

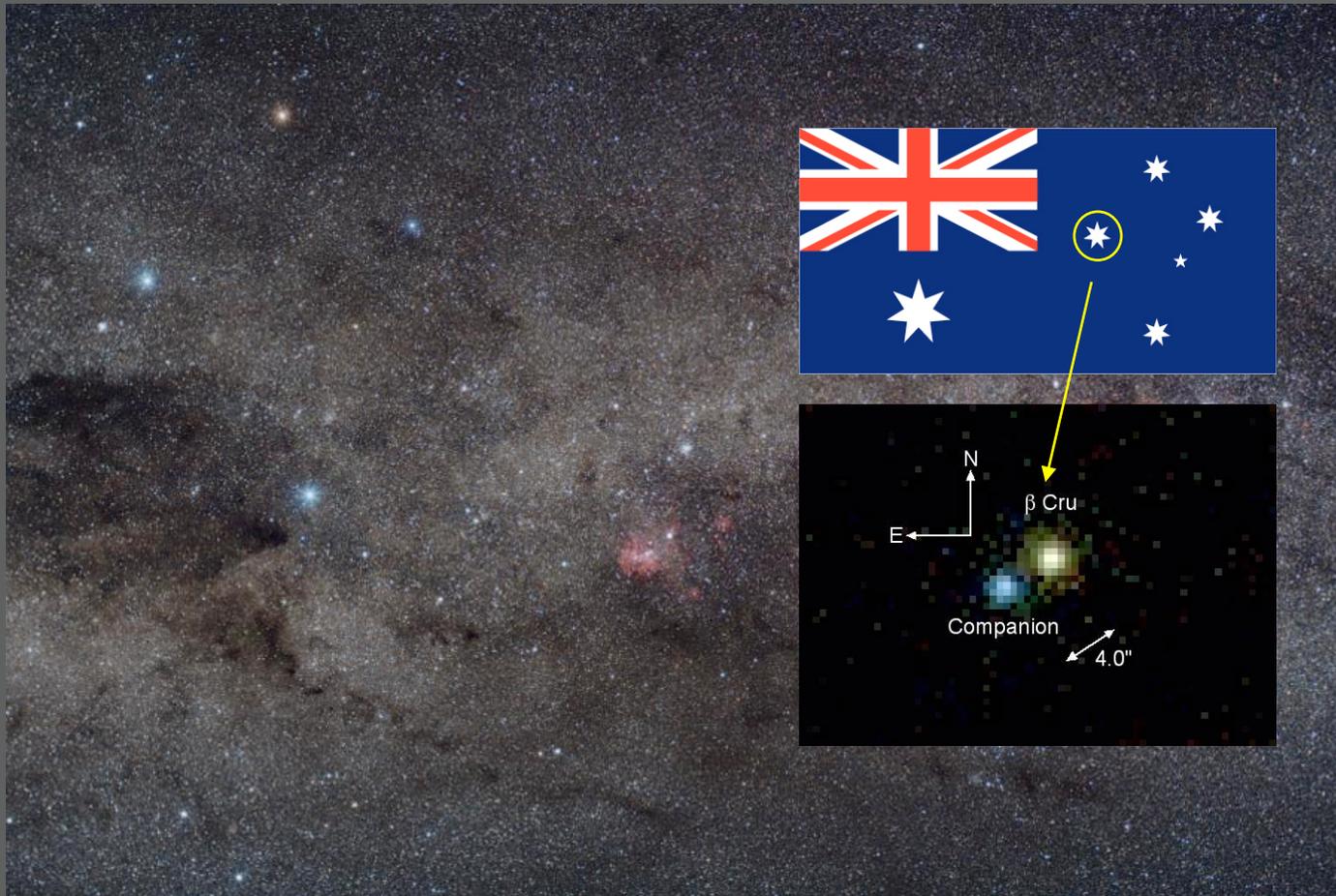
When I heard the learn'd astronomer
When the proofs, the figures, were ranged in columns
before me
When I was shown the charts and the diagrams, to add,
divide, and measure them
When I, sitting, heard the astronomer, where he lectured
with much applause in the lecture-room

How soon, unaccountable, I became tired and sick
Till rising and gliding out, I wander'd off by myself
In the mystical moist night-air, and from time to time
Look'd up in perfect silence at the stars.

Walt Whitman

Two Stars in the Southern Cross

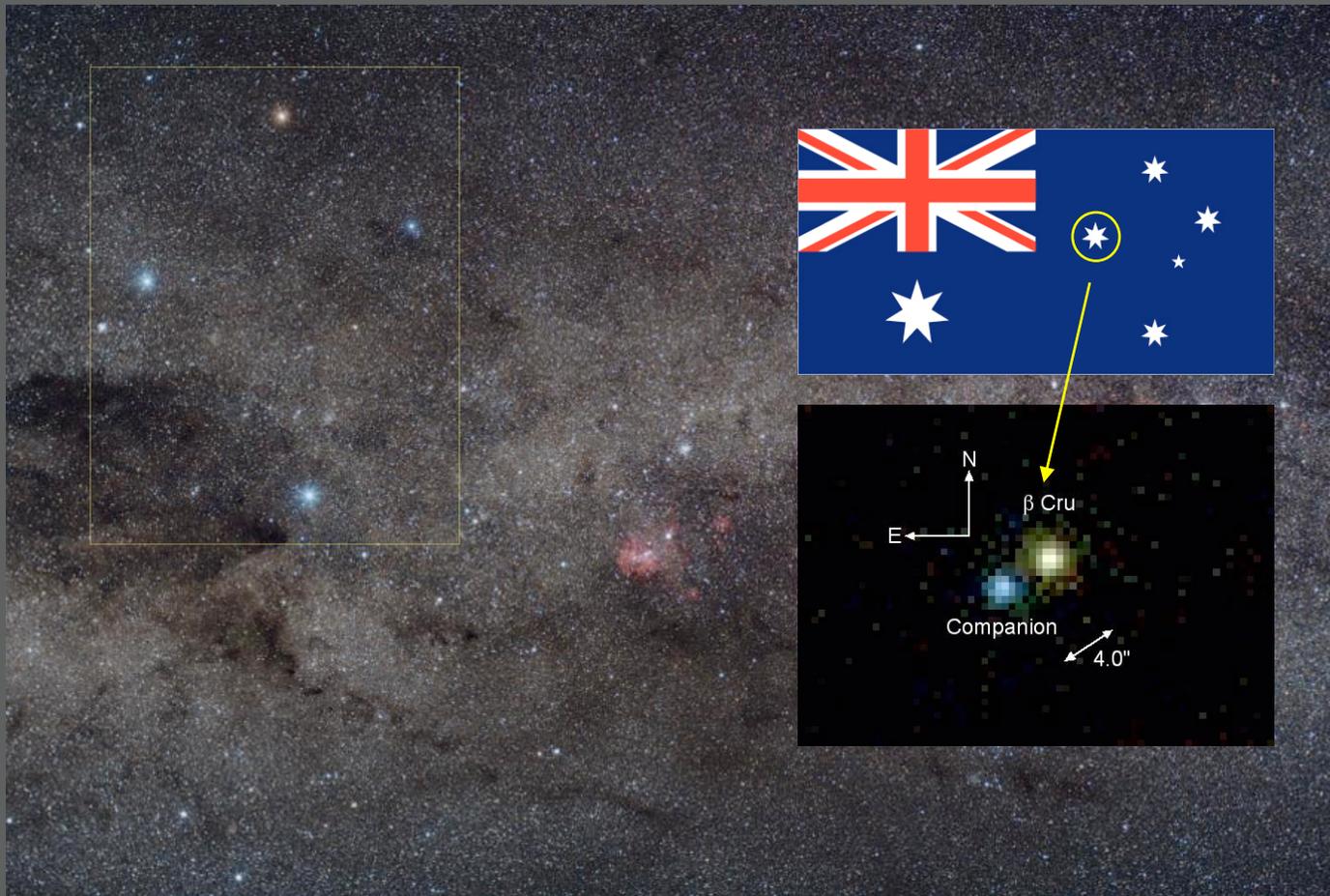
David Cohen
Physics and Astronomy



with Eric Jensen (Swarthmore), Mike Kuhn ('07), and Marc Gagné (West Chester)

Two Stars in the Southern Cross

David Cohen
Physics and Astronomy



with Eric Jensen (Swarthmore), Mike Kuhn ('07), and Marc Gagné (West Chester)

my arcane, tiny research question:

Why do massive stars emit X-rays?

X-rays from Massive Stars

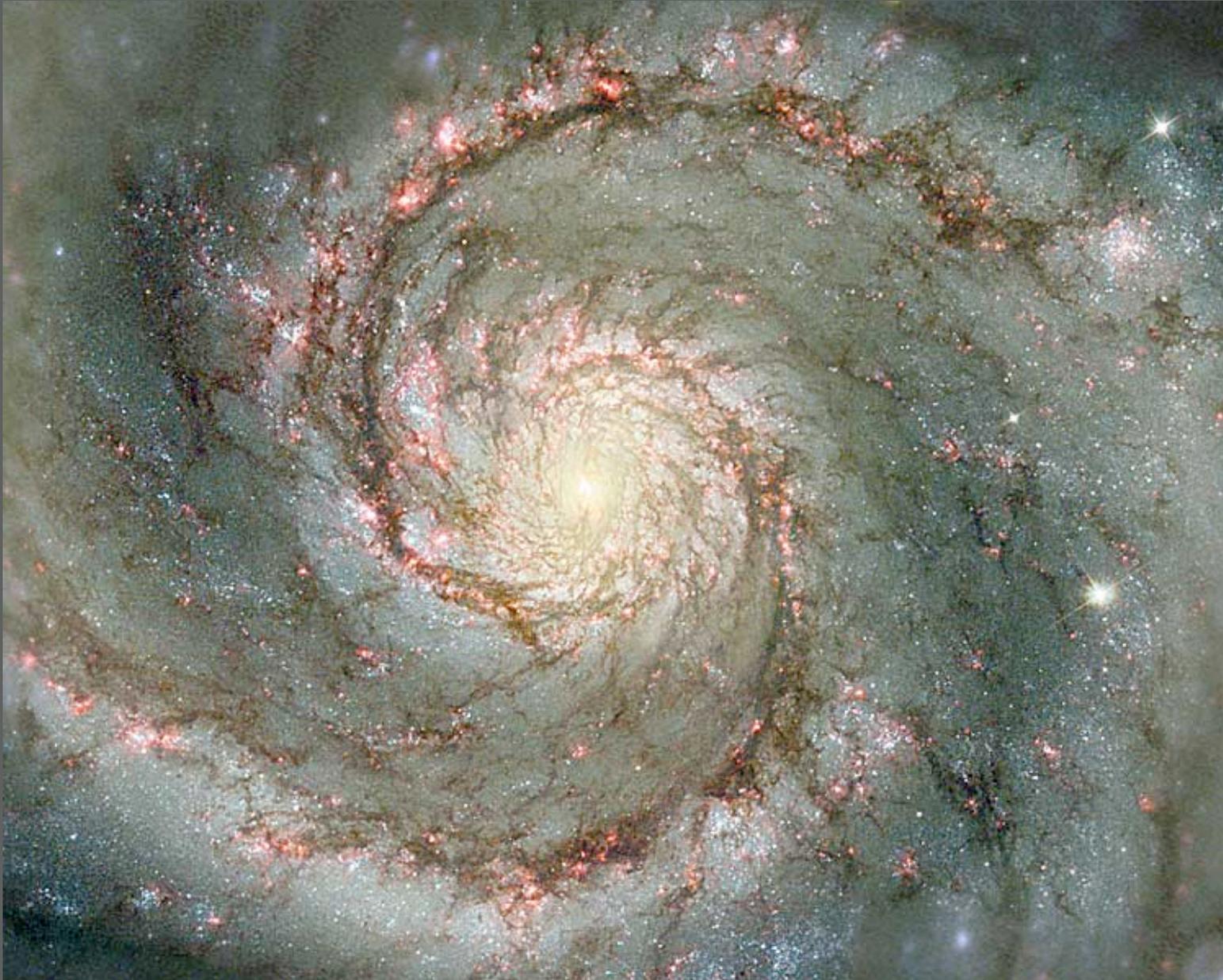
X-rays are just light... very, very blue light

Red	7000 Å	4000 Kelvin
Blue	4000 Å	7000 Kelvin
X-ray	10 Å	10 million Kelvin

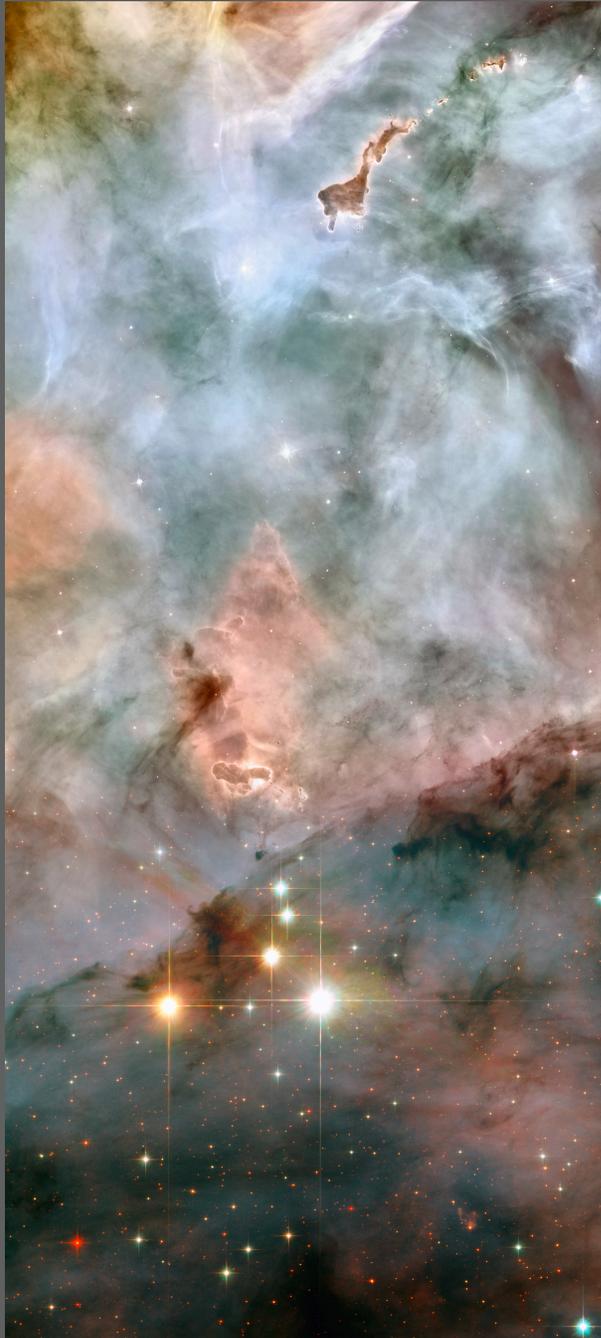
Some energetic process is happening on these stars and heating gas to millions of degrees...

First, some big-picture context...

The galaxy is an ecosystem...stars drive its evolution

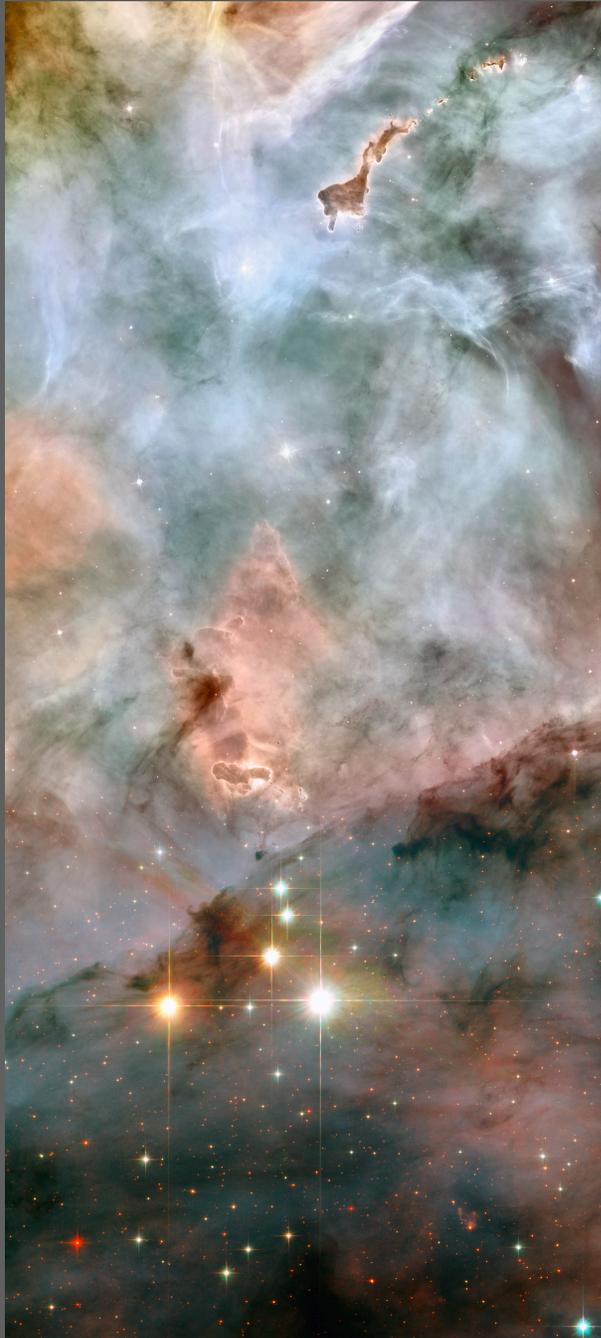


M51/Whirlpool Galaxy (HST)



Massive stars, by virtue of their prodigious luminosities light up and sculpt interstellar gas.

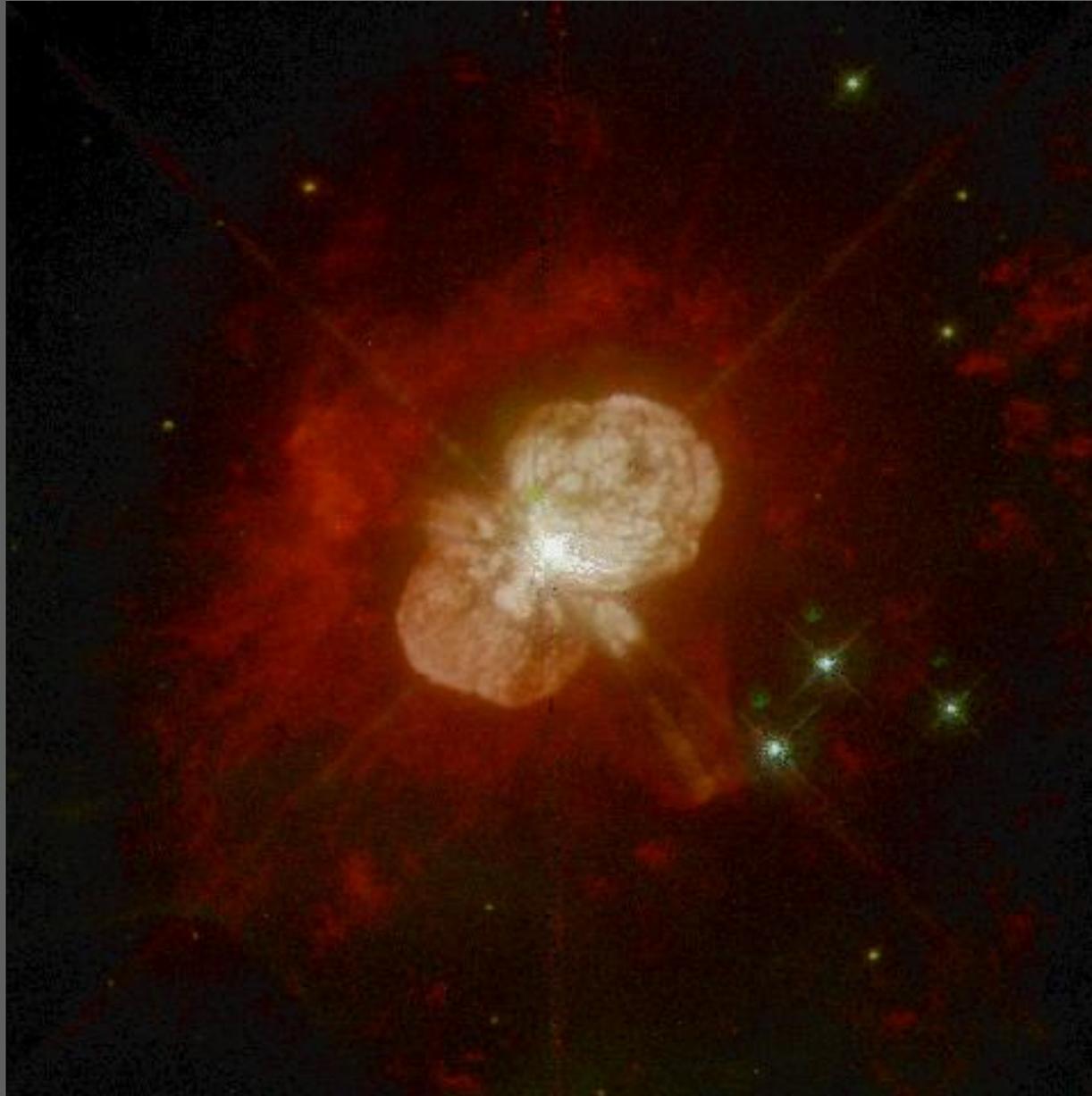
The Carina/Keyhole Nebula (HST)



Massive stars also turn hydrogen into heavy elements. *The iron in the hemoglobin in your blood was made inside a massive star.*

The Carina/Keyhole Nebula (HST)

explosive mass loss



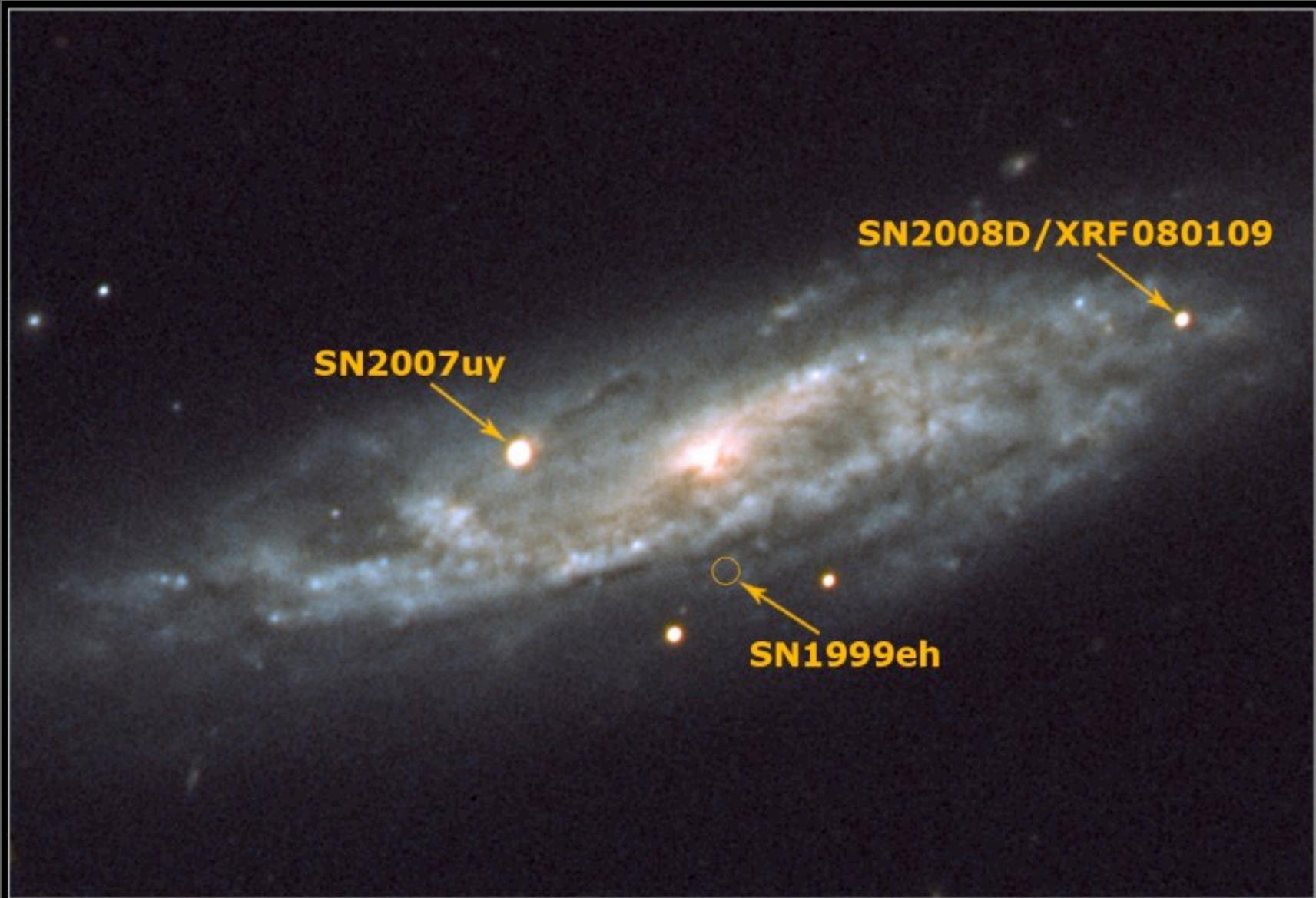
eta Carina (HST)

wind-blown bubble: steady mass-loss



NGC 6888 Crescent Nebula (Tony Hallas)

Massive stars explode as supernovae



NGC 2770 (A. de Ugarte Postigo, ESO & the Dark Cosmology Centre)

1000 yr old supernova remnant



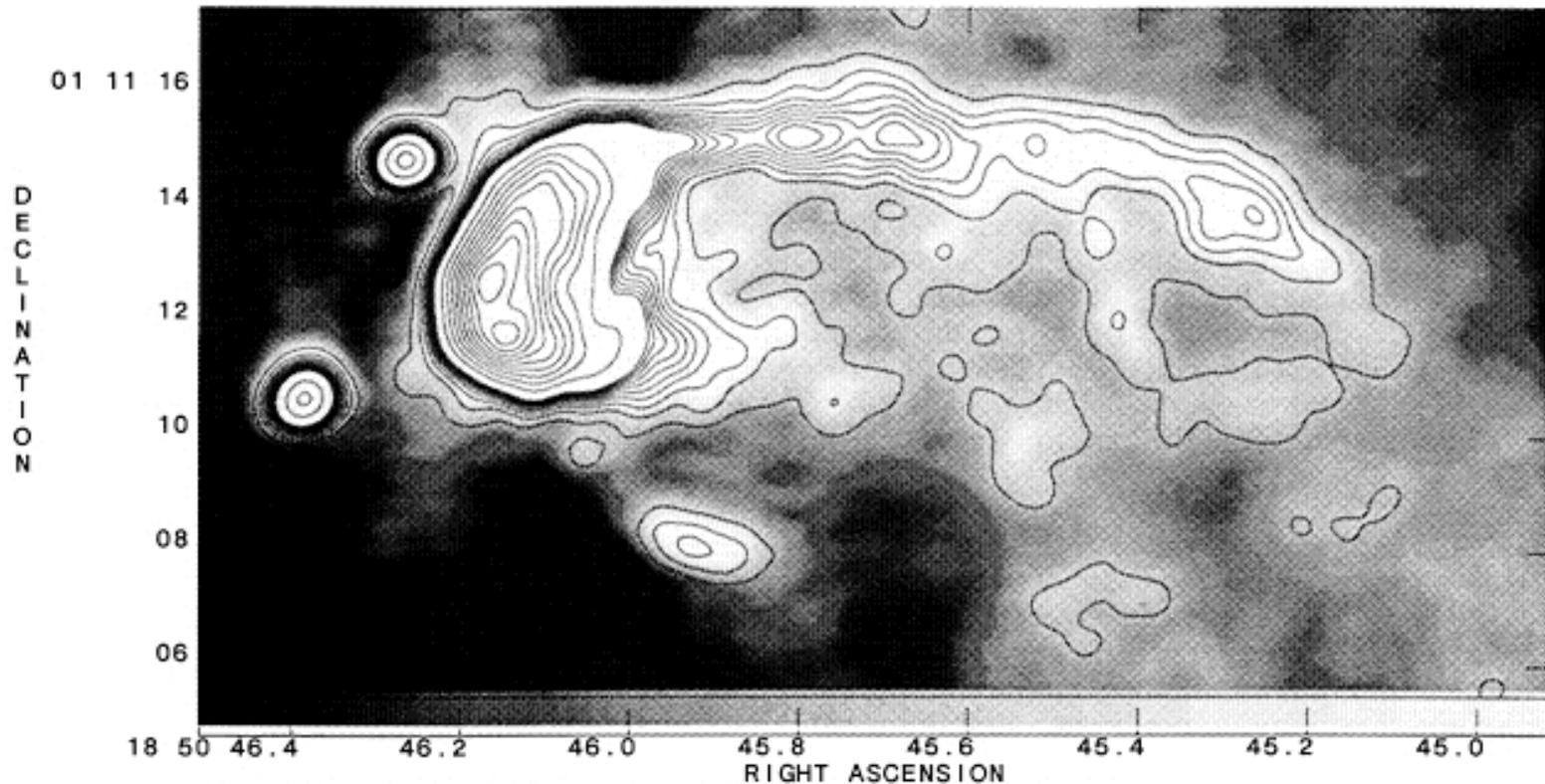
Crab Nebula (WIYN)

The alchemized material drifts back into the interstellar medium



Simeis 147: supernova remnant (J-P Metsävainio)

PLOT FILE VERSION 6 CREATED 27-SEP-1989 15:55:53
G34.26 IPOL 8414.900 MHZ G34 2SC.ICLN.1

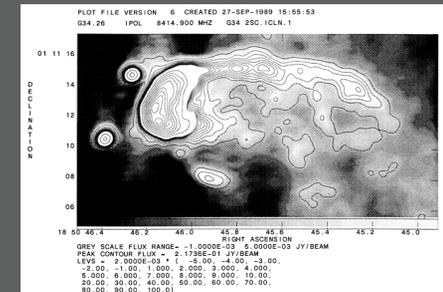


GREY SCALE FLUX RANGE = $-1.0000E-03$ $5.0000E-03$ JY/BEAM
PEAK CONTOUR FLUX = $2.1736E-01$ JY/BEAM
LEVS = $2.0000E-03 * (-5.00, -4.00, -3.00,$
 $-2.00, -1.00, 1.000, 2.000, 3.000, 4.000,$
 $5.000, 6.000, 7.000, 8.000, 9.000, 10.00,$
 $20.00, 30.00, 40.00, 50.00, 60.00, 70.00,$
 $80.00, 90.00, 100.0)$

Radio telescope observations of a *forming*
massive star



This quilt (made by Deborah Shepard) is a rendition of 3.6-cm (8.4 GHz) radio continuum data taken by D. Wood & E. Churchwell at the VLA (Van Buren et al. 1990, ApJ 353, 570) . This object is the prototype for cometary, ultracompact HII regions; it is believed that a massive, early B star is forming within this cloud (Hunter et al. 1998), which is moving supersonically and creating a bow shock. [from Prof. Sally Oey]



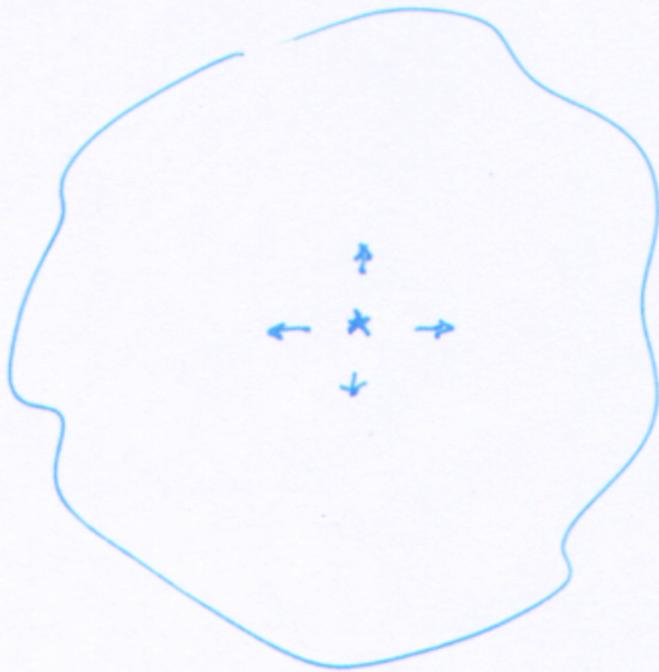
X-ray production in massive stars seems to be associated with their stellar winds.



This isn't really even the stellar wind itself...

...the important stuff is down by the star;

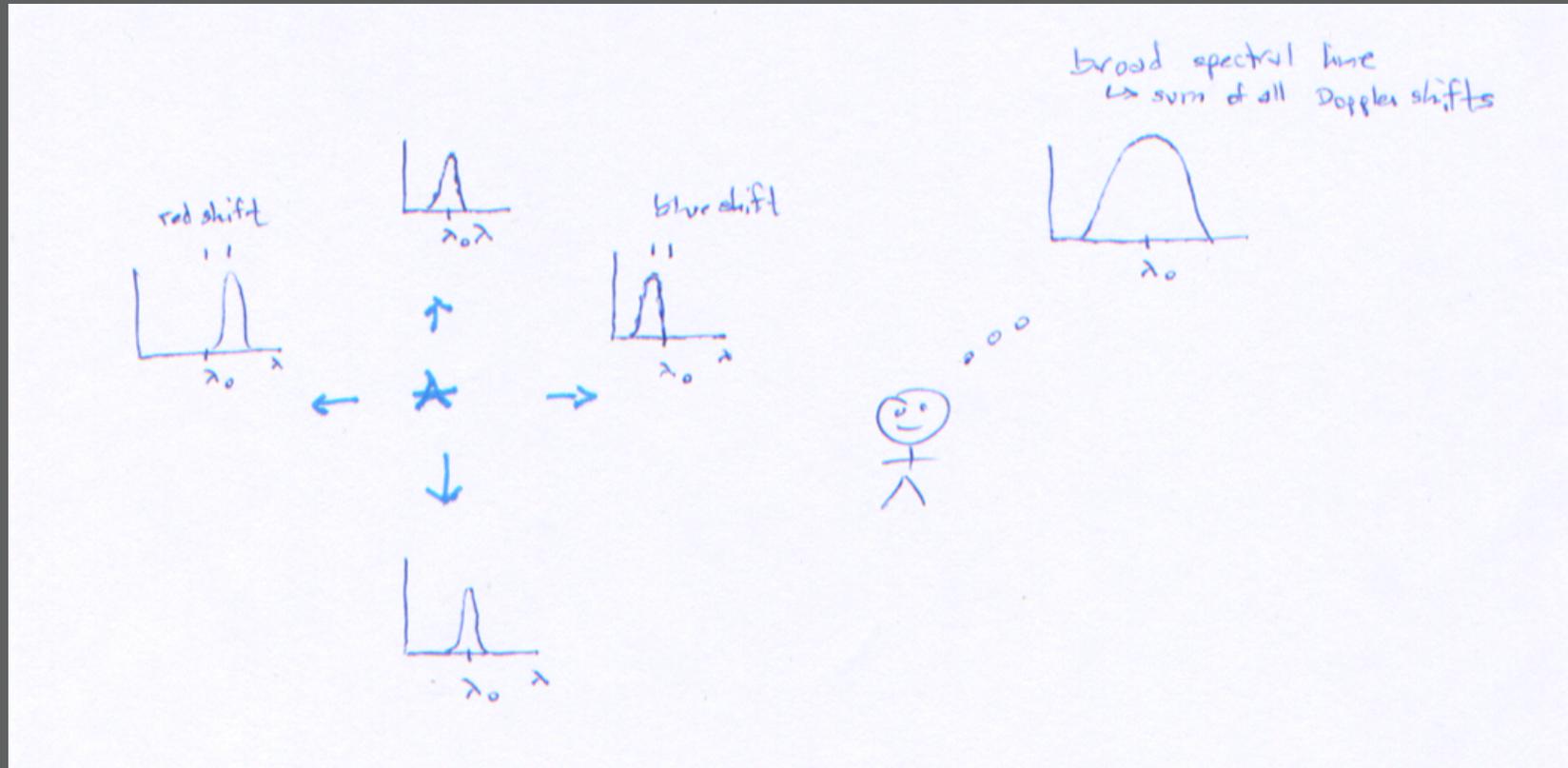




$$V(r) = V_0 \left(1 - \frac{R_0}{r}\right)^2$$

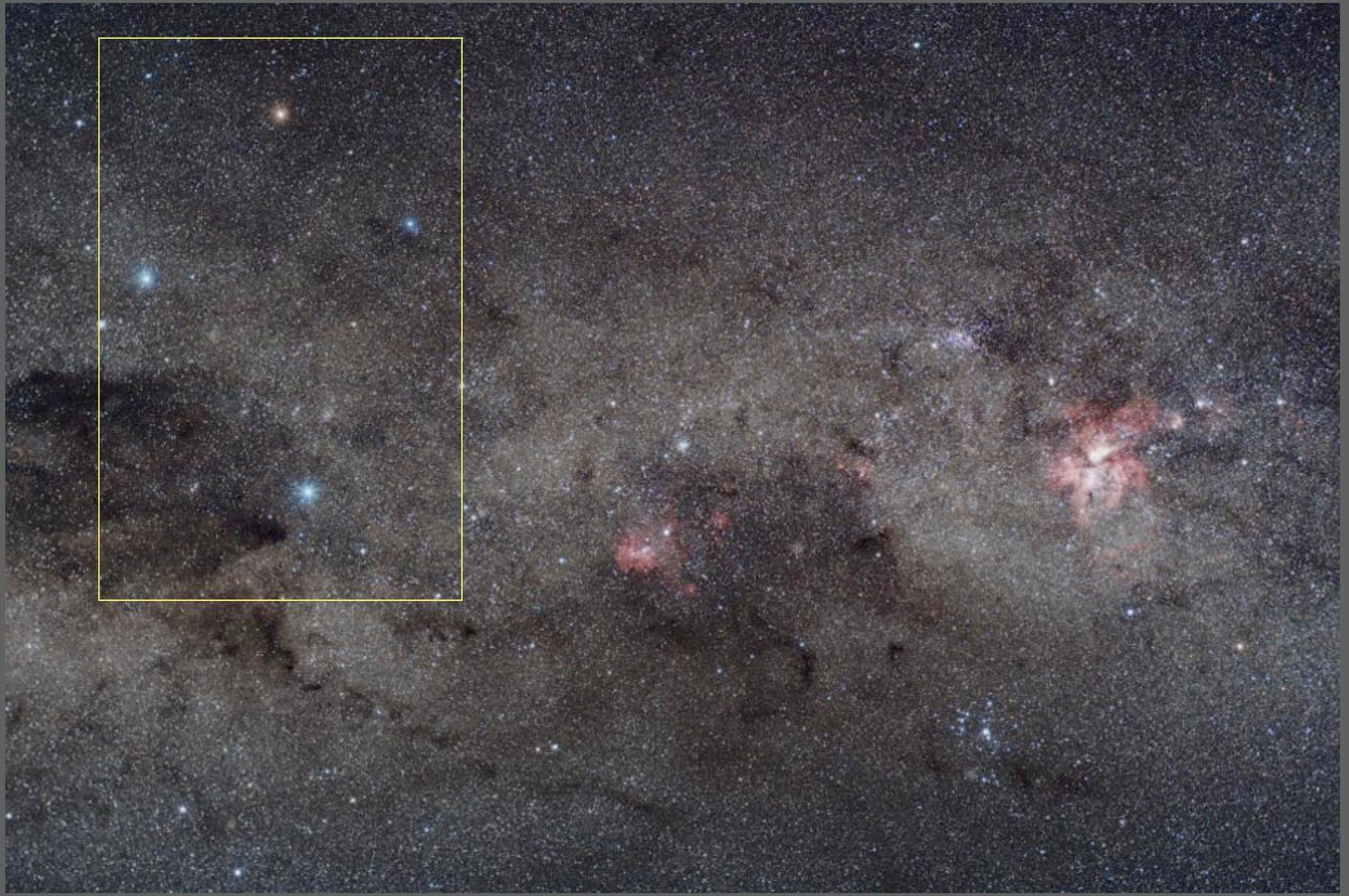


The *Doppler shift* tells us about the velocity of the light-emitting material





Yuri Beletsky (ESO)



Yuri Beletsky (ESO)



Yuri Beletsky (ESO)

β Crucis

aliases:

Mimosa

HD 111123

a massive ($16 M_{\text{sun}}$),
luminous ($34,000 L_{\text{sun}}$),
hot ($30,000 \text{ K}$) star

a “B star”









*Crux –
our Southern
heritage*

by Magda Streicher
magda@pixie.co.za

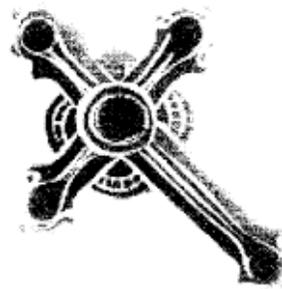


Image source: Stellarium

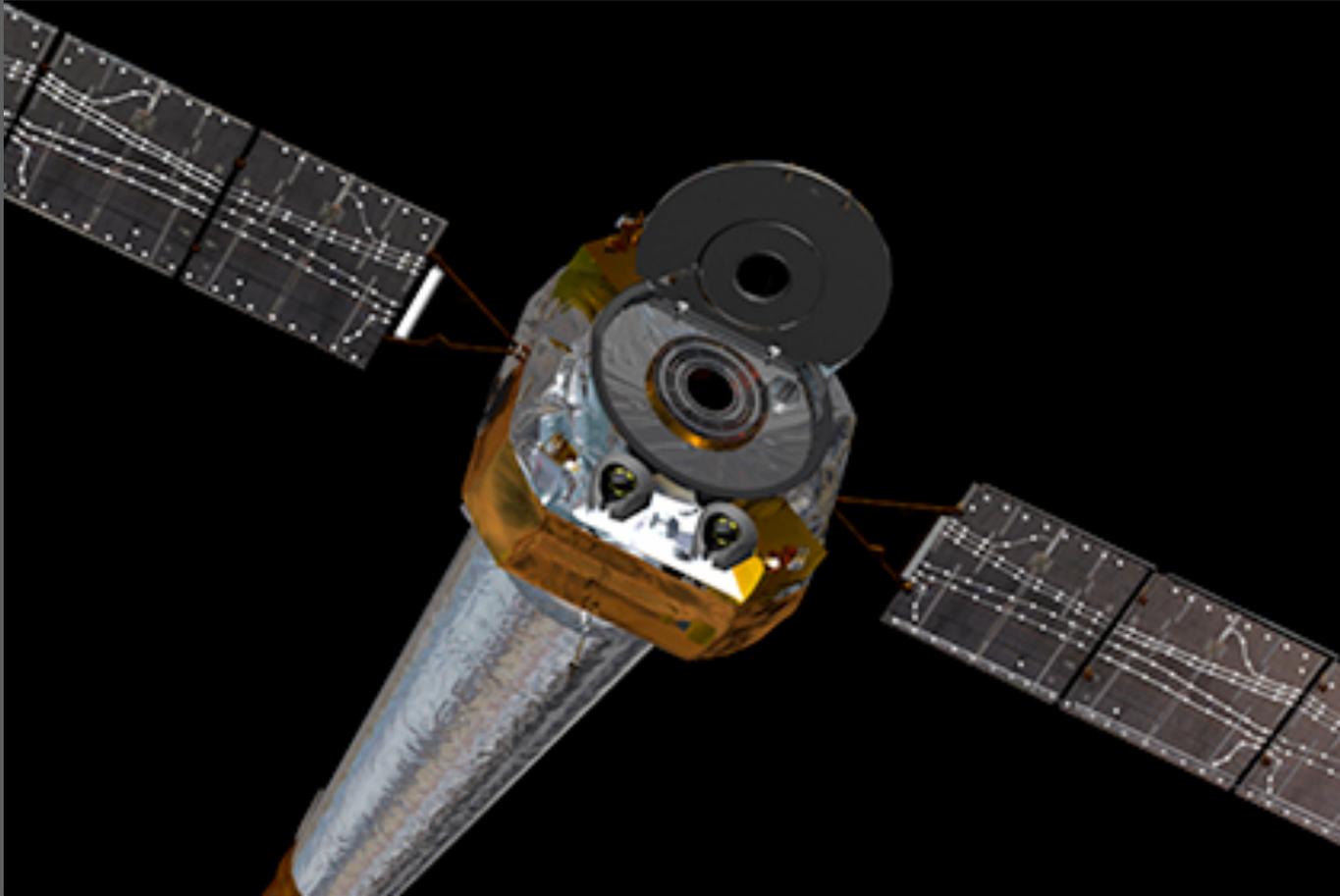
It has long been overdue that we explore our own southern trophy, the Crux constellation. Not only is it the smallest constellation of a total of 88 in the sky, but it is also one of the most popular. The Southern Cross reminds me of the many crosses planted by the early explorers, today found along the coast amongst the rocks and between lighthouses. We are indeed privileged to see a starry cross in our sky, especially since this cross aptly shows the direction to real south. Drawing a line through Gamma to Alpha Crucis and extending it some 25 degrees, roughly gets us to the south celestial pole.

The Portuguese navigators saw Crux as the symbol of their faith. It is also honoured on the flags of Australia and New Zealand. Ptolemy assigned Beta, Gamma and Delta Crucis to Centaurus, but it is generally believed that the French astronomer Augustin Royer gave Crux its own identity. The starry cross was mentioned by the Italian Navigator Amerigo Vespucci way back in 1501. The constellation Centaurus literally stands guard over the cross on three of its sides – Musca lies to its South.

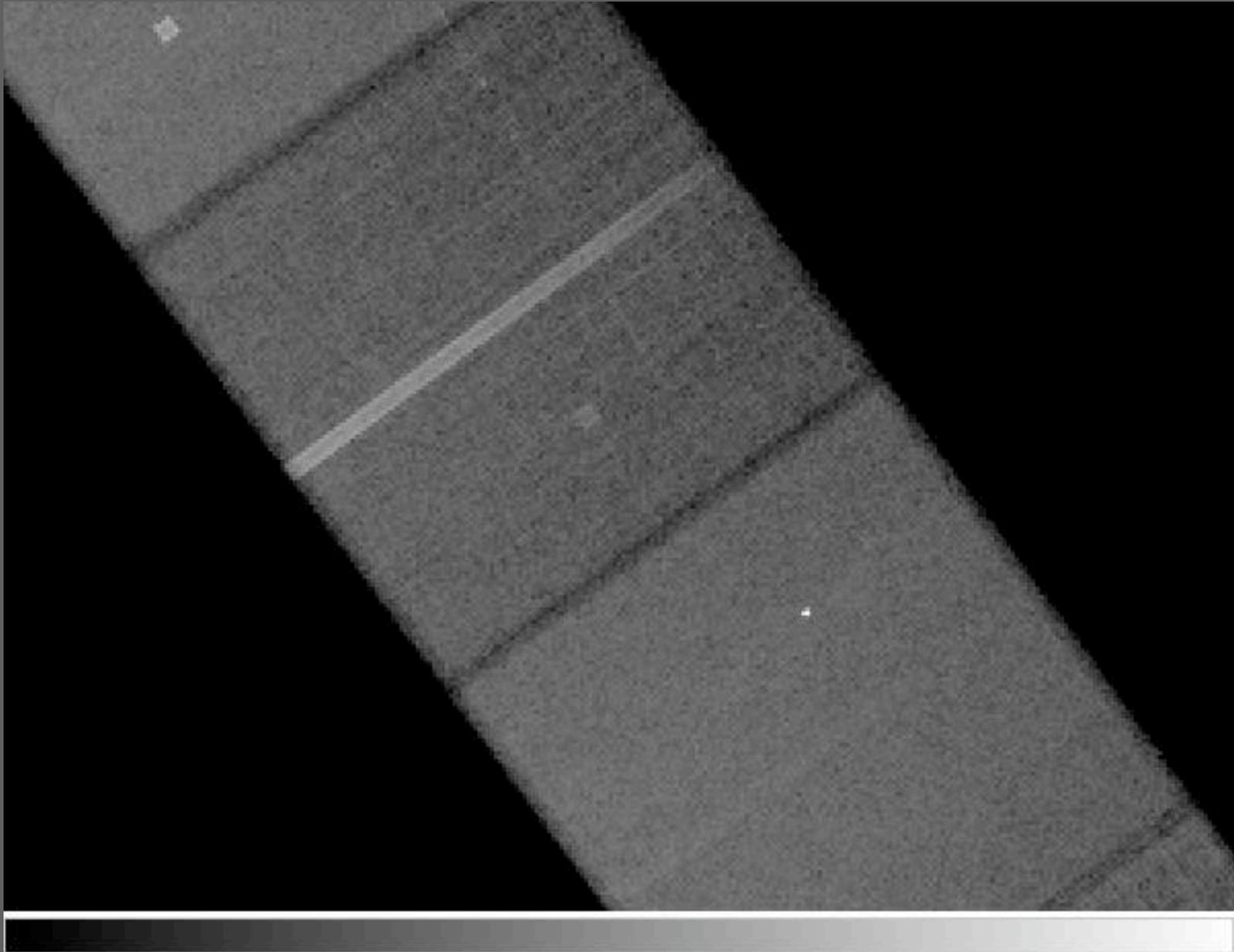
Each of the four corner stars has its own

fascination. **Alpha Crucis**, at magnitude 1.4, occupies the southern tip of Crux and is a brilliant bluish-white pair, 370 light years distant. The neighbouring **Beta Crucis**, sometimes also known as “Mimosa”, is another brilliant white star of magnitude 1.3, lying east on the short arm of Crux. It is also the 20th brightest star in the sky, around 500 light years distant. A crimson-red star of magnitude 8.6 lies just 2.4' west of it, making a fine contrast. On the western end of Crux's short arm the variable star **Delta Crucis**, magnitude 2.7. It is some 360 light years distant and has a massive expanding stellar shell and a rotation period of only 3.6 days. North of Alpha, on the opposite side of the cross, is **Gamma Crucis**, the reddish beacon star of the constellation. It is a red giant (type M4) of magnitude 1.6 and is the nearest of the four Crux stars, some 220 light years away. It is also the nearest red giant, similar in fact to the red giant star Antares in Scorpius. The true fifth wheel on the Crux wagon is magnitude 3.5 Epsilon, situated between Alpha and Delta Crucis. In a way it spoils the cross shape, but at the same time distinguishes it from the other crosses in the sky.

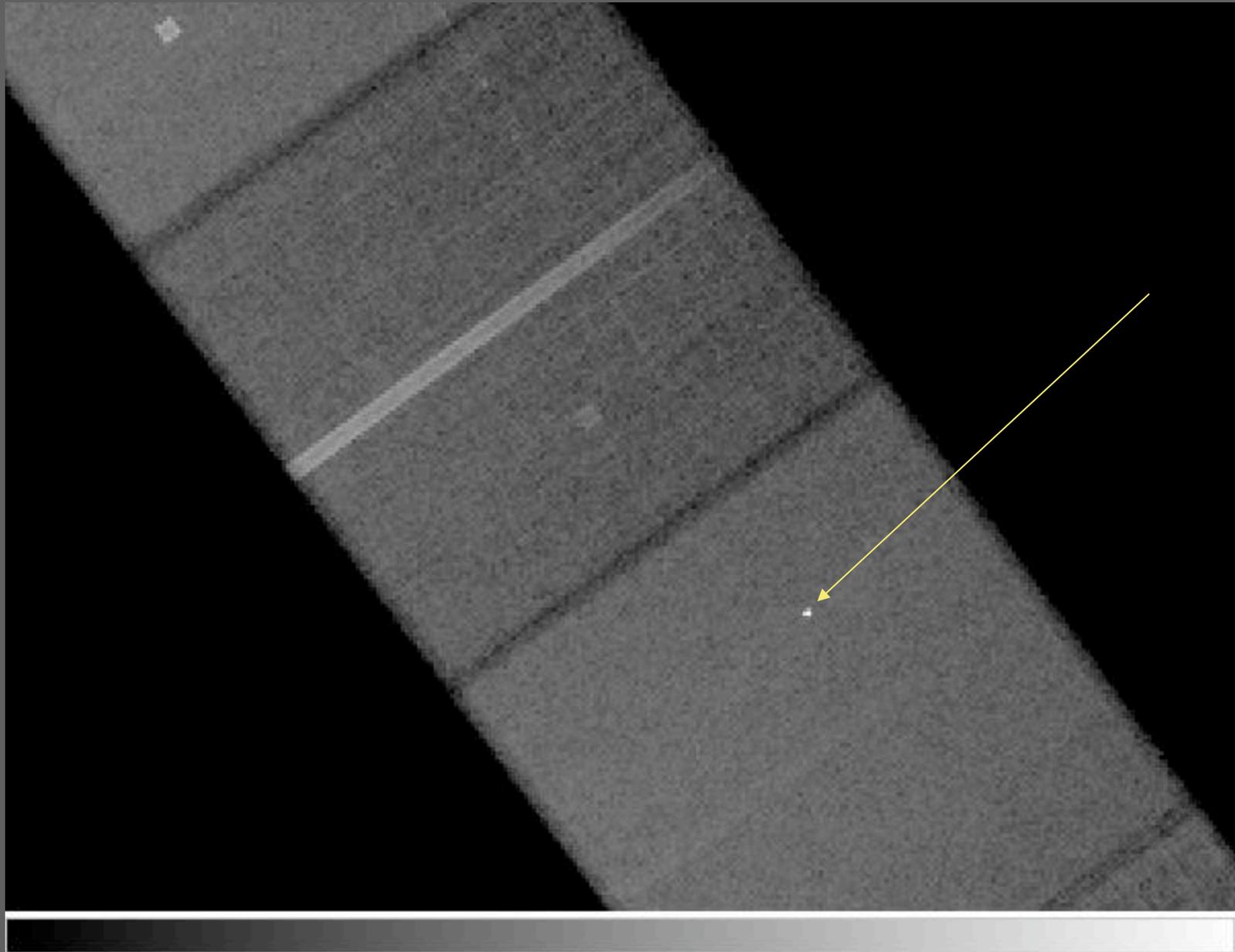
The Chandra X-ray Telescope

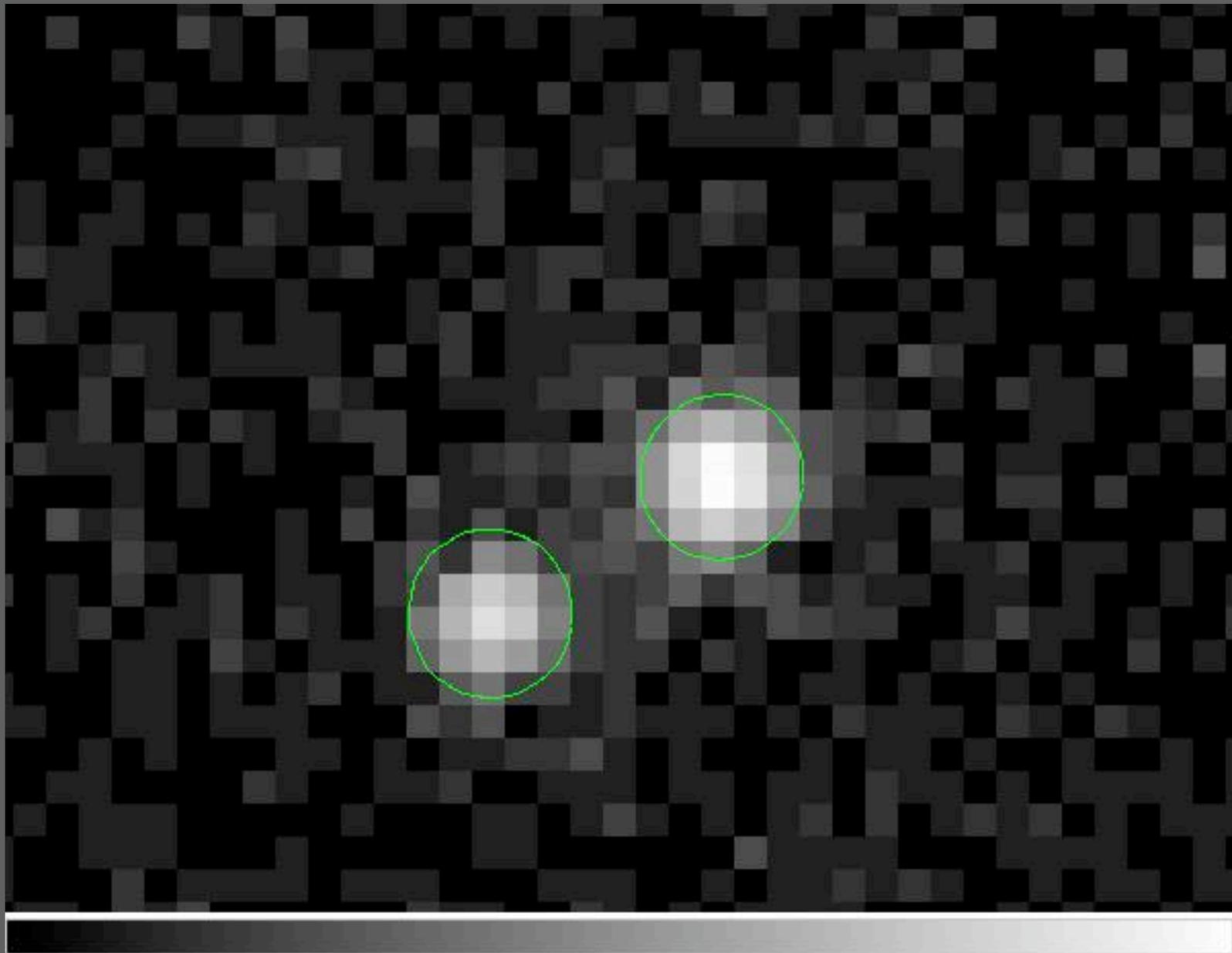


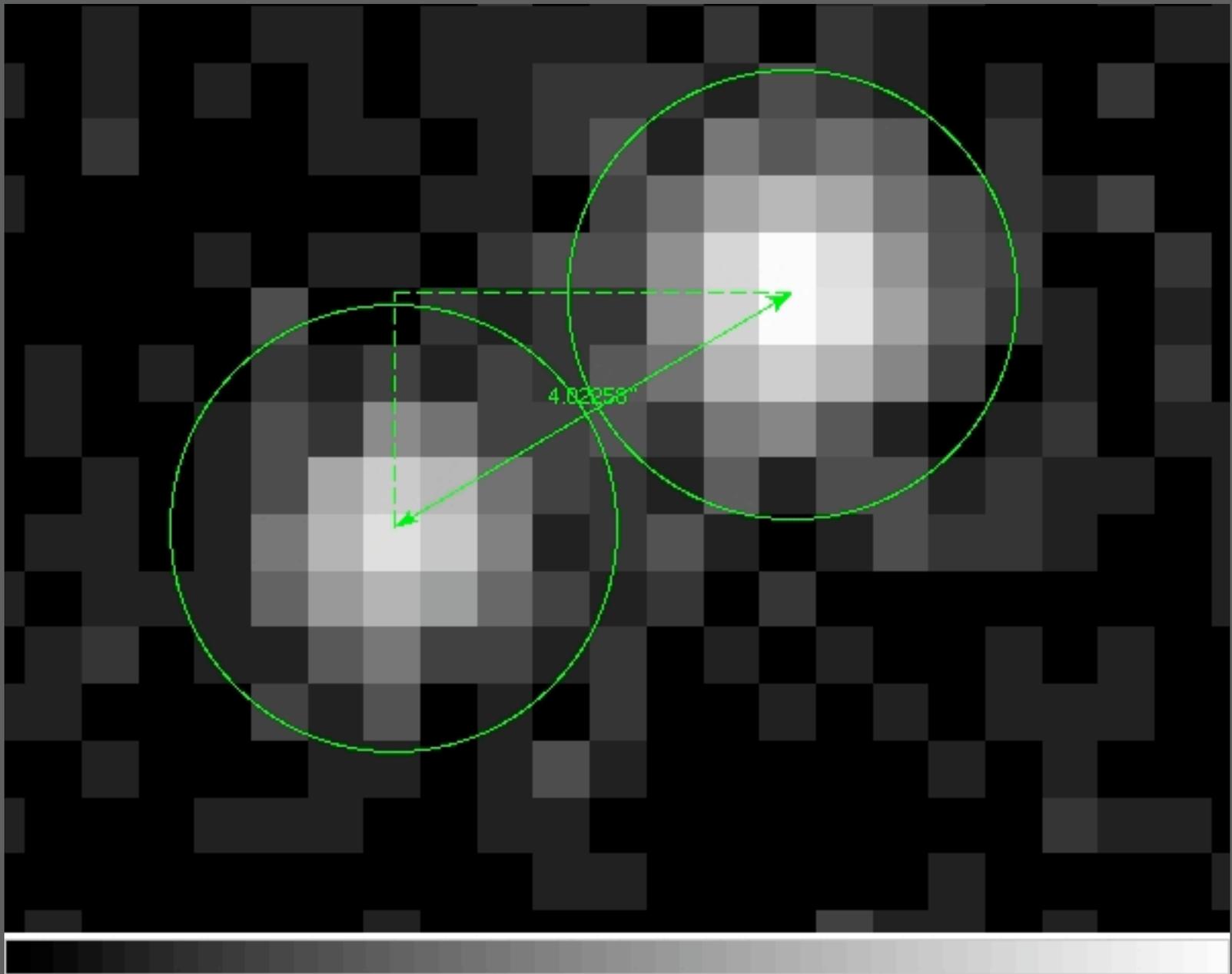
The data



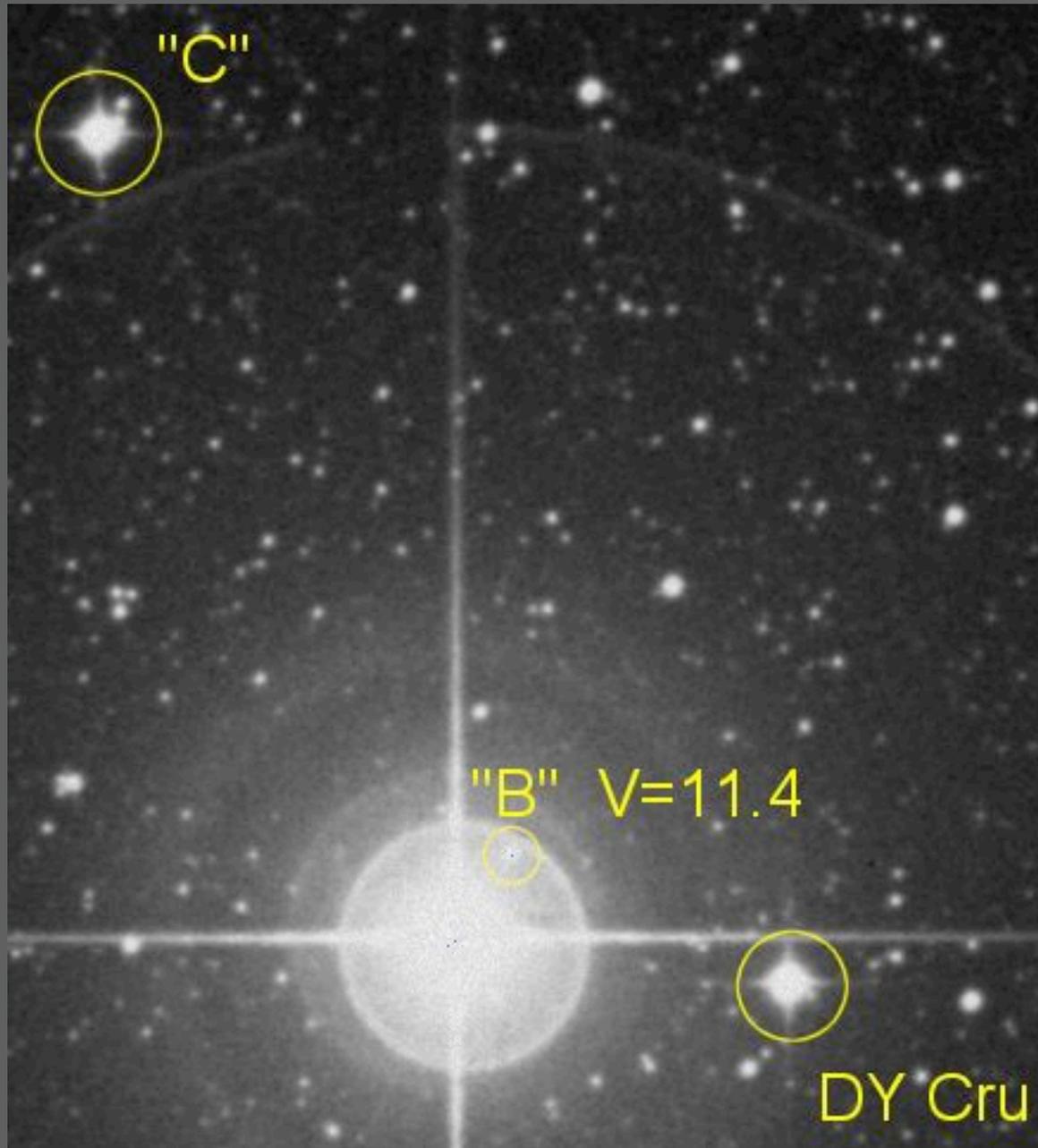
The data





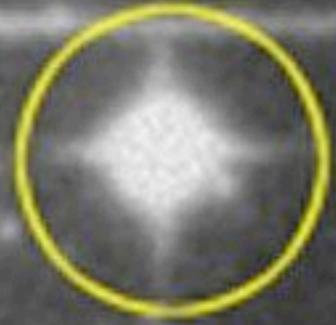


Why has this binary companion to such a prominent star never been seen before?



Courtesy Psychohistorian blog, Auke Slotegraaf

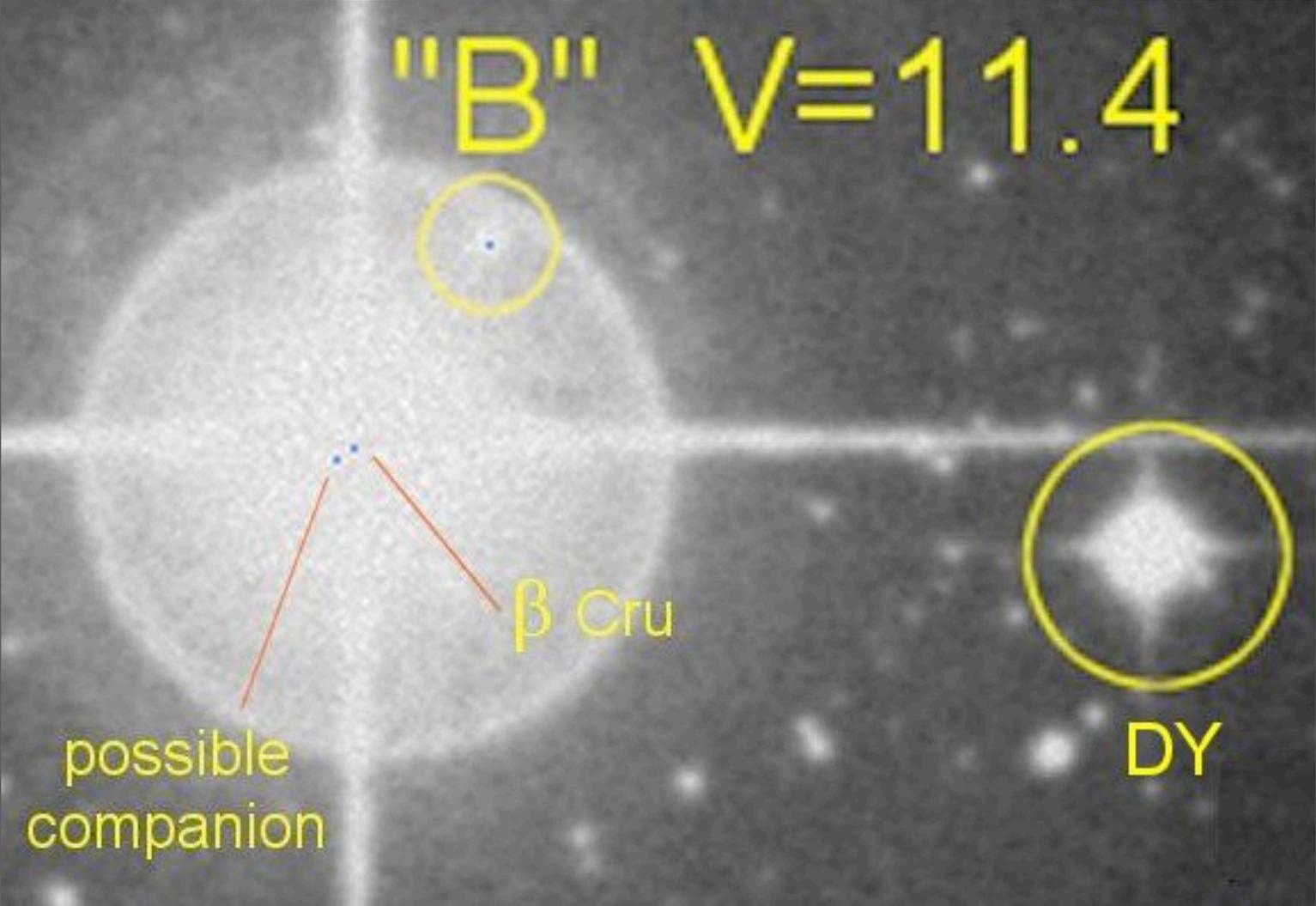
"B" V=11.4



β Cru

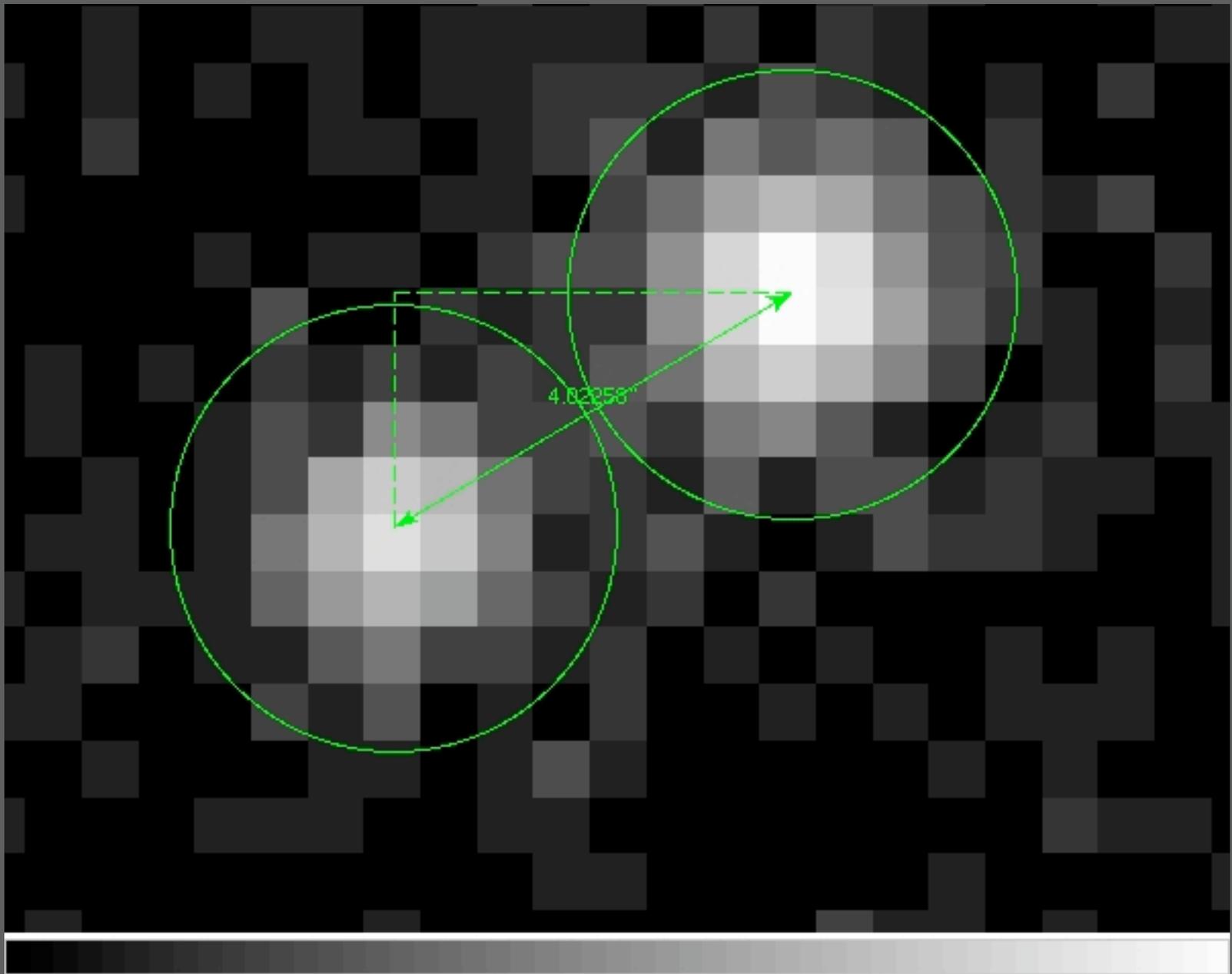
possible
companion

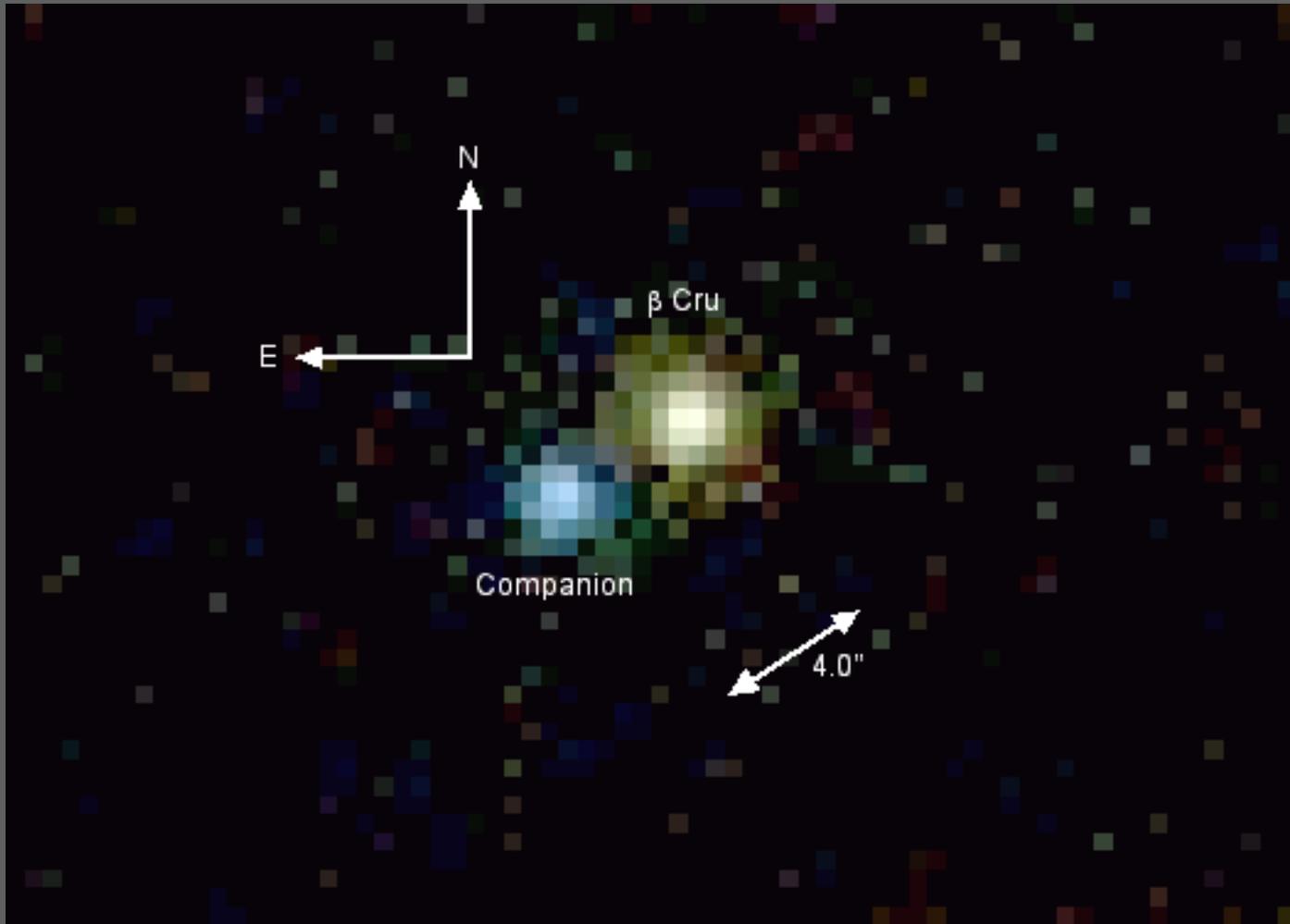
DY



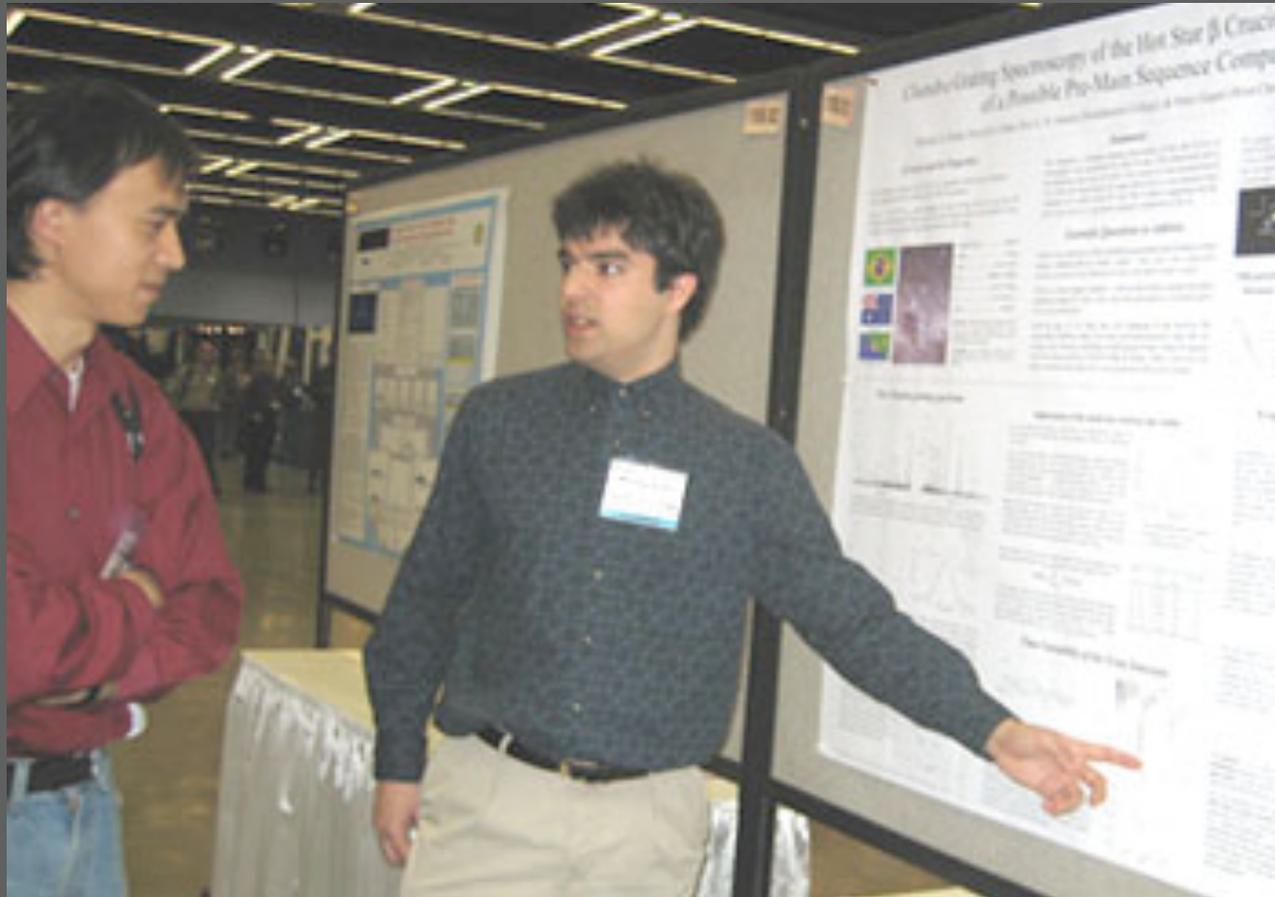
In X-rays, the contrast is only 3:1

In visible light, it's more like 30,000:1



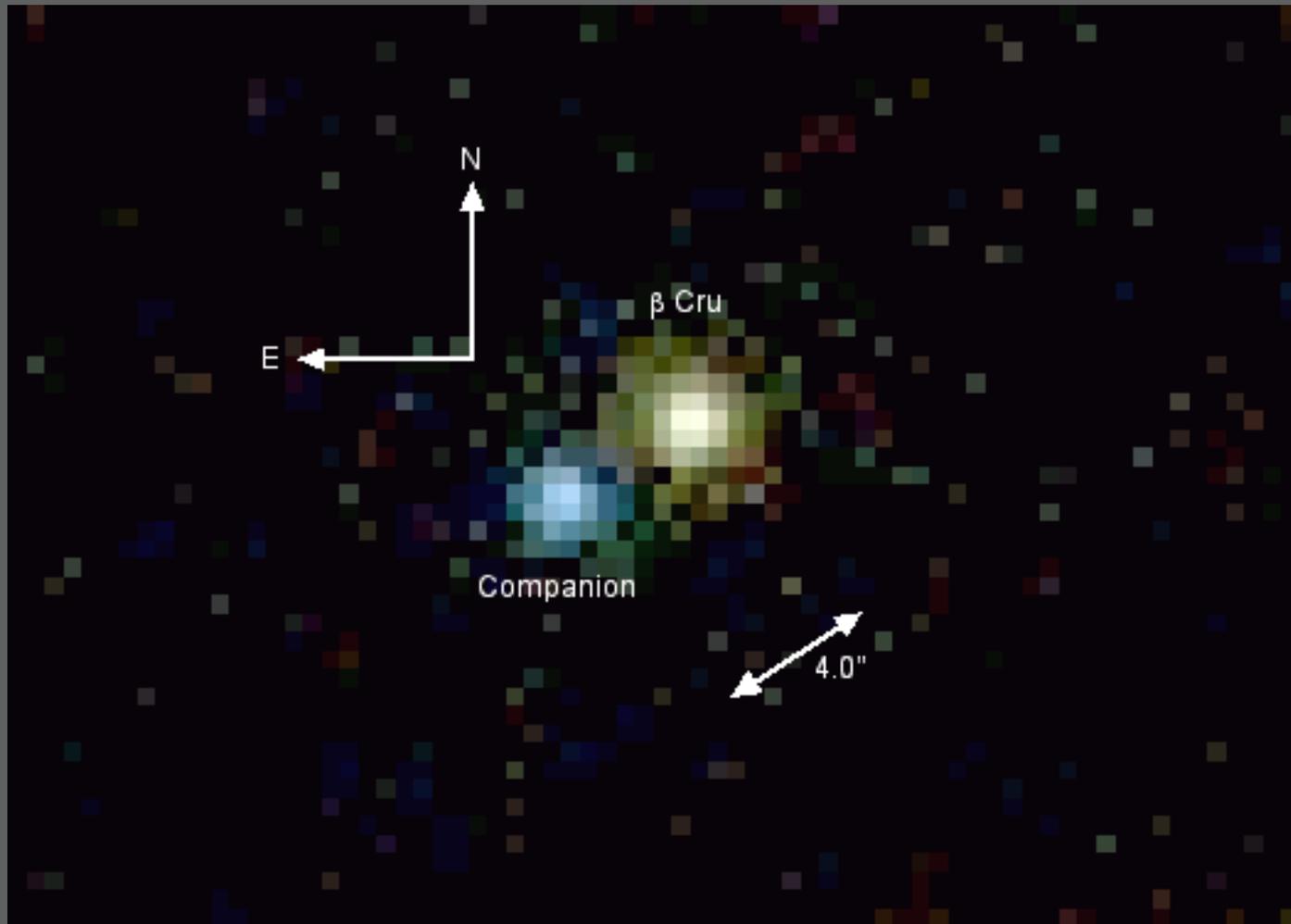


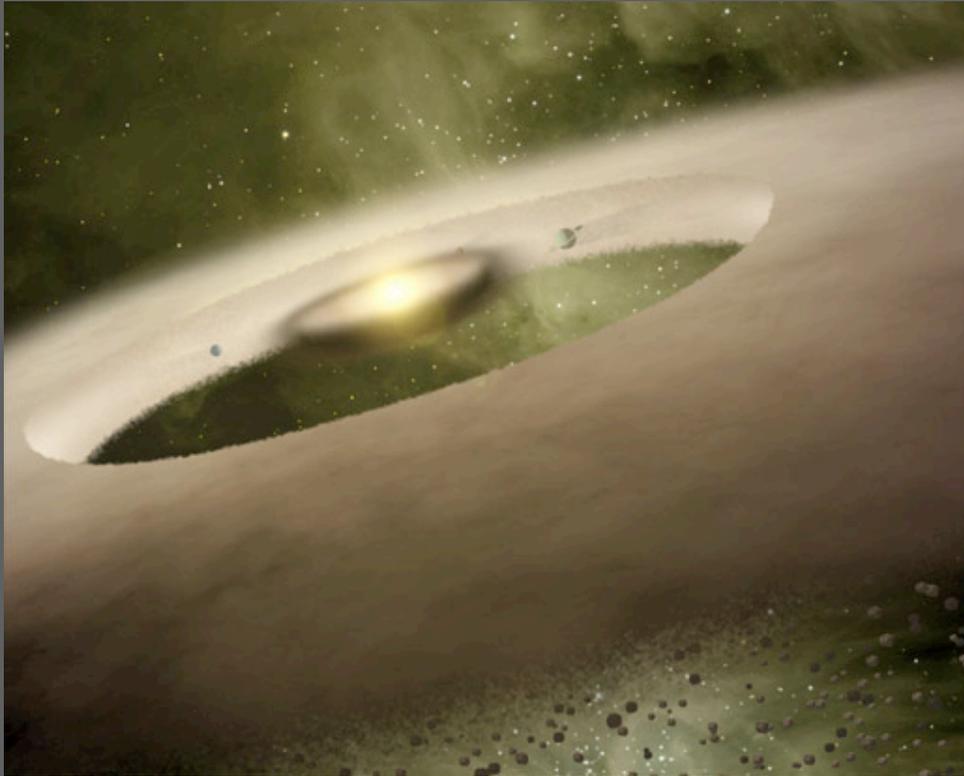
Red is used for $E < 0.5$ keV, green is used for $0.5 \text{ keV} < E < 1.0$ keV, and blue is used for $E > 1.0$ keV. [Mike Kuhn, '07]



Mike Kuhn ('07) presenting our results at the American Astronomical Society meeting

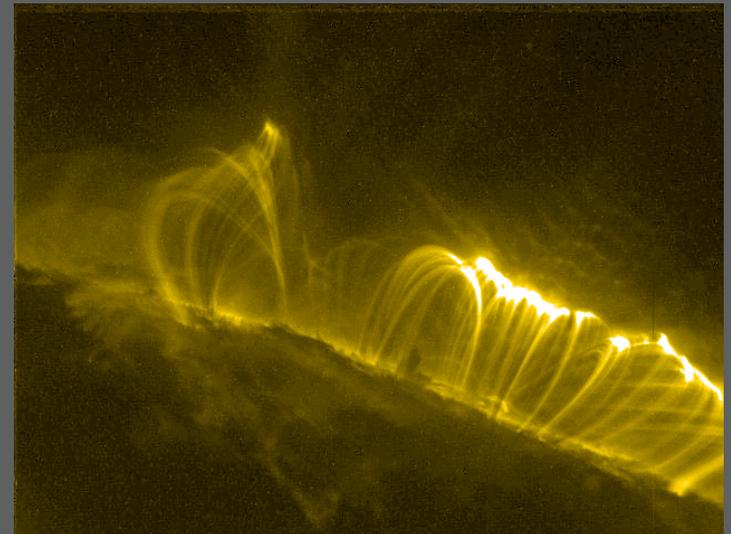
The X-ray “colors” (energies) indicate that the companion is a low-mass star ($\sim 1/20$ th the mass of beta Crucis)



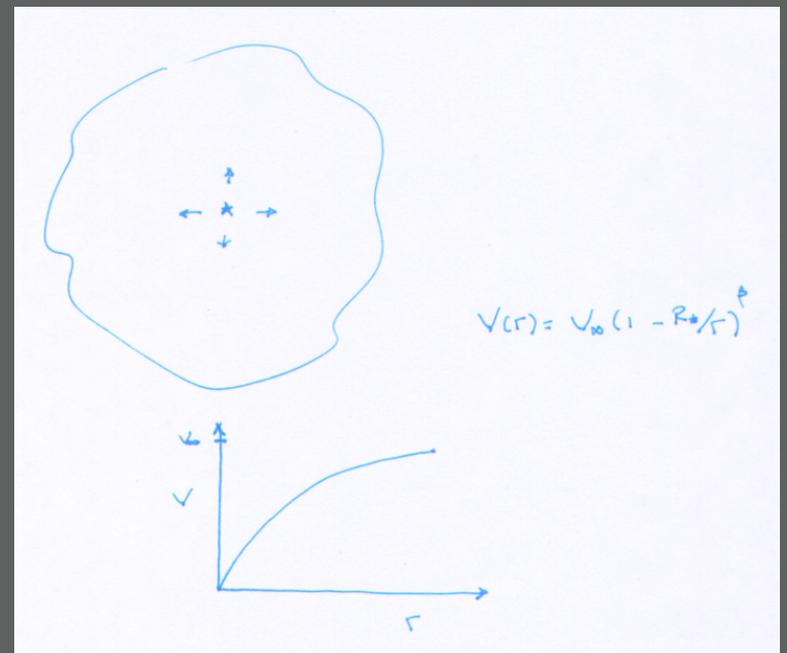


Artist's conception (NASA/JPL)

Young, low-mass stars
(left): X-rays from
magnetic activity, as on
the Sun (below)

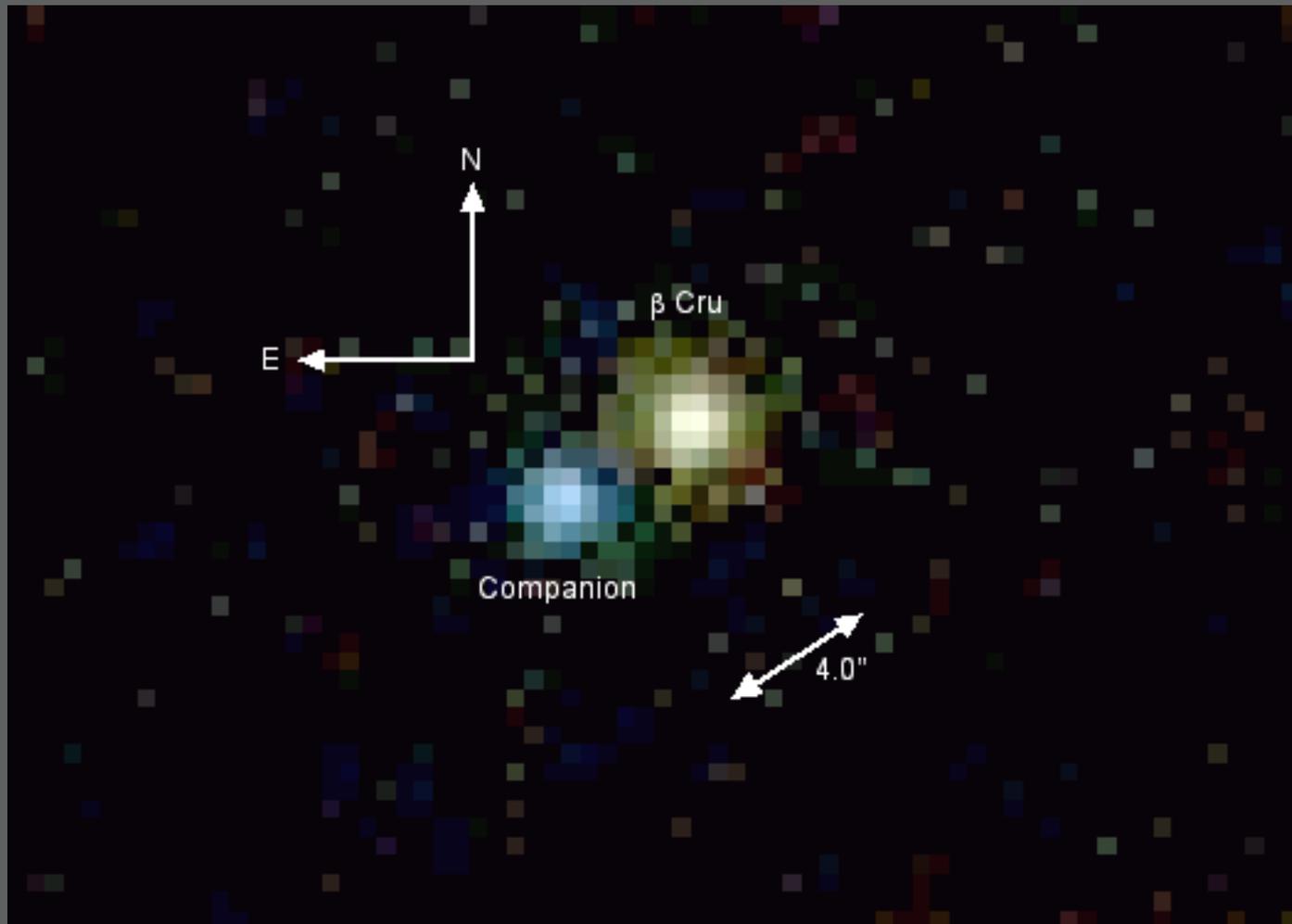


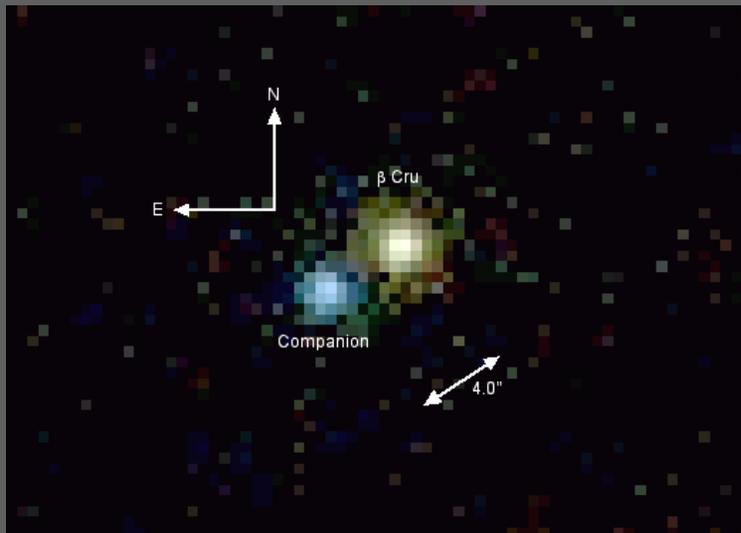
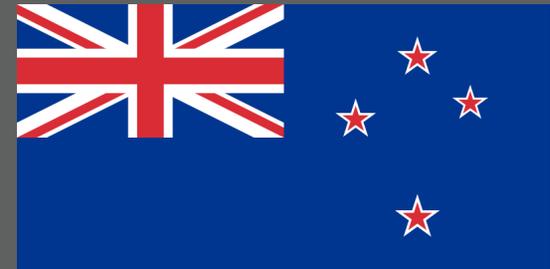
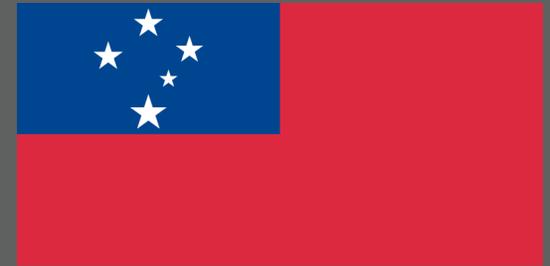
High mass stars (left):
X-rays from shock-
heating of the stellar
wind (below)

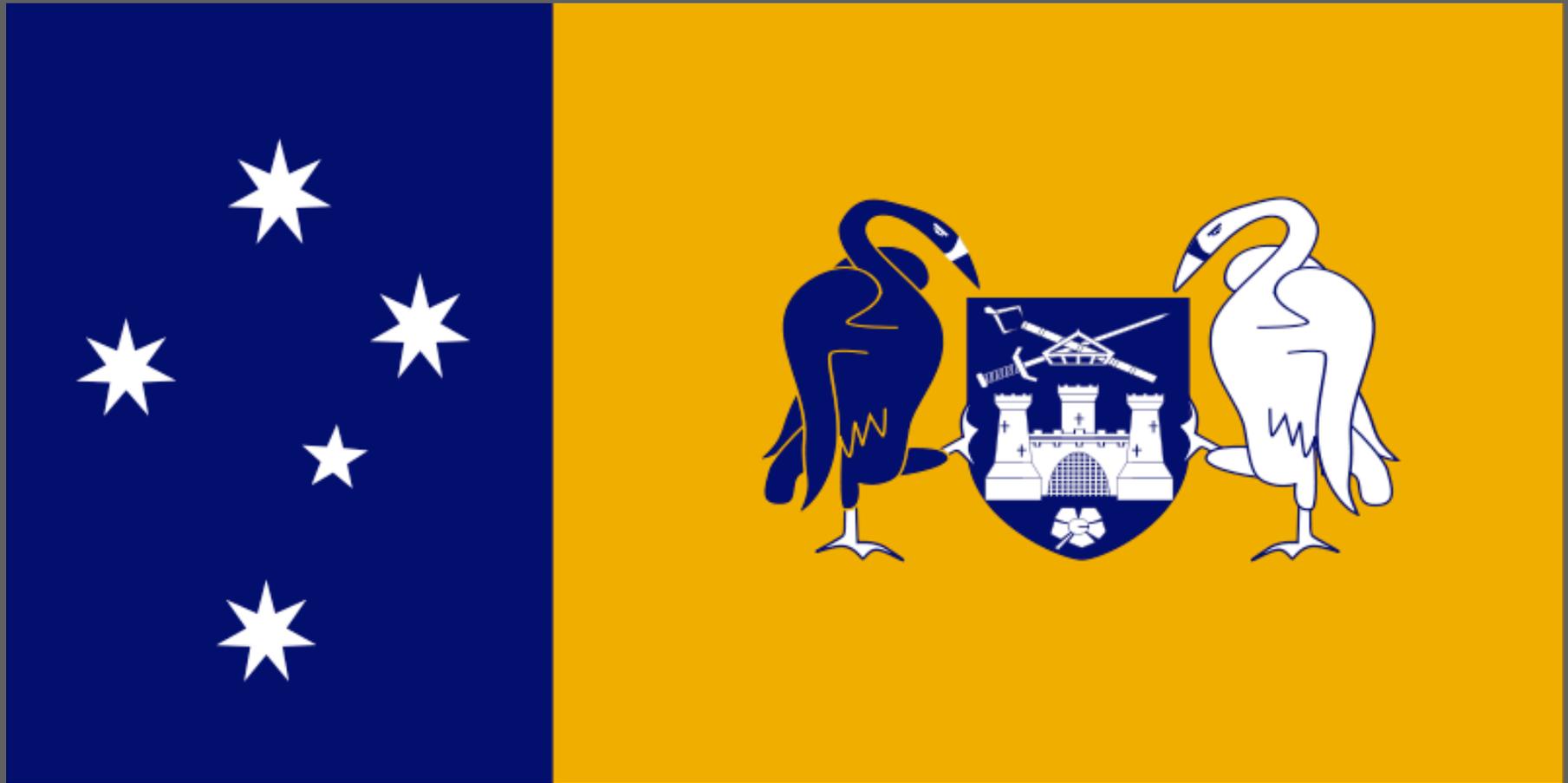


The binary system is ~10 million years old:

Massive stars like beta Cru: on their way to exploding as supernovae, **BUT** low-mass stars like the companion: still in the process of forming







Flag of the Australian Capital Territory

Astronomers May Have Found New Star in Southern Cross

By NICHOLAS BAKALAR

Astronomers may have found another star to add to the Southern Cross, one of the most familiar constellations in the southern sky. Beta Crucis, the bright star that forms one arm of the cross, apparently has a small companion undetectable by optical telescopes.

Like other binary stars, the two appear to be bound by gravity, orbiting around each other. The discovery was incidental to the aims of the team's research. While using NASA's Chandra X-ray Observatory to study the stellar winds of Beta Crucis, researchers found two sources of X-rays instead of the one that they expected.

Finding new companion stars is not an especially rare event in astronomy. Beta Crucis has another companion star that has been known for some time based on wobbles that it causes in the Beta Crucis orbit.

But this latest discovery is surprising, "because we think it's a star of the 11th magnitude, which should be fairly easily detectable," said Michael Kuhn, a senior at Swarthmore College and a co-author of a paper published last month in *The Monthly Notices of the Royal Astronomical Society*.

"It may be that Beta Crucis is so bright that it completely overwhelms the area," Mr. Kuhn said.

Beta Crucis, about 16 times the size of the

Sun and 350 light-years from Earth, is brighter than all but 18 stars in the night sky.

Scott Wolk, a staff scientist at the Chandra X-ray Observatory in Cambridge, Mass., who was not involved in the research, said the work "appears essentially incremental — most good work is — but finding a young sun hiding in such a well-known and easy-to-find spot always makes you feel a bit more accepted by the universe."

The new star is probably about the size of the Sun and relatively young, at 11 million years old. It is more than 37 billion miles from Beta Crucis, or 400 times the distance from the Earth to the Sun.

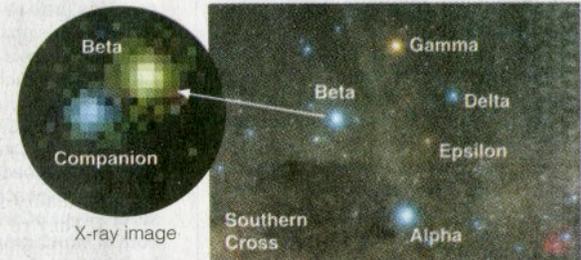
"This image is evidence that the new X-ray source is a star that is physically associated with the Beta Crucis system," Mr. Kuhn said. "But we still need follow-up observations to conclusively prove it."

Five countries — Australia, Brazil, New Zealand, Papua New Guinea and Samoa — display the Southern Cross on their flags.

Although Beta Crucis is a star near the end of its life, according to David Cohen, the lead author of the paper and an associate professor of astronomy at Swarthmore, no one need fear that the designs will become obsolete. Beta Crucis, Dr. Cohen said, will continue to outshine everything nearby for at least the next few million years.

New Companion

Scientists have discovered a companion to Beta Crucis, an arm of the Southern Cross constellation featured on the flags of several countries.



Brazil



Samoa



Papua New Guinea



Australia



New Zealand

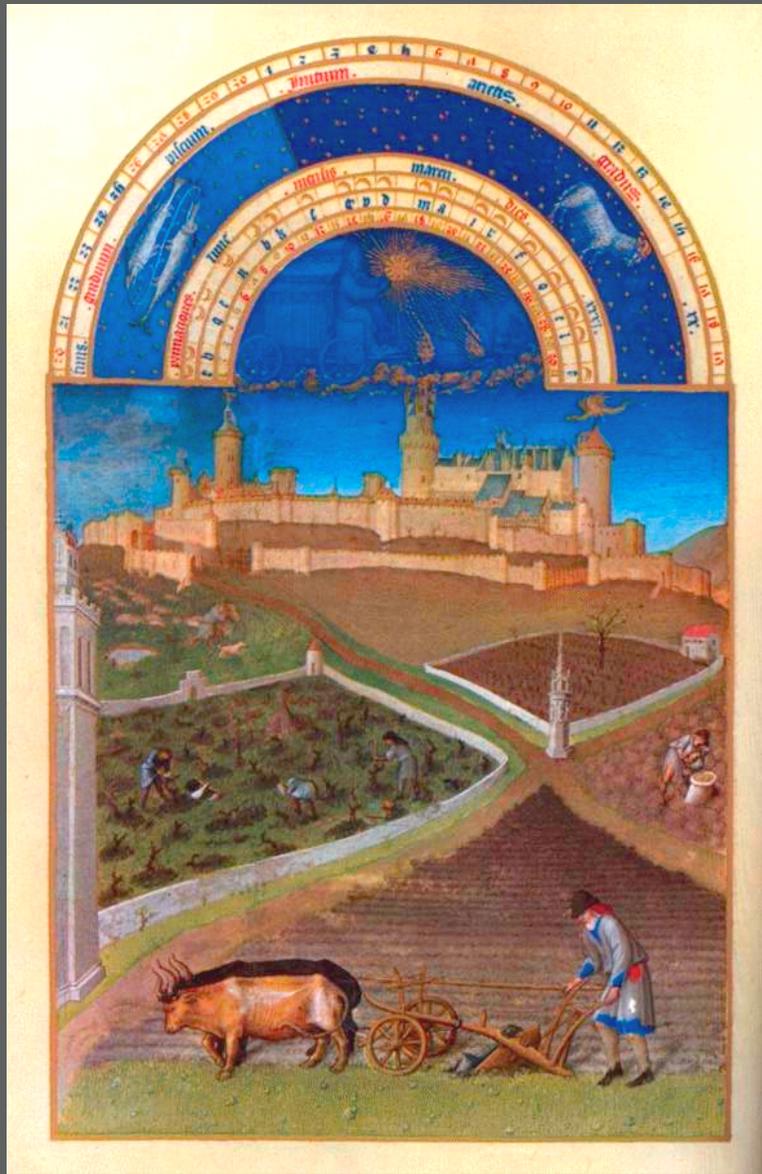
Source: David Cohen, Swarthmore College

The New York Times; X-ray image courtesy Swarthmore College; constellation photo by Photo Researchers

THE NEW YORK TIMES, TUESDAY, FEBRUARY 27, 2007







Limbourg brothers, early 15th Cen.



de Brunhoff



Rousseau



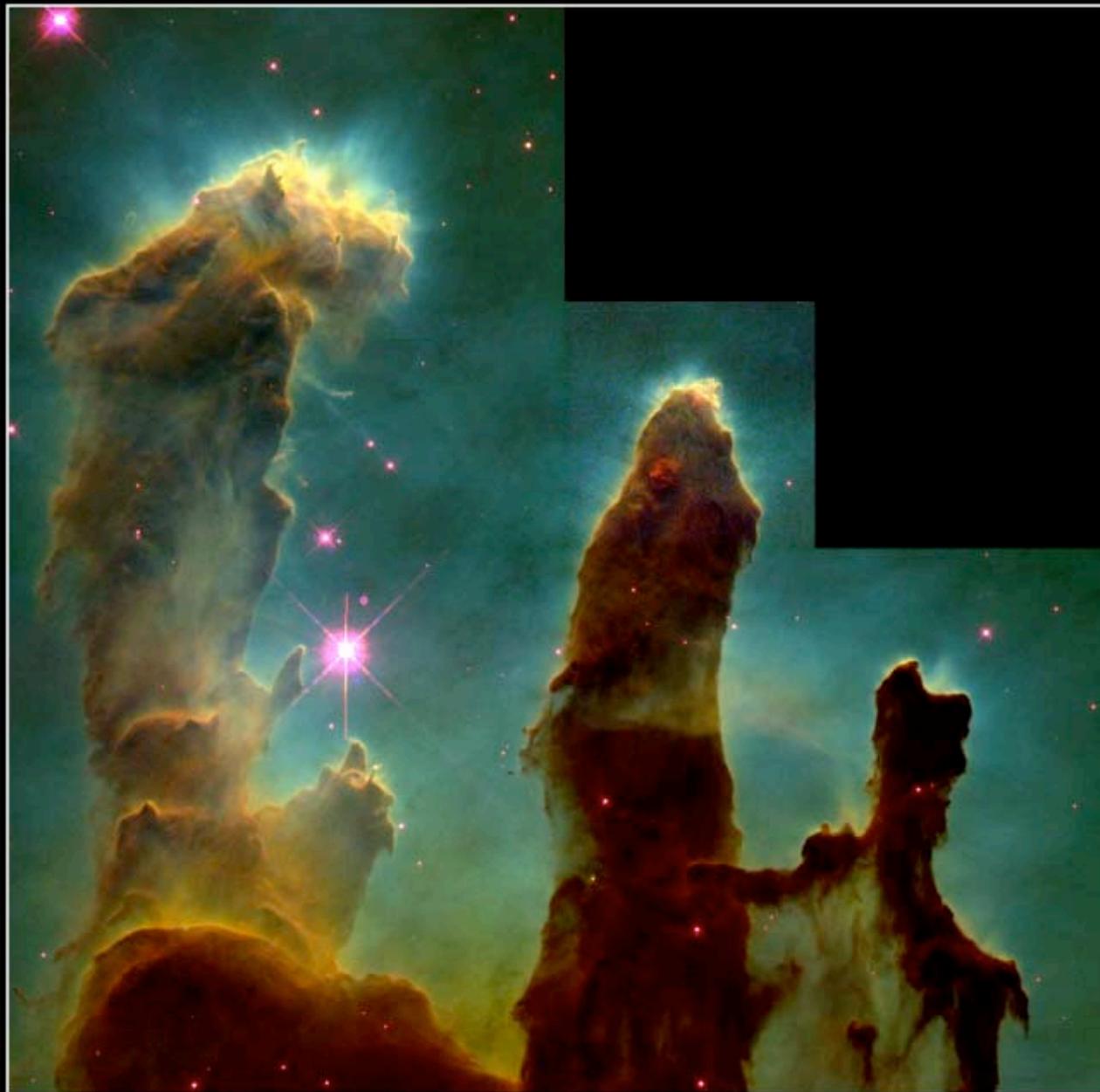


Wide-Field IR-View of Eagle Nebula (Messier 16)
(VLT ANTU + ISAAC)

ESO PR Photo 37a/01 (20 December 2001)

© European Southern Observatory





Gaseous Pillars · M16

HST · WFPC2

PRC95-44a · ST Sci OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA



Star-Birth Clouds • M16

HST • WFPC2

PRC95-44b • ST ScI OPO • November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

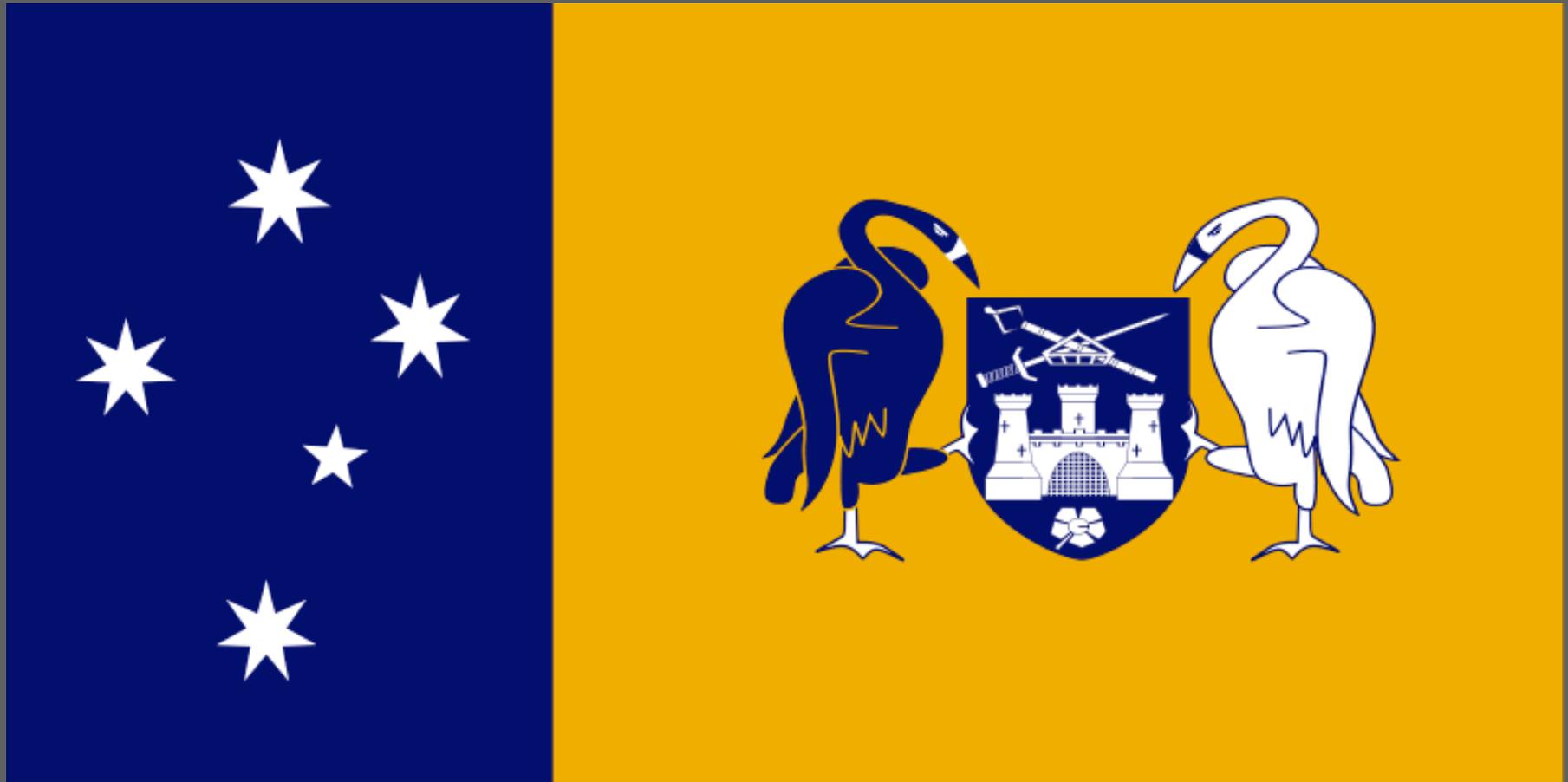
The Pleiades (the 'seven sisters')



The Pleiades (the 'seven sisters')



SUBARU.



Flag of the Australian Capital Territory

COCKTAIL MENU



Soju Cocktails *Soju*: alcohol made from barley 6.75

Jasmine Blossom (lychee and jasmine tea)

It's Pearrrr-tea (asian pear and tea)

I know Kung Fu (ginger infused soju, ginger, and fresh lemons)

Thai Iced Tea-ni (Thai iced tea and cream)

Guava Madras (guava and pineapple)

Coco-colada (coconut and pineapple)

Lychee Martini (lychee) 7.75

Sparkling Wine Cocktails 5.75

B Star Mimosa (fresh squeezed orange juice)

Guavallini (guava nectar)

Lychee Me (lychee)

