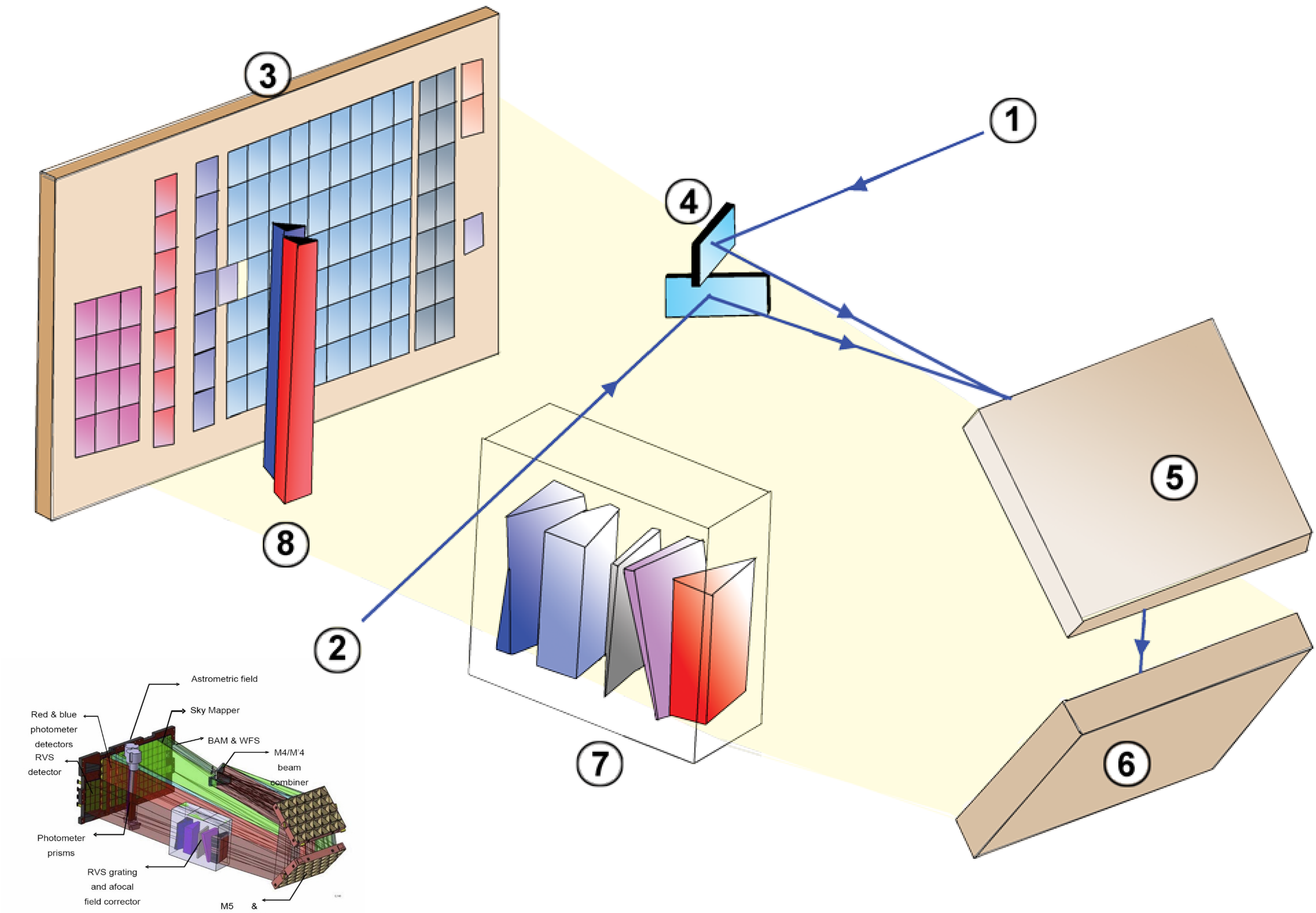
Detection and Characterization of Brown Dwarfs in the Gaia Catalogue

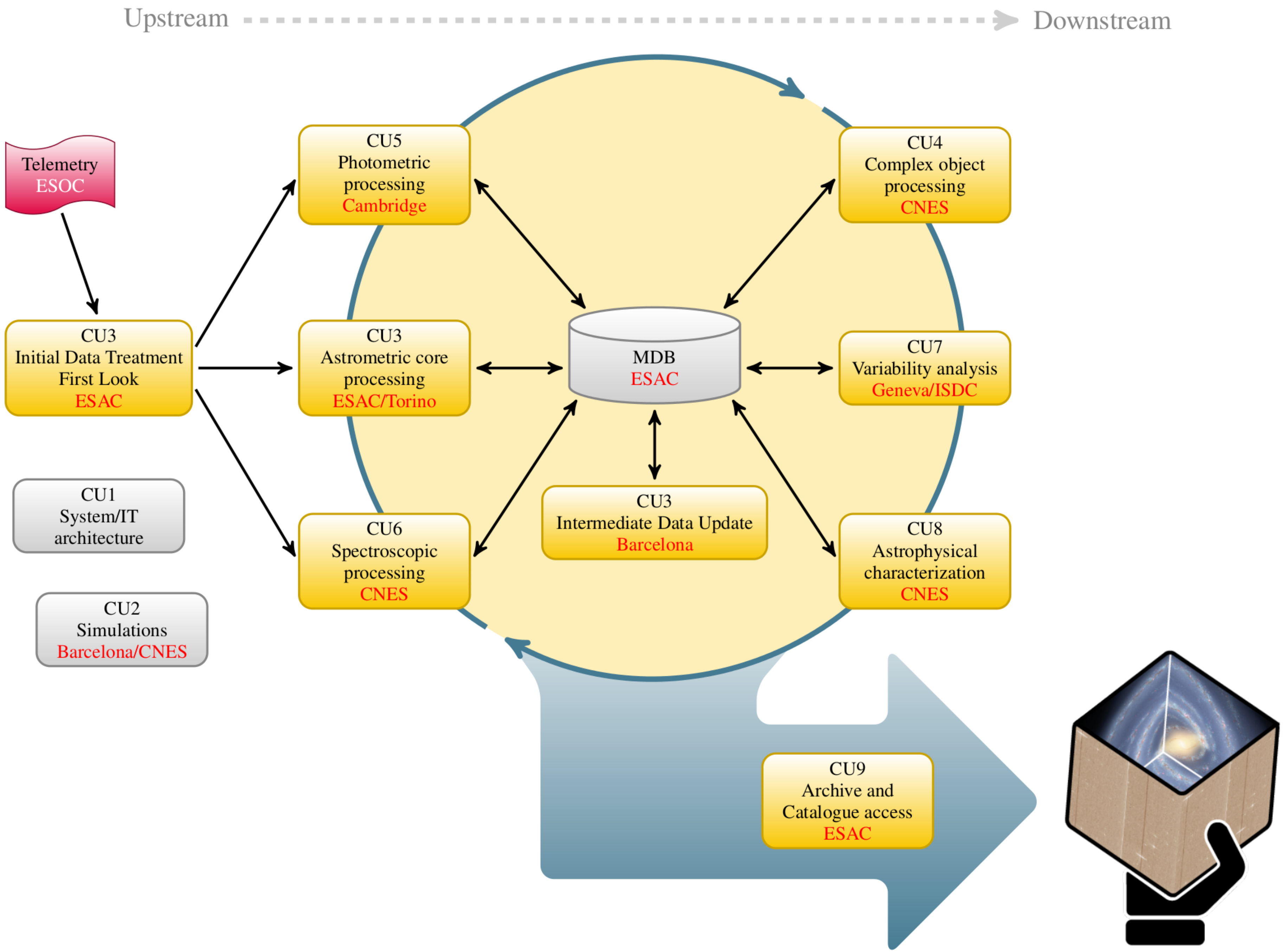
Luis Sarro (on behalf of the Gaia DPAC CU8)

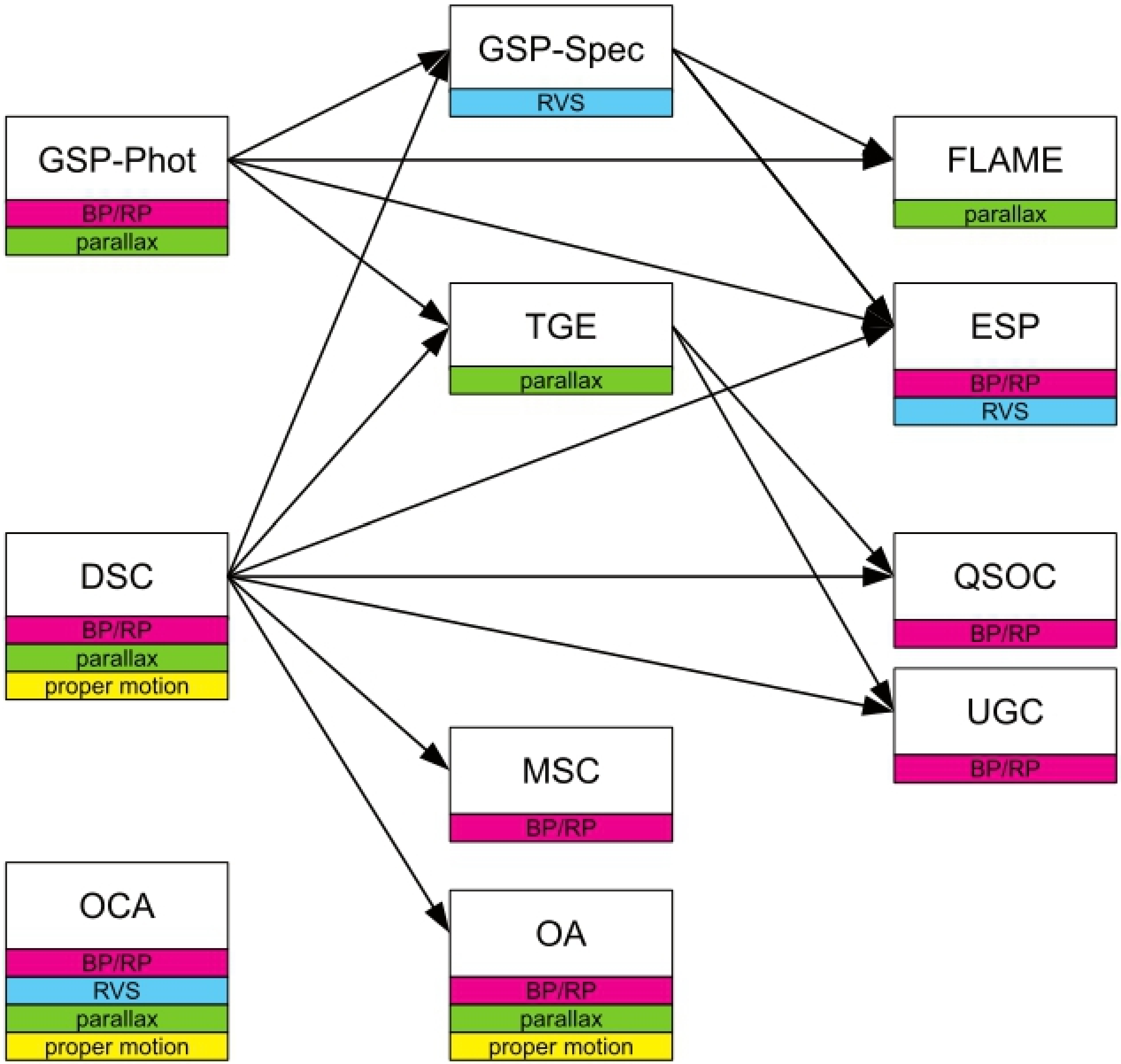
Block 1 – Gaia Context: Instruments → DPAC → CU8/Apsis → ESP-UCD

Block 2 – The ESP-UCD module in detail: Principles and performance

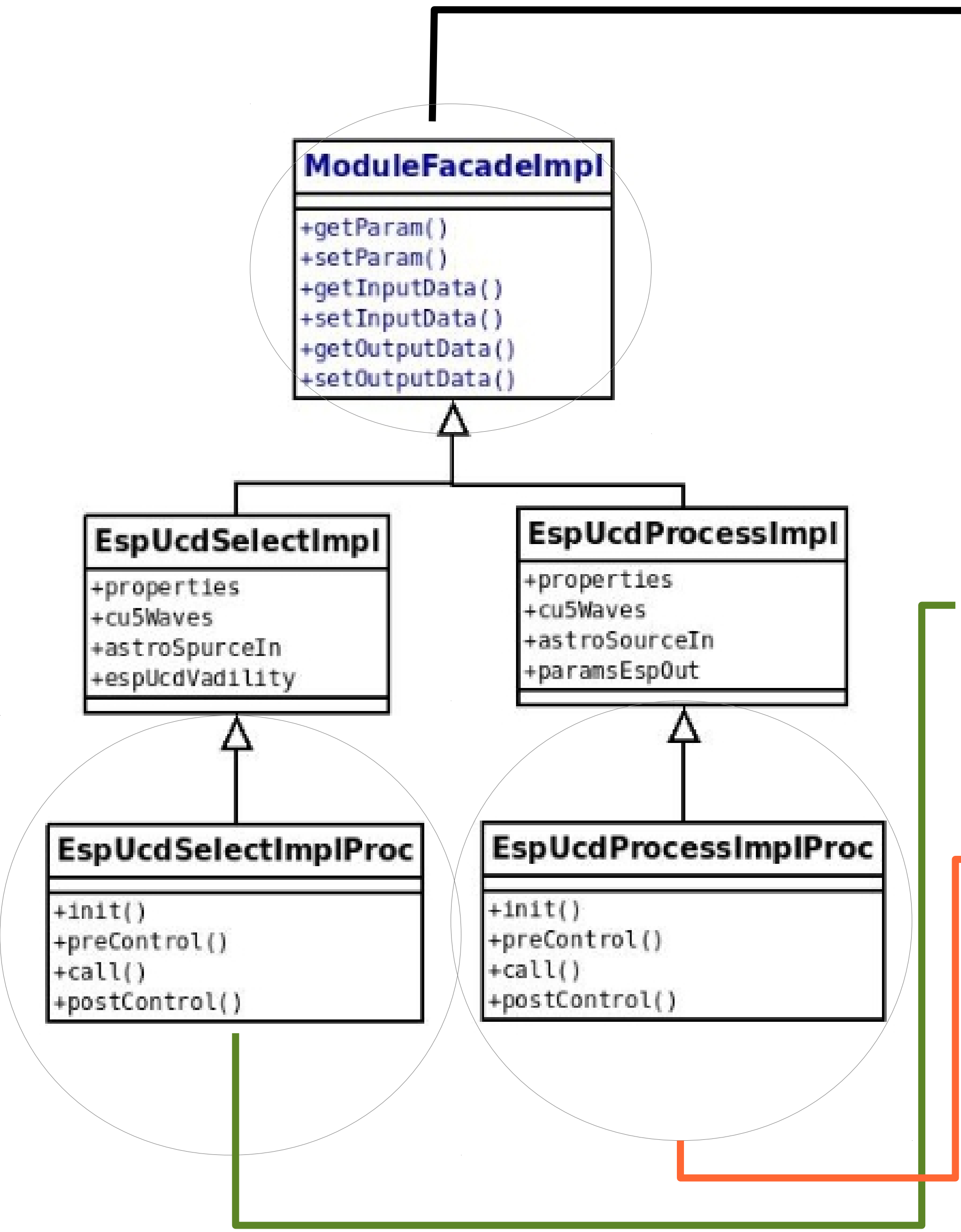
Block 3 – Estimates of the expected number of UCDs


3
1
4
5
8
2
7
6
Astrometric field
Red & blue photometer detectors
Sky Mapper
RVS detector
BAM & WFS
M4/M'4 beam combiner
Photometer prisms
RVS grating and afocal field corrector
M5 & fold mirrors


Upstream
Downstream
Telemetry
ESOC
CU3
Initial Data Treatment
First Look
ESAC
CU1
System/IT
architecture
CU2
Simulations
Barcelona/CNES
CU5
Photometric
processing
Cambridge
CU3
Astrometric core
processing
ESAC/Torino
CU6
Spectroscopic
processing
CNES
MDB
ESAC
CU3
Intermediate Data Update
Barcelona
CU4
Complex object
processing
CNES
CU7
Variability analysis
Geneva/ISDC
CU8
Astrophysical
characterization
CNES
CU9
Archive and
Catalogue access
ESAC


GSP-Spec
RVS
GSP-Phot
BP/RP
parallax
FLAME
parallax
TGE
parallax
ESP
BP/RP
RVS
DSC
BP/RP
parallax
proper motion
QSOC
BP/RP
UGC
BP/RP
MSC
BP/RP
OCA
BP/RP
RVS
parallax
proper motion
OA
BP/RP
parallax
proper motion

Block 2 - ESP-UCD: Architecture



DPAC processes 10^9 sources

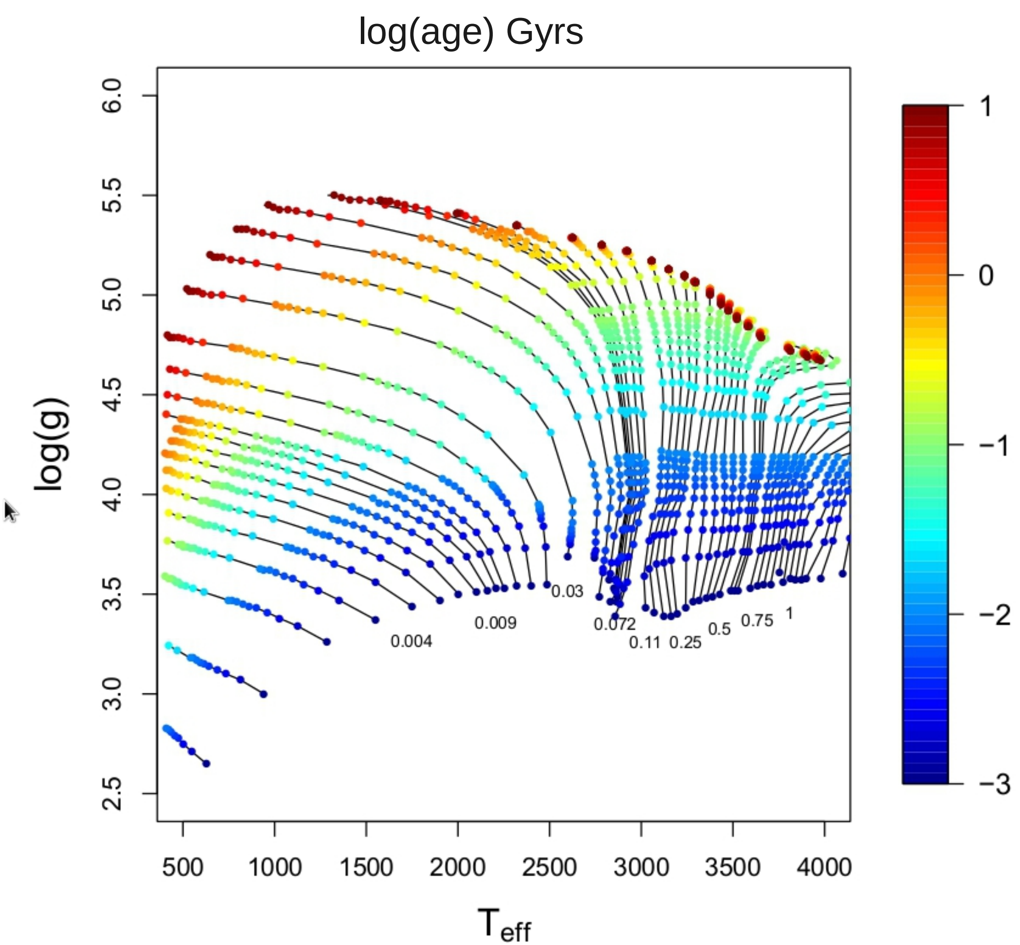
Modules do not have direct access to the database

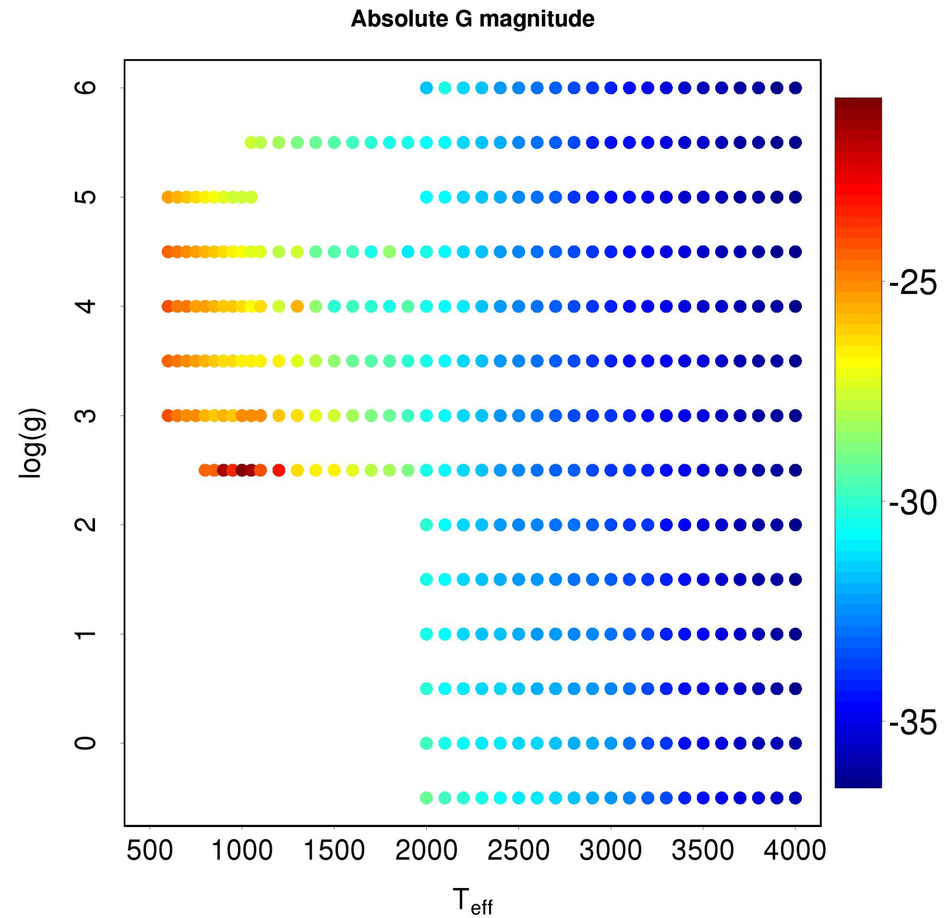
Data are made available via so-called ***façades***

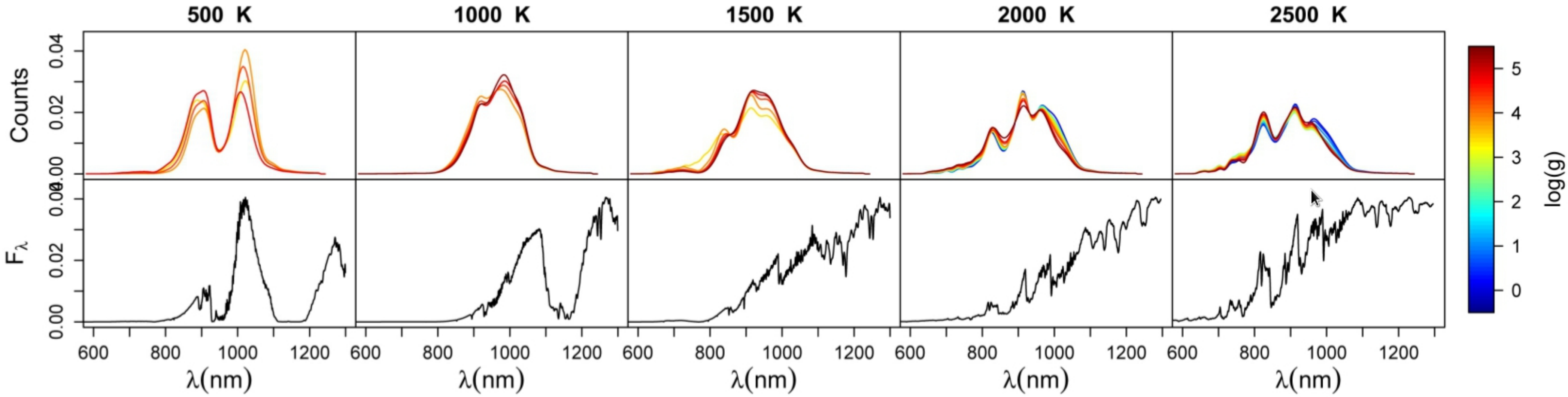
ESP-UCD is divided in two blocks:

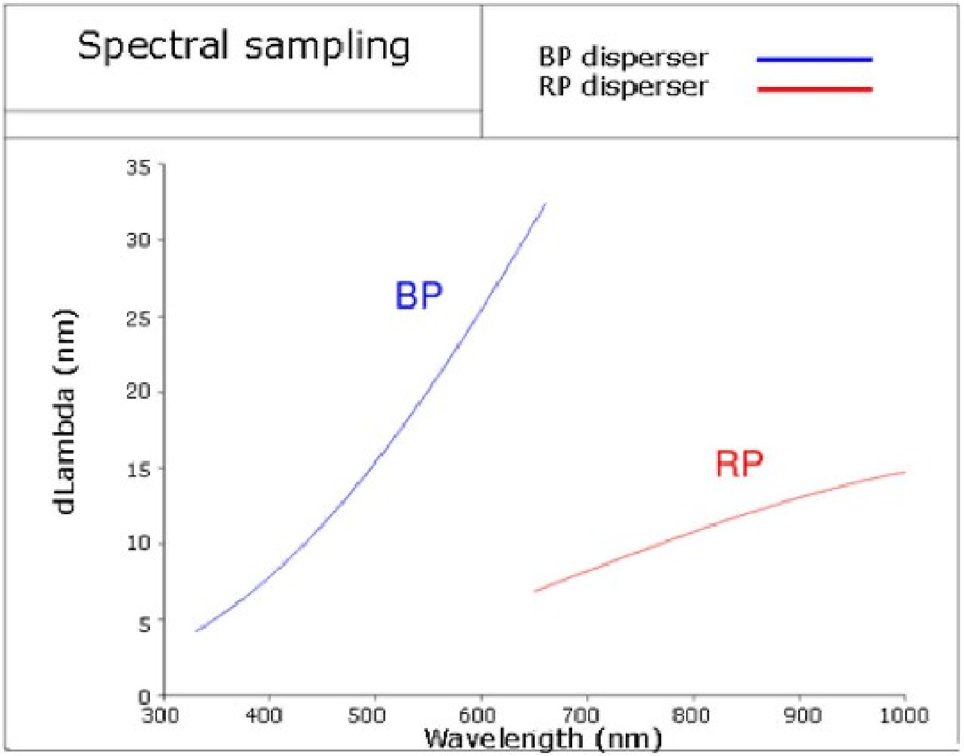
- ***Select*** decides if a source is a UCD candidate based on
  I. Parallax & proper motions
  II. apparent G magnitude
  III. BP-RP colour index
- ***Process*** estimates physical parameters (T_{eff} and log(g)) from RP spectrum

We need a consistent framework as basis for the modelling of the relationship between RP spectra and physical magnitudes → BTSettl models



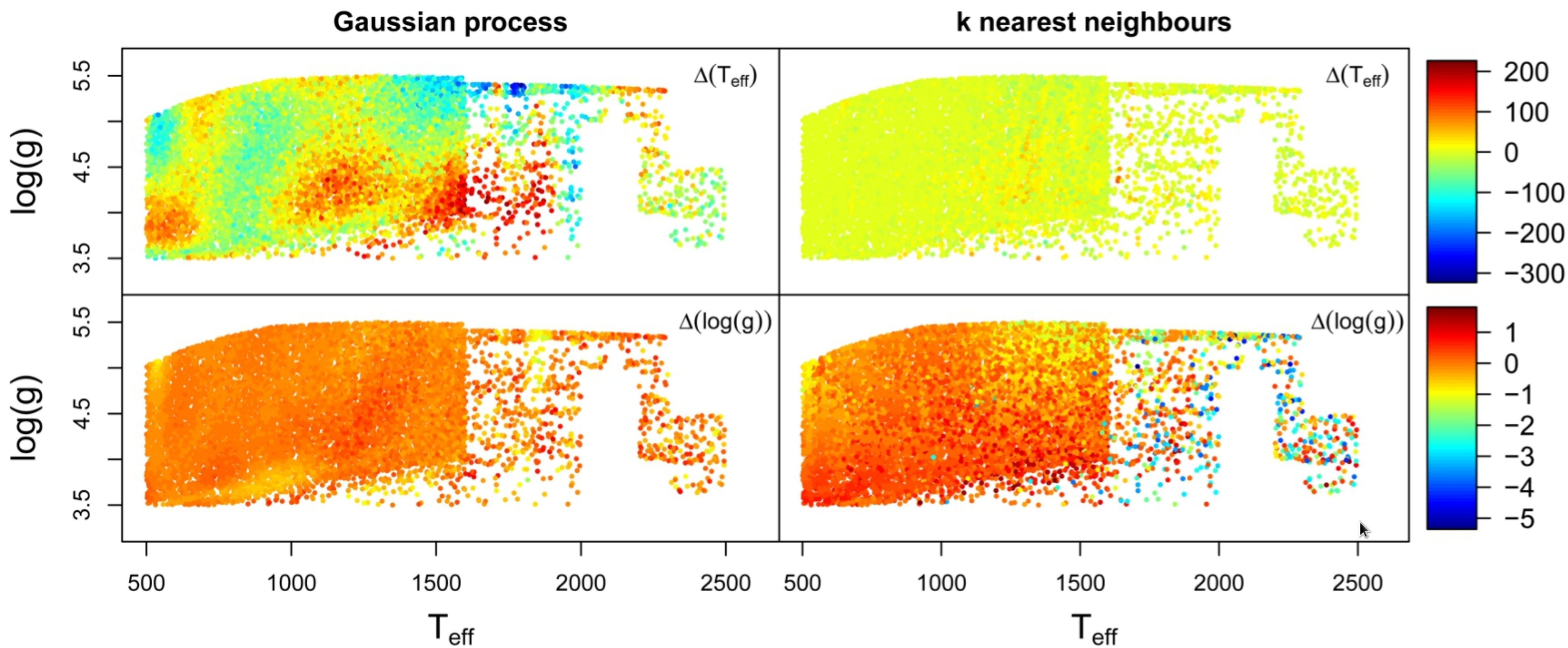






- BP spectra will probably contain nothing but noise
- Sensitivity to gravity limited to certain ranges of temperature

Block 2 – ESP-UCD: Internal estimate of the prediction errors at G=20



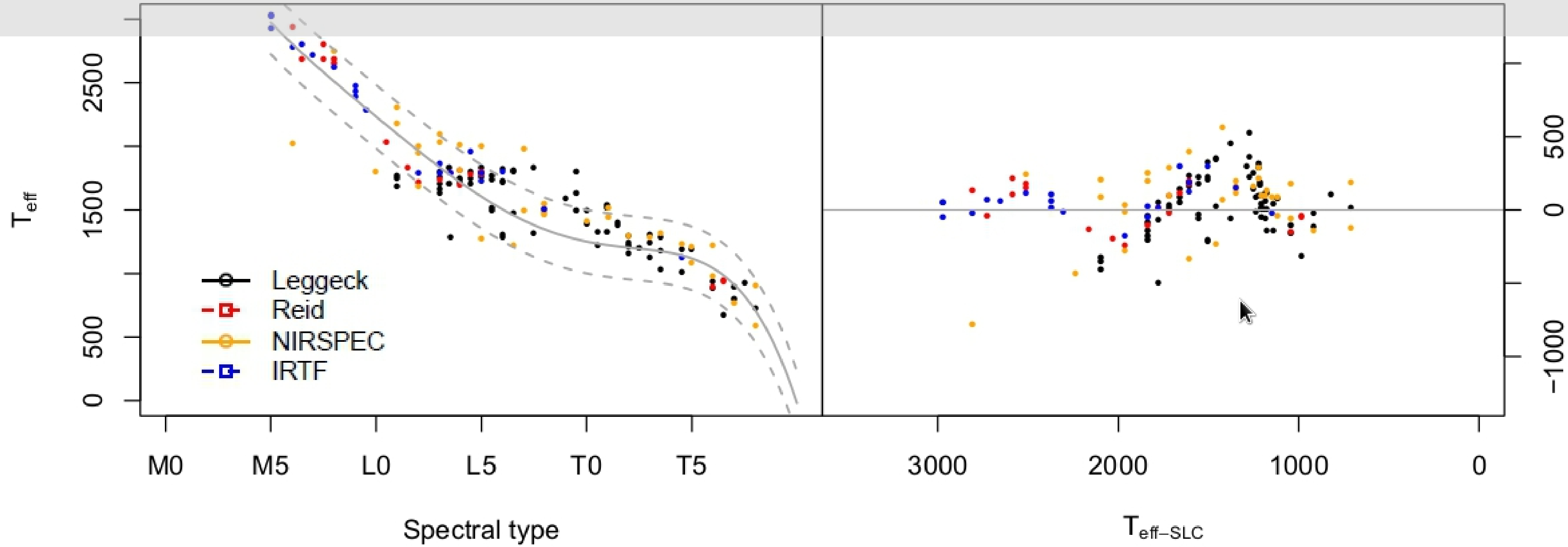
<u>Procedure</u>:

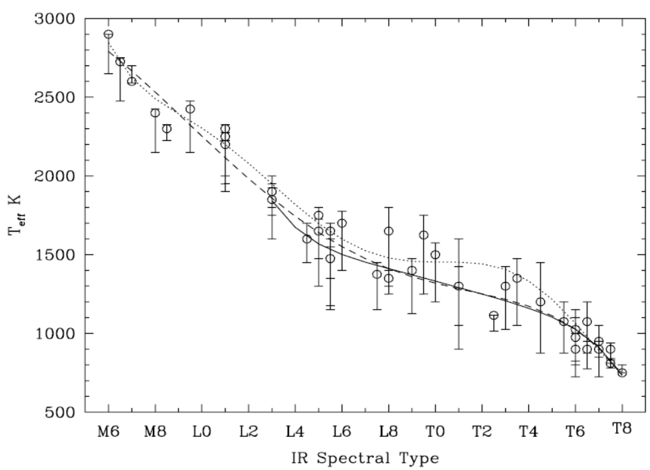
I. Use a fixed-step grid of values in Teff/logg and corresponding BT Settl spectra
II. Add noise to the grid for different values of G
III. Build models of the map (RP → Teff/logg) with various algorithms, and algorithm parameters
IV. Decide best model/parameters by computing the prediction error for a set of 10000 noisy (G=20) spectra with random parameters not used in the training phase.

Block 2 – ESP: Expected performance as assessed on independent real data sets

Background reasoning: We cannot do better with RP than we would with better resolution spectra in the same wavelength range

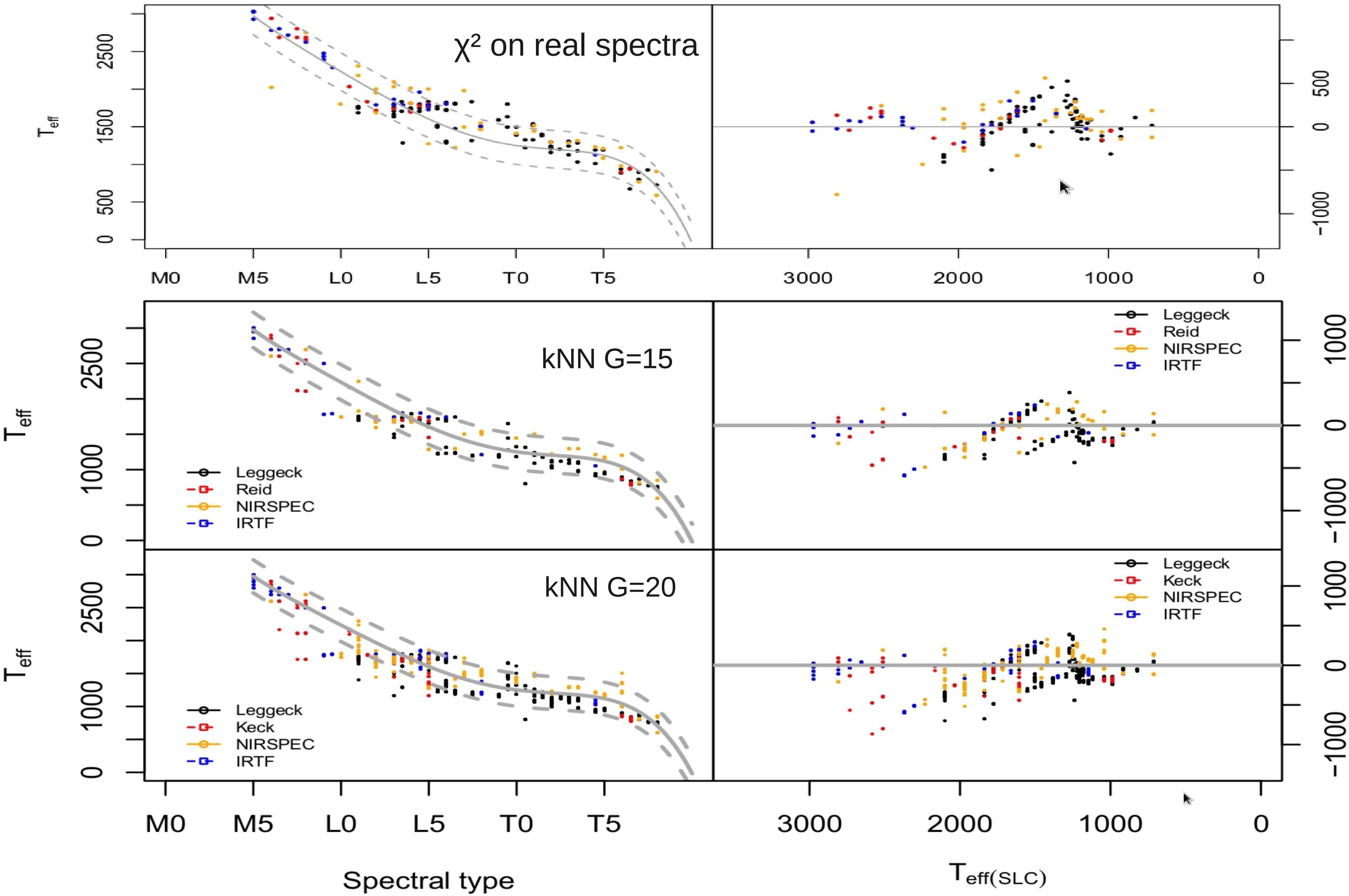
We compute estimates of Teff and logg from (possibly completed) real spectra of UCDs using χ^2



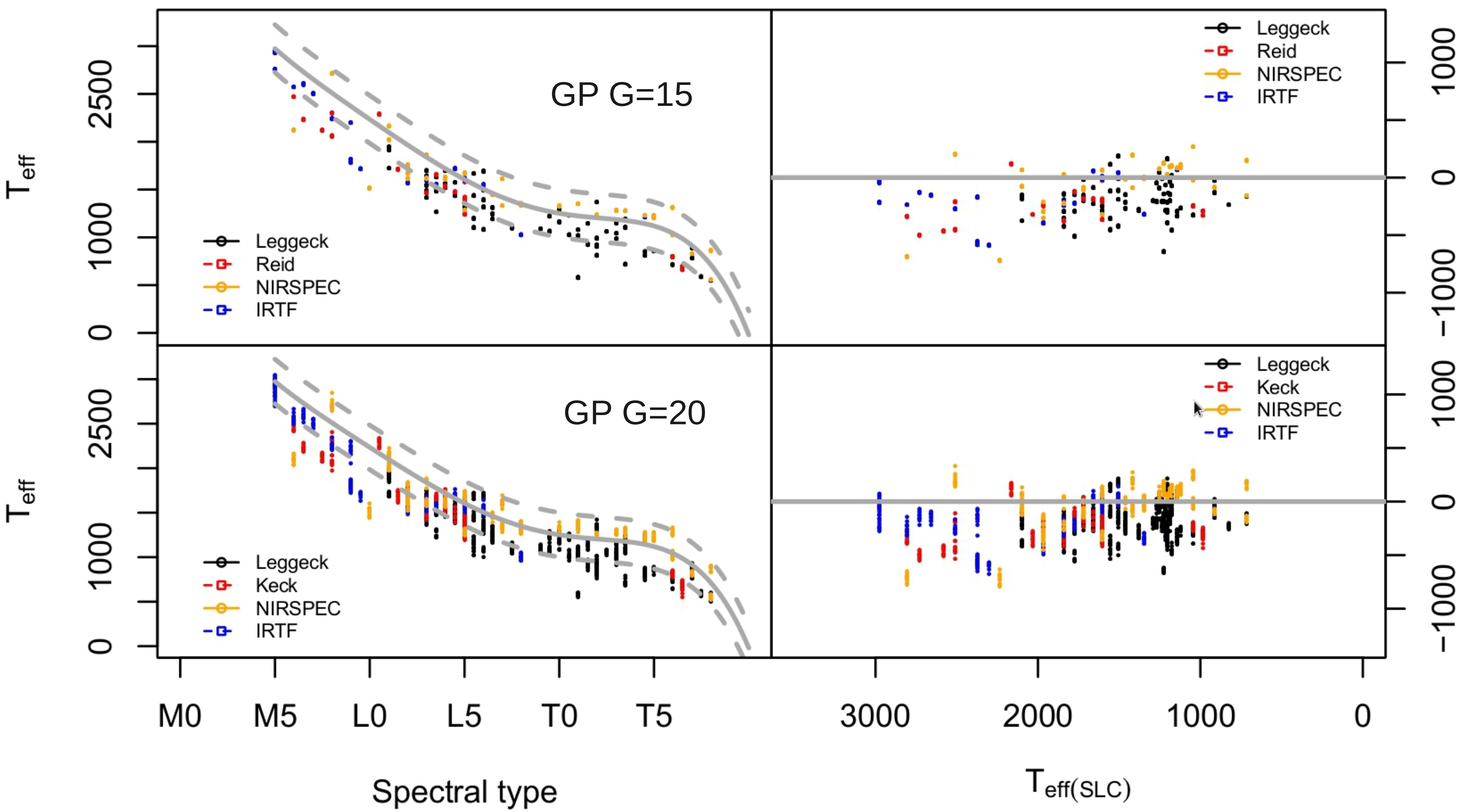


We have used Stephens, Leggett, Cushing et al. (2009) to convert spectral types to T_{eff}

Block 2 — ESP-UCD: Estimates of the prediction errors



Block 2 — ESP/UCD: Estimates of the prediction errors



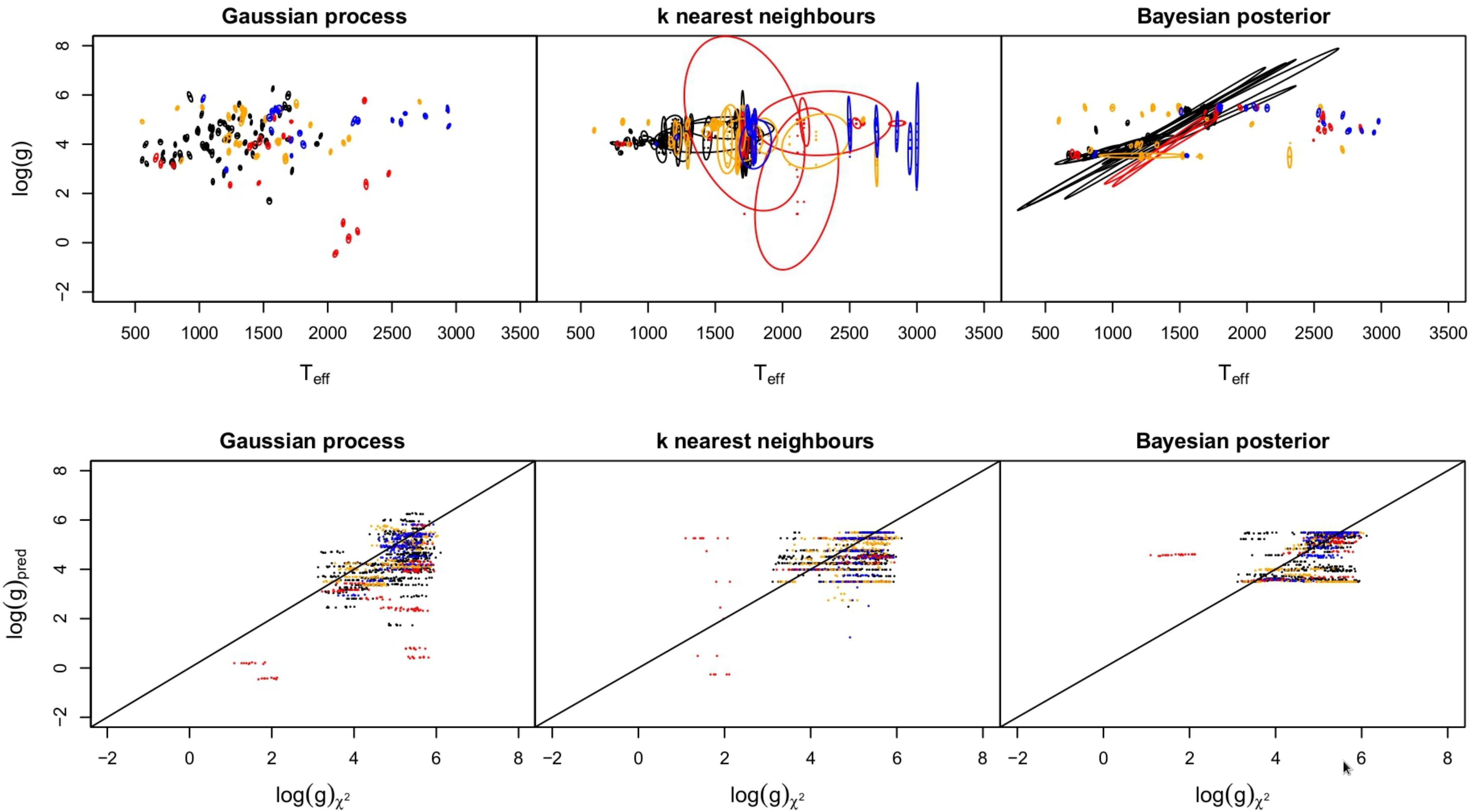
RMSE – χ^2 – full resolution spectra

Library	μ (BT-Settl)	σ (BT-Settl)	RMSE (BT-Settl)
Leggett	42	196	199
Reid	41	72	143
NIRSPEC	67	177	256
IRTF	53	63	126

RMSE – kNN/GP – RP

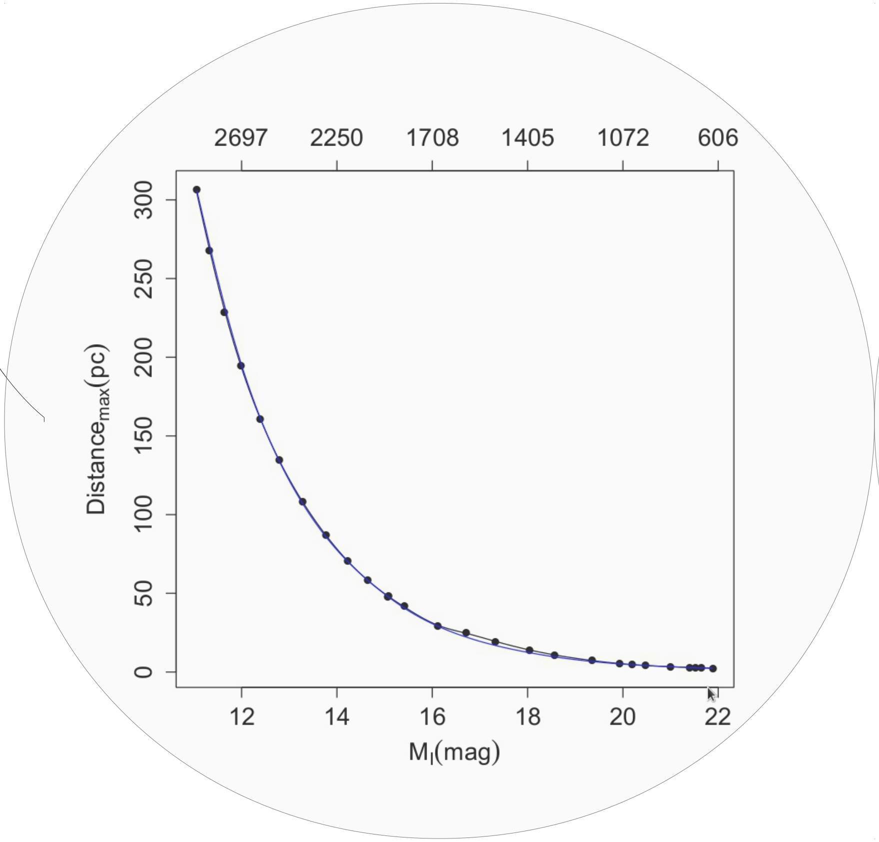
Number of transits	28			70		
G	15	18	20	15	18	20
GP-G20	257 (192)	260 (194)	266 (201)	256 (191)	257 (192)	260 (196)
PCA-GP-G20	266 (199)	270 (203)	281 (216)	264 (197)	266 (200)	272 (207)
kNN-G20	209	210	213	207	209	213
PCA-kNN-G20	211	213	215	209	207	210
Bayes BT-Settl	230.5	235.7	239.0	243.4	241.6	239.7
Bayes COND/DUSTY	252.6	252.3	255.0	257.5	257.6	258.0

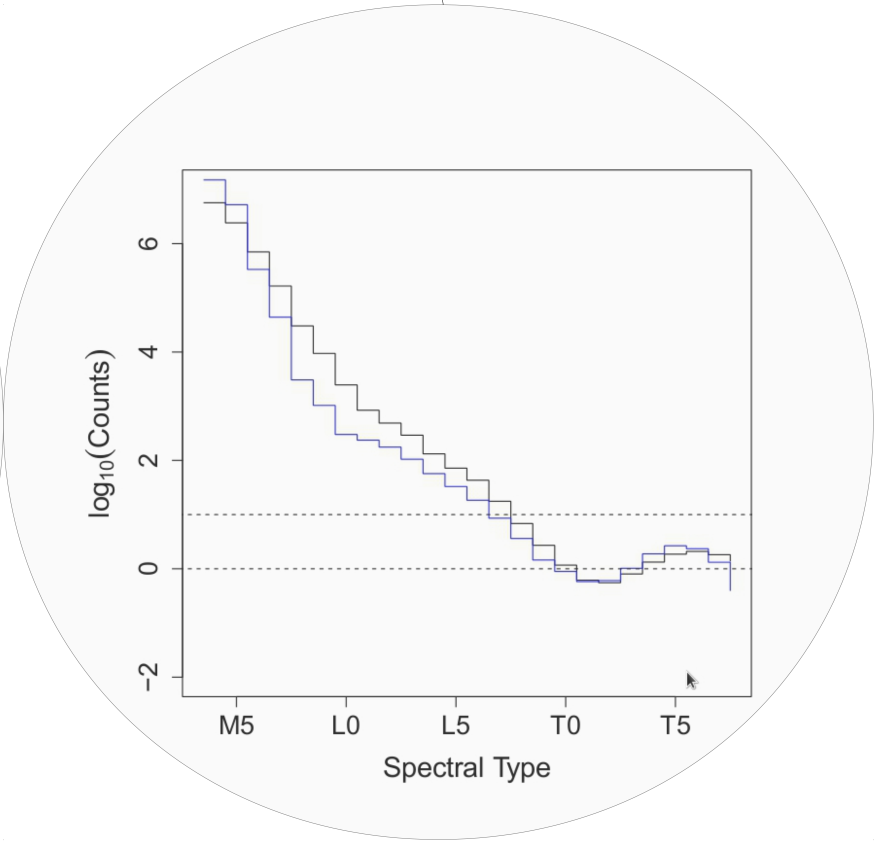
Block II — ESP-UCD: Prediction errors for logg



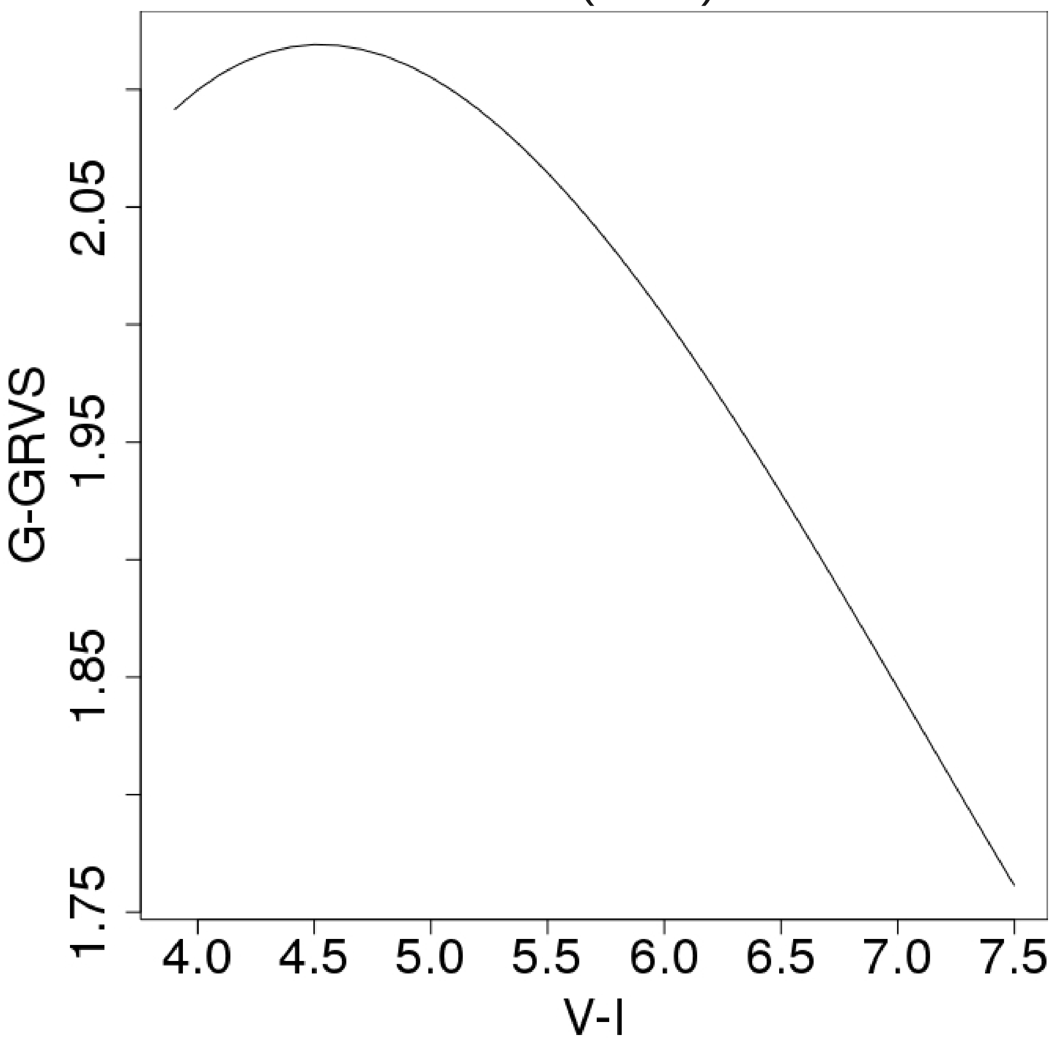
Procedure:

I. Asume local density as a function of spectral type (Caballero et al. 2008)
II. Asume a map between spectral types and temperatures (Stephens et al. 2009)
III. Asume a map between effective temperatures and absolute magnitudes
IV. For each spectral type compute the distance r at which a source would have G=20.
V. E[counts]=Density x Volume(r)





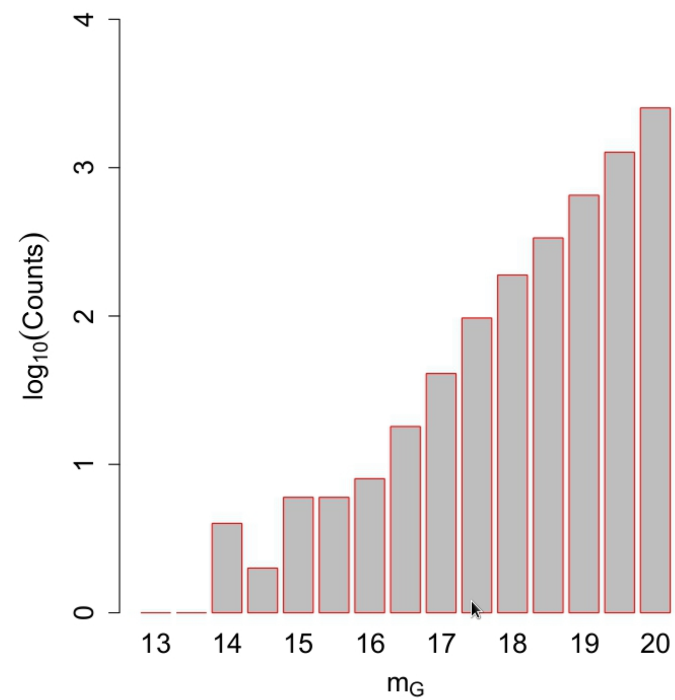
Jordi et al. (2010)



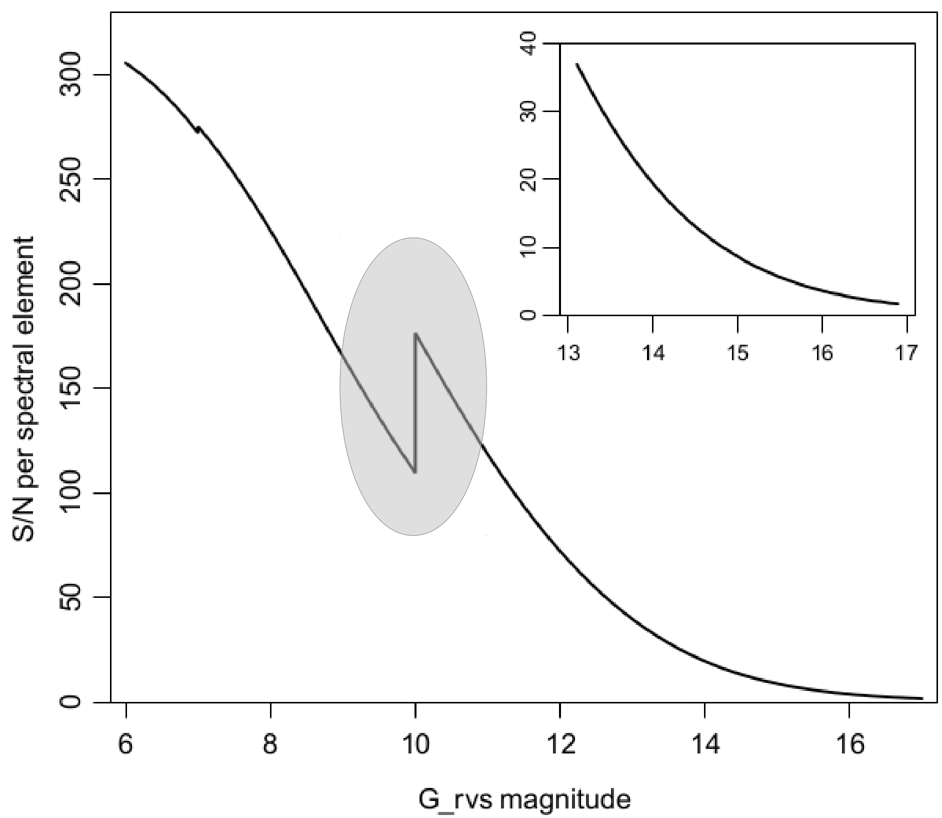
Expected range for UCDs according to BT Settl models

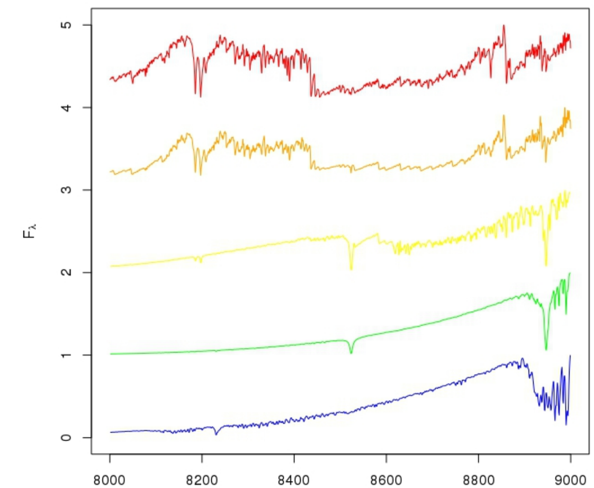
RVS limit at G_{RVS}=16

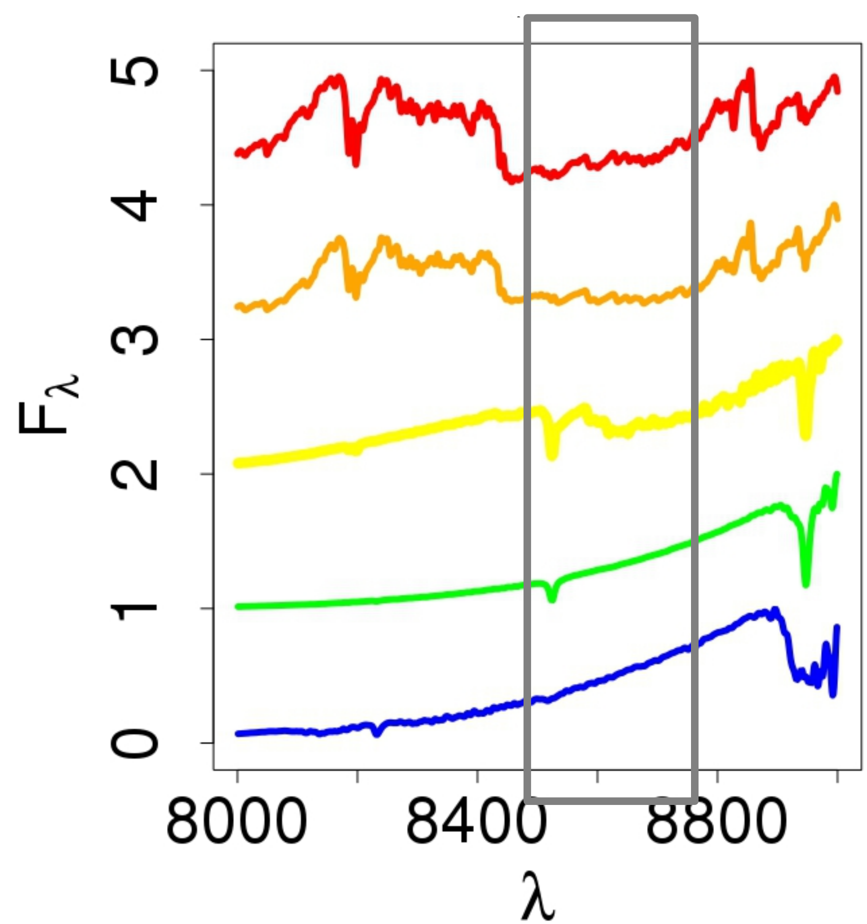
So, depending on V-I, this translates into $G_{lim} \in$ (18.1,17.75)



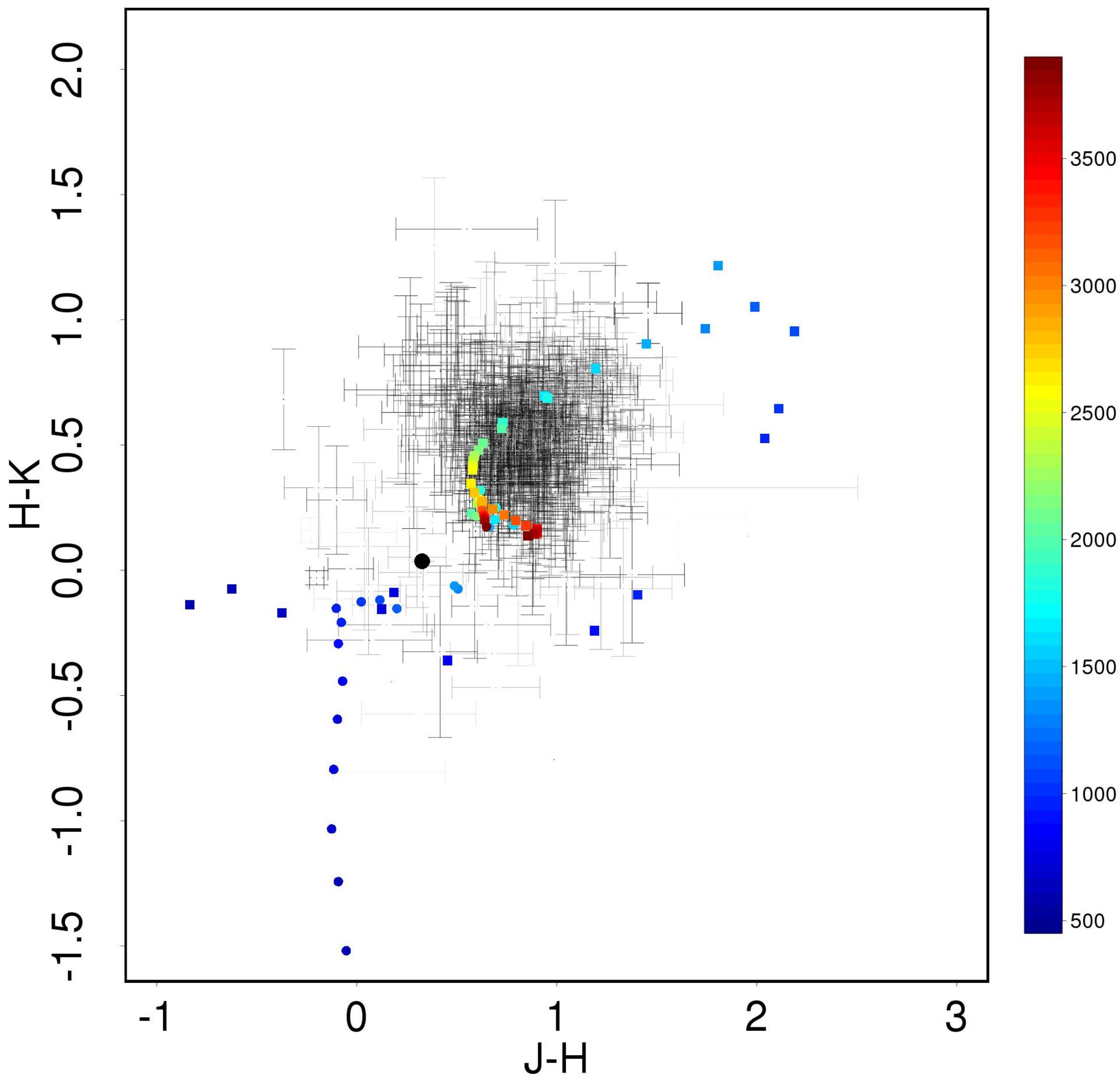
End-of-mission S/N per spectral element







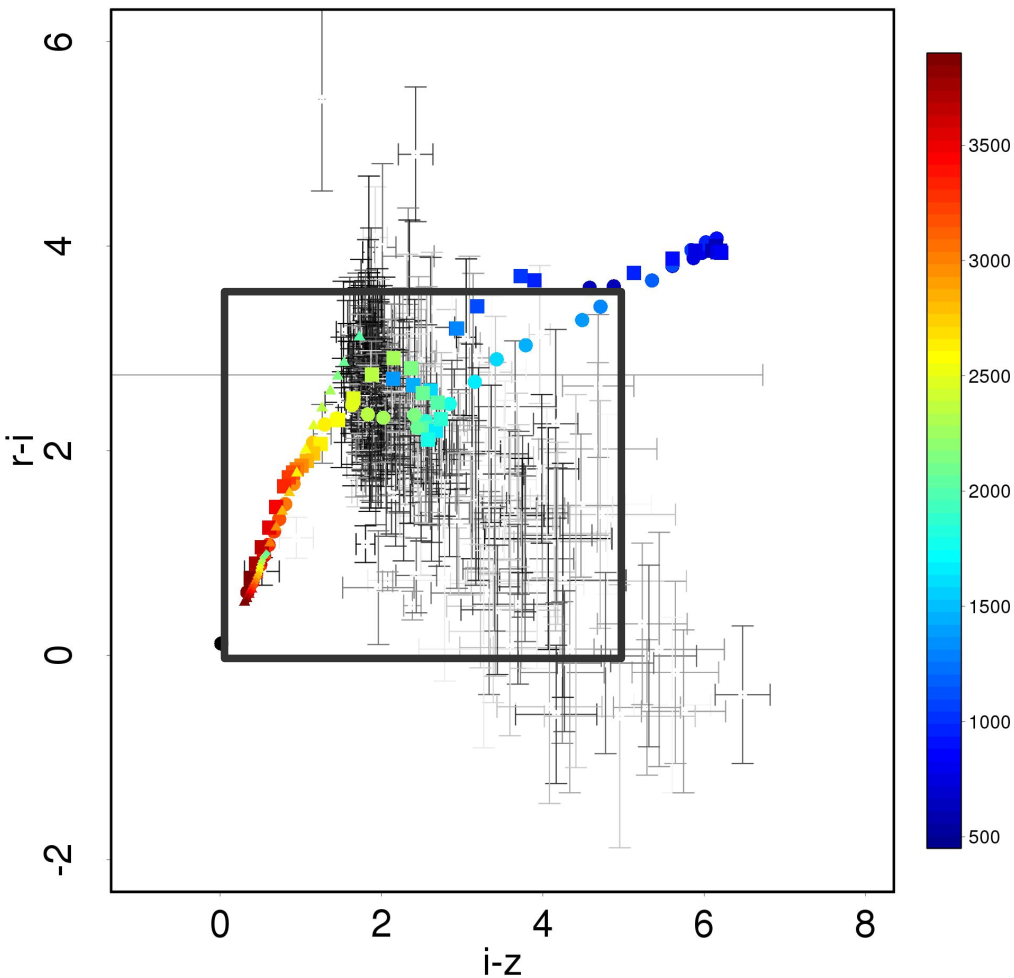
What known UCDs will we see with Gaia?



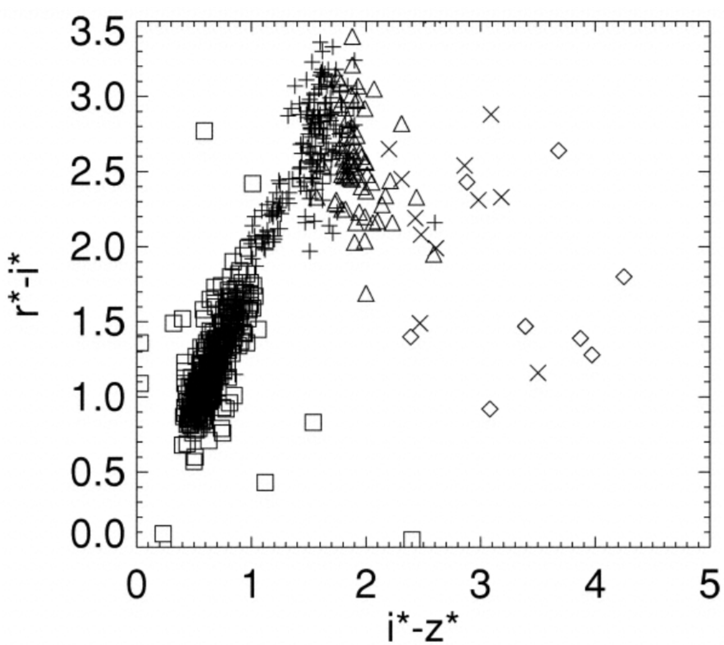
Cross match of Dwarf Archives with SDSS and UCAC

- 1281 sources in Dwarf Archives
- 948 with cross matches in SDSS/UCAC4
- 587 below 2 arcsec
- 484 below 1 arcsec
- 227 below 0.2 arcsec

What known UCDs will we see with Gaia?



CHARACTERIZATION OF M, L, AND T DWARFS IN THE SDSS
S.L. HAWLEY et al. (2002)



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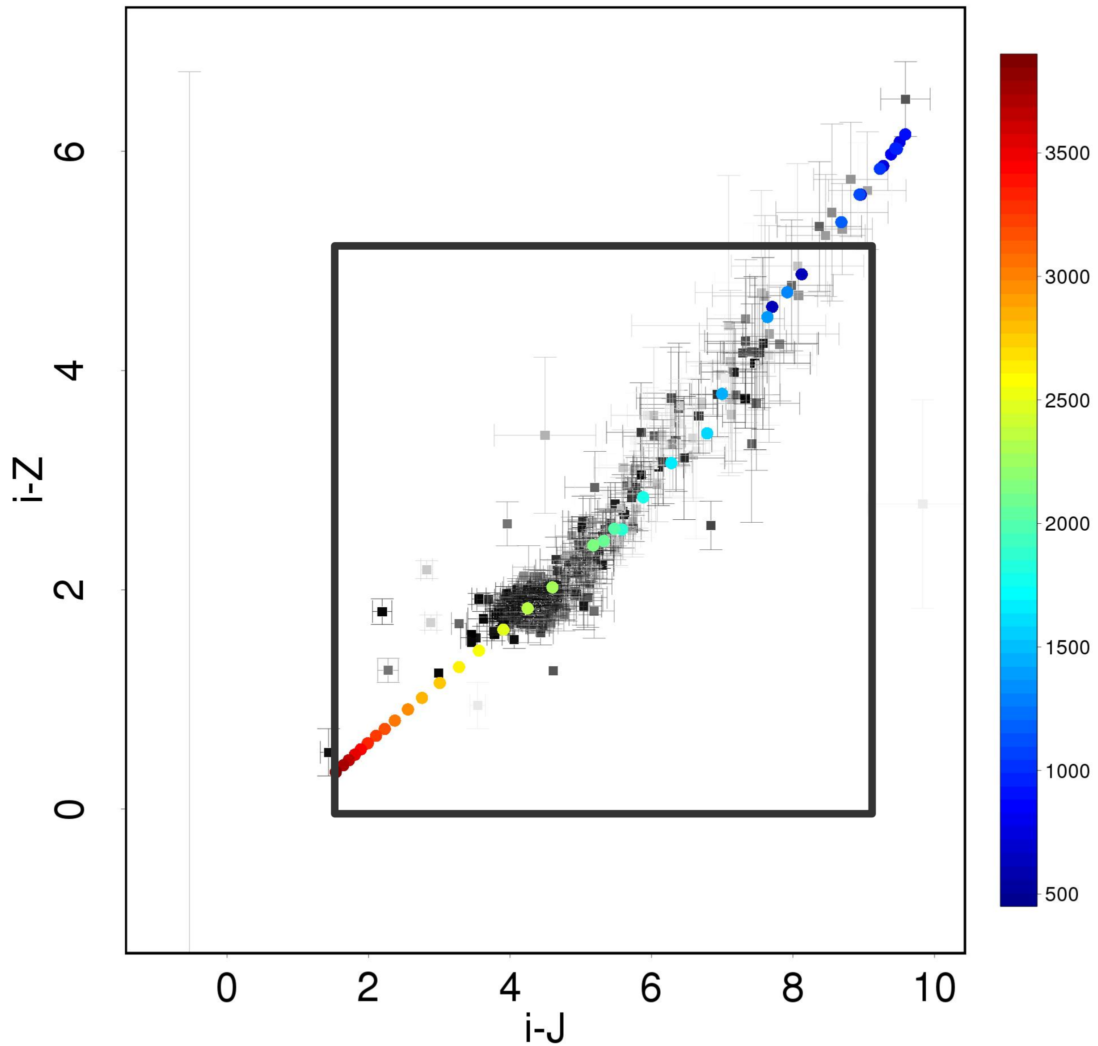

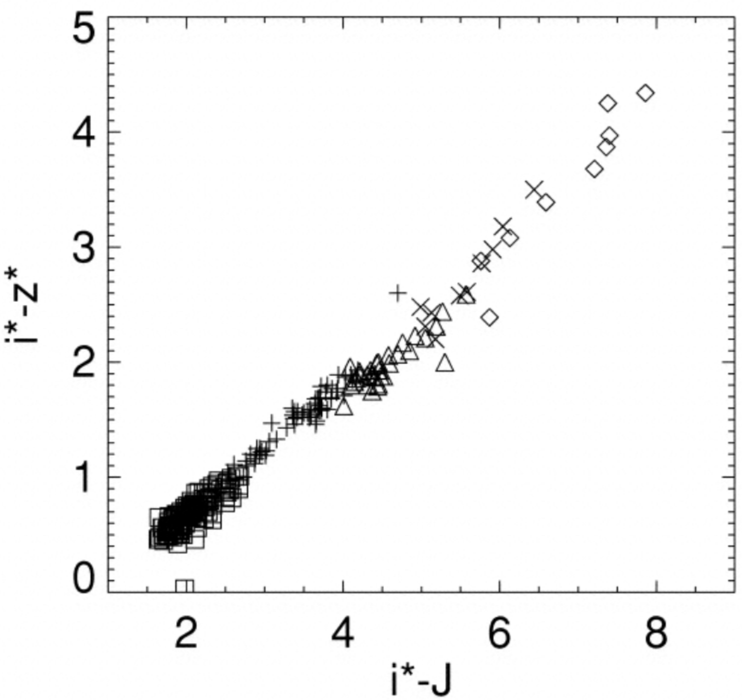

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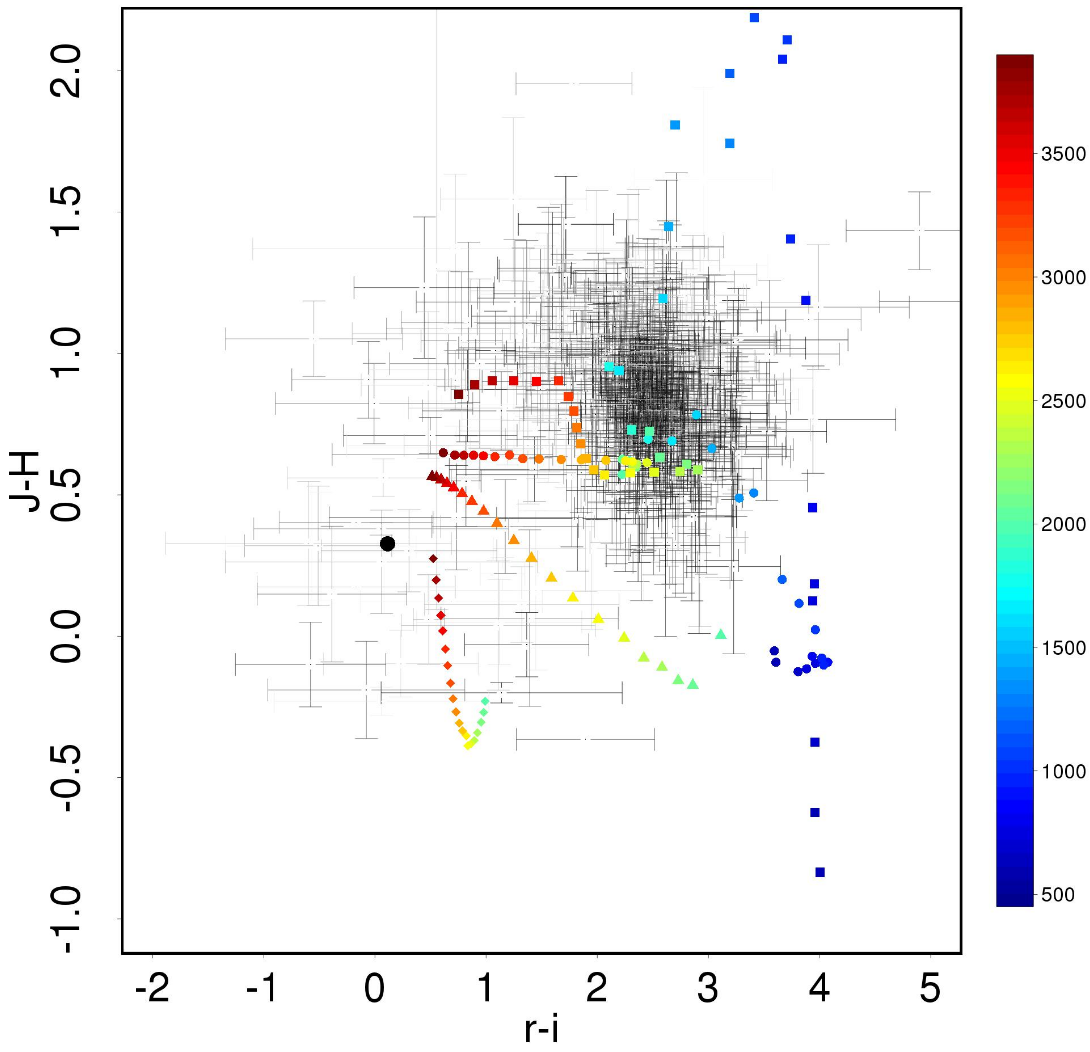
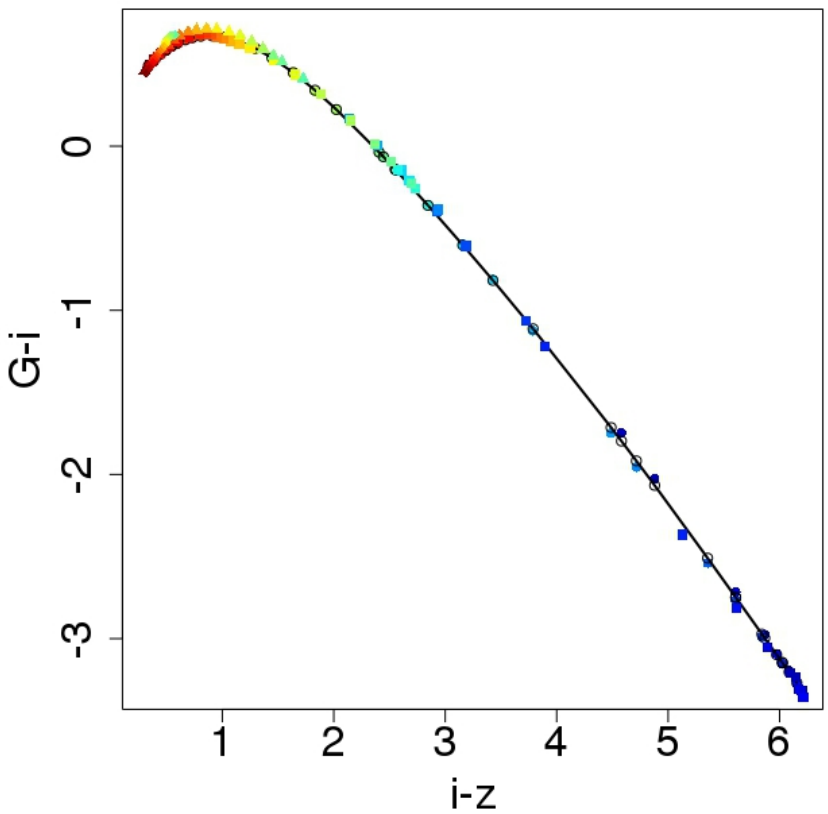
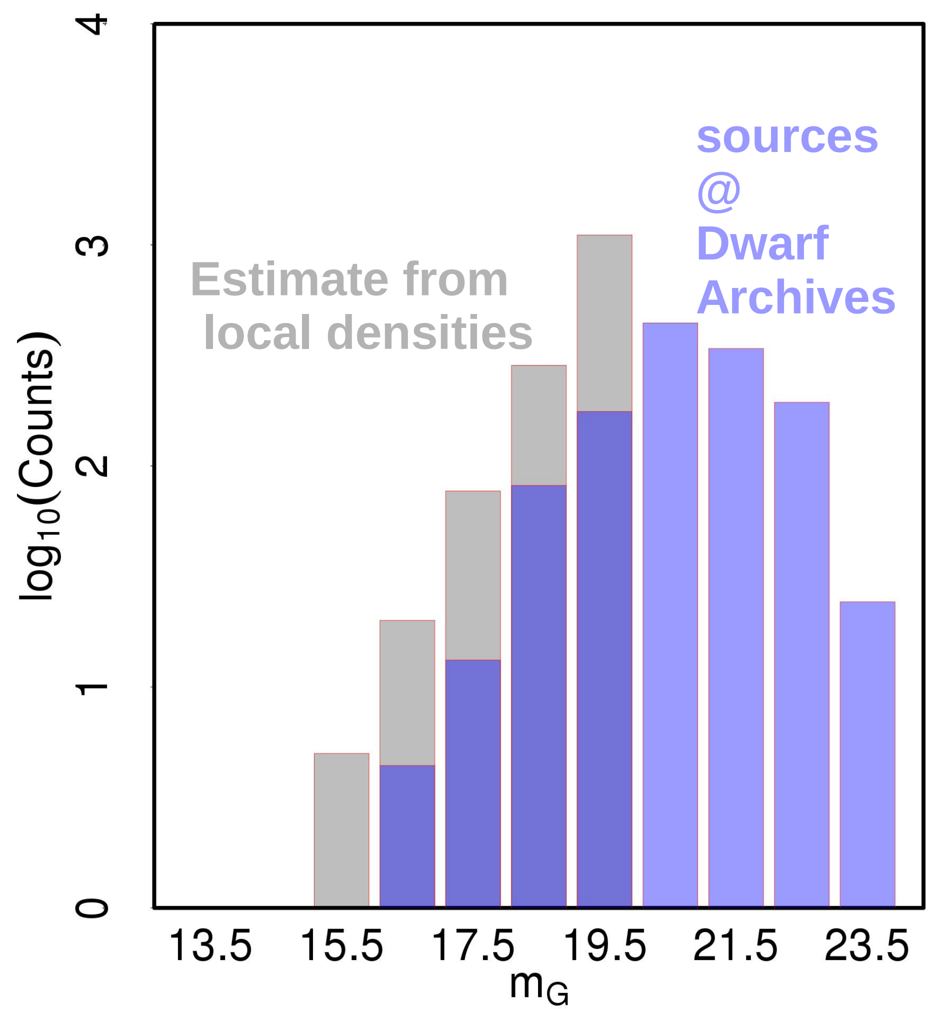
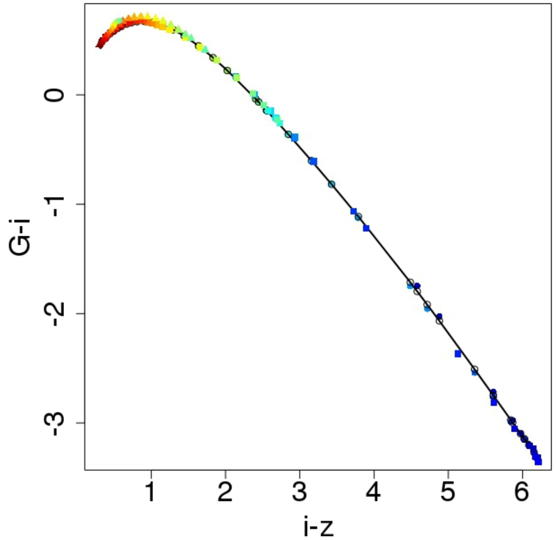


What known UCDs will we see with Gaia?

Corrected for the fraction of sources without counterparts.







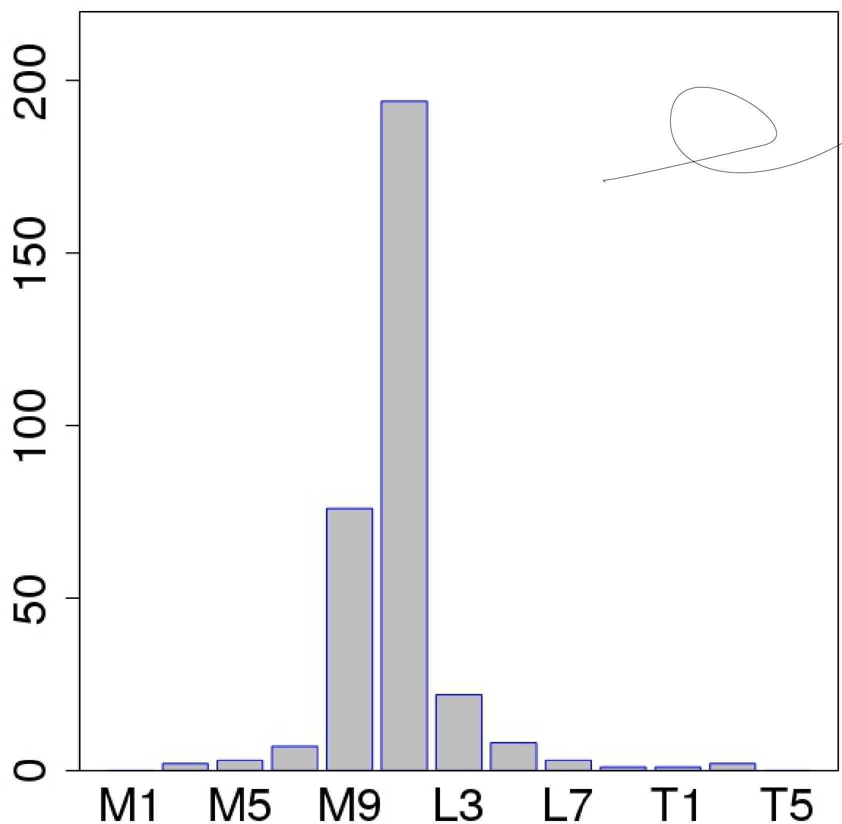
1- Compute expected apparent G from i-z and filter G > 21

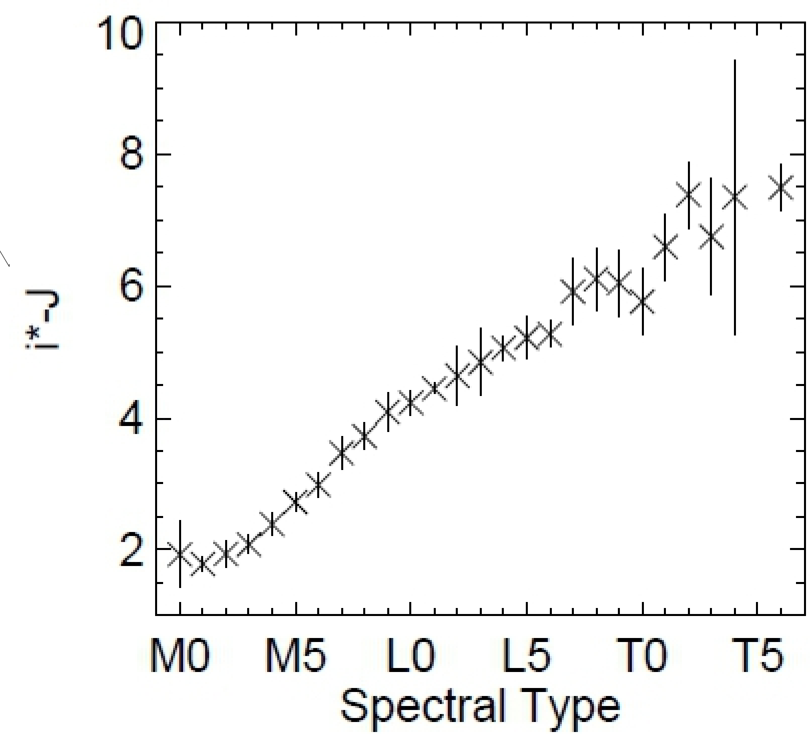
(i, z needed)

2- Compute spectral type from i-J and calibration from Hawley et al (2003)

(J needed)

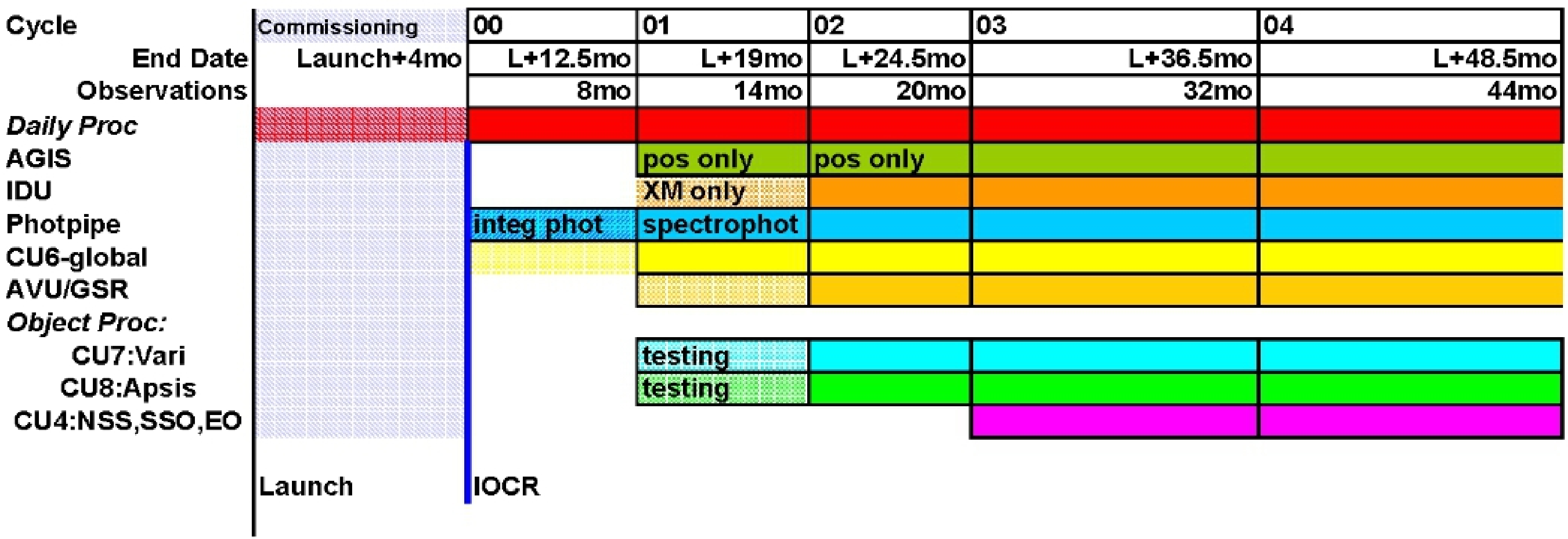
3- Histogram results





SFR	Distance	Age	Dimmest MI	Mass	Teff	Sp Type
rho Oph	120-145 pc	1 Myr	13.05	10	2247	L0
Taurus	140 pc	1-2 Myr	12.70	16	2364	M9
Serpens	260 pc	2 Myr	11.38	27	2563	M8
Cha I / II	140 pc	1-3 Myr	12.70	18	2394	M9
Lupus I / II / III	140 pc	1-3 Myr	12.70	18	2394	M9
IC348	385 pc	2-4 Myr	10.54	37	2703	M7
Tr37	800 pc	4 Myr	7.83	201	3232	M7
Sigma Ori	400 pc	3-5 Myr	10.45	42	2752	M7
Collinder 69	400 pc	5-10 Myr	10.45	49	2794	M7
Upper Sco	145pc	5 Myr	12.62	21	2435	M8
NGC7160	800 pc	10 Myr	7.83	317	3380	M7
IC2391	175 pc	30-55 Myr	12.21	45	2635	M7
IC2602	160 pc	30-50 Myr	12.41	42	2601	M7
IC4665	350 pc	45 Myr	10.77	91	2950	M7
Alpha Per	185 pc	80 Myr	12.09	60	2707	M7
Blanco 1	270 pc	100 Myr	11.31	83	2876	M7
Pleiades	150 pc	125 Myr	12.55	58	2638	M7
Hyades	50 pc	600 Myr	14.99	37	2202	L0
Praesepe	187 pc	800 Myr	12.07	72	2750	M7

Context III: Data processing cycles



- DR1: L+22M – RA, Dec, G, HTPM (Hipparcos), 90% single sources
- DR2: L+28M – DR1 + PPM & parallax (90% sky), BP & RP, APs, V_{rad} (90% bright stars)
- DR3: L+40M – DR2 + binaries + Class & APs + RVS
- DR4: L+65 – DR3 + Variability + SSO + non-single
- FR: End-of-mission + 3 years