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IKONOS Calculation of MTF using Stellar Images

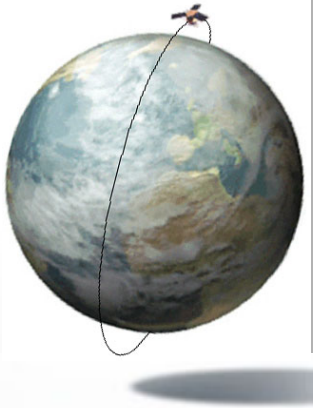
Howard S. Bowen

Vehicle Payload Specialist

Gene Dial

Product Engineering Manager

IKONOS Stellar Scene Information



- Stellar images were already being collected as part of Radiometric Stability verification
- On 21 FEB 2002 at 20:30:26.5 Z an image was collected of the Hyades Cluster (image was centered about: Tau θ1-77 @ RA = 04:28:34.50 (h:m:s) J2000, DEC = 15:57:43.9 (d:m:s) J2000)

Star Name	SAO #	HIP #	Comment	Pan	MS
Tau 70	93925	na	Max = 80	No	No
Tau 71	93932	na	Max = 432	Yes	No
Tau 75	93950	na	Max = 465	Yes	No
Tau θ1-77	93955	20885	Max = 1094	Yes	Yes
Tau θ2-78	93957	na	Max = 1620	Yes	Yes
Tau 80	93970	na	2 Max = 149, 29	No	No
Tau 81	93978	na	Max = 194	Yes	No
Tau 85	93993	na	Max = 107	No	No
SAO 93975	93975	na	Max = 464	Yes	No

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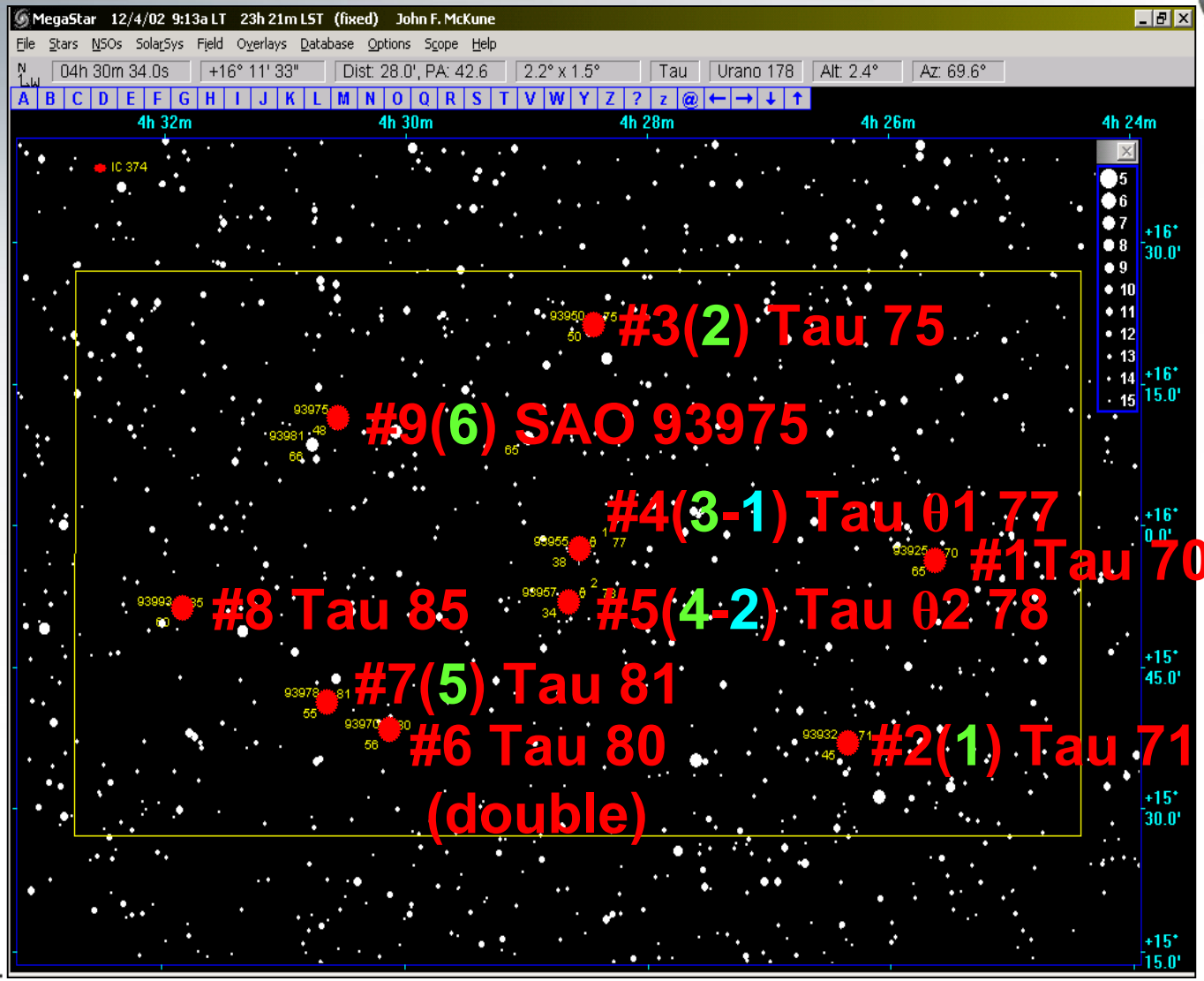
Hyades Cluster Stellar Image Scene



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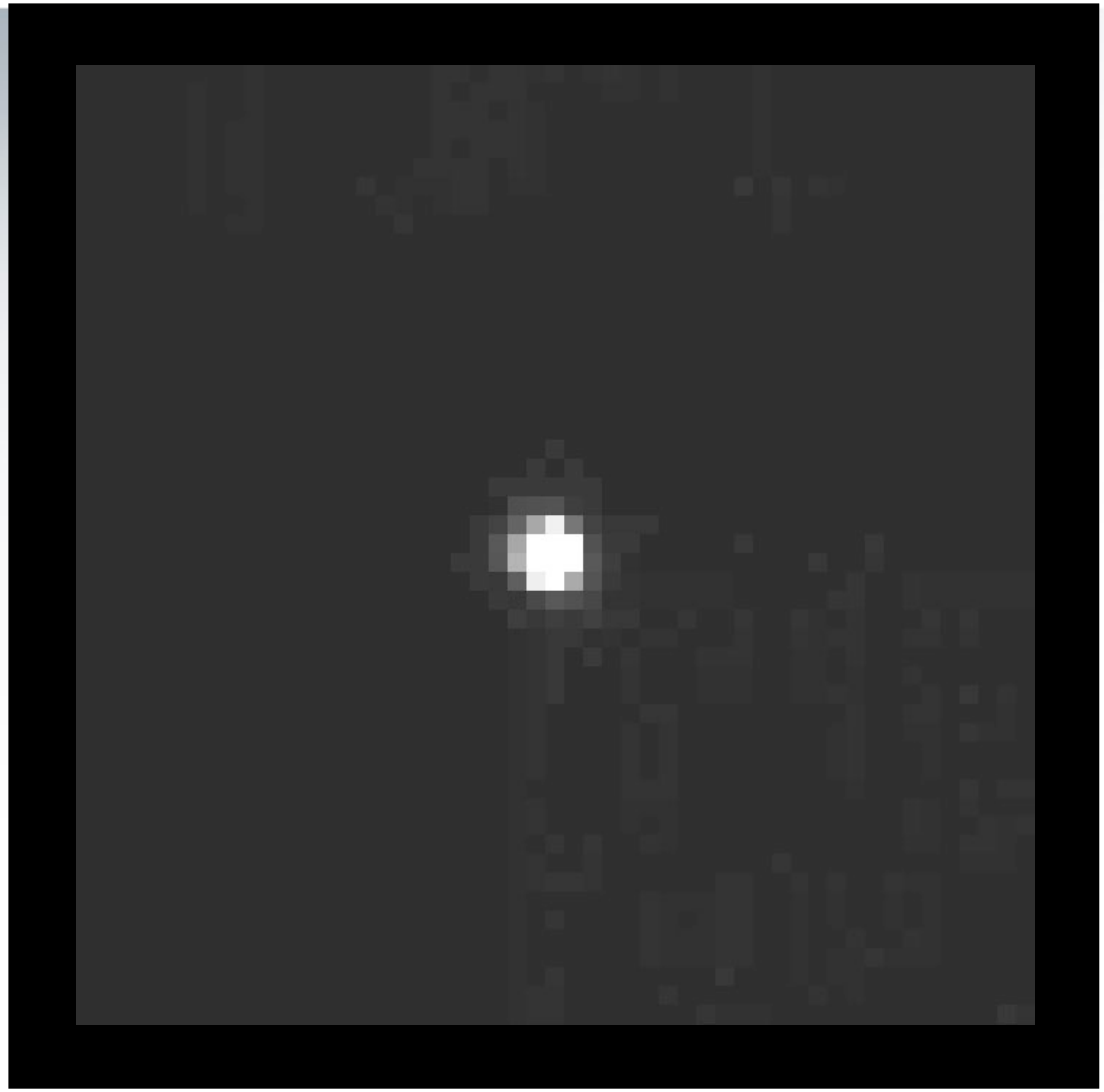
IKONOS Stellar MTF Calculations

- MatLab routine written to calculate MTF of a Point Source
- MTF calculated using 2D Fast Fourier Transform function

```
% Calculate the 2D mtf
for i = 1:N,
  xf(:,:,i) = fft2(z(:,:,i));
  rl(:,:,i) = real(xf(:,:,i));
  im(:,:,i) = imag(xf(:,:,i));
  mag(:,:,i) = sqrt((rl(:,:,i).^2)+(im(:,:,i).^2));
end
```

Tau θ2-78 Stellar Point Source (fwd)



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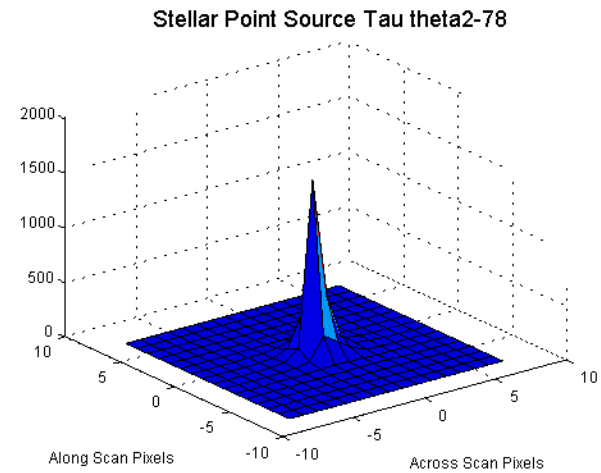
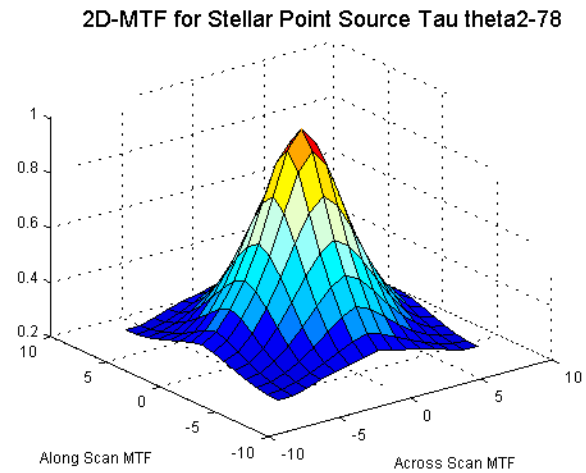
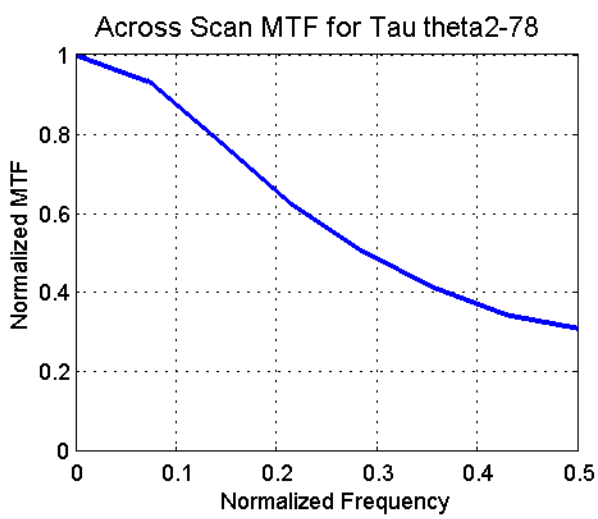
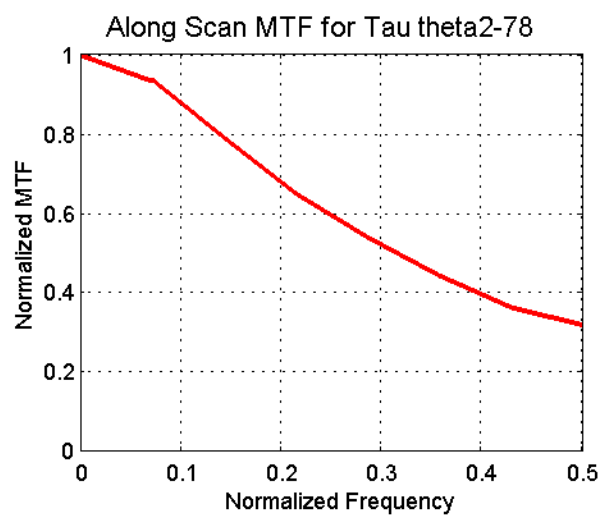
Tau θ2-78 PSF to MTF (fwd)









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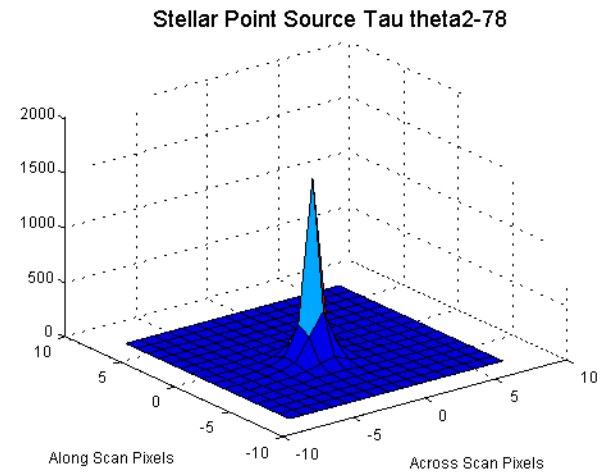
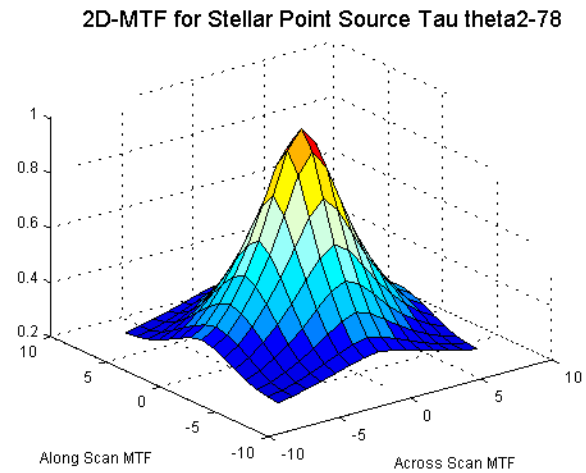
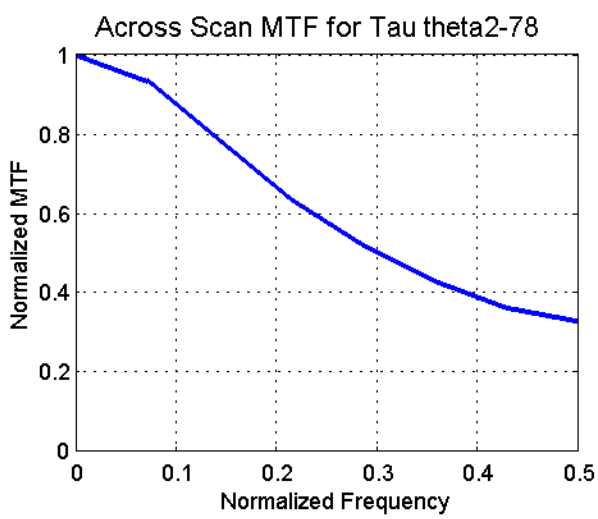
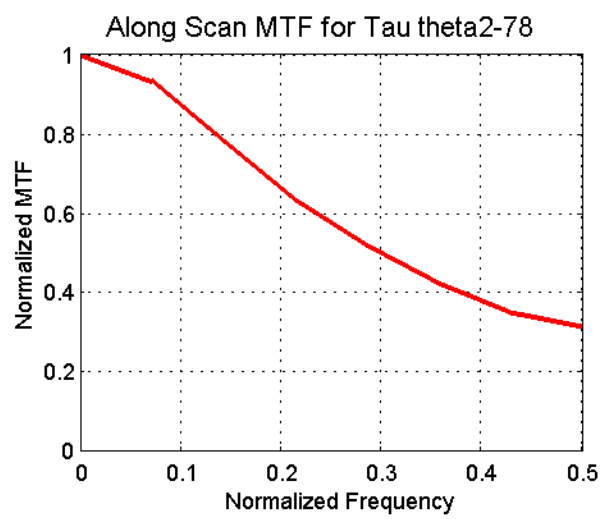
Tau θ2-78 PSF to MTF (rev)









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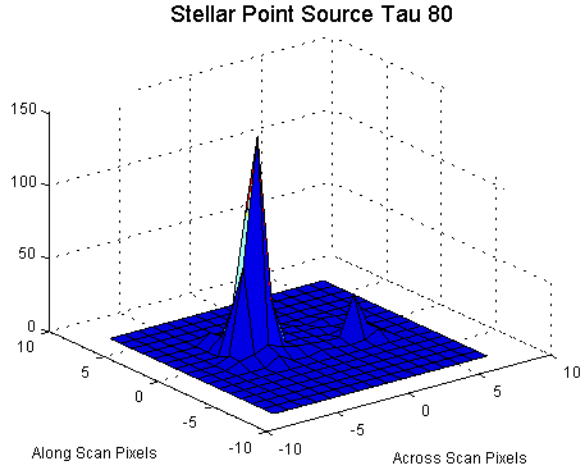
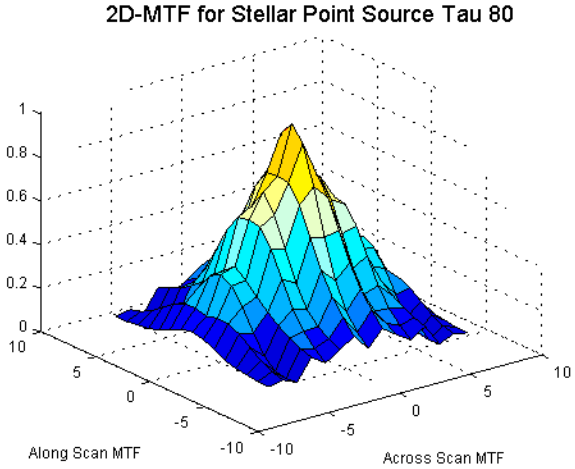
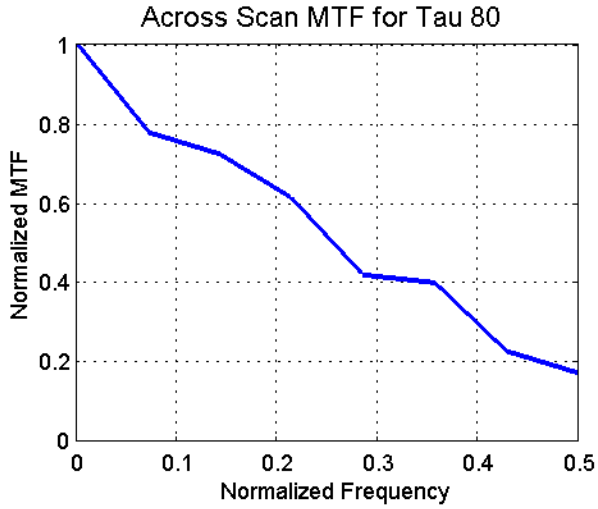
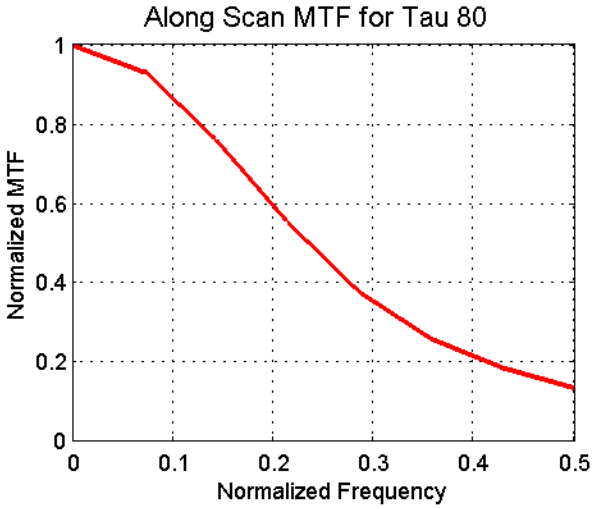
Tau 80 (double star) PSF to MTF (fwd)









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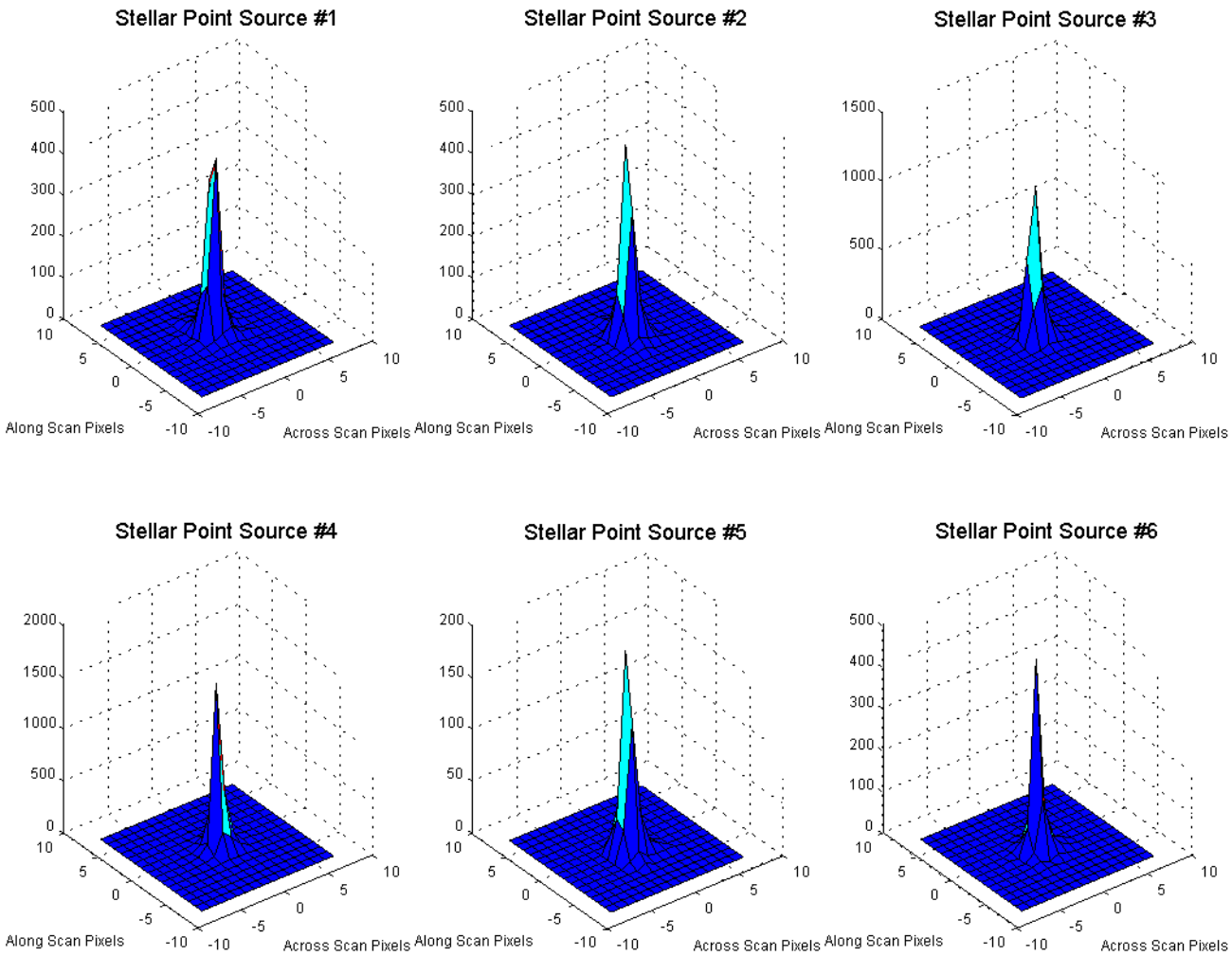
Pan Forward Image Stellar Point Sources



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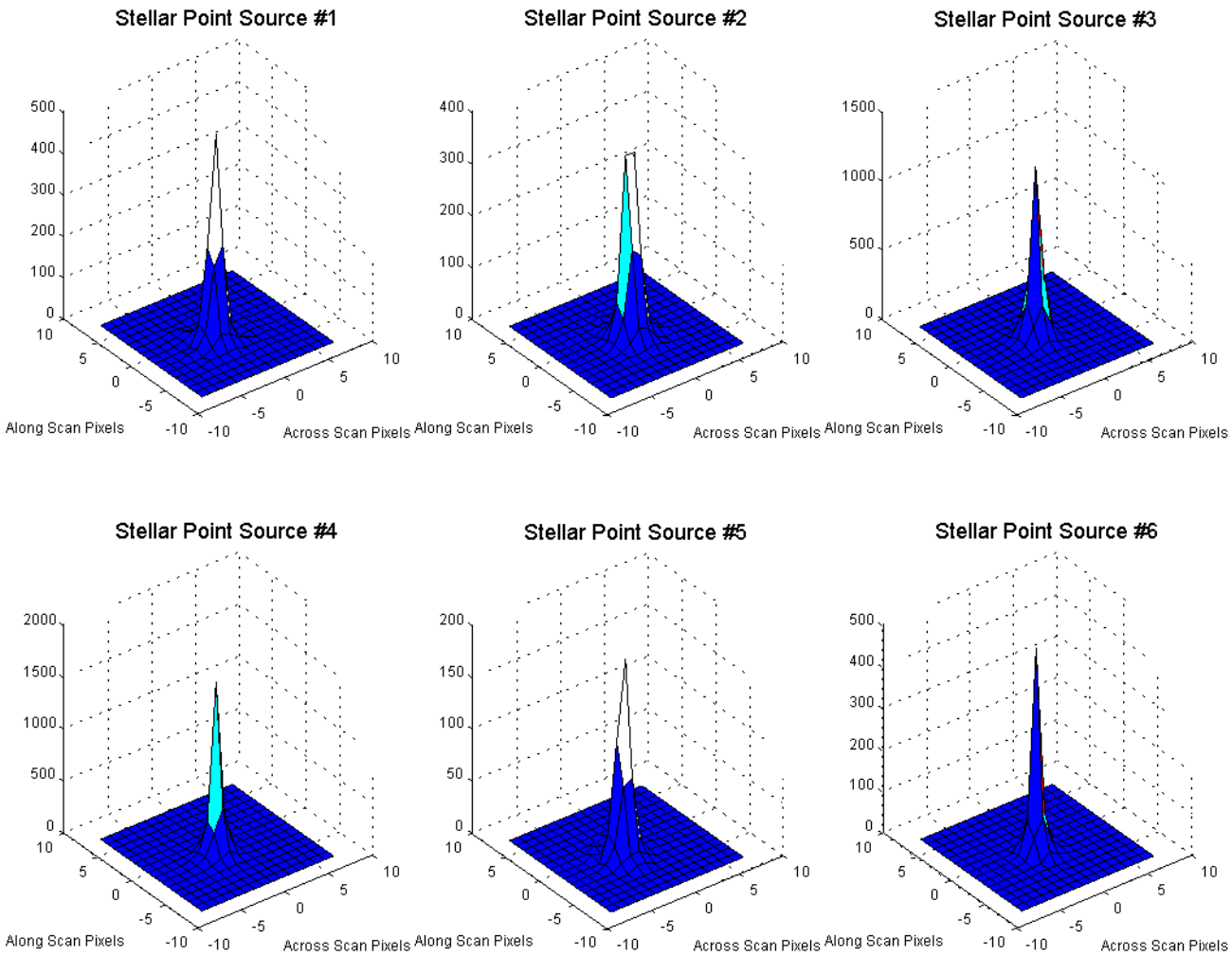
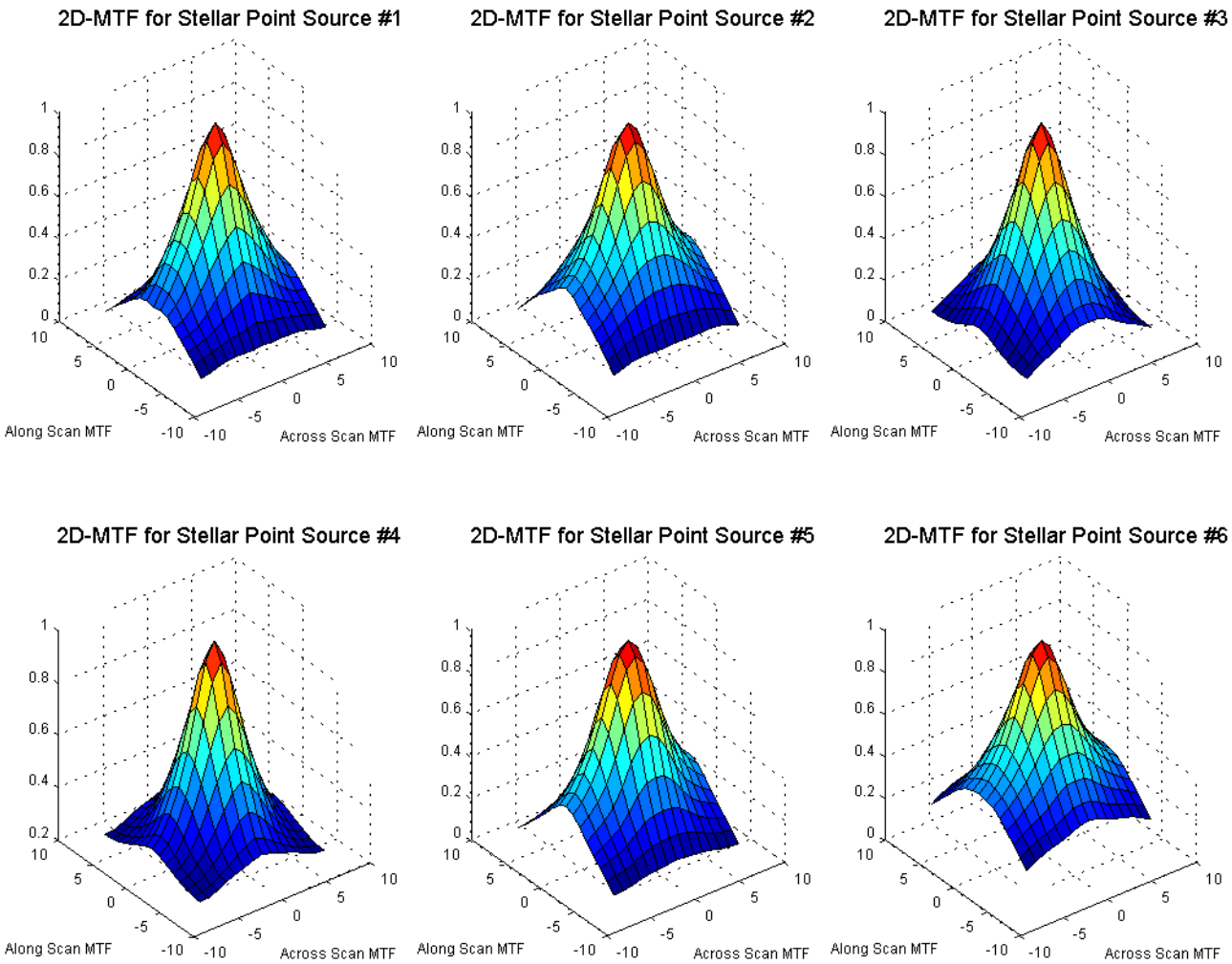
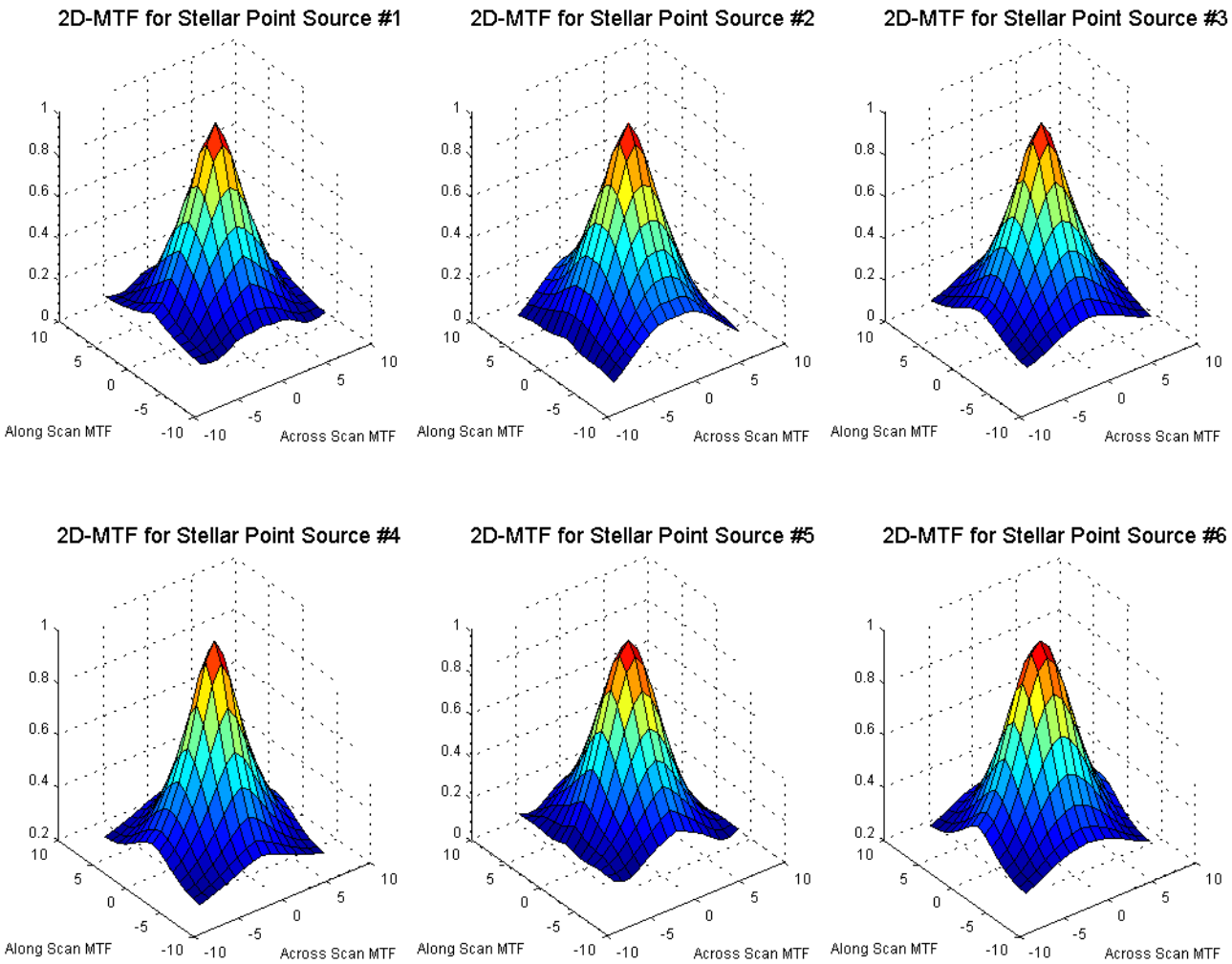
Pan Reverse Image Stellar Point Sources



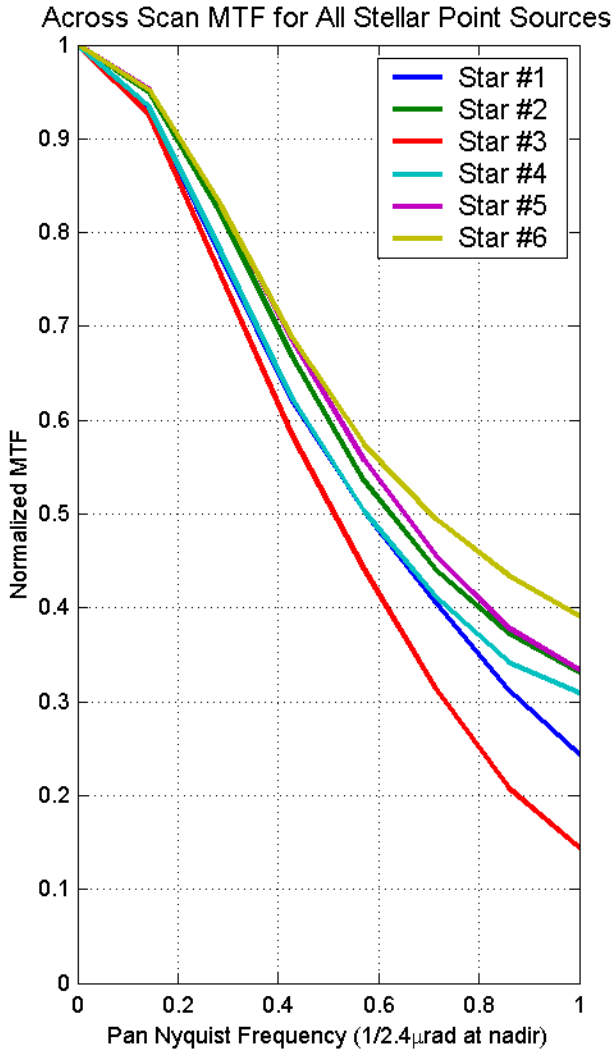
Pan Forward Image 2D MTF Plots

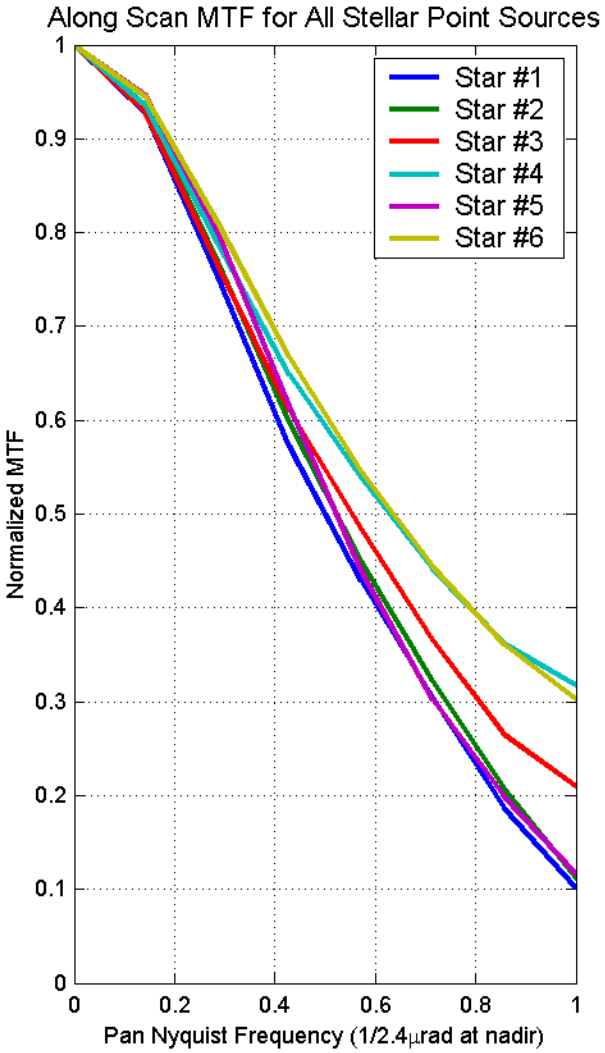


Pan Reverse Image 2D MTF Plots



Pan Forward Across & Along Scan MTF





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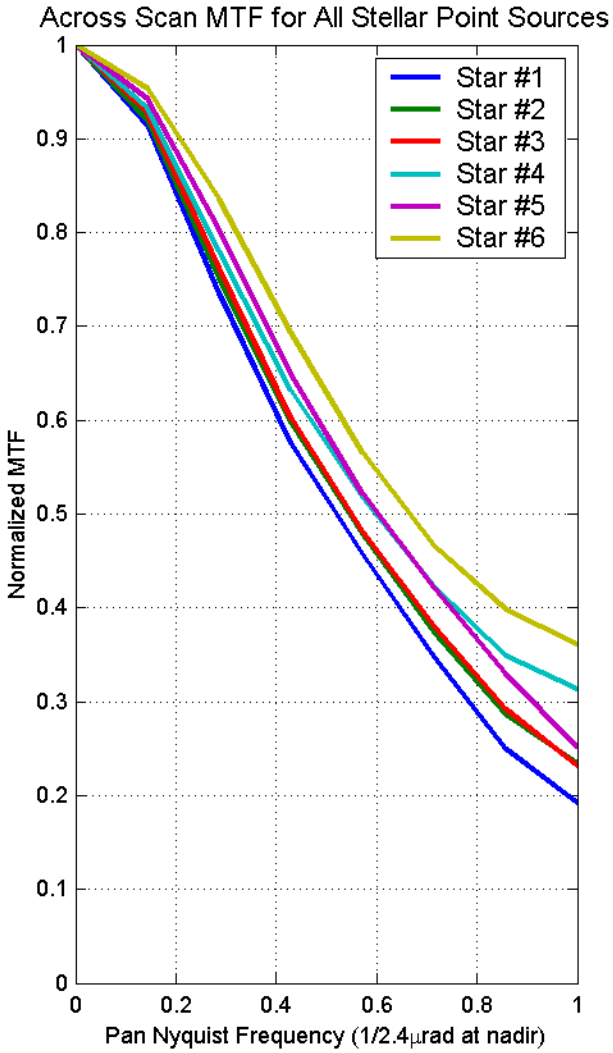
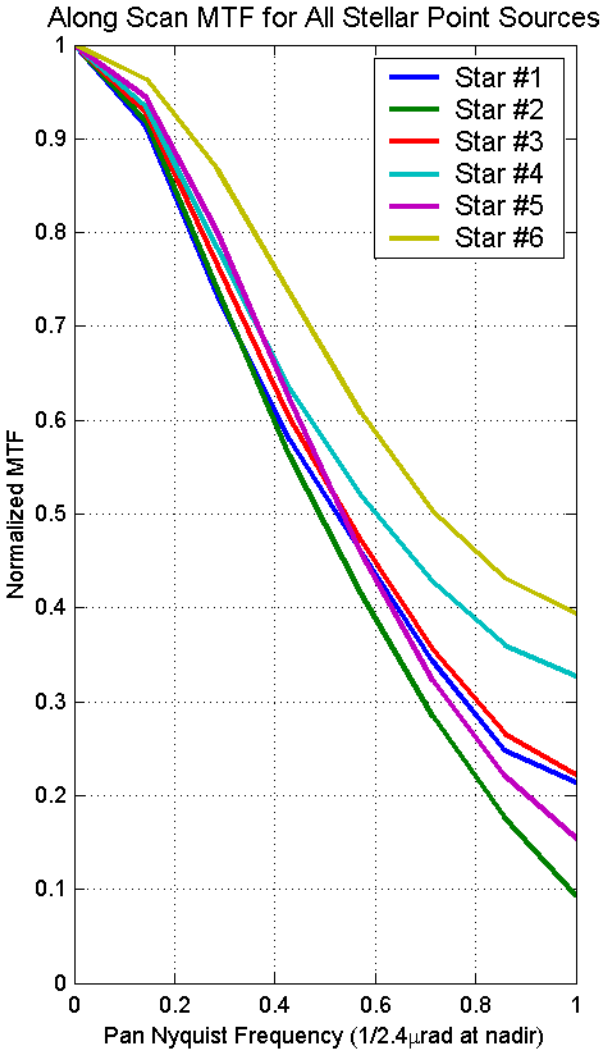
Pan Reverse Across & Along Scan MTF





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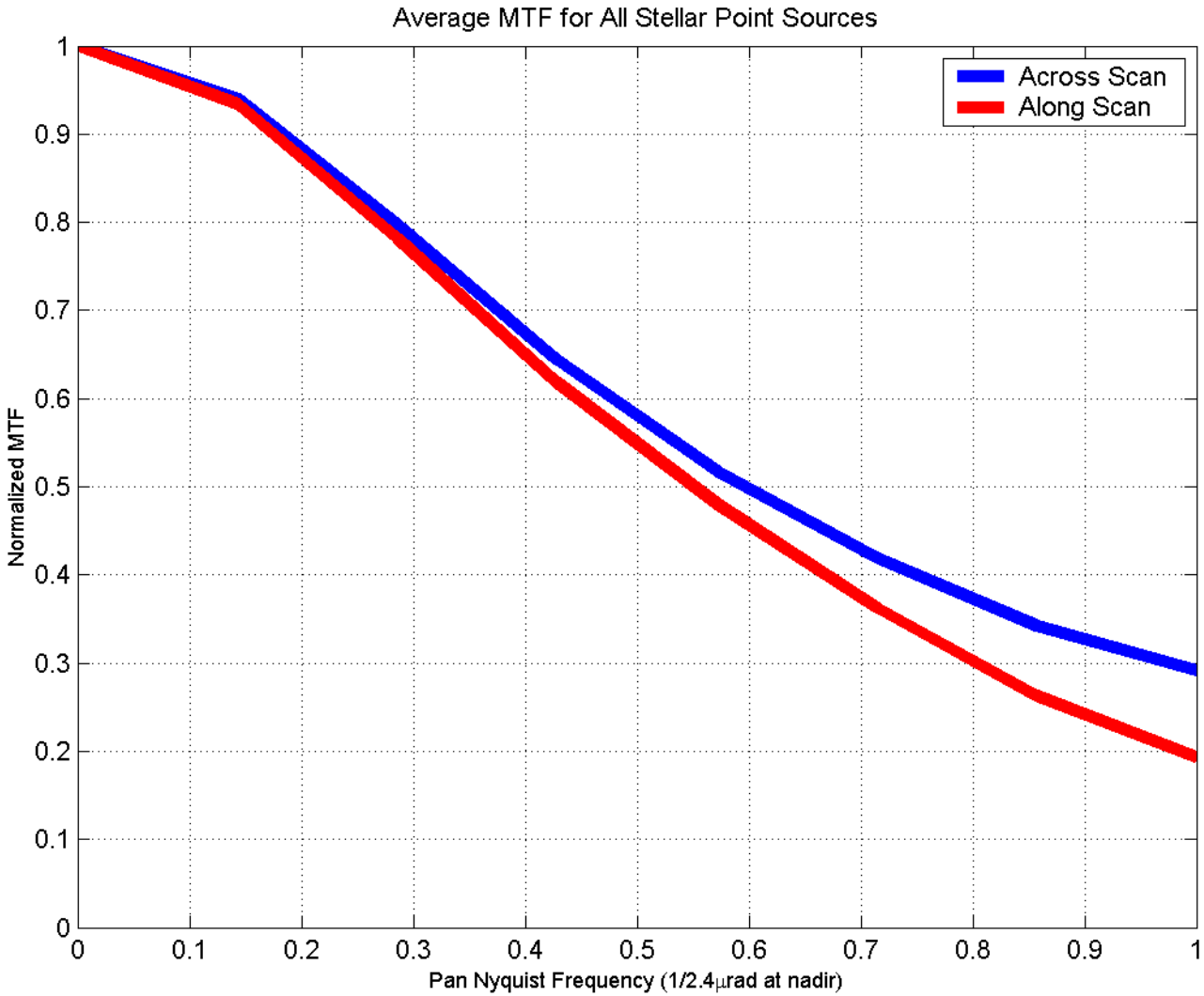
Average MTF for Pan Forward Image



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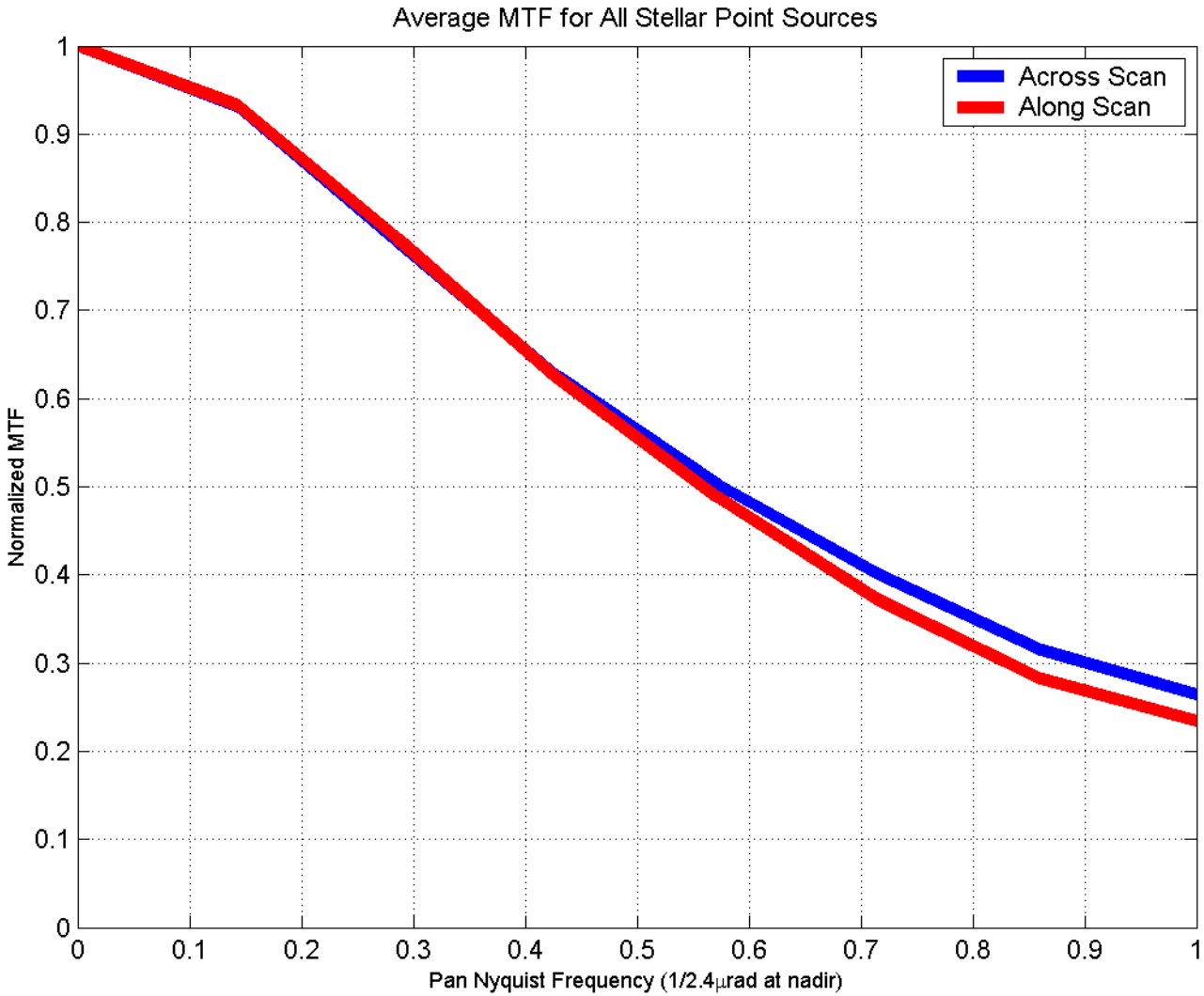
Average MTF for Pan Reverse Image



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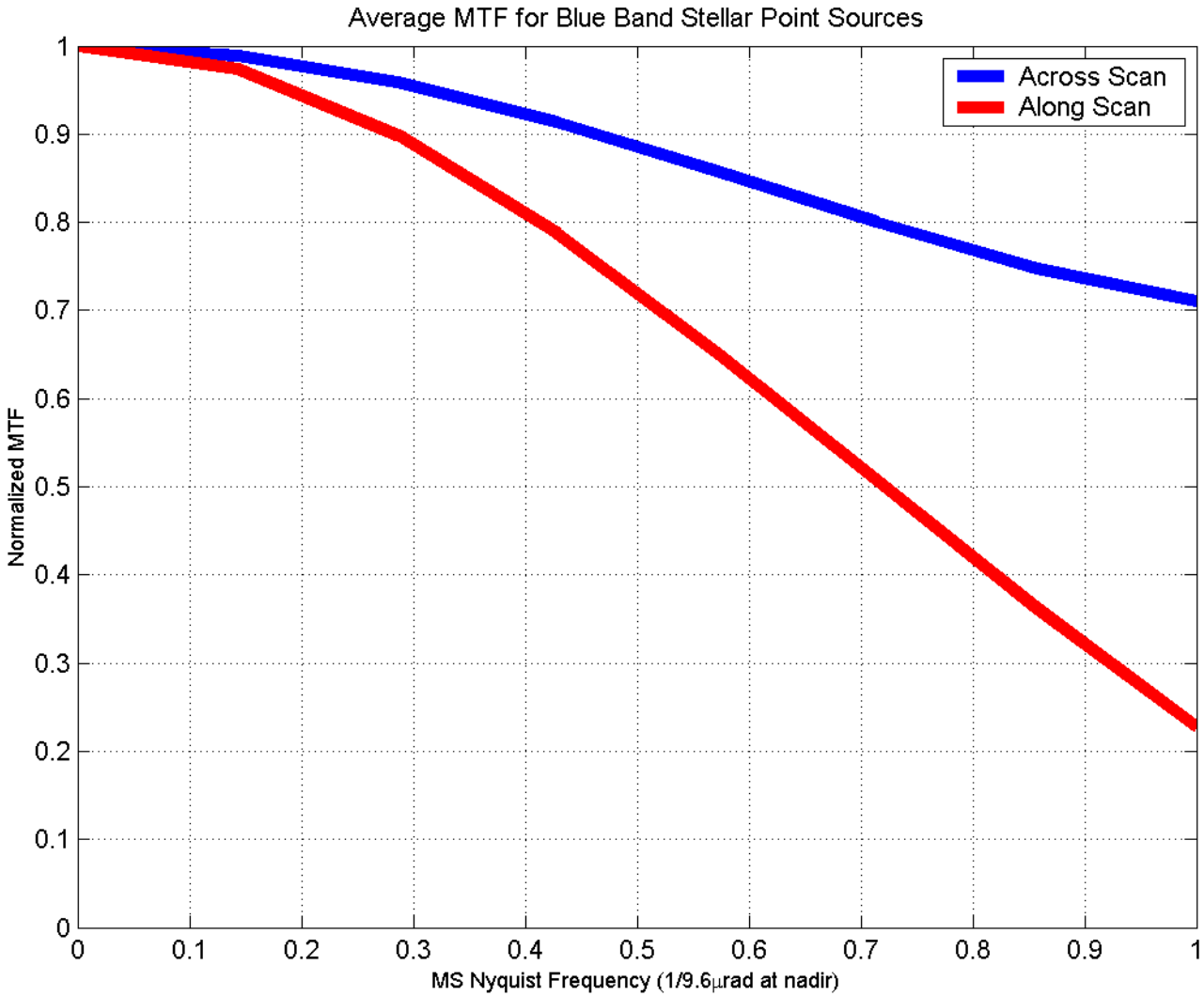
Average MTF for Blue Band Images



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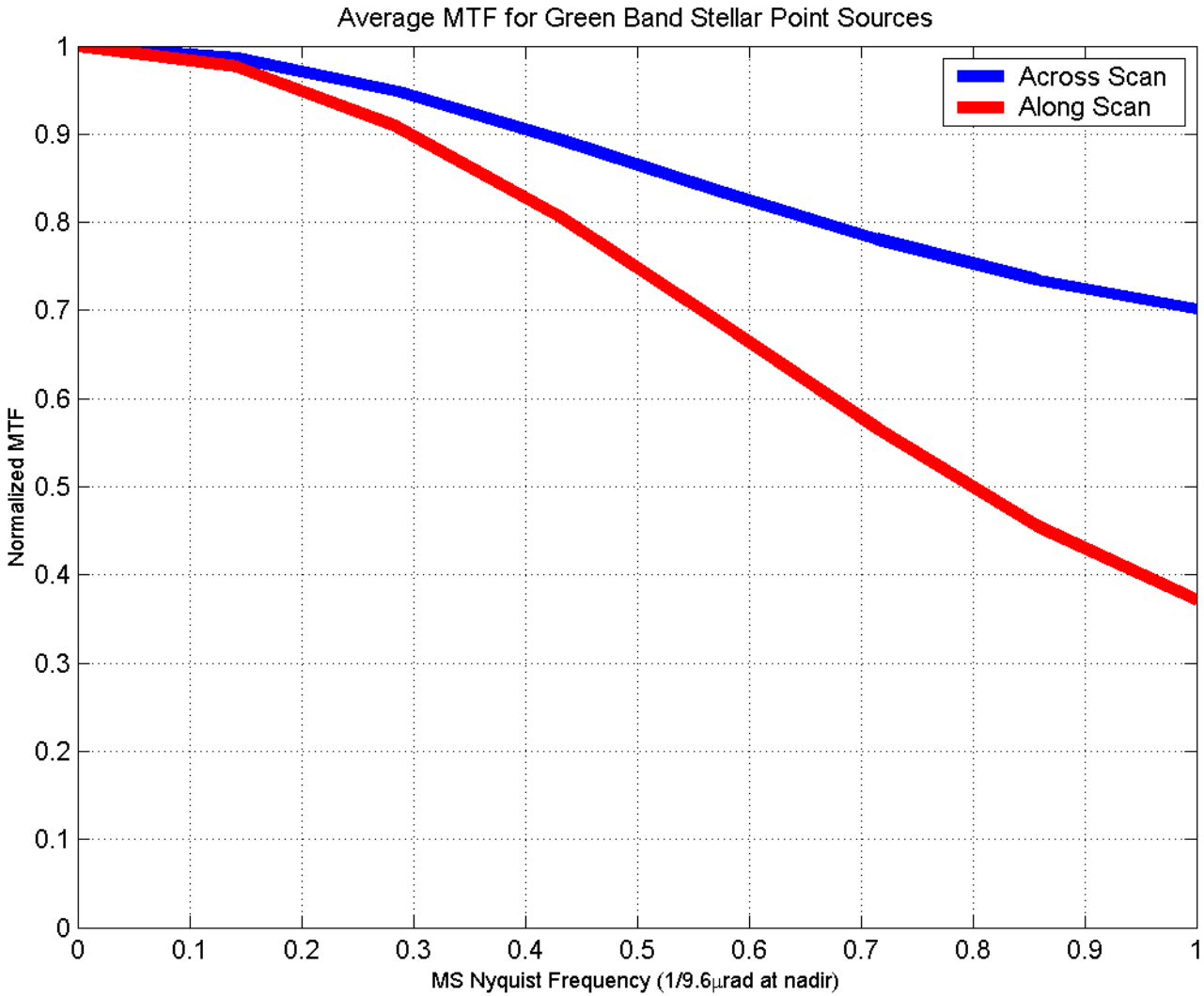
Average MTF for Green Band Images



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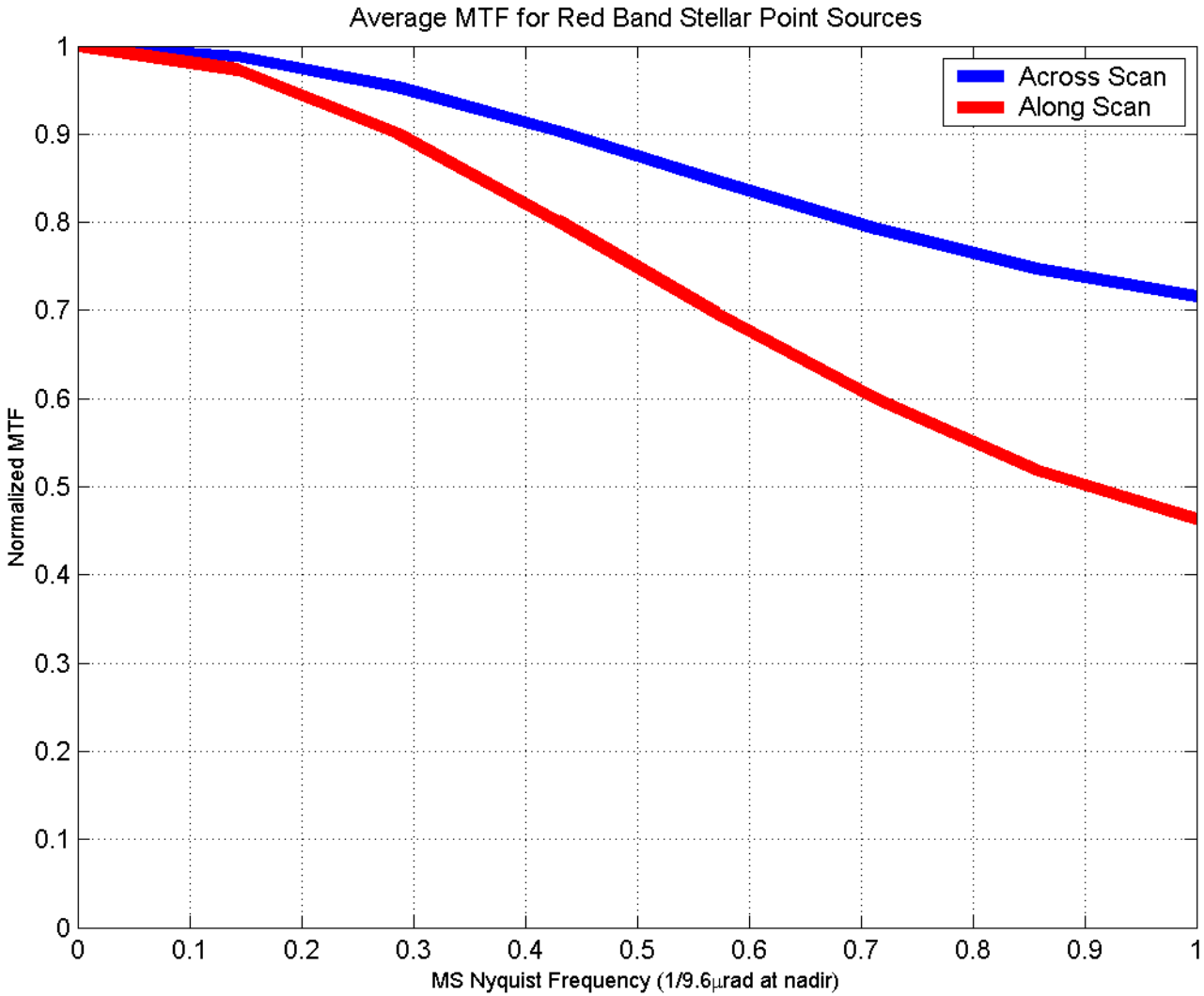
Average MTF for Red Band Images



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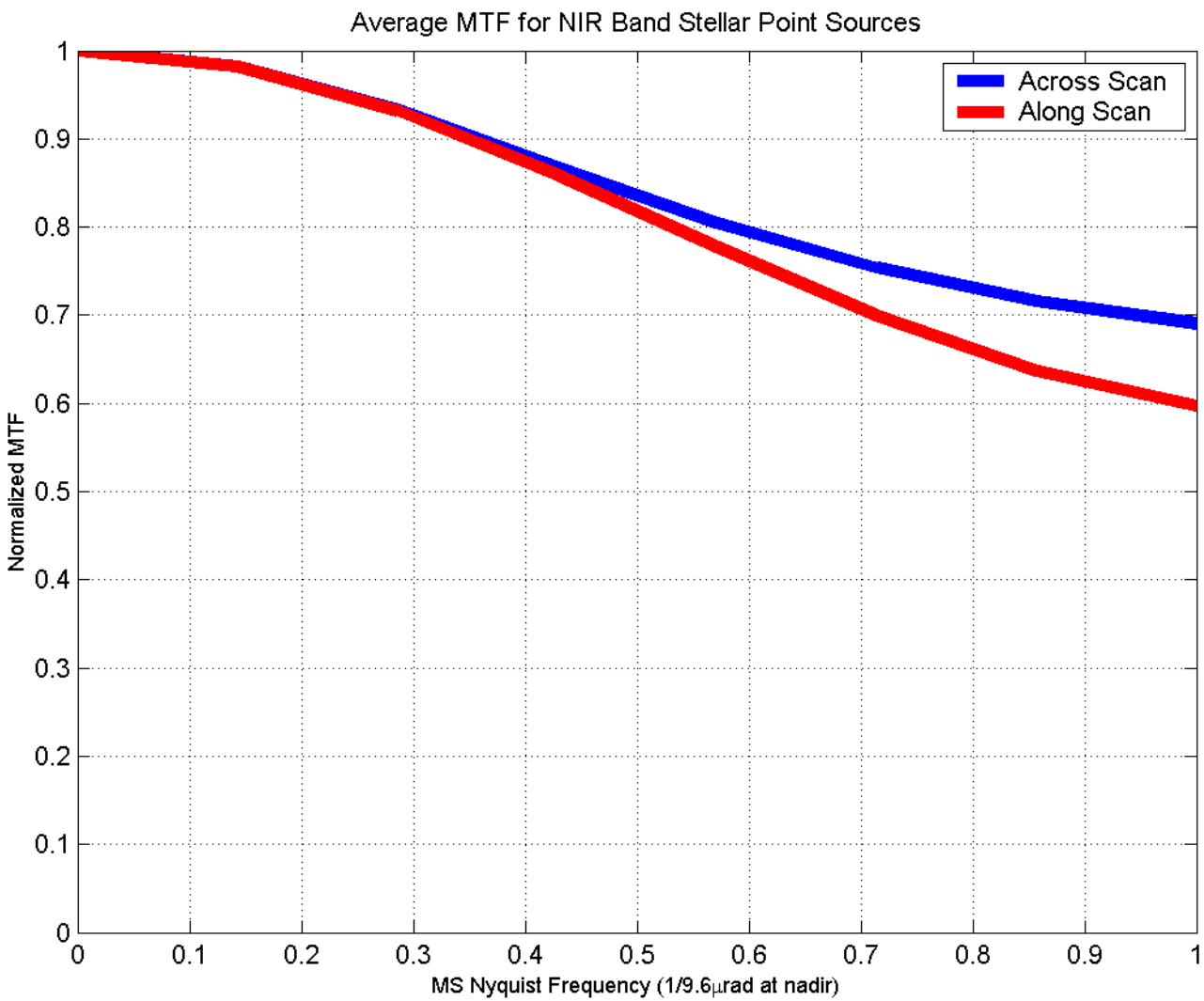
Average MTF for Near-IR Band Images



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MTF Derived from Stellar Point Sources

- **Panchromatic**: average from 6 separate stellar point sources within one image of each direction (forward and reverse)

Signal (DN)	Noise (DN)	SNR	xsMTF	asMTF	Direction
1620	1	1620	0.292	0.193	Fwd
1631	1	1631	0.264	0.234	Rev

- **Multi-spectral**: average from 2 separate stellar point sources within 3 images (collected in the forward pan direction)

Signal (DN)	Noise (DN)	SNR	xsMTF	asMTF	Band
224	1	224	0.710	0.228	Blue
263	1	263	0.735	0.371	Green
183	1	183	0.716	0.464	Red
144	1	144	0.691	0.597	NIR

Stellar Scene Derived MTF Summary

- Stellar images used were originally collected as part of Radiometric Accuracy verification
- The Hyades Cluster provided nine (9) stellar point sources within a single image
- Only brightest stellar point sources were used in MTF Calculations (6 for pan, 2 for MS)
- Does not take into consideration defocus at infinity
- Achieved the highest possible SNR
- Well defined PSF
- No atmospheric effects
- Good representation of sensor MTF

Purchase your copy of the Hyades Cluster image

- Hyades Cluster is located 151 light years from earth
- Area covered is 13.89 light years^2
- Approximately 10^{25} Equivalent Images (EI)
- At a cost of approximately $1,000 per EI
- Hyades Cluster image can be yours for only $\$10^{28}$

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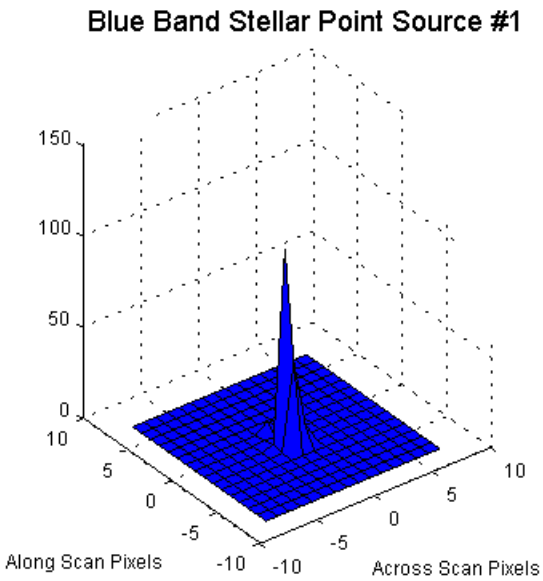
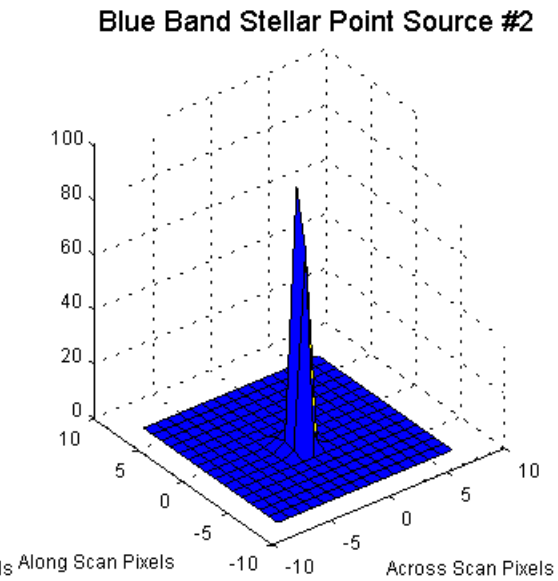
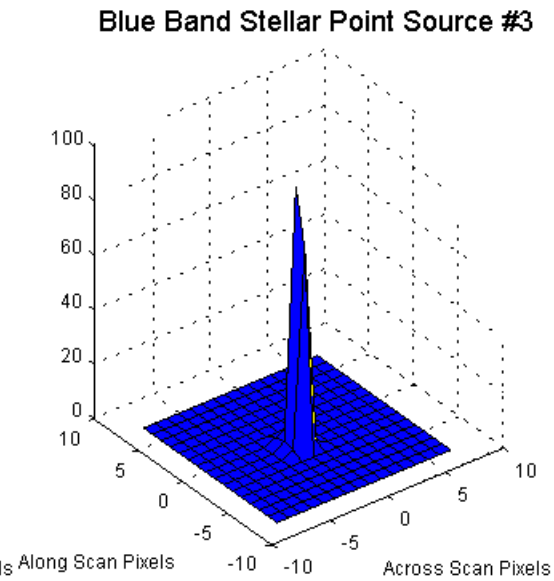
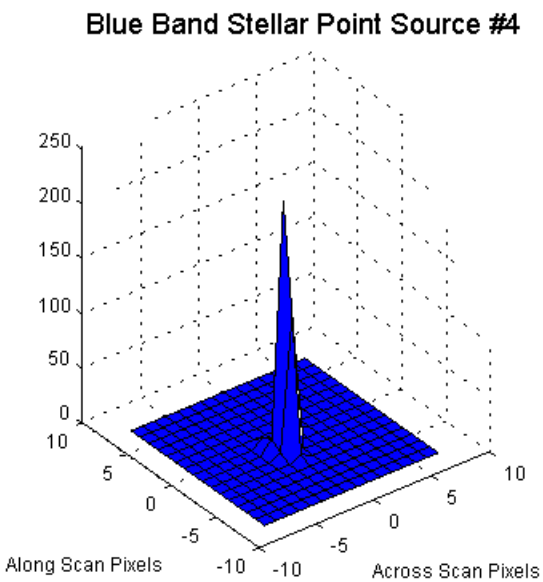
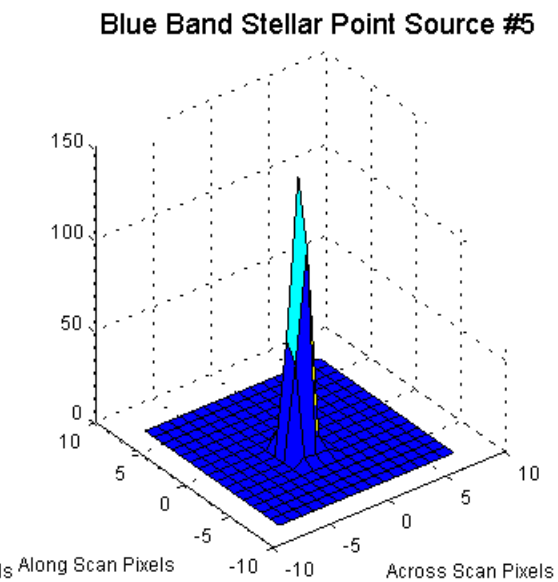
The next 16 slides are included for completeness.
They contain plots of the multi-spectral data sets.
They are not part of the formal presentation.

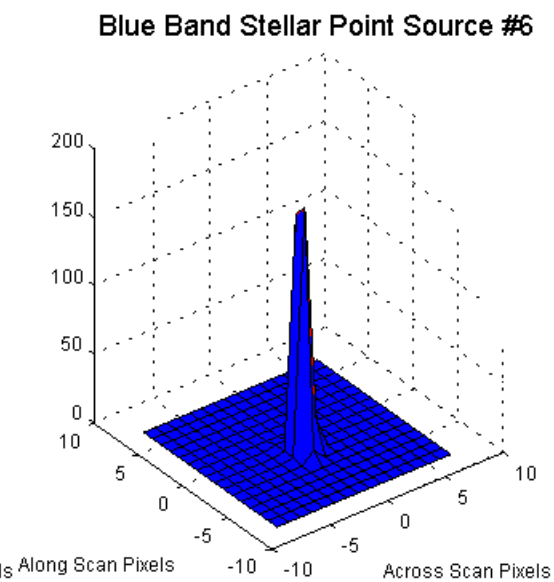

Blue Band Stellar Point Source #1
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

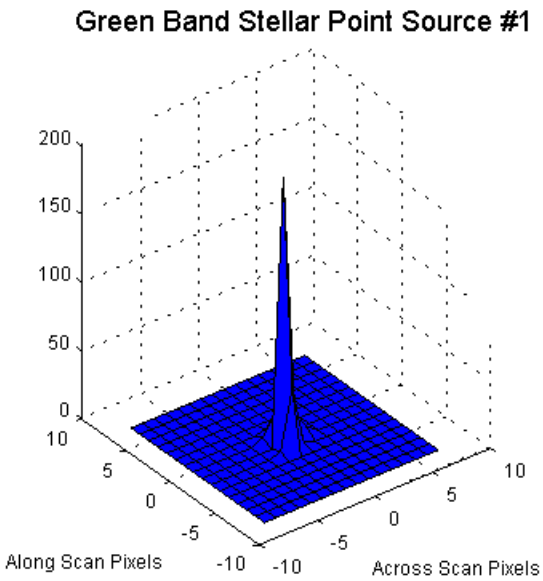

Blue Band Stellar Point Source #2
100
80
60
40
20
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

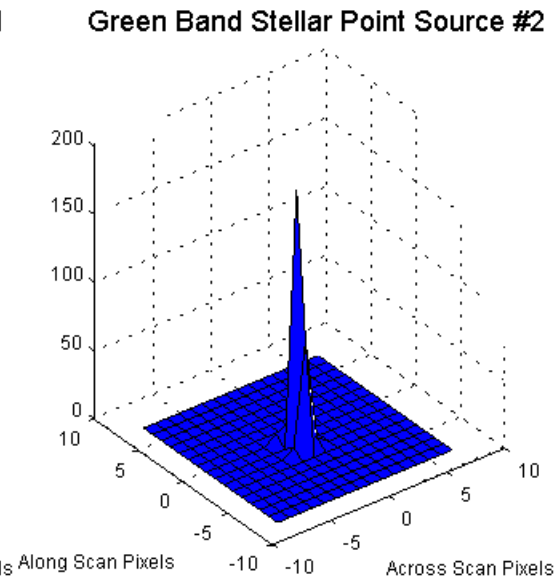

Blue Band Stellar Point Source #3
100
80
60
40
20
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

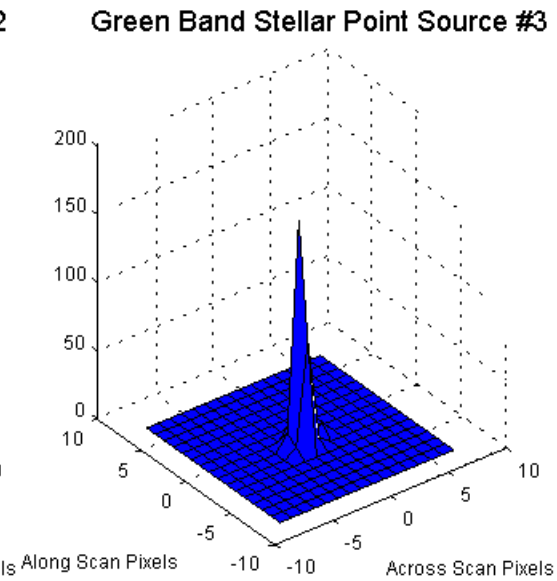

Blue Band Stellar Point Source #4
250
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

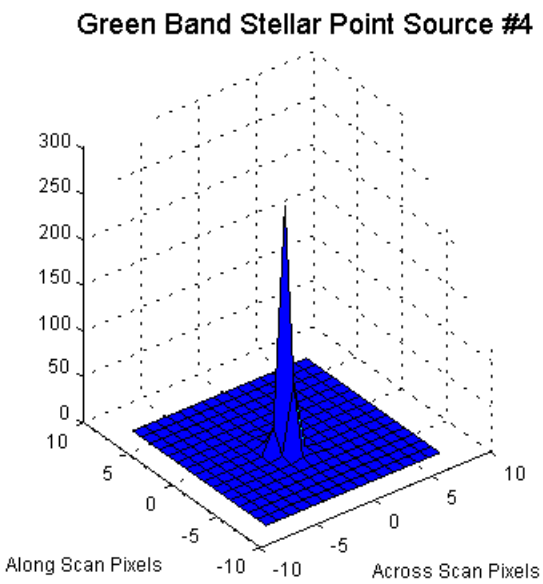

Blue Band Stellar Point Source #5
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

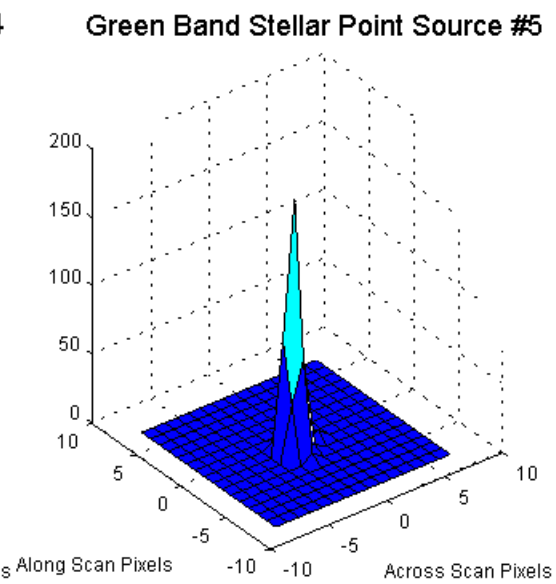

Blue Band Stellar Point Source #6
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

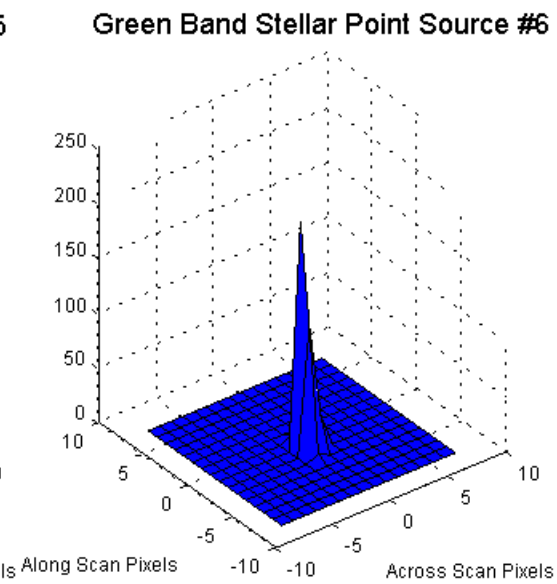

Green Band Stellar Point Source #1
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

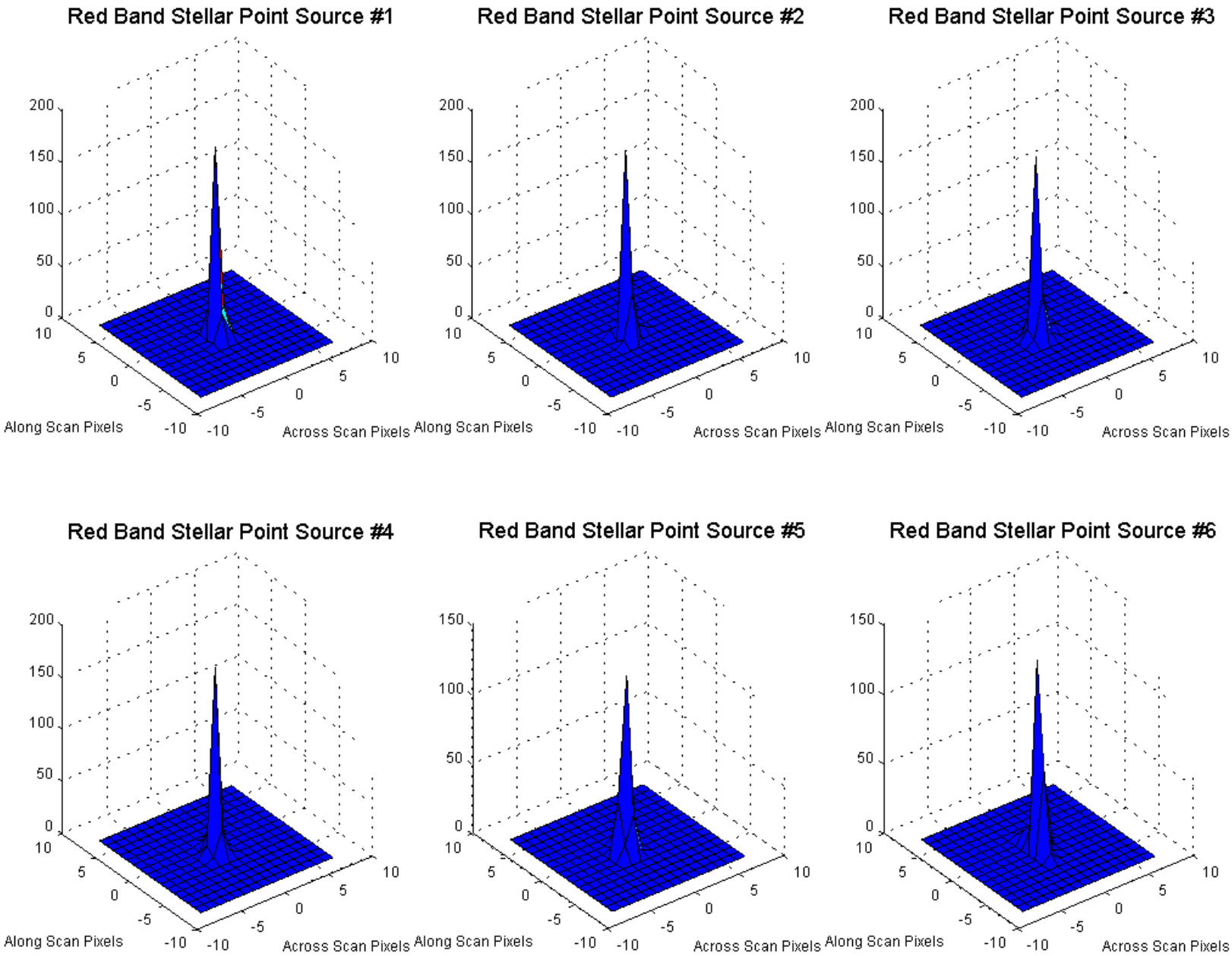

Green Band Stellar Point Source #2
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

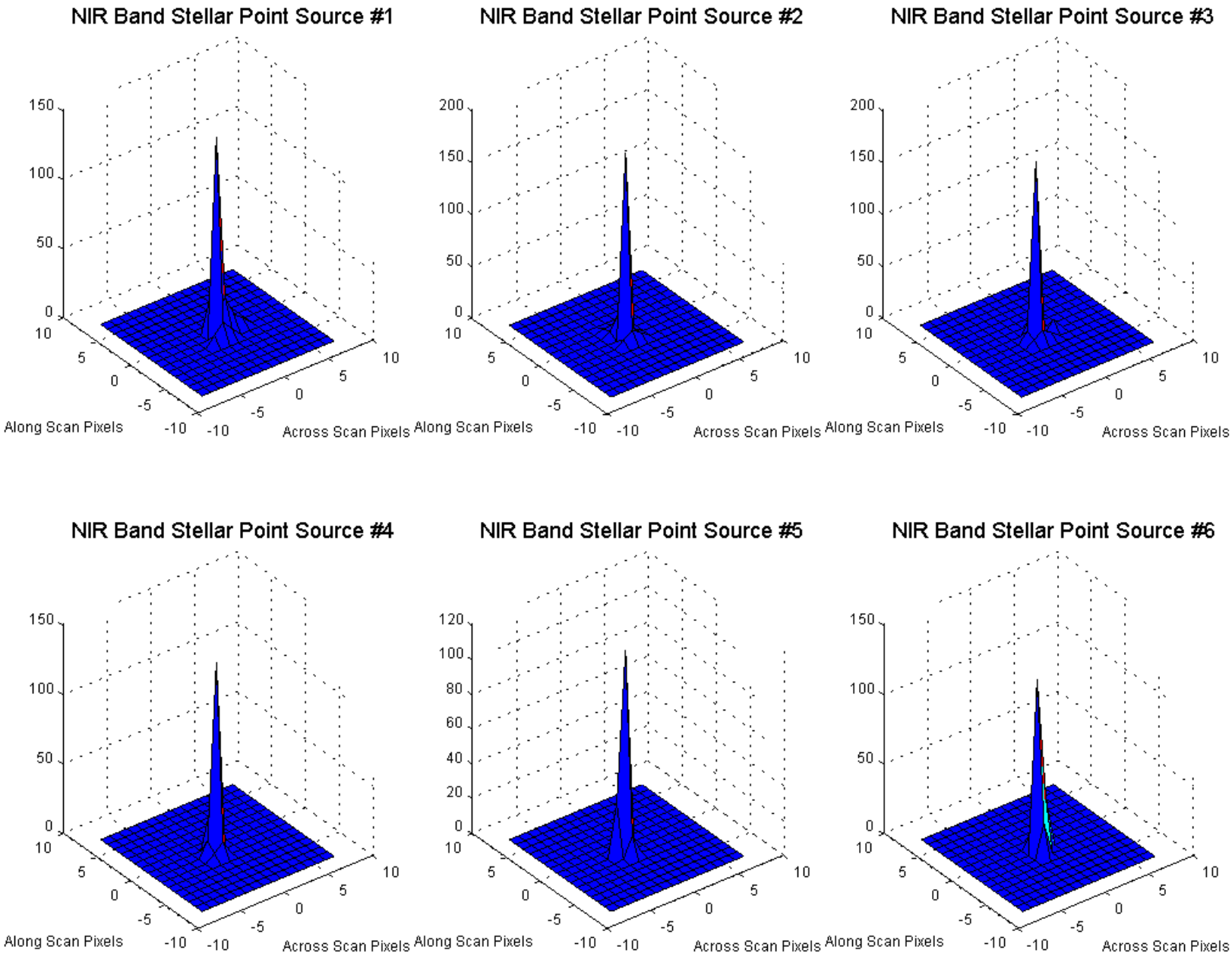

Green Band Stellar Point Source #3
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels


Green Band Stellar Point Source #4
300
250
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

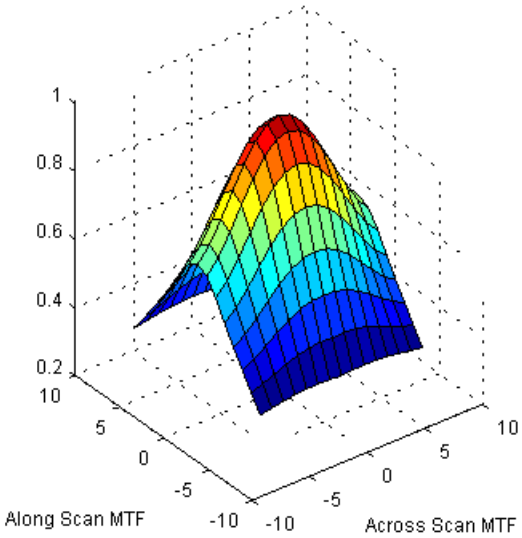

Green Band Stellar Point Source #5
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels


Green Band Stellar Point Source #6
250
200
150
100
50
0
10
5
0
-5
-10
Along Scan Pixels
-10
-5
0
5
10
Across Scan Pixels

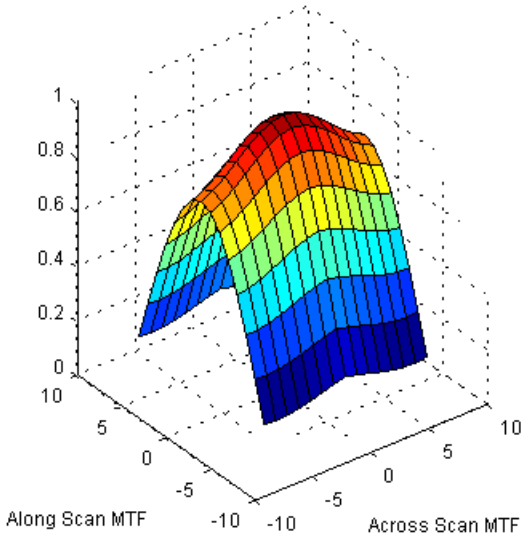

Red Band Stellar Point Source #1
Red Band Stellar Point Source #2
Red Band Stellar Point Source #3
Red Band Stellar Point Source #4
Red Band Stellar Point Source #5
Red Band Stellar Point Source #6
Along Scan Pixels
Across Scan Pixels


NIR Band Stellar Point Source #1
NIR Band Stellar Point Source #2
NIR Band Stellar Point Source #3
NIR Band Stellar Point Source #4
NIR Band Stellar Point Source #5
NIR Band Stellar Point Source #6
Along Scan Pixels
Across Scan Pixels

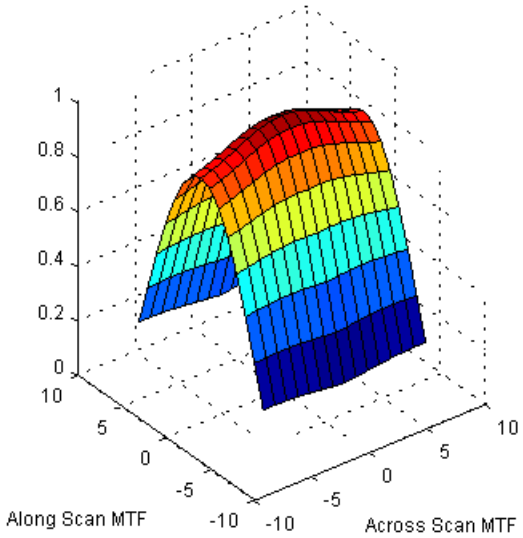
2D-MTF for Blue Band Stellar Point Source #1



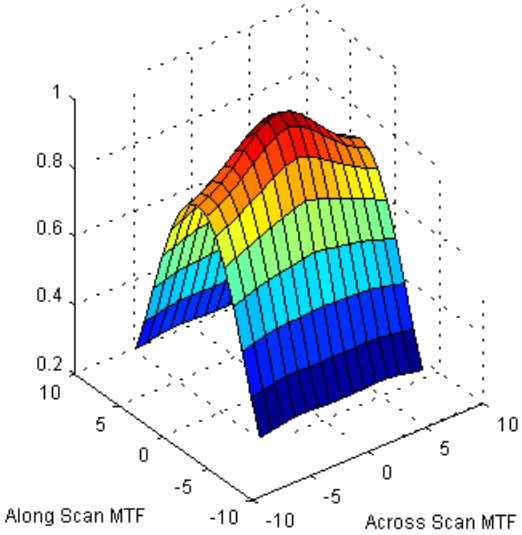
2D-MTF for Blue Band Stellar Point Source #2



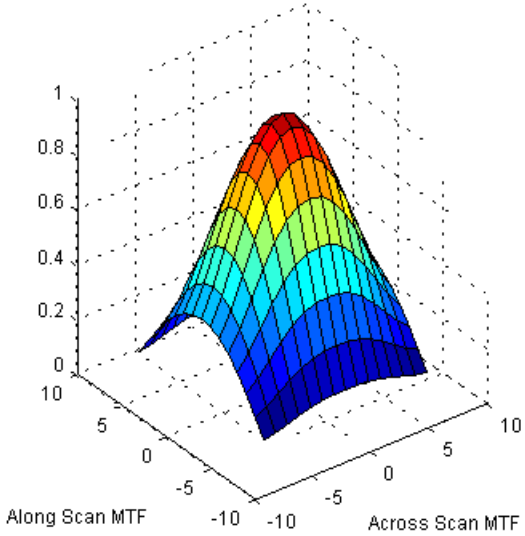
2D-MTF for Blue Band Stellar Point Source #3



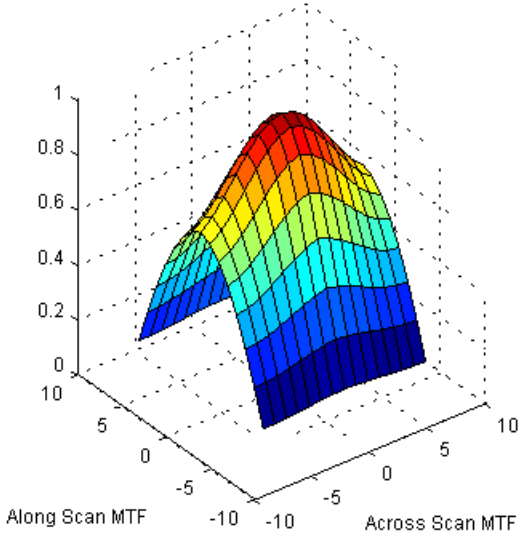
2D-MTF for Blue Band Stellar Point Source #4



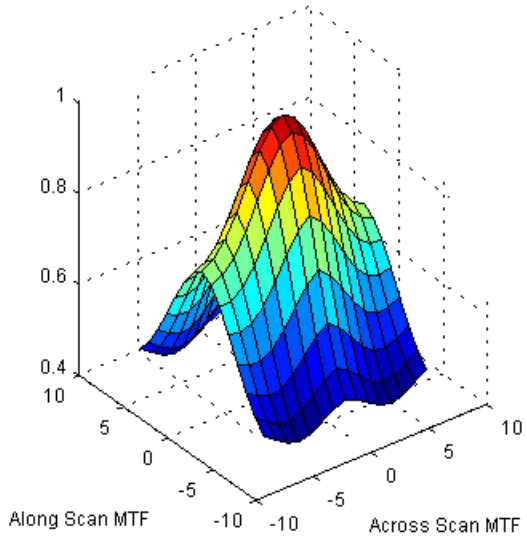
2D-MTF for Blue Band Stellar Point Source #5



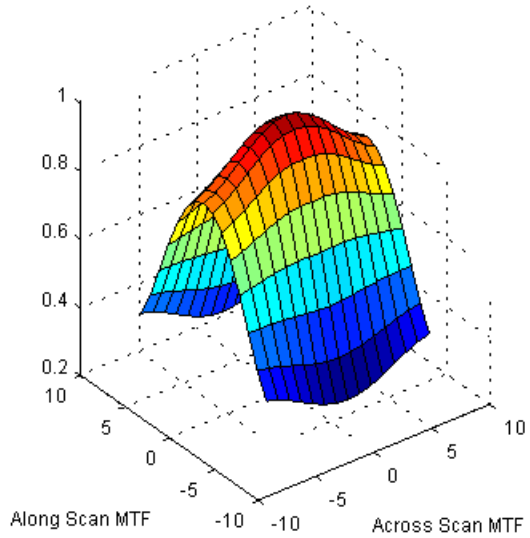
2D-MTF for Blue Band Stellar Point Source #6



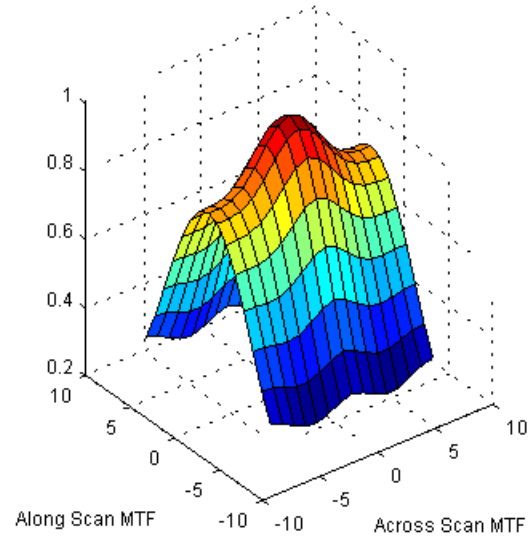
2D-MTF for Green Band Stellar Point Source #1



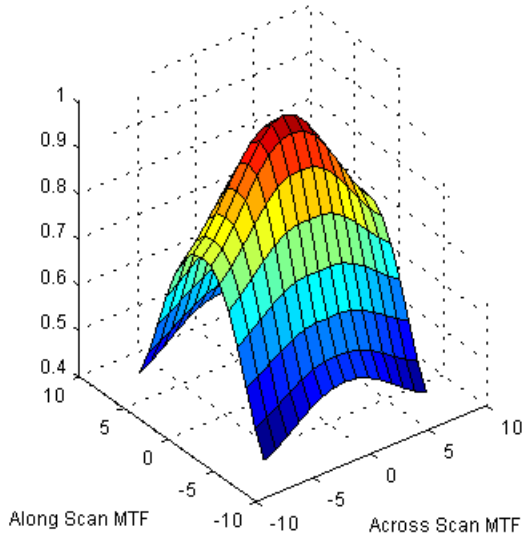
2D-MTF for Green Band Stellar Point Source #2



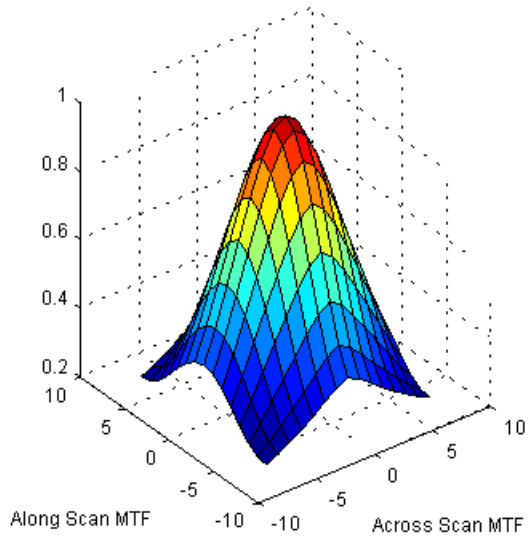
2D-MTF for Green Band Stellar Point Source #3



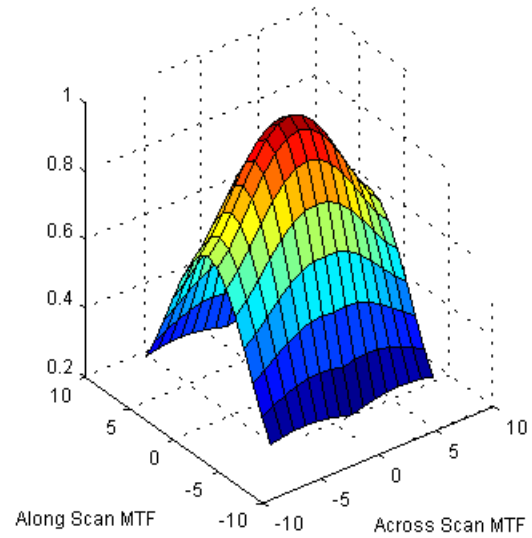
2D-MTF for Green Band Stellar Point Source #4



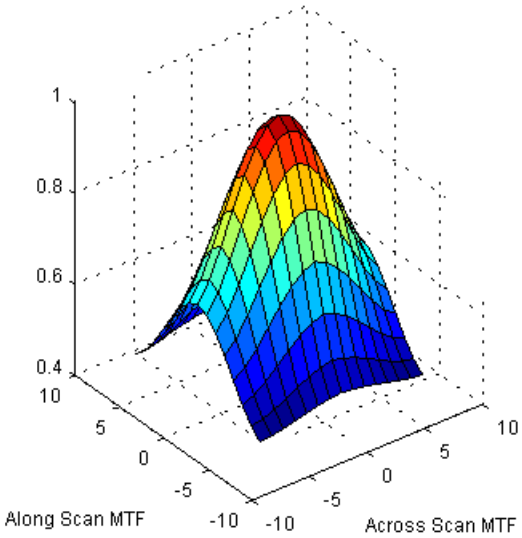
2D-MTF for Green Band Stellar Point Source #5



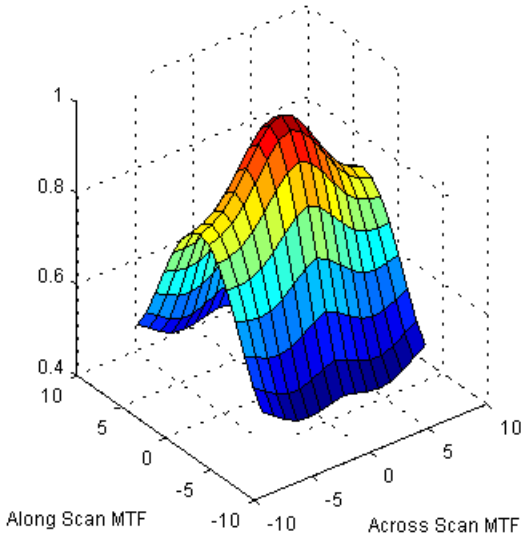
2D-MTF for Green Band Stellar Point Source #6



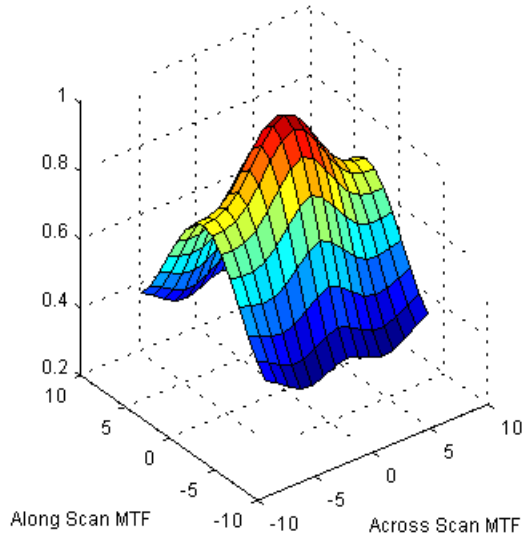
2D-MTF for Red Band Stellar Point Source #1



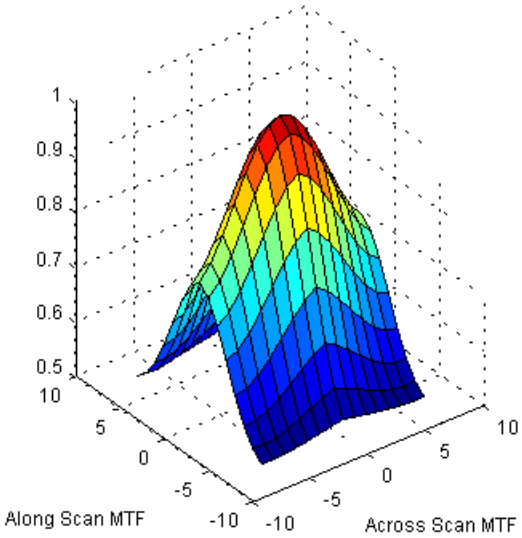
2D-MTF for Red Band Stellar Point Source #2



2D-MTF for Red Band Stellar Point Source #3



2D-MTF for Red Band Stellar Point Source #4



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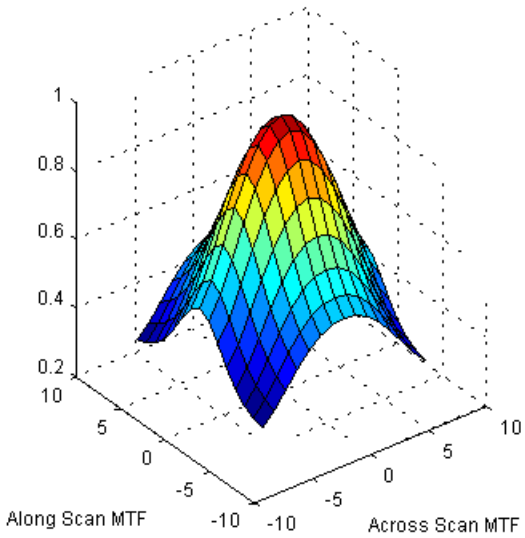
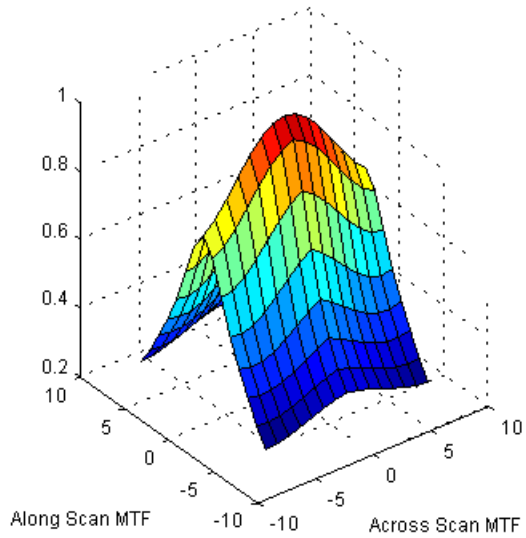
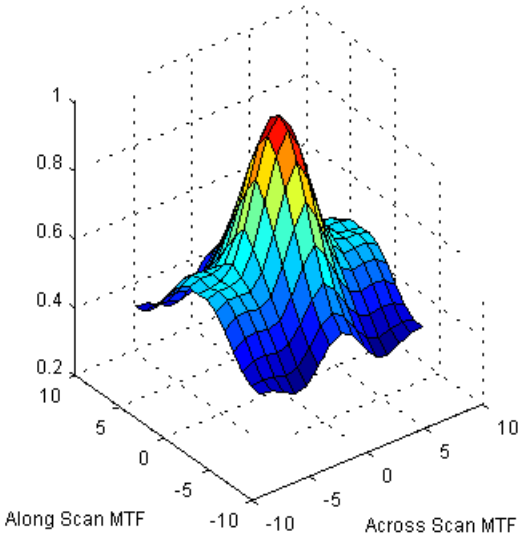


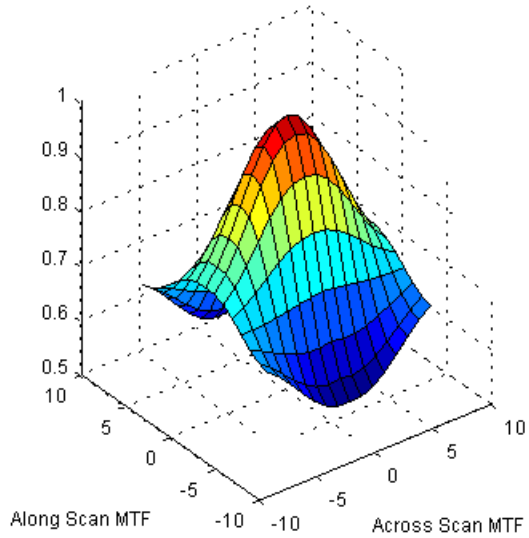
2D-MTF for Red Band Stellar Point Source #6



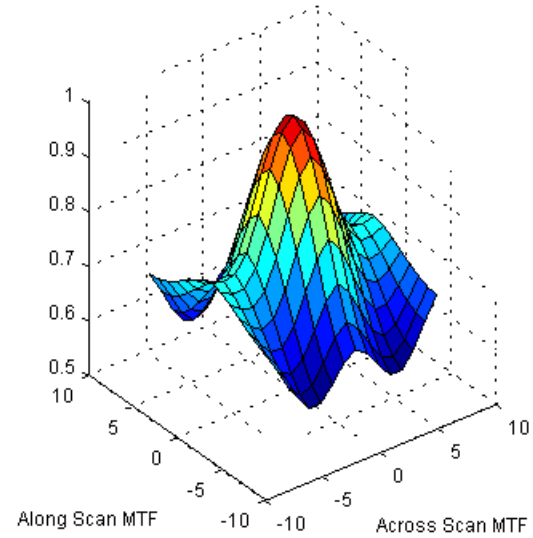
2D-MTF for NIR Band Stellar Point Source #1



2D-MTF for NIR Band Stellar Point Source #2



2D-MTF for NIR Band Stellar Point Source #3



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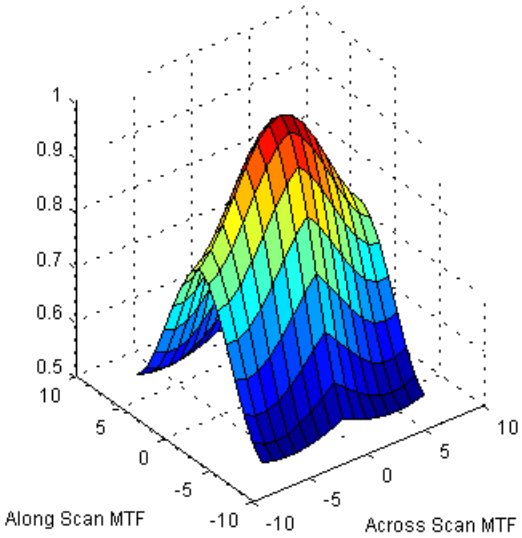
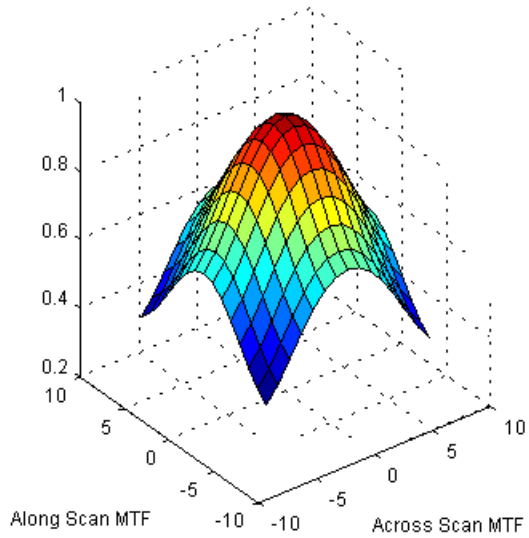
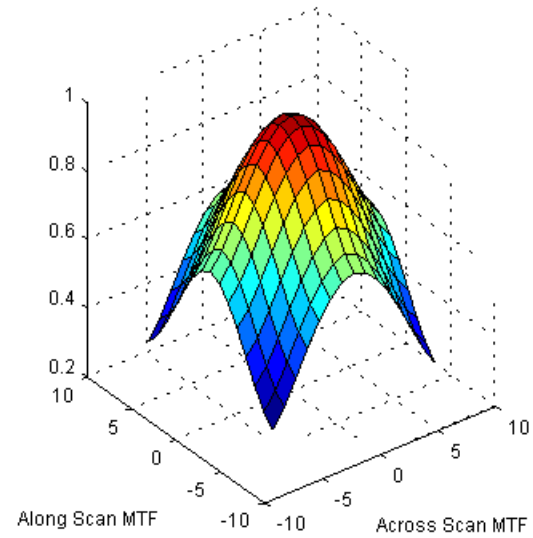
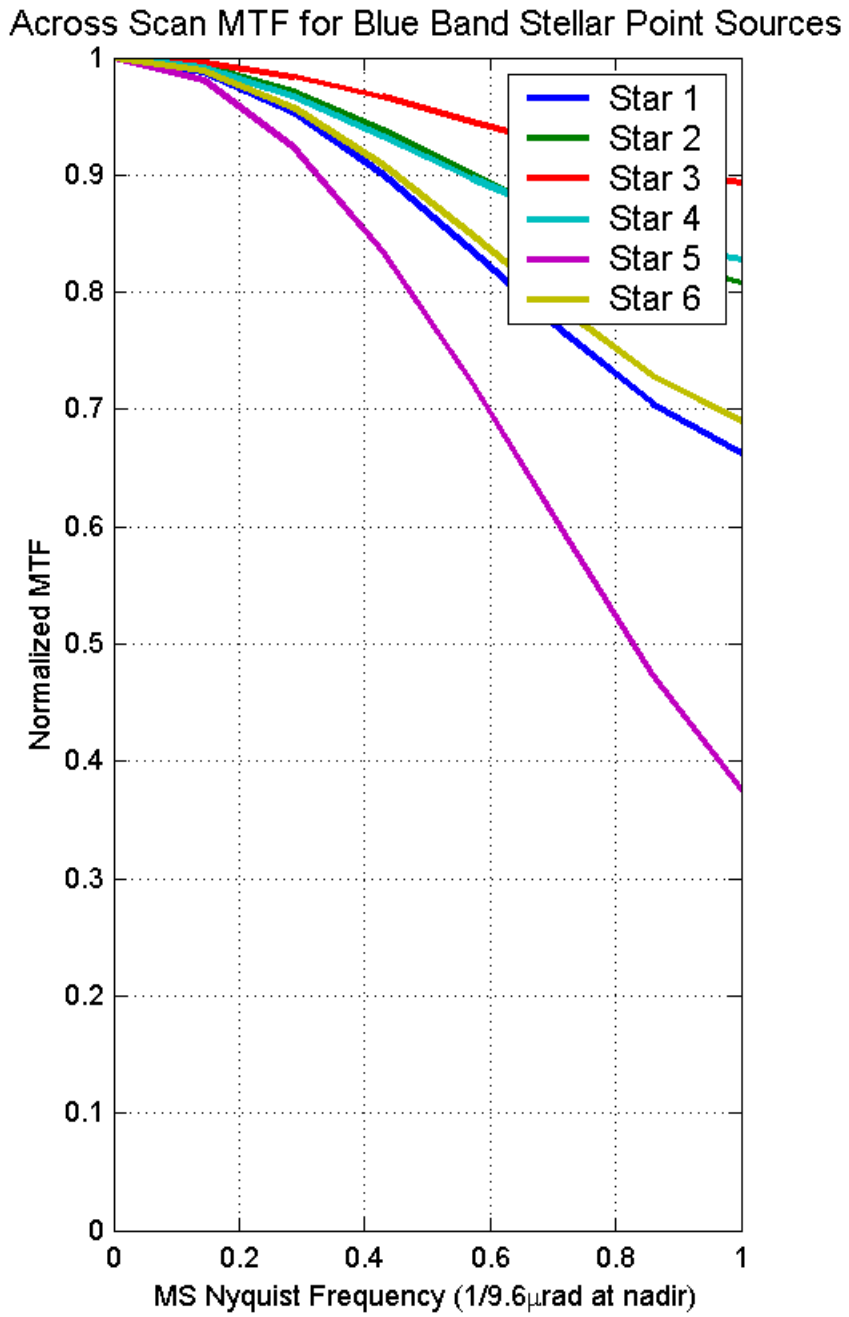


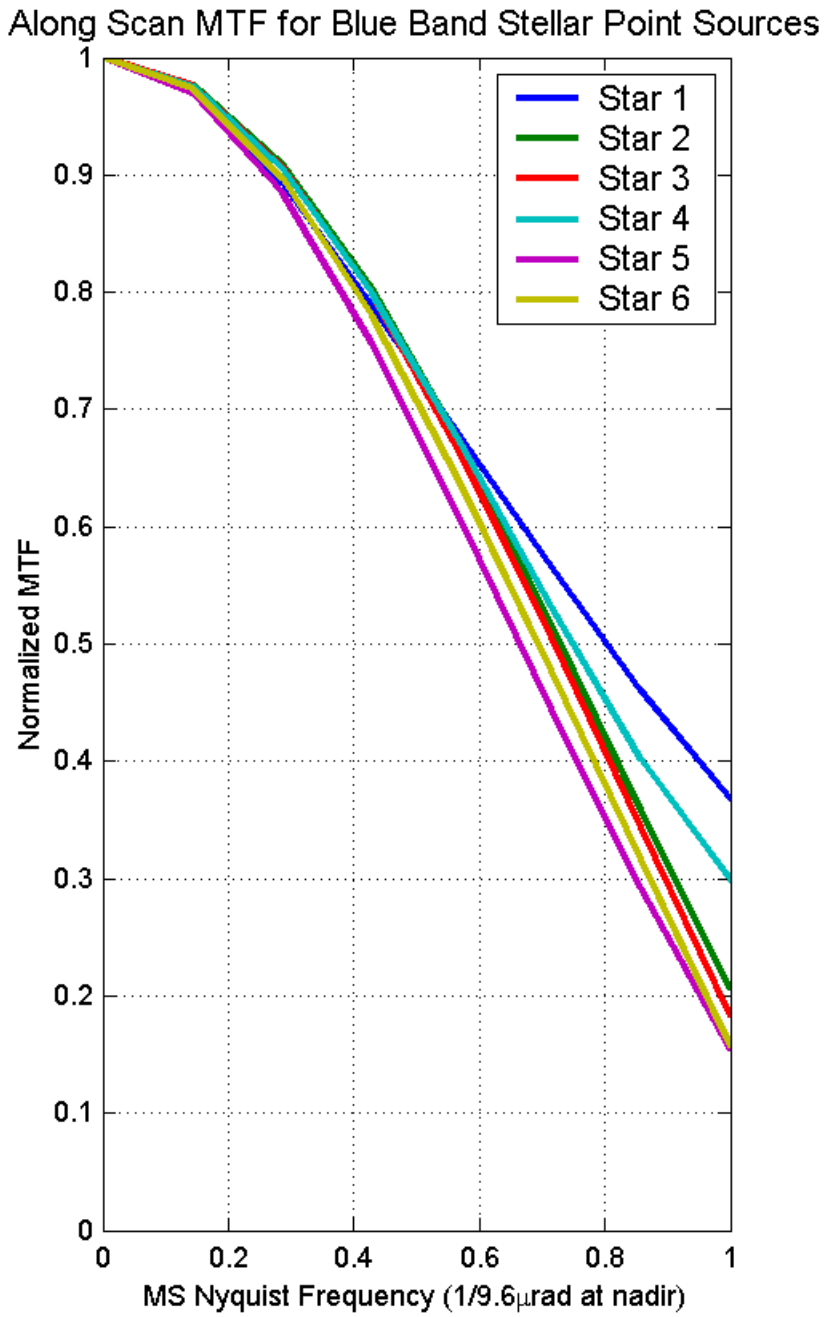
2D-MTF for NIR Band Stellar Point Source #5

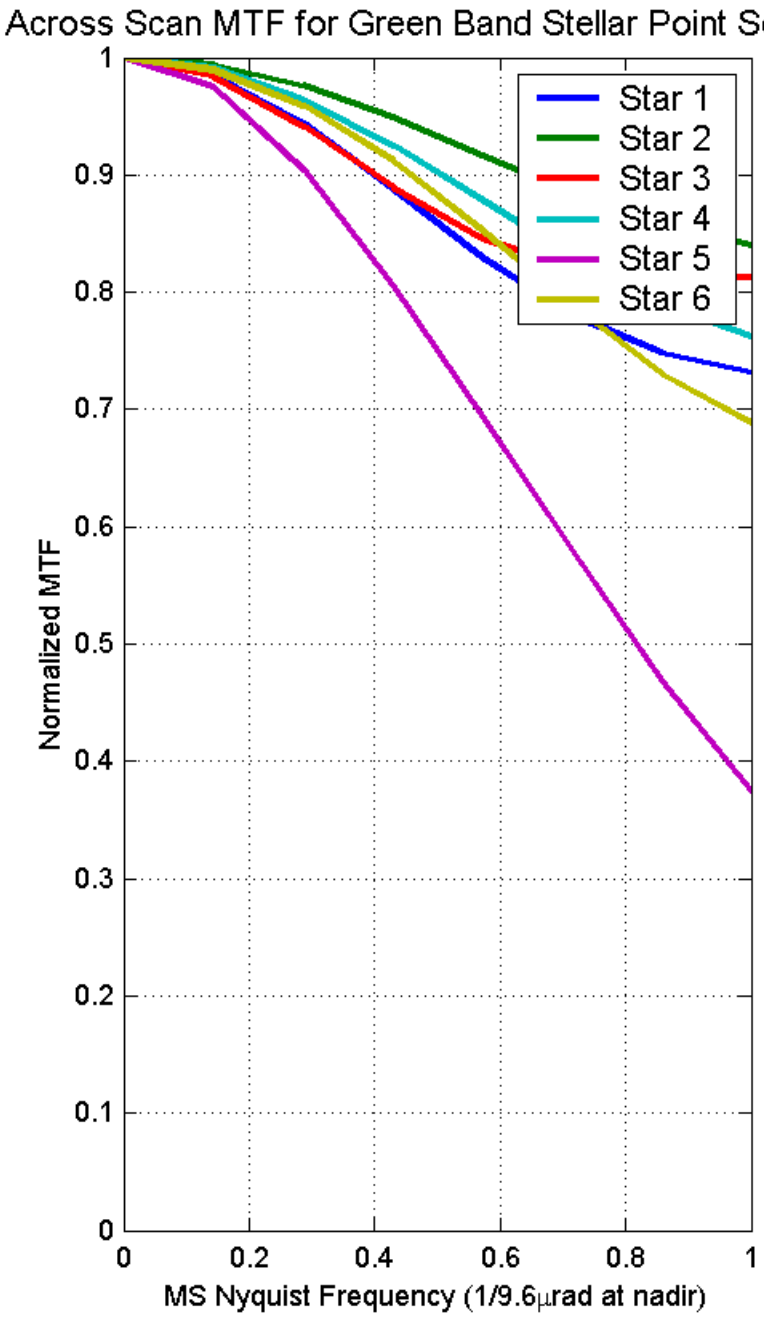


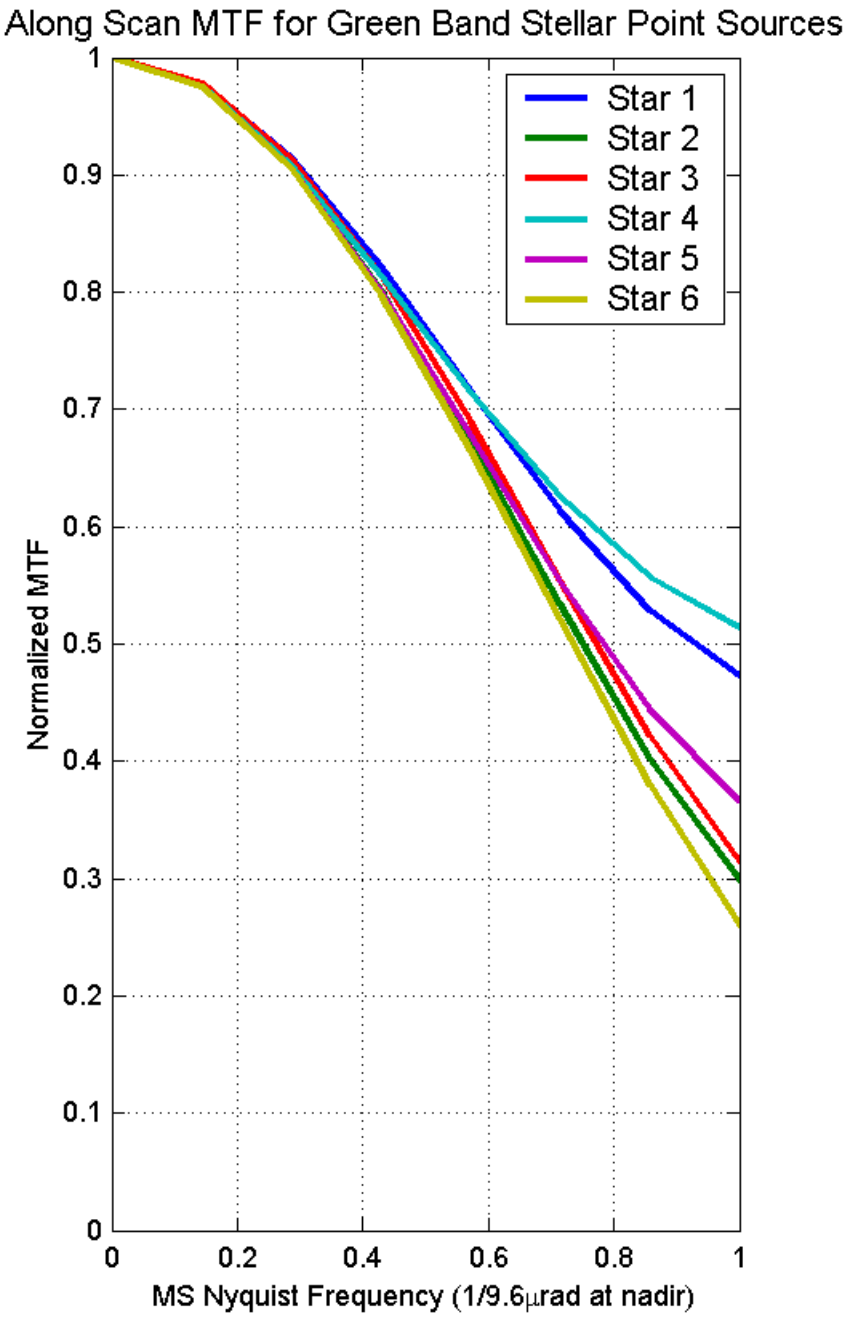
2D-MTF for NIR Band Stellar Point Source #6

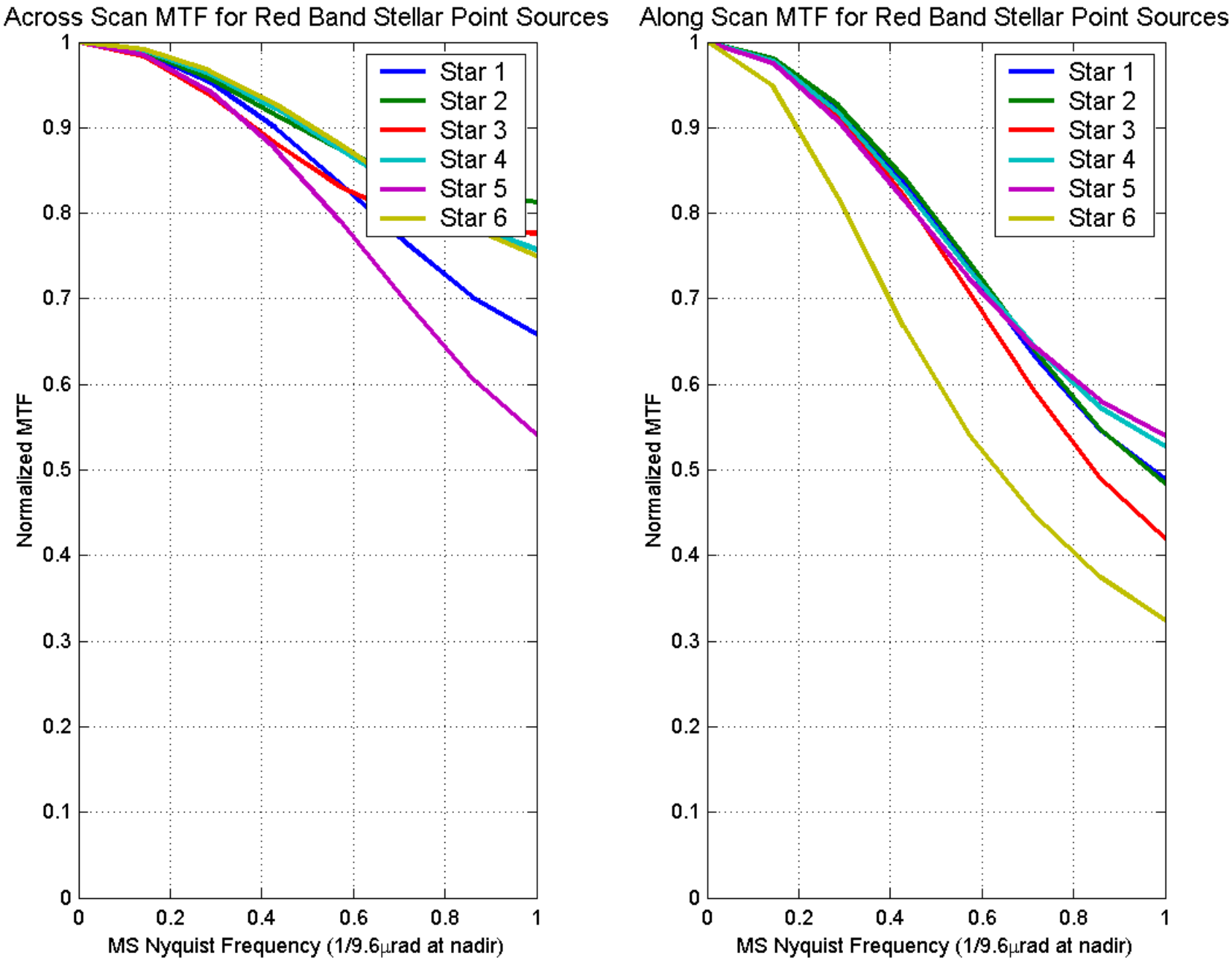


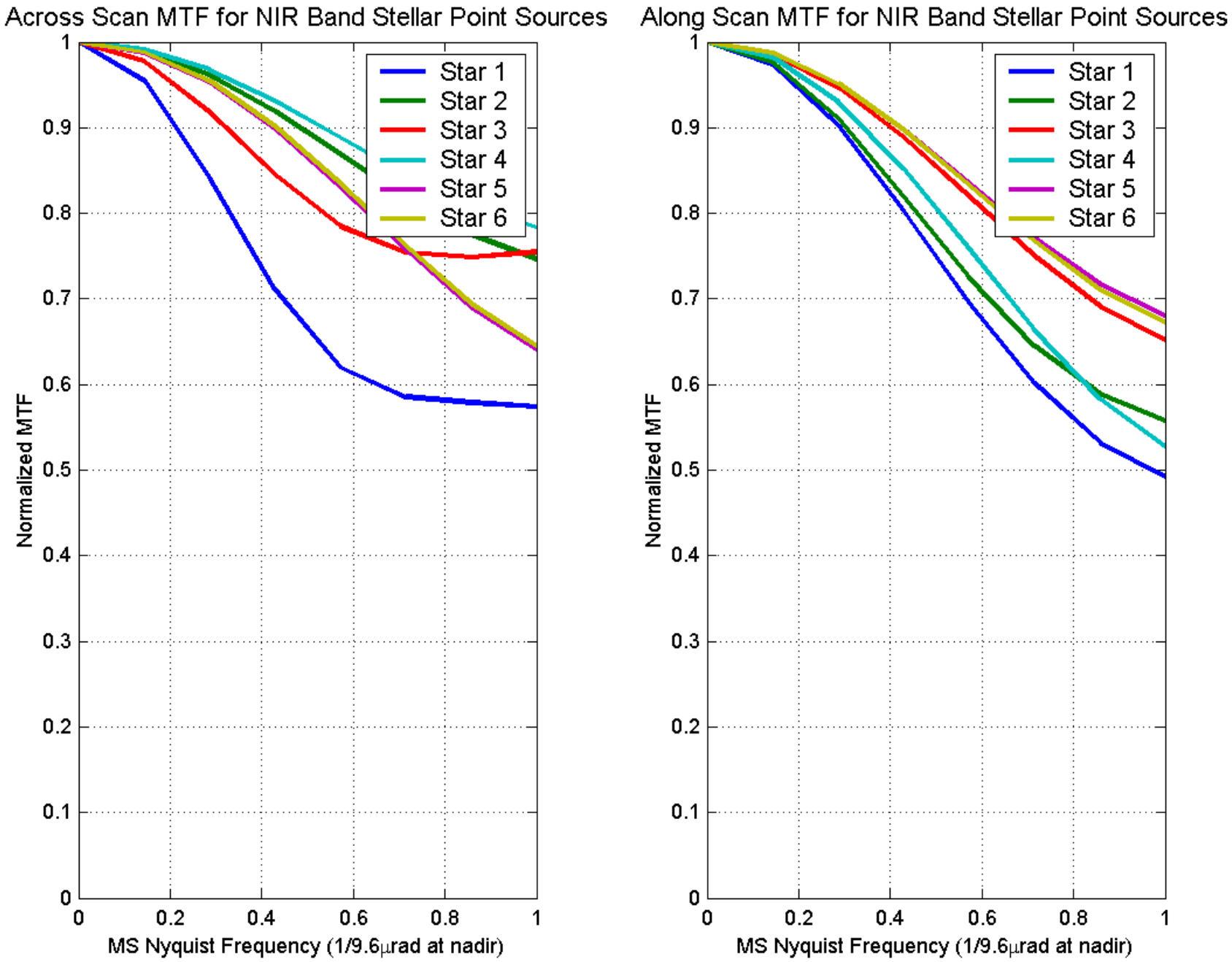

Across Scan MTF for Blue Band Stellar Point Sources
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
Star 1
Star 2
Star 3
Star 4
Star 5
Star 6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

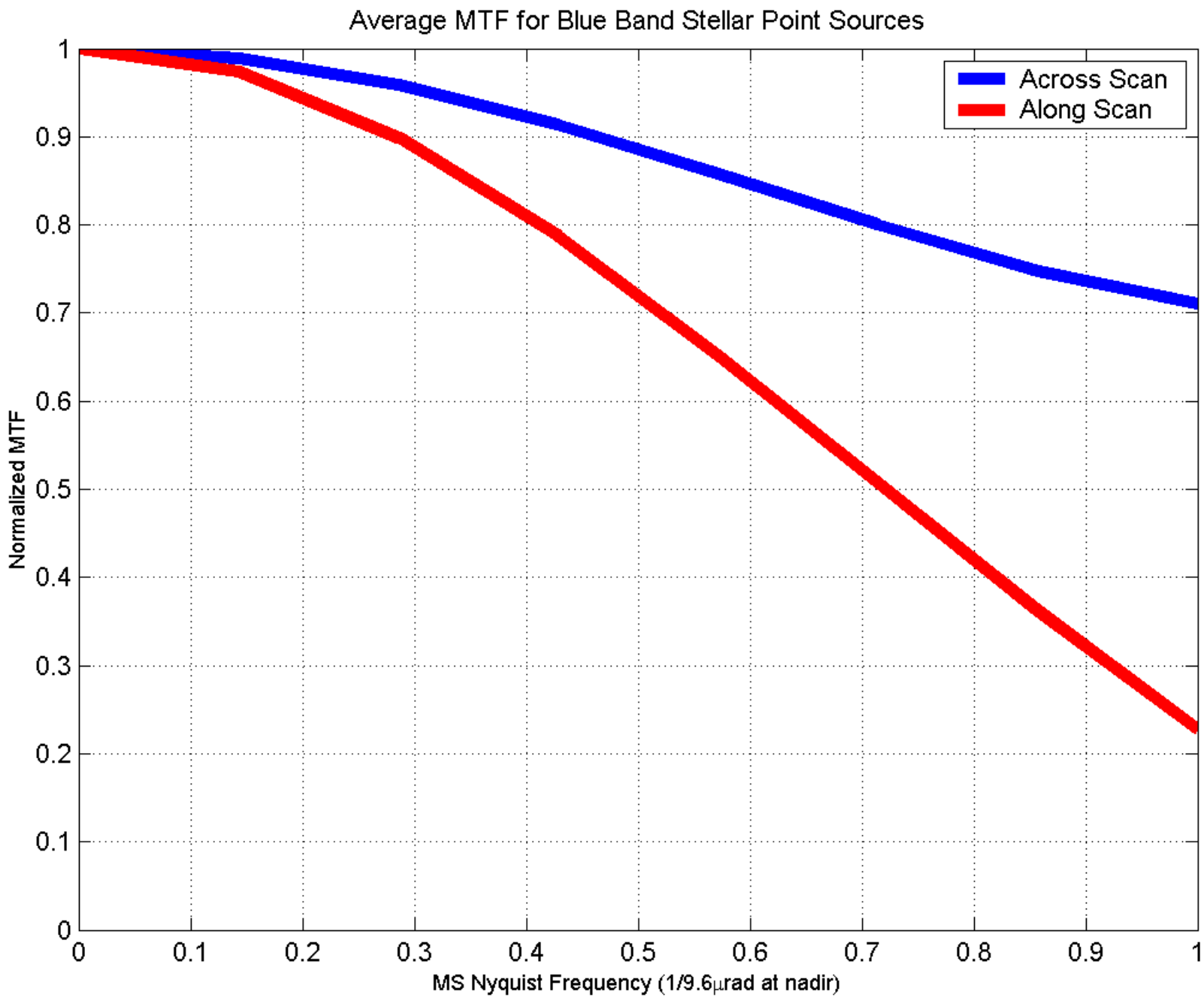

Along Scan MTF for Blue Band Stellar Point Sources
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
Star 1
Star 2
Star 3
Star 4
Star 5
Star 6
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

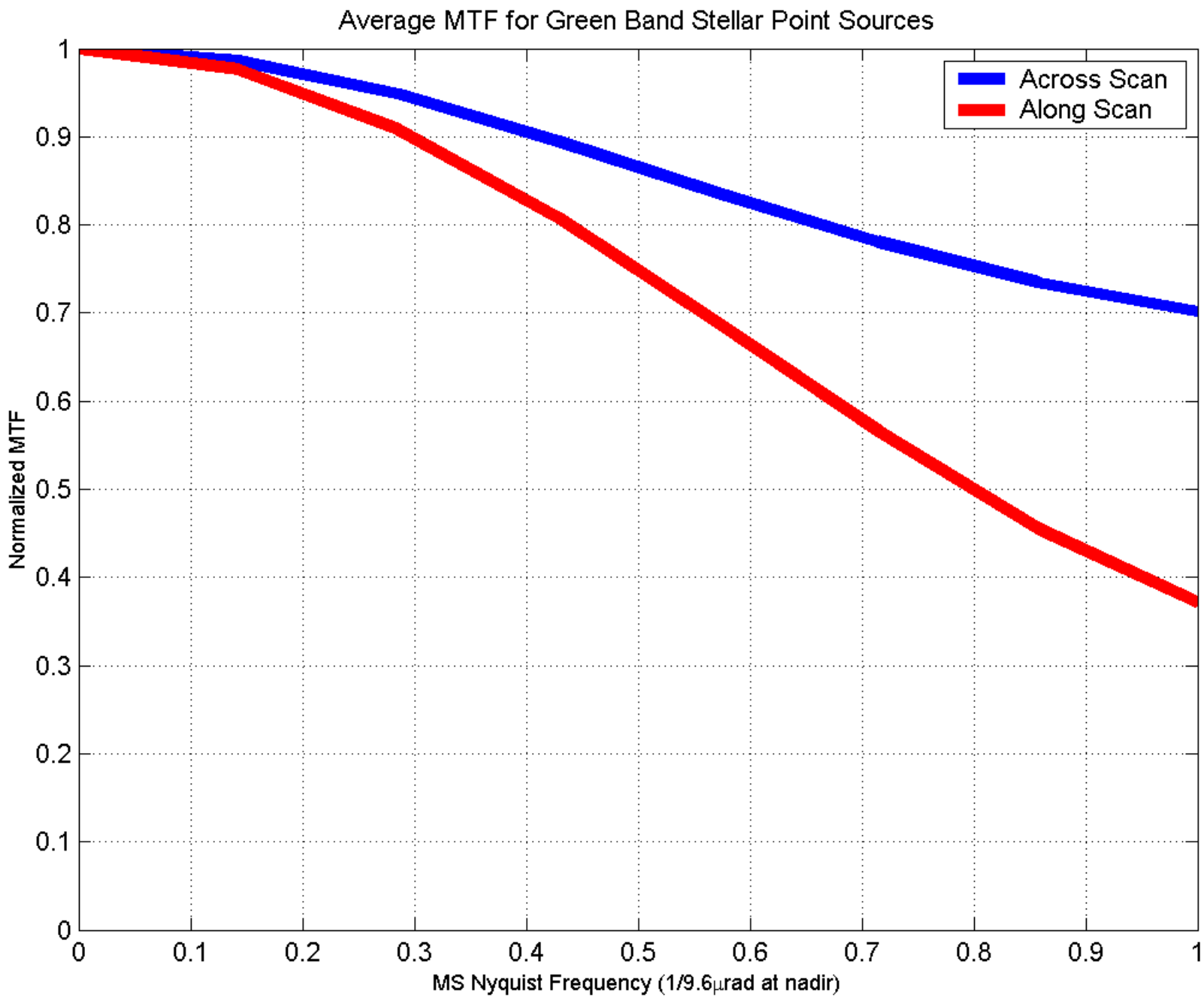

Across Scan MTF for Green Band Stellar Point Sources
Star 1
Star 2
Star 3
Star 4
Star 5
Star 6
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

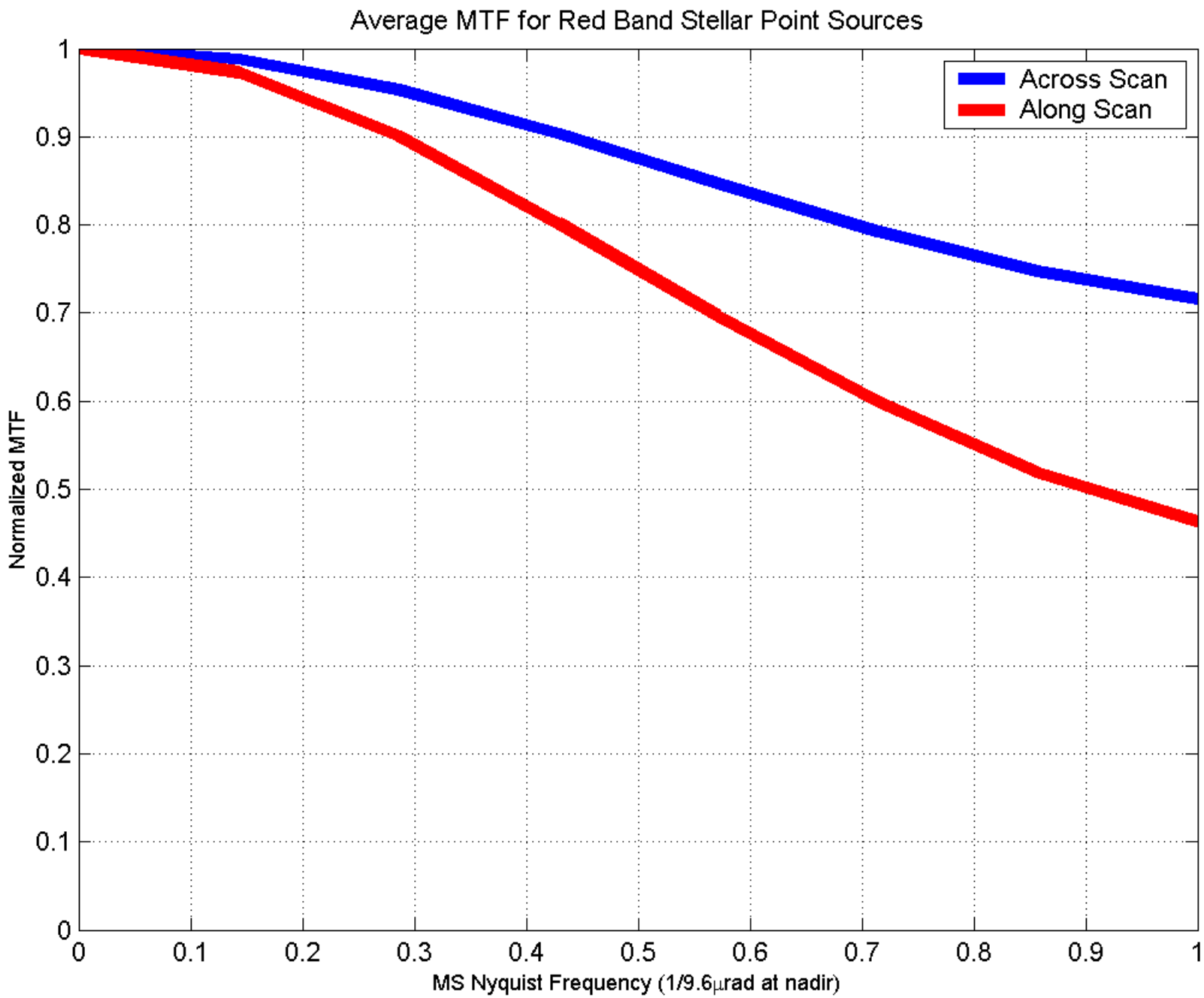

Along Scan MTF for Green Band Stellar Point Sources
Star 1
Star 2
Star 3
Star 4
Star 5
Star 6
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

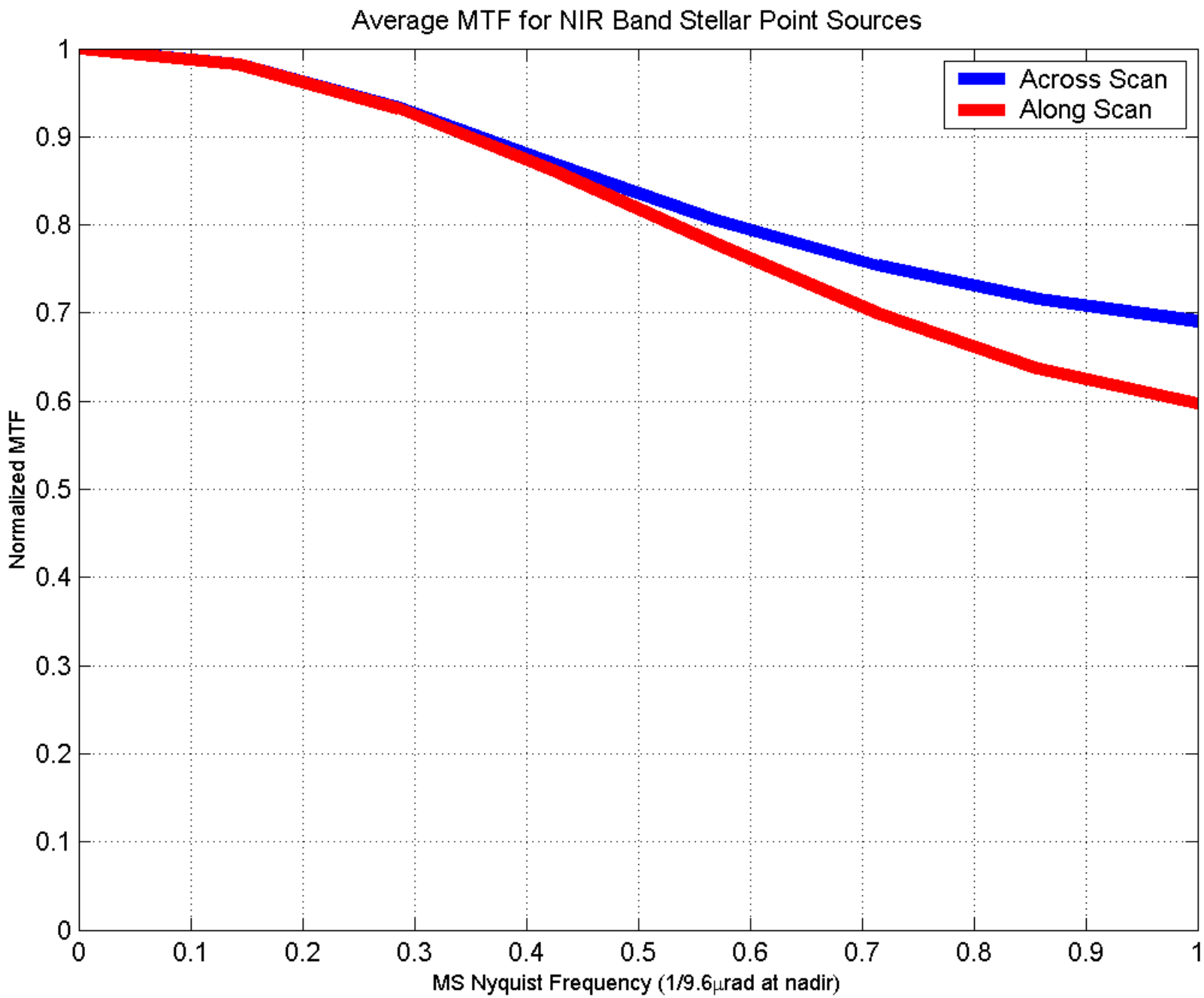

Across Scan MTF for Red Band Stellar Point Sources
Along Scan MTF for Red Band Stellar Point Sources
Star 1
Star 2
Star 3
Star 4
Star 5
Star 6
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1


Across Scan MTF for NIR Band Stellar Point Sources
Along Scan MTF for NIR Band Stellar Point Sources
Star 1
Star 2
Star 3
Star 4
Star 5
Star 6
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1


Average MTF for Blue Band Stellar Point Sources
Across Scan
Along Scan
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Average MTF for Green Band Stellar Point Sources
Across Scan
Along Scan
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Average MTF for Red Band Stellar Point Sources
Across Scan
Along Scan
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Average MTF for NIR Band Stellar Point Sources
Across Scan
Along Scan
Normalized MTF
MS Nyquist Frequency (1/9.6μrad at nadir)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1