

New Horizons  
*examines*  
the Universe !

**ALICE** in the

Richard Conn Henry

Director,

NASA's **Maryland Space Grant Consortium**

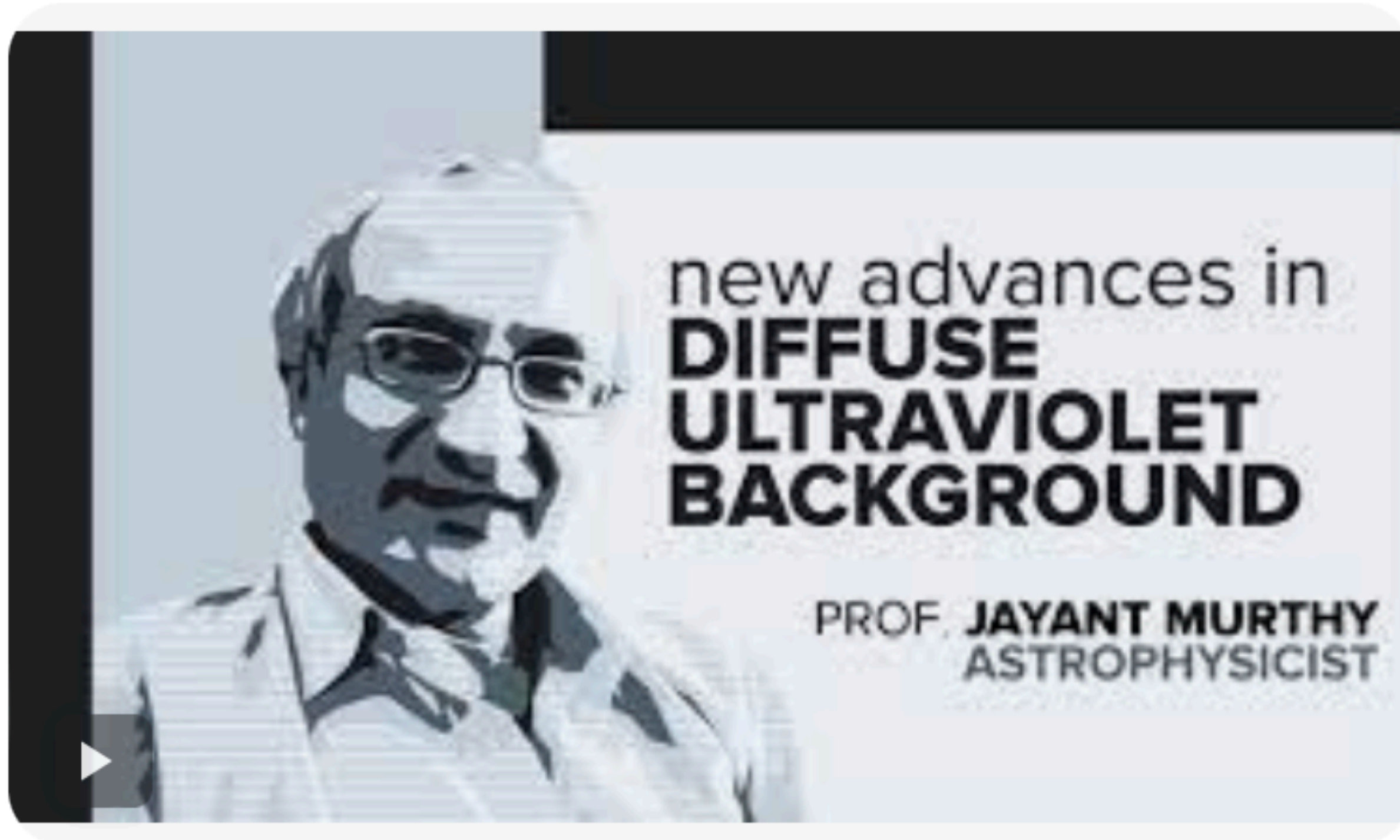
The Johns Hopkins University

Diffuse Ultraviolet  
Background

**THANKS**

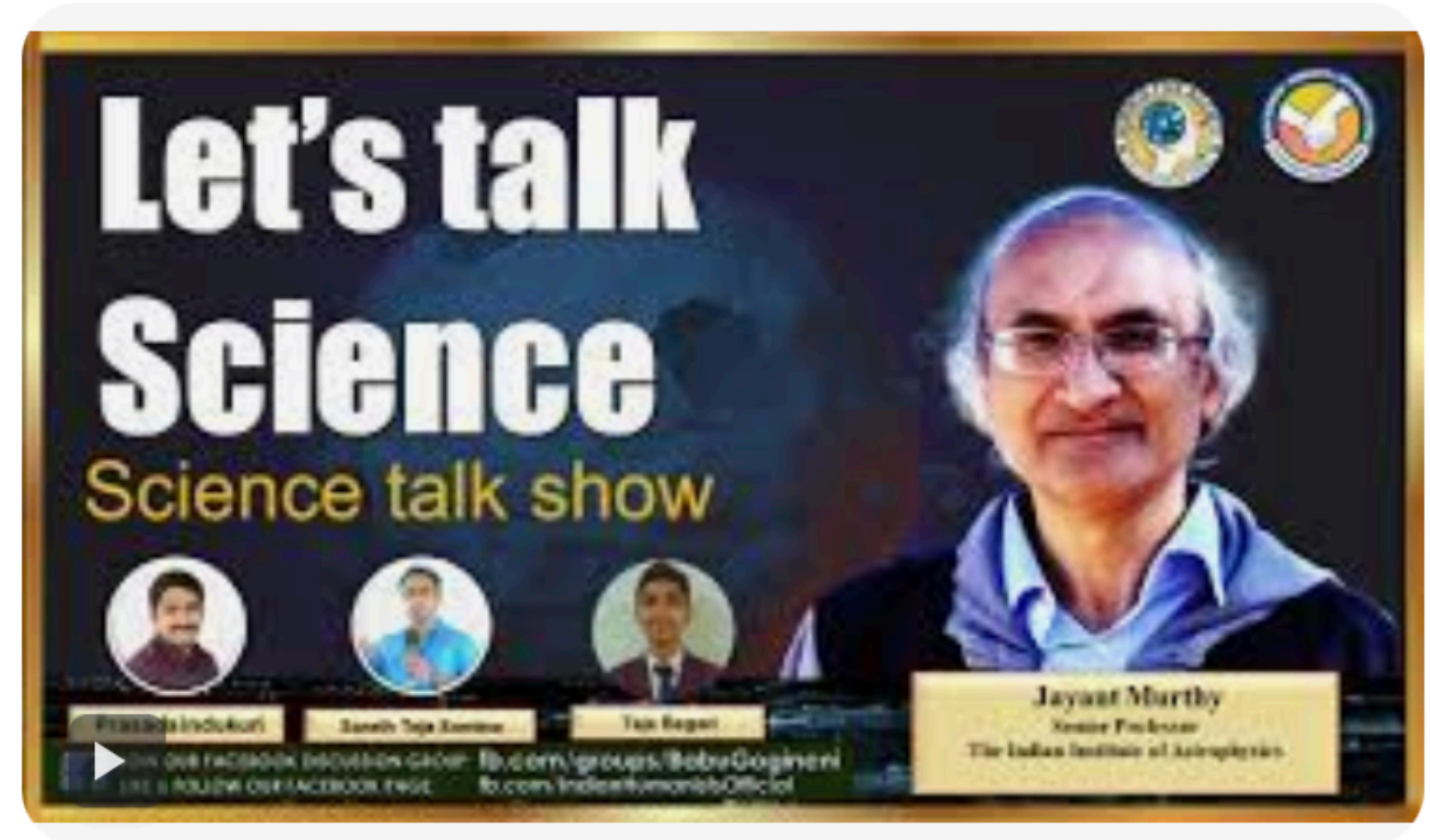
from Dick Henry to the  
whole **New Horizons Team**;  
above all, to my colleague

# Professor Jayant Murthy



 YouTube

Prof. Jayant Murthy | New Advances in ...



 Facebook

Jayant Murthy ...

One-time Director, Indian Institute of Astrophysics, Bengaluru

# Dick Henry's first paper on the Diffuse Ultraviolet Background: 1973 !

**HALF a CENTURY of unremitting toil...**

**ULTRAVIOLET BACKGROUND RADIATION**

**RICHARD C. HENRY\***

**And  
Today ?**

The E. O. Hulburt Center for Space Research, Naval Research Laboratory,  
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*Received 1970 October 30; revised 1972 July 28*

## ABSTRACT

The high-galactic-latitude ultraviolet background flux has been measured and is  $1900(+0, -950)$  photons  $(\text{cm}^2 \text{ s sterad } \text{Å})^{-1}$ , at  $1450 \text{ Å}$ , as seen with a  $10^\circ$  field-of-view detector. This is in good agreement with a value obtained by Lillie with the Wisconsin experiment on OAO-2, which had a much smaller field of view.

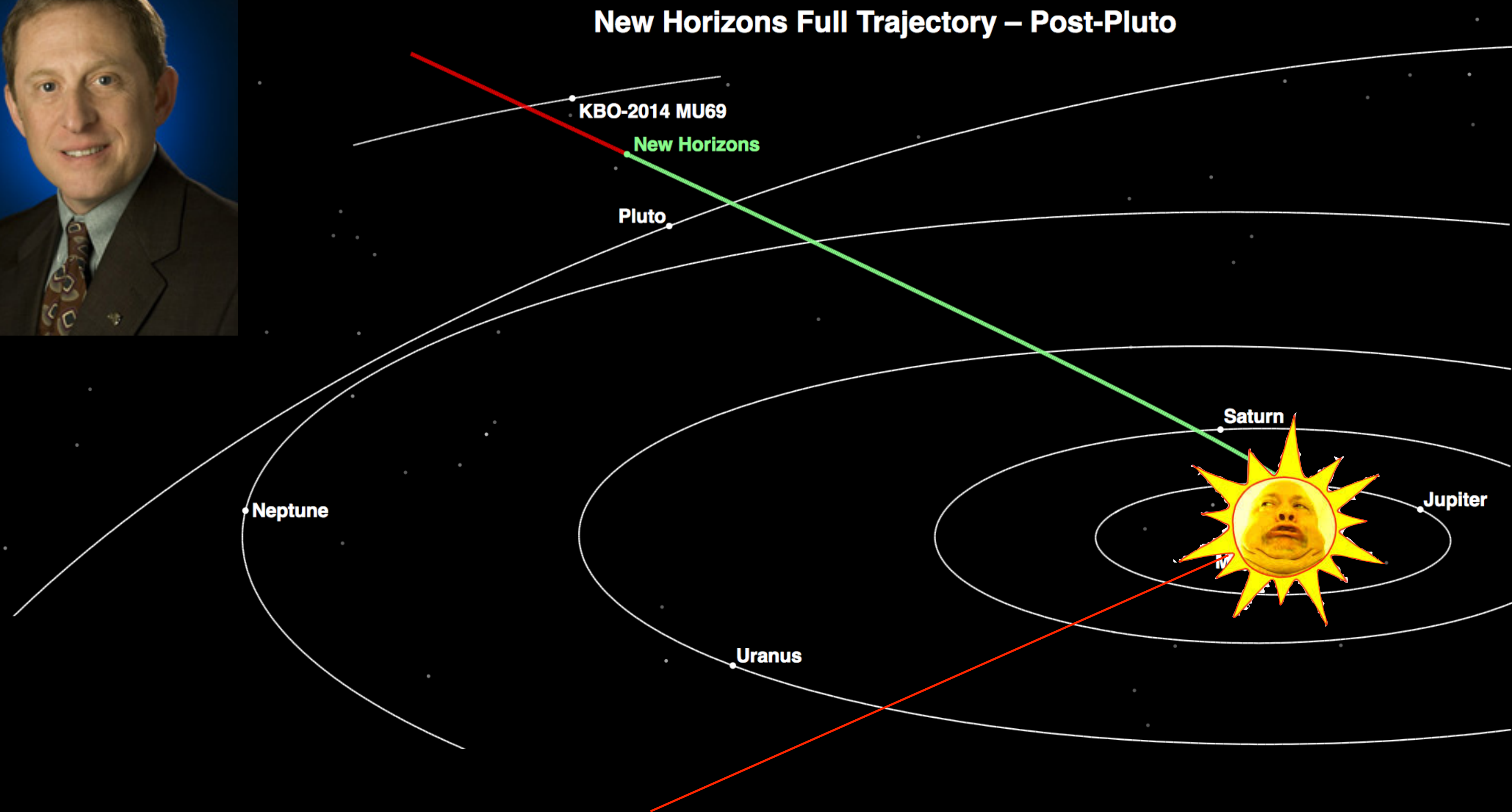
*Subject headings:* cosmology — galaxies, clusters of — ultraviolet

## I. INTRODUCTION

Ultraviolet radiation observed at high galactic latitudes can be caused by direct emission from stars, scattering of the ultraviolet radiation of stars by dust, or by emission from diffuse or discrete extragalactic sources. We report here the results of observations in narrow bands centered on  $1115$ ,  $1425$ , and  $1446 \text{ Å}$  of the flux from an empty high-galactic-latitude region and from several stars. We also set an upper limit to the flux from the Coma cluster of galaxies.

Alan Stern

Alice ultraviolet spectrometer: 9 Å resolution!



Horrible source of bright hydrogen *Lyman- $\alpha$*  which scatters to all wavelengths

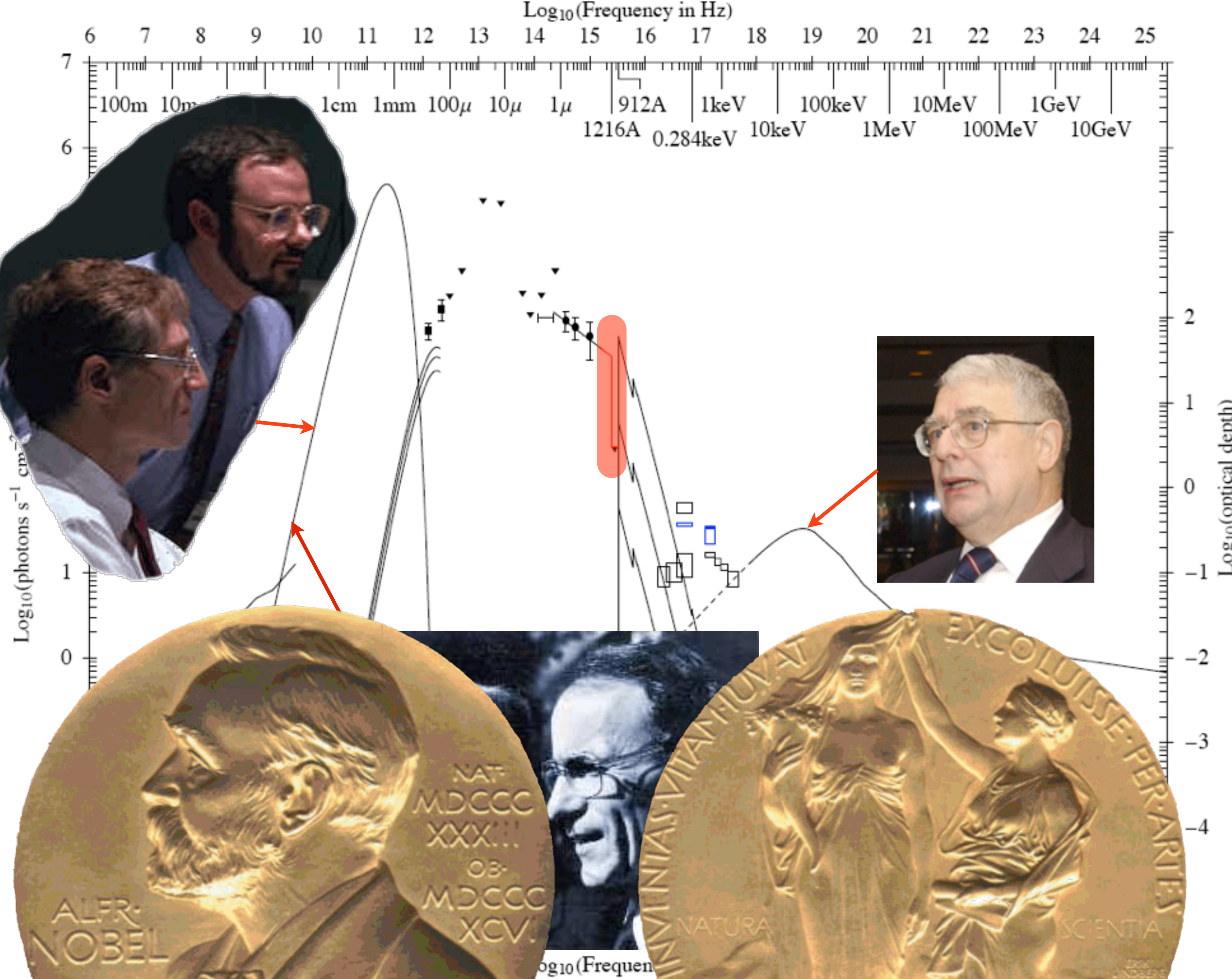
New Horizons' **Alice** (now **57** Astronomical Units from the Sun)

is the **best-ever COSMIC UV-BACKGROUND** instrument :

- 1) It is far from the Sun: with its **nasty Lyman  $\alpha$**  (and  **$\beta$** , etc.)
- 2) **First** instrument to observe continuum **shortward** of Lyman  **$\alpha$**
- 3) Far-better spectral **resolution** ( **9 Å** ) than **ever before!**

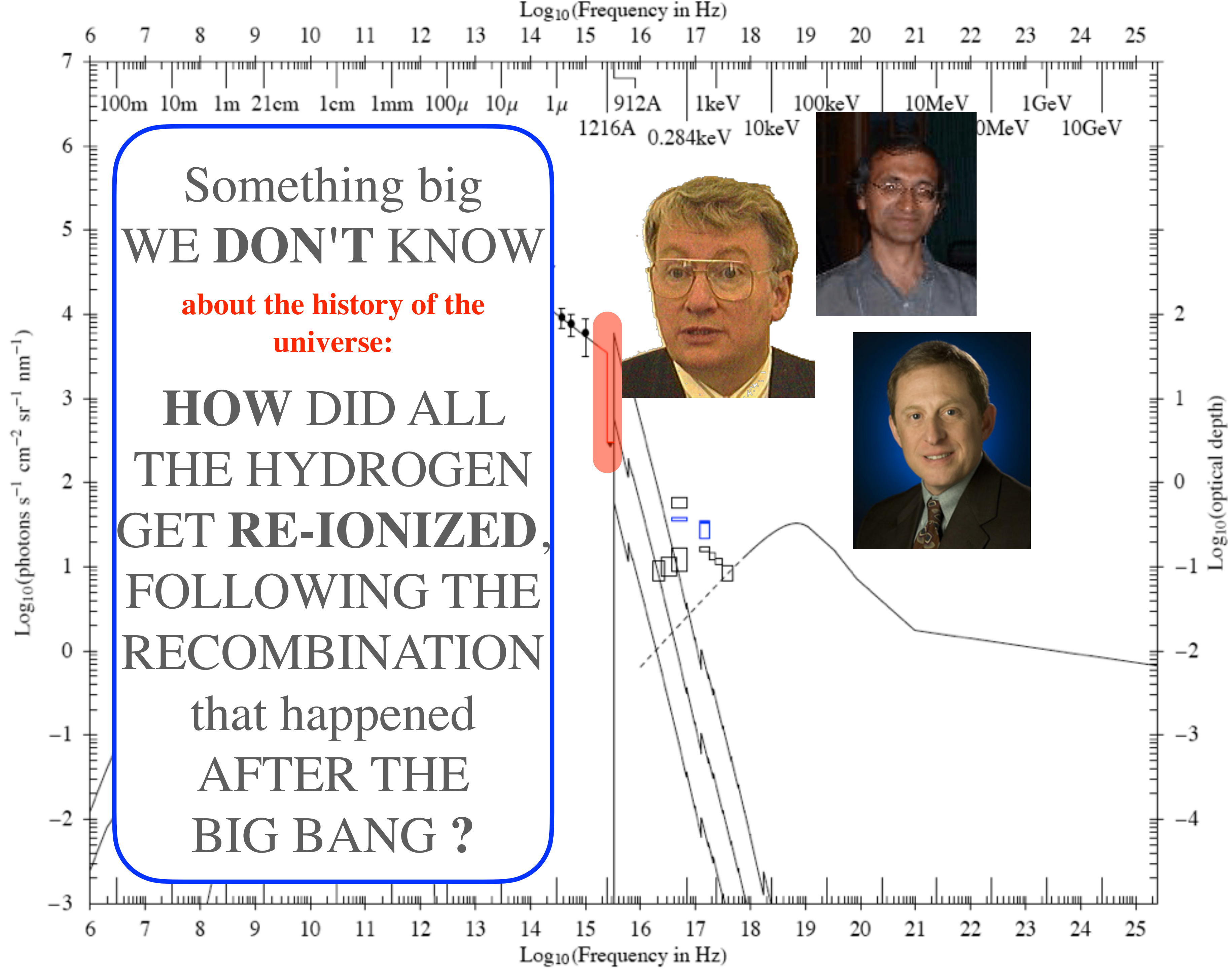
**In short, Alice rocks !**

RADIO



GAMMA RAYS





Something big  
**WE DON'T KNOW**

about the history of the  
 universe:

**HOW DID ALL  
 THE HYDROGEN  
 GET RE-IONIZED,  
 FOLLOWING THE  
 RECOMBINATION  
 that happened  
 AFTER THE  
 BIG BANG ?**

Log<sub>10</sub>(Frequency in Hz)  
 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25  
 100m 10m 1m 21cm 1cm 1mm 100μ 10μ 1μ 912A 1keV 100keV 10MeV 1GeV  
 1216A 0.284keV 10keV 10MeV 10GeV

Log<sub>10</sub>(photons s<sup>-1</sup> cm<sup>-2</sup> sr<sup>-1</sup> nm<sup>-1</sup>)

Log<sub>10</sub>(optical depth)

Log<sub>10</sub>(Frequency in Hz)

The Universe **Recombined** at age **379,000** years

**BUT** today, **>98%** of the Hydrogen in the Universe is **IONIZED !**

THE ASTROPHYSICAL JOURNAL LETTERS, 789:L32 (5pp), 2014 July 10

**2014**

doi:[10.1088/2041-8205/789/2/L32](https://doi.org/10.1088/2041-8205/789/2/L32)

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**IONIZING**  
THE PHOTON **UNDERPRODUCTION** CRISIS  
^

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ROMEEL DAVÉ<sup>6,7,8</sup>, MARK FARDAL<sup>5</sup>, PIERO MADAU<sup>9</sup>, CHARLES DANFORTH<sup>3</sup>, AMANDA B. FORD<sup>10</sup>,  
MOLLY S. PEEPLES<sup>11</sup>, AND JOSEPH MCEWEN<sup>2</sup>












**"CRISIS"** : Stars *can't do it !*

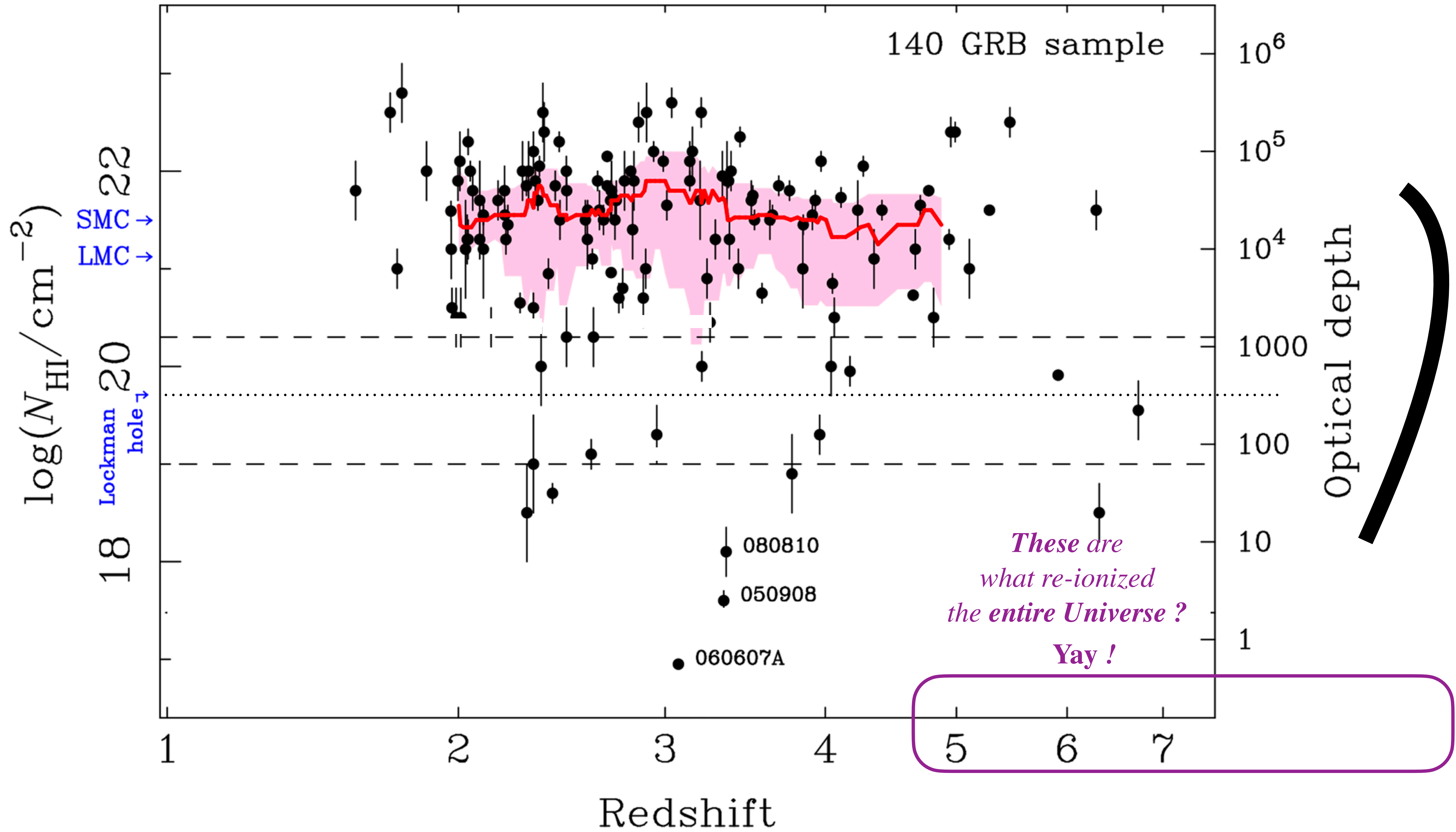
**"CRISIS"** : Supernovae *can't do it !*

**Let me show you just how desperate the situation is today !**



# The fraction of ionizing radiation from massive stars that escapes to the intergalactic medium

N. R. Tanvir , <sup>1</sup>★ J. P. U. Fynbo , <sup>2</sup> A. de Ugarte Postigo, <sup>3</sup> J. Japelj, <sup>4</sup> K. Wiersema, <sup>5,1</sup>  
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B. Milvang-Jensen, <sup>2</sup> E. Berger, <sup>9</sup> Z. Cano , <sup>3</sup> R. Chornock, <sup>10</sup> S. Covino , <sup>11</sup>  
A. Cucchiara, <sup>12</sup> V. D’Elia, <sup>13,14</sup> A. Gargiulo, <sup>15</sup> P. Goldoni, <sup>16</sup> A. Gomboc, <sup>17</sup>  
K. E. Heintz, <sup>2,18</sup> J. Hjorth, <sup>2</sup> L. Izzo , <sup>3</sup> P. Jakobsson, <sup>18</sup> L. Kaper, <sup>4</sup> T. Krühler , <sup>19</sup>  
T. Laskar, <sup>20</sup> M. Myers, <sup>21</sup> S. Piranomonte, <sup>13</sup> G. Pugliese, <sup>4</sup> A. Rossi, <sup>22</sup>  
R. Sánchez-Ramírez , <sup>3</sup> S. Schulze, <sup>23</sup> M. Sparre , <sup>2,24</sup> E. R. Stanway , <sup>5</sup>  
G. Tagliaferri, <sup>11</sup> C. C. Thöne, <sup>3</sup> S. Vergani, <sup>25</sup> P. M. Vreeswijk, <sup>26</sup> R. A. M. J. Wijers , <sup>4</sup>  
D. Watson <sup>2</sup> and D. Xu <sup>27</sup>

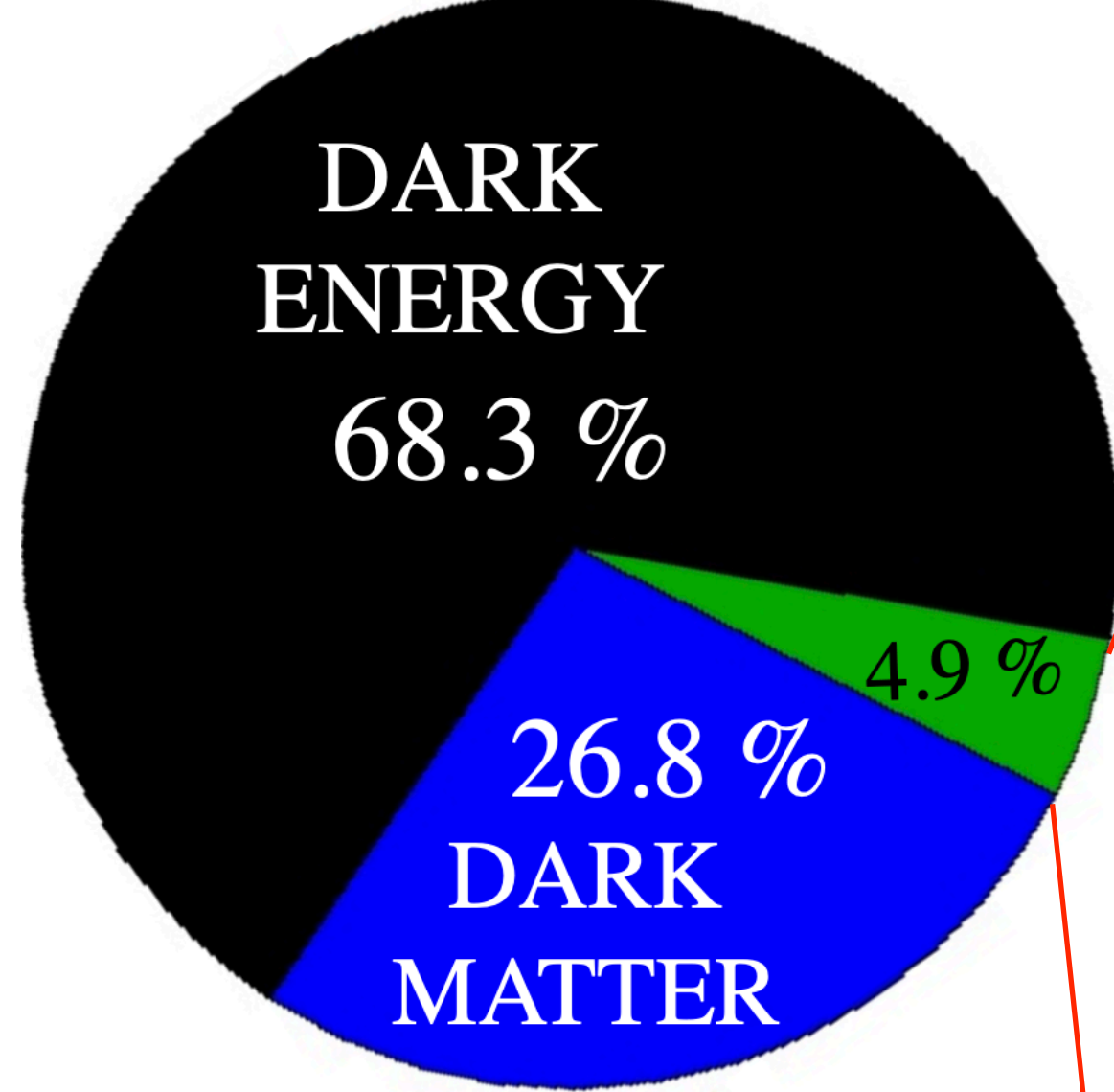


Dick Henry has *LONG SUSPECTED* that  
**Dark Matter Decay Radiation**  
(which I predict to extend **just a BIT short of** the  
**Hydrogen Ionization Edge**)  
is **what must surely** have re-ionized the Universe.

Why do I believe that ?

Simply because there is **NOTHING ELSE**  
that *I* can think of that **could** have done it.

Let's take a look at the composition of the universe !



4.9 % Ordinary Matter →

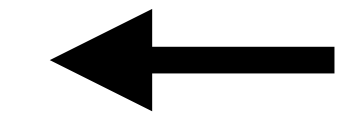
**Alice**  
**may detect**  
**Dark Matter**  
**decay radiation**

Standard Model Lagrangian Density

google → Cottingham & Greenwood; Shiflett 2015

$$\mathcal{L} = -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{8}\text{tr}(\mathbf{W}_{\mu\nu}\mathbf{W}^{\mu\nu}) - \frac{1}{2}\text{tr}(\mathbf{G}_{\mu\nu}\mathbf{G}^{\mu\nu})$$

E&M	Weak	Strong
U(1)	SU(2)	SU(3)
Photons	Z <sup>0</sup> &W <sup>±</sup>	Gluons



SU3 X SU2 X U1

$$+(\bar{\nu}_L, \bar{e}_L)\bar{\sigma}^\mu iD_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} + \bar{e}_R \sigma^\mu iD_\mu e_R + \bar{\nu}_R \sigma^\mu iD_\mu \nu_R + (\text{h.c.})$$

← Leptons dynamical terms.

LEPTON mass terms:

← Electron, Muon, Tauon

← Neutrino

$$-\frac{\sqrt{2}}{v} \left[ (\bar{\nu}_L, \bar{e}_L) \phi M^e e_R + \bar{e}_R M^e \bar{\phi} \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \right]$$

$$-\frac{\sqrt{2}}{v} \left[ (-\bar{e}_L, \bar{\nu}_L) \phi^* M^{\nu} \nu_R + \bar{\nu}_R \bar{M}^{\nu} \phi^T \begin{pmatrix} -e_L \\ \nu_L \end{pmatrix} \right]$$

$$+(\bar{D}_\mu \phi) D^\mu \phi - m_h^2 [\bar{\phi} \phi - v^2/2]^2 / 2v^2 \quad m_h \cong 125.09 \text{ GeV}$$

← Higgs dynamical and mass terms  
 (inside e.g. electrons, giving them mass)



$$D_\mu \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \equiv \left[ \partial_\mu - \frac{ig_1}{2} B_\mu + \frac{ig_2}{2} \mathbf{W}_\mu \right] \begin{pmatrix} \nu_L \\ e_L \end{pmatrix}$$

$$D_\mu e_R \equiv [\partial_\mu - ig_1 B_\mu] e_R$$

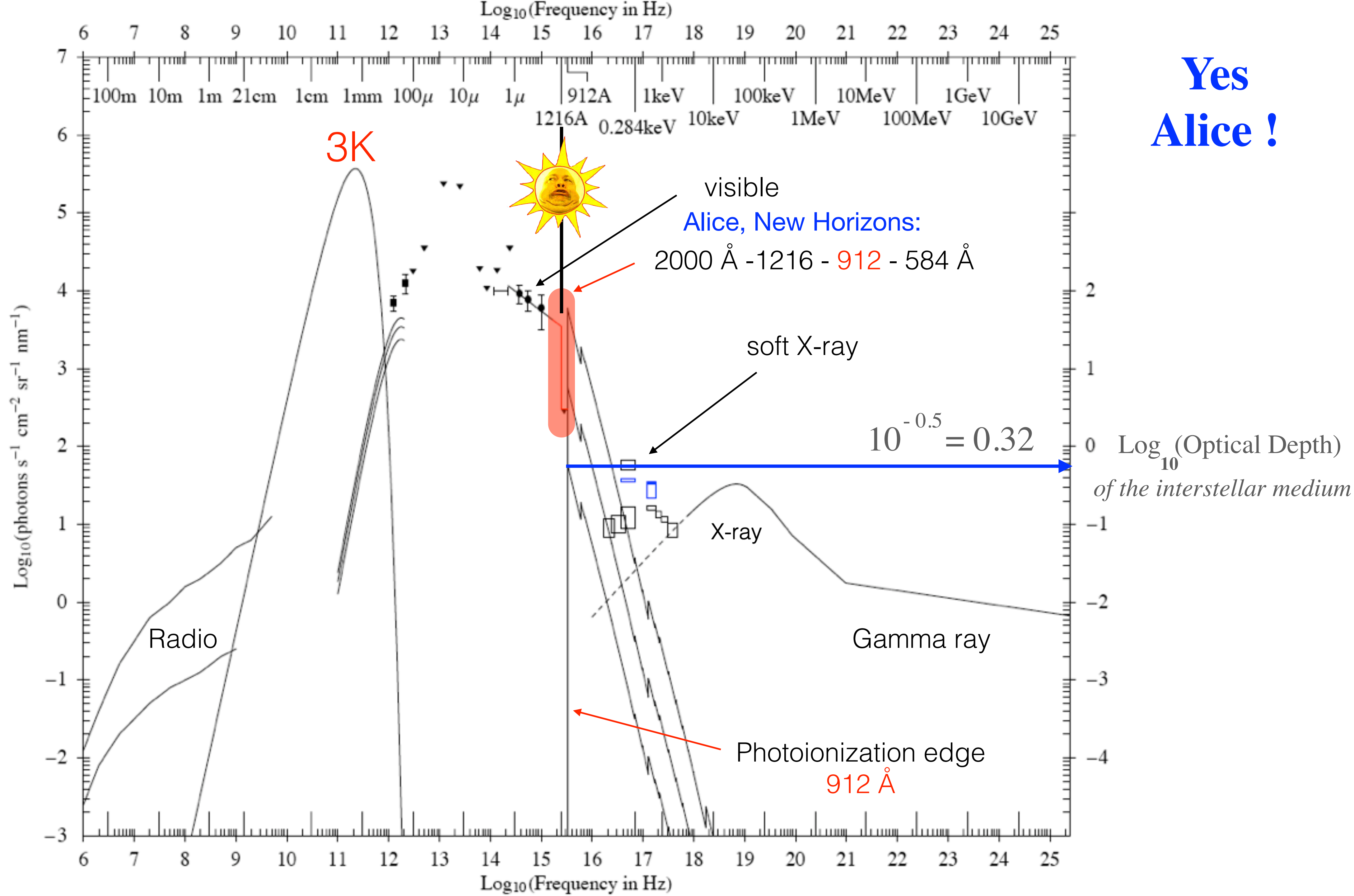
$$D_\mu \nu_R \equiv \partial_\mu \nu_R$$

$$D_\mu \phi \equiv \left[ \partial_\mu + \frac{ig_1}{2} B_\mu + \frac{ig_2}{2} \mathbf{W}_\mu \right] \phi \quad \leftarrow \text{Higgs dynamical} \quad \uparrow \text{Leptons dynamical} \quad \downarrow \text{Quarks dynamical}$$

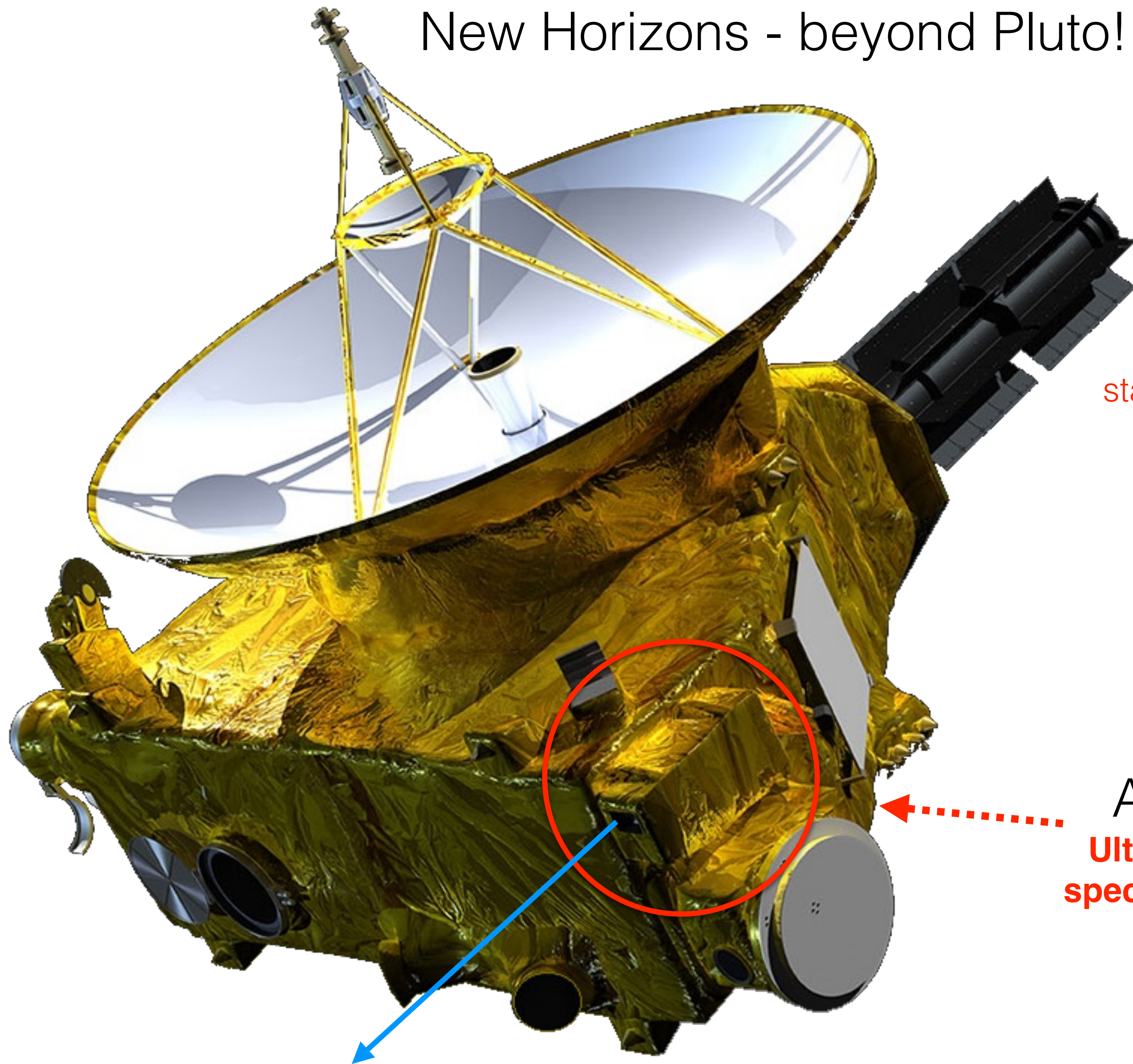
$$D_\mu \begin{pmatrix} u_L \\ d_L \end{pmatrix} \equiv \left[ \partial_\mu + \frac{ig_1}{6} B_\mu + \frac{ig_2}{2} \mathbf{W}_\mu + ig \mathbf{G}_\mu \right] \begin{pmatrix} u_L \\ d_L \end{pmatrix}$$

$$D_\mu u_R \equiv \left[ \partial_\mu + \frac{i2g_1}{3} B_\mu + ig \mathbf{G}_\mu \right] u_R$$

$$D_\mu d_R \equiv \left[ \partial_\mu - \frac{ig_1}{3} + ig \mathbf{G}_\mu \right] d_R$$



# New Horizons - beyond Pluto! And Arrokoth!



RTG

introduces a statistically well-behaved particle background in

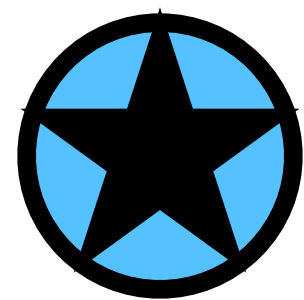
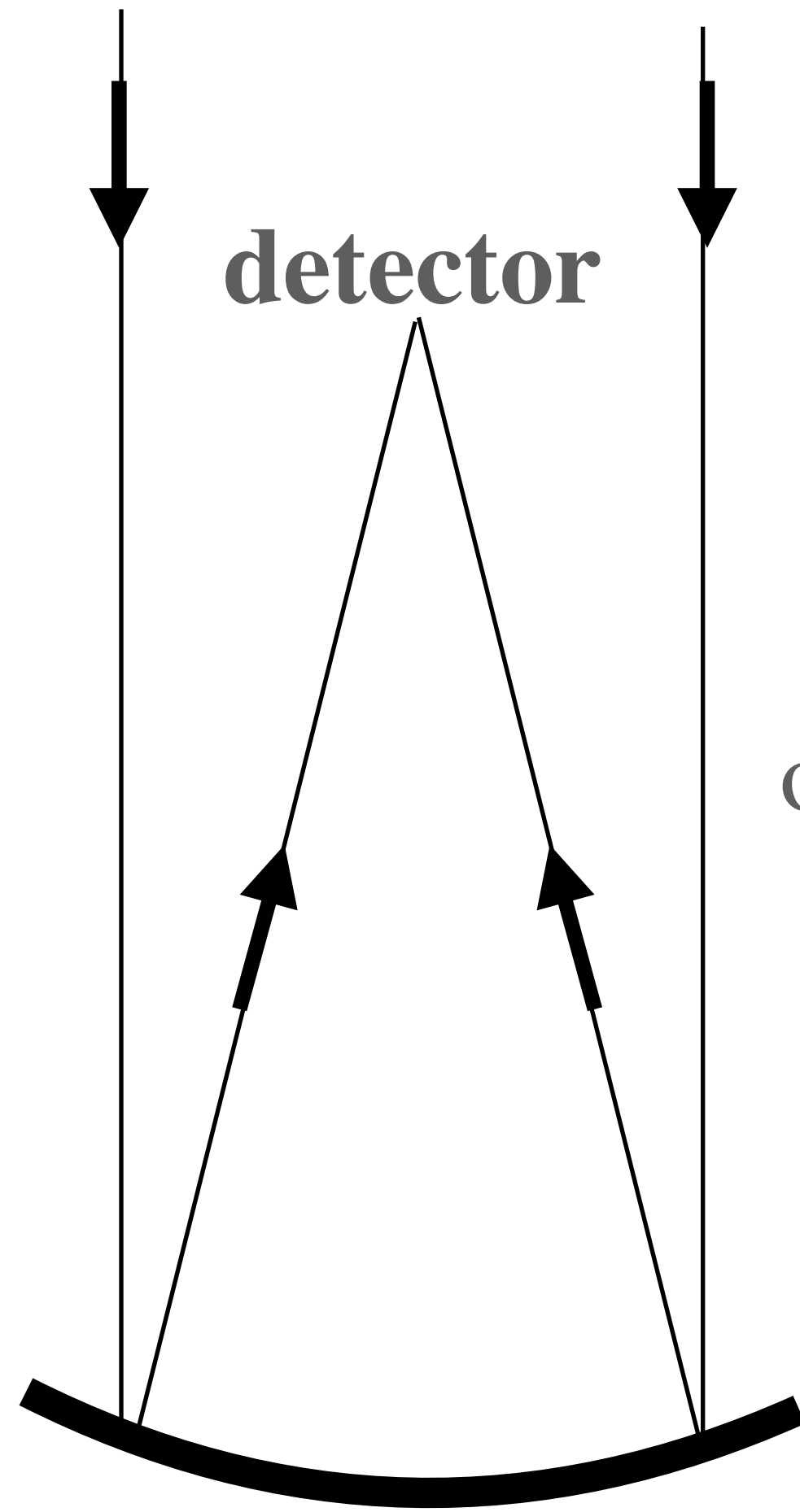
Alice

Ultraviolet spectrometer

4.4 kg !

Pretty puny ?

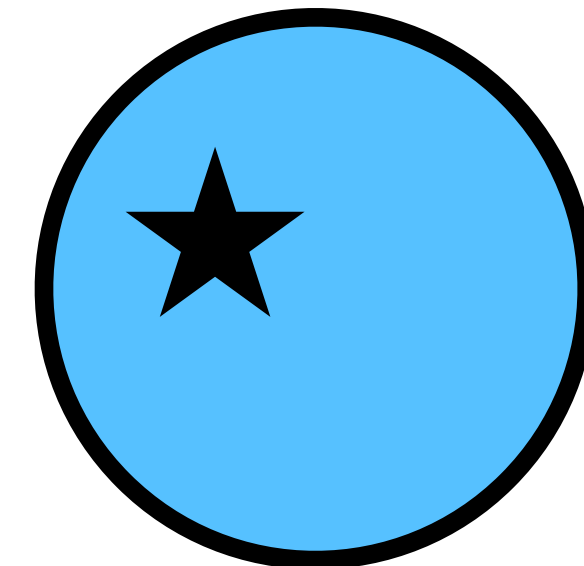
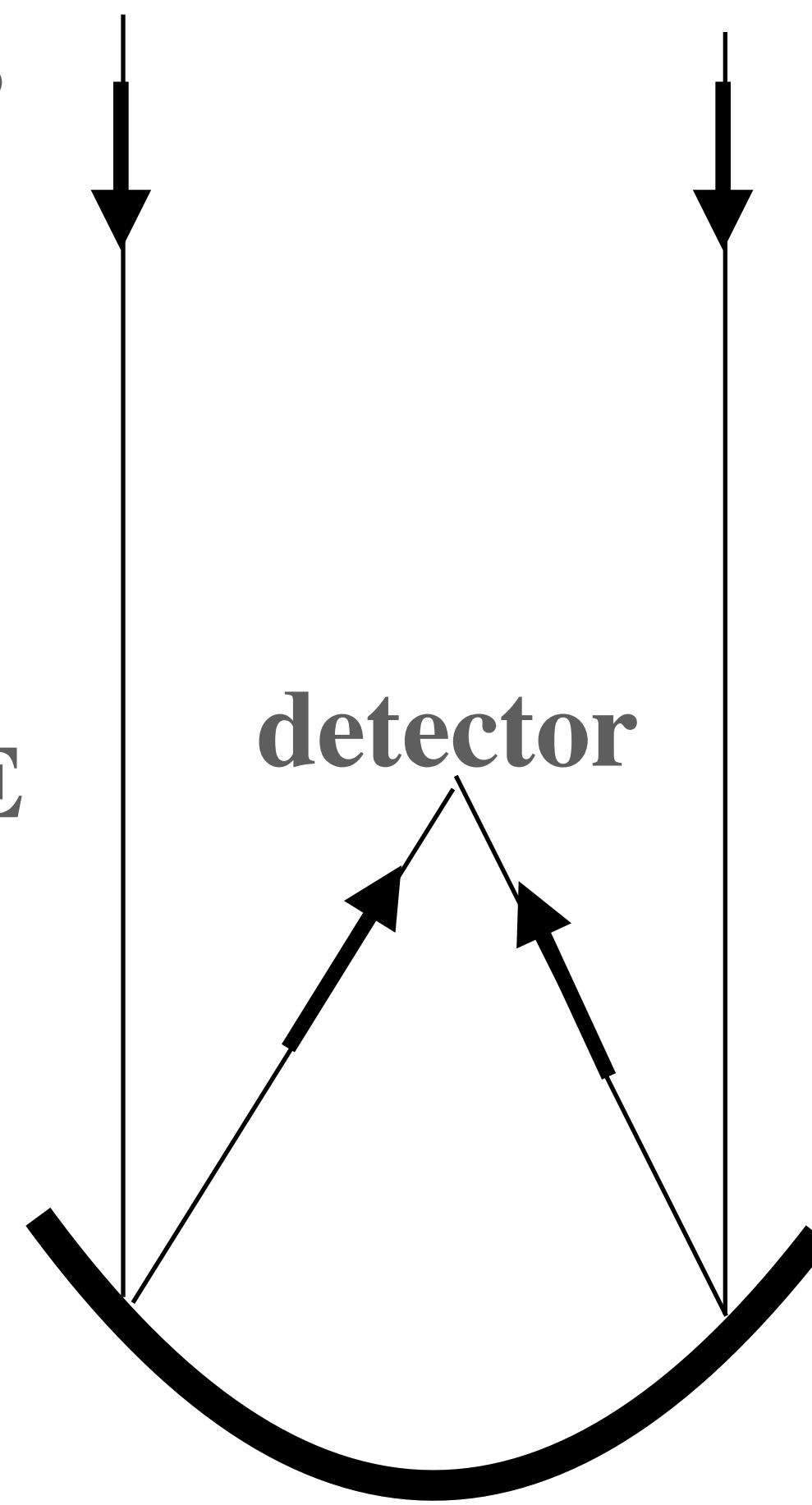
Hubble  
 $f/24$



TINY field  
of view

The effectiveness  
for diffuse  
background  
radiation  
**IS INDEPENDENT**  
of telescope APERTURE  
**!!!!!!!**  
and it goes  
inversely as the  
**SQUARE** of the  
focal ratio !

Also, in choosing  
targets, we **avoid**  
**UV-bright** stars



Alice  
on  
New  
Horizons  
 $f/3$  !  
Alice is  
A FACTOR  
**SIXTY-FOUR**  
BETTER THAN  
HUBBLE !

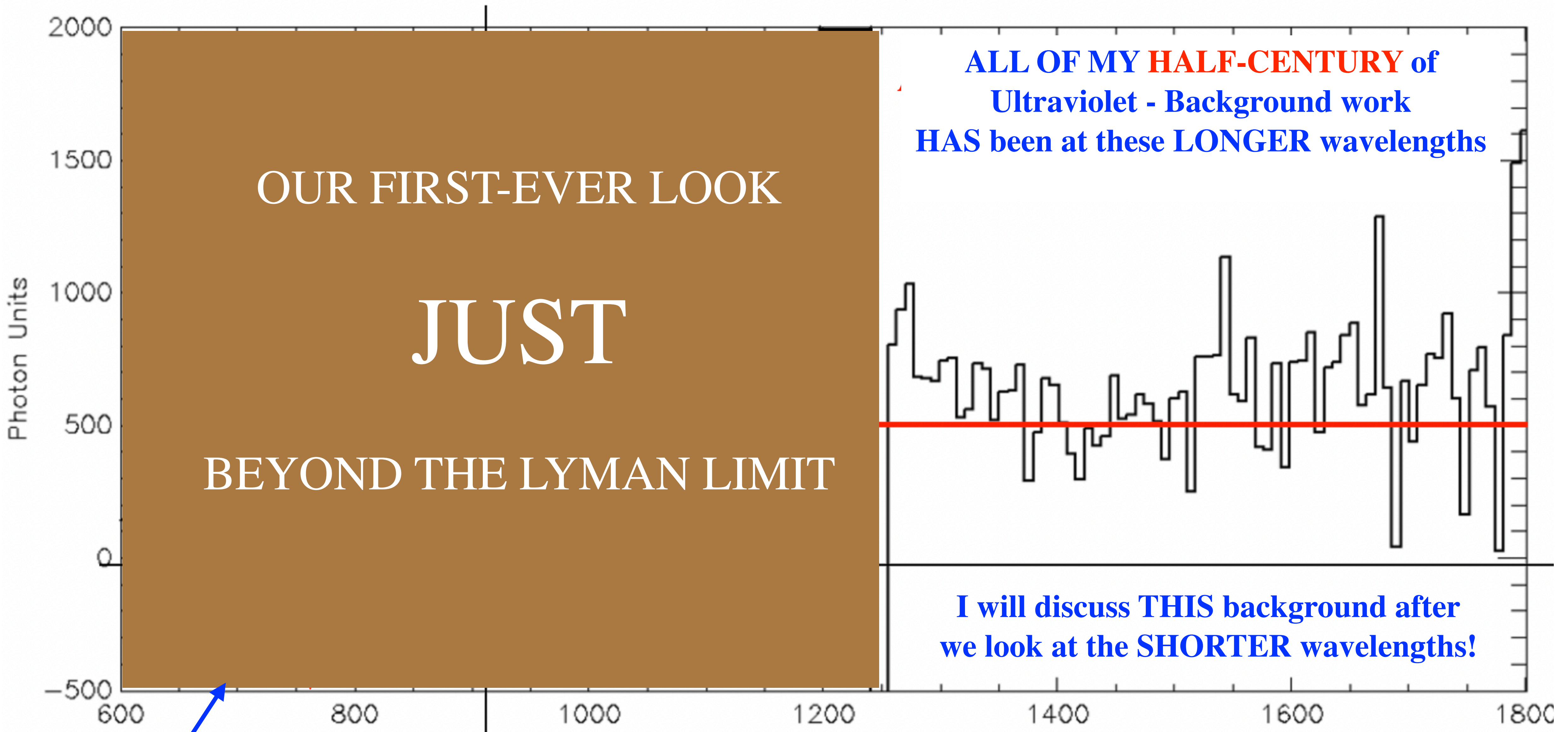
I will **now show you**  
an **actual Alice** long-exposure spectrum  
of the cosmic UV background,  
taken with Alice two years ago: just a 'sighting shot' !

The spectrum **is not** 'official', and  
I show it **ONLY** to explain  
**why** Dick Henry is so **OPTIMISTIC** about  
what we might find in the 19 new 'official' spectra.

But, we **will glance first** at the **longer**-wavelength half of the spectrum.



# The CUVB observed with Alice, New Horizons Mission



Stu Bowyer

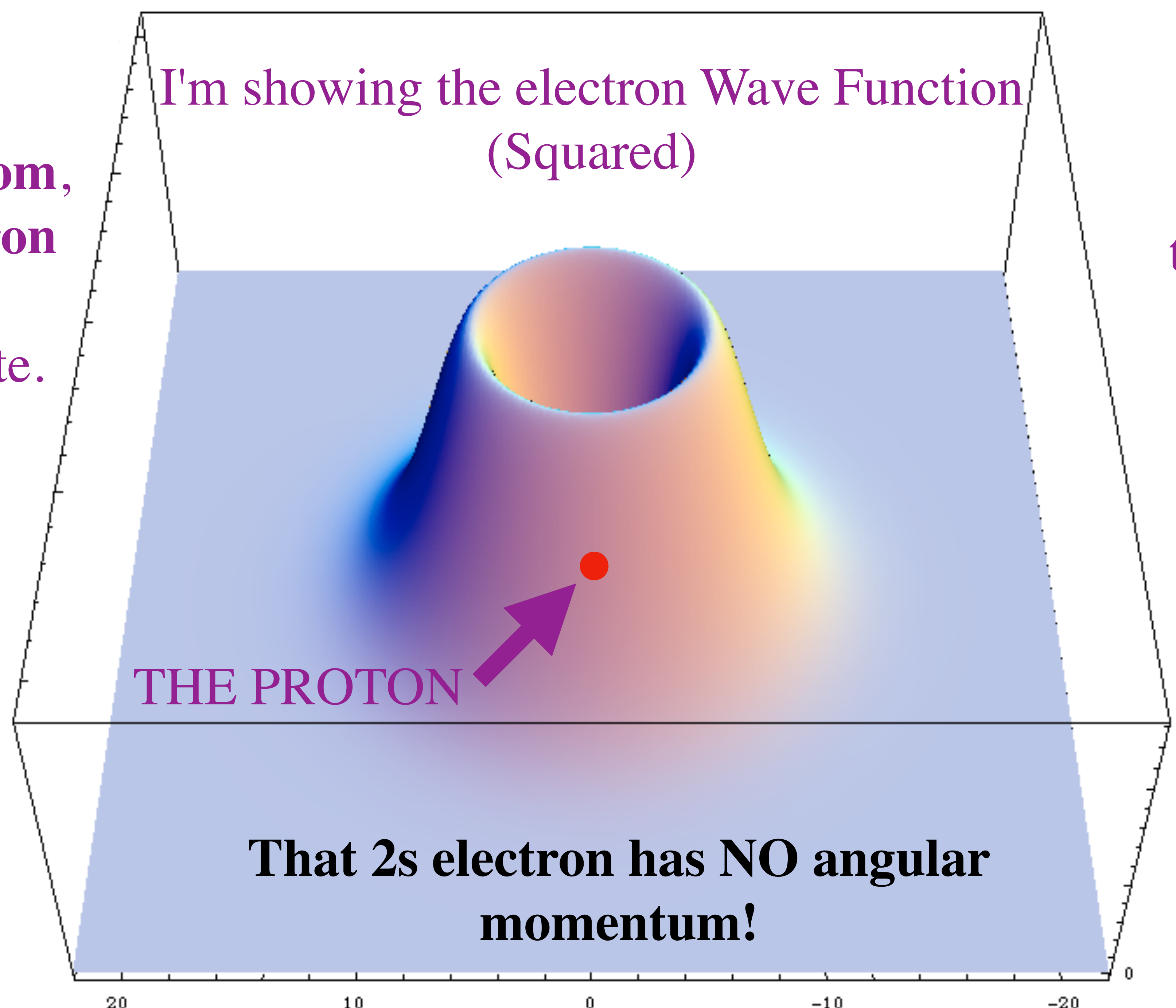
912 Å

How, exactly, might Dark Matter Decay?

Here is a  
**Hydrogen Atom,**  
with its **electron**  
up in the  
**2s** energy state.

I'm showing the electron Wave Function  
(Squared)

The electron  
**cannot** get to  
the ground state  
by emitting  
**a photon**  
because  
**a photon HAS**  
angular  
momentum.



THE PROTON

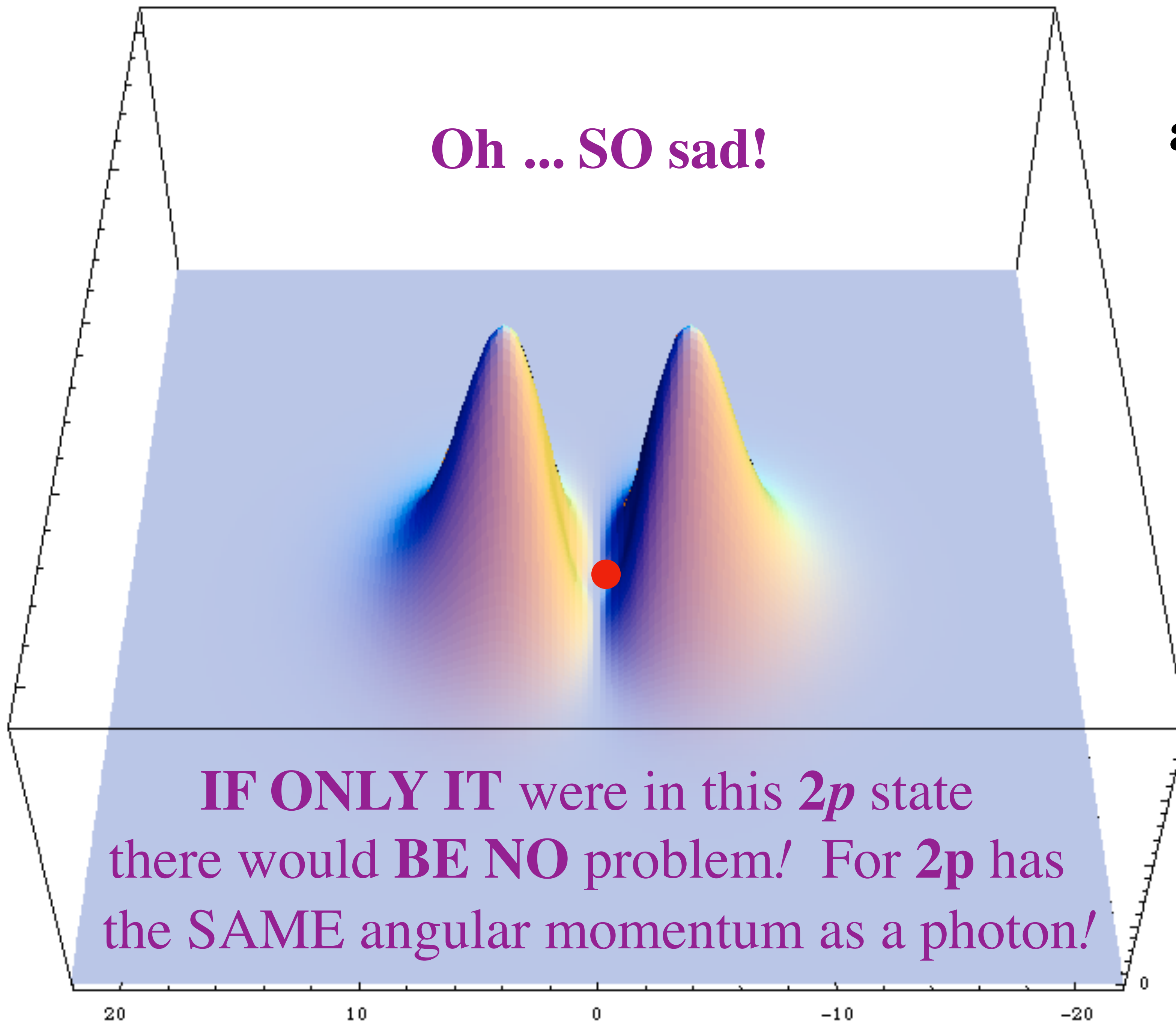
**That 2s electron has NO angular  
momentum!**

20 10 0 -10 -20 0

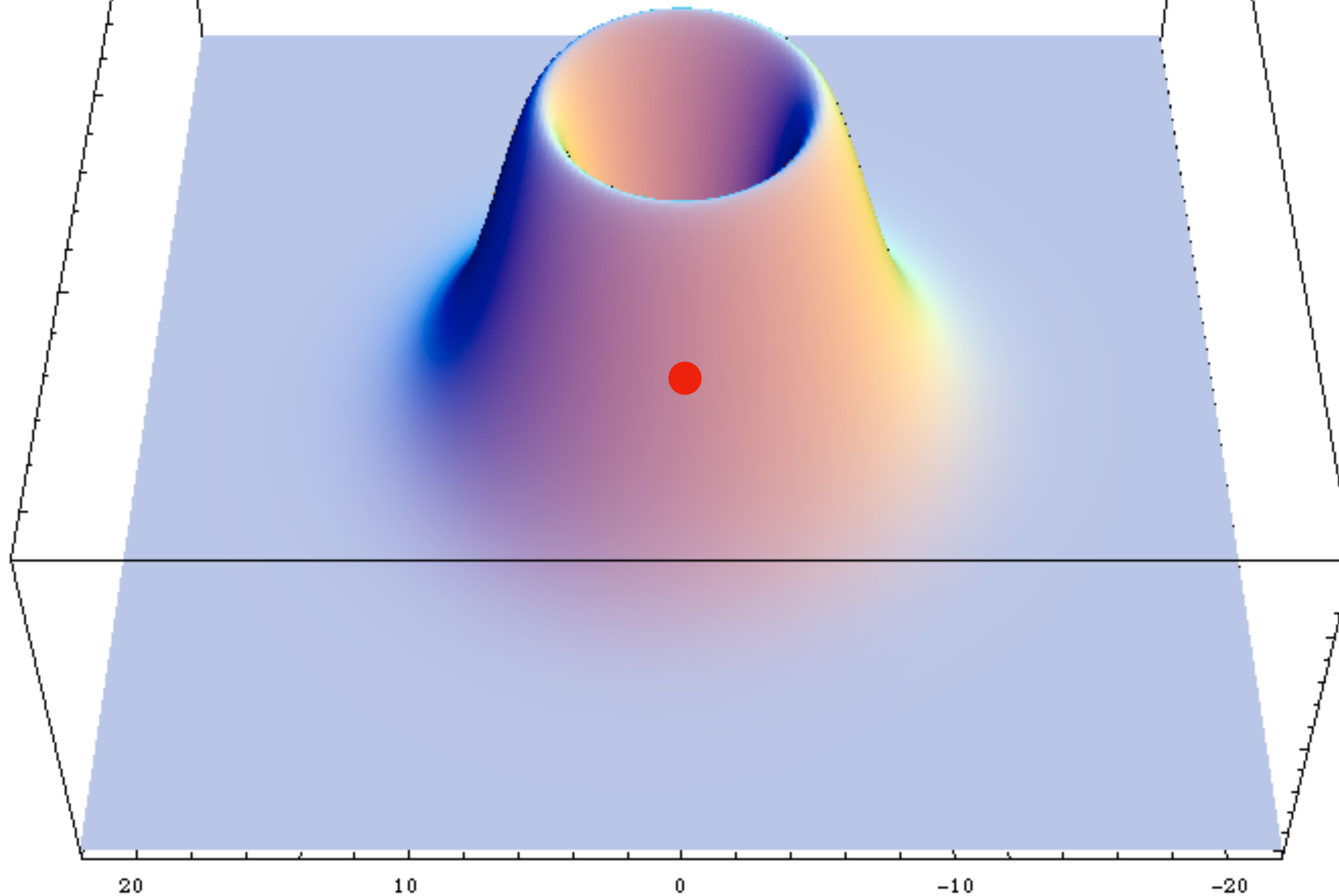
Oh ... SO sad!

as long as  
an electron is  
**IN** any state,  
**NOTHING**  
**CHANGES!**

**IF ONLY IT** were in this  $2p$  state  
there would **BE NO** problem! For  $2p$  has  
the **SAME** angular momentum as a photon!



**... but from this 2s state :  
Conservation of Angular Momentum  
would be violated !**



A FORBIDDEN  
TRANSITION:  
Abrupt, **but:**

**SLOW  
TO  
HAPPEN !**

which **IS**  
**JUST** what  
we **EXPECT**

for  
**DARK  
MATTER**  
decay !

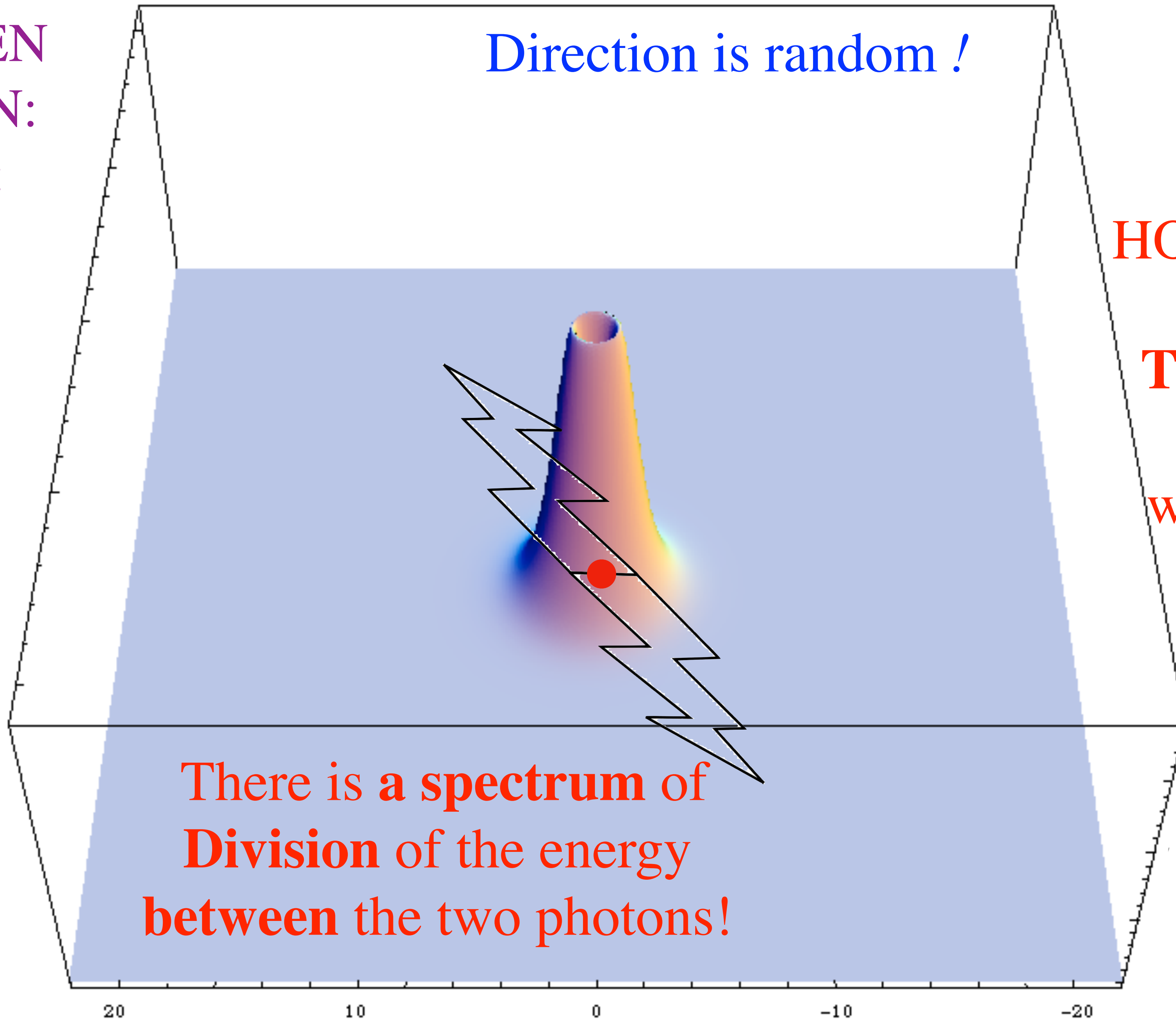
Direction is random !

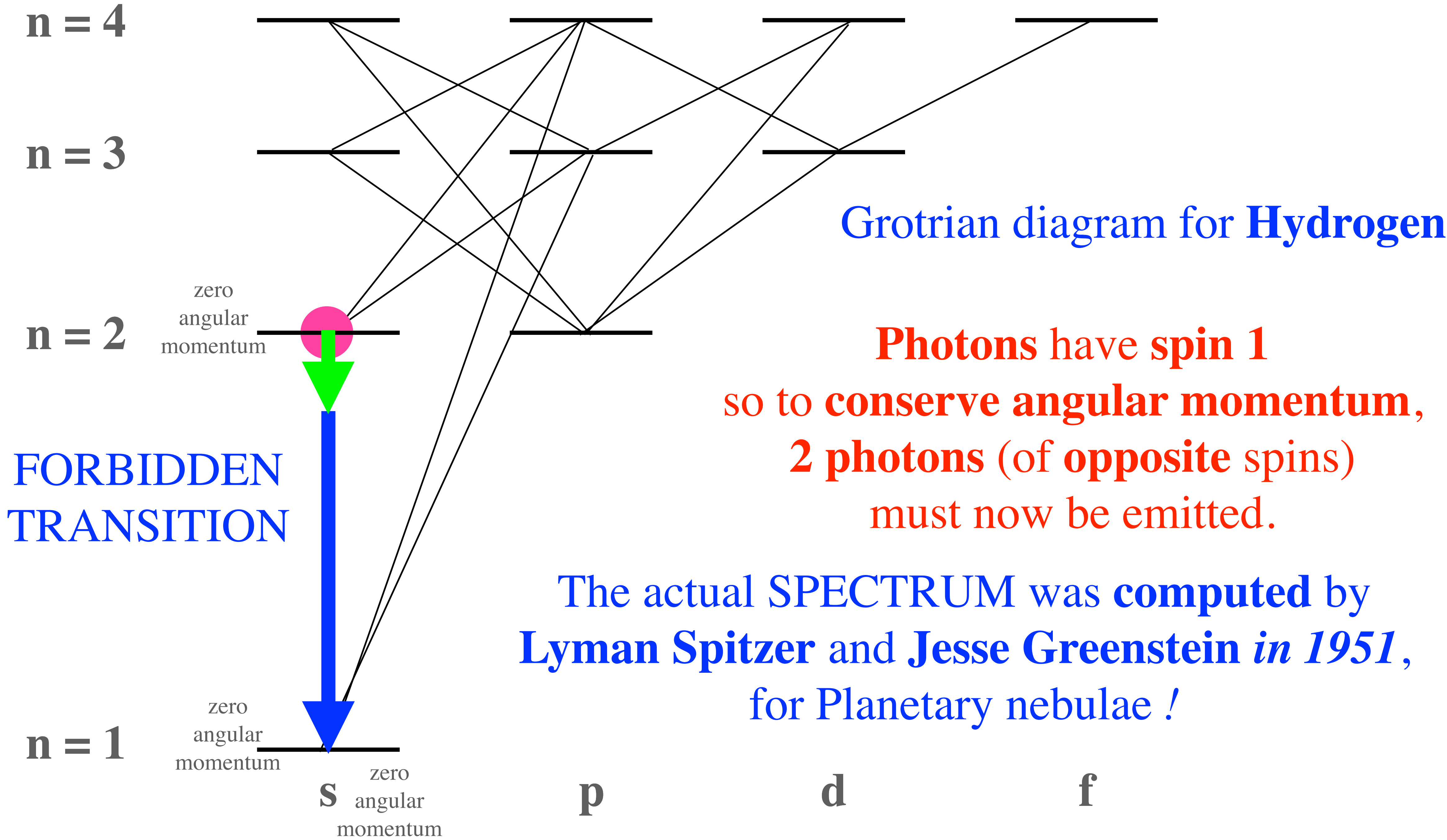
**BUT LOOK!**  
It managed it!

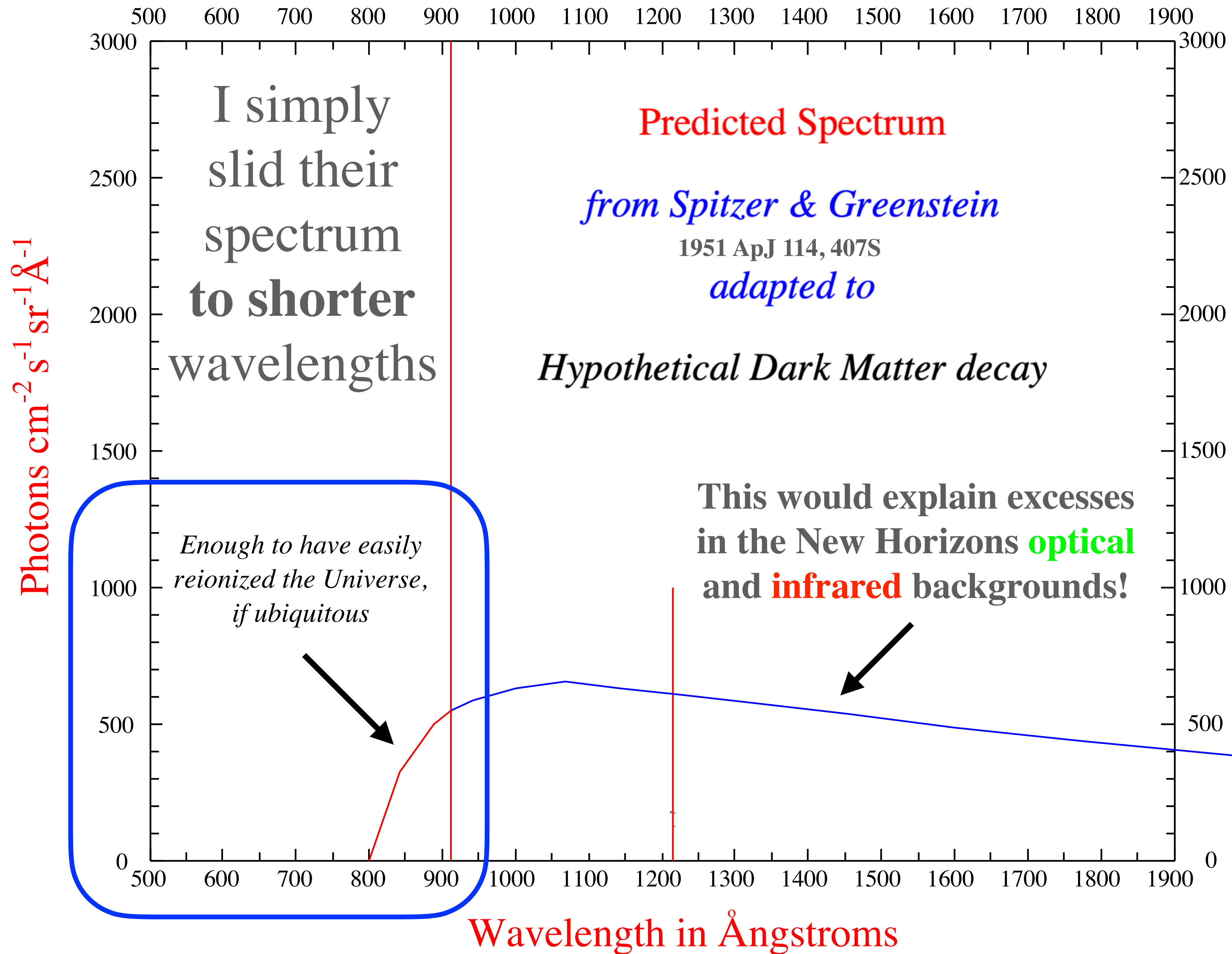
**HOW** did it **DO** it?

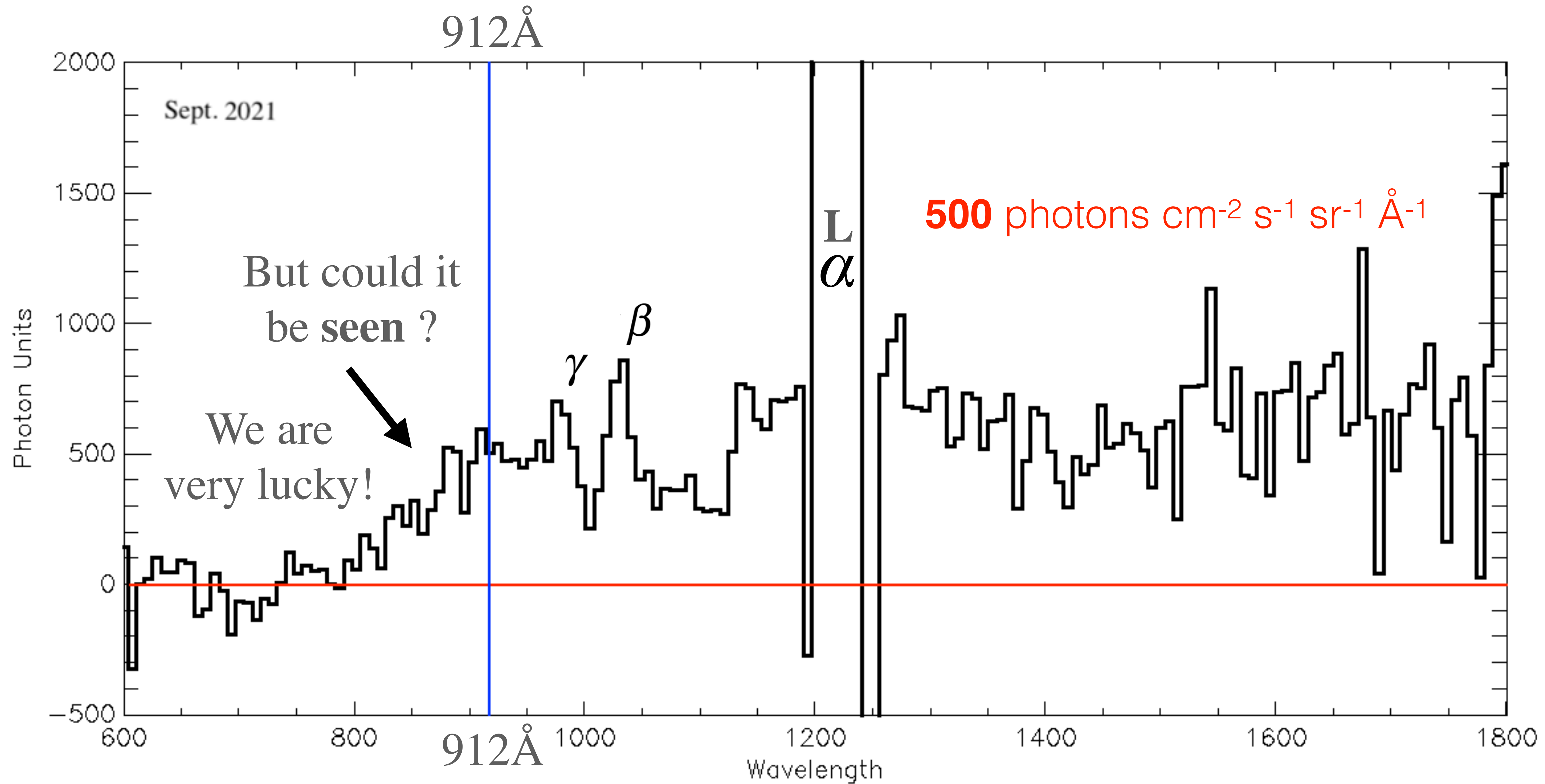
**TWO PHOTONS**  
were emitted  
with **OPPOSITE  
SPINS !**

There is a **spectrum** of  
**Division** of the energy  
**between** the two photons!











Thanks to this  
seeming miracle

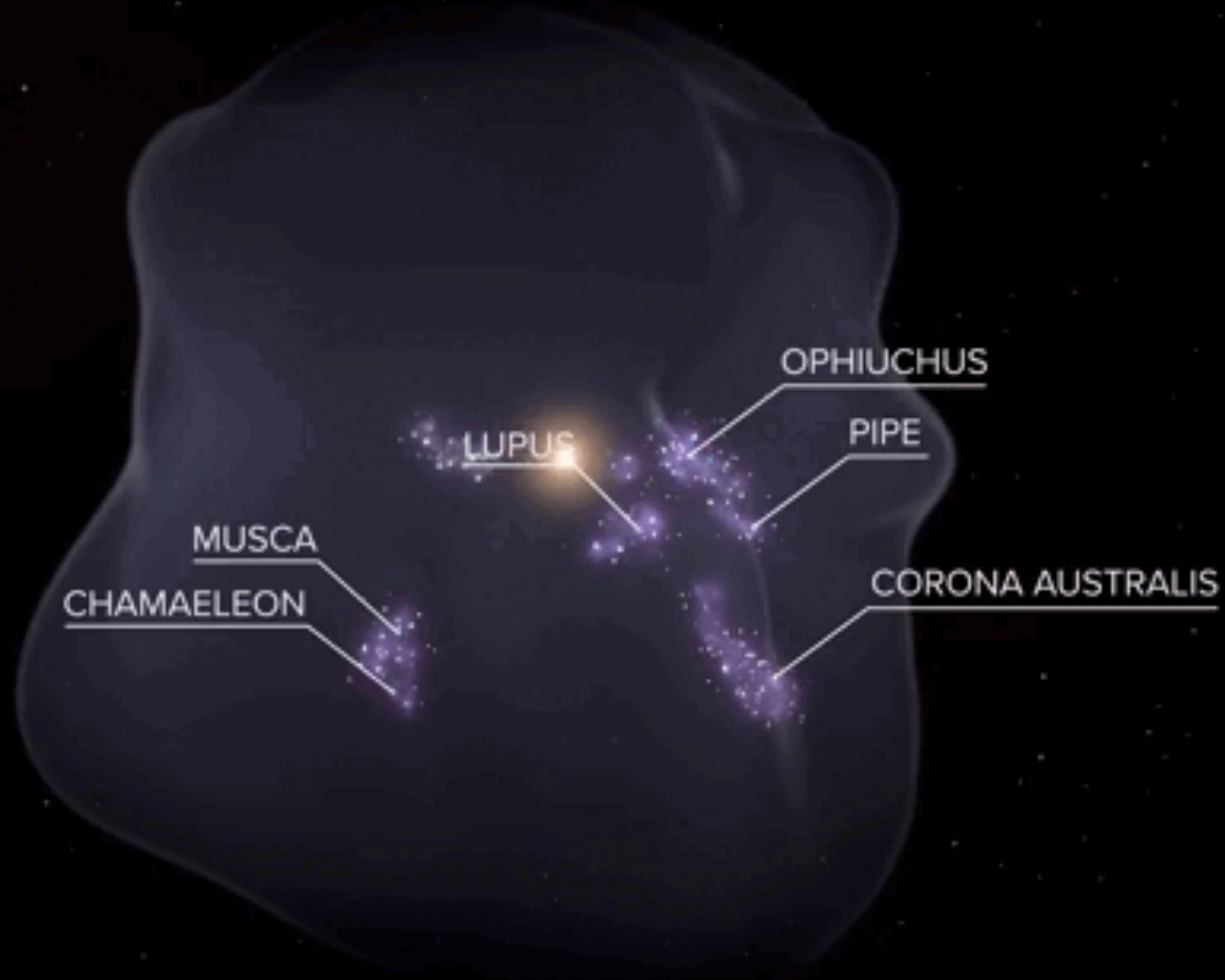
We terrestrial astronomers (blessedly) have almost  
**UNIMPEDED ACCESS TO THE UNIVERSE**

14 13 12

MILLION YEARS AGO

North Galactic Pole

The  
Local  
Bubble :



South Galactic Pole

## That Local Bubble

is filled with ( *I suspect, slowly-decaying* ) **DARK MATTER**

( just as everywhere else is)

**BUT** thanks to that **Supernova !!** our cavity has  
**REMARKABLY LITTLE NEUTRAL HYDROGEN !**

**SO: Alice MIGHT** detect **dark-matter decay-radiation CLOSE to 912 Å**

**IF** the **DARK MATTER**

**DOES** slowly **decay** over billions of years

(producing what Alice **MAY** be seeing), well then, OK, yes  
that **WOULD SOLVE** the problem of how the universe got re-ionized,

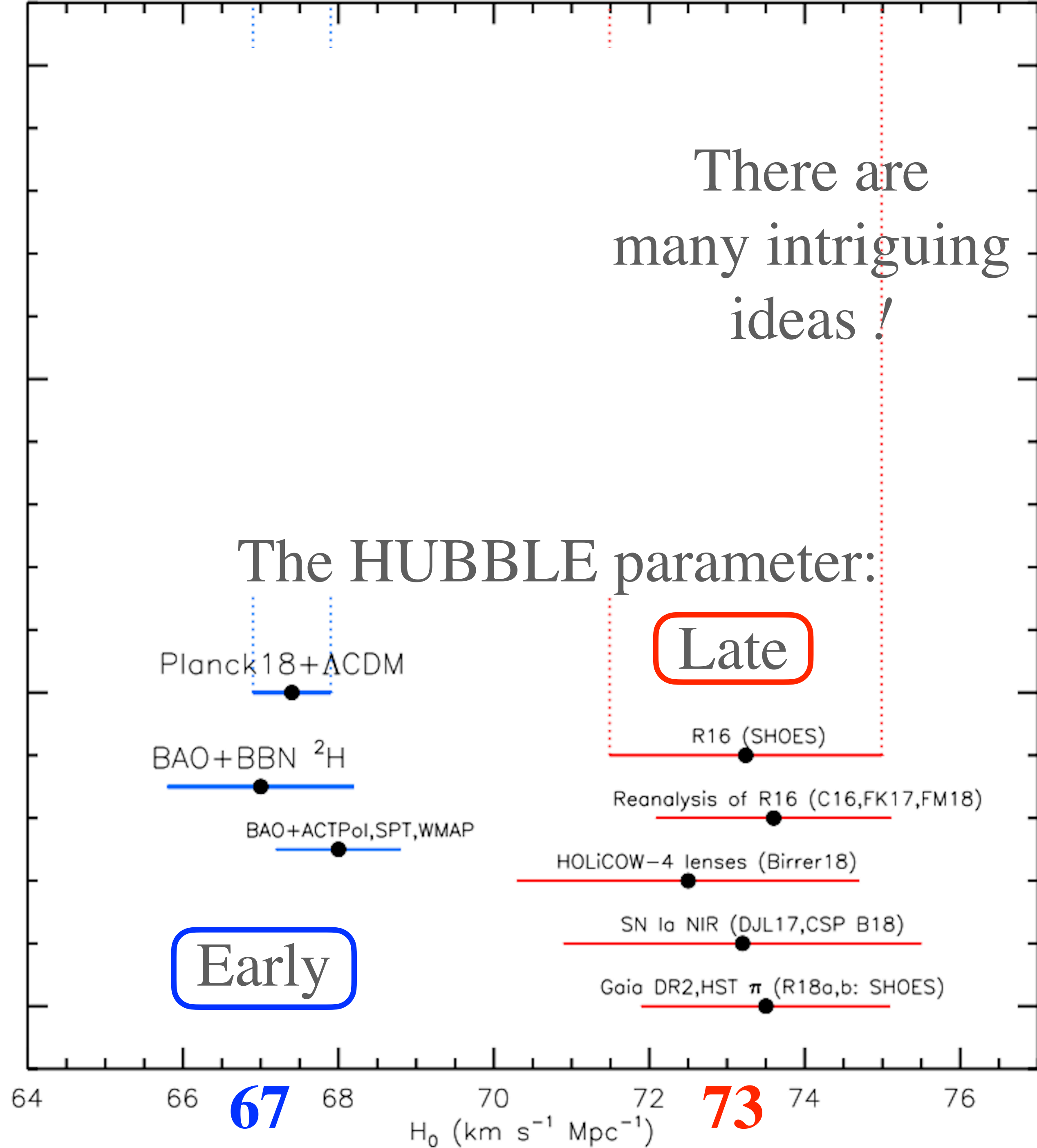


**BUT ALSO** (Adam Riess explained to me, some years ago)  
**WOULD reconcile** the great **Hubble Parameter differences**  
that have disturbed cosmologists for so many years now:

There are many intriguing ideas !

Dark Matter DECADEY could be the answer

The HUBBLE parameter:



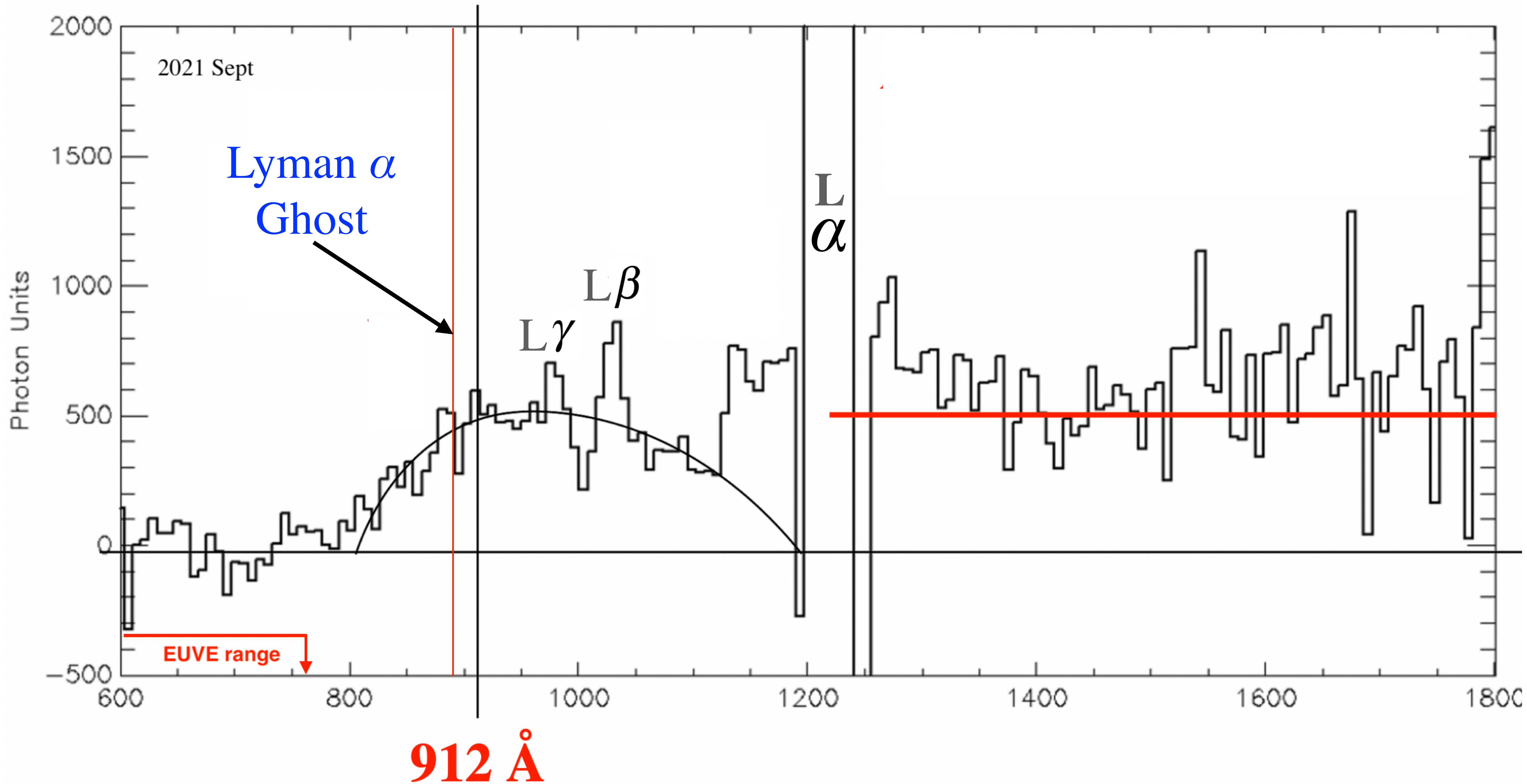
Early

Late

67

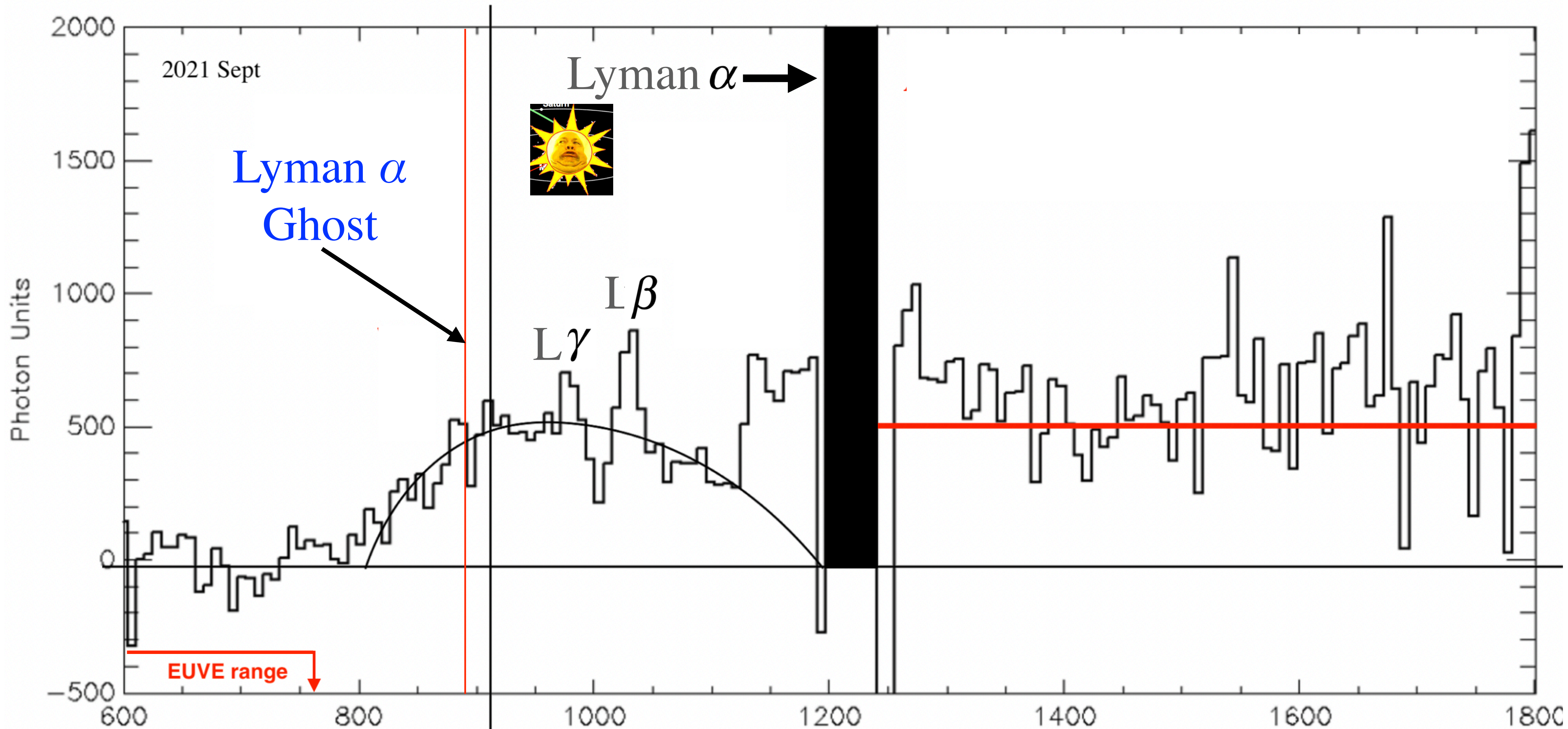
73

# The CUVB observed with Alice, New Horizons Mission



The Ghost appears at  $893 \text{ \AA}$   
which is **annoyingly** close to  $912 \text{ \AA} !$

# The CUVB observed with Alice, New Horizons Mission



# The CUVB observed with Alice, New Horizons Mission

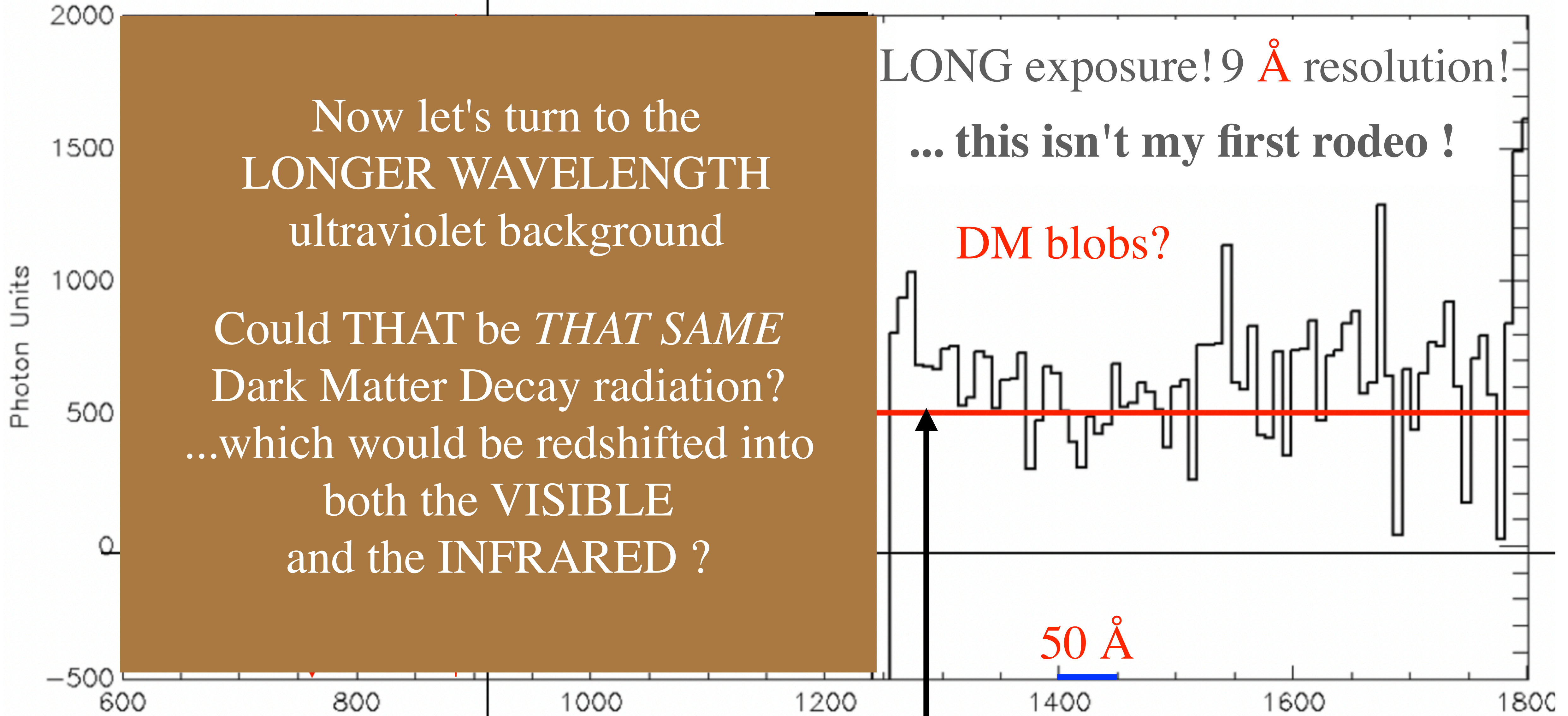
Now let's turn to the  
LONGER WAVELENGTH  
ultraviolet background

Could THAT be *THAT SAME*  
Dark Matter Decay radiation?  
...which would be redshifted into  
both the VISIBLE  
and the INFRARED ?

LONG exposure! 9 Å resolution!

... this isn't my first rodeo !

DM blobs?

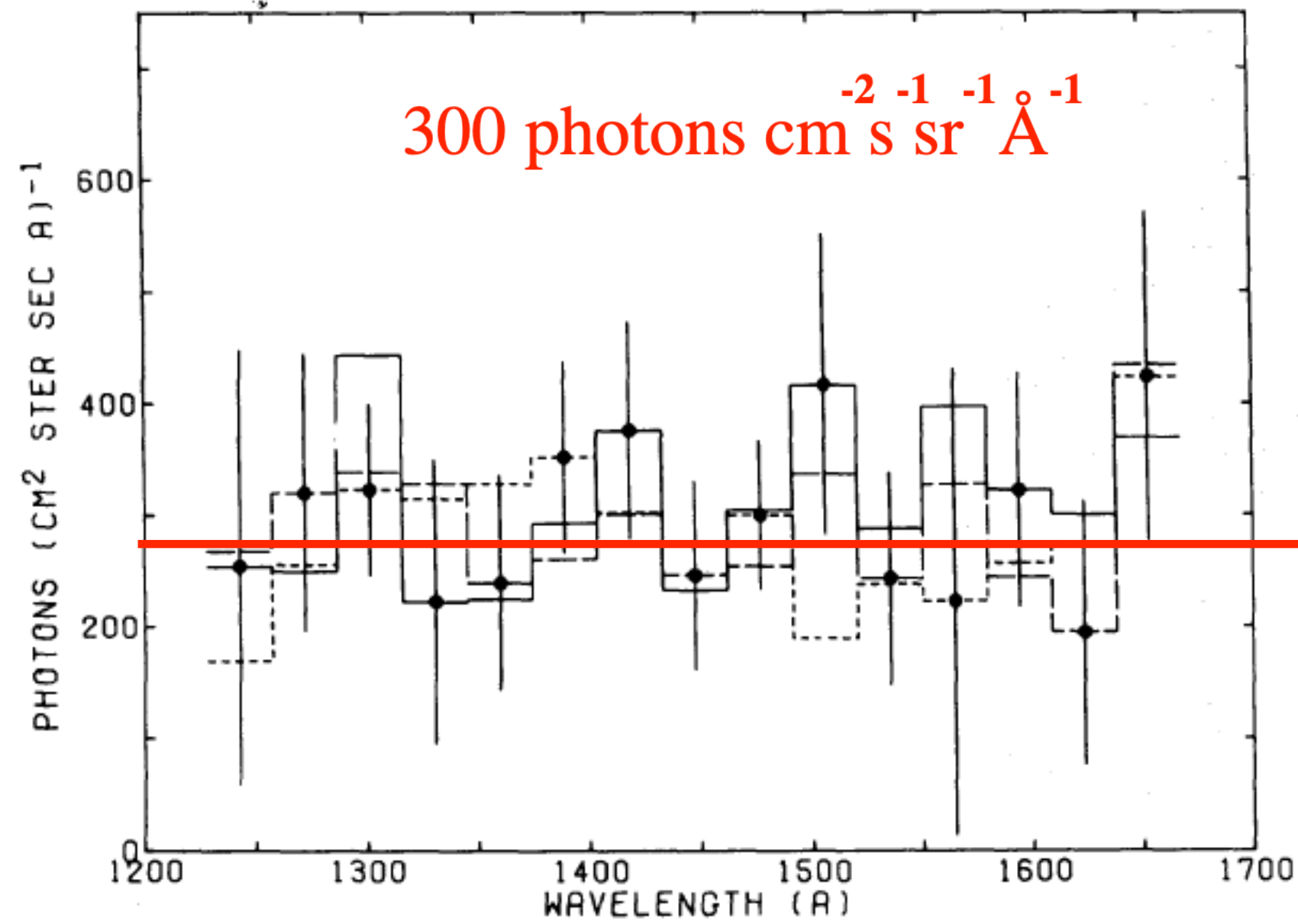


912 Å

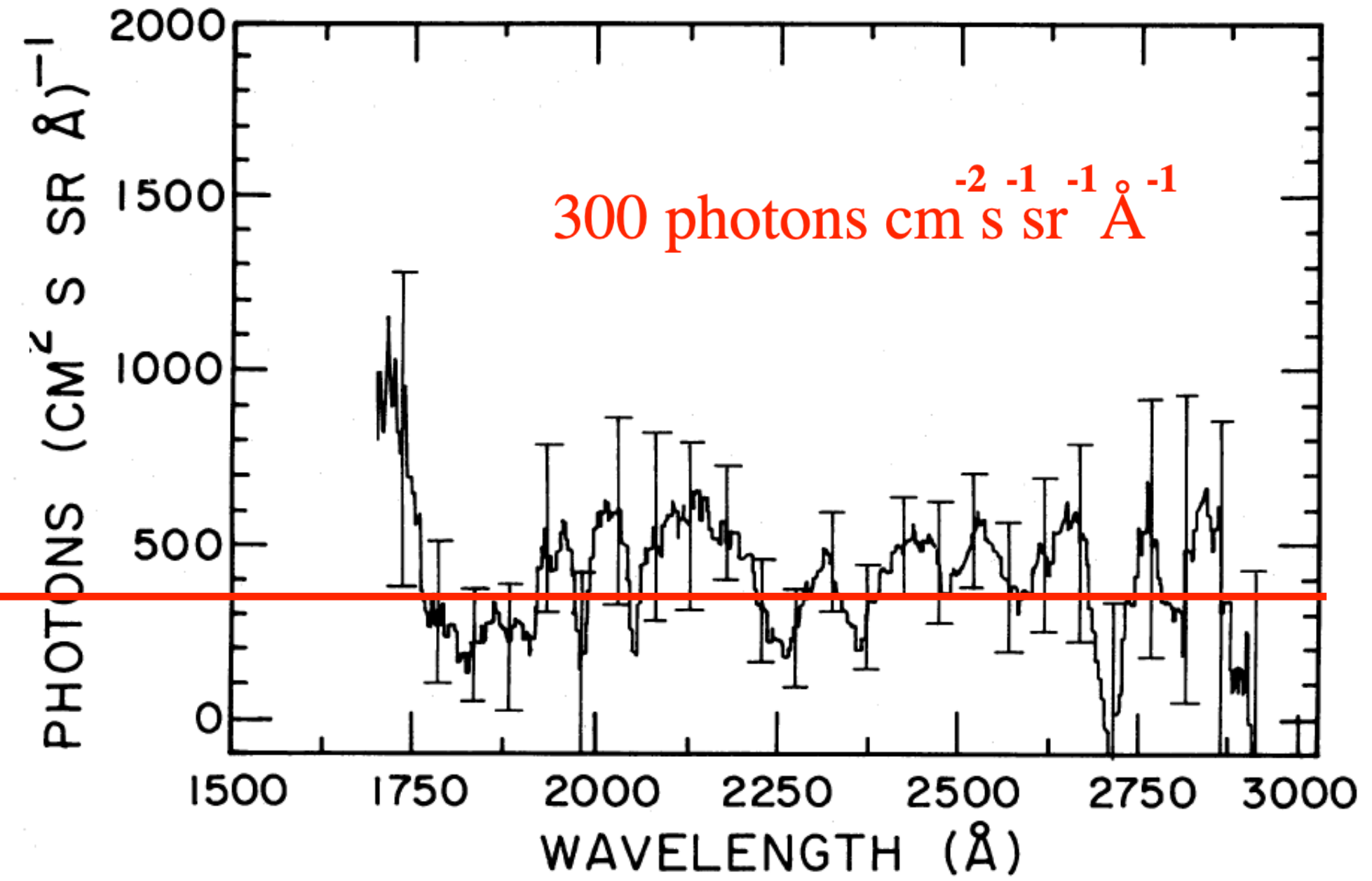
500 photons cm<sup>-2</sup> s<sup>-1</sup> sr<sup>-1</sup> Å<sup>-1</sup>



60Å resolution



60Å resolution



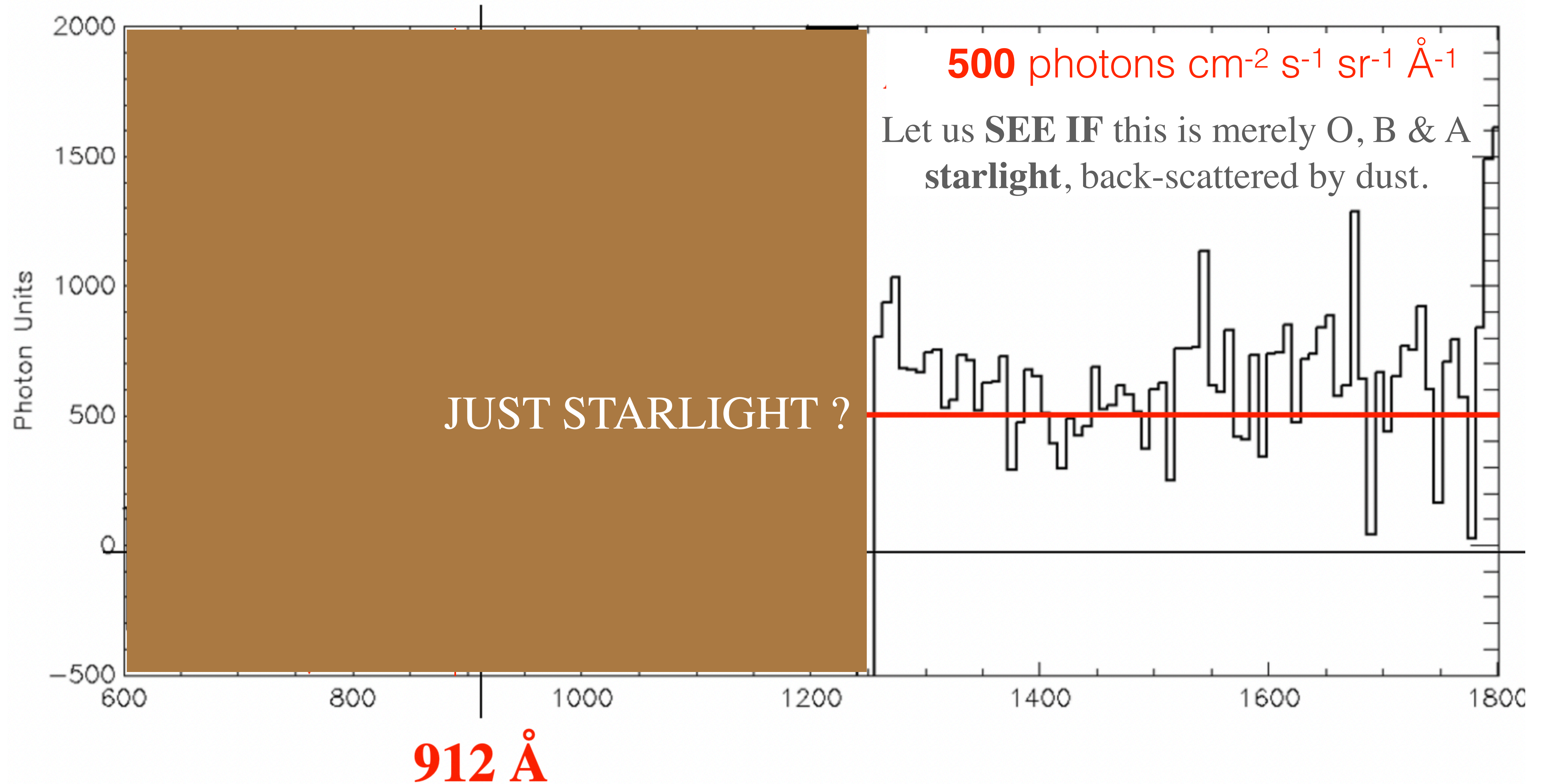
My student,  
Rod  
Anderson  
1979

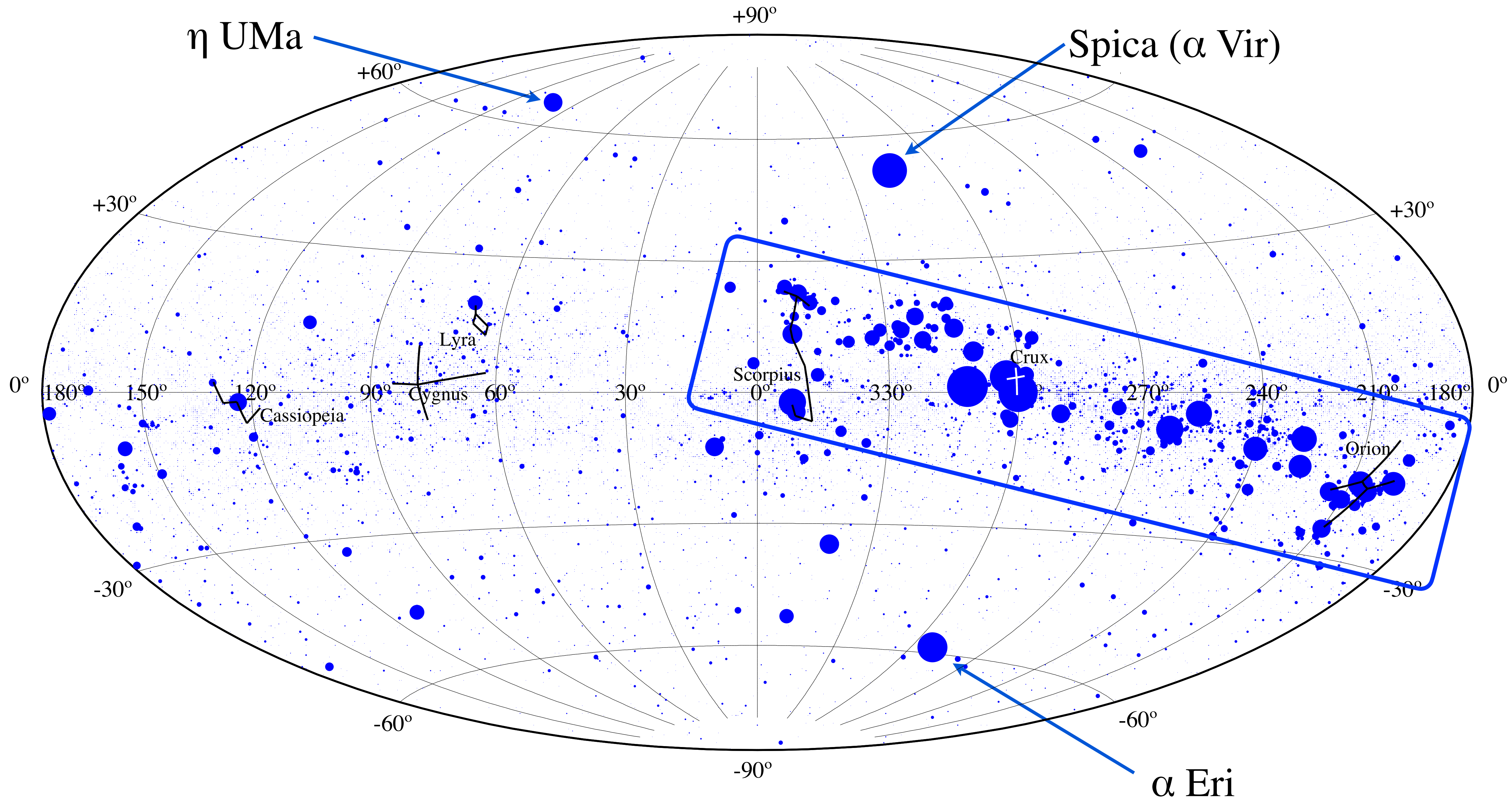


My student,  
Pete  
Tennyson  
1988



# The CUVB observed with Alice, New Horizons Mission





$\eta$  UMa

+90°

Spica ( $\alpha$  Vir)

+60°

+30°

+30°

0°

180°

150°

120°

90°

60°

30°

0°

330°

300°

270°

240°

210°

180°

0°

Cassiopeia

Cygnus

Lyra

Scorpius

Crux

Orion

-30°

-30°

-60°

-60°

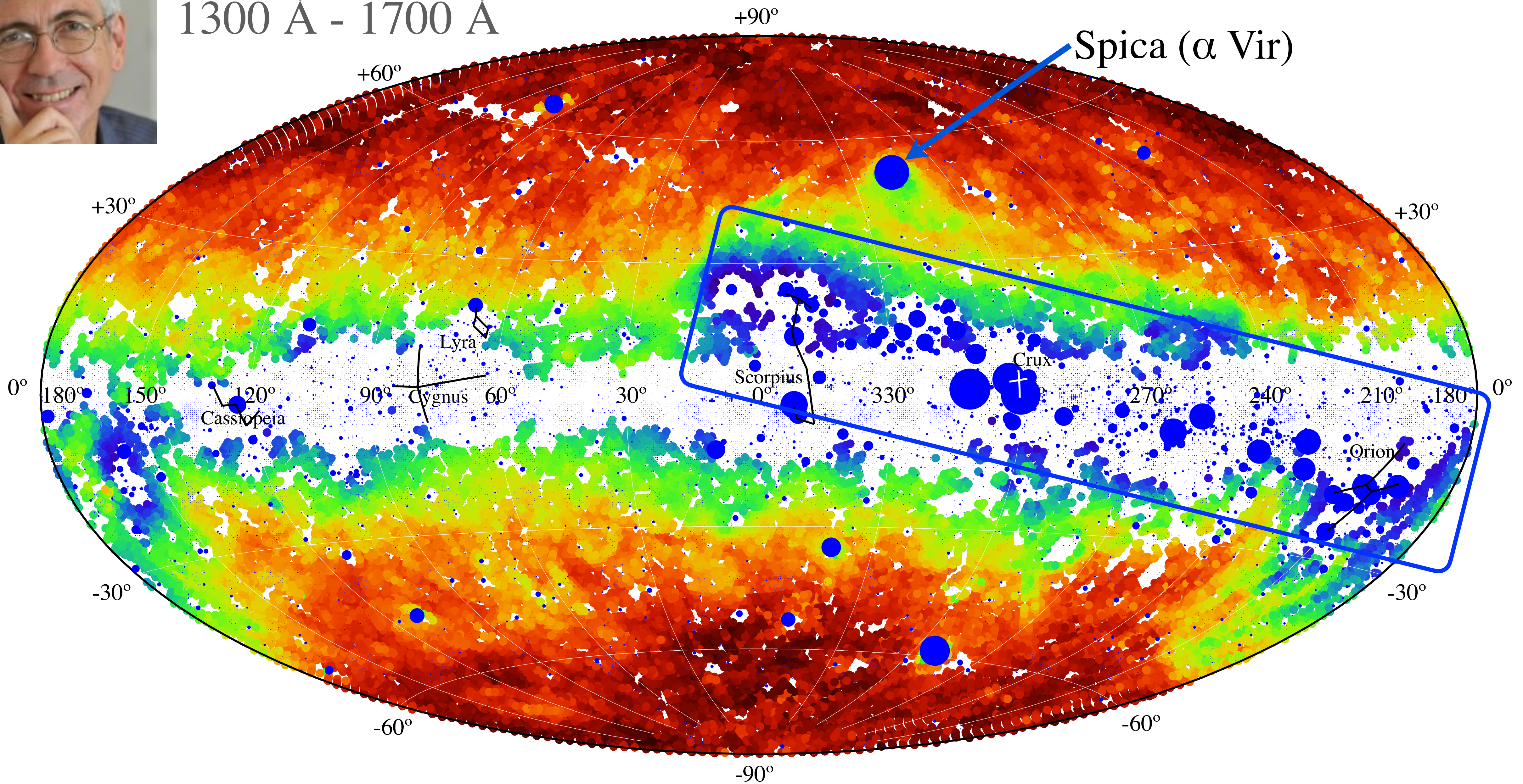
-90°

$\alpha$  Eri



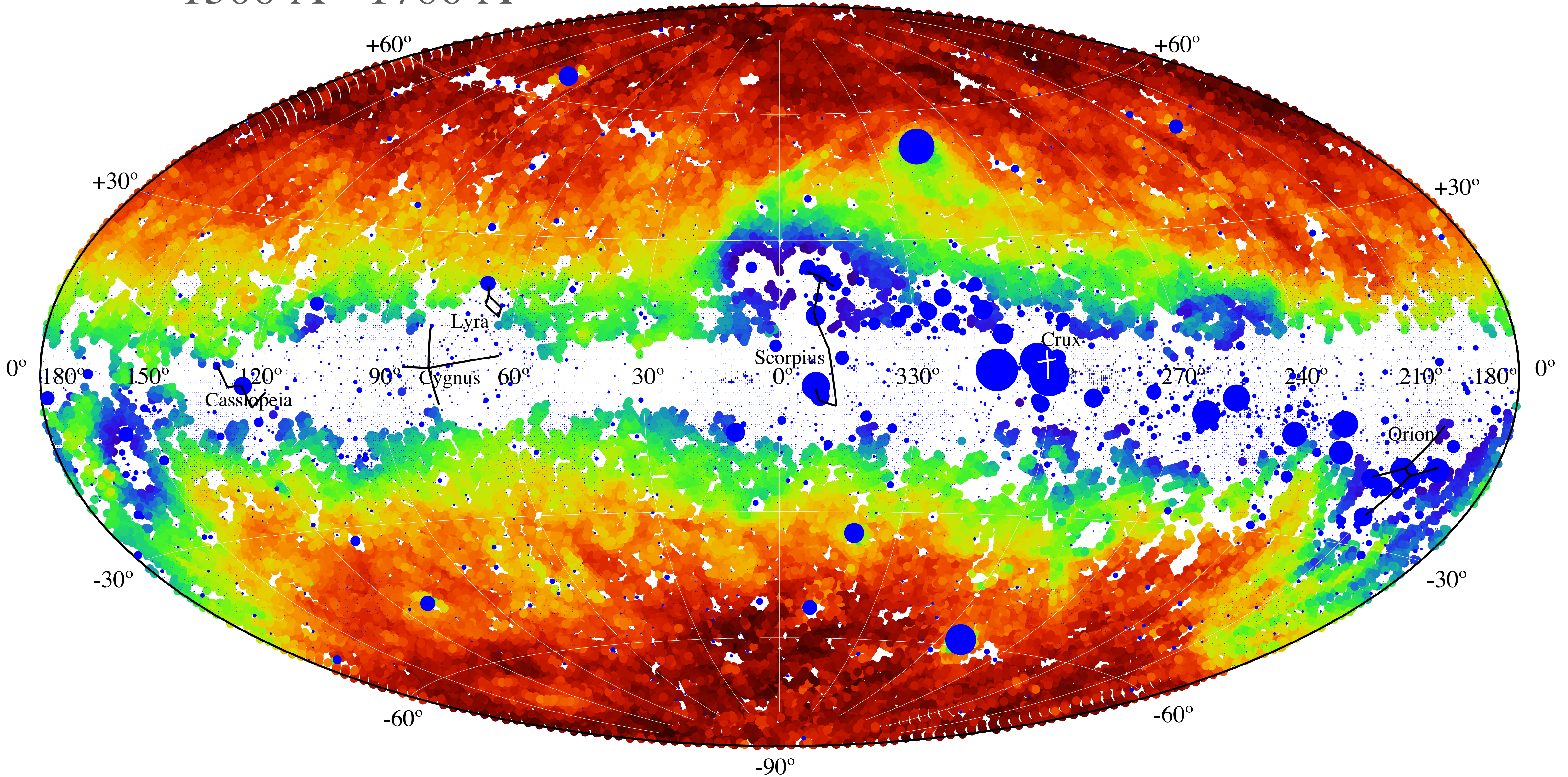
# Chris Martin: GALEX

1300 Å - 1700 Å

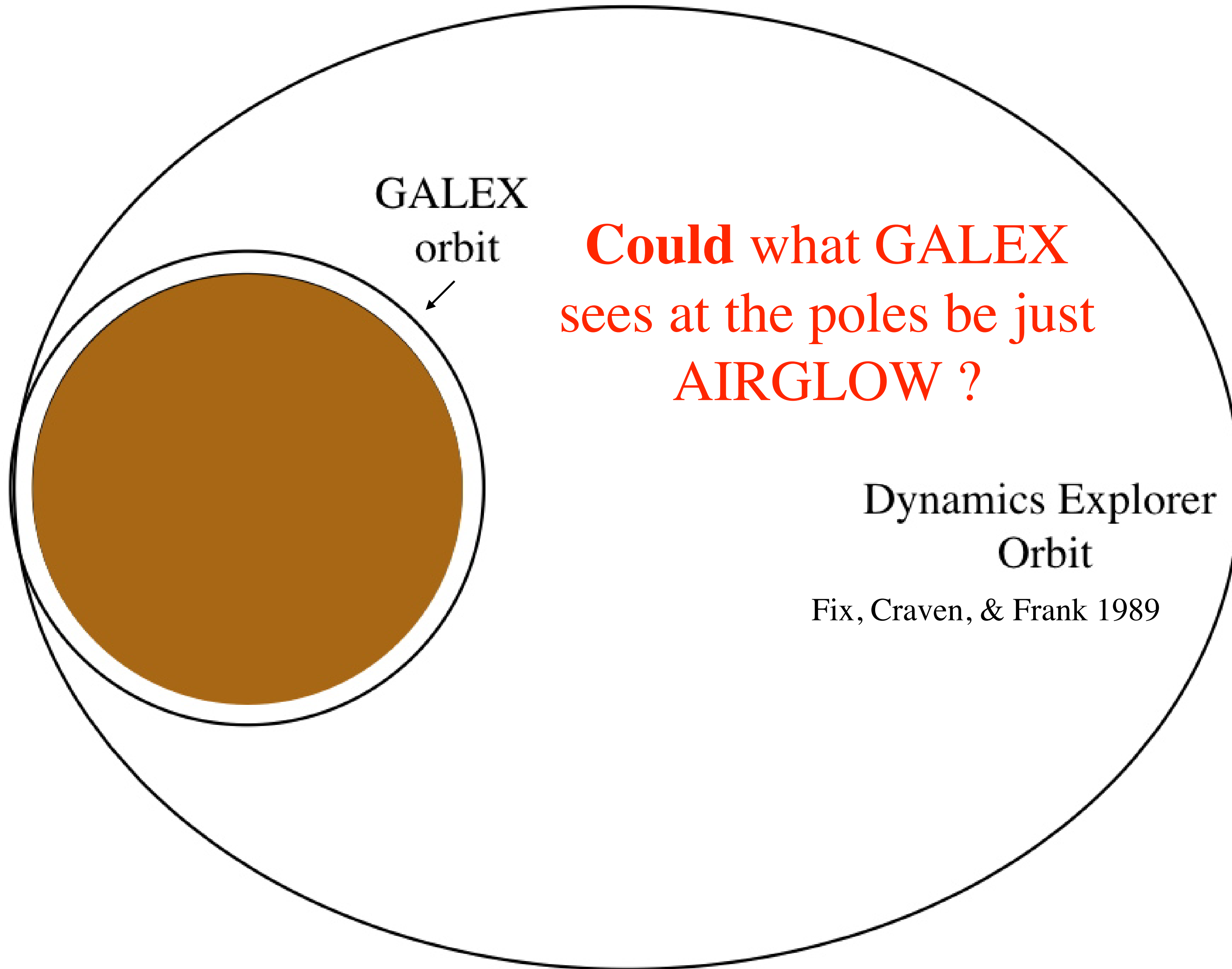


# North Galactic Pole

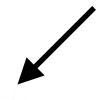
1300 Å - 1700 Å



# South Galactic Pole



GALEX  
orbit

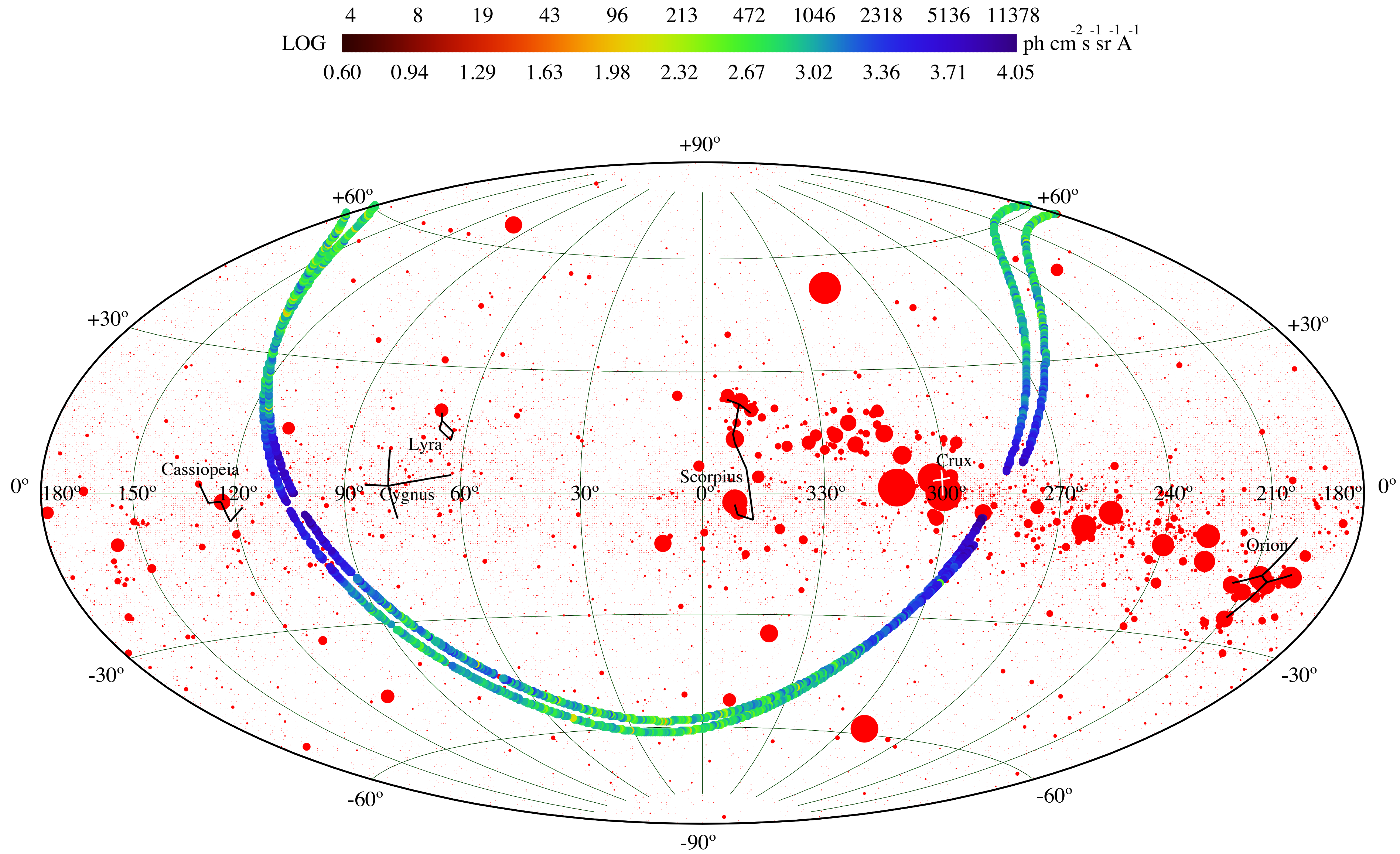


**Could what GALEX  
sees at the poles be just  
AIRGLOW ?**

Dynamics Explorer  
Orbit

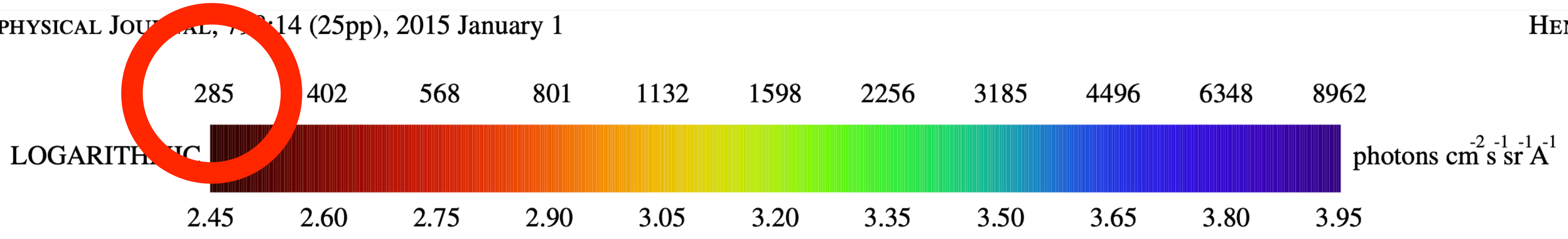
Fix, Craven, & Frank 1989

Dynamics  
Explorer observes  
mostly **HERE**,  
at apogee !



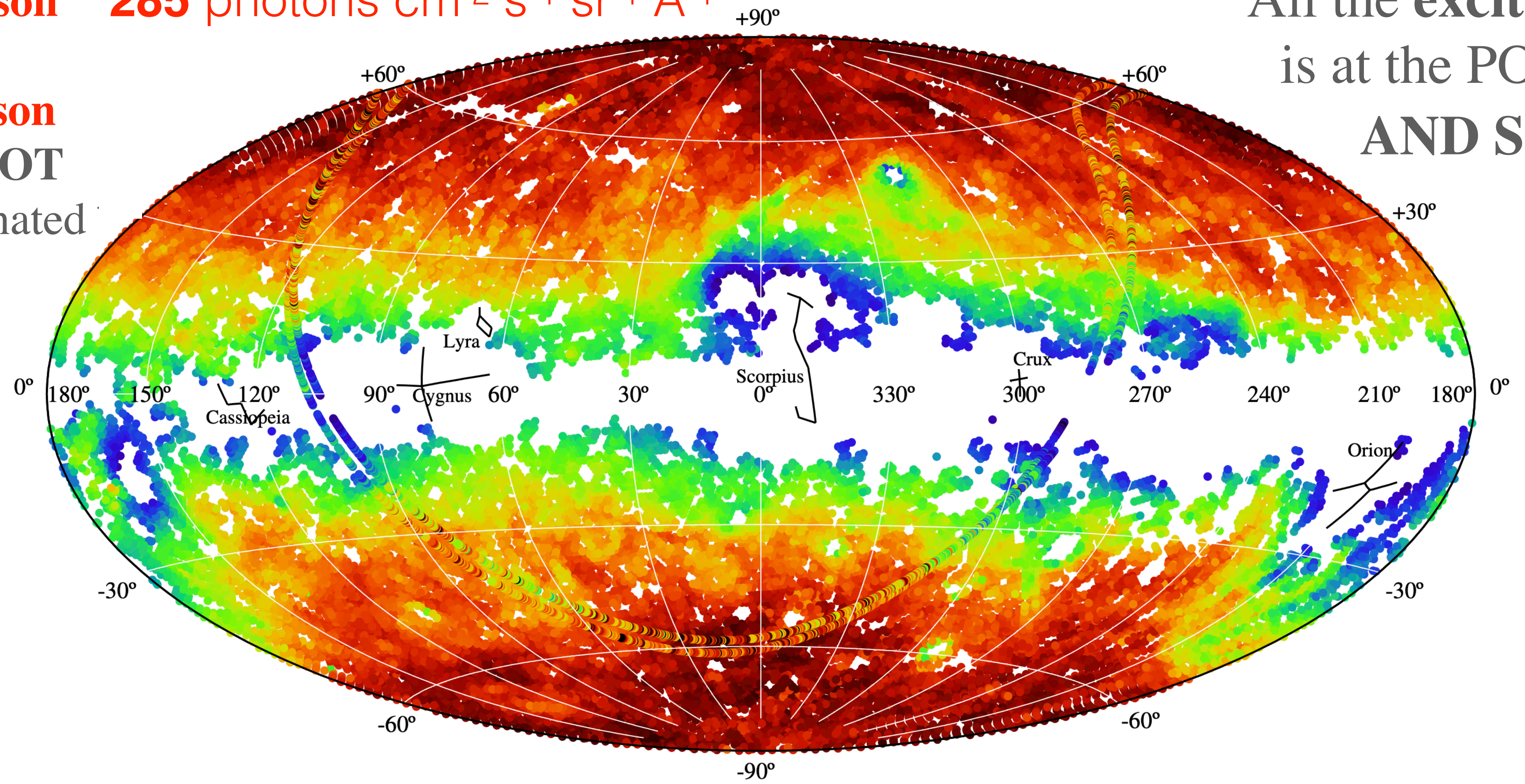
Dynamics Explorer (Fix, Craven, & Frank 1989)

DE shows  
that **GALEX**  
&  
**Anderson**  
&  
**Tennyson**  
ARE NOT  
contaminated



**285** photons  $\text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1} \text{\AA}^{-1}$

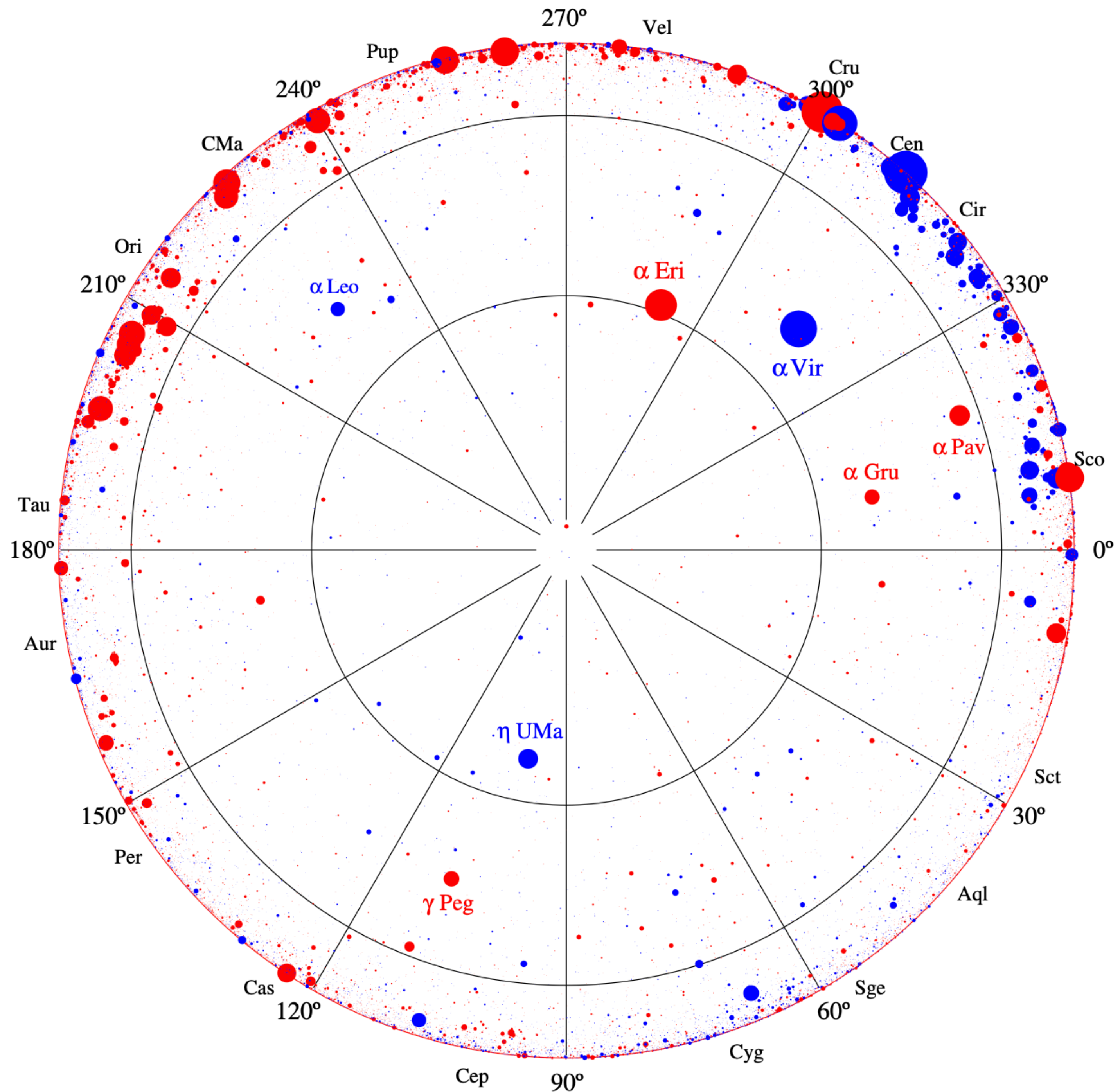
All the excitement  
is at the POLES  
**AND SO !**

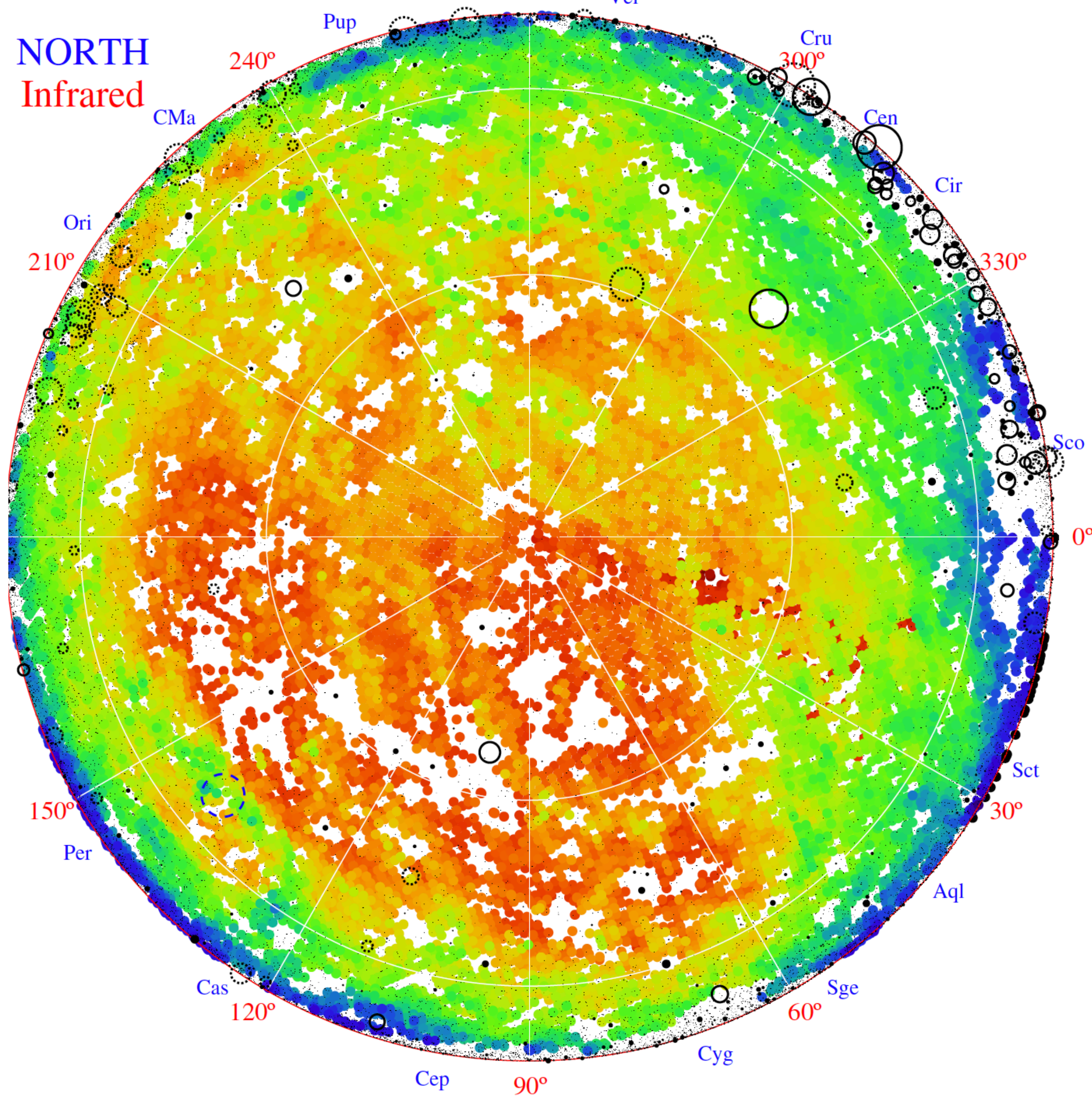
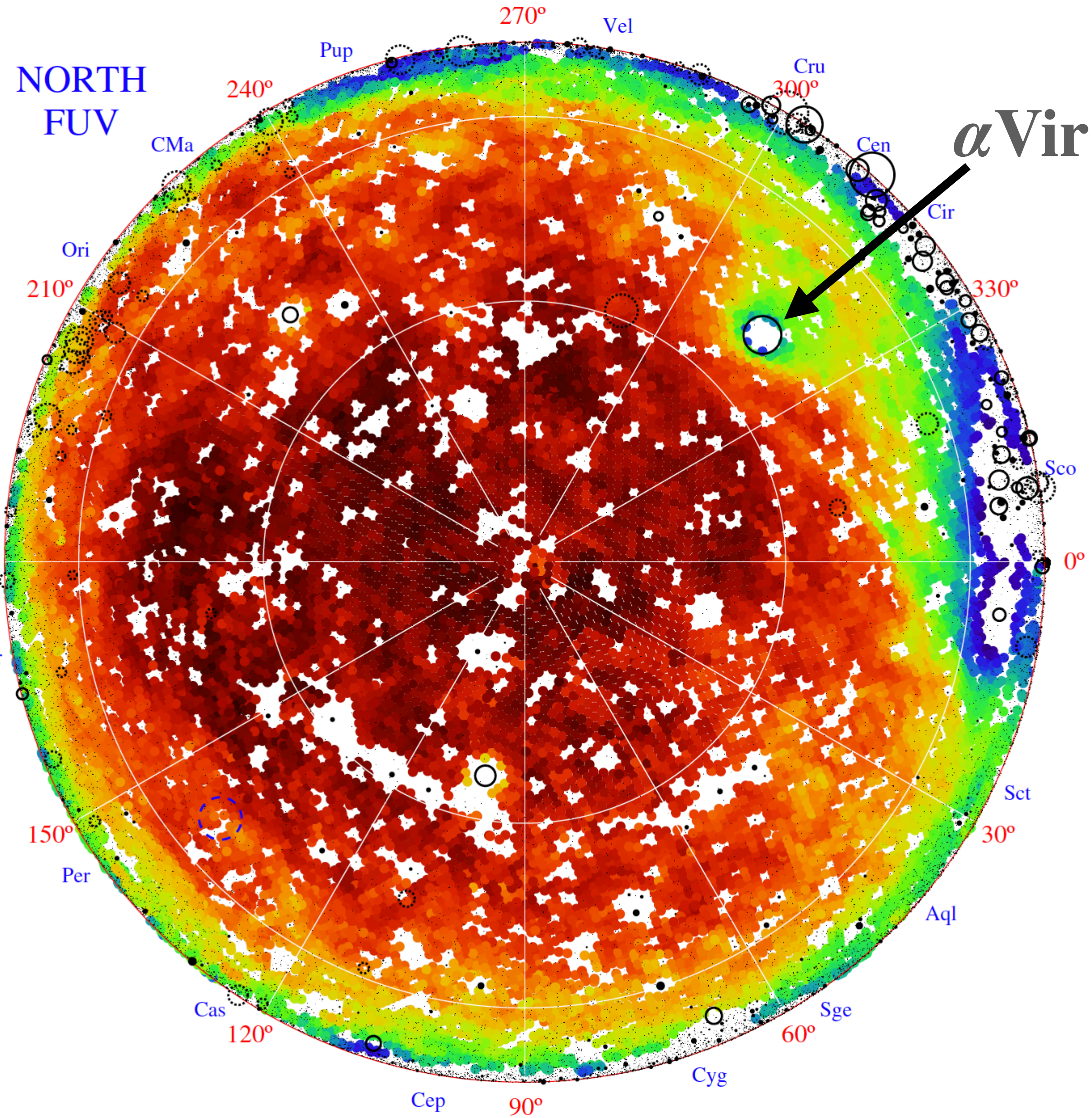
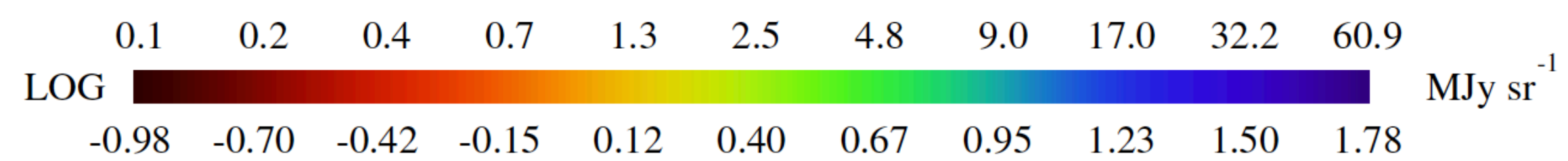
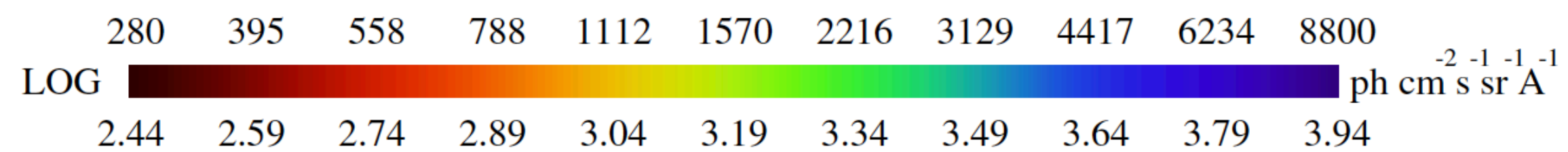


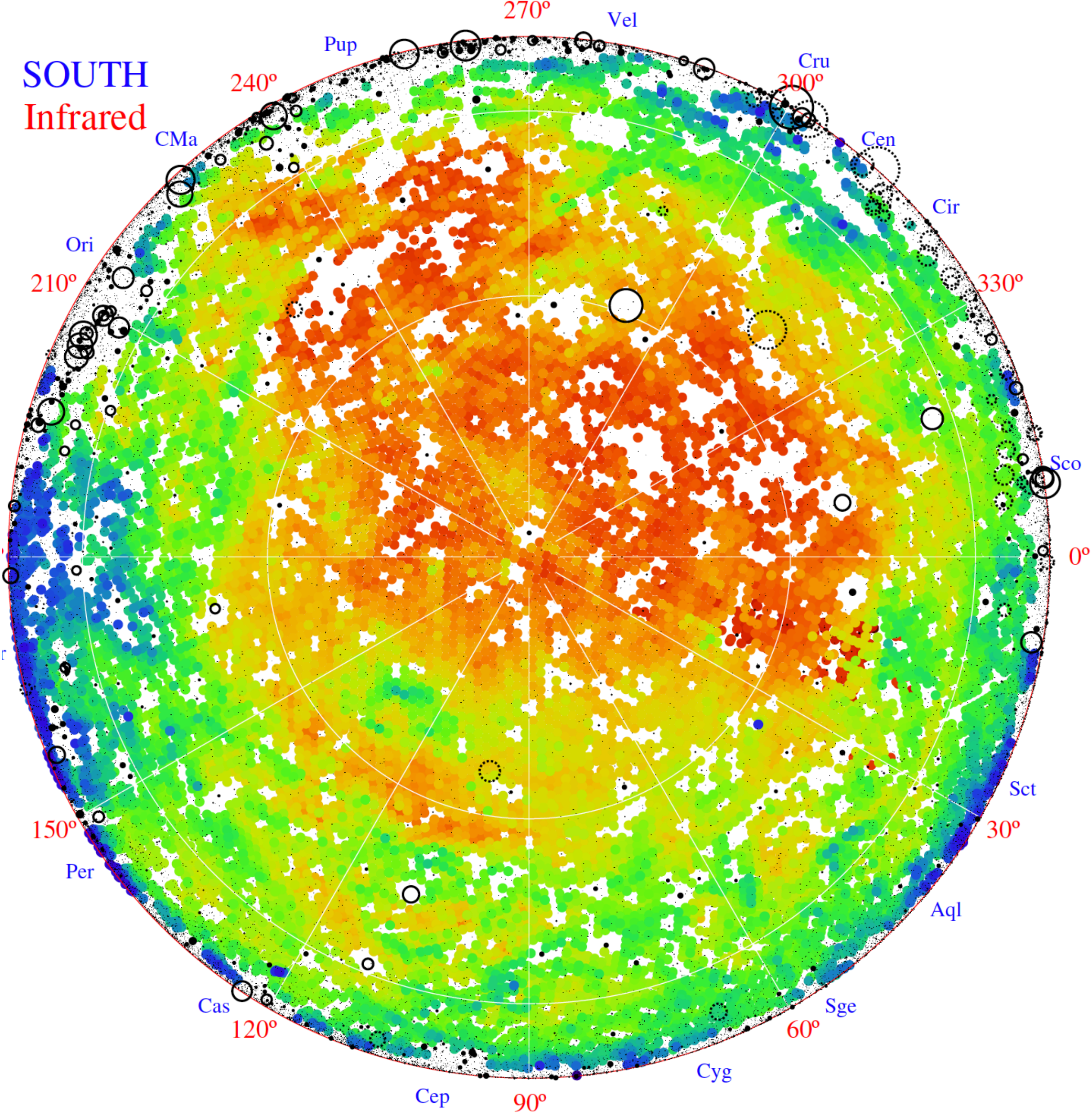
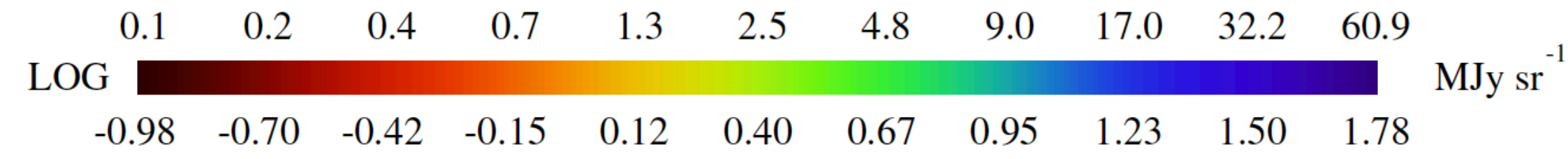
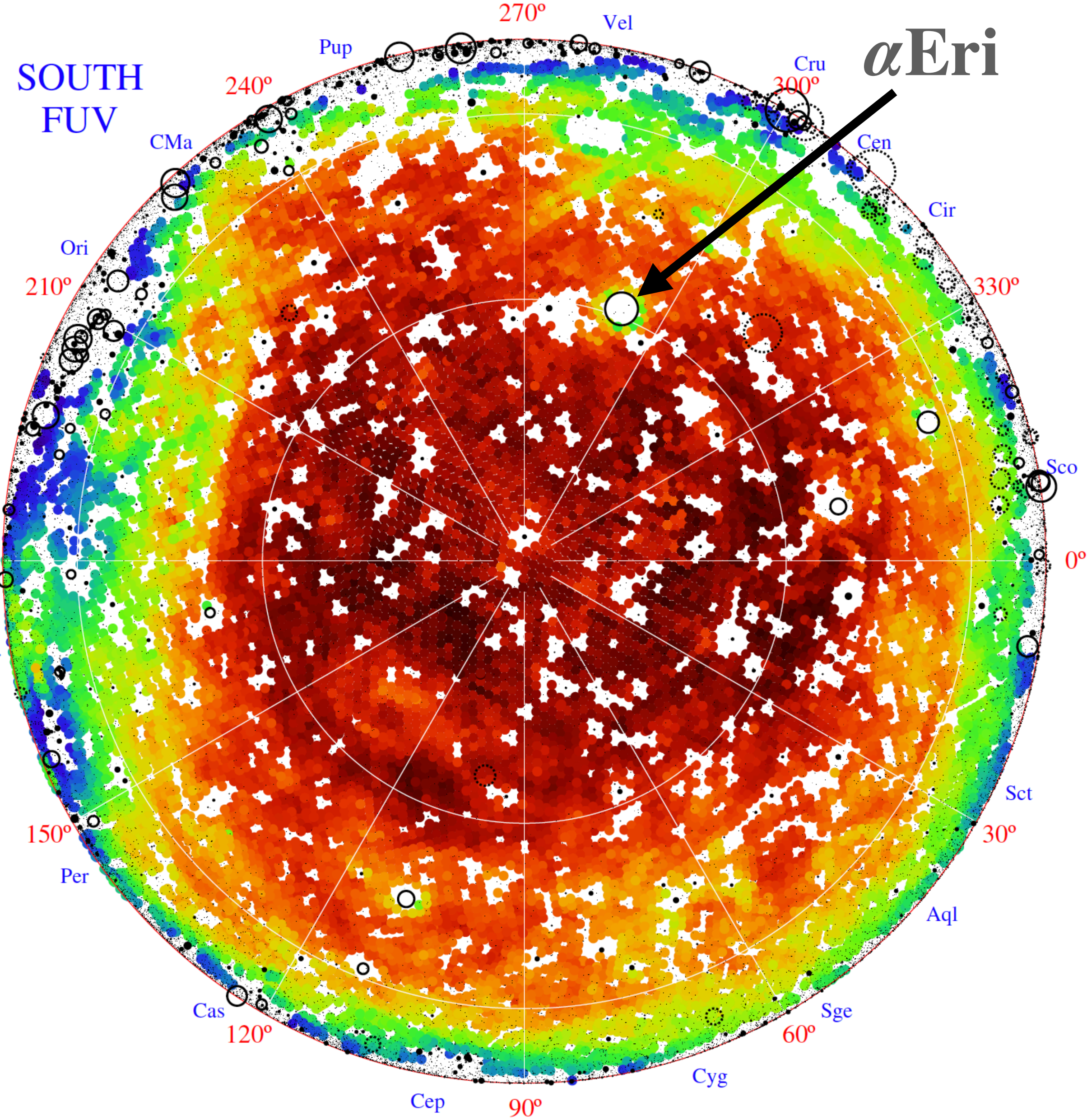
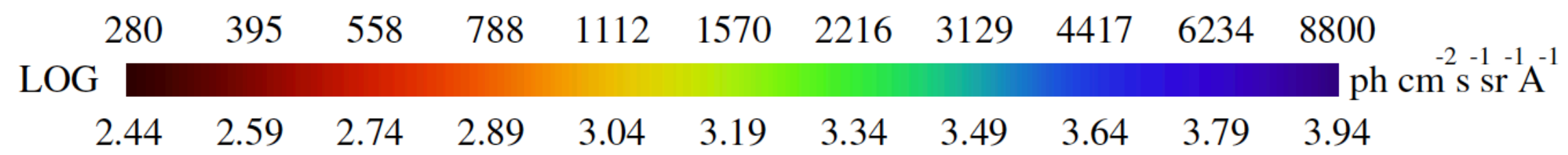


Red: Southern  
Galactic Hemisphere

Blue: Northern  
Galactic Hemisphere







**My conclusion is ...**

**that New Horizons,  
with its **Broad Team of Super Experts****

**IS an **HISTORIC PLANETARY** mission**

**and also has the **POTENTIAL**  
of becoming an **HISTORIC ASTROPHYSICS** mission !**

