Nulling Interferometric Observations of the Nearest Stars

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The Nearest Stars

Stellar Fluxes (Visual)

stellar type	M_v	Ratio to G2	Rel diameter
B2	-2.45	724	5.0
A2	1.3	22.9	2.1
F2	3.6	2.75	1.4
G2	4.7	1.00	1.0
K2	6.4	0.21	0.8
M2	9.9	.0083	0.5

Numbers of Nearest Stars

distance	A	F	G	K	M
6-7 pc			3	3	17
5-6 pc	1		1	6	18
4-5 pc				1	17
3-4 pc		1	1	4	9
2-3 pc	1				2
1-2 pc					1
0-1 pc			1	1	1

Source: Allen's Astrophysical Quantities

Names of Nearest Stars

distance	A	F	G	K	M
6-7 pc			ε Eri δ Pav ξ Boo	Gl 783A Gl 892 Gl 667A	17
5-6 pc	Altair= α Aql		η Cas	ω2 Eri, 70 Oph σ Dra, Gl 570A Gl 664, 36 Oph	18
4-5 pc				Gl 380	17
3-4 pc		Procyon=αCmi	τ Ceti	ε Eri 61 Cyg A 61 Cyg B ε Ind	9
2-3 pc	Sirius= α CMa				Gl 411 Gl 729
1-2 pc					Barnard
0-1 pc			αCen A	αCen B	αCen C

Potential Rejection Criteria

- Proximity – only α Cen
- Stellar type – main sequence F,G,K (but not A's?)
- Close (<10″) binaries
- High dust content
- High declination angle (near ecliptic pole)
- Not clear yet: not in Ebbet's list
  - may be binaries or variable
- Hot Jupiters in system (not included yet)

Culling the Herd: Few Left Standing!

distance	A	F	G	K	M
6-7 pc			e Eri δ Pav (-63°) ~~ξ Boo~~	Gl 783A Gl 892 (57°) Gl 667A	
5-6 pc			η Cas (57°)	ω2 Eri, 70 Oph α Dra (-57°), Gl570A ~~Gl 664, 36 Oph~~	
4-5 pc				Gl 380	
3-4 pc				61 Cyg A 61 Cyg B ε Ind (-57°)	
2-3 pc					
1-2 pc					
0-1 pc			αCen A (-60°)	αCen B (-60°)	

The Survivors

distance	A	F	G	K	M
6-7 pc			1-2	1-3	
5-6 pc			0-1	2-4	
4-5 pc				1	
3-4 pc				2-3	
2-3 pc					
1-2 pc					
0-1 pc					

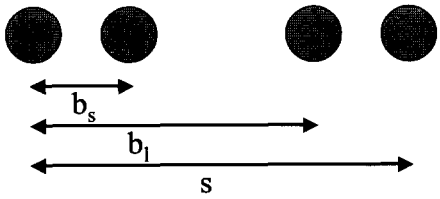
Conclusions from a Thorough Cull

- Very few stars survive as TPF targets (as currently defined) inside of 5 pc:
  - 2-5 stars near 3.5 pc
- The numbers finally start to rise at 5 pc:
  - need good interferometer response for 5-20 pc or so to get at lots of stars.
- Need some interferometer response near 3.5 pc for a paltry number of stars.
  - Optimization not necessary due to higher flux.
- High ecliptic angles important to keep a larger fraction of nearest stars (at < 7 pc), and to keep the maximum distance shorter
- Need to re-consider rejection criteria

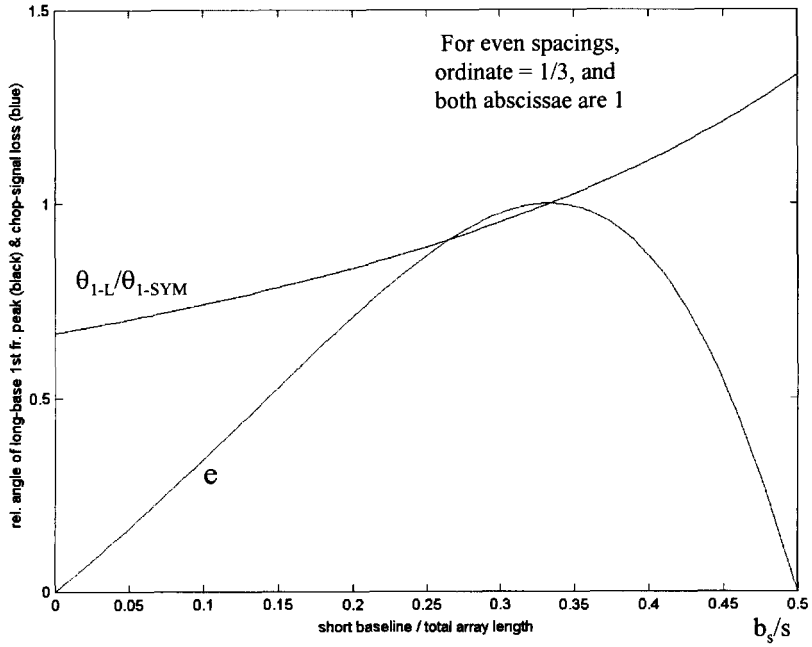
Nulling with Unevenly-Spaced Dual-Bracewell Linear Arrays

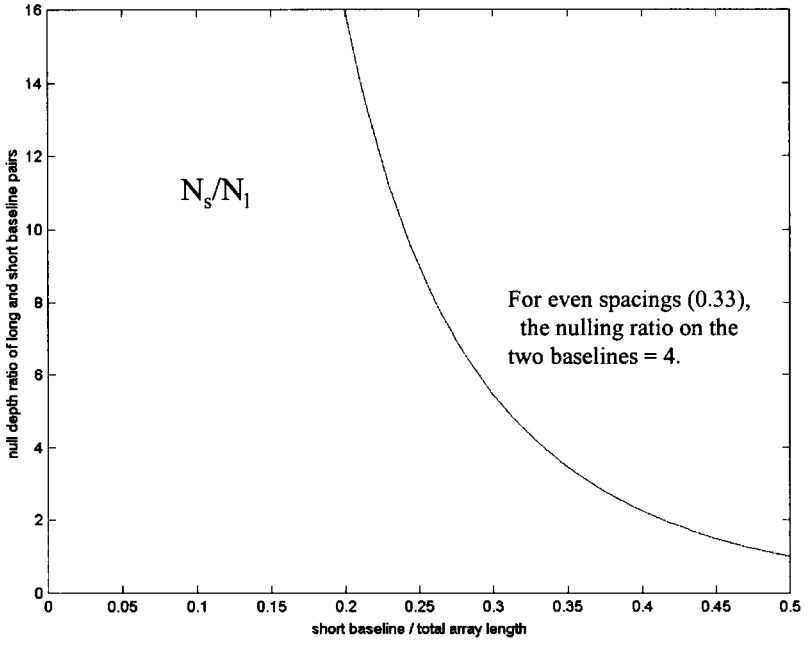
Unevenly-spaced chopped dual-Bracewell

- Have two nulling baseline lengths, even for equal spacings
- For equal spacings,
  $b_s=s/3$; $b_l=2s/3$; $N_s=4N_l$
- Maximum SNR for $b_l=2b_s$
- Maximum resolution for $b_l=s$
- The optimum is in between



- First constructive peak (long bl):
  $\theta_{1\text{-}L}/\theta_{1\text{-}SYM} = (2/3)/(1-b_s/s)$
- Chopped signal efficiency, relative to symmetric case
  $e=\sin[\pi(1-2b_s/s)/(1-b_s/s)]$

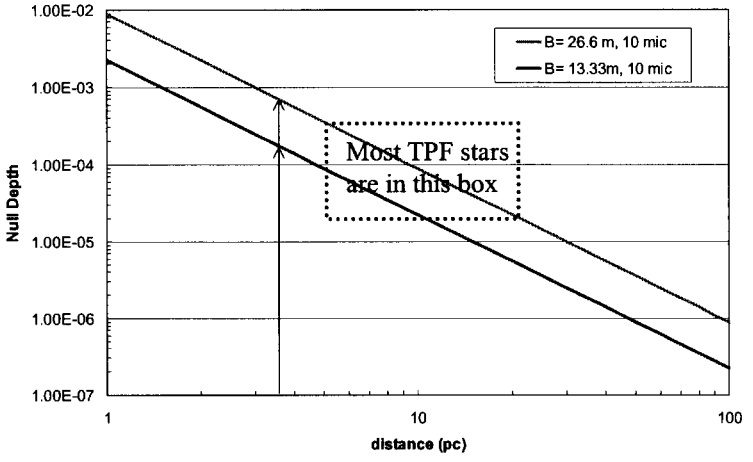




Uneven Bracewell Examples

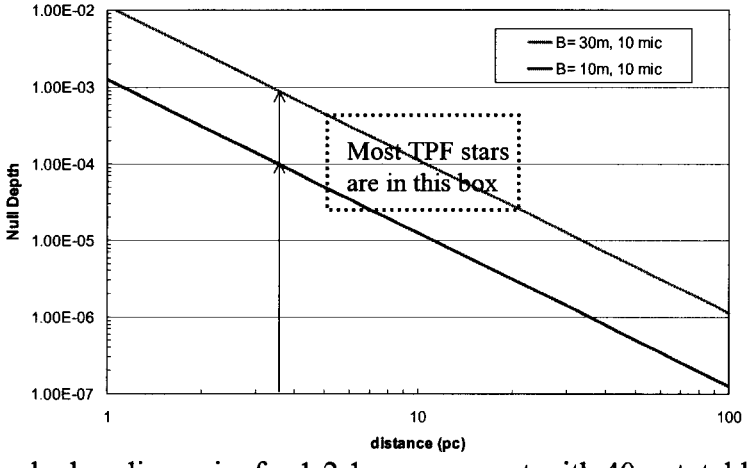
b_s/s	e	$\theta_{1\text{-}L}/\theta_{1\text{-}SYM}$	N_s/N_l
1/5	$1/\sqrt{2}$	5/6	16
1/4	$\sqrt{3}/2$	8/9	9
1/3	1	1	4
1/2	0	4/3	1

Null Depths for Symmetric Dual-BW



- For a single nulling baseline, the null depth improves as distance^{-2}
- Example: baseline pairs for 1:1:1 arrangement with 40 m total length
- Short baselines provide a factor of 4 improvement in null depth

Nulls vs. Baseline Length



- Example: baseline pairs for 1:2:1 arrangement with 40 m total length
- Short baselines provide a factor of 9 improvement for in null depth
- Long baselines provide 8/9 IWD of symmetric case

Conclusions

- Need good interferometer response at ≈ 5-20 pc to get lots of stars. Using a 10 pc reference, there's a factor of ±4 null depth variation for a given stellar diameter (i.e., type) in this range, using the long baselines in a symmetric dual-BW.
- Need some interferometer response at 3.5 pc for a small number of stars. Symmetric dual-BW long-baseline nullers optimized for 10 pc have nulls worse by only a factor of 8. Might be acceptable.
- Can improve nulls on nearest stars by factor of 4 by also using short baselines in symmetric dual-BW. (This also loses a factor of 2 in resolution,OK for near stars).
- Can further improve the nulls on the short baselines (by another factor of 2 or 3) by going to asymmetric dual-BW (uneven spacings)
- ⇒ Can get an order of magnitude null depth difference on the short and long baselines relatively easily (1:2:1)
- This impacts relatively few stars, so is it worth it?
- This also simultaneously improves the long b.l. angular resolution (by 11%), with a similar signal loss (13%), so it's worth considering
- This also degrades resolution on short baselines again, but that's probably OK for the nearest stars

Main Conclusions

- There aren't many really nearby stars acceptable to TPF
- Doing the nearest stars is definitely NOT a problem, especially if the short baselines in the chopped dual-BW configuration are made use of