



Key Issues in Choosing Targets for Direct Imaging of Earths

I. Scientific Objectives

(1) Achieve a 95% probability of detecting an Earth in the habitable zone

(2) Characterize those planets

II. Astrophysical Constraints

(3) Eta_Earth: Spec for $\sim 10\%$

**(4) Exozodiacal Dust:
Spec for 100 zodis**

(5) Background sources

(6) True locations on the sky

III. Engineering, Cost Constraints

Assume Some Baseline:

- 65 mas IWA
- 4×10^{-11} limiting FPB (26 mag)
- 4-m telescope

50% throughput

V band

1-m

4-m

8-m

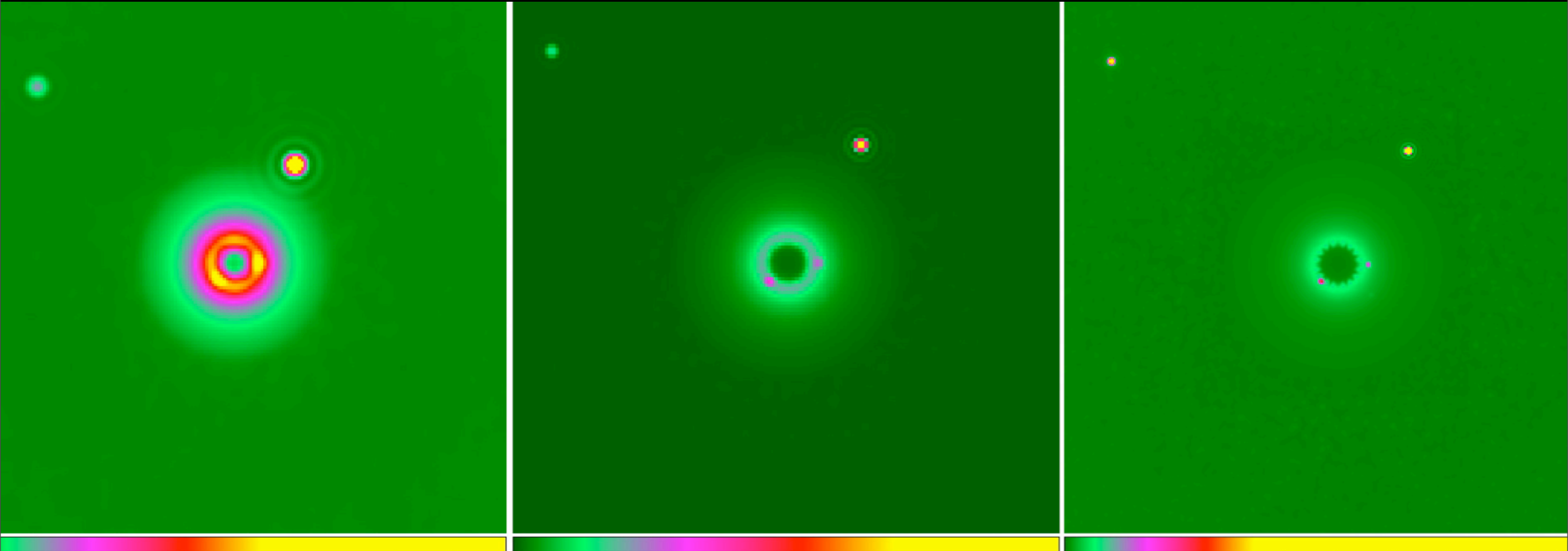


Image credit: T. Glassman

Dust models:

Kuchner & Stark 2010

Kelsall et al. 1998 + zodipic

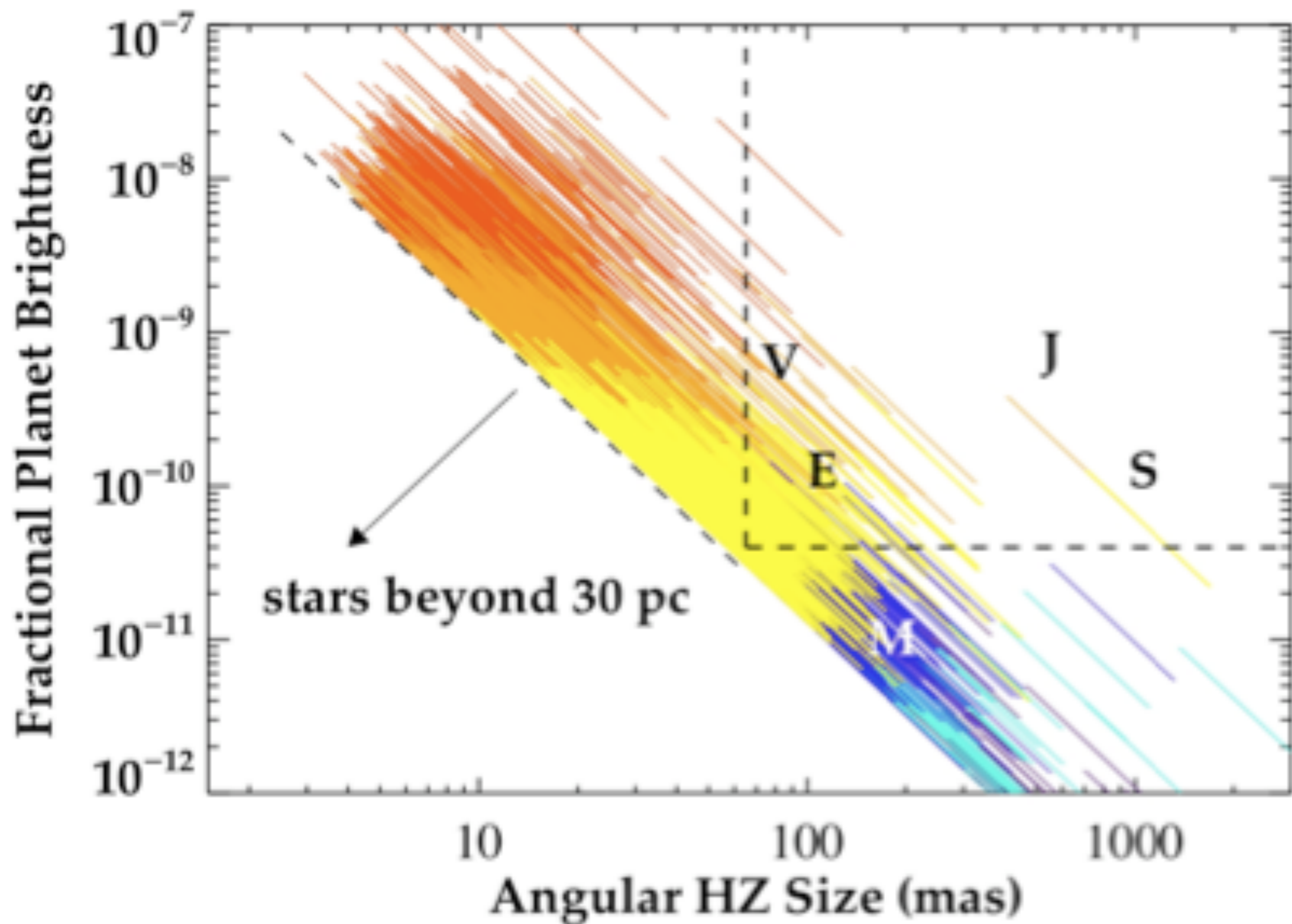
Mission Critical:

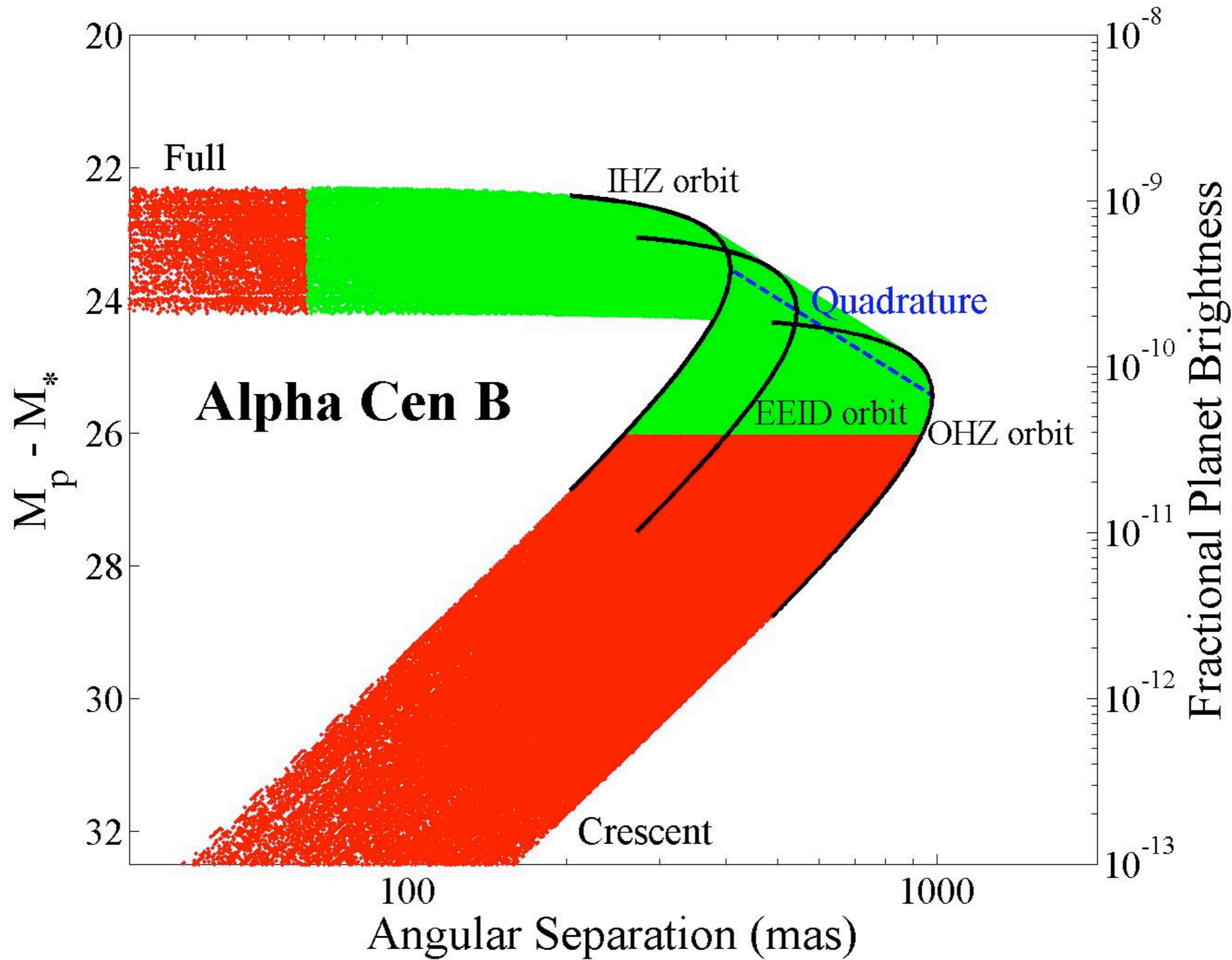
(1) What is the minimum number of targets we must acquire in order to execute a successful mission?

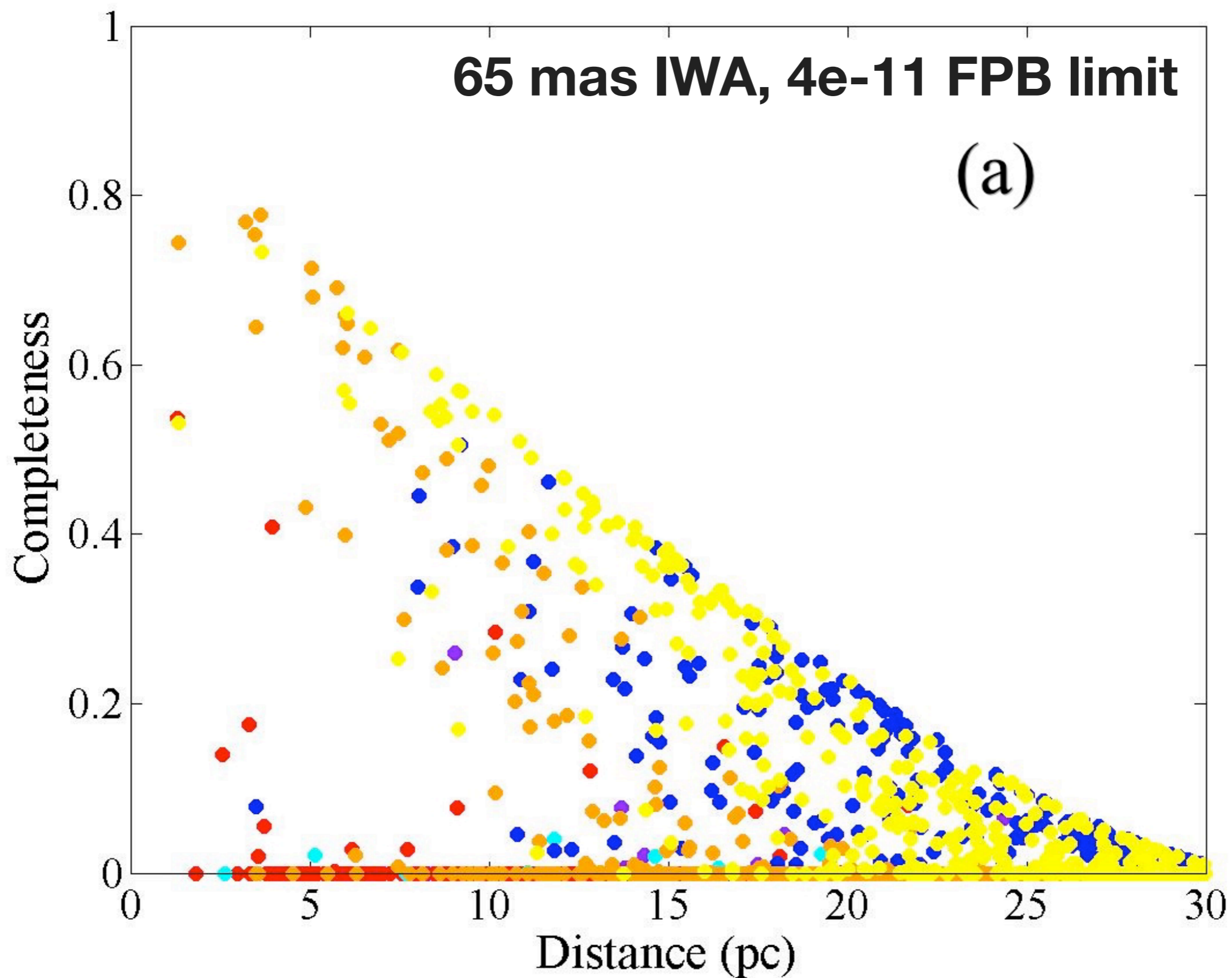
(2) Which ones are they and do they make “good” targets in terms of habitability and detectability of planets?

Stars in the 30-pc Hipparcos Sample

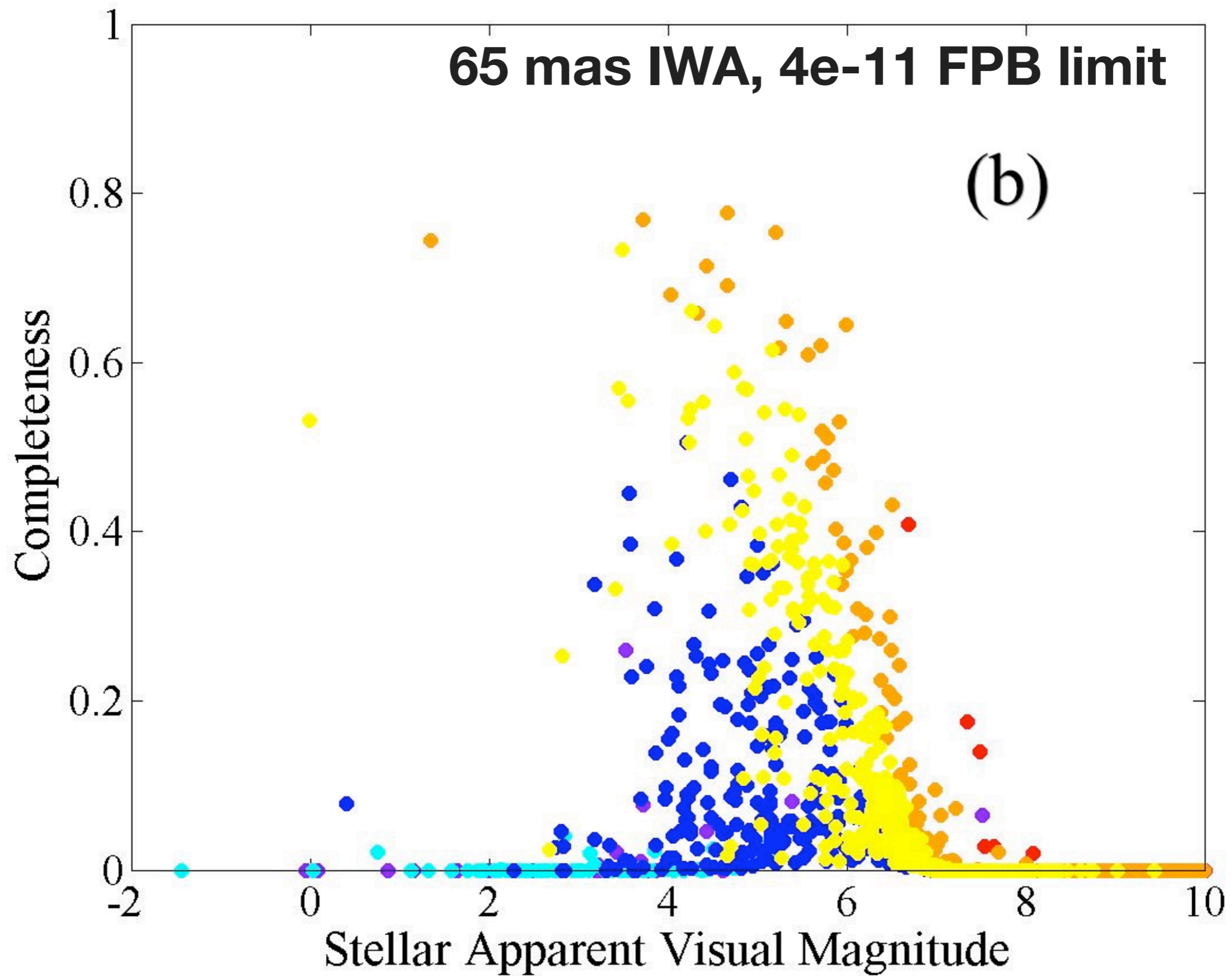
Spec Type	N _{HIP30}	d _{comp} (pc)	N(30pc)	% _{HIP30}
B	4	30	4	100
A	59	30	59	100
F	243	30	243	100
G	436	30	436	100
K	781	16	936	83
M	678	4	4640	15
giants	36	30	36	100
sub-MS	62	--	--	--
no data	51	--	--	--
total	2350	--	6354	37%



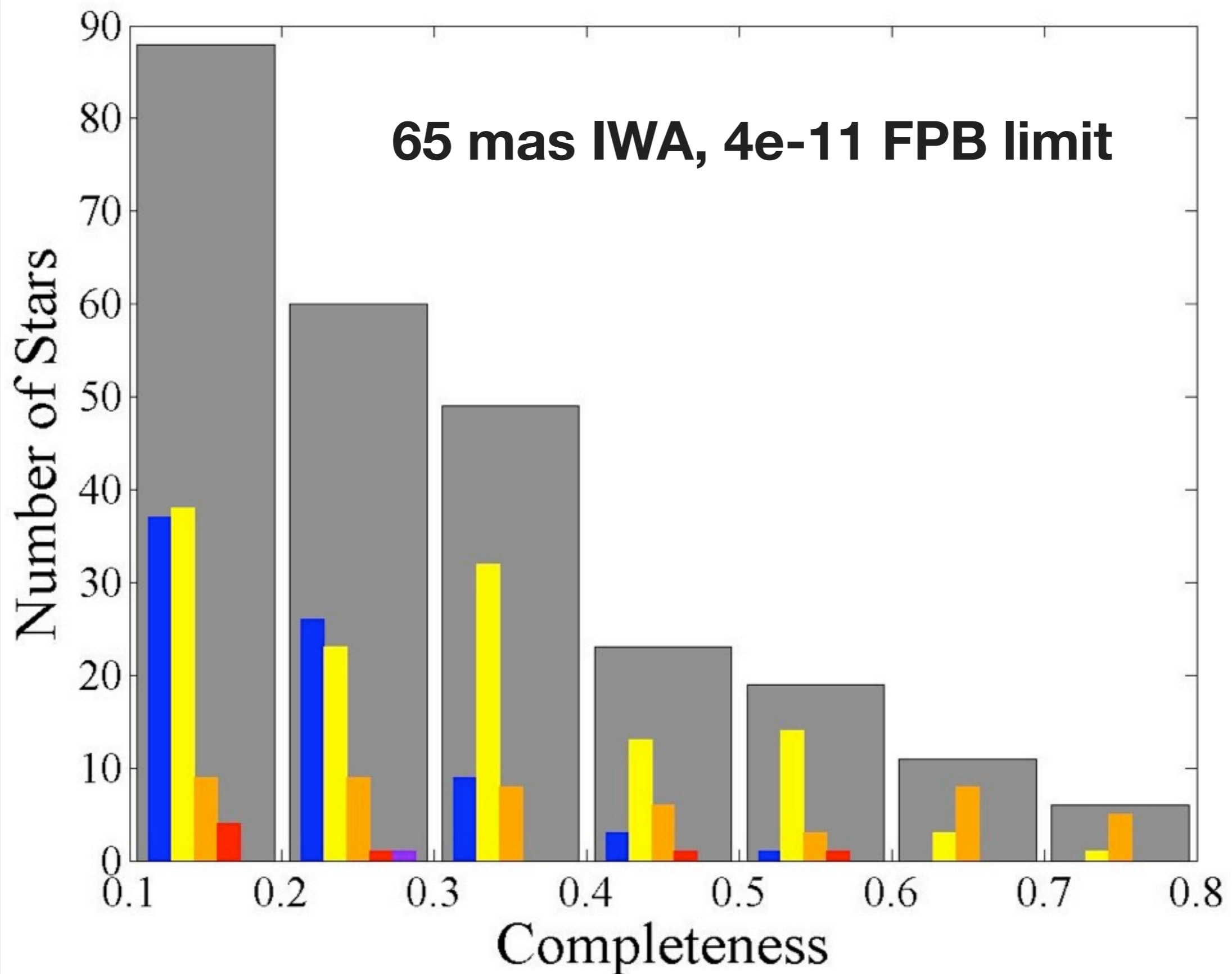




Ask: What is the minimum # of targets for success?



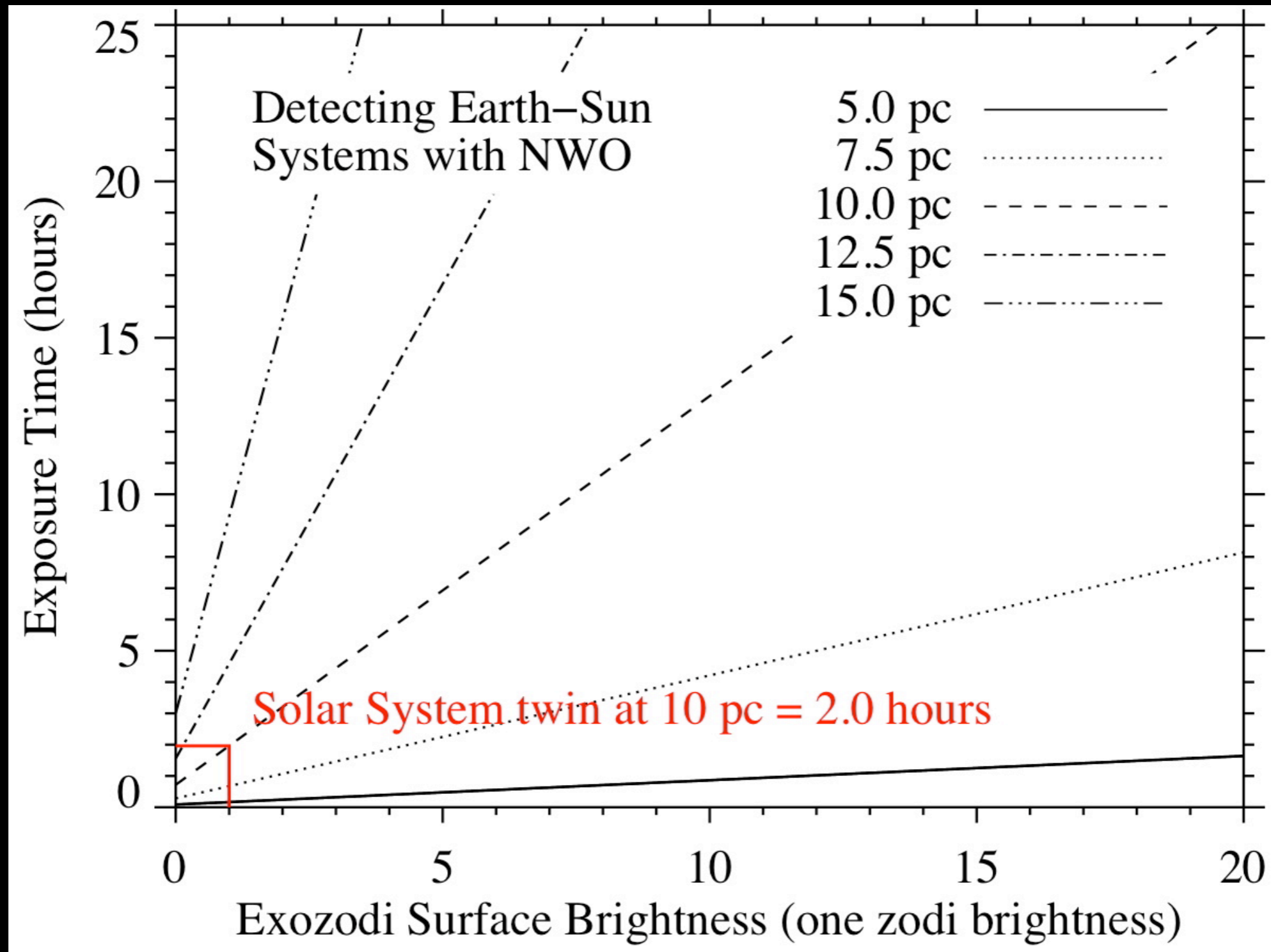
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Assigning “Priority” to the Stars

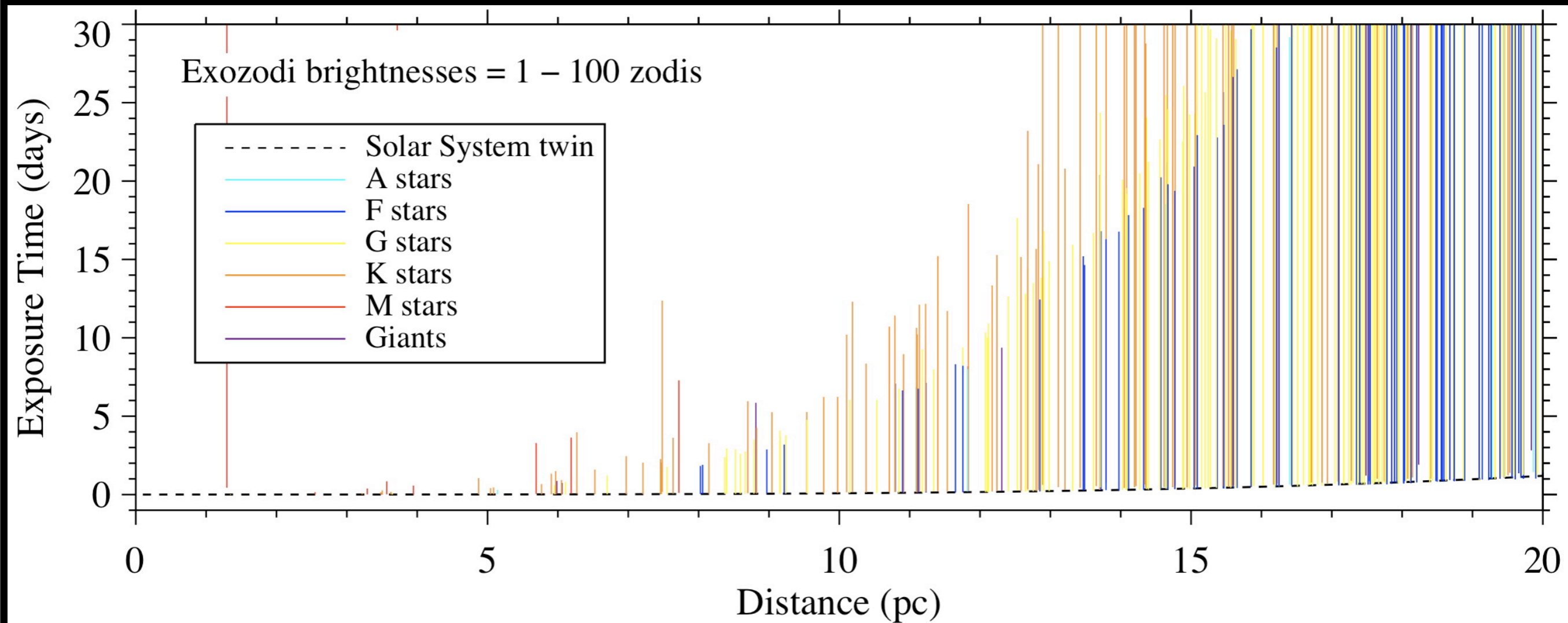
Priority = Completeness / Exposure Time



Ask: What is the minimum # of targets for success?

Assigning “Priority” to the Stars

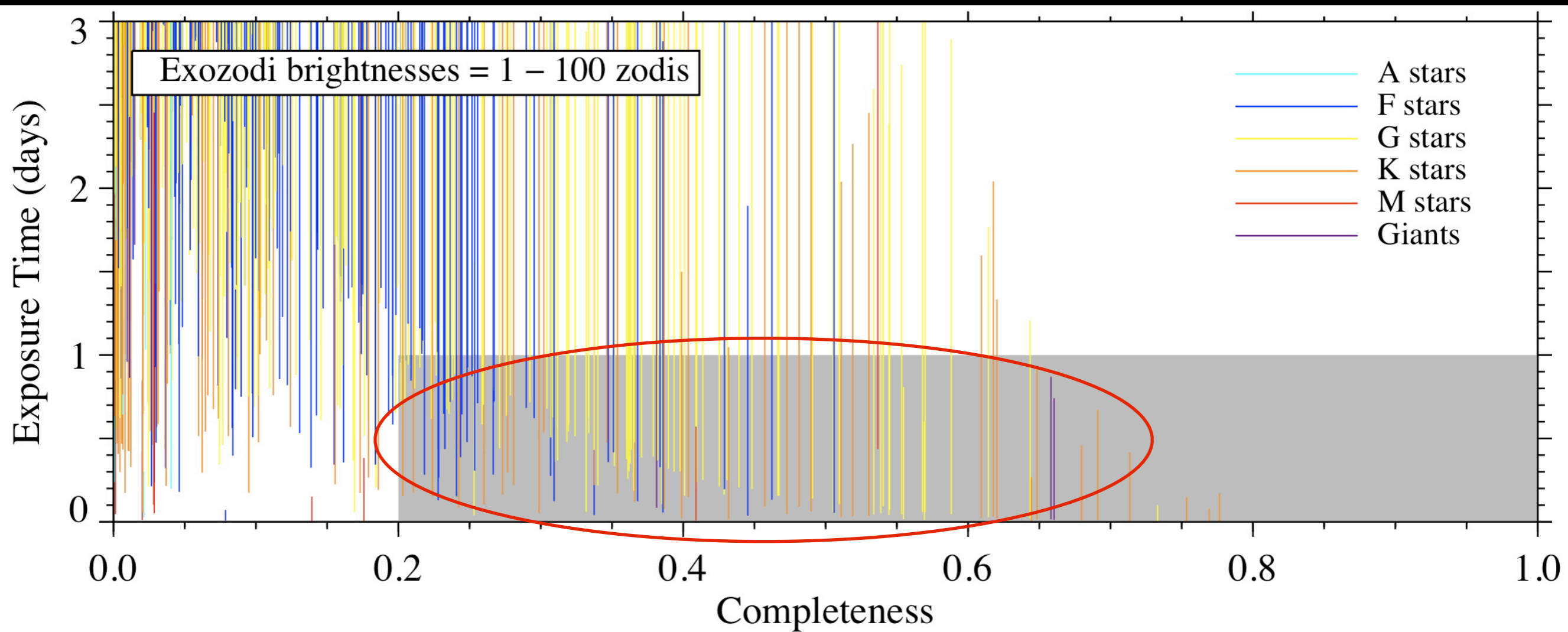
Priority = Completeness / Exposure Time



Ask: What is the minimum # of targets for success?

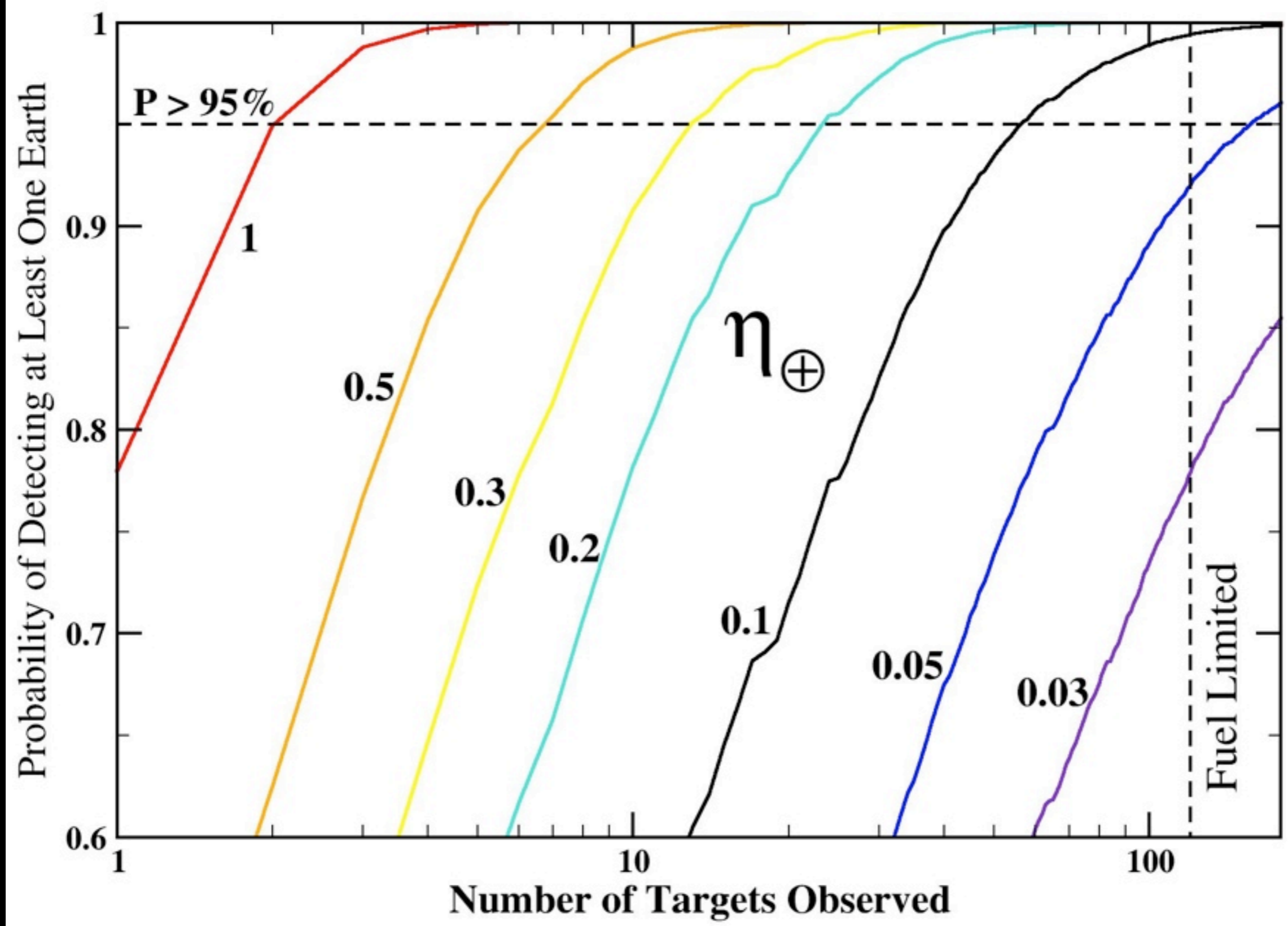
Assigning “Priority” to the Stars

$$\text{Priority} = \text{Completeness} / \text{Exposure Time}$$



Ask: What is the minimum # of targets for success?

Eta Earth and Probability of Mission Success



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Minimum Number of Targets for Mission Success

Medium Exozodi Brightness ($\epsilon = 1.0$)									
η_{\oplus}	0.03	0.05	0.06	0.08	0.1	0.2	0.3	0.5	1
N_{targets}	>671	158	119	79	57	24	13	7	2
$\overline{C_n}$	0.13	0.38	0.42	0.46	0.52	0.60	0.70	0.74	0.77
$\sum_n C_n$	90	59	50	37	29	14	9.1	5.2	1.5
$\langle N_{\text{php}} \rangle$	2.7	3	2.9	2.9	2.9	2.9	2.7	2.6	1.5

Minimum Number of Targets for Mission Success

		dM = 25 mag			dM = 26 mag			dM = 27 mag		
		$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$	$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$	$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$
IWA = 50 mas	A stars	0	0	0	0	0	0	2	0.3	2
	F stars	3	0.4	7	5	2	11	5	3	11
	G stars	21	8	75	18	10	42	13	10	24
	K stars	35	18	151	21	15	35	19	15	28
	M stars	7	2	18	4	2	4	4	2	4
	TOTALS	66	29	251	48	29	93	43	29	68
	max dist	12 pc			10 pc			9 pc		
	t_{tel}	573 days			251 days			197 days		
	t_{travel}	726 days			528 days			473 days		
	t_{tot}	3.6 years			2.1 years			1.8 years		

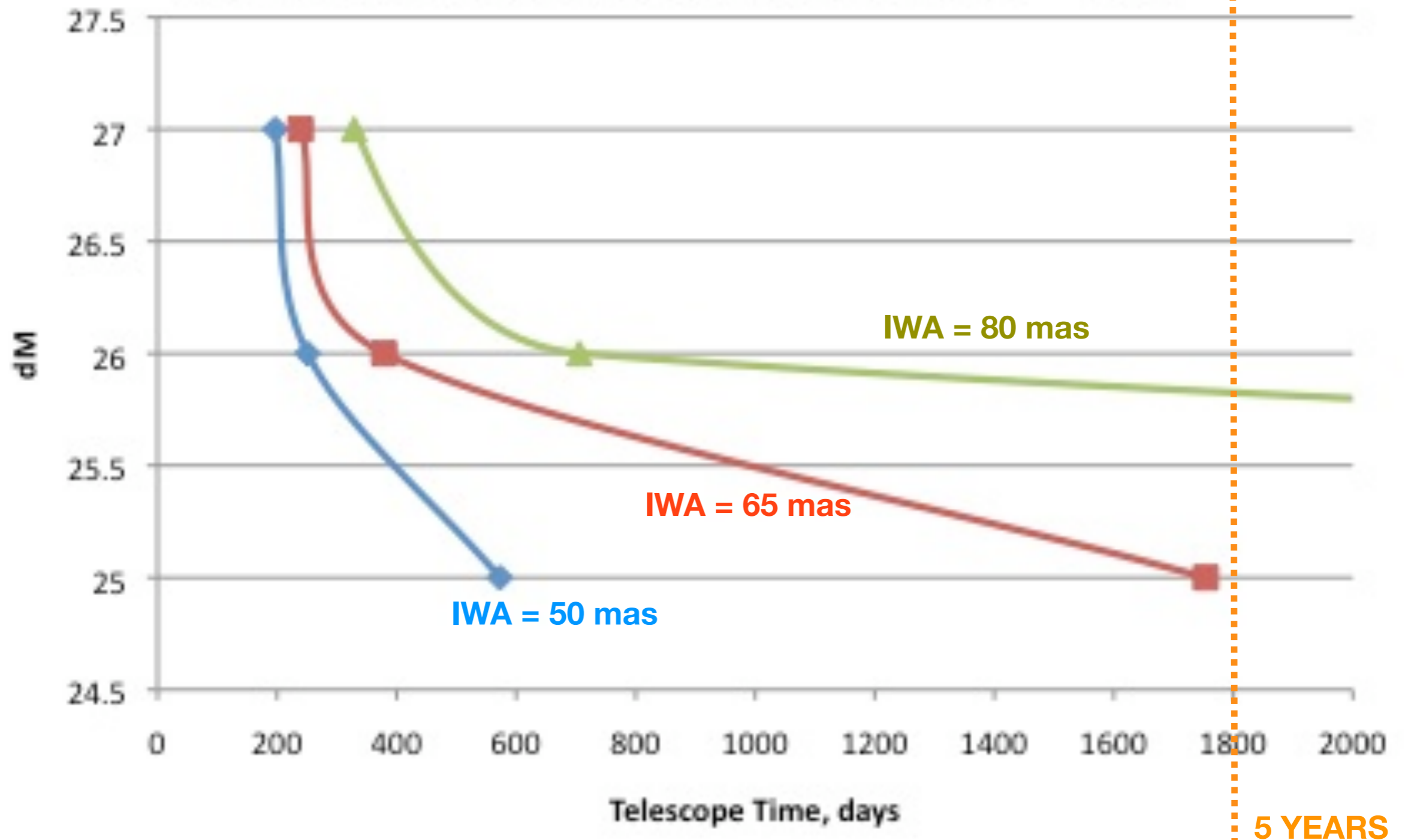
Minimum Number of Targets for Mission Success

		dM = 25 mag			dM = 26 mag			dM = 27 mag		
		$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$	$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$	$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$
IWA = 65 mas	A stars	0	0	0	1	0.02	1	2	0.3	2
	F stars	9	1	66	6	2.2	19	5	2.9	11
	G stars	54	11	669	22	12	70	18	12.4	42
	K stars	46	15	329	25	14	59	19	12.8	28
	M stars	7	1	58	3	1	3	3	0.7	3
	TOTALS	116	29	1122	57	29	152	47	29	86
	max dist	16 pc			12 pc			10 pc		
	t_{tel}	1754 days			379 days			239 days		
	t_{travel}	1276 days			627 days			517 days		
	t_{tot}	8.3 years			2.8 years			2.1 years		

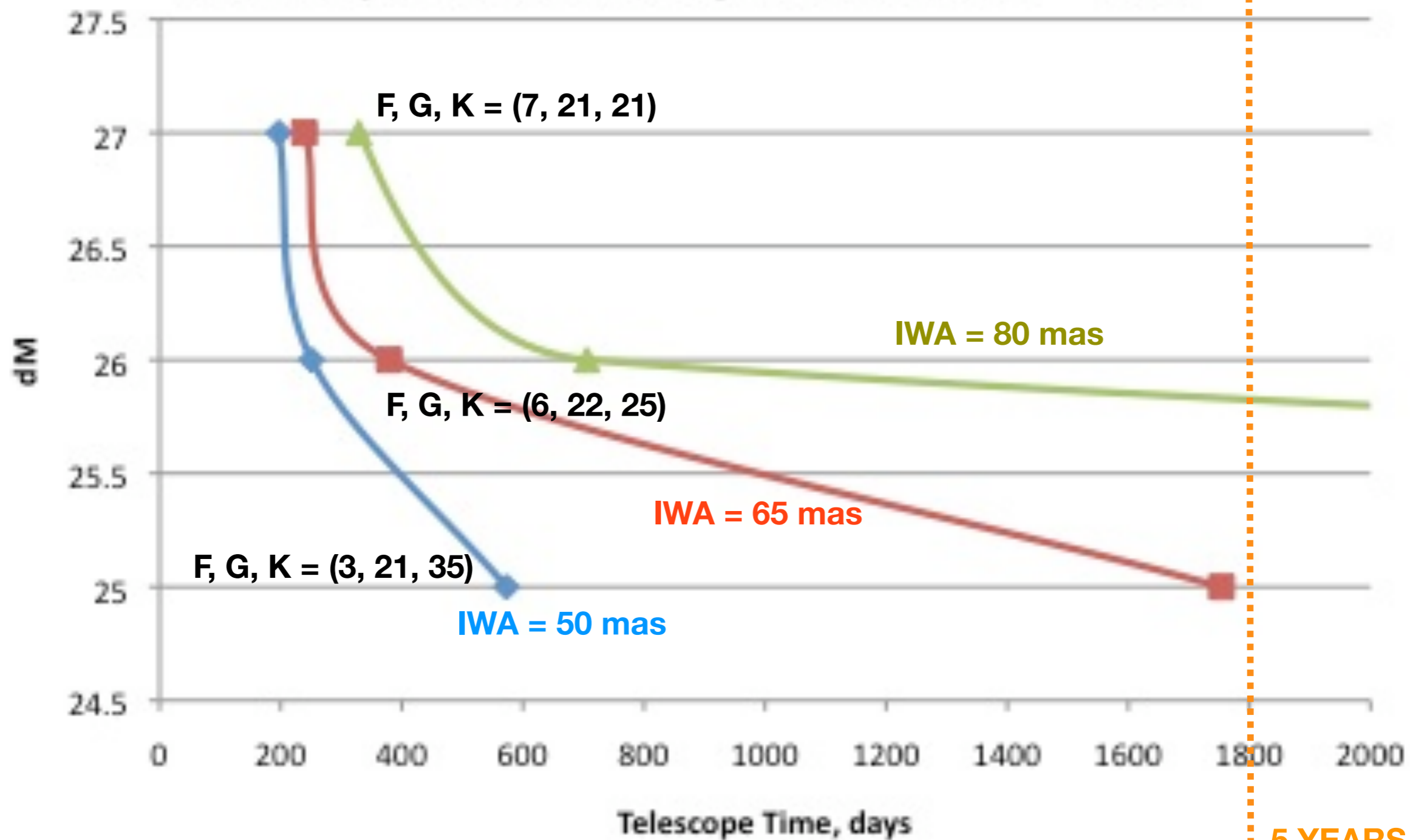
Minimum Number of Targets for Mission Success

		dM = 25 mag			dM = 26 mag			dM = 27 mag		
		$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$	$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$	$N_{targets}$	$\sum_n C_n$	$t_{det} (d)$
IWA = 80 mas	A stars	NA	NA	NA	1	0.02	1	2	0.3	2
	F stars	NA	NA	NA	11	3	60	7	4	25
	G stars	NA	NA	NA	32	14	197	21	13	61
	K stars	NA	NA	NA	28	11	83	21	11	37
	M stars	NA	NA	NA	3	0.2	3	1	0.2	1
	TOTALS	--	--		75	29	343	52	29	126
	max dist		--			13 pc			11 pc	
	t_{tel}		--			706 days			329 days	
	t_{travel}		--			825 days			572 days	
	t_{tot}		--			4.2 years			2.5 years	

Telescope Time for Eight Missions: "95%"



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5 YEARS

What is happening here?

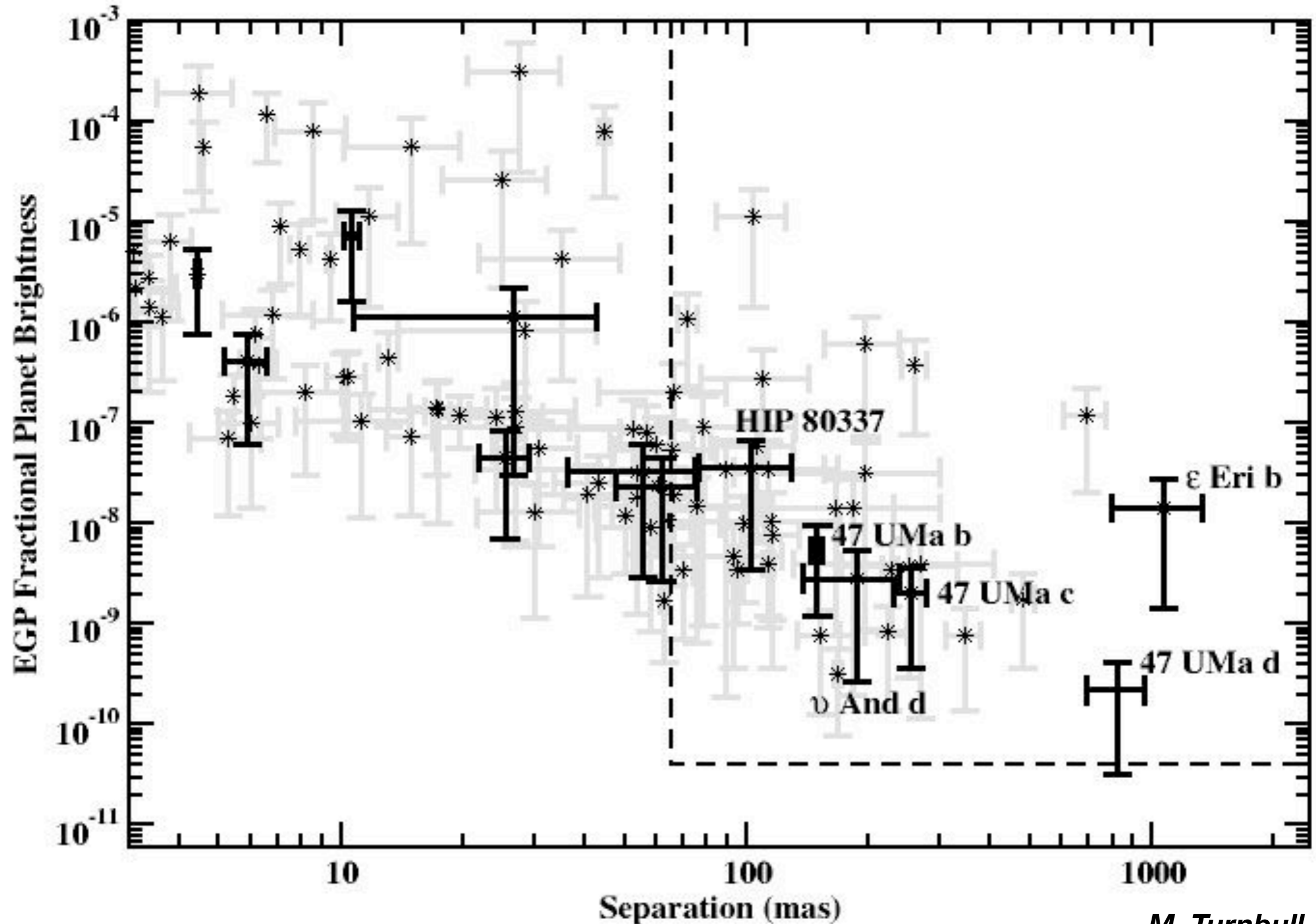
Baseline: dM = 26, IWA = 65mas

Highest Priority Targets in the Search for Habitable Exoplanets

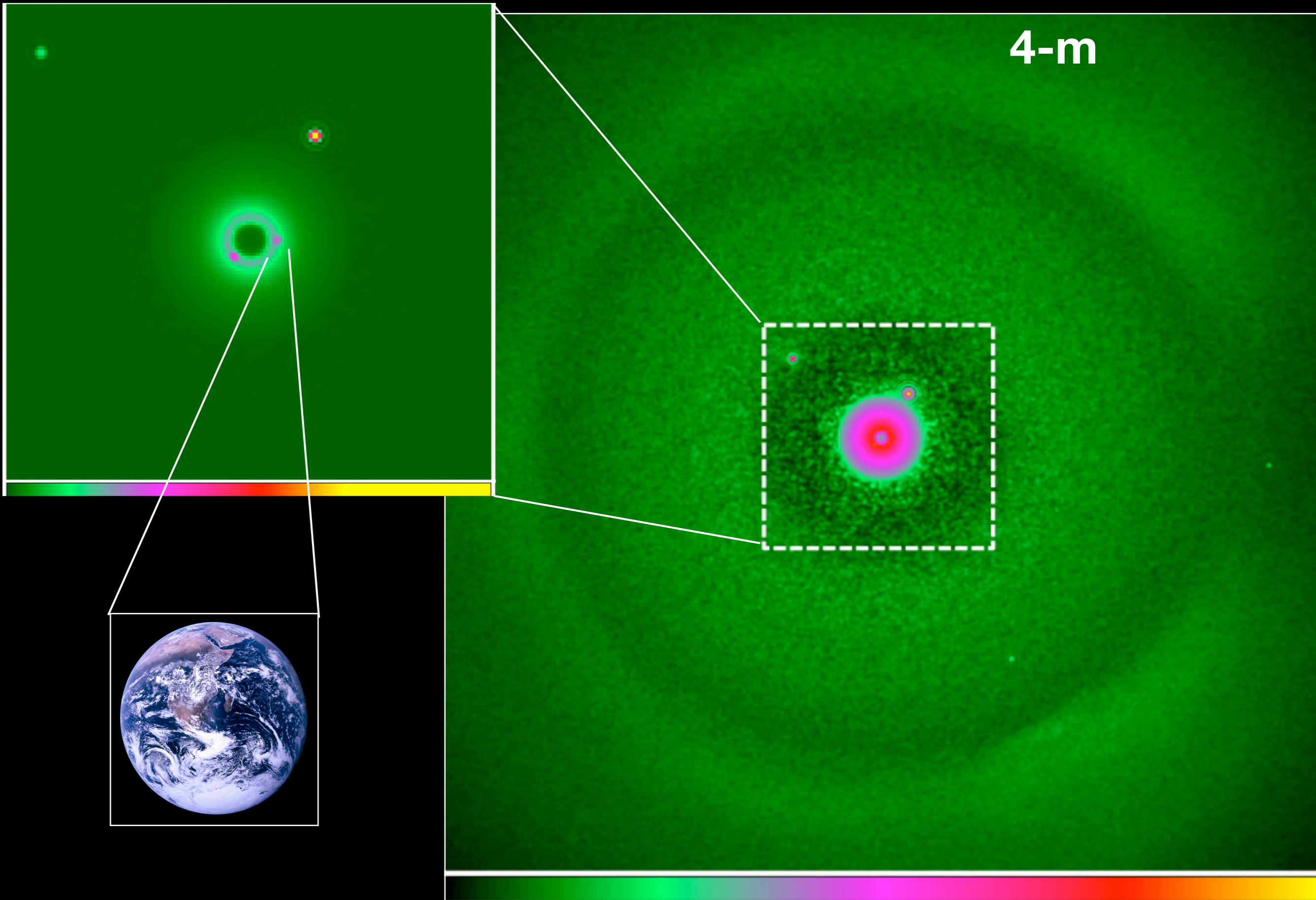
n	HIP	Name	Spec Type	d (pc)	C	t_image (sec)	t_spec (days)	[Fe/H]	N-WDS	N_p	Debris	strlt	BG-stars
1	108870	eps Indi	K4V	3.6	0.78	1571	1.0	-0.08	3	-	N	OK	low
2	16537	eps Eri	K2V	3.2	0.77	737	1.0	-0.14	2	1	Y	?	med
3	104214	61 Cyg A	K5V	3.5	0.75	1347	1.0	-	6	-	N	strlt	high
4	71681	alf Cen B	K1V	1.3	0.75	31	1.0	0.21	4	-	N	strlt	high
5	8102	tau Cet	G8V	3.7	0.73	938	1.0	-0.47	2	-	Y	OK	low
6	104217	61 Cyg B	K7V	3.5	0.65	2407	1.0	-	6	-	N	strlt	high
7	71683	alf Cen A	G2V	1.3	0.54	40	1.0	0.24	4	-	N	strlt	high
8	19849	omi Eri A	K0V	5	0.72	3796	1.5	-0.29	5	-	?	OK	med
9	88601	70 Oph A	K0- V	5.1	0.68	4232	1.6	-0.01	10	-	?	strlt	high
10	96100	sig Dra	K0V	5.8	0.69	6130	2.4	-0.2	2	-	N	OK	high
11	3821	eta Cas A	F9V	6	0.57	5696	2.2	-0.28	8	-	N	OK	high
12	15510	HR 1008	G6V	6	0.66	6808	2.6	-0.4	1	-	Y	OK	low
13	84405	36 Oph A	K0V	5.9	0.66	7980	3.1	-0.31	5	-	?	strlt	high
14	105090	HD 202560	M1V	3.9	0.41	5128	2.0	-	1	-	?	OK	low
15	99461	HR 7703	K2.5V	6	0.65	8389	3.2	-0.6	2	-	N	strlt	med
16	99240	del Pav	G8IV	6.1	0.56	7601	2.9	0.47	1	-	N	OK	med
17	72659	xi Boo A	G7V	6.7	0.65	11033	4.3	-0.17	5	-	?	strlt	low

Are They Any “Good”?

Highest Priority Targets: Known EGPs

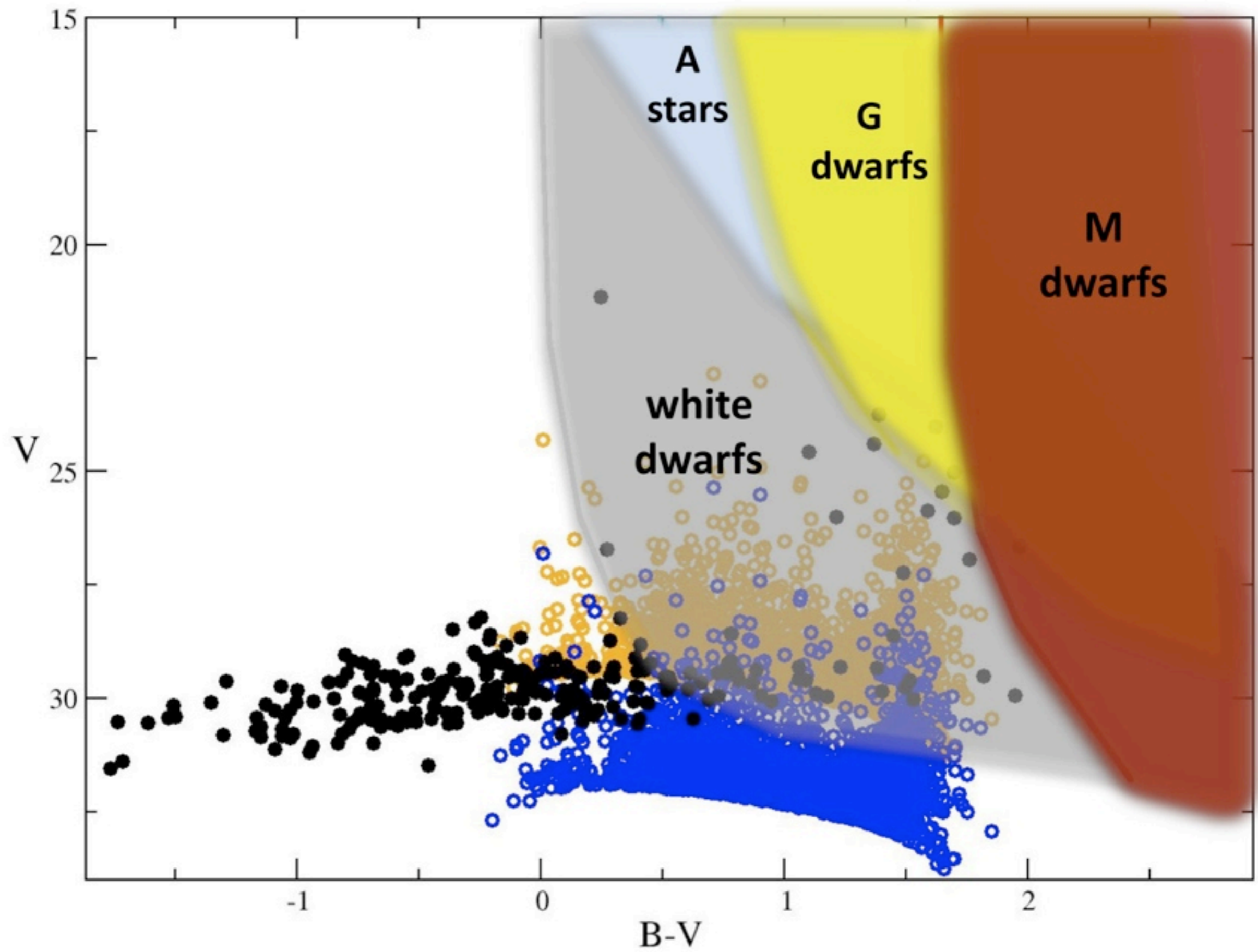


M. Turnbull

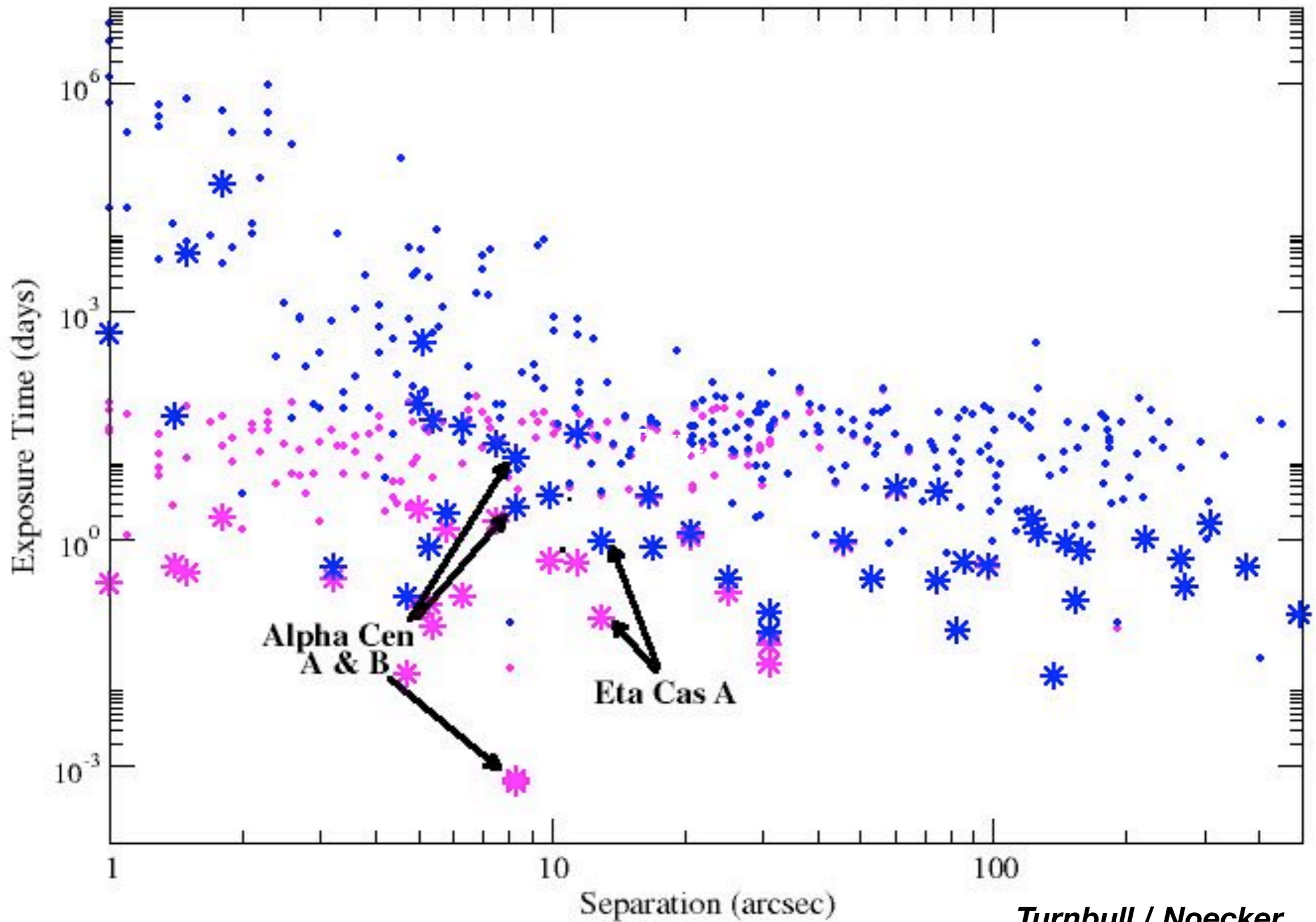


HUDF, 25'' box

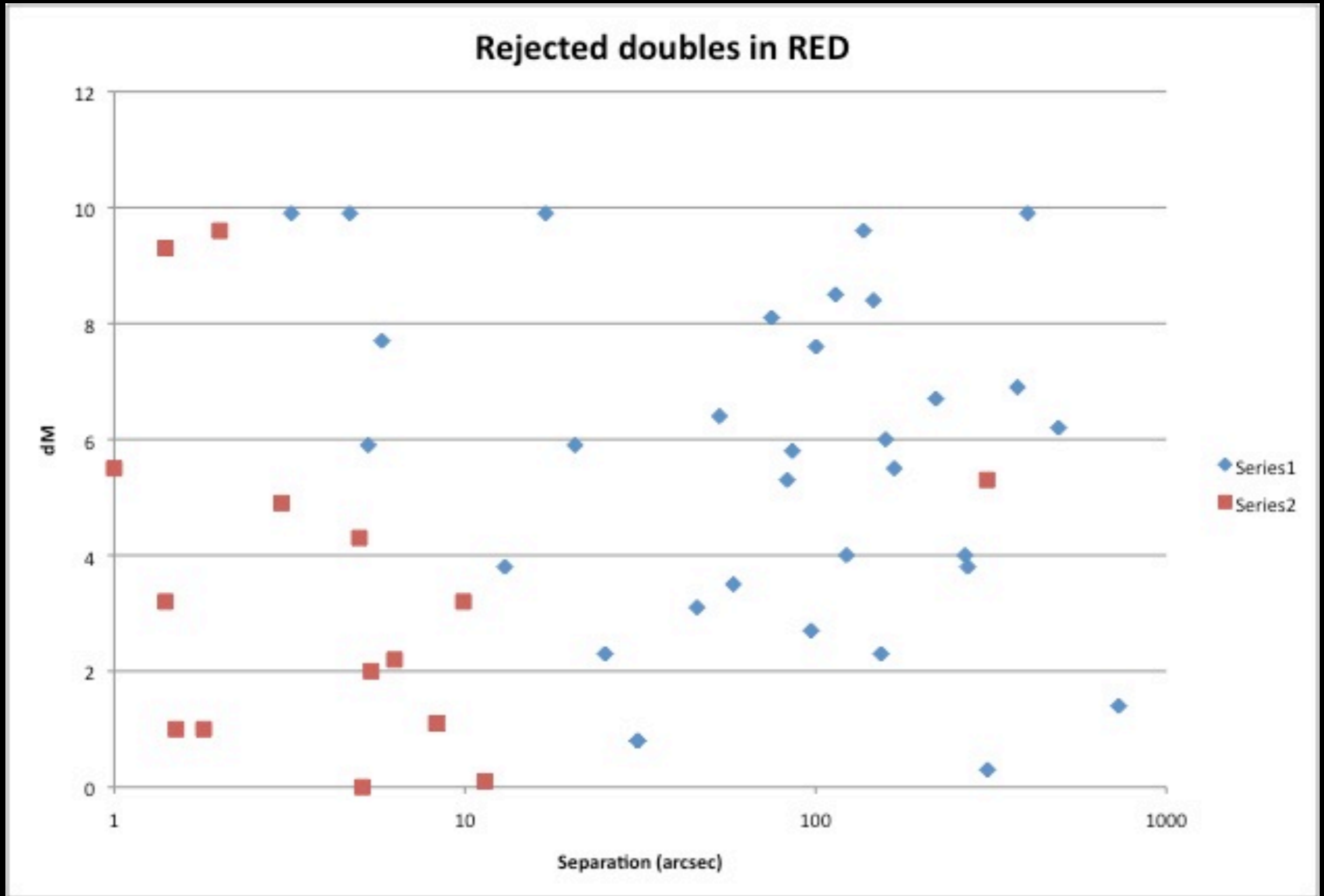




Highest Priority Targets: Binaries



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Highest Priority Targets: Issues

- 1. Binaries - stray light**
- 2. Binaries - HZ stability**
- 3. Background - “bright” faint stars**
- 4. Background - very faint extragalactic**
- 5. Background - EZ and clumps**
- 6. Other things useful to know**
 - equatorial inclinations**
 - RV “nothing there” space**
 - completeness vs time**