Now, for something different…

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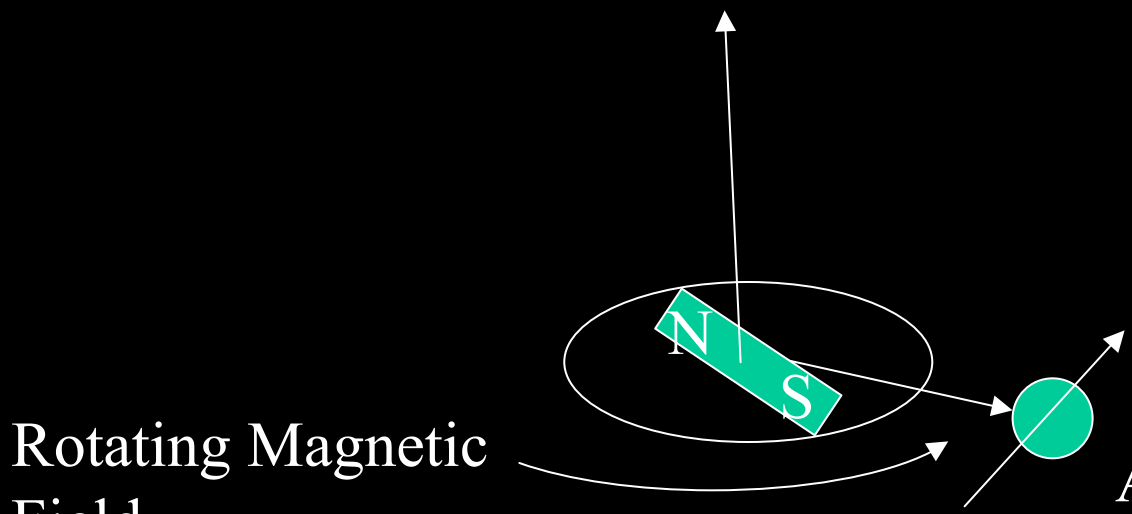


Velocity

Rotating Magnetic Field

Arbitrary electron at a radius

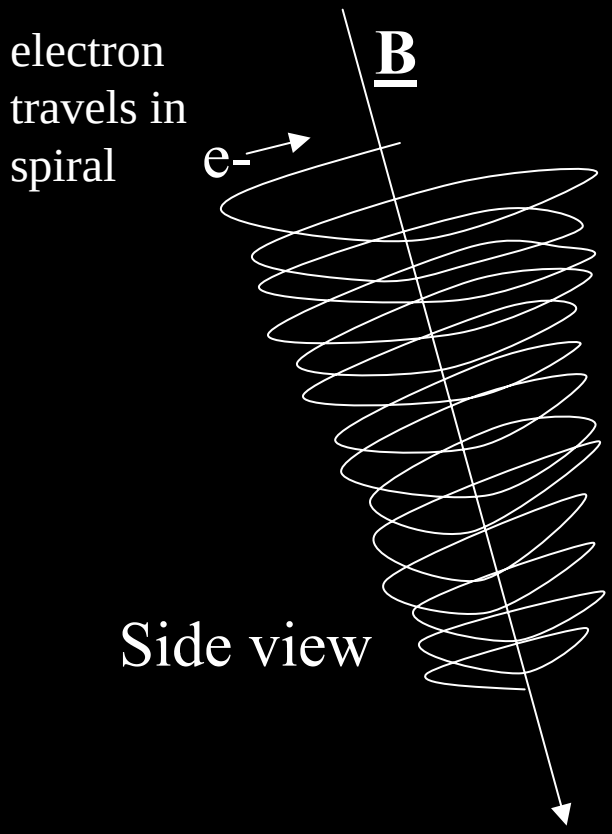
Rotation of Neutron Star

The free electrons are trapped in a synchronous orbit and their velocity increases as the radius increases. There's a critical radius where their velocity approaches the speed of light….

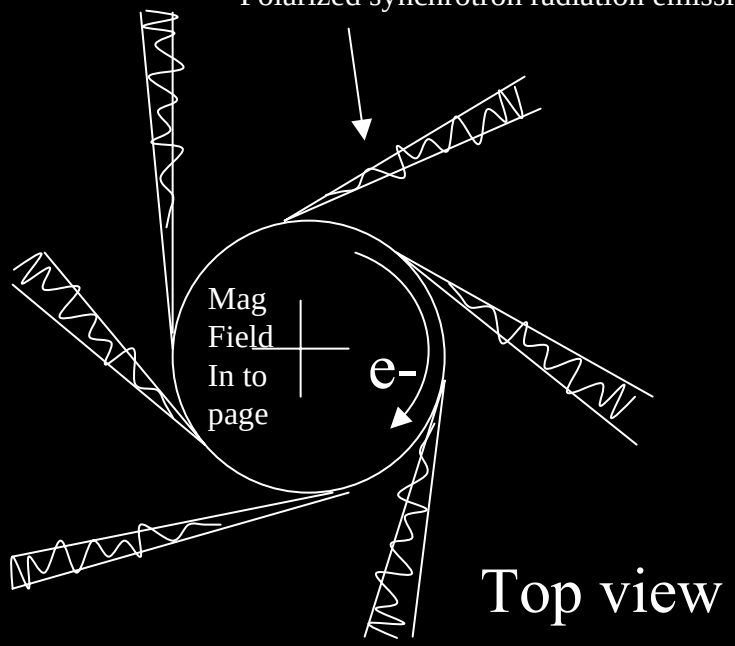
A charged particle experiencing acceleration will emit (or absorb) electromagnetic radiation (photons)

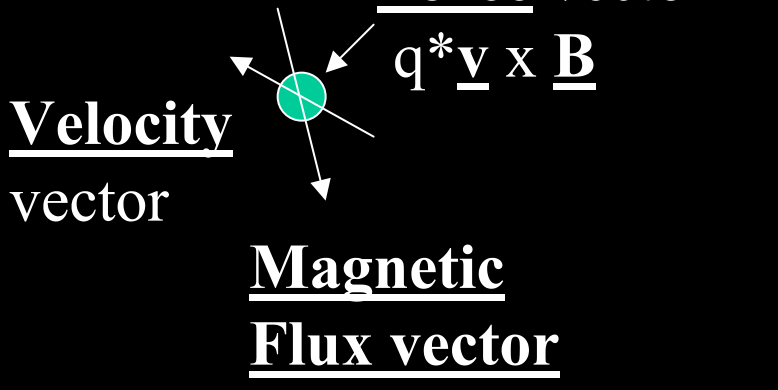
Ultra-relativistic (traveling near the speed of light) electrons traveling in strong magnetic fields generate synchrotron radiation

Synchrotron radiation has a continuous spectrum including the visible spectrum

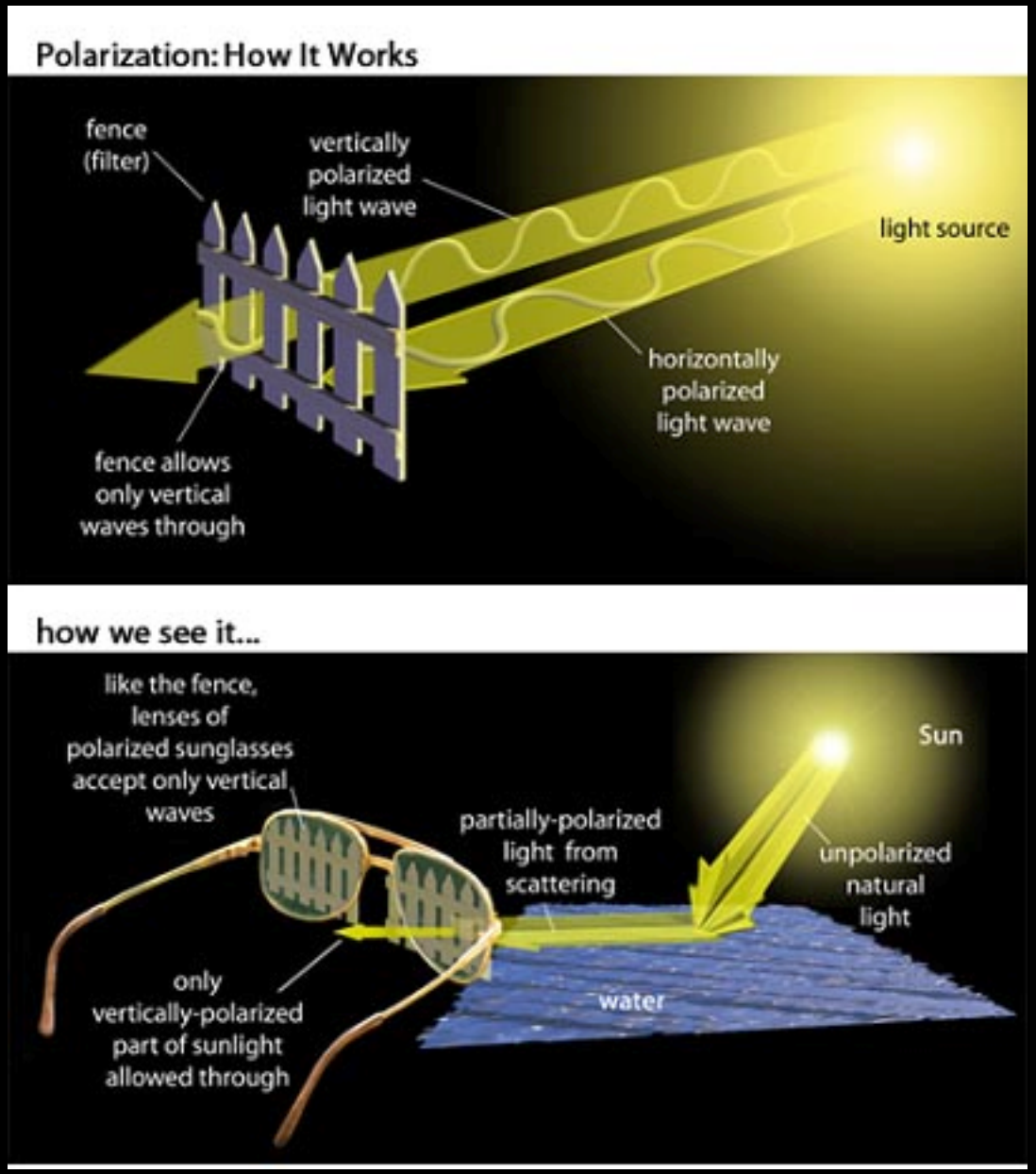


Linearly
Polarized
emission



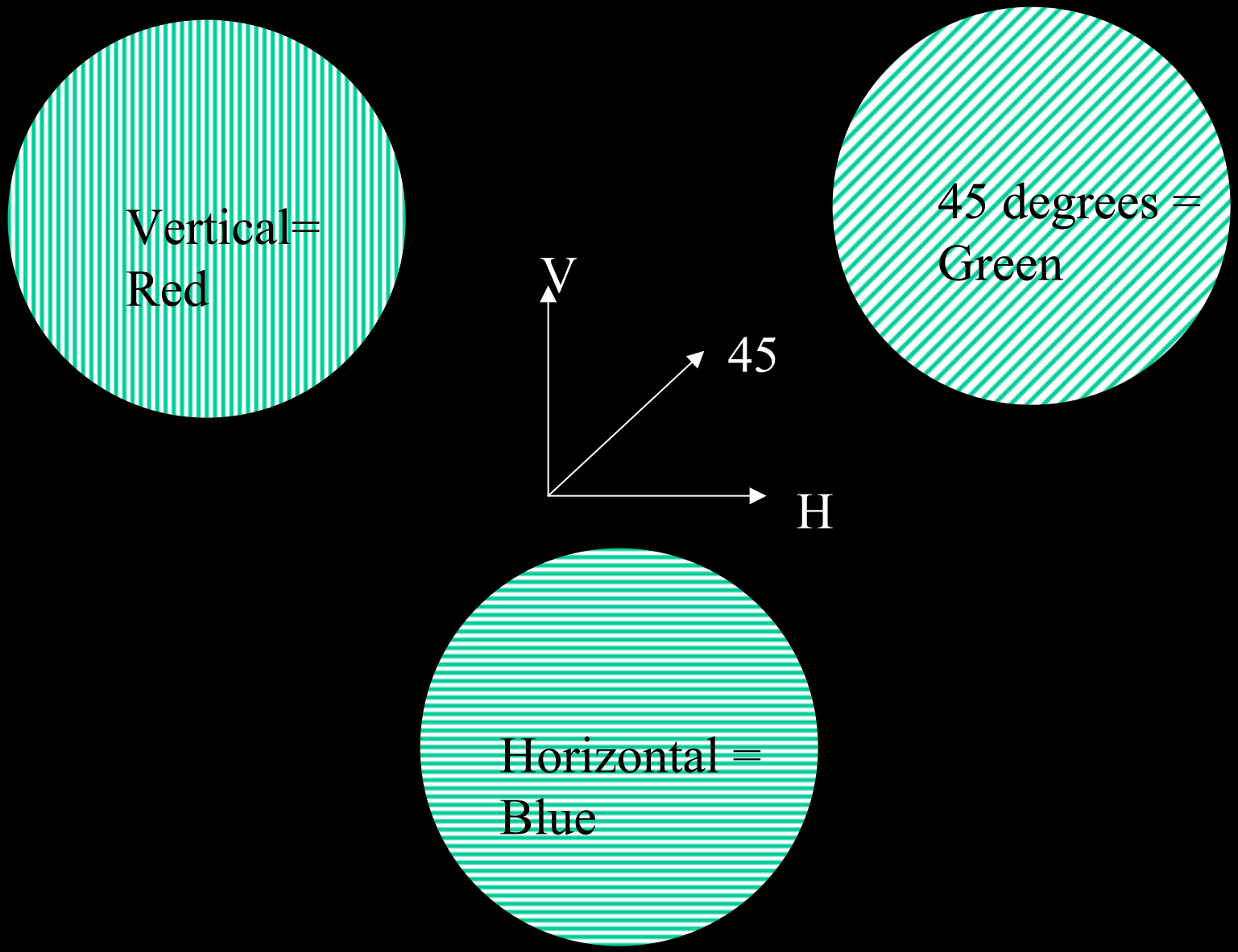


Electron moving in
magnetic field travels in
spiral and
emits linearly polarized
electromagnetic
radiation
(ie synchrotron radiation)

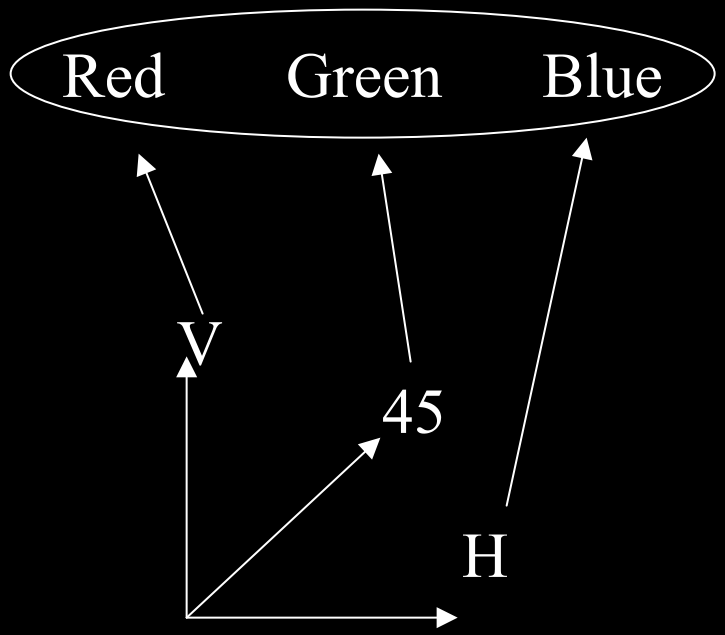


Polarizing filters will select waves on the basis of polarization

A reflecting horizontal surface acts as a horizontal polarizer



A simple Polarigram: Assign each polarizer orientation to a single color channel



Polarizer outputs directly assigned
to color channels (simple polarigram)

Three Optical Views of The Crab

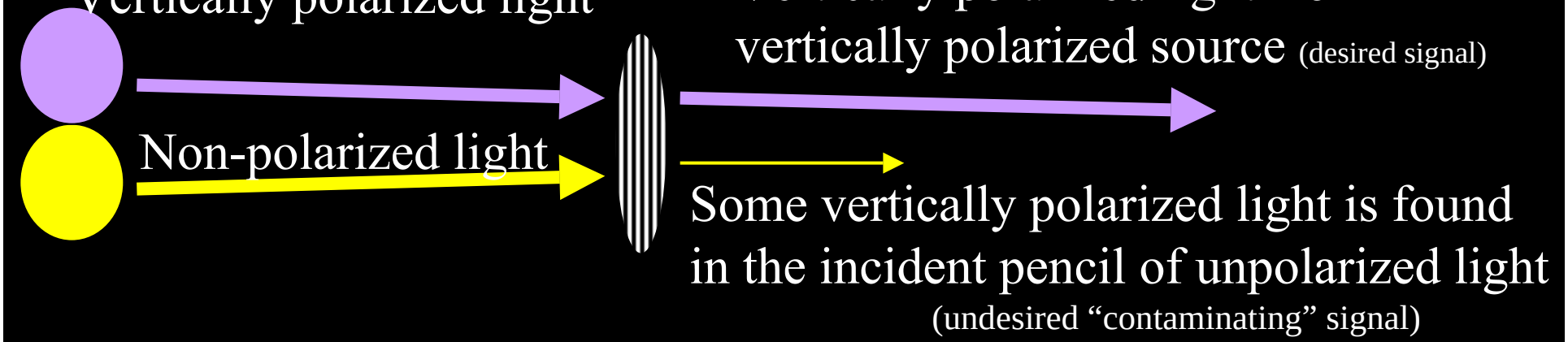
Standard LRGB
(broadband image)

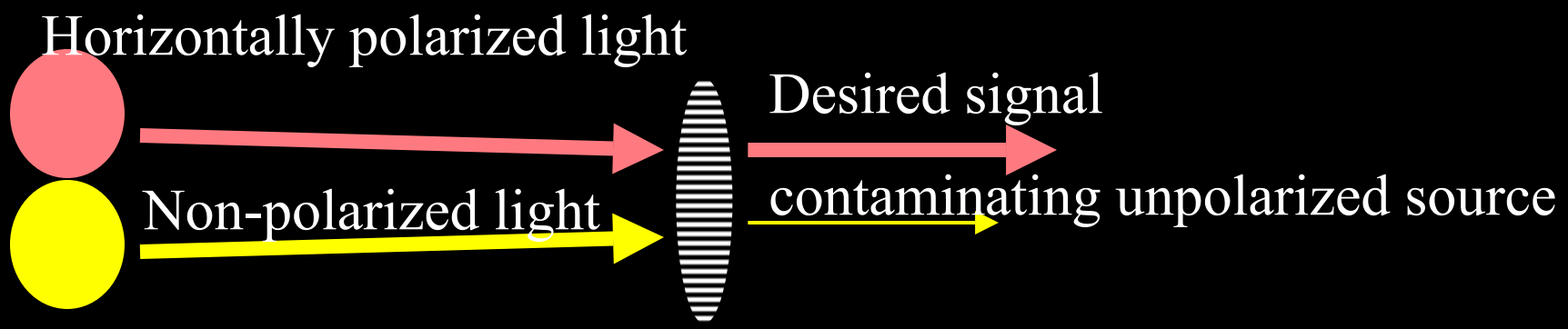
[SII], Halpha, [OIII] = RGB
(narrowband emission line image)

Simple polarigram
(broadband image)

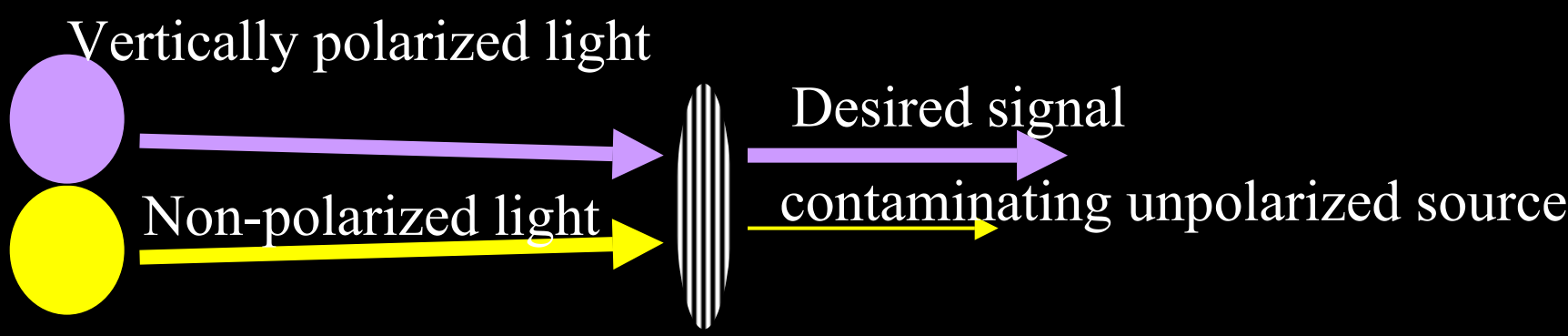
What about this unpolarized light that is “common mode” in the outputs of all the polarizers?

---if the goal is to show only the polarization it will “contaminate” the image





= H + unpolarized common mode



= V + unpolarized common mode

The raw filtered results from the Vert and Horiz polarizers contains contaminating "common mode" light from unpolarized source

Stokes Parameters (aka polarization differencing) solve the common mode contamination problem.

Stokes Parameter Method:

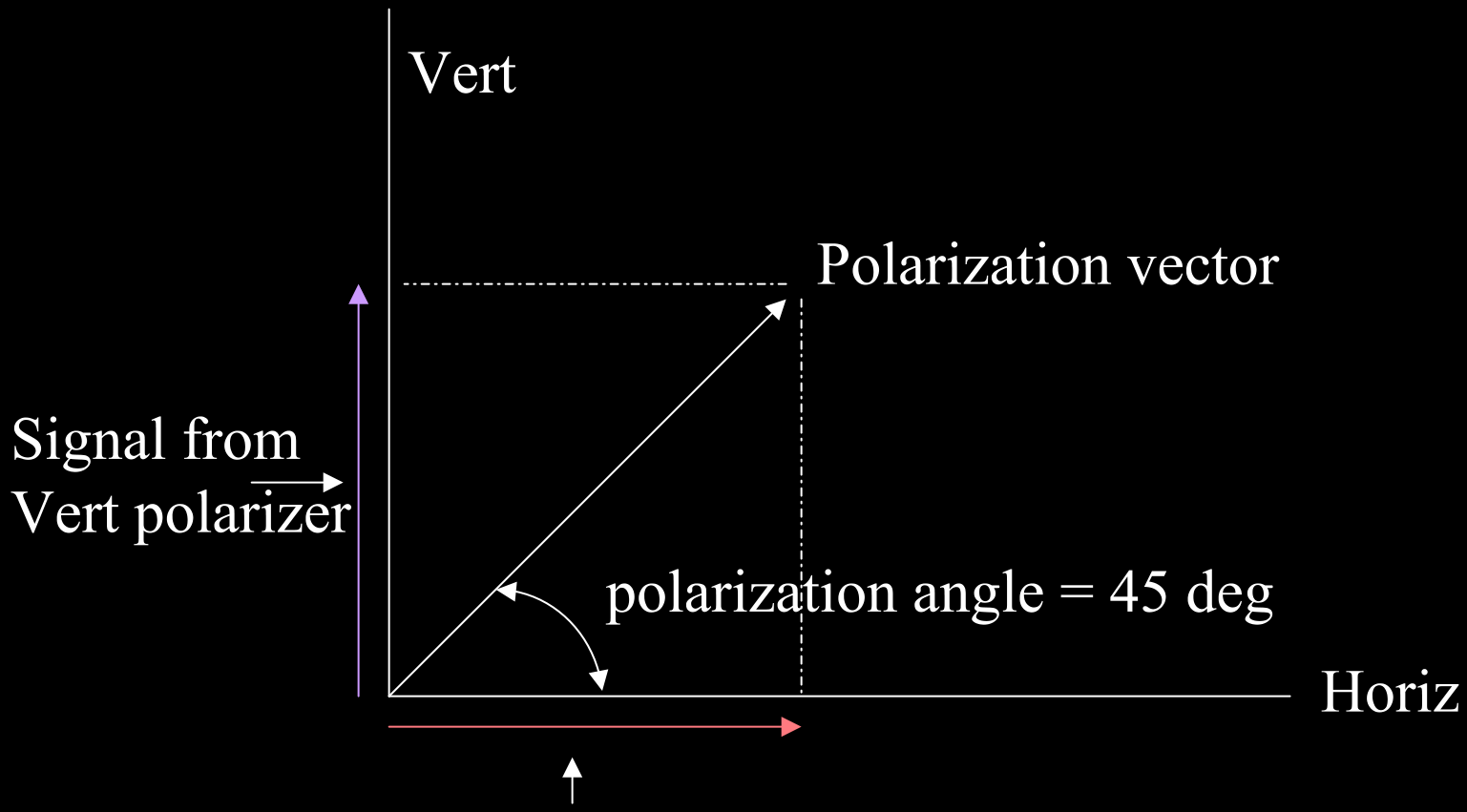
For each color channel use the difference between data from a pair of polarizers. This removes the "common mode" light as explained before and the remaining signal is the:

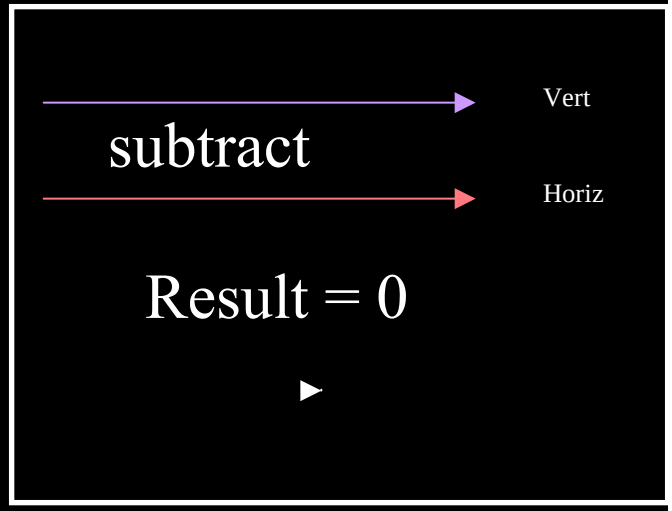
…difference in the polarization between two polarizers…

only light originating from a polarized source would remain after this subtraction provided the images are linear and non-saturated

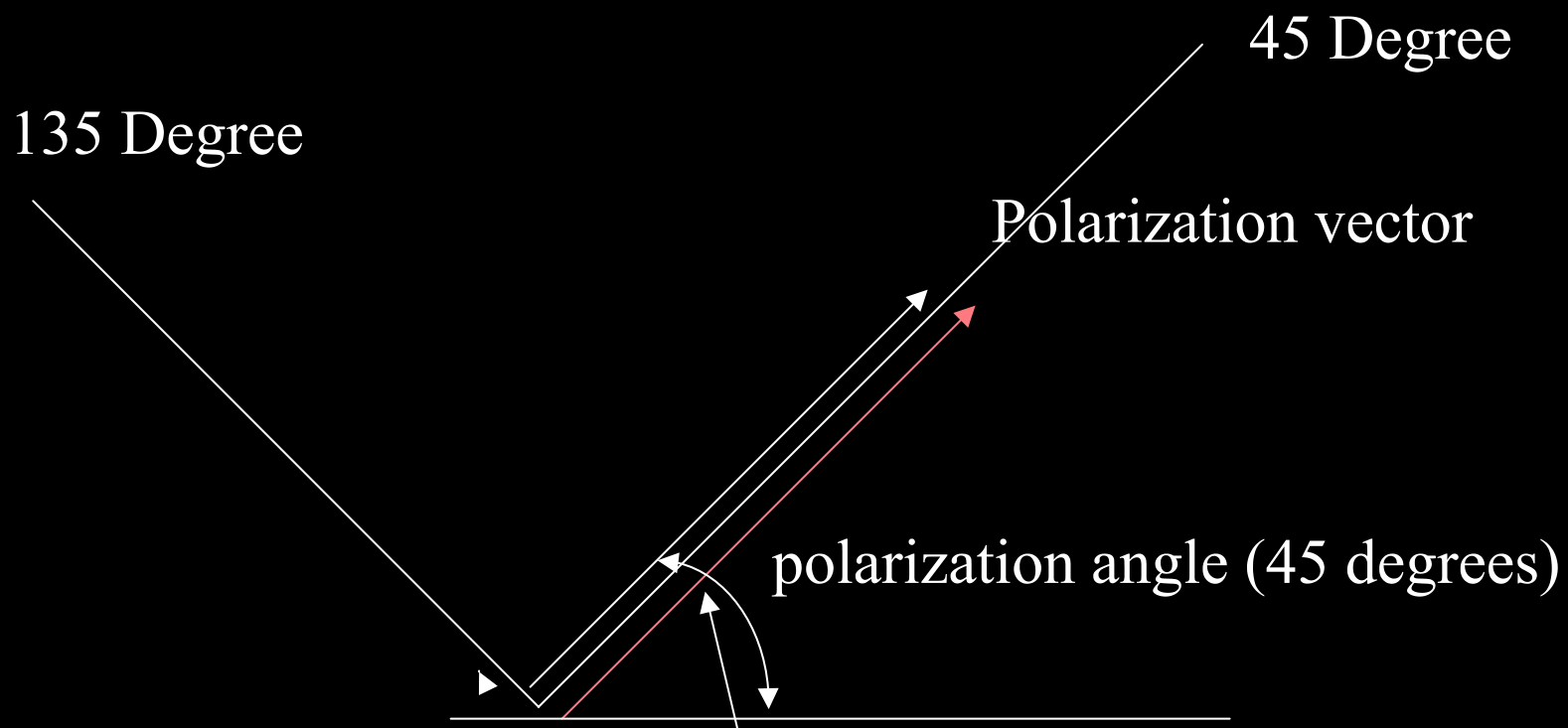
Example: Vertical Polarizer Output – Horizontal Polarizer Output
= V + common mode - (H + common mode)

= **V – H** = delta polarization from the Vertical and Horizontal Polarizers
it is pure polarization with no common mode



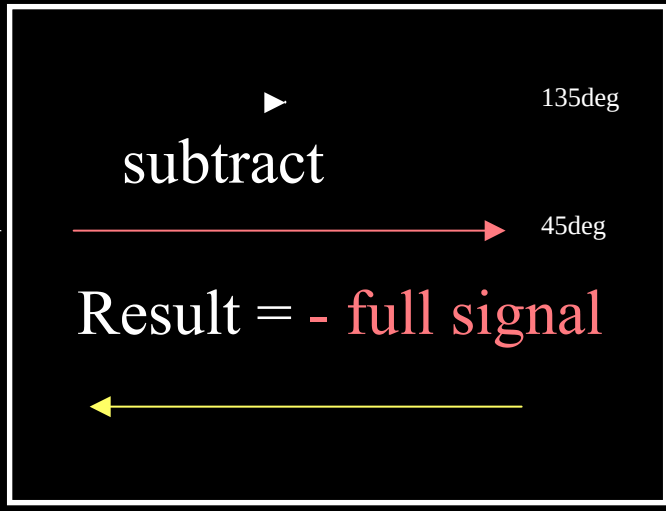


Case 1: polarization angle = 45 degrees, vertical and horizontal polarizers



Signal from
135degree polarizer
(zero in this case)

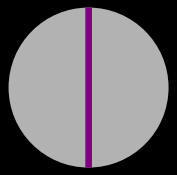
Signal from
45 degree polarizer
(full signal strength
In this case)



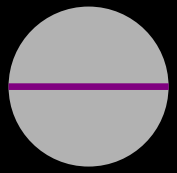
Case 1: polarization angle = 45 degrees
(45 degree and 135 degree polarizers)

Polarization Angle determination

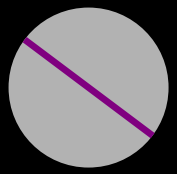
- If (135 deg – 45 deg) is zero and (vert – horiz) positive, the wave is vertically polarized



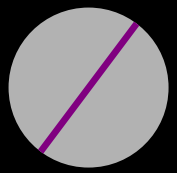
- If (135 deg – 45 deg) is zero, and (vert – horiz) negative, the wave is horizontally polarized.



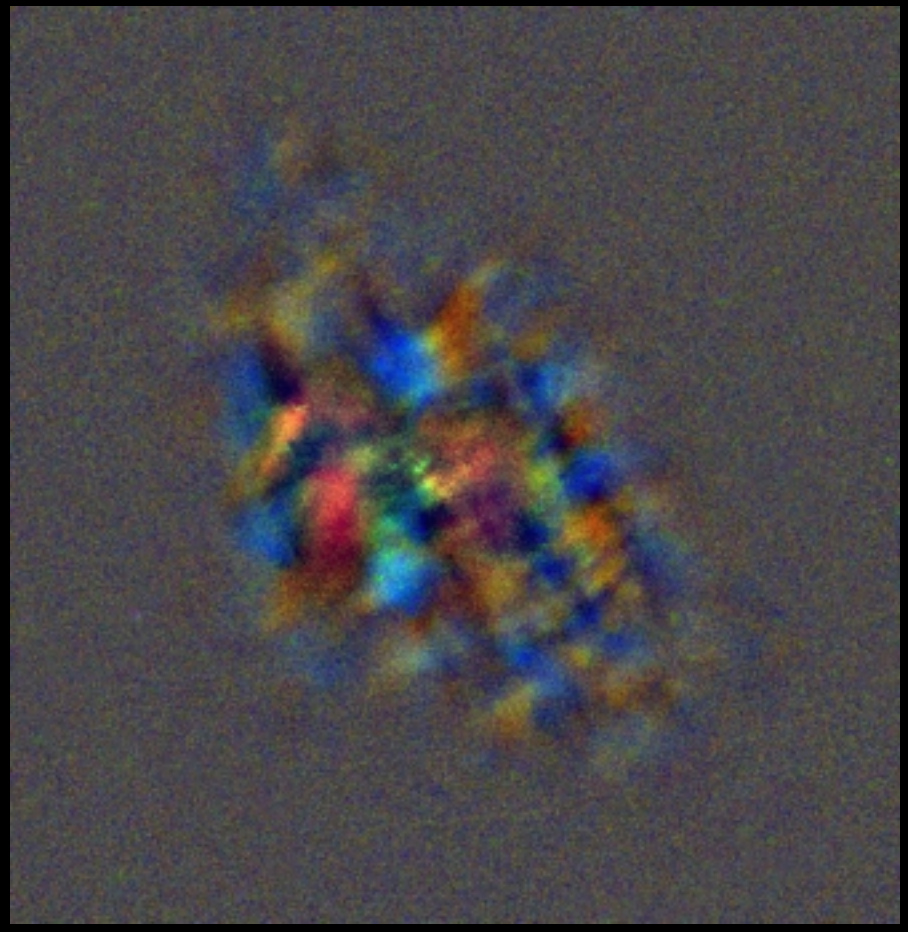
- If (vert – horiz) is zero, and (135 deg – 45 deg) positive, the wave is polarized at pa = 135 deg

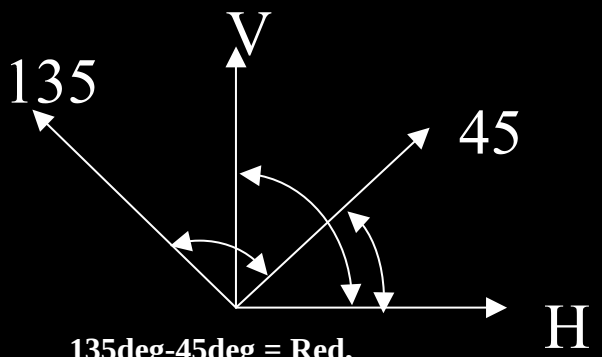


- If (vert – horiz) is zero, and (135 deg – 45 deg) negative, the wave is polarized at pa = 45 deg



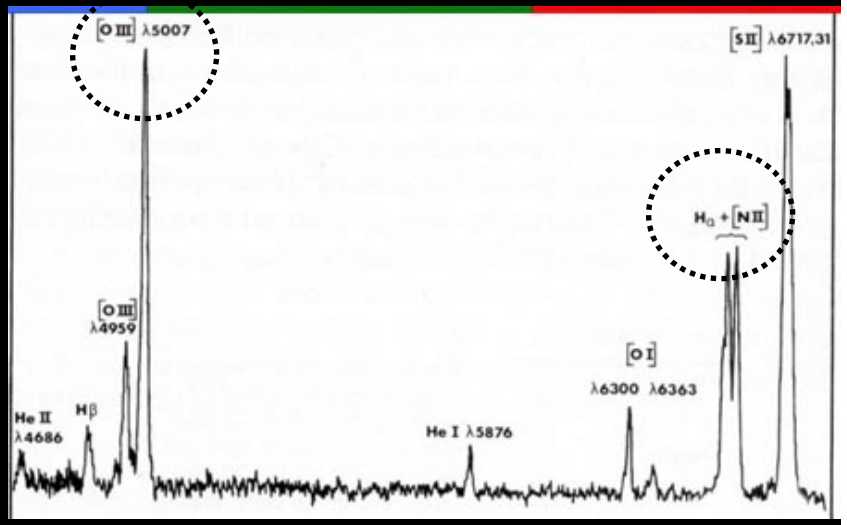
- Use trigonometry to solve the other cases….





135deg-45deg = Red,
Vert-Horiz = Green,
45 degrees – Horiz = Blue

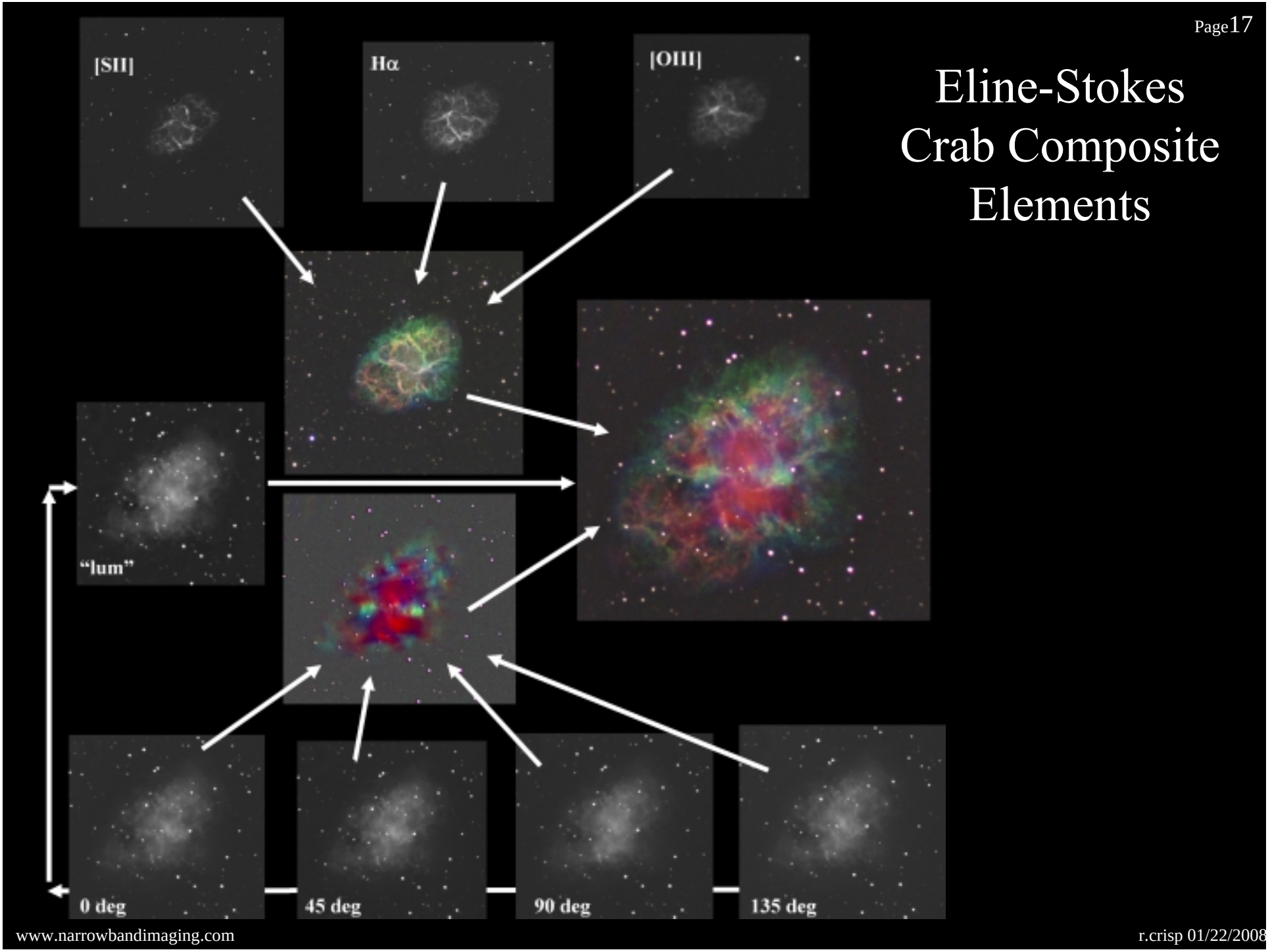
Stokes polarigram reveals synchrotron polarization structure

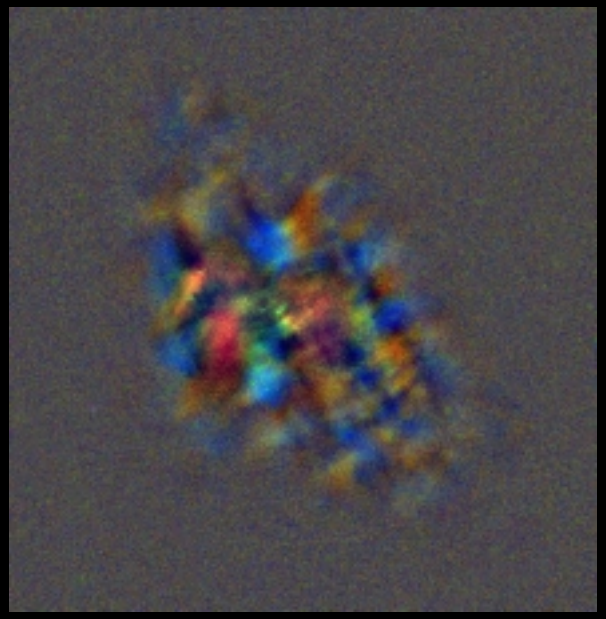


[NII] = Red, Ha = Green, [OIII] = Blue

Emission line image highlights emissive filaments

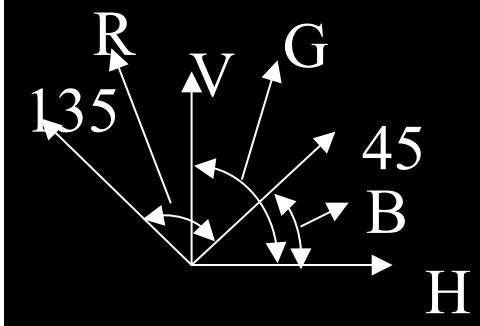
Eline-Stokes Crab Composite Elements





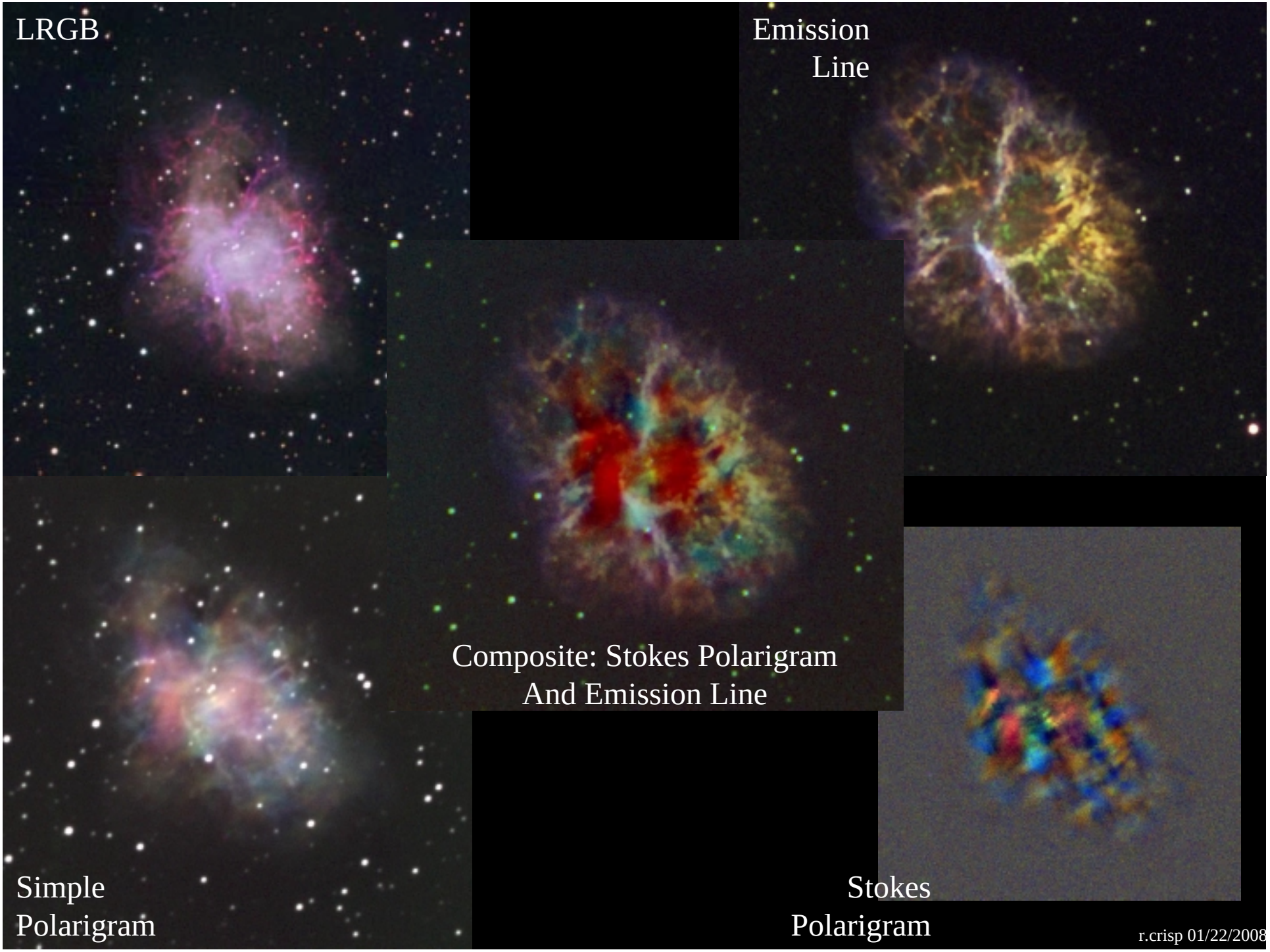
Stokes polarigram highlights synchrotron

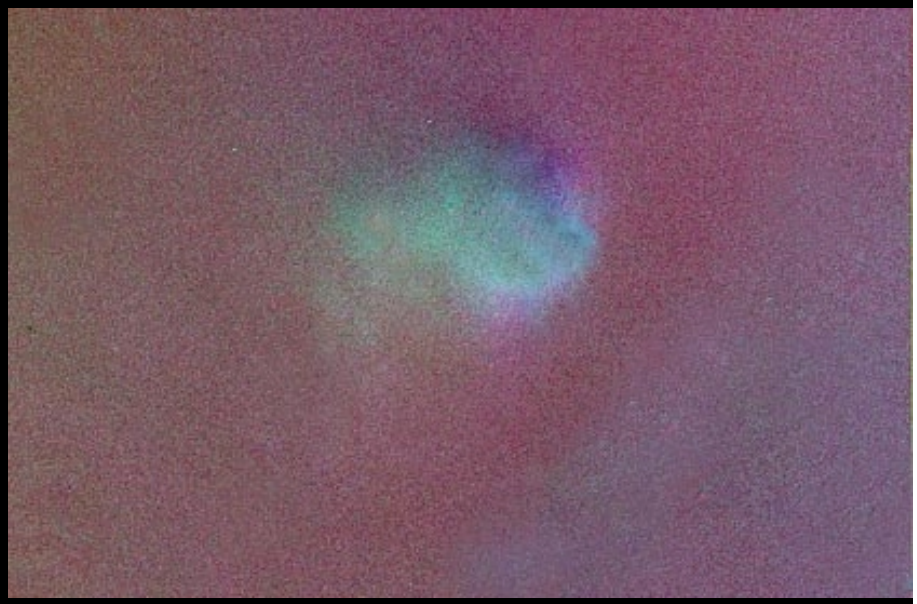
Emission line image highlights filaments



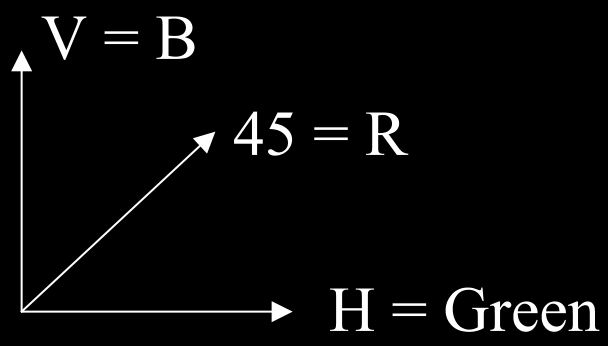
[SII] = Red, Ha = Green, [OIII] = Blue

Composite image: Stokes polarigram plus emission line image combined

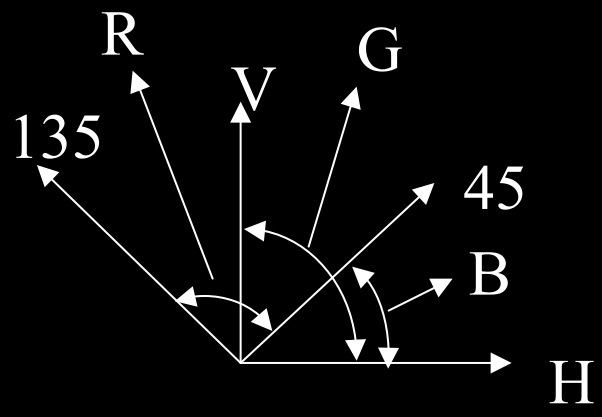

LRGB
Emission
Line
Composite: Stokes Polarigram
And Emission Line
Simple
Polarigram
Stokes
Polarigram
r.crisp 01/22/2008



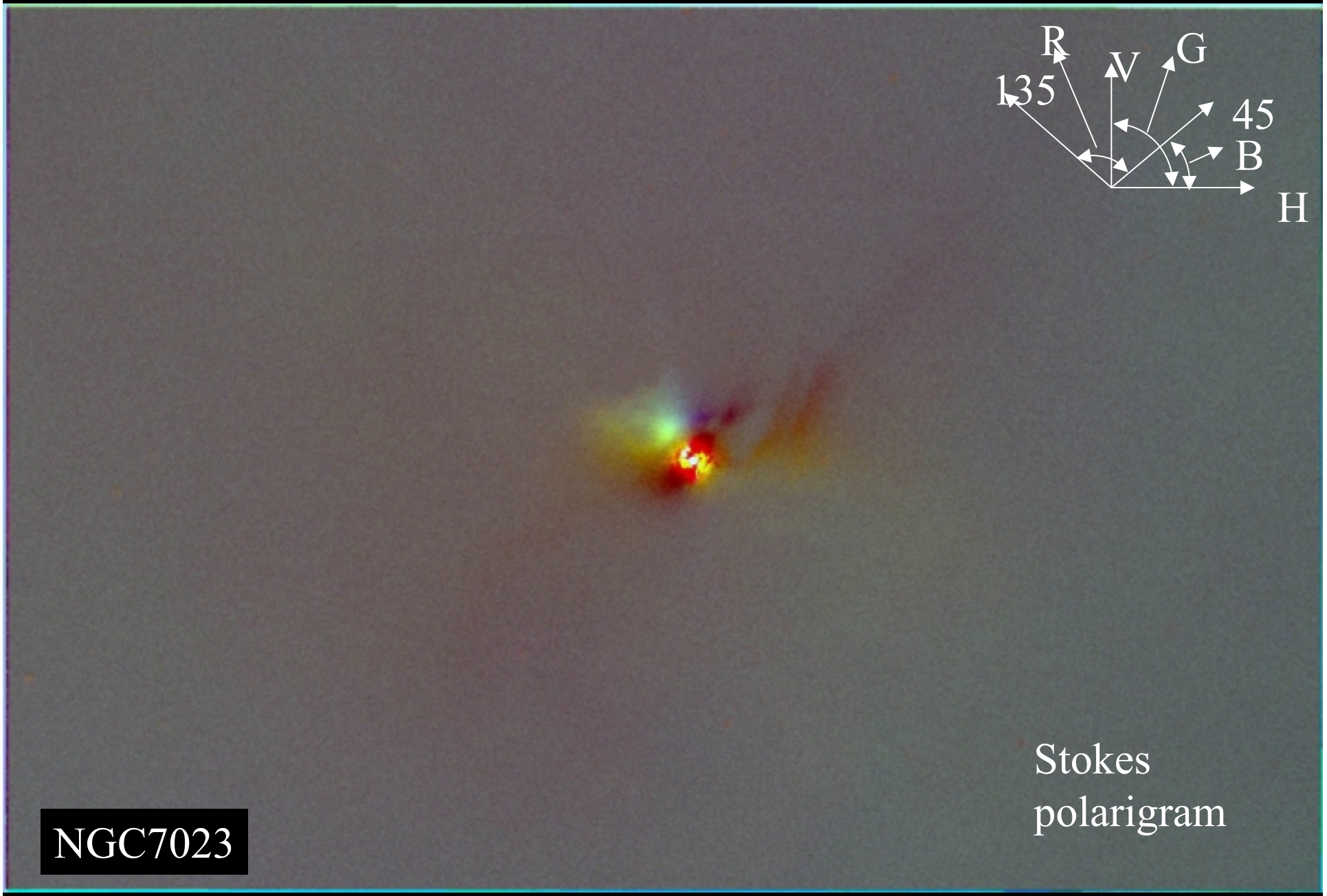
Simple polarigram

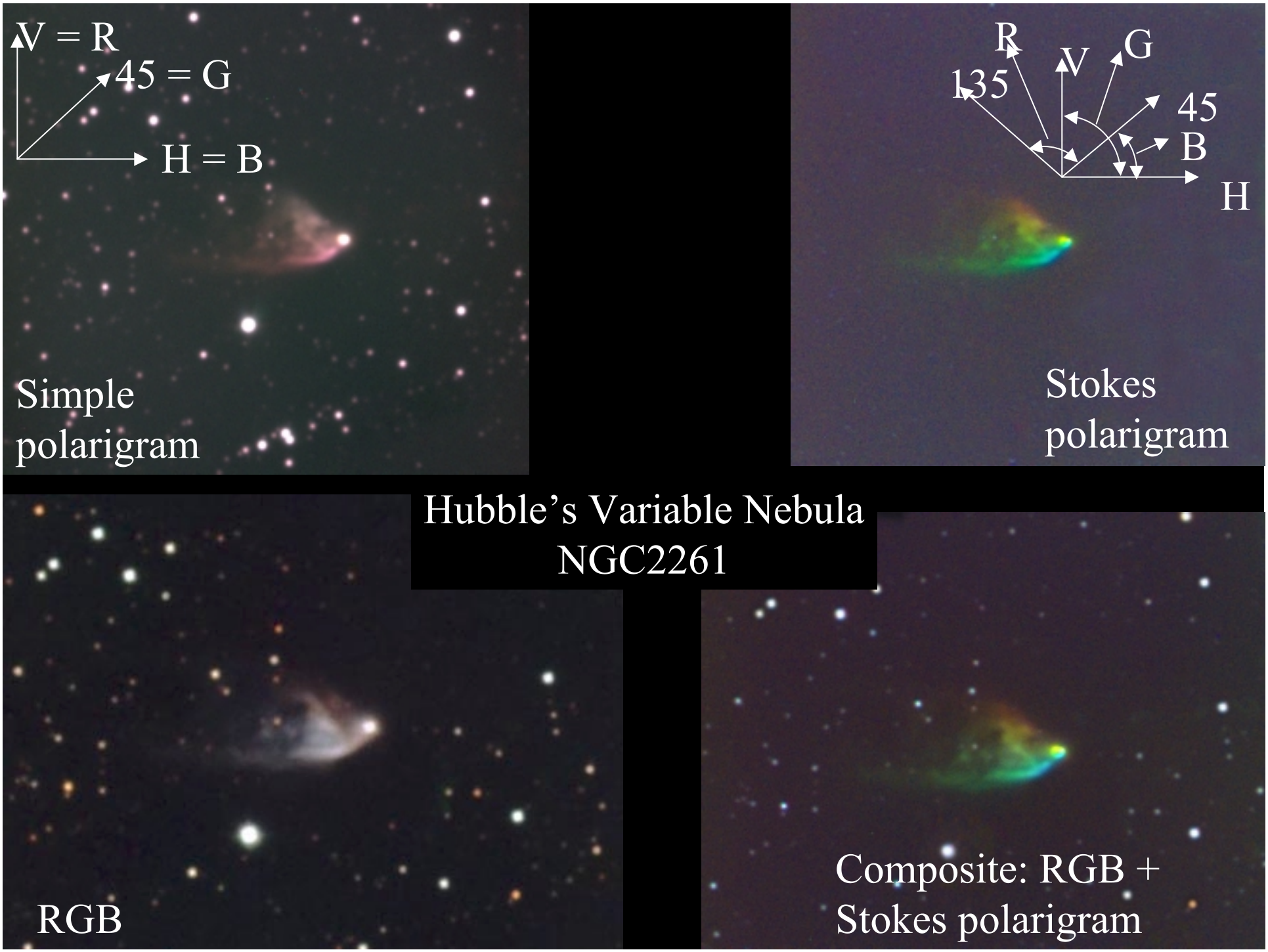


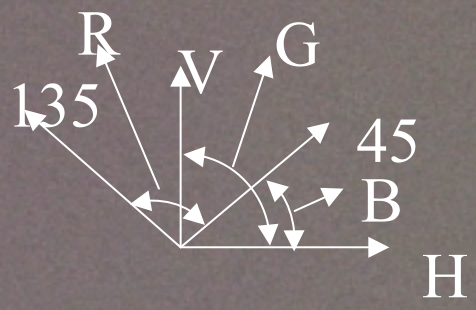
Stokes polarigram



M78 Reflection Nebula


R
V
G
135
45
B
H
Stokes
polarigram
NGC7023

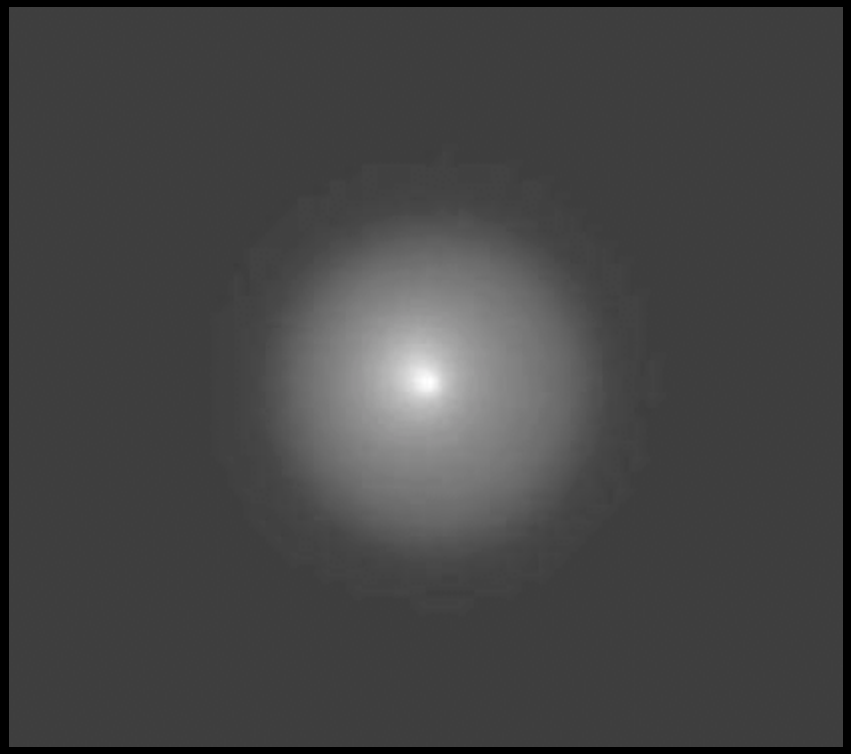

V = R
45 = G
H = B
Simple polarigram
R
135
V
G
45
B
H
Stokes polarigram
Hubble's Variable Nebula
NGC2261
RGB
Composite: RGB +
Stokes polarigram



M82

Stokes
polarigram

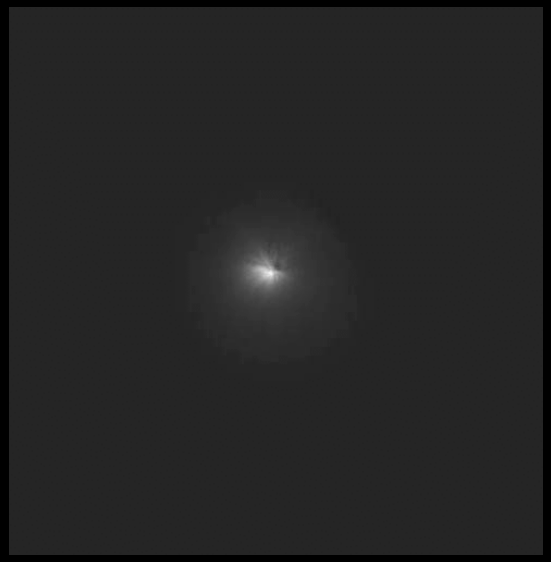
Comet 17P/Holmes



White Light Image
2007-1025-0500UTC

Polarization Difference Images = Stokes Polarigram

90 - 0 degrees



135 - 45 degrees

135 - 0 degrees

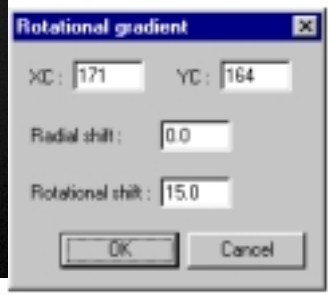
2007-1025-0500UTC

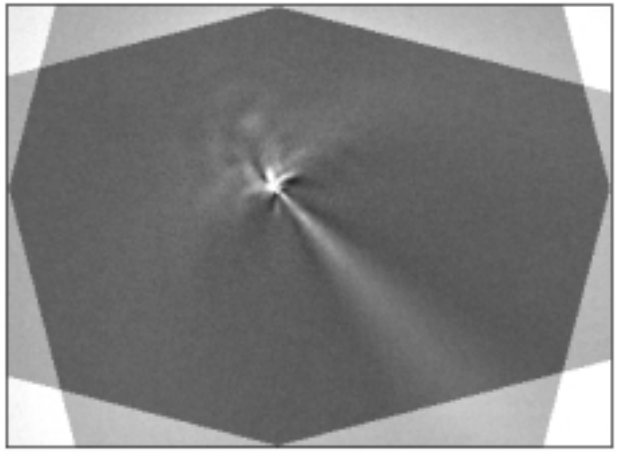
Polarization Difference Image

Polarization Difference Image
by Crisp taken on
UTC 10/25/2007

True Color Image
Found on Internet from
UTC 10/25/2007
author unknown

Rotational Gradient Image Processing Explained

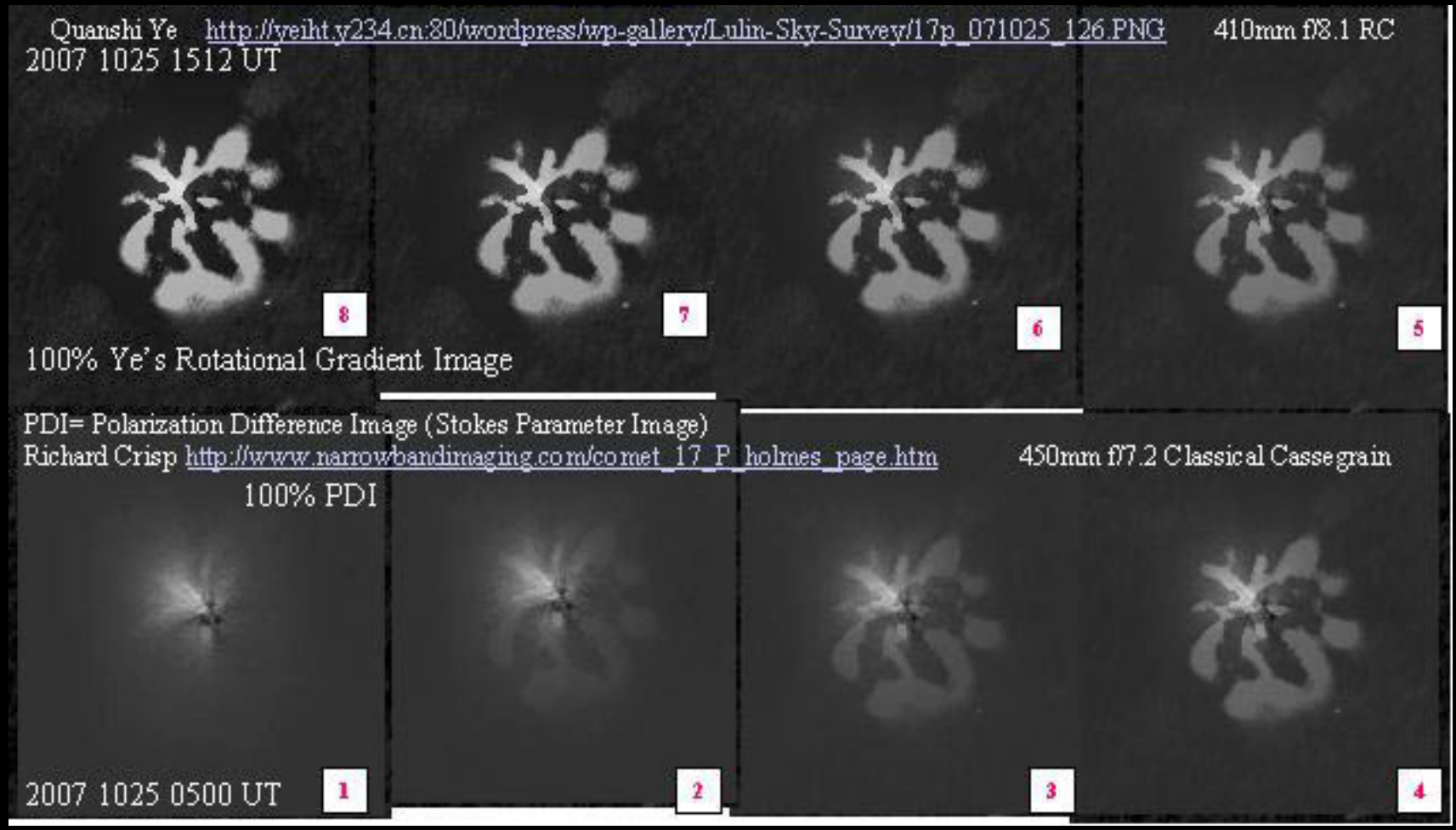




Hyakutake image after RGRADIENT processing. Several jets are clearly revealed by this method.

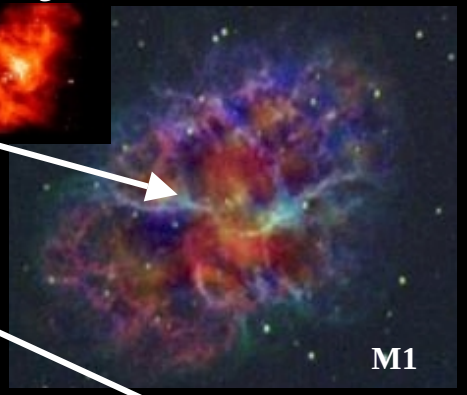
- Co-register two identical images
- Pick a “center” point
- Rotate one image relative to the other
- Some latent details can be revealed such as jets in the coma
- Artifacts are introduced so must understand your errors!!

Rotational Gradient morphed to Polarization Difference Image

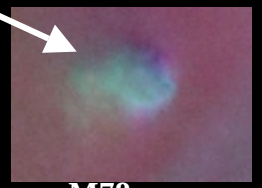


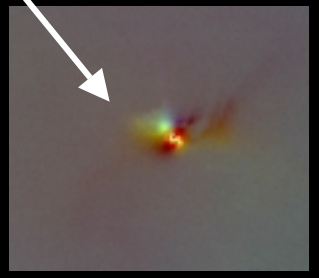
Summary

- Linear Polarization found in Astronomical objects
  - Synchrotron radiation from Pulsars
  - Dusty nebulae in star-forming regions possibly with jets
  - Circumstellar disks
  - Active galactic nuclei
  - Dusty comets


M1


Hubble's Variable Nebula


M78


NGC7023


M82


17P / Holmes

I used the Edmund Industrial Optics 50mm round unmounted glass polarizer for this work. It costs about $34.00

Other equipment

- I use Finger Lakes Cameras (CM10, IMG1024S "Dream Machine, IMG6303E) for imaging, SBIG ST7E/ST7ME for guiding
- Astro-Physics AP1200GTO mounts
- Custom Scientific and Baader Planetarium narrowband emission line filters
- Maxim DL for camera/filter wheel and guider control

Thank you for your attention

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