Re: Cassini: where are colors and detail?

Source: http://sci.tech−archive.net/Archive/sci.astro.amateur/2004−07/2416.html

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From: Roger N. Clark (change username to rnclark) (*username_at_qwest.net*)
Date: 07/15/04

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Date: Wed, 14 Jul 2004 21:34:21 −0600
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Martin Brown wrote:

> In message <40F1B695.3040102@qwest.net>, "Roger N. Clark (change
> username to rnclark)" <username@qwest.net> writes
>
>> Chris L Peterson wrote:
>
>
>>> I haven't seen a color
>>> detector suitable for the latter. Even the 300D, which is the best I've
>>> evaluated, produces numerous identical RGB values for different
>>> wavelengths
>>> between 450nm and 520nm.
>>
>>
>> With the filter response curves I have I do not see how this is
>> possible. While one filter response may be dropping as you change
>> wavelength toward the red (e.g. blue filter), another will be increasing
>> and both red and green increasing at a different rate. Thus
>> R, G, and/or B values continue to change as wavelength is scanned.
>
>
> There are definitely ambiguities in the accurate rendition of green
> monochromatic light with classic Bayer filter arrays. That is one of the
> reasons why Sony added the "Emerald" lighter green filter to enhance
> precision in the green response. They claim it is an improvement...

ALL filters provide ambiguities to monochromatic light.
Consider a perfect square wave filter bandpass. All wavelengths in the band would give the same response. Consider a gaussian−shaped bandpass. For any given wavelength, there is a second wavelength on the other side of the Gaussian maximum that gives identical response. Now consider 2 Gaussian bandpasses, separated by some amount in wavelength. Since the second filter provides a second intensity measurement of the monochromatic light, the two numbers uniquely identify the wavelength and avoid the ambiguity of one filter. But then you can be confused by two monochromatic lines, separated in wavelength. So add a third

filter to resolve the ambiguity. Not with square bandpass filters
you can't do this as you have either all or no response in the
bandpass. So the gaussian−shaped bandpass is better to understand
ambiguities. Bayer filters are approximately Gaussian compared
to interference filter response, which are more square wave.

There is no multi−filter system that you can design and not
have ambiguities. You can go to a full spectrometer and still
have ambiguities at the level of the spectrometer bandpass.
You design your system to answer the scientific questions at hand.
The fact that commercial point and shoot digital camera software
has problems with some monochromatic lines is
irrelevant to a spacecraft mission.

You confuse precision with accuracy in your statement about
the sony camera, above.
Precision comes through fine enough A/D conversion and noise
specification. Accuracy relates to making that converted number
scientifically meaningful. In the context of science interpretations
of the signal through a filter, the scientific value is mostly
tied to accurate knowledge of the bandpass profile and NOT the specifics
of the profile.

Here is the scenario: You measure a scene at high resolution with
an N−band filter system (say N = 3 to 12). You construct color
images to delineate composition so you can interpret certain
features in the image to certain compositions. No matter what
you do, from 3 to 12 bands (and more) you will have ambiguities
regardless of the filter response functions.
This is shown well in one of my recent papers:

Clark, R. N., G. A. Swayze, K. E. Livo, R. F. Kokaly,
S. J. Sutley, J. B. Dalton, R. R. McDougal, and C. A. Gent,
Imaging spectroscopy: Earth and planetary remote sensing with
the USGS Tetracorder and expert systems, J. Geophys. Res.,
108(E12), 5131, doi:10.1029/2002JE001847, December, 2003.
http://speclab.cr.usgs.gov/PAPERS/tetracorder

See Figures 7A and 7B.

But now combine that image with lower resolution imaging spectroscopy,
and you can resolve many of those discrepancies (see Figures 9A
and 9B) in the above paper.

You confuse cheap consumer digital camera problems with bayer sensor
problems. In both high−end digital SLRs as well as any spacecraft
application, the data are/would be treated in raw mode with
full 12−bit digitization, just like with a monochrome CCD.
The filter responses on top end cameras like the Canon 10D,
which have been rated as the highest accuracy color response of
any camera, digital or film, would be excellent in a spacecraft

application. And in fact the response profiles of the 10D
bayer filters are better than other filters that have flown on
spacecraft and that returned scientificly valuable data,
like Voyager and Viking.

>
> Algorithms in consumer cameras for interpreting Bayer sensors also go
> crazy when illuminated with pure monochromatic light and can give images
> with false colours that depend on both the intensity and wavelength of
> the light in complex non−linear ways.

As noted above, this is irrelevant to spacecraft applications,
which would use a compressed raw format, not some cheap consumer
camera algorithm.
>
> Almost all consumer cameras have their response compromised in the
> purple to ensure that flesh tones are subjectively pleasing in the
> market they are sold (the same also being true of colour films). I find
> this defect much more of a problem when photographing certain purple
> flowers.

If you mean for accurate color response to match the human eye,
then yes. But this does not mean a custom bayer filer could not or
would not be constructed for a spacecraft application.
>
>>
>>
>>> Again, I'm not saying you can't use a color detector for scientific
>>> applications.
>>
>>
>> Chris, this is from one of your previous posts:
>>
>>> They let other wavelengths through that contaminate the data, there are
>>> ixel−to−pixel non−uniformities that are difficult to quantify, and
>>> the Bayer
>>> pattern results in a loss of resolution and a decoupling of the
>>> spatial and
>>> color information. In short, they are not very useful for any real
>>> science.
>>
>>
>> You have constantly waffled back and forth. I entered this
>> thread trying to clear up some confusion about why cassini
>> didn't use bayer filters. I responded:
>>
>> "The main reason not to fly a RGB digital camera sensor
>> is that it would be too limiting to have only 3 colors. ..."
>>
>> You responded:
>> "I said the reason was that color sensors don't provide good data..."

>>
>> I responded:
>> "Color RGBG sensors do provide good data, are linear and are great
>> scientifically as far as they go."
>
>
> They are good for high resolution colour snapshots, but I would hate to
> have to do spectrometry using a Bayer filtered CCD as the sensor.
>
>>
>> Let me summarize the way I see the use of Bayer and similar sensors.
>> I do this as a current planetary scientist on multiple
>> planetary missions, and I am currently a co−investigator on
>> 6 proposed missions, including mars landers (MSL), asteroid
>> and moon missions. I have also served/serve
>> on multiple NASA committees that define future science.
>>
>> 1) RGB Bayer cameras are now space qualified and a reputable
>> manufacturer is delivering cameras (e.g. Malin Space Systems).
>>
>> 2) The future of imaging from spacecraft is changing. The cameras
>> have less role in spectroscopy.
>
>
> And that is the clincher. There are times when a single shot colour
> image is more useful than three or more individually filtered images
> taken at different times of a rapidly changing target.

Given a 1−megapixel sensor with 3 filters in a wheel (3 megapixels
sent down for color), versus a 3−megapixel bayer sensor, I would choose
the bayer sensor, because 1) it has higher reliability (no moving parts),
2) less mass and therefore cost, 3) color data are inherently registered,
4) the inherent spatial resolution would be higher by about 1.6x
over the monochrome sensor. Both systems can deliver equally
accurate 12−bit data.

>
>> So, Chris, despite you saying bayer sensors are no good for spectral
>> data and science, the scientific field is and will continue to move
>> forward and use them, and I'm sure with great results.
>
>
> I am inclined to agree with him. A monochrome sensor is much easier to
> calibrate. Spectral data from a Bayer sensor will necessarily be flawed.

Your conclusion is not scientifically justified. Spectral
data from a bayer sensor is not flawed any more than other
broad−band filters, as I've explained above. The fact that
such sensors are being space qualified indicates they will
be used in future missions, and for science. The bayer bandpasses
of today are of higher quality than filters on the Voyager and

Mars viking missions. If you say bayer filters are too crappy
for science, I guess the Voyager and Viking missions
were a waste. NOT!

Finally, don't confuse consumer digital camera properties
and limits with fundamental bayer sensor technology.

Roger