Stof tot Nadenken

Summer Research 2020

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also acknowledging Bhairavi Chandersekhar,
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Brief Introduction to Astrophysical Dust

Dust as Nuisance

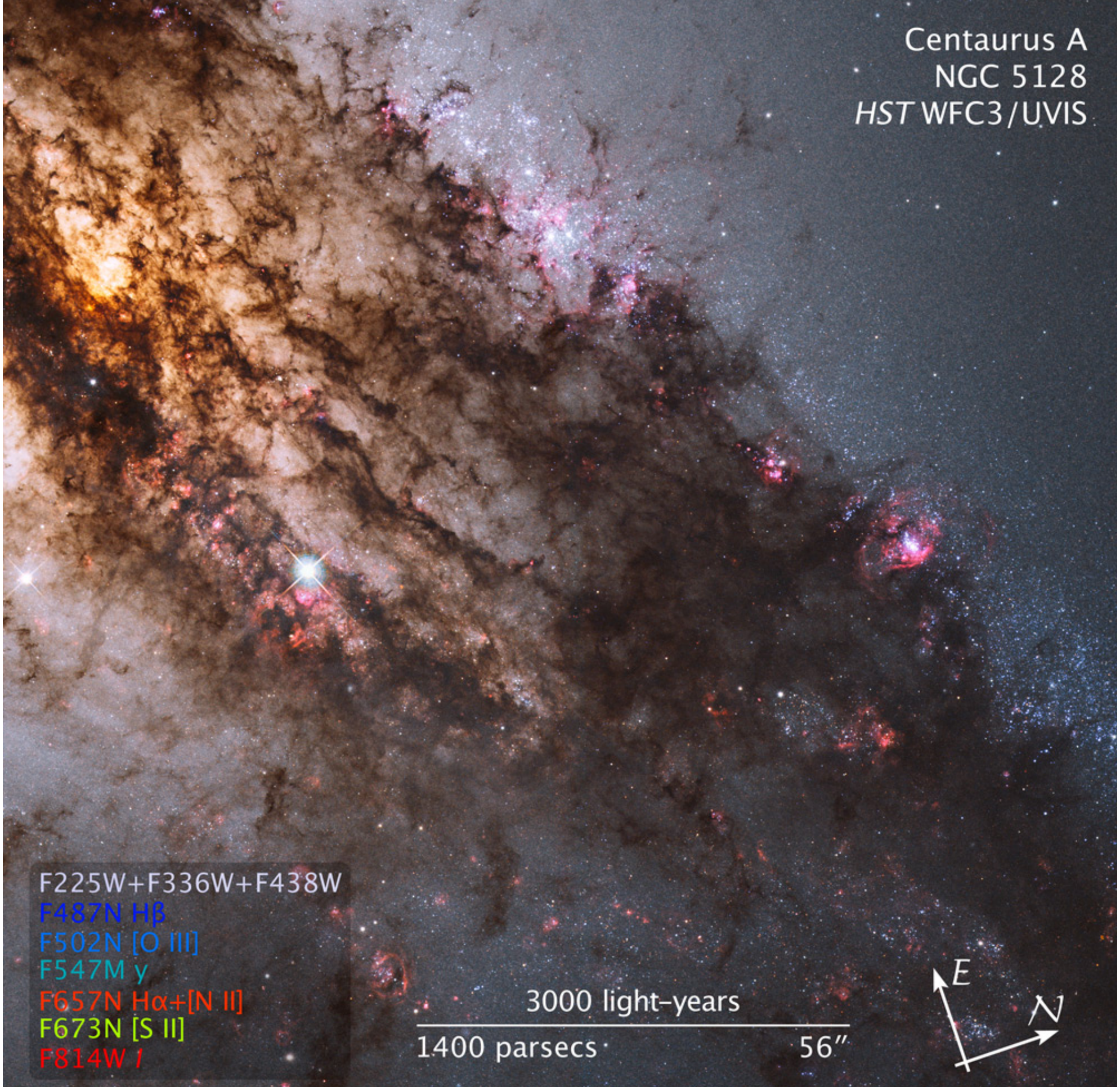
dust in the interstellar medium
dust and extinction; the distance to
Standard Candles; cosmology

Dust as Opportunity

time delays, 'seeing the past';
finding counterparts to gravitational wave sources

the Milky Way over the Hudson Valley

credit: Nicholas Isabella


Centaurus A
NGC 5128
HST WFC3/UVIS
F225W+F336W+F438W
F487N Hβ
F502N [O III]
F547M y
F657N Hα+[N II]
F673N [S II]
F814W *I*
3000 light-years
1400 parsecs
56″
E
N

Astrophysical Dust

Just like in your house:
carbon-rich or silicate particles, size ~ 0.1-1 μm

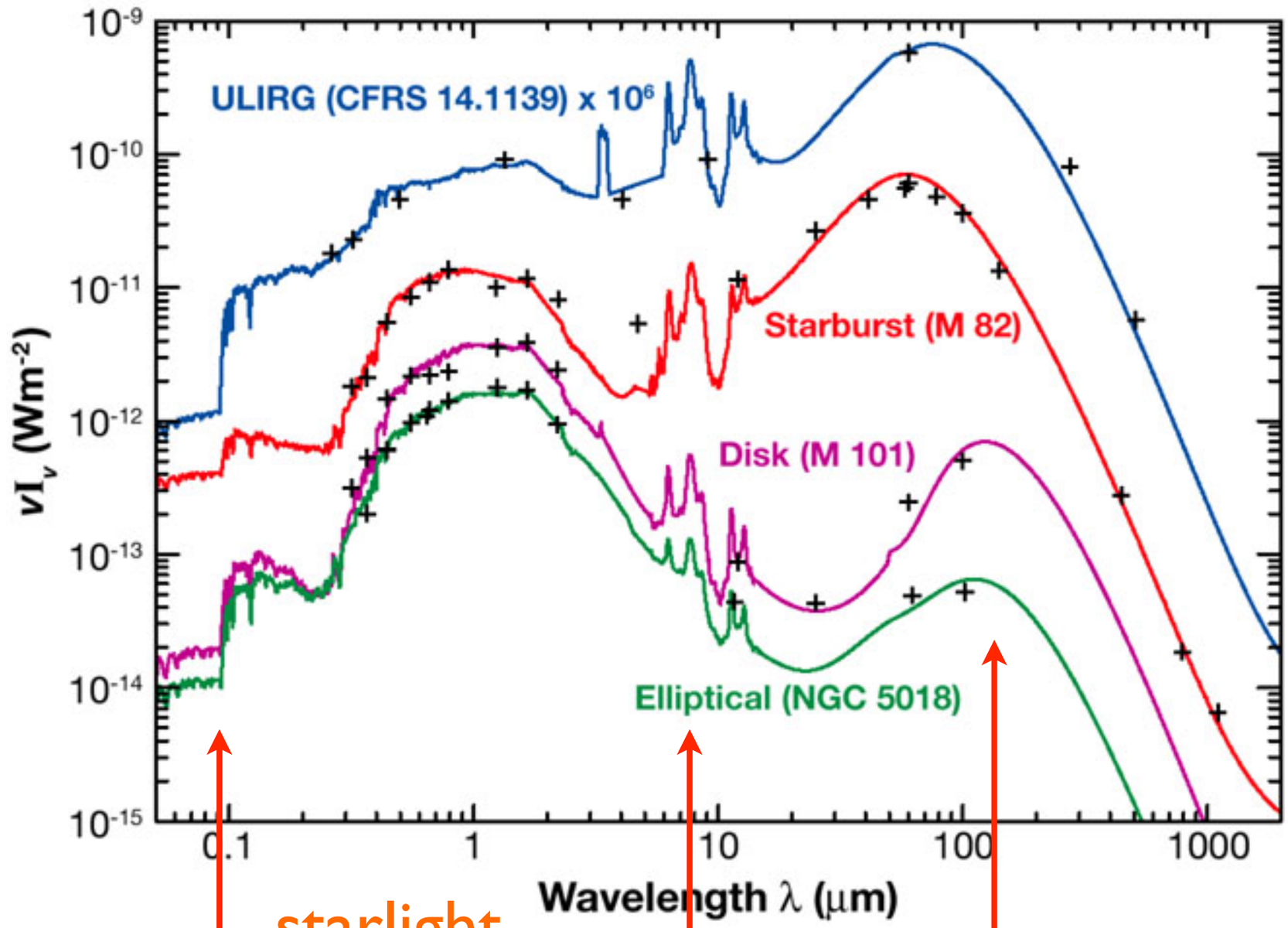
Sources: atmospheres of cool, evolved stars; exploding massive stars; maybe some of it forms 'in situ'

particles of radius *a* scatter light of wavelengths $\lambda \lesssim a$
(significant phase shift across the particle)

what does dust do? It 'reddens' and 'extincts' light
(extinction = absorption + scattering)

Causes progressive *reddening* of stars with increasing distance
Degree of reddening also proportional to *total* light loss

emission from warm dust often most luminous component of rapidly star-forming galaxies; *visible all across the Universe*



starlight

H Ly edge

silicates, C

enormous black body: 100 K dust

[Galliano 2004]

1. physical properties of astrophysical dust

many open questions-
for instance: what form is most of the interstellar carbon?
graphite? *graphene*? polycyclic molecules?

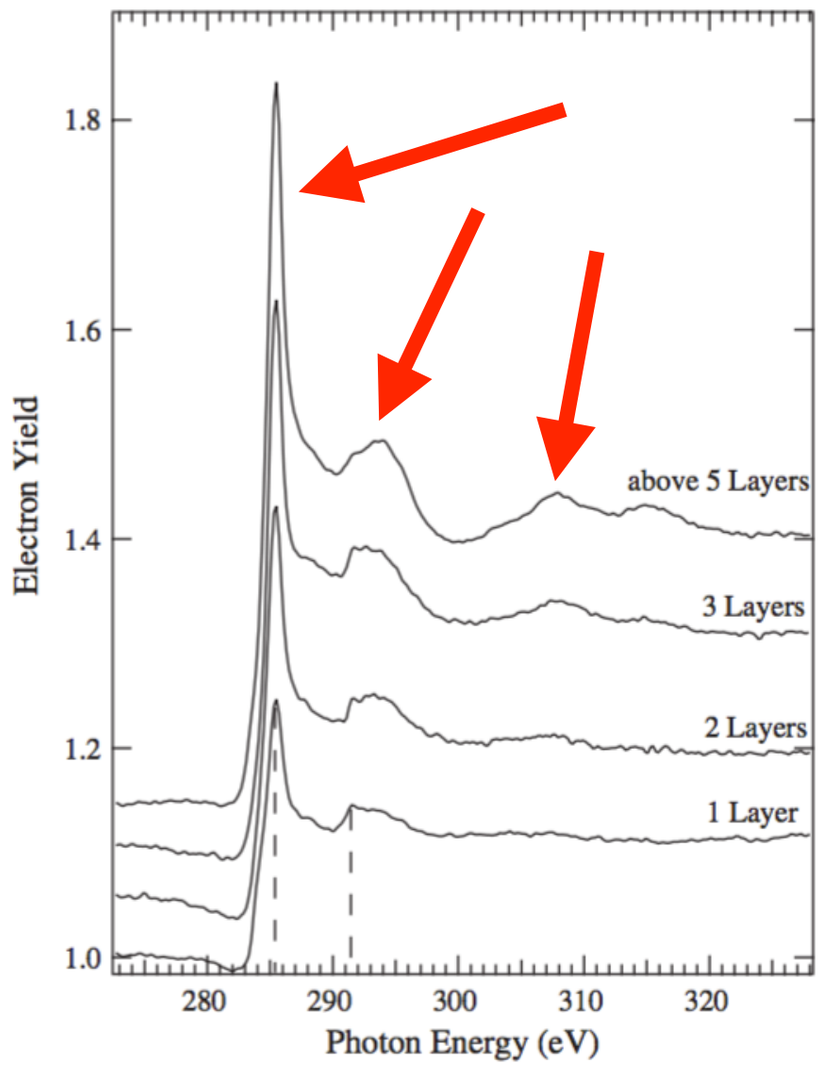
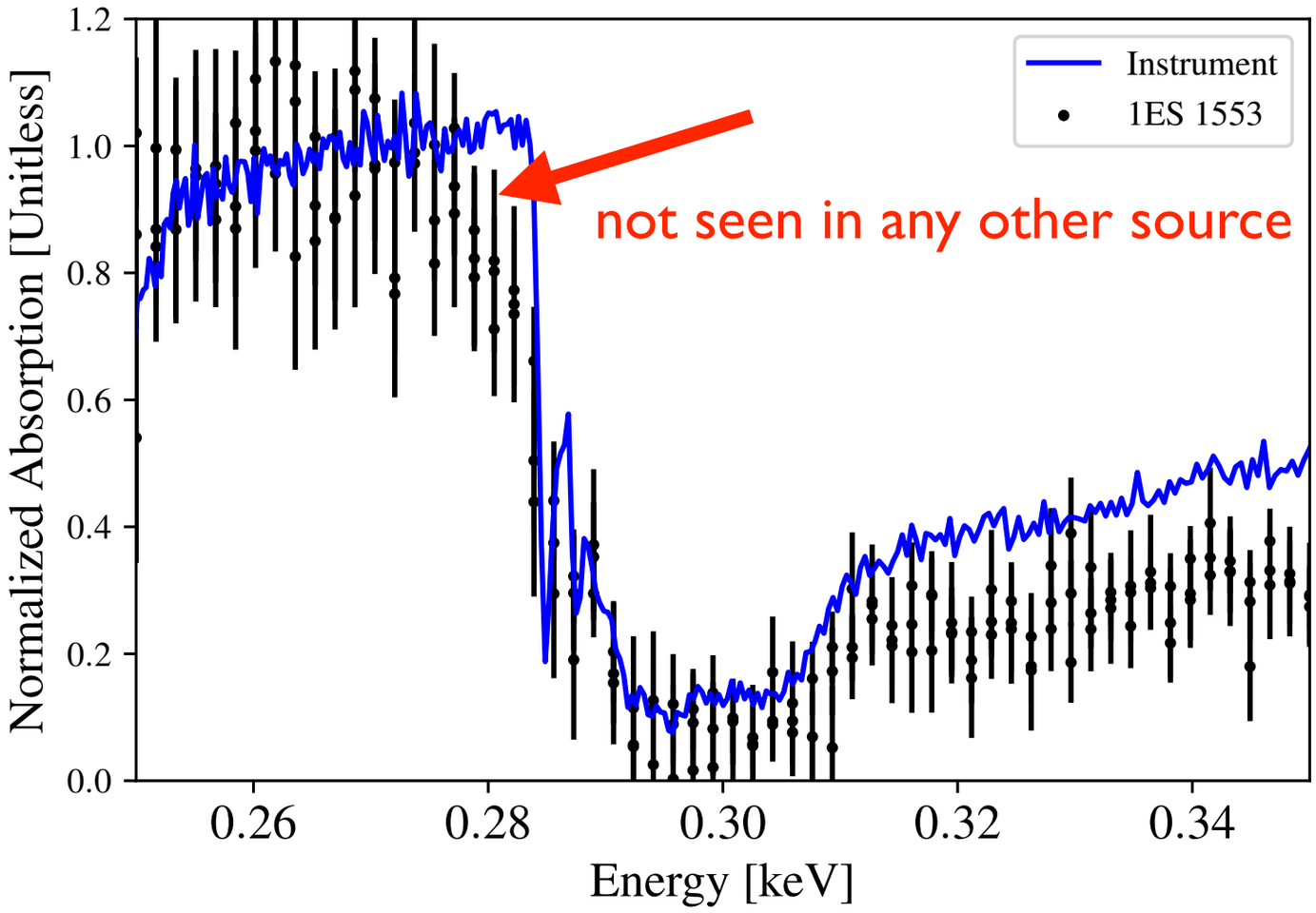


FIG. 2. C *K*-edge photoabsorption spectra of (from the bottom): graphene, bilayer graphene, and FLG samples. The dashed lines show the C 1*s* π^* and C 1*s* σ^* transitions.

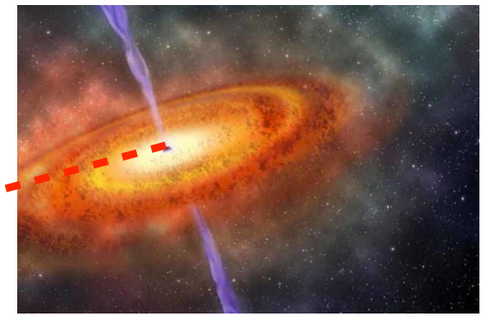
X-ray spectroscopy can tell us:

absorption spectroscopy
of the interstellar medium around the carbon-K edge (280 eV), using the
Low Energy Transmission Grating Spectrometer
on the Chandra *X-ray Observatory*
(with John Staunton)



X-ray spectrum of the quasar 1ES1553+113: 'red shoulder' on n=1-2 absorption line in neutral interstellar C: *scattering by graphite particles!*

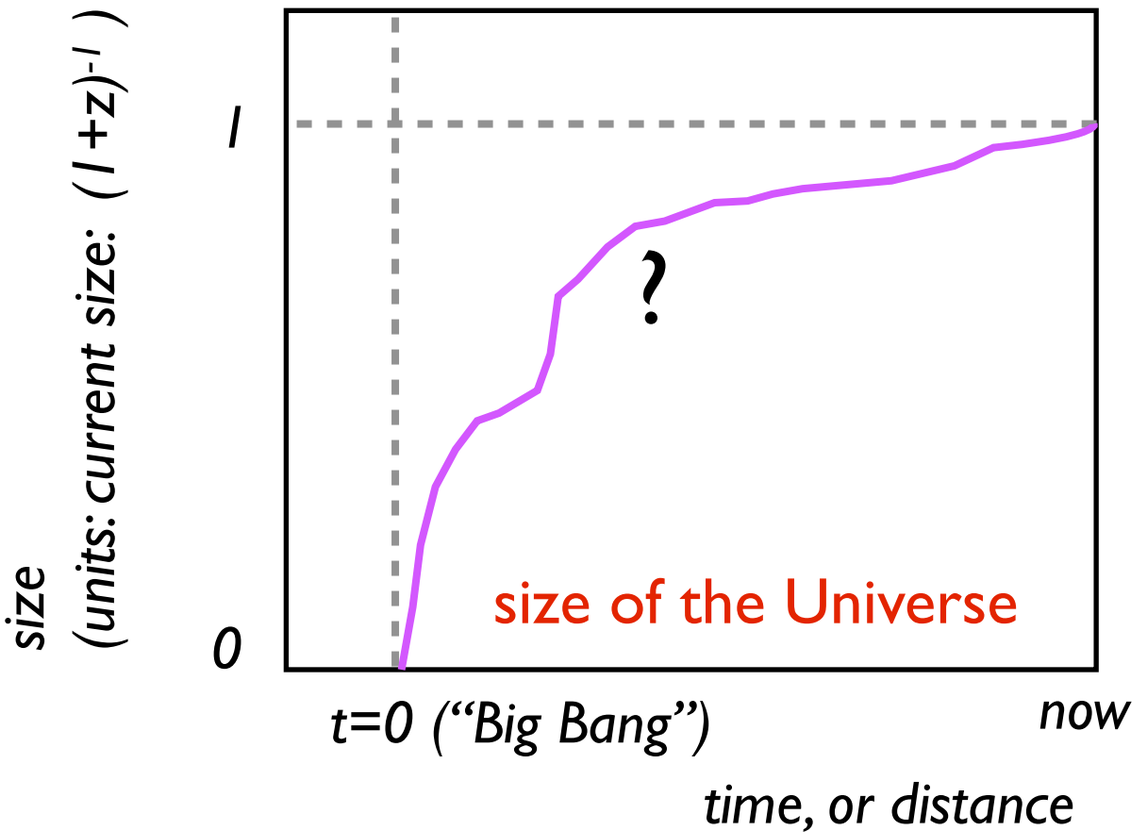
(and maybe detection of polarized X-rays and alignment of graphite particles in Galactic magnetic field…)



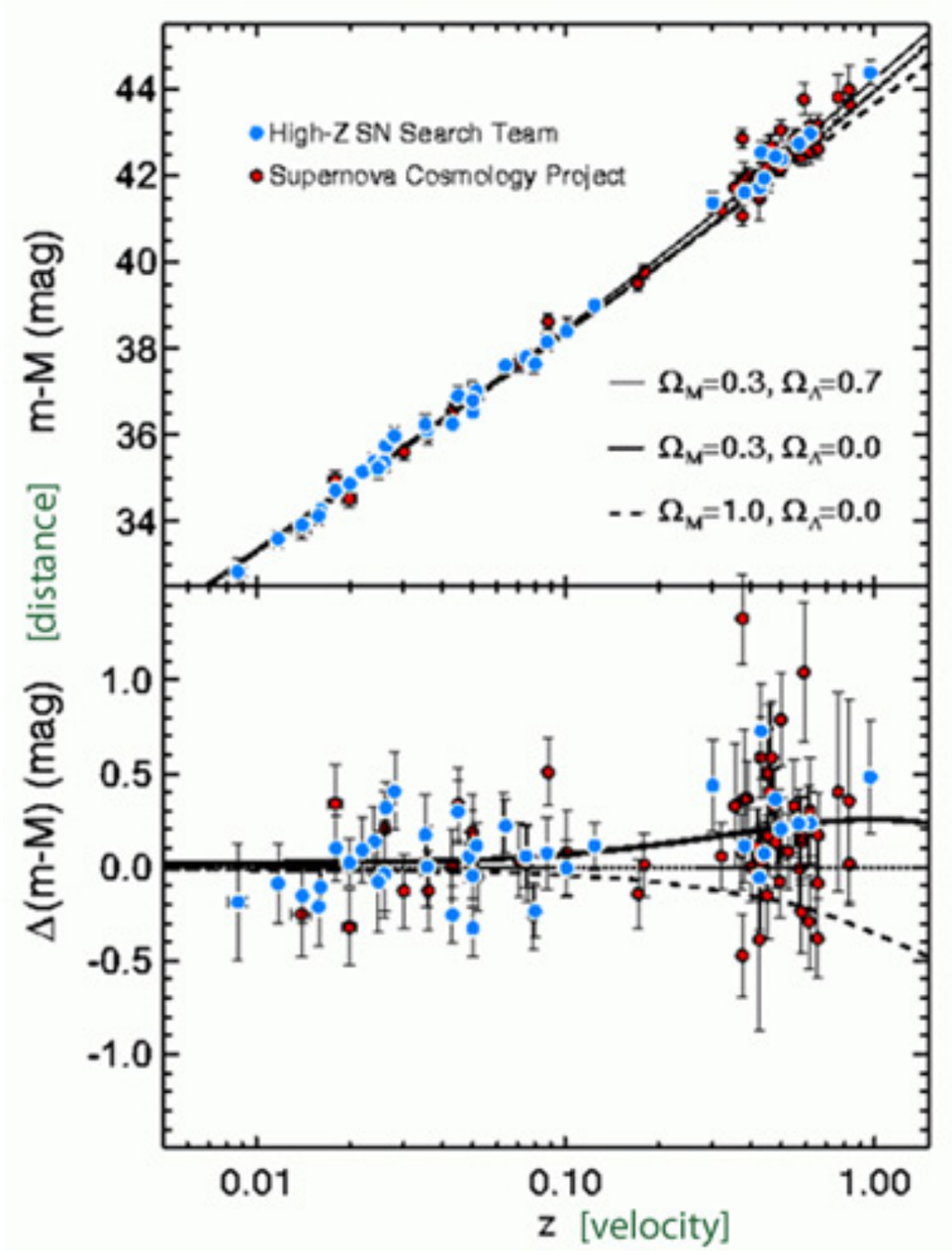
strong extragalactic X-ray source (quasar)

interstellar medium

2. Cosmology, the Cosmic Distance Scale, and Intergalactic Dust



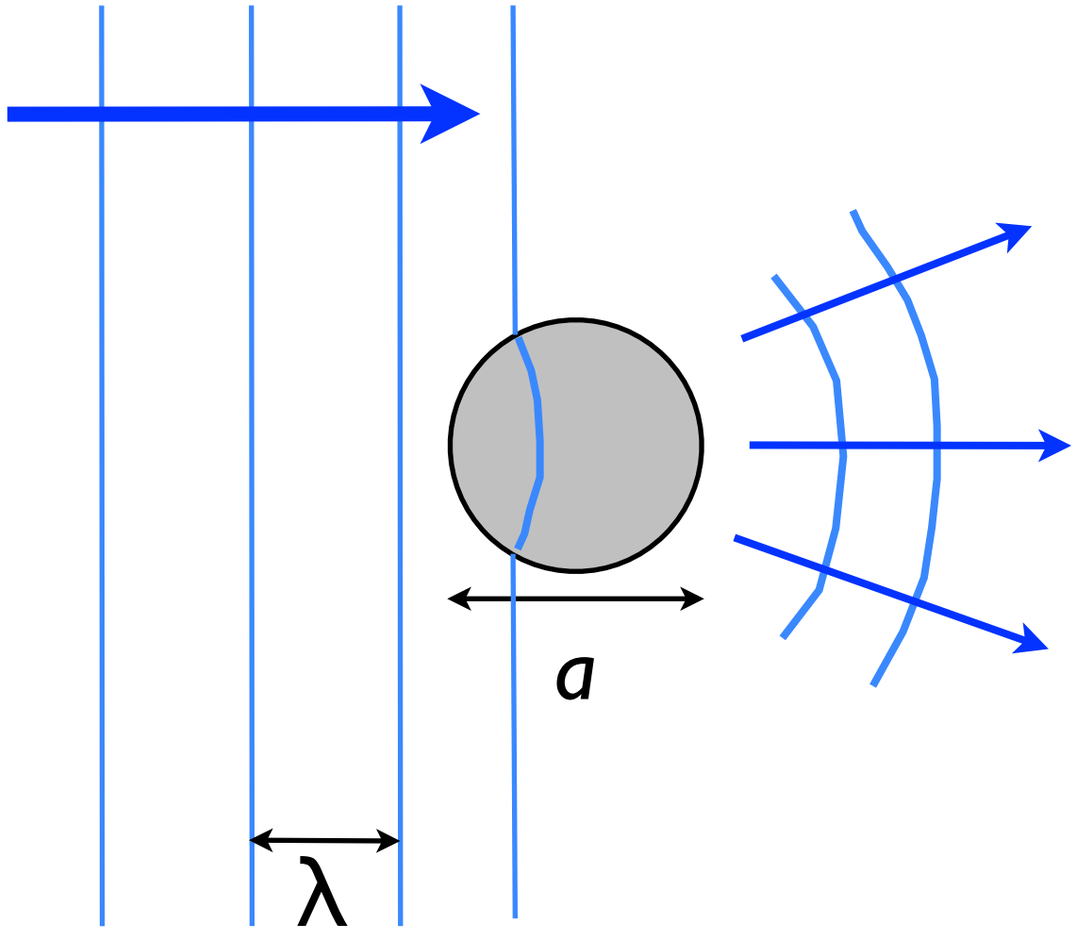
All Type Ia Supernovae identical luminosity (*'Standard Candles'*)[?]; plot measured brightness compared to brightness predicted from 'coasting' expansion: sources *dimmer* than expected: *expansion speeding up?*



© High-Z Supernova Search Team.

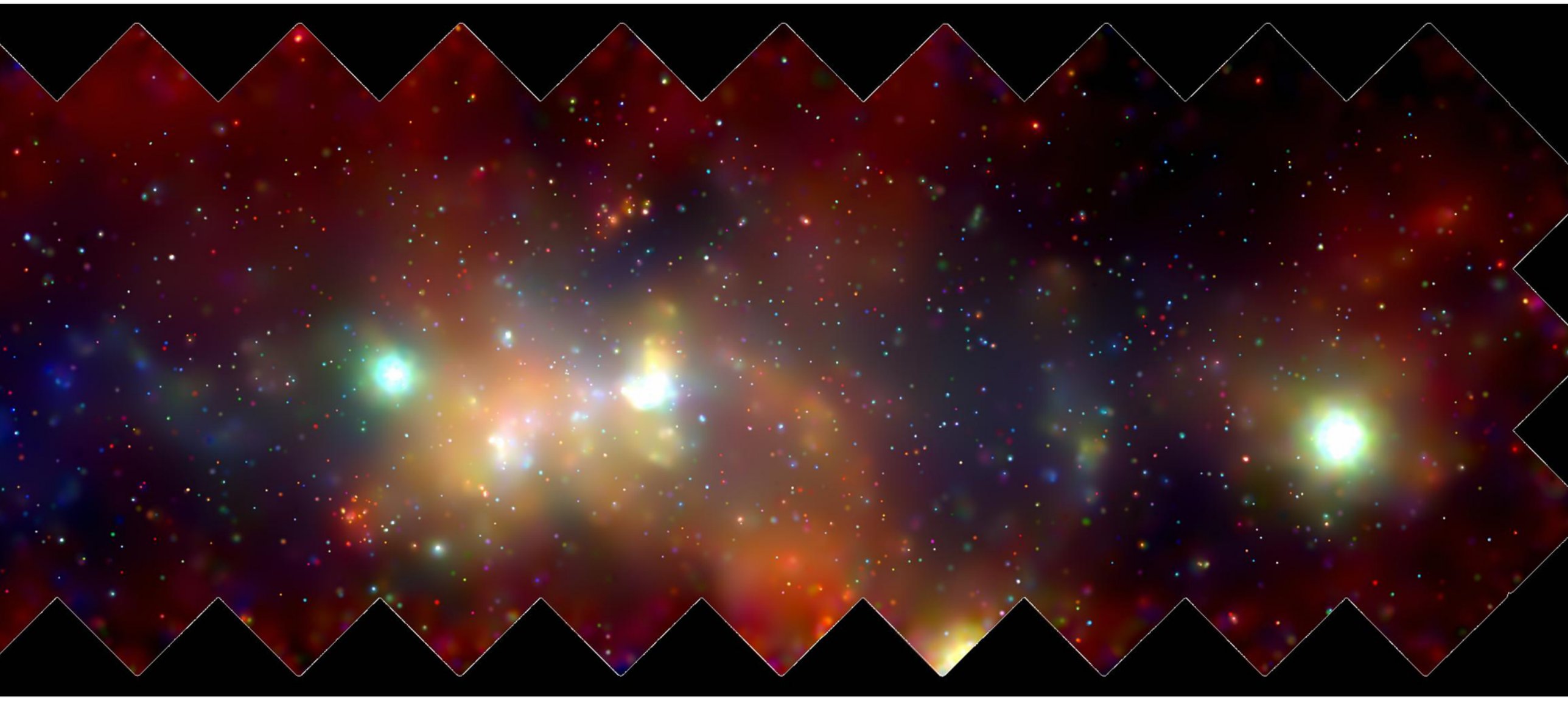
But *intergalactic dust also dims the light from distant objects!!*
And we don't have an extragalactic 'standard crayon'(*) to detect reddening...

Dust particles very effectively scatter X-rays!!
Search for X-ray dust scattering halo around bright distant X-ray source



invoke Huygens' Principle;
scattering angles ~ λ/a ~ arcminutes
for a ~ μm and λ ~ 10 Å

(*) Josh Peek, STScI



X-ray image of the Galactic Center region
Green: X-ray scattering halos around bright Galactic point sources

Daniel Wang, Eric Gotthelf; UMass/Columbia; *Chandra* ACIS image

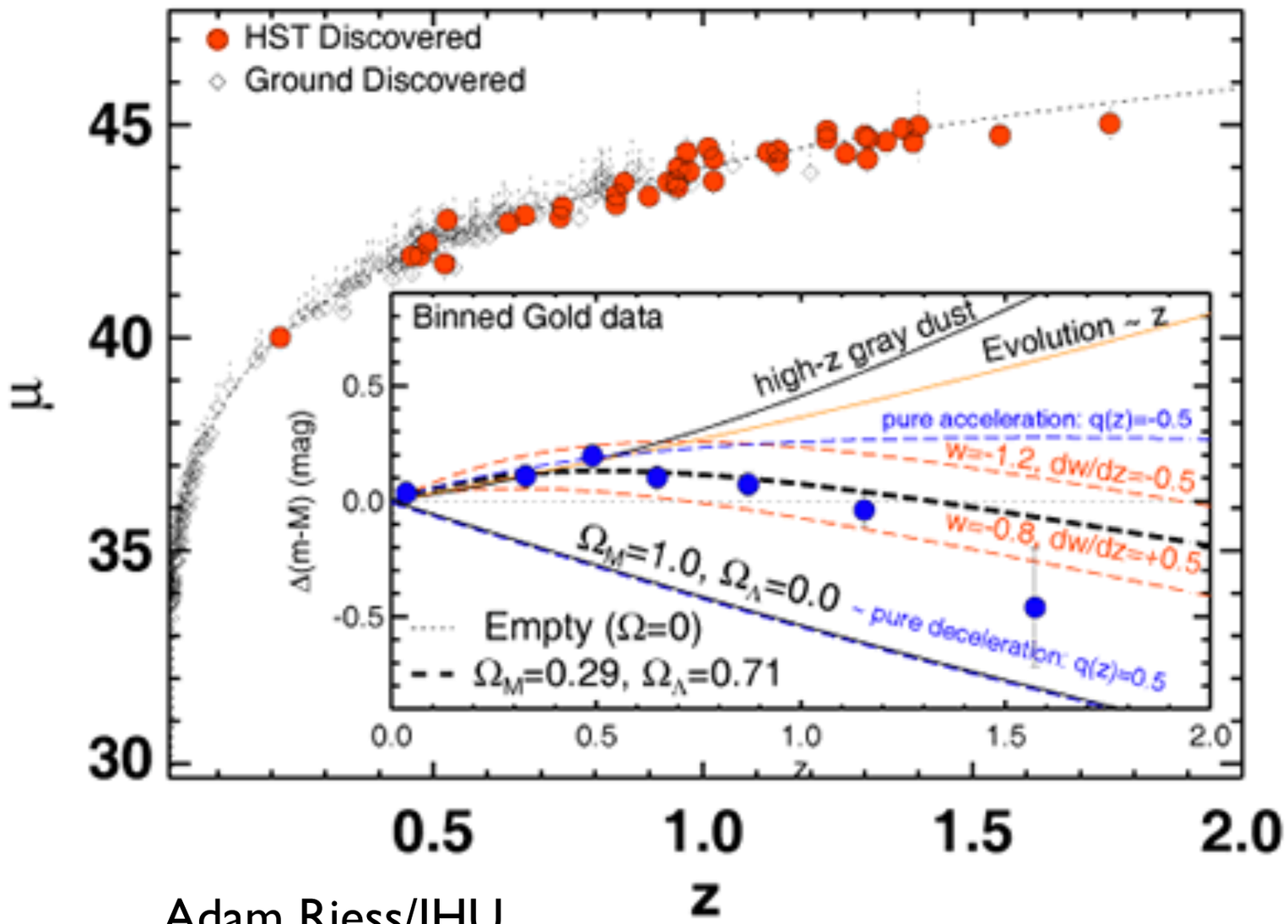
prediction for a dusty Universe

quasar QSO B1508+572, z = 4.31 / *Chandra* ACIS-S

At high redshift ($z > 1$) now see the expected *deceleration* of the expansion (gravity is king, early on)

Consistent with the absence of a bright X-ray scattering halo: 'dimming' at $z < 1$ not due to extinction

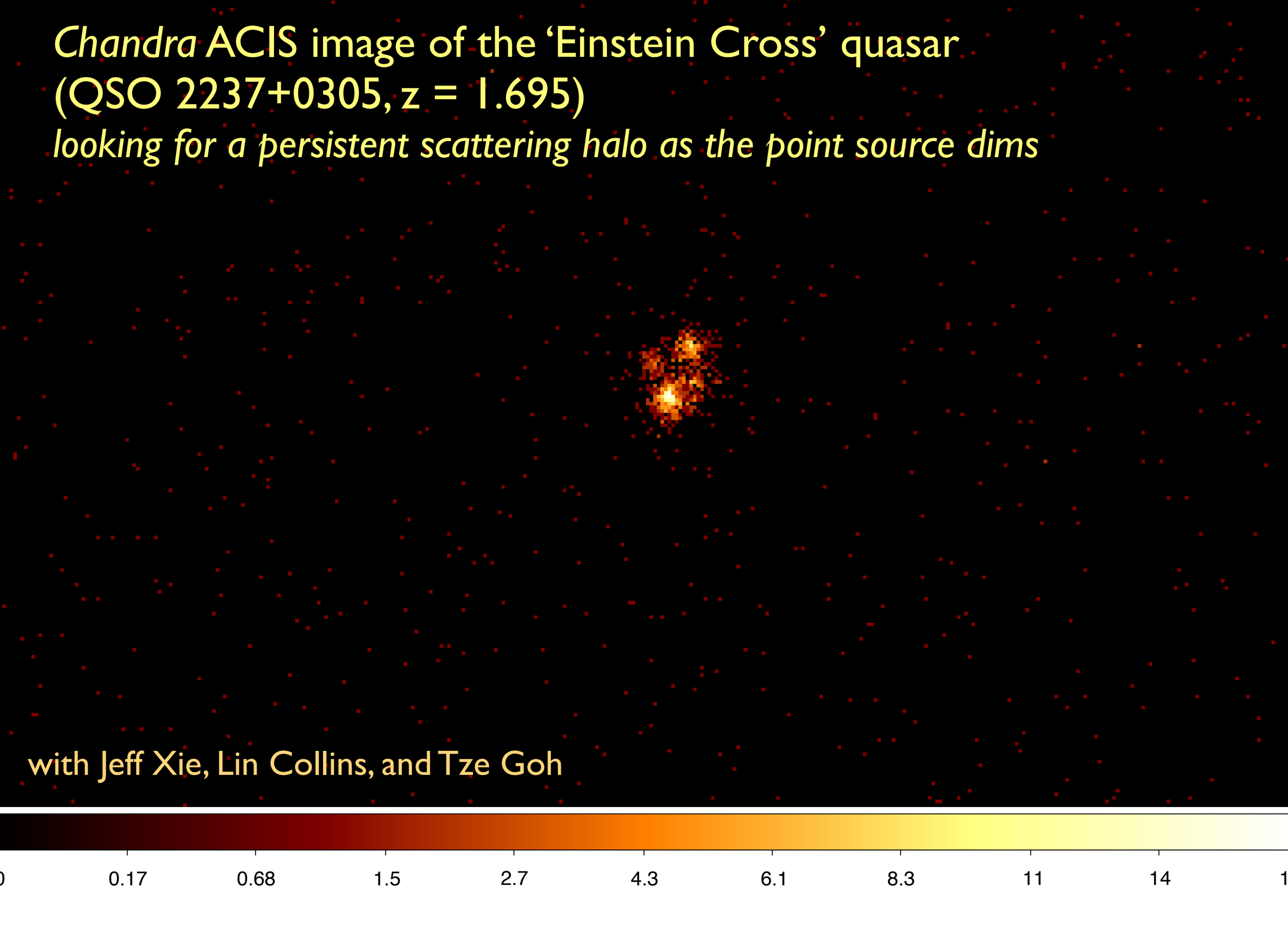
But...any extinction will still skew the Hubble Diagram and the expansion measurement !



Adam Riess/JHU

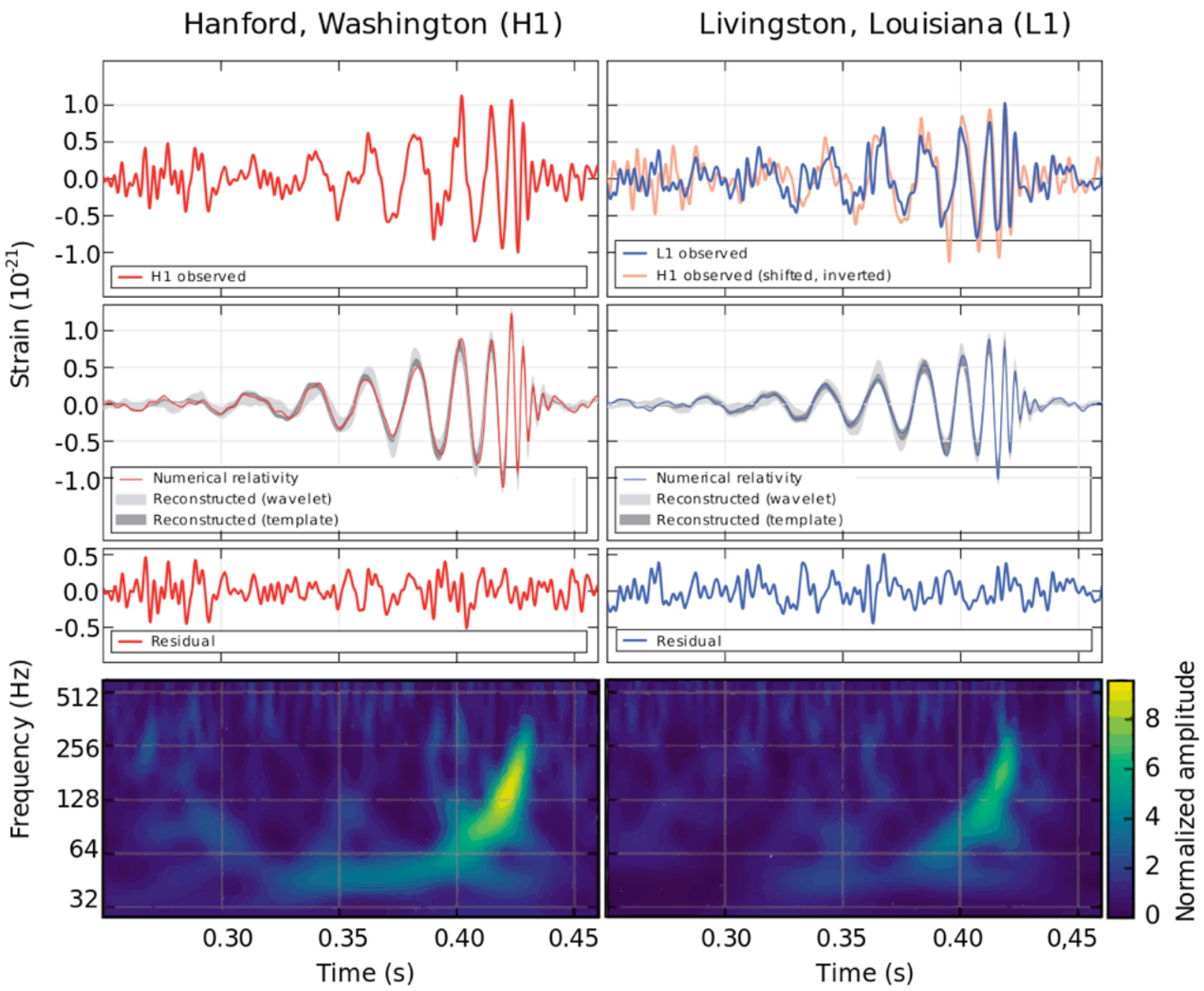
Chandra ACIS image of the 'Einstein Cross' quasar
(QSO 2237+0305, z = 1.695)

looking for a persistent scattering halo as the point source dims



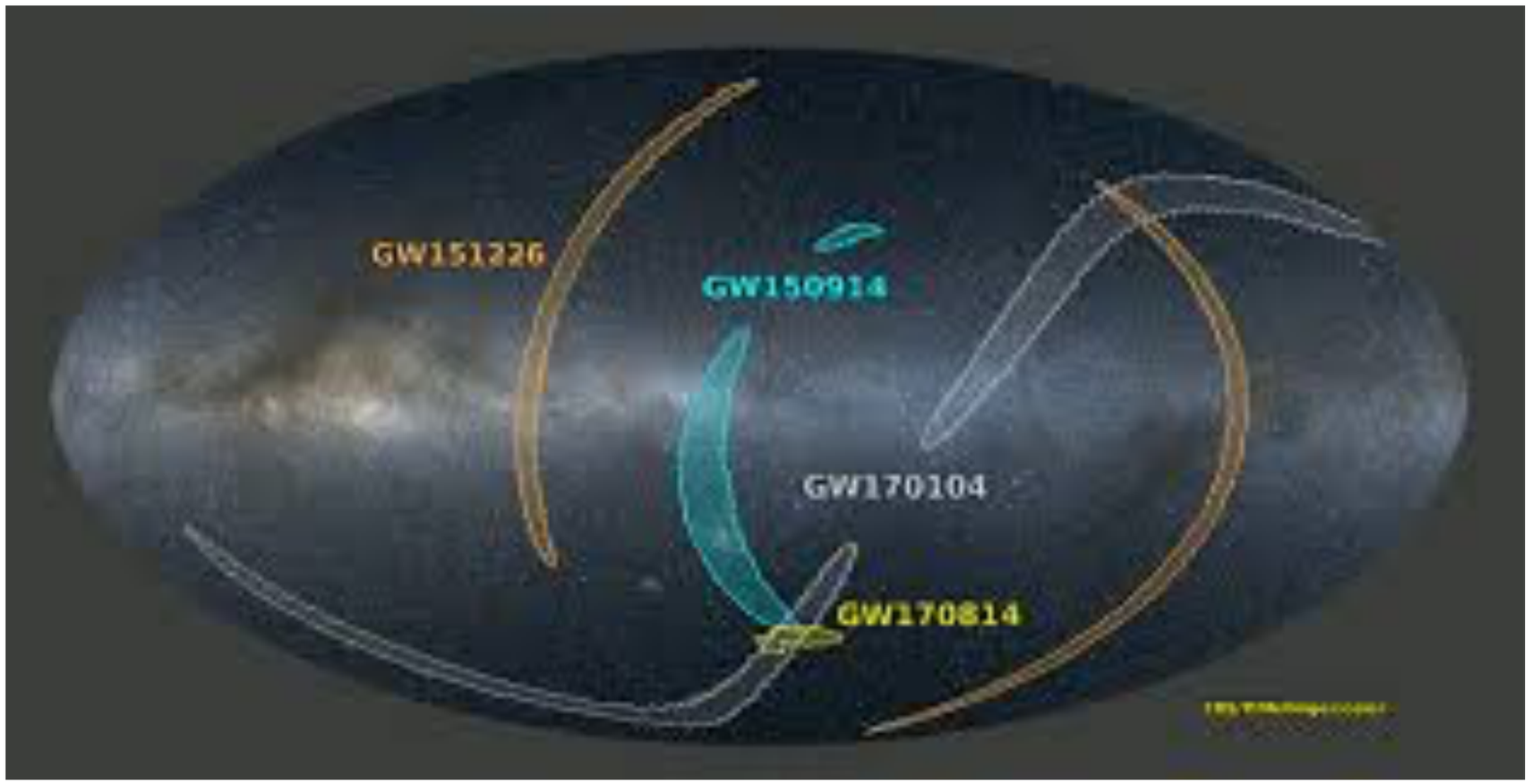
with Jeff Xie, Lin Collins, and Tze Goh

3. Finding and Locating the Counterparts to Gravitational Wave Sources, and the *Standard Siren*



GW source: from shape of the 'chirp', get *luminosity distance* in absolute measure! Combine with redshift: cosmology.
For redshift, need position (host galaxy) to fraction of arcmin...

GW positions uncertain for foreseeable future

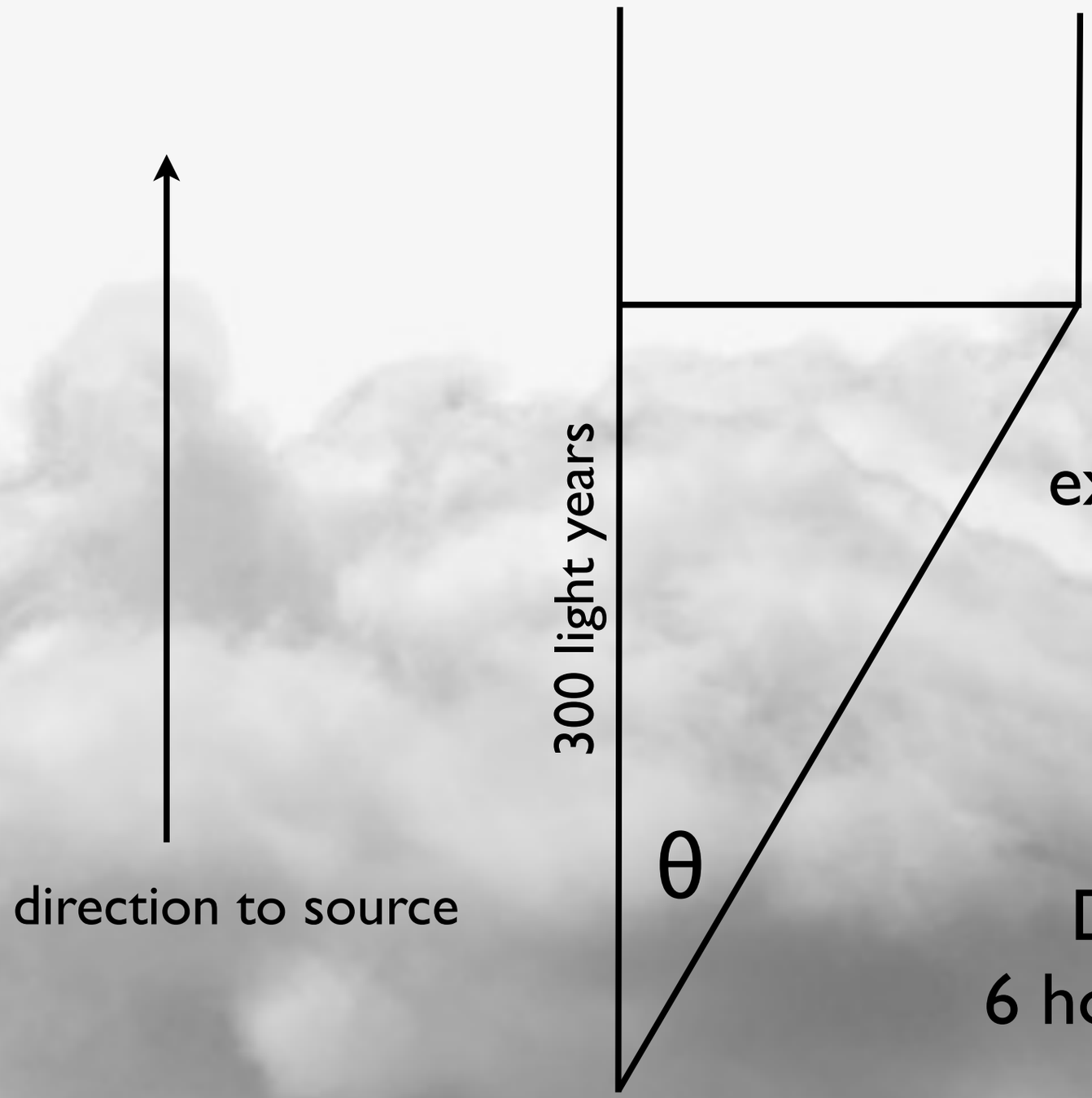


Also, possibly considerable time delay after GW passage

density on sky of possible counterpart galaxies out to z ~ 1:
need accuracy to *fraction of arcmin* for unique ID

What if our Galaxy kept a record in the sky for a day?

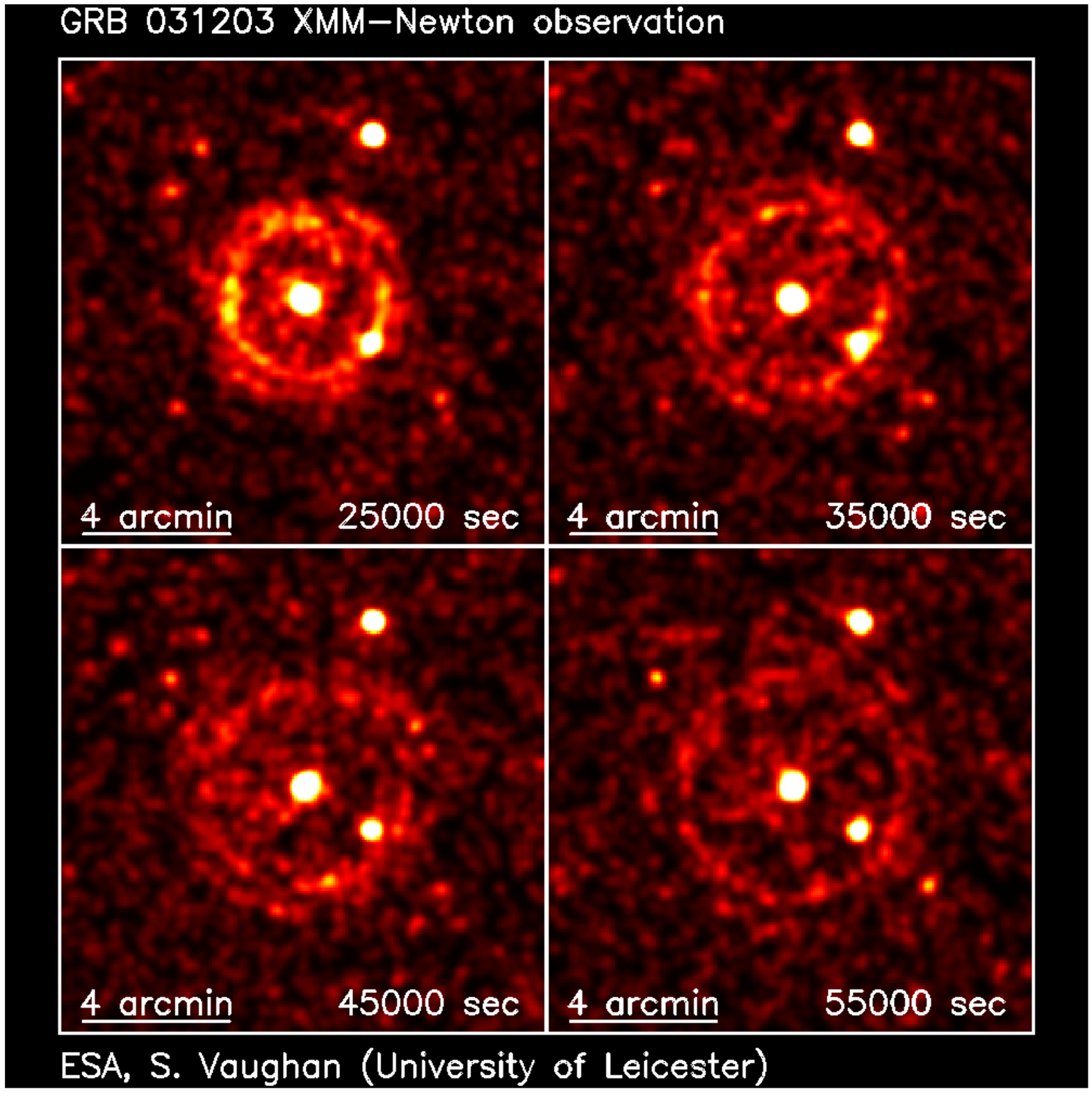
A flash of X-rays would leave an X-ray dust scattering 'echo'!



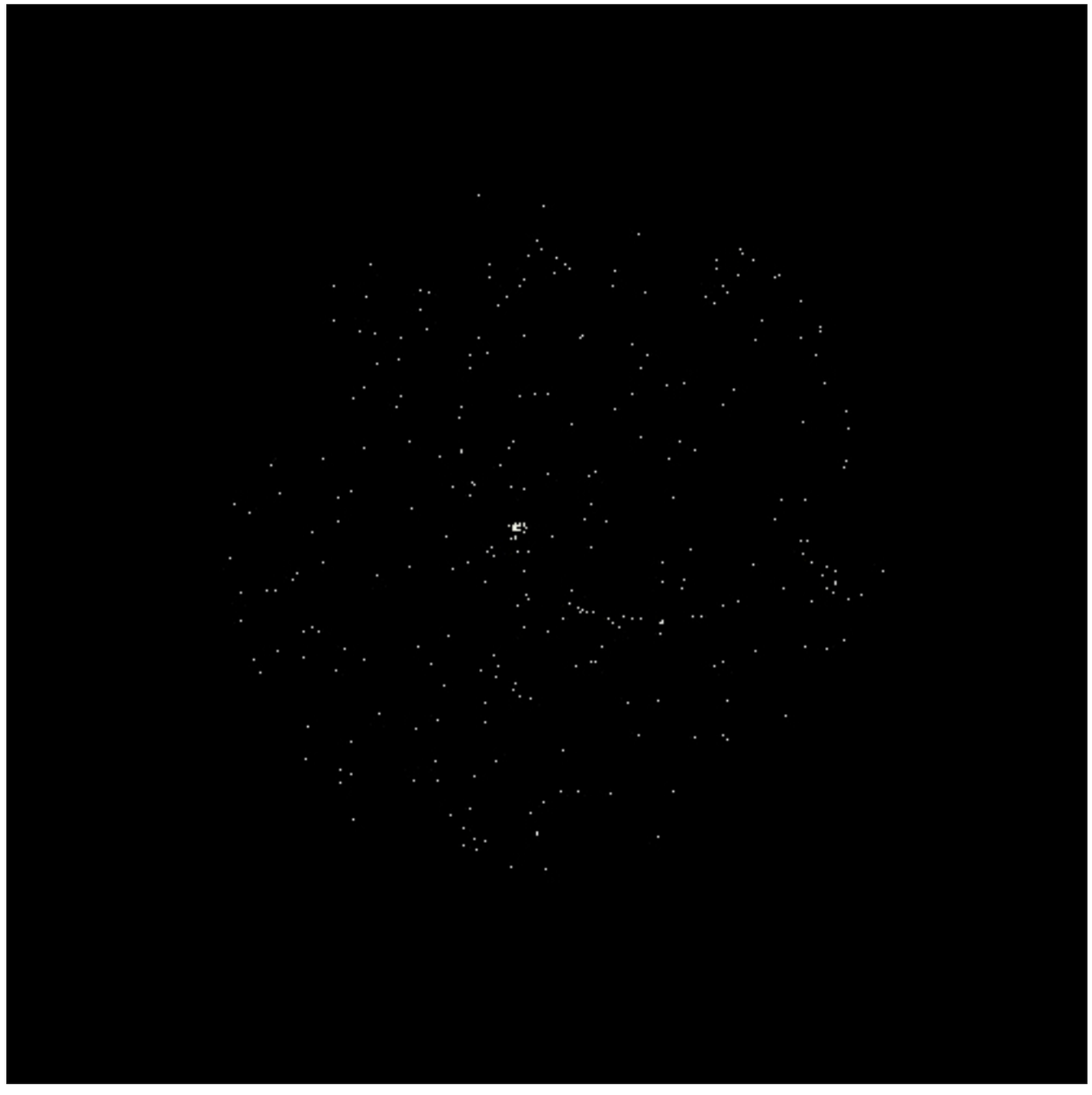
extra light travel time
after direct flash:
$\Delta t = (1/2)\ (d/c)\ \theta^2$

Detect a thin annular halo;
6 hours after, radius ~ 10 arcmin

proof of the idea: halos seen after Gamma-ray Bursts

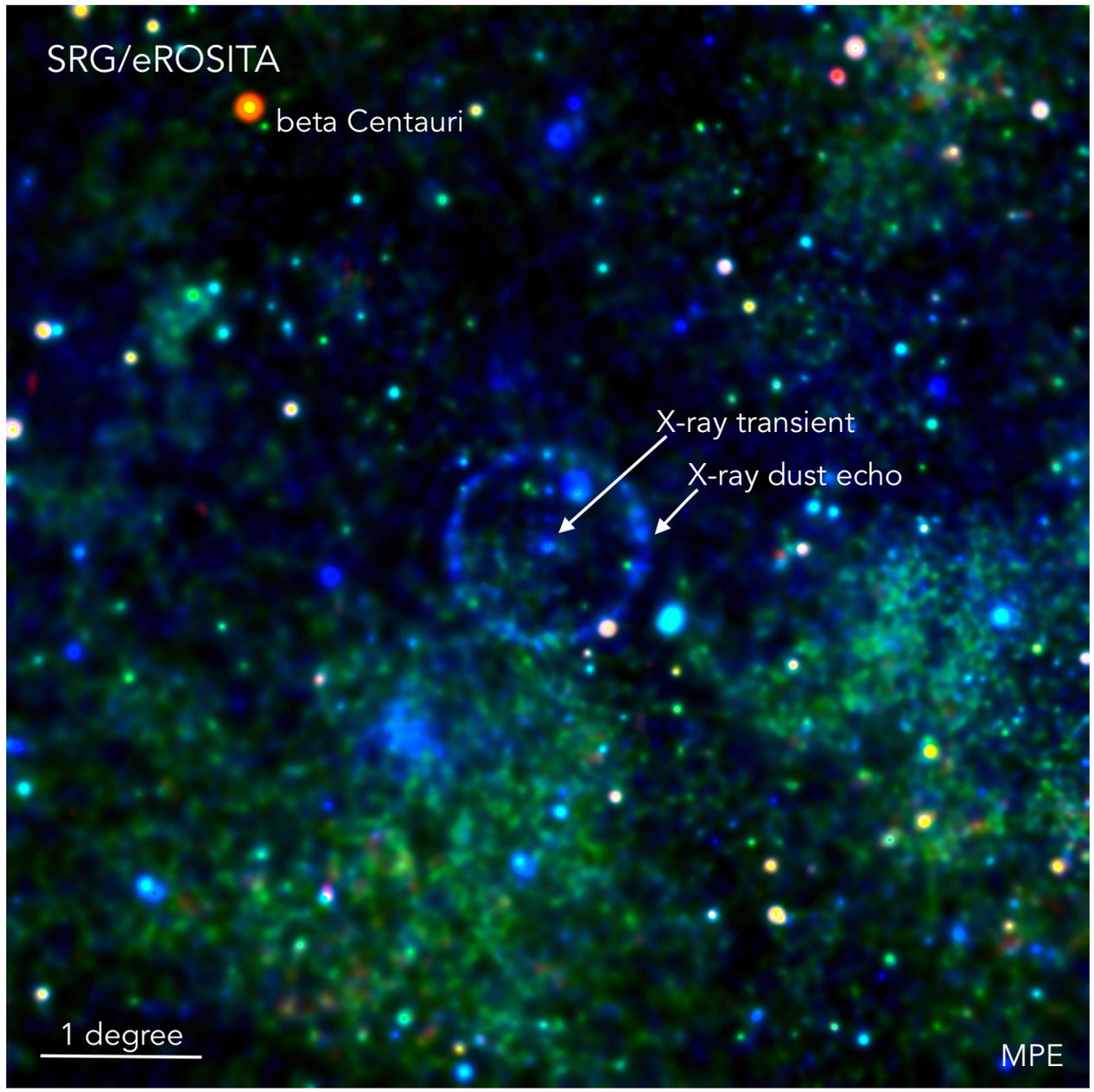


Simulated image of a field 0.5 x 0.5 deg, 1000 sec exposure;
6 hours after GW passage; dust at 300 lt yrs
Corresponds to X-ray telescope on *Swift* satellite



with Richard Nederlander, Joheen, Margo, Susannah, Kate, Kate, Kyle, Tanisha, Hunter

and if a GW source went off in the direction of the Galactic Center, there could be an echo for a *decade!*



Proof of this idea: the eROSITA survey sees an echo from an outburst from MAXI J1348-630 two years ago!

notes on Why and How did I become a scientist

Laboratory for Space Research, Utrecht,
the Netherlands


MAX. 215 KG
esa