

Effective Pictorial Information Capacity as an Image Quality Metric

- ◇ 10% LSF Information Capacity
- 50% LSF Information Capacity

$$y = 0.9225x + 0.3694$$

$$R^2 = 0.9952$$

$$y = 0.3302x + 0.3694$$

$$R^2 = 0.96$$

R.B. Jenkin and S Triantaphillidou

Cranfield University, Shrivenham, SN6 8LA, UK

Motivation

- Quality metrics are useful!
- Question complexity of formulae
 - Correlation Achieved
 - Use of the results
 - Physical basis
- Goal - To create a simple metric using a pragmatic approach

Quality Metrics are Useful!

- No one can deny that quality metrics in principal are useful!
- Compare systems!
- Predict results before build system based on design parameters!
- Fascinating area!

But they are complicated...

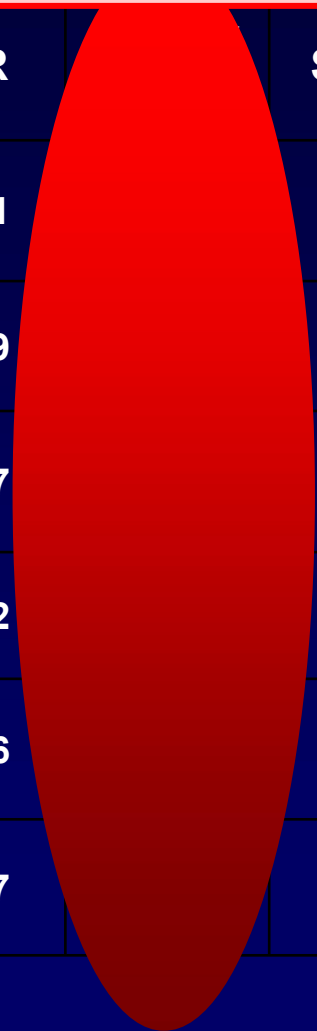
All that to tell us whether one system will produce a preferable image to another!

So lets make it really complicated by applying it to JPEG!

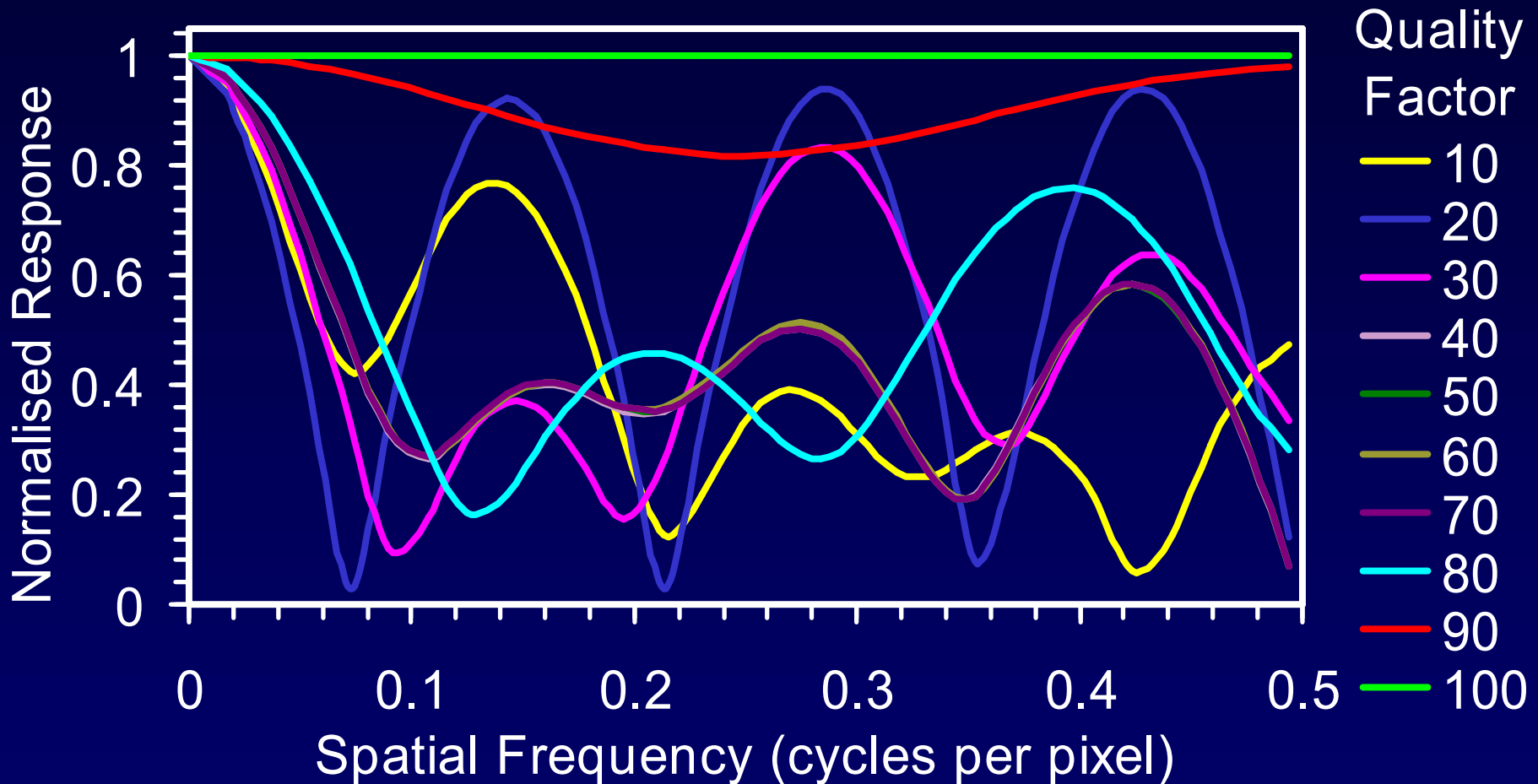
Don't get excited about the correlation coefficients – its only r not r^2 !

Its

| Scenes | RMSE | SNR | SQRIn | PIC |
|--------|-------|-------|-------|-------|
| Alps | 0.978 | 0.971 | 0.980 | 0.983 |
| Bigben | 0.881 | 0.789 | 0.966 | 0.952 |
| Conns | 0.913 | 0.957 | 0.976 | 0.974 |
| Dock | 0.987 | 0.952 | 0.956 | 0.931 |
| Dolly | 0.870 | 0.776 | 0.880 | 0.885 |
| Port | 0.940 | 0.867 | 0.951 | 0.970 |

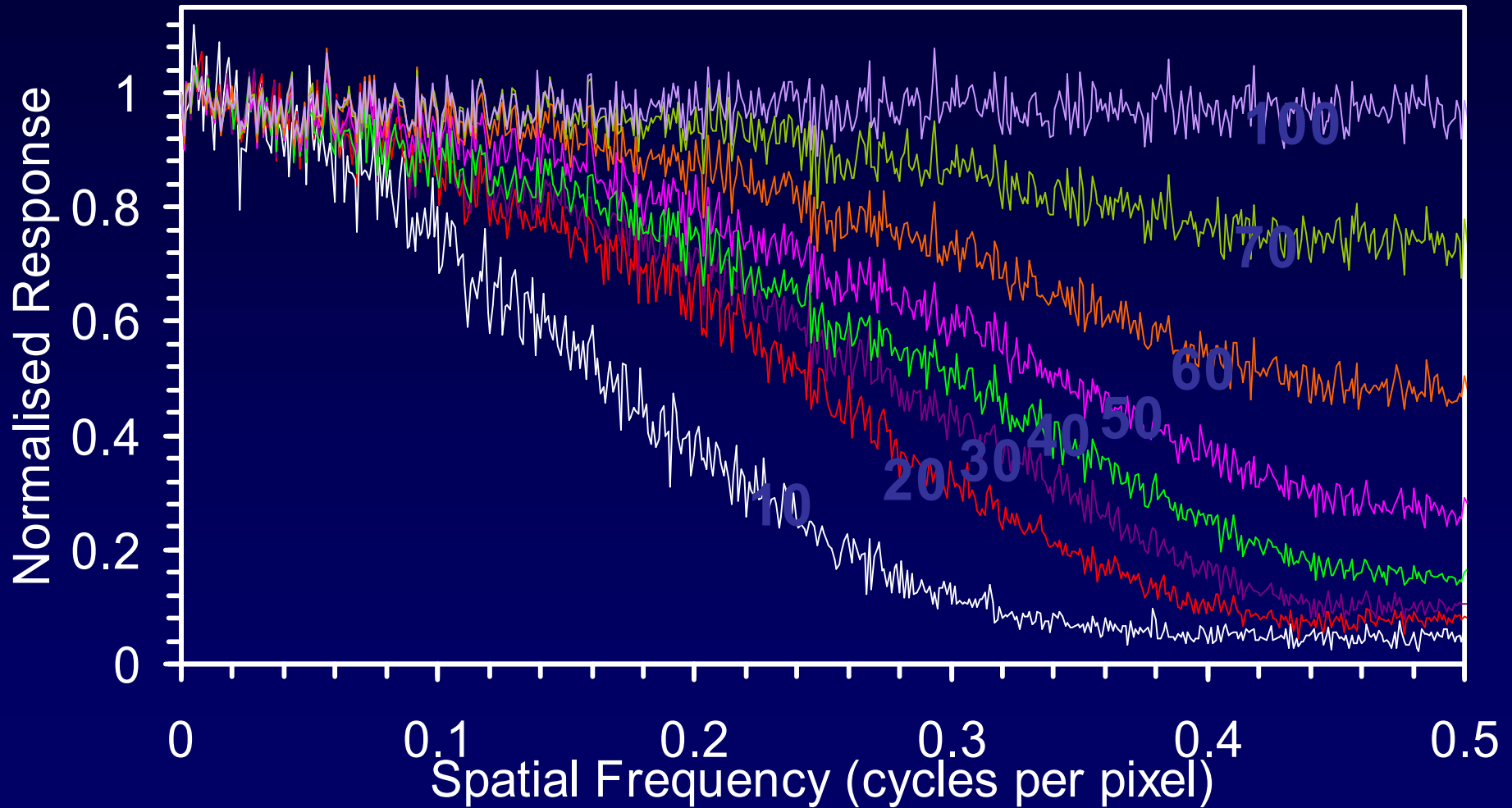


Fords Sine Wave MTF Results



So with a fistful of new MTFs we skip and dance and apply them to the data...

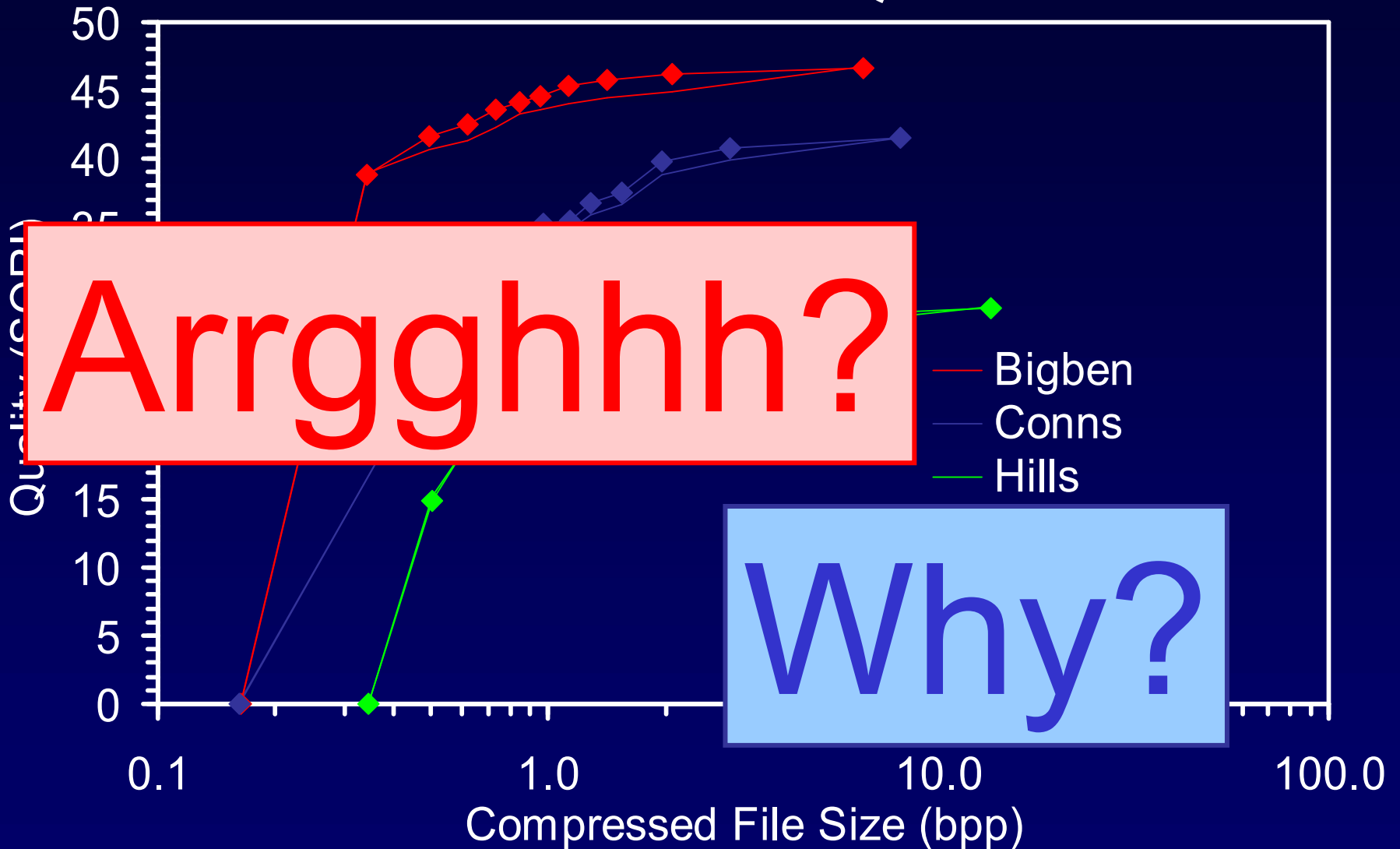
Fs



New Results

| Scenes | RMSE | SNR | Quality Factor | SQRIn | PIC | New SQRIn | New PIC |
|--------|-------|-------|----------------|-------|-------|-----------|---------|
| Alps | 0.978 | 0.971 | 0.985 | 0.980 | 0.983 | 0.985 | 0.980 |
| Bigben | 0.881 | 0.789 | 0.906 | 0.966 | 0.952 | 0.909 | 0.927 |
| Conns | 0.913 | 0.957 | 0.919 | 0.976 | 0.974 | 0.970 | 0.981 |
| Dock | 0.987 | 0.952 | 0.962 | 0.956 | 0.931 | 0.971 | 0.957 |
| Dolly | 0.870 | 0.776 | 0.884 | 0.880 | 0.885 | 0.860 | 0.890 |
| Port | 0.940 | 0.867 | 0.937 | 0.951 | 0.970 | 0.981 | 0.986 |

SQRI Results



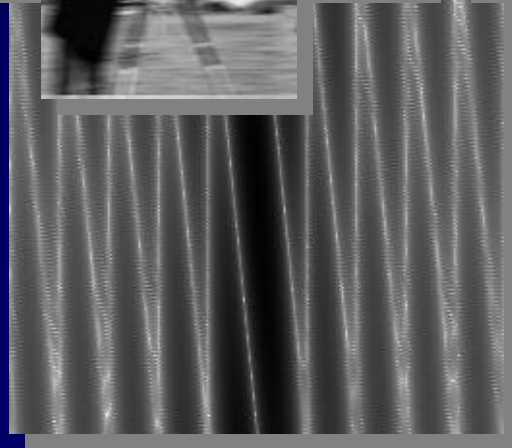
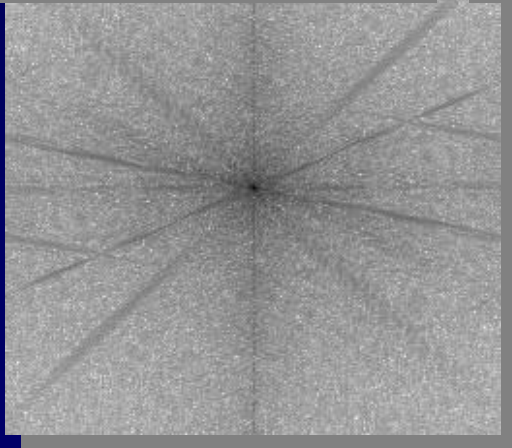
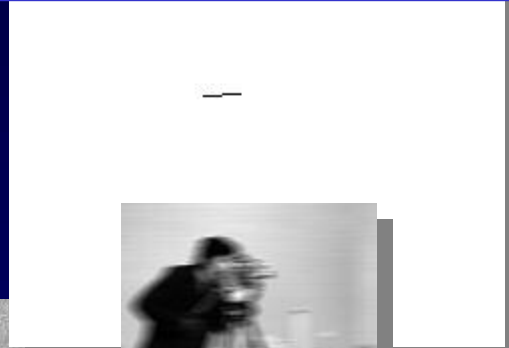
Arrggghhh?

Why?

Bigben
Conns
Hills

Signal and Noise Interaction

Signal and noise are irreversibly combined!



Metric

10

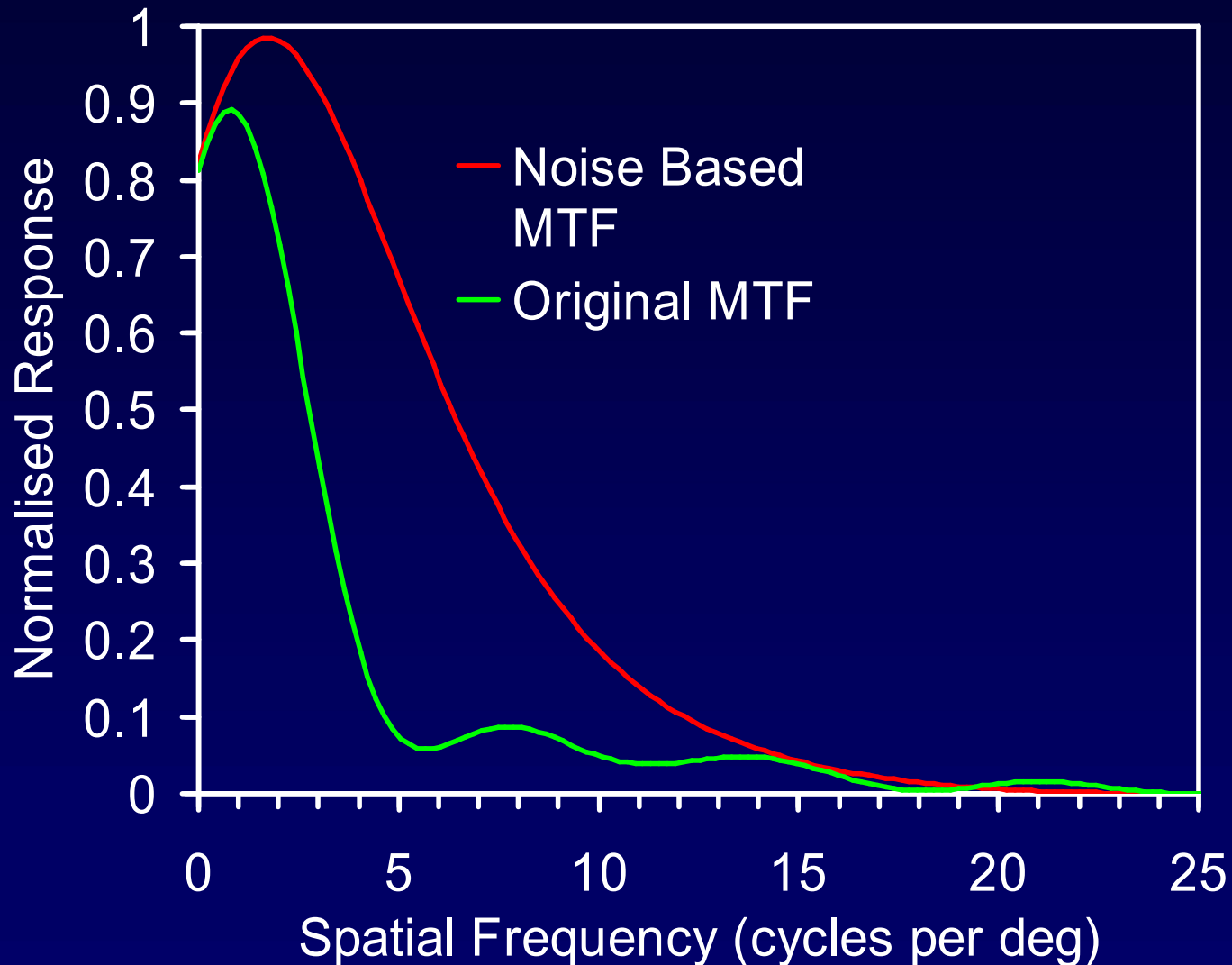
Signal and Noise Interaction

Also need absolute
MTF and NPS...

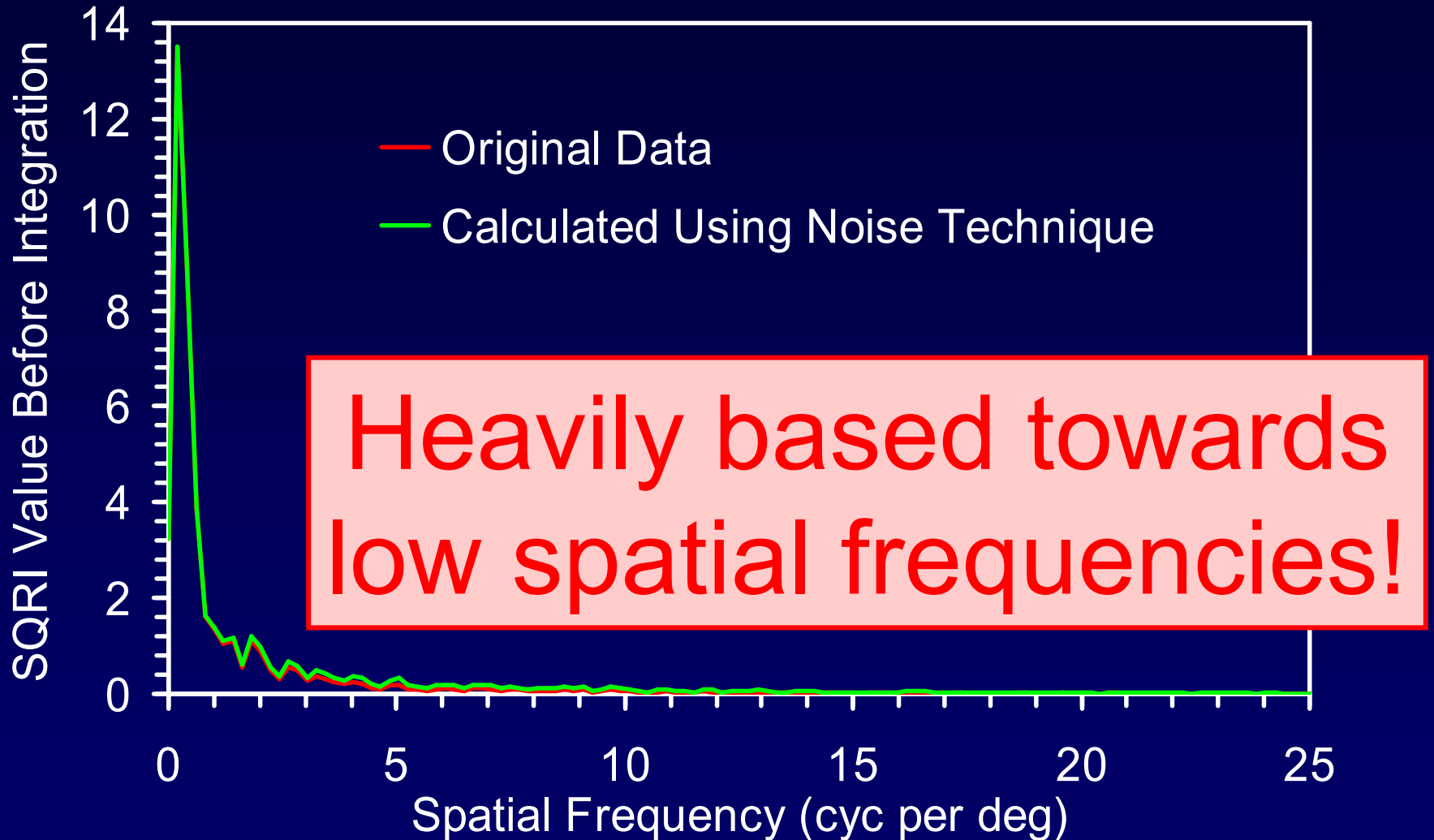
$$OUT_{A+B+C} = (MTF_A(MTF_B) + NPS_B) \times MTF_C + NPS_C$$

$$\begin{aligned} OUT_{A+B+C} &= MTF_A MTF_B MTF_C SIG_A \\ &+ MTF_B MTF_C NPS_A \\ &+ MTF_C NPS_B \\ &+ NPS_C \end{aligned}$$

Difference in MTFs



SQRI before Integration

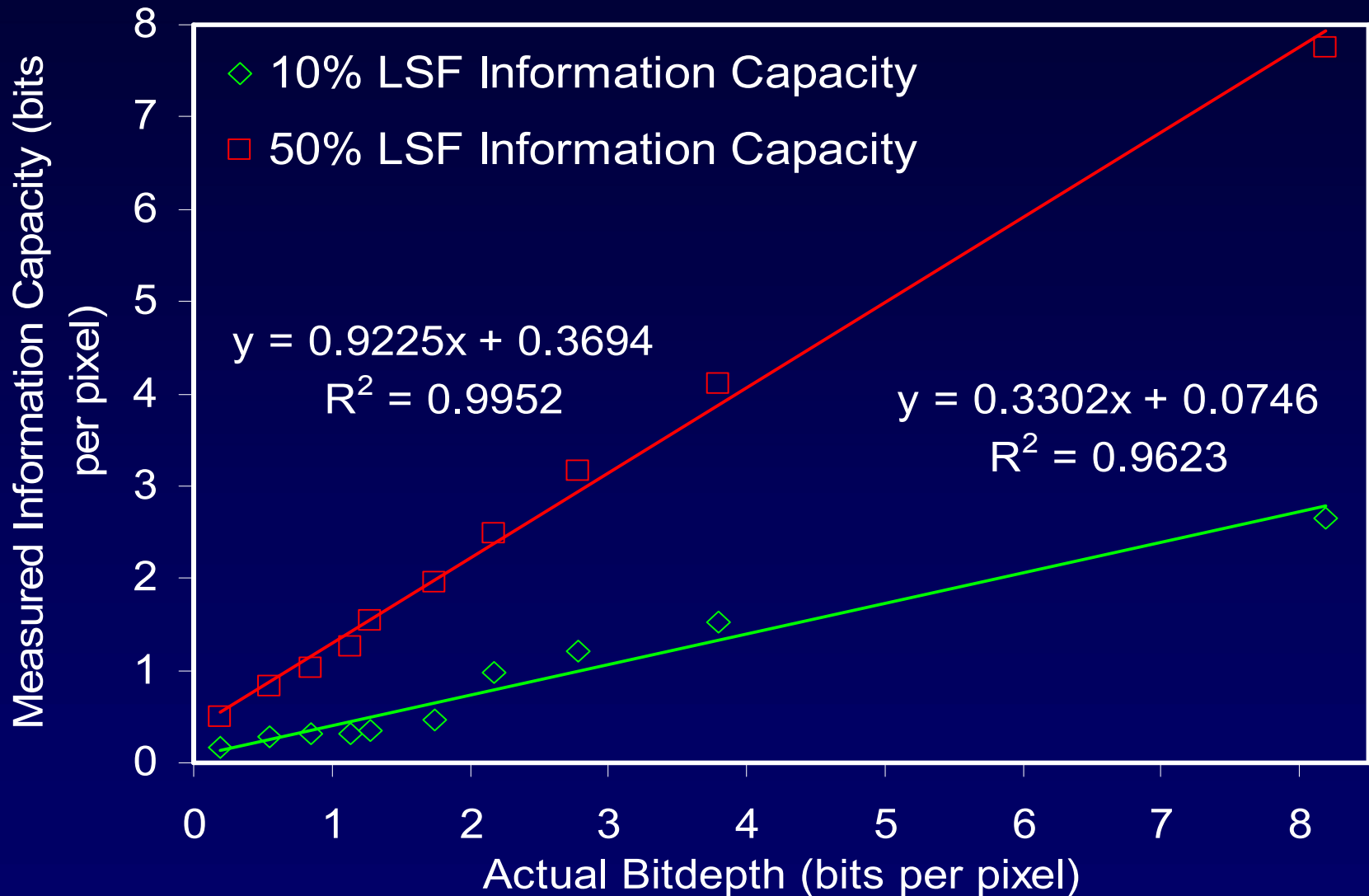


Heavily based towards low spatial frequencies!

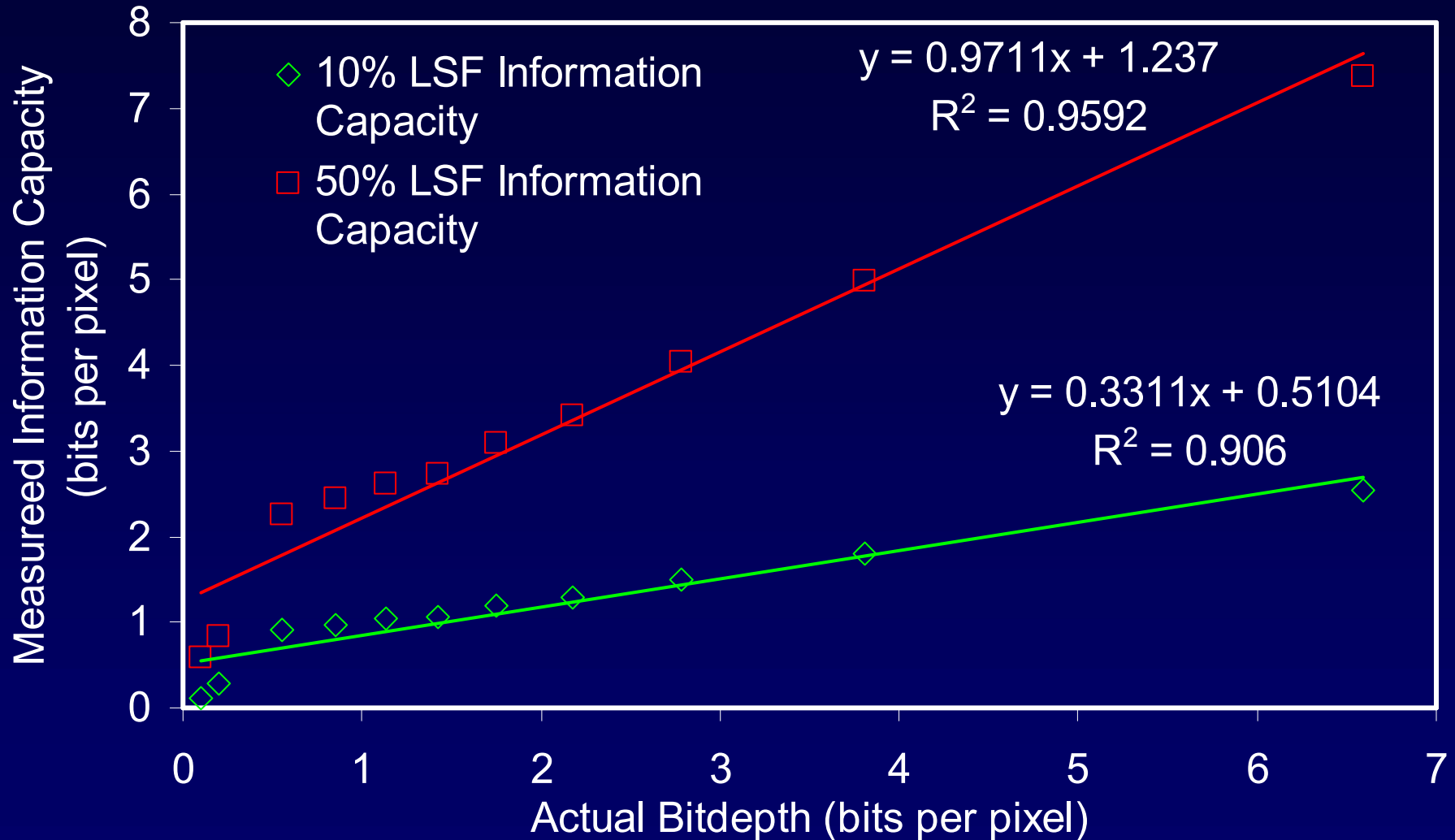
Information Capacity

- Long been known to have correlation with quality...
- Use this as a basis to form a metric...

JPEG 6b - Monochrome



JPEG 2000 - Monochrome



Information Capacity

Information Capacity
(bits)

C

$=$

\log_2

m

Number of 'Cells'

Number of 'Levels'

Information Capacity

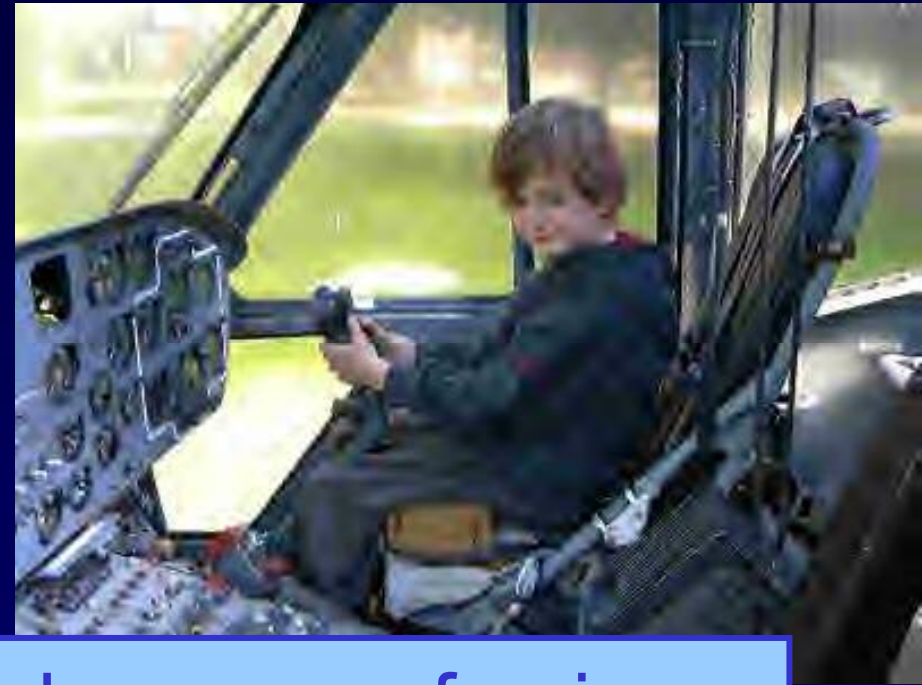
Same Number of 'Pixels'

Determine the number of individual imaging cells by measuring the Point Spread Function...

of Cells

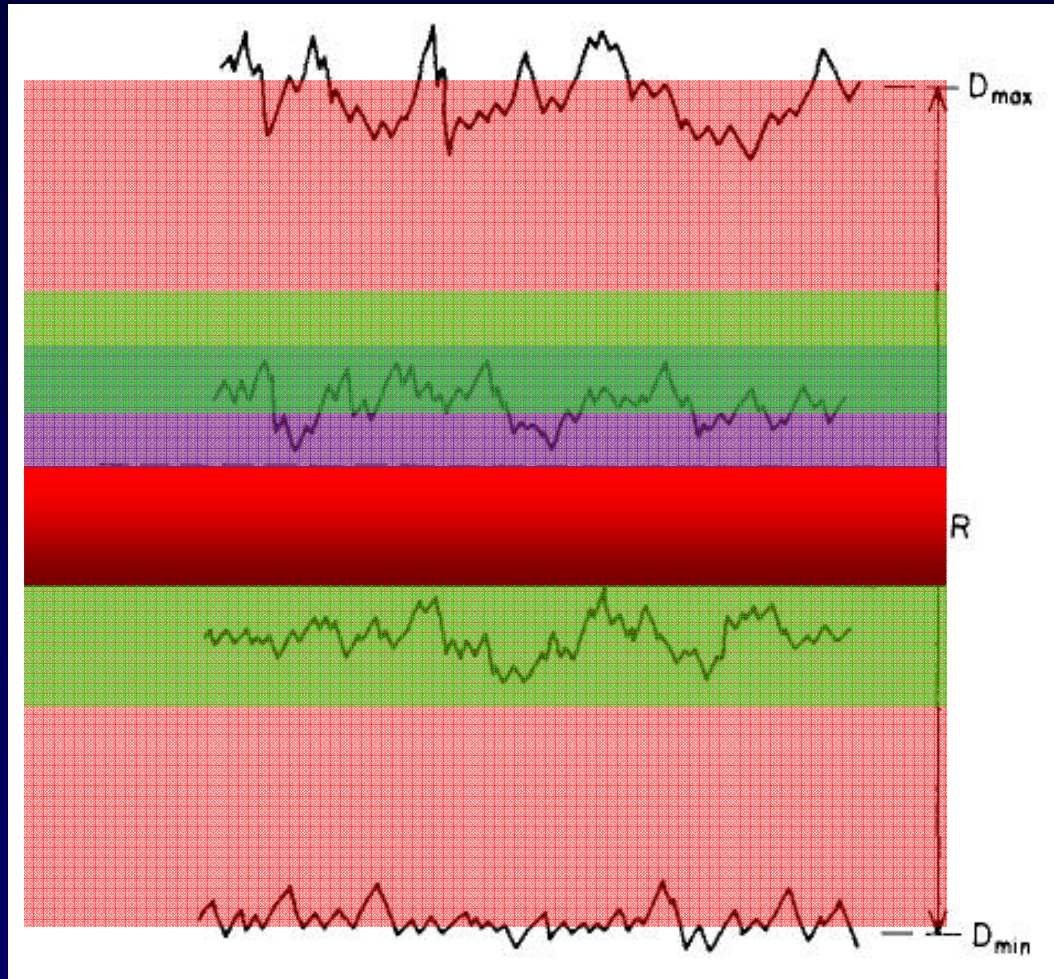
of Cells

Information Capacity



Less effective levels because of noise...
Measure using SD...

Information Capacity

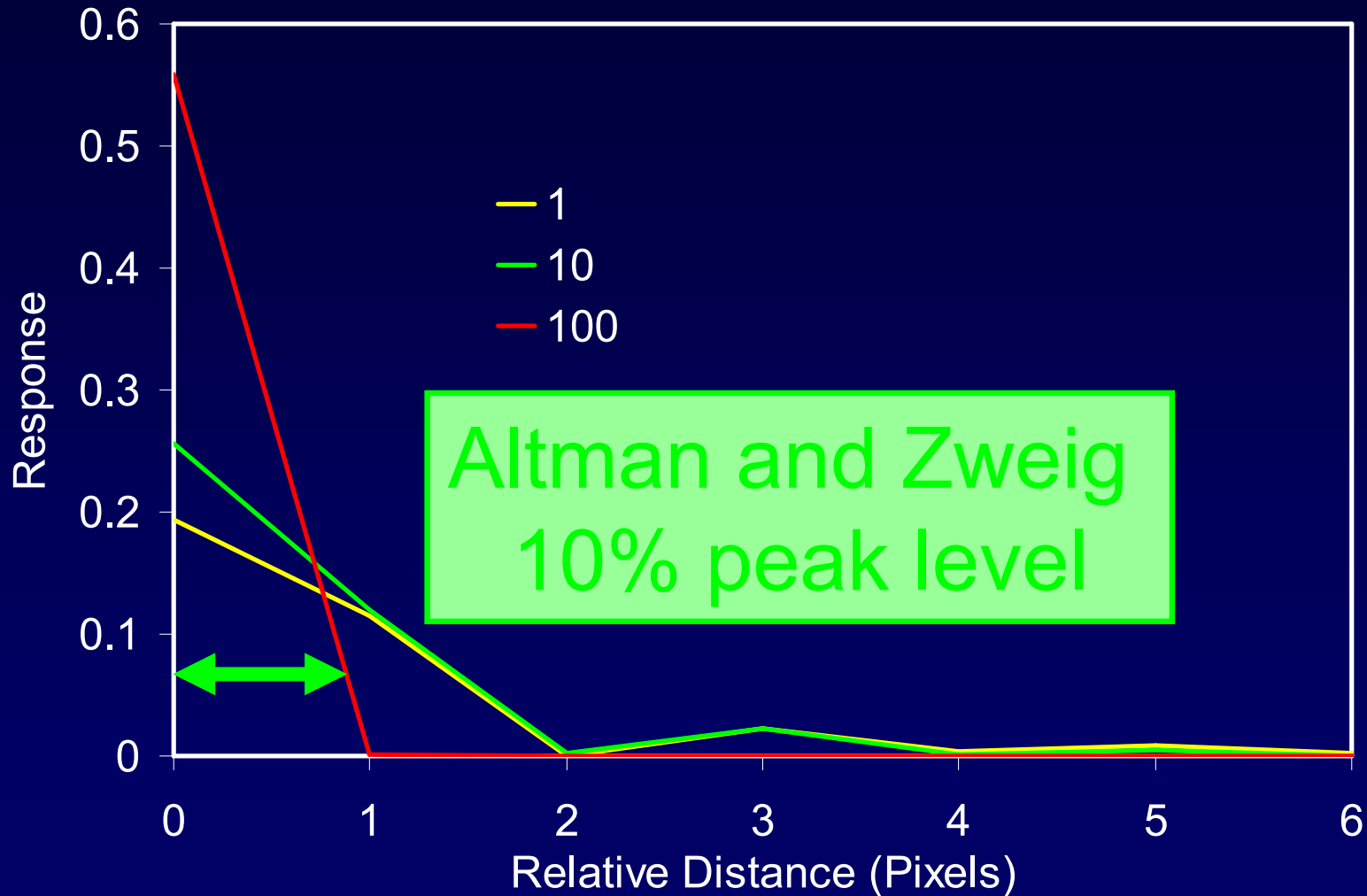


Reproduced from J. C. Dainty and R. Shaw, *Image Science*, Academic Press, London, 1974. Page 358

Information Capacity

- Measuring Information Capacity is easy...
- Estimate cell size, usually using PSF...
- Estimate noise...
- Any local deviation of the imaging chain from the global MTF we treat as noise...

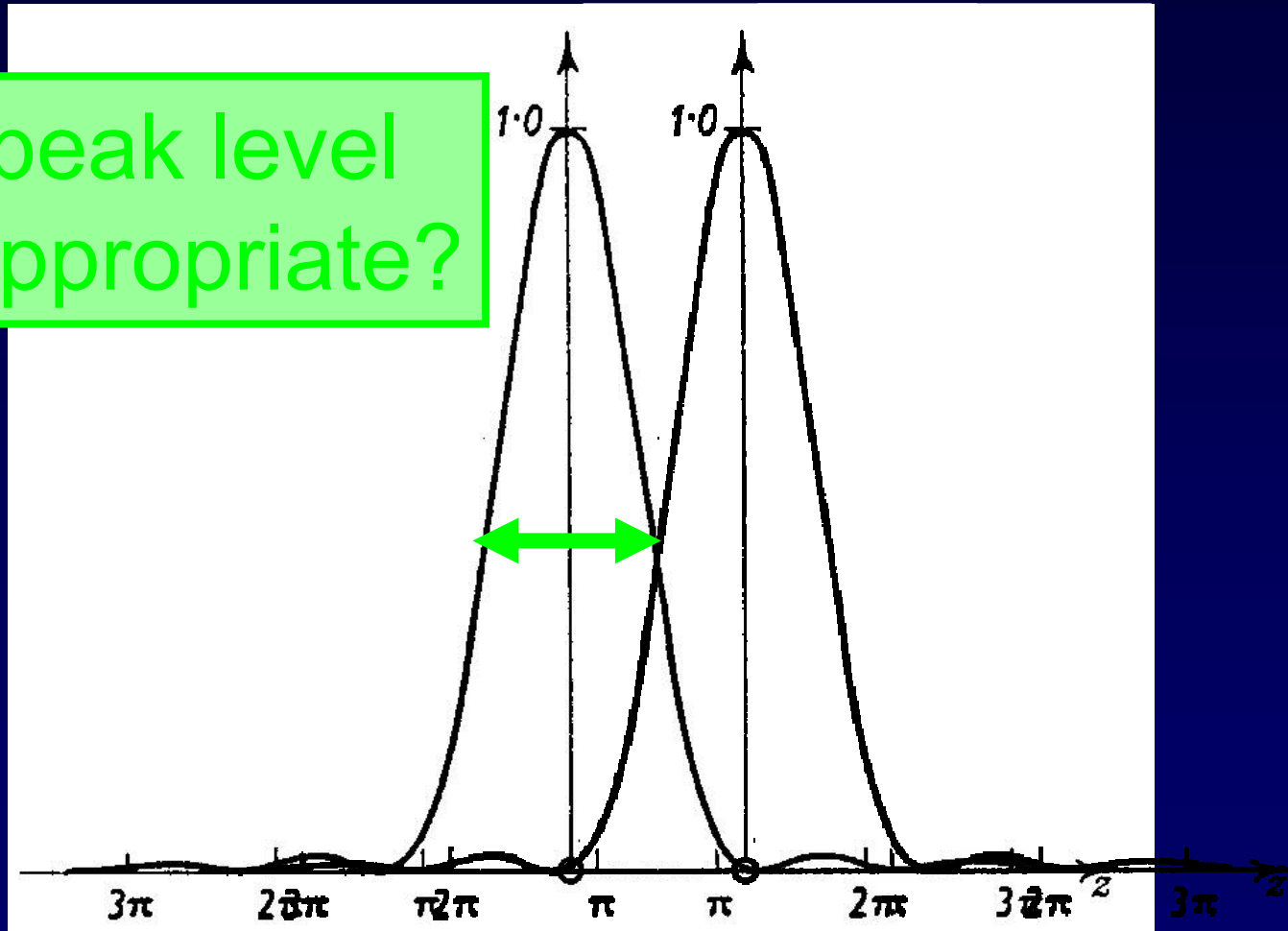
PSF Examples



Separation

- Rayleigh

50% peak level
More appropriate?



Estimating Noise Levels



Number of levels

Selwyn Granularity

$$M \approx \frac{DS}{\text{Density Range}} + 1$$

Scaled standard deviation

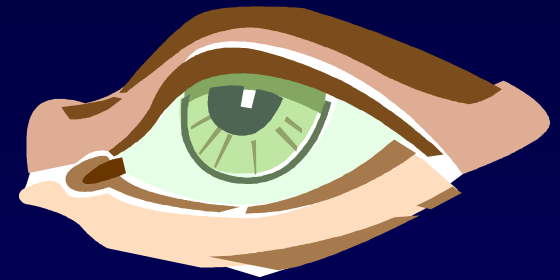
Density Range

$$G = \sigma \sqrt{A}$$

$$\sigma_A = \frac{G}{L}$$

How do you turn this into a qual

Assume anything
beyond retina is the
same for all images –
Interested in global response



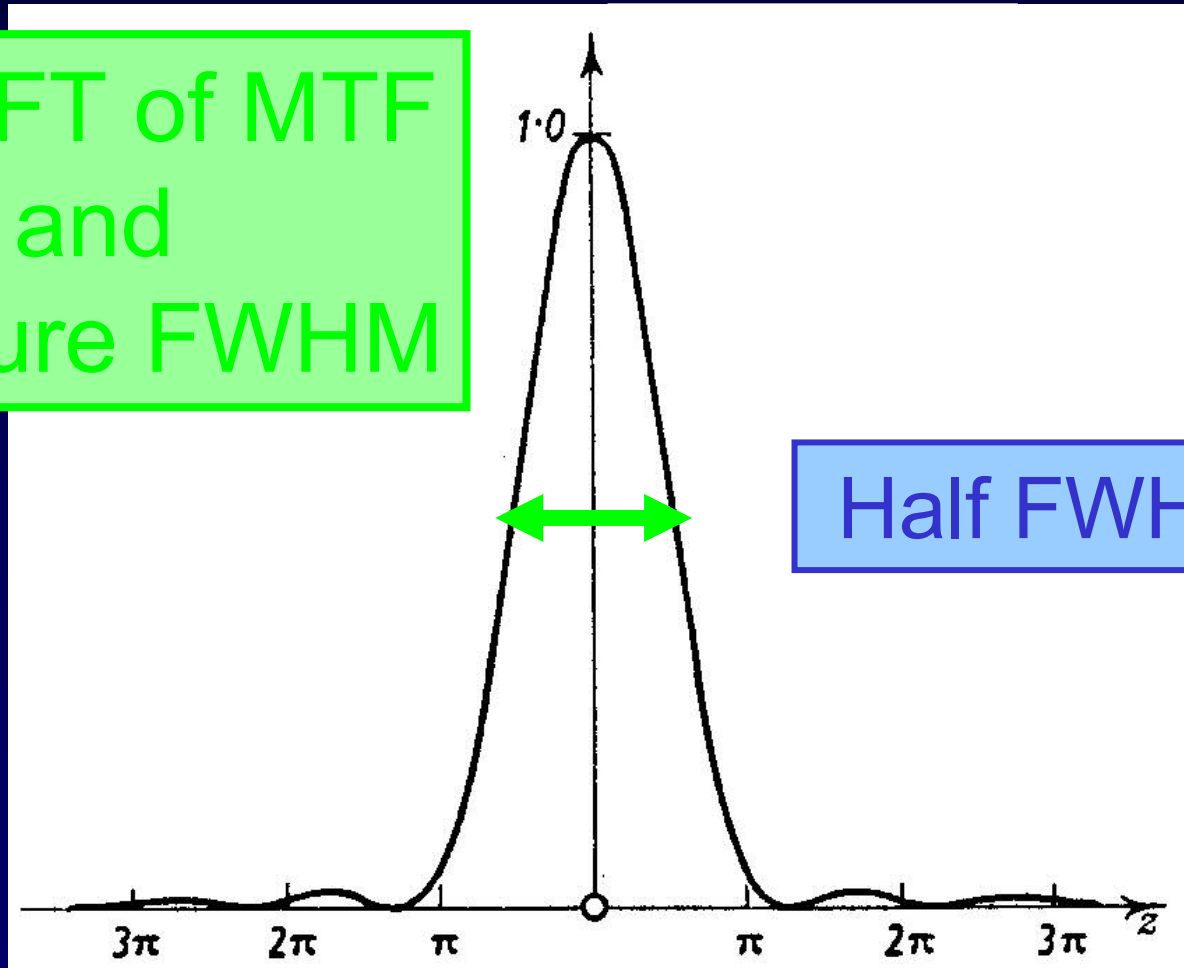
Cascade MTFs of each stage...

Use Optical MTF of eye...

Do calculation in a single plane...

PSF width

Take FT of MTF
and
Measure FWHM



Half FWHM is r

Pixels per unit area...

- For Round Use

$$\frac{1}{2\pi r^2}$$

- Or Square Use

$$\frac{1}{(2r)^2}$$

- To give number of 'pixels' per unit area
- Multiply by area of displayed image to get total number of pixels...

Adding Noise

- Noise described using Standard Deviation of the fluctuations in each part of the chain...

$$\sigma_T^2 = \sigma_C^2 + \sigma_D^2 + \sigma_E^2$$

- Noise addition is similar to cascading errors in any other branch of science...

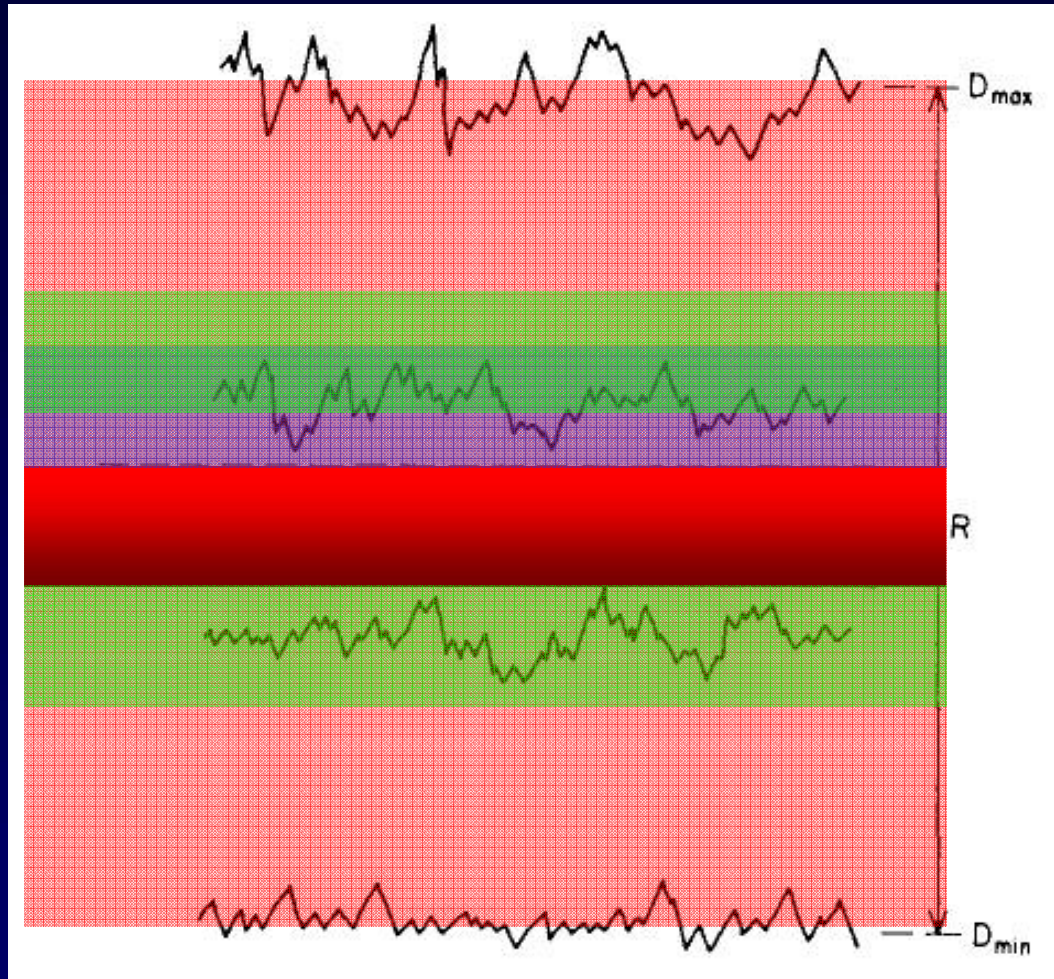
Correcting Noise for Cell Size

- As cells get bigger – noise is integrated...
- ...therefore correct measured SD...

$$G = \sigma \sqrt{p}$$

$$\sigma_A = \frac{G}{\sqrt{2\pi r^2}}$$

Number of Levels



Reproduced from J. C. Dainty and R. Shaw, *Image Science*, Academic Press, London, 1974. Page 358

Information Capacity

$$C = n \log_2 m$$

Number of Kb Per Steradian

- Convert to Kb per Steradian to account for viewing distance...

$$\Omega = \frac{A_I}{R^2}$$

$$I = \frac{C}{\Omega}$$

Clip

- Clip for Max information input into eye calculated using similar manner...
- ...if necessary
- Approx 3000 Kb per steradian

Conclusions...

| | RMSE | SNR | QF | SQRI | PIC | EPIC(C) | EPIC(CD) | EPIC(CDE) |
|---------|-------|-------|-------|-------|-------|---------|----------|-----------|
| Big Ben | 0.560 | 0.801 | 0.906 | 0.882 | 0.915 | 0.924 | 0.932 | 0.936 |
| Conns | 0.557 | 0.727 | 0.919 | 0.653 | 0.824 | 0.971 | 0.971 | 0.972 |
| Dolly | 0.828 | 0.894 | 0.884 | 0.875 | 0.950 | 0.785 | 0.832 | 0.883 |
| Port | 0.522 | 0.788 | 0.937 | 0.610 | 0.812 | 0.981 | 0.974 | 0.962 |
| Ave | 0.617 | 0.803 | 0.912 | 0.755 | 0.875 | 0.915 | 0.927 | 0.938 |

Further Work

- Lots...

Thank You

Robin Jenkin

Electro-Optics Group

Department of Aerospace Power and Sensors,

Cranfield University,

Shrivenham,

SN6 8LA, UK.

Telephone: +44 (0)1793 785 369

Email: r.b.jenkin@cranfield.ac.uk