Cosmic backgrounds due to the formation of the first super-massive black holes

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The microwave background and its ripples

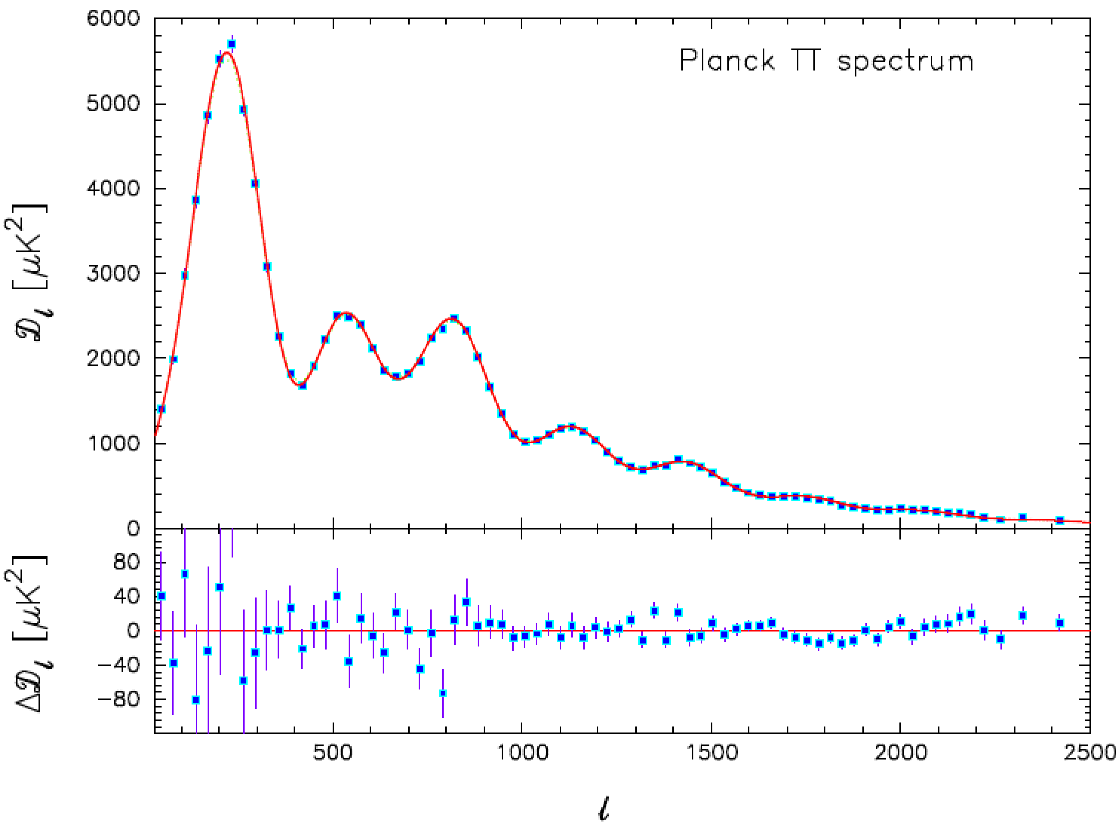

Figure 1 Cleaned temperature power spectrum. Source Planck Coll. 2013 XVI 2013. This does not show a constant background, many overlapping extended sources nor many point sources. Some of these could be searched for in polarization. **Polarized background ripples partially caused by gravitational waves left from <u>inflation</u>. Model Cold Dark Matter (CDM), or Warm Dark matter (WDM), combined with Dark Energy (Λ), so ΛCDM, or ΛWDM?**

Dark night sky paradox? or Olbers' paradox

- Actually already formulated by Kepler in 17th century, and probably earlier by others. Historically known as **"Olbers' paradox"** (1823).
- Think sky volume, concentric spheres of factors of 2 in distance; then every sphere using the same density has 8 times the number of stars/galaxies/... and 1/4 the brightness per object, so factor of 2 in total brightness every time; add it up −> **infinite brightness** of sky.
- Solutions: a) **Density in universe fractal** (Mandelbrot, and earlier/later), average density decreases with volume sampled, so integral can converge
- b) **Age finite** of universe, stars/galaxies/Active Galactic Nuclei (AGN)/... , then integral finite...

Known backgrounds I: The Galaxies and Active Galactic Nuclei (AGN)

- Galaxies and **starburst** galaxies (= galaxies with a temporary **burst of extreme star formation**) correlation Far-Infra-Red (FIR), radio and X-ray emission
- Maximum contribution **moderate redshift**
- Active Galactic Nuclei (AGN: **Big Black Holes**) show a dichotomy in such correlations, with the strongest variation due to radio emission: **radio-loud and radio-weak**
- AGN sometimes combination of starburst with active nucleus, confusing interpretation, but allowing (Ultra High Energy) **UHE nuclei injection**, Cosmic Rays (CRs); so UHECRs

Known backgrounds II: The Galaxies and Active Galactic Nuclei (AGN)

- AGN all seem to have **relativistic jet**; if that jet pointed at us, and dominant, huge selection effects, and sometime flat spectra right from radio through the infrared (as for S5 1803+78)
- Selecting at 5 GHz, or 6 cm radio wavelength, **half of all compact radio sources pointed at us**
- There we can expect also at least these broad classes in their corresponding radio/ FIR/ X-ray/ γ-ray/ UHECR/ gravitational wave (GW)/ neutrino emission
- In all known source classes maximum contribution at moderate redshift as well - but much we do **not know**
- Testable via **compact radio source counts**

UHE CR background: $> 10^{18.5}$ eV

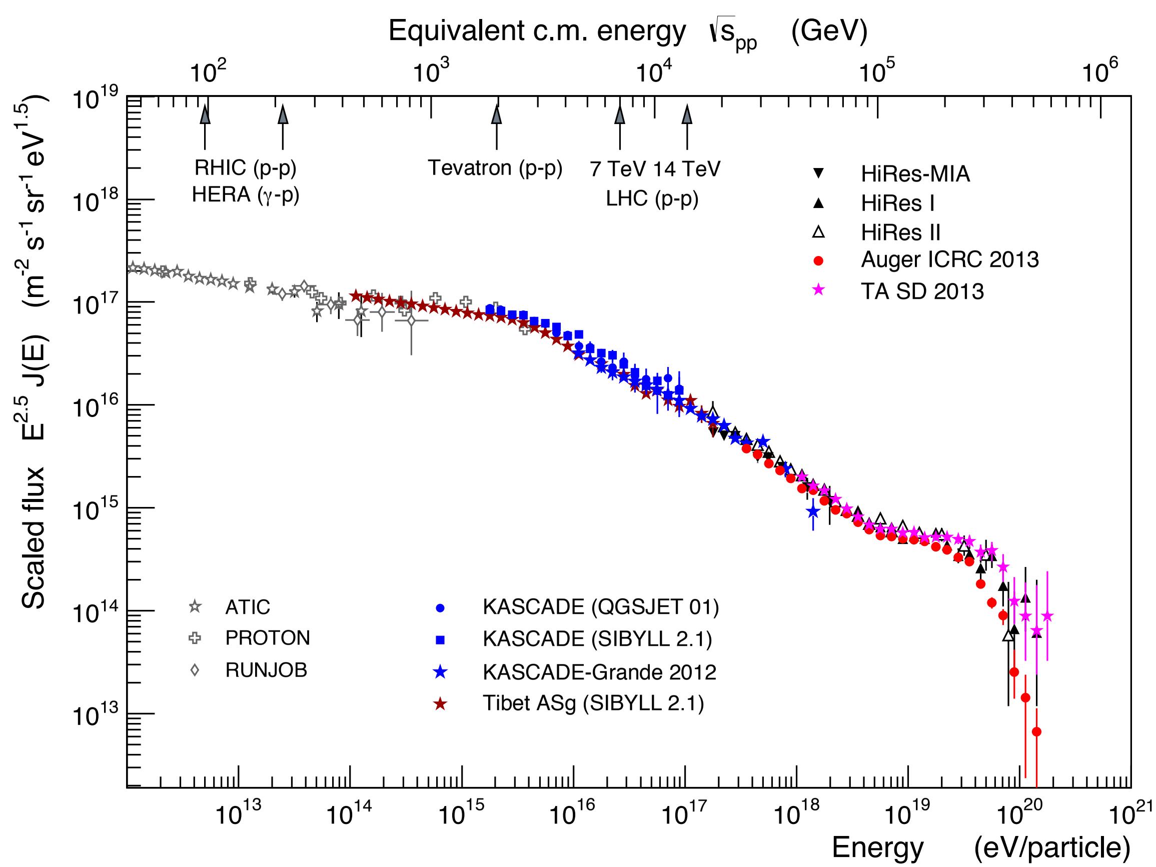

Figure 2 The cosmic ray spectrum above TeV; note knee, ankle. In Erice 2014 lecture he says <around 10^{18} eV 60 - 80 % of events are extragalactic protons >. Question: How many Supernovae contribute CRs near 10^{15} eV to 10^{16} eV, and yet allow the spectrum to be to show such a well-defined kink? Source: Ralph Engel Sep 18, 2013

UHE heavy nuclei > $10^{9.5}$ GeV

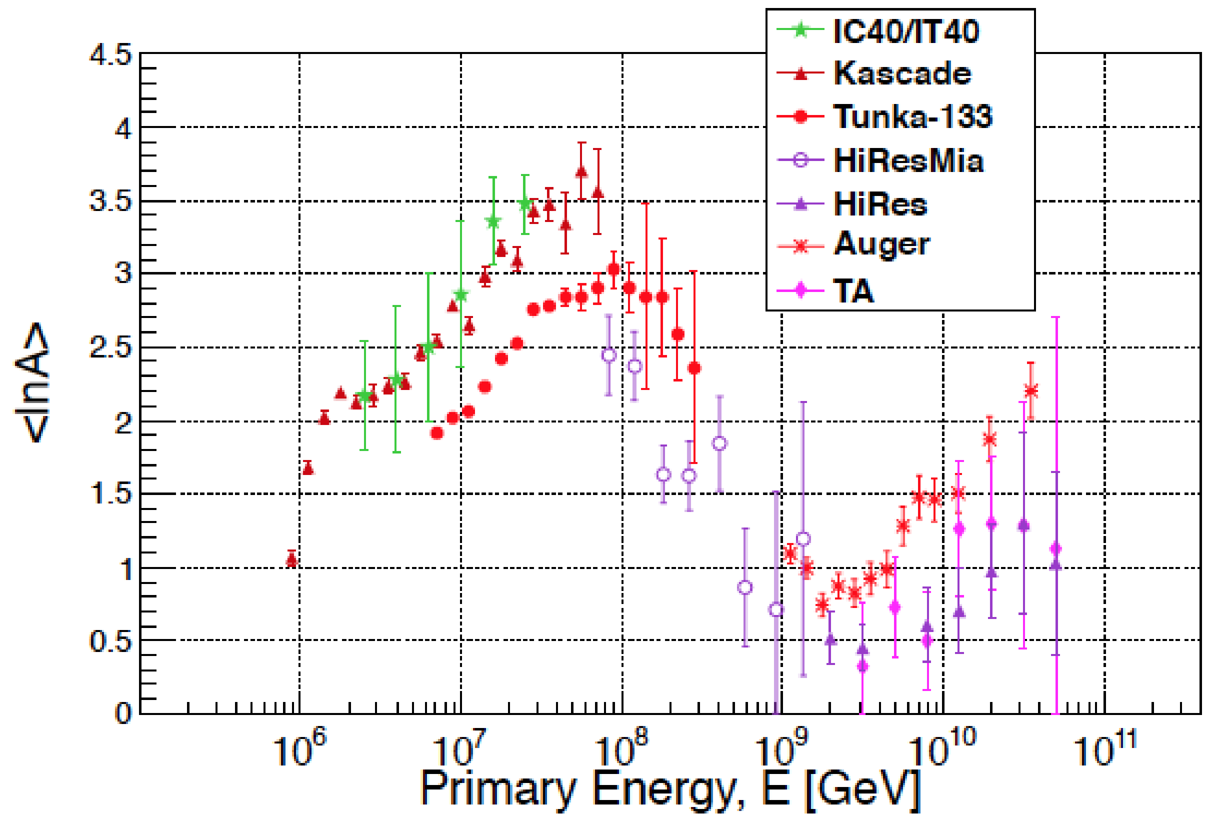

Figure 3 Gaisser, Stanev & Tilav 2014; $< \ln A >$; when comparing TA and Auger, consider the error bars. Examples: 1) 25 % each of H, C, O, Fe give $< \ln A > = 2.3$, and 33 % of each C, O, Fe give 3.1, while pure H gives 0, and pure Fe gives 3.9. Source: Serap Tilav 2014 Erice lecture, p.6

The Auger sky $> 10^{10.74}$ GeV: Cen A?

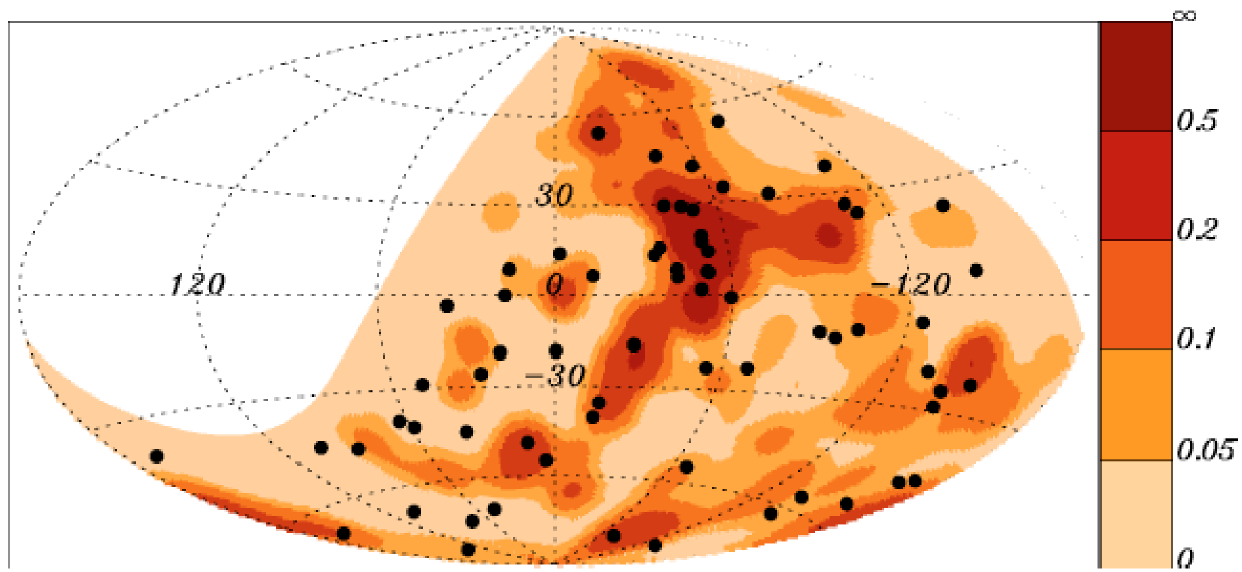

Figure 3:

Arrival directions of cosmic rays with energy $E \geq 55$ EeV detected by Auger (black dots) in an Aitoff-Hammer projection of the sky in galactic coordinates. The solid line represents the field of view of the Southern Observatory for zenith angles smaller than 60°. Overlaid is the density map of AGN of the 58-month Swift-BAT catalog, smoothed with an angular scale of 5°. Source: Abreu et al. (2010).

Figure 4 Arrival directions of Auger events. Galactic Center (GC) at center. If these events are heavy nuclei, then they come from only rather small distances. Source Kotera, & Olinto 2011 ARAA

Early backgrounds?

Just after recombination and all its ripples:

- **First stars** (**earlier in ΛWDM**)
- **DM: Illusion? Heavy: ΛCDM? Light: ΛWDM?**
- **First supernovae**: first heavy elements, $\boldsymbol{Z}$, first Cosmic Rays **(CRs)**
- **First super-massive stars**, their hyper-novae, their super-massive black holes (**BHs**)

all produce backgrounds in

- **Radio, far-infrared, X-rays, γ-rays (horizon)**
- **Ultra-High Energy Cosmic Rays (horizon)**
- **Neutrinos**
- **Gravitational waves (inflation contribution!)**

New radio background

- Three papers (Fixsen et al., Kogut et al., and Seiffert et al. 2011) claim the detection of an isotropic cosmic radio background, with a relatively flat spectrum.
- All known foregrounds have been subtracted. New Planck results (May 2014 on arXiv). **Foreground dust only relevant at higher radio frequencies**. BICEP2 problem (2014 PRL)?
- This background compares with the known radio source counts: **no known compact radio source population** could explain it (Condon et al. 2012).
- This background is also **so smooth, that it again defies all known compact radio sources** (e.g. Holder 2014).

IceCube detection: HE neutrino background

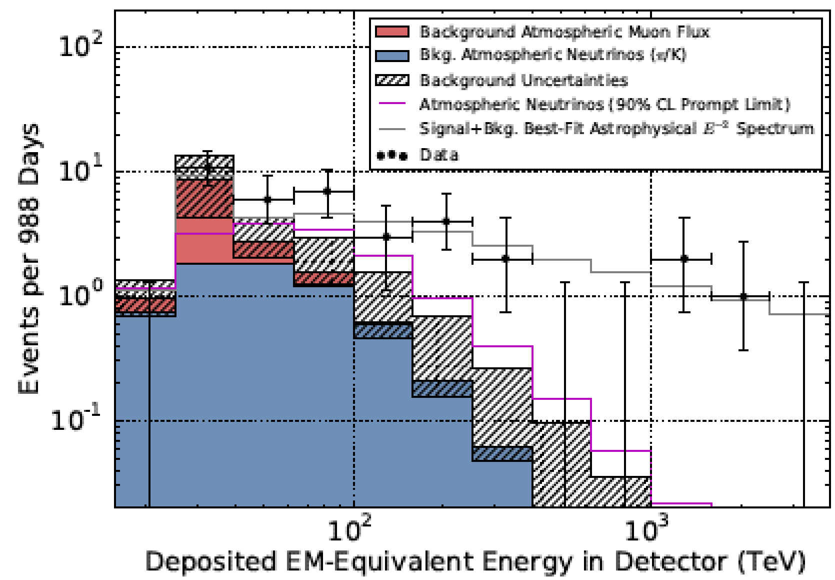

FIG. 2. Deposited energies of observed events with predictions. The hashed region shows uncertainties on the sum of all backgrounds. Muons (red) are computed from simulation to overcome statistical limitations in our background measurement and scaled to match the total measured background rate. Atmospheric neutrinos and uncertainties thereon are derived from previous measurements of both the π/K and prompt components of the atmospheric ν_μ spectrum [9]. A gap larger than the one between 400 and 1000 TeV appears in 43% of realizations of the best-fit continuous spectrum.

Figure 5 The 2014 High Energy (HE) neutrino background. Source IceCube Coll., 2014 PRL

The sky in HE neutrinos

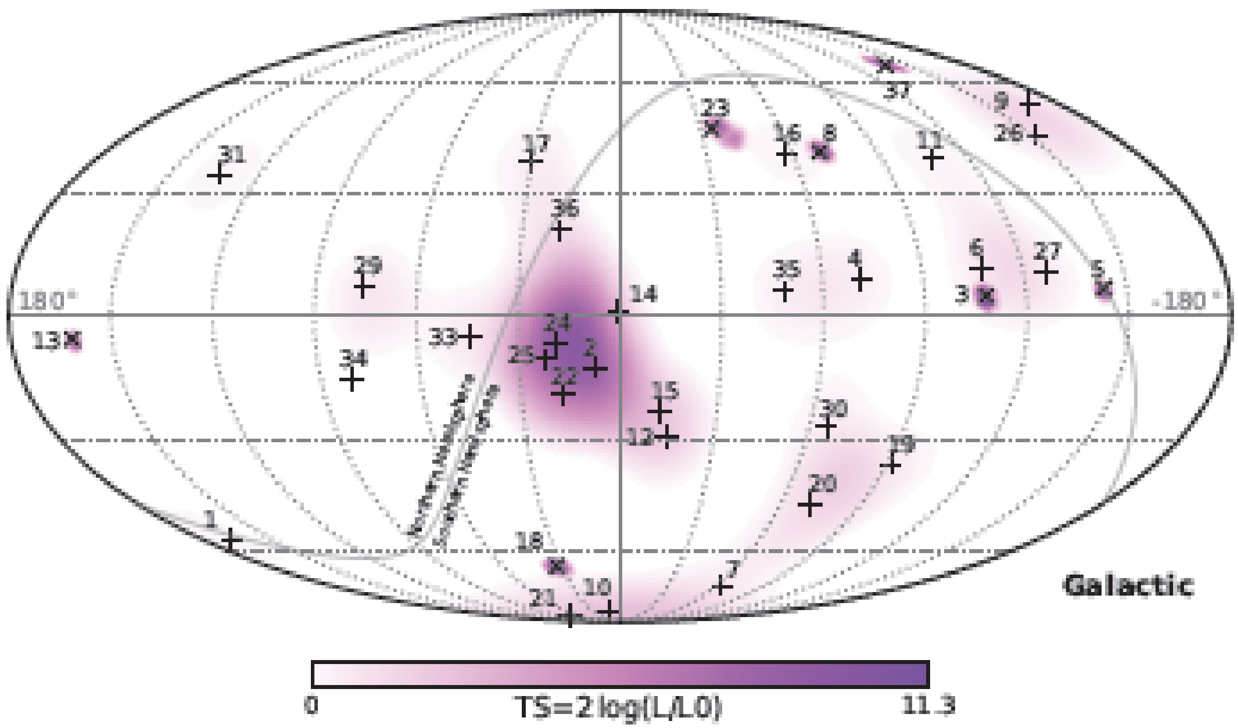

Figure 6 High Energy (HE) Neutrino events on the sky 2014. GC at center. Sources marked with an × have more precise directions, about a degree, sources marked with a cross are shower-events, with very imprecise directional information. Source IceCube 2014 PRL

Neutrino background

- The high energy neutrino background has been detected (IceCube-Coll. 2013, 2014), with a relatively flat spectrum (just the radio emission), and **no identified** plausible sources
- Shower like events 10 - 20 degrees, track-like events about one degree, in precision of directionality
- The spectrum seems to cut off around several PeV. This cut-off could be apparent if the spectrum is slightly steeper than E^{-2}
- This neutrino background appears to be **isotropic**, but has a weak non-significant clustering around the Galactic Center (GC), providing clear limit to anisotropy.

Black holes (BHs) > $3 \cdot 10^7 M_\odot$: colors are distance: Black, Blue, Green, Orange, Red

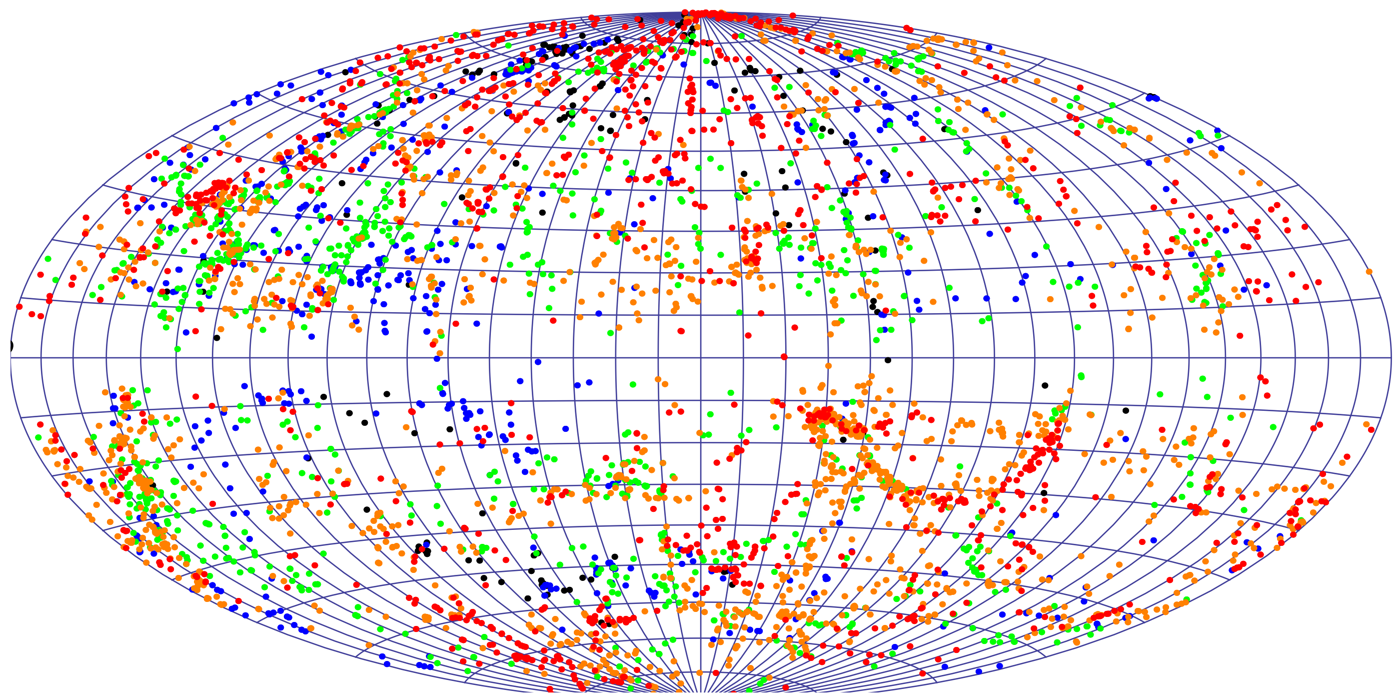

Figure 7 The sky in black holes, $\gtrsim 3 \cdot 10^7 M_\odot$: The color code corresponds to distance: Black, Blue, Green, Orange, Red for the redshifts intervals 0, 0.005, 0.01, 0.015, 0.02, 0.025, corresponding to distance intervals of 0, 60, 120, 180, 240, and 300 million light-years: (−> Caramete & PLB 2011); coordinate system with Galactic plane across center, and Galactic Center (GC) at the right edge

Integral BH mass fct starts at $\sim 3 \cdot 10^6\, M_\odot$

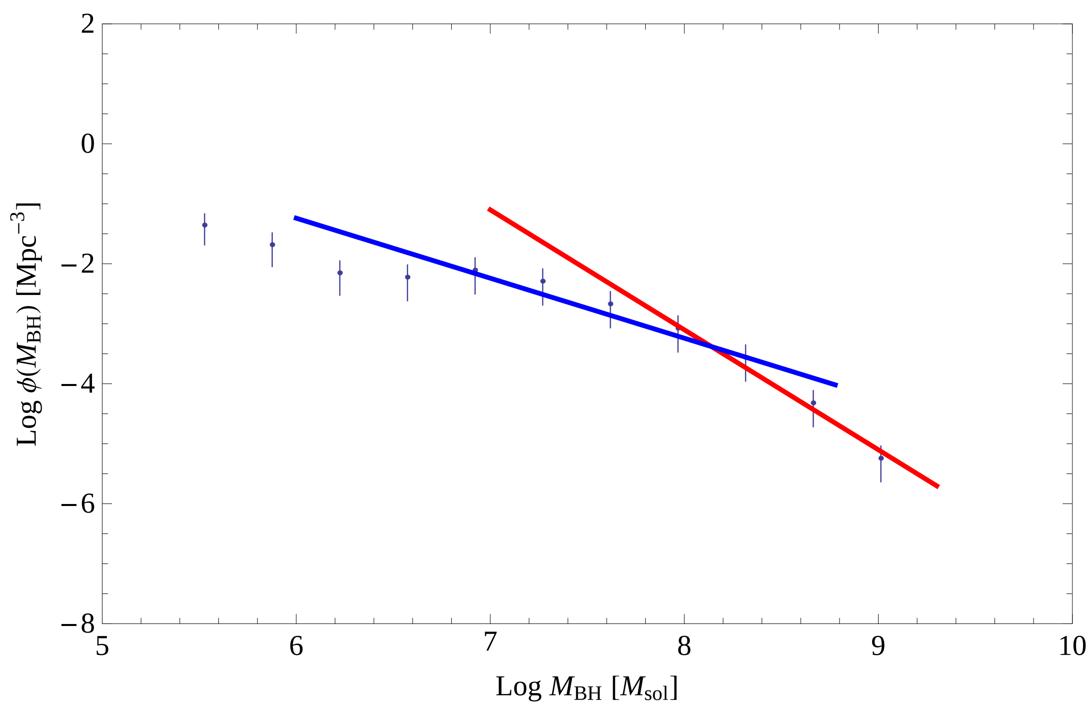

Figure 8 Integral mass function corrected for Hubble type sampling, 2928 objects, the slope of the lines is: red −2.0 fitting $> 10^8\, M_\odot$, and blue −1.0 fitting between $10^7\, M_\odot$ and $10^8\, M_\odot$. See Caramete & PLB, *Astron. & Astroph.* **521**, id.A55 (2010); arXiv:0908.2764. This mass function suggests that black holes start near $3 \cdot 10^6\, M_\odot$, possibly at redshift of order $\sim$ 30 to 80, and grow by merging (see PLB & Kusenko 2006, PRL): Note that redshift 80 corresponds to only 22 million years after Big Bang

Why Black Holes of around $3 \cdot 10^6\, M_\odot$?

- First massive stars form in dense groups in gravitational potential of **DM of dwarf galaxy**: stars agglomerate rapidly to form more massive star
- Massive stars also have **winds**, driven by radiation interaction with heavy elements (Lucy & Solomon 1970 and many later papers): So maximum mass several hundred $M_\odot$ at most (Yungelson et al. 2008)
- At **zero heavy element abundance** massive stars can grow to **much higher mass**, close to $\mathbf{10^6}\, M_\odot$
- Massive stars hit an **instability**, combining radiation pressure with subtle effects of General Relativity (Appenzeller & Fricke 1972a, b) just below this mass
- So with infall the mass of about $\mathbf{3 \cdot 10^6}\, M_\odot$ possible

First CRs: radio and neutrino background

Super-massive stars form and explode, making a **Big Black Hole (BH)**, producing a background:

$$F_\nu = 10^{-19.8} N_{BH,0,0}\, \eta_{B,-1}^{0.8}\, \eta_{CR,e,-1}^{+1}\, E_{57}^{1.3}\, z_{1.3}^{+0.8}\, \nu_{9.0}^{-0.60}\, \mathrm{erg s^{-1} Hz^{-1} cm^{-2} sr^{-1}}\,.$$

- Predicted (2012) neutrinos - observed (IceCube 2013).

$$F_{neutr} = 10^{-7.5} N_{BH,0,0}\, E_{57}\, \eta_{CR,p,-1}\, z_{1.3}^{0.8}\, \mathrm{GeV\, cm^{-2}\, s^{-1}\, sr^{-1}}\,,$$

Mass of shell in gas (Kormendy et al. 2010, 2011)

$$M_{shell} = 10^{10.4}\, \mathrm{M}_\odot\, E_{57}^{3/5}\, z_{1.3}^{-3/5}$$

- Can explain **massive bulge-less disk galaxies** and their high redshift growth (Conselice et al. 2011 +)

The neutrino (and gamma) background

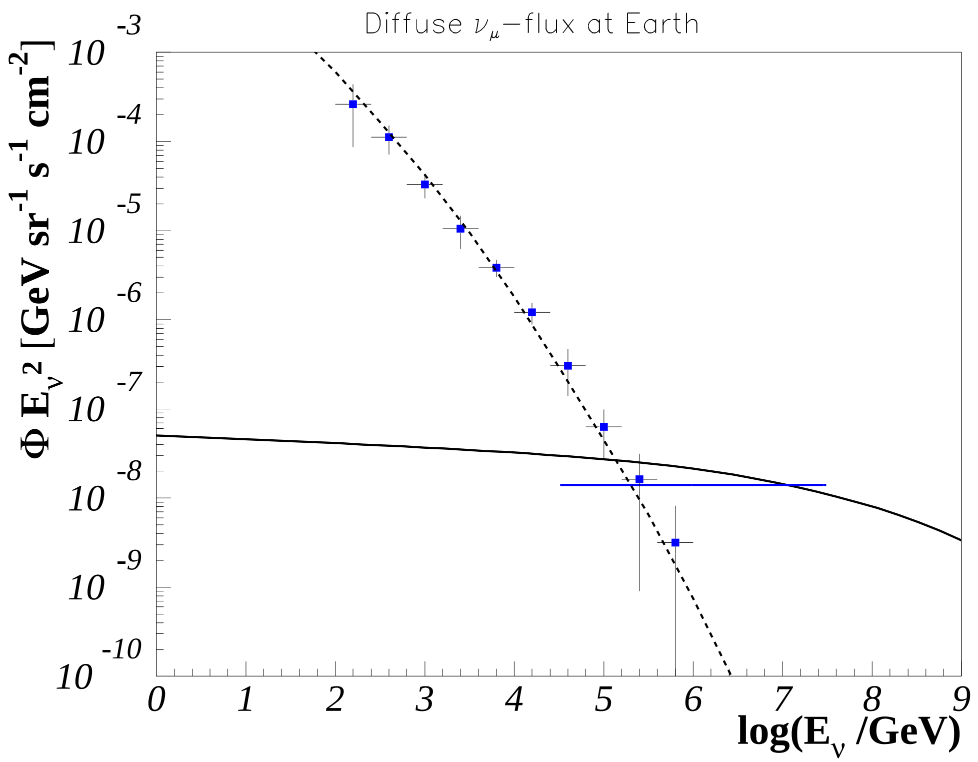

Figure 9 Predicted background neutrino flux and IceCube data: source Julia Becker Tjus 2013, included in paper PLB et al. 2014. The Limit is an integral for an assumed spectrum of $E{-}2$ without cutoff; here we have $E^{-2.2}$ and a cutoff, so it is consistent. There is a accompanying γ-ray background close to what is observed.

Neutrino background: Alternatives I

- **Starburst and normal galaxies**: CR-interactions, using Galactic CRs give spectral kink down at $\sim$ 100 TeV, spectrum below E^{-2} to $E^{-2.3}$.
- **Question**: does this kink energy depend on $\boldsymbol{Z}$?
- **Test**: point at our own Galaxy, at lower Z galaxy M33, and at starburst galaxies such as M82
- **Seyfert galaxies and quasars** interact strongly near central BH; maximum energy limited by losses:
- **Test**: point at prominent Seyfert galaxies
- **Radio galaxies** are relativistic jets oriented elsewhere: Combined with starburst best bet for UHE nuclei
- **Test**: point at M87, For A, Cen A, ...

Neutrino background: Alternatives II

- **Blazars** are relativistic jets pointed at us! most correspond to low power radio galaxies, maximum energy constrained
- **Test**: point at 3C279, ...
- **Interactions in the IGM** = **I**ntergalactic **G**alactic **M**edium, following Essey & Kusenko:
- **Test**: point at blazars
- **The earliest stellar BHs**: Mirabel et al. 2011
- **Test**: Range of redshifts (low $\boldsymbol{Z}$)
- **The earliest Big BHs** as proposed here:
- **Test**: detection via absorption lines (near zero $\boldsymbol{Z}$)

CONCLUSIONS: HE Nuclei Interactions!

- Radio, FIR, X-rays, γ-ray backgrounds
- UHE nuclei, Gravitational Waves (GWs), Neutrinos
- Making Big BHs –> GW background?
- Massive shells –> Massive disk galaxies
- γ-ray propagation: possible in FIR bg?
- Cosmic Magnetic Fields and their structure
  - Test I: Identify UHE nuclei sources
  - Test II: Nuclear interaction debris
  - Test III: Detect original explosion

Thank you!

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Cosmic backgrounds due to the formation of the first super-massive black holes

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We observe i) a high energy neutrino background, and there are repeated claims of a radio background, ii) a large number of super-massive black holes, with a low mass cut-off in their distribution around $3 \cdot 10^6\ M_\odot$, and iii) a large number of massive disk galaxies that never merged. We propose that a first generation of super-massive black holes forms by the agglomeration of massive stars; the en-

suing super-massive star blows up around 10^6 $M_\odot$ due to an instability, and forms a black hole. The explosion then produces a hyper-nova remnant, which gives rise to a background in radio emission, gamma emission, neutrino emission, matching the observations. This explosion distributes fairly strong magnetic fields. The explosion also produces a massive gaseous shell, allowing the formation of massive disk galaxies that never need to merge to grow. There has to be an ensuing background in polarized radio emission, as well as gravitational waves. This simple concept pulls together a large body of observational evidence, and allows predictions for future observational tests to be made. The paper is in *Month. Not. Roy. Astr. Soc.* **441**, 1147 - 1156 (2014); arXiv:1403.3804; coauthors are Biman B. Nath[5], Laurenţiu I. Caramete[1,6], Ben

C. Harms[3], Todor Stanev[7], & Julia Becker Tjus[8], [5] Raman Research Institute, Bangalore, India; [6] Institute for Space Sciences, Bucharest, Romania; [7] Bartol Research Inst., Univ. of Delaware, Newark, DE, USA; [8] Dept. of Phys., Univ. Bochum, Bochum, Germany.

Remember Dark Matter (DM):

- Jan Oort 1932 for matter, which is unseen, and which exerts gravitational force
- **Fritz Zwicky in 1933: clusters of galaxies**
- **Idea 1**: It does not exist (P. Kroupa et al.)
- **Idea 2**: Gravitational field "MOND" theory (MOdified Newtonian Dynamics: M. Milgrom et al.)
- **Idea 3**: Beauty requires really heavy particle
- **Idea 4**: Dwarf elliptical galaxies give keV scale (Hogan & Dalcanton 2000, 2001; Gilmore et al. 2006, Gentile et al., Salucci et al., Sanchez et al., ...):
- Right-handed neutrino decays with order 10^8 Hubble times, **detectable** decay X-ray photon $\boldsymbol{m_{DM}c^2/2}$

News: DM 2014

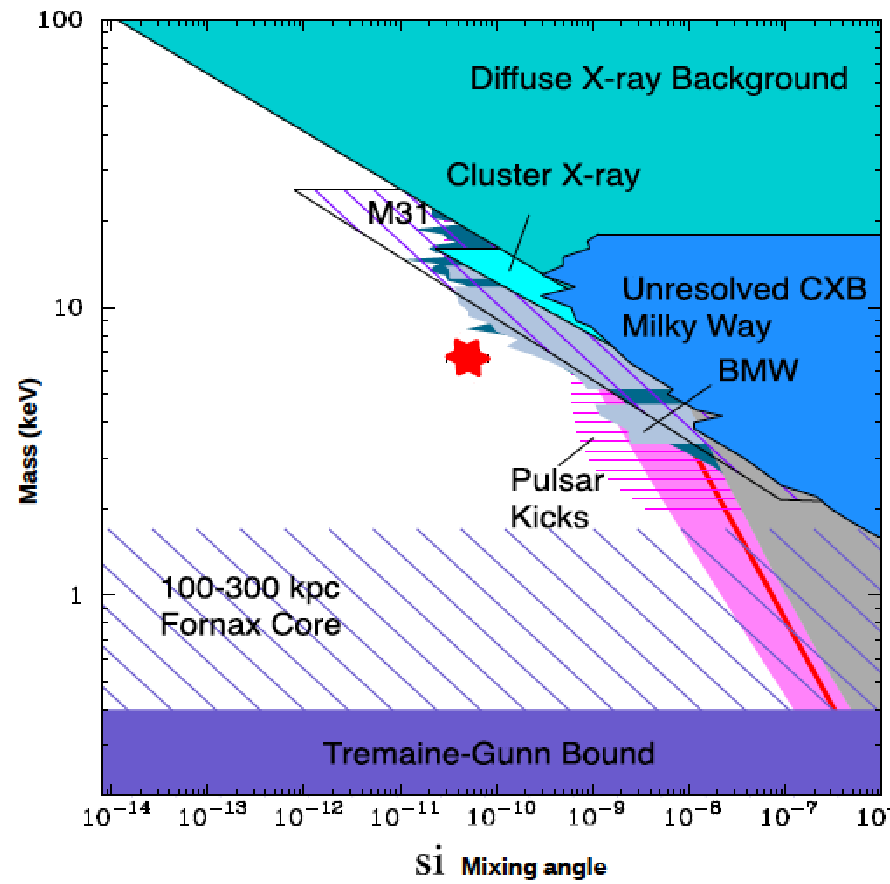
- **Claimed DM detection at 7 keV**, via X-ray detection of 3.5 keV line (Bulbul et al. ApJ 789, 13; Boyarski et al. 1402.4119, 1408.2503, 1408.4388; Jeltema & Profuma 1408.1699).
- Dwarf elliptical properties $->$: sub-thermal right handed neutrino at 7 keV, average momentum of 2 keV neutrino (Abazajian PRL 112, 161303; PRD 90, 6526).
- $->$: Star formation may begin at redshift 100 (PLB & Kusenko 2006 PRL; 7 keV was one example).
- $->$: Detection of unexplained excess ionization matching WDM decay (Kollmeier et al. 2014 ApJL)
- **Echos** from unseen radiation fields (Keel et al.)?

News: DM decay emission line?

- Could this be a sterile neutrino decay signature?
- Warmdark matter candidate sterile neutrinos decay into an activeneutrinoandemission line
- Neutrino Properties

Mass=2E$_{\gamma}$

$$\text{Mixing Angle} \propto \frac{F_{DM}}{(1+z)} \frac{D_L^2}{M_{DM}^{FOV}} \frac{1}{m_s^4}$$



The diffuse X-ray background (Boyarskyet al. 2006), cluster X-ray (Boyarskyet al. 2006b), BMW (Boyarskyet al. (2007), M31 (Watson et al. 2006 theTremaine-Gunn bound (Bode et al. 2001), andFornaxdwarf galaxy (Strigariet al. 2006)

Figure 10 The X-ray evidence. For echo effects see Keel et al.. Source Esra Bulbul lecture Head-meeting 2014, p.20

News: Observed echoes (W. Keel)!

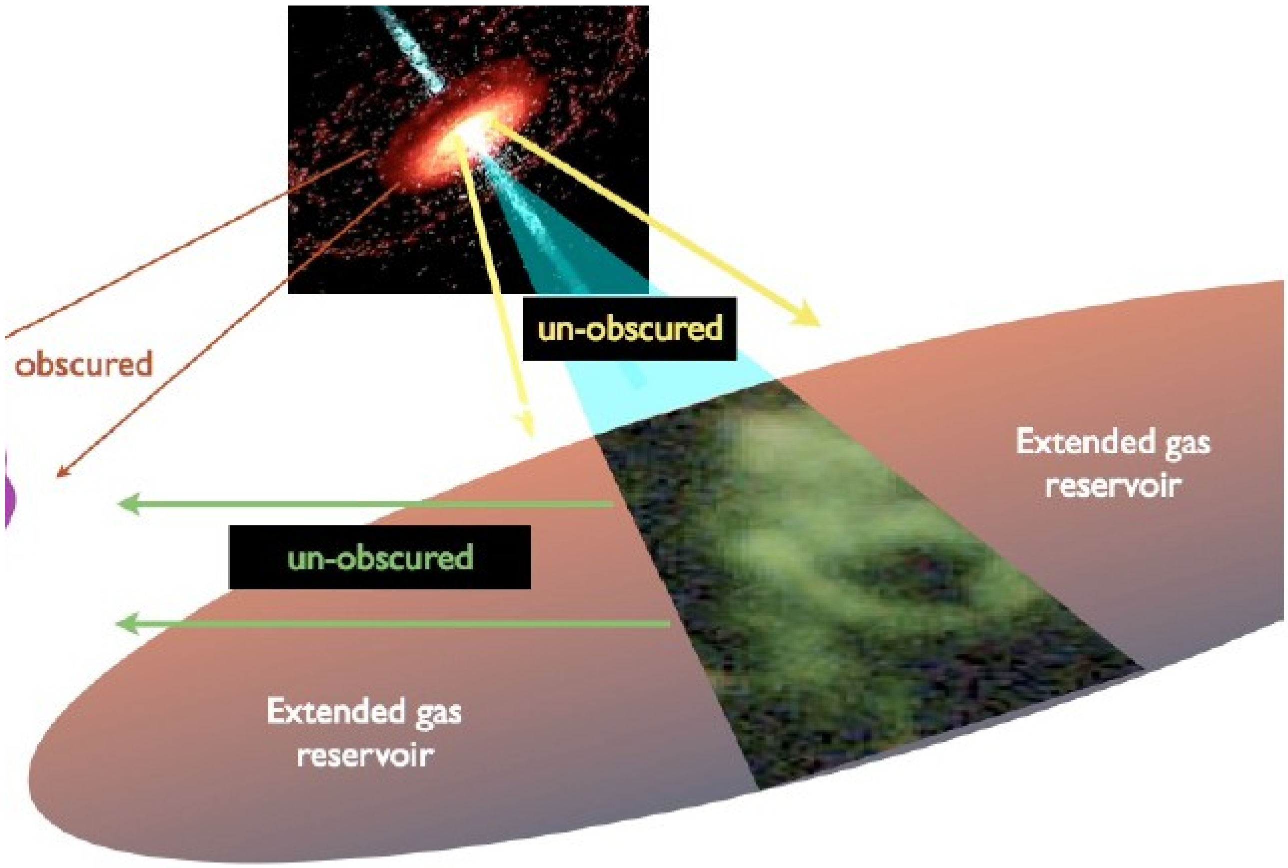


Figure 11 A real echo detected in optical. Source W. Keel et al. 2011.2784, Fig.2

Known backgrounds III: The Far-infrared background and γ-ray propagation

- γ-ray AGN detected to TeV from 2 Gpc with "known" FIR background (Essey & Kusenko 2010 +), **why?**
- Proposal: Proton interaction near us, make pions, pions decay, leptons interact. **Condition: Magnetic field minuscule** (but see Kronberg +, Ryu +)
- Observations and MHD simulations show that **average** energy density in magnetic fields much **larger**
- **Alternatives?**

  a) Magnetic fields much more **structured**.

  b) FIR background **very much lower** outside Solar system, outside our own Galaxy (1406.0239).

  c) **UHE neutrino interactions**?

Odd coincidence: GW background?

- Then energy budget of making a black hole is of order

$$\boldsymbol{\frac{1}{2} N_{BH,0}\, M_{BH}\, c^2 (1 + z_\star)^3}$$

- Gravitational waves?
- For $N_{BH,0} = 1\, Mpc^{-3}$, $M_{BH} = 3 \cdot 10^6\, M_\odot$, and $z_\star = 50$ the number is $\sim 10^{-8}\, erg/cc$, same as DE
- Large uncertainties in $N_{BH,0}$, M_{BH}, and also $z_\star$.
- Can stimulated emission and so energy transfer from “dark side” mimic equation of state $P = -\rho\, c^2$? Perhaps (PLB & Harms arXiv:1305.0498).
- Could be detected by pulsar timing arrays (PTAs)

References

[1] Aartsen, M. G., et al. for the IceCube-Coll., *Phys. Rev. Letters* **113**, id.101101 (2014); 1405.5303; Title: Observation of High-Energy Astrophysical Neutrinos in Three Years of IceCube Data

[2] Abazajian, K. N., *Phys. Rev. Letters* **112**, Issue 16, id.161303 (2014); Title: Resonantly Produced 7 keV Sterile Neutrino Dark Matter Models and the Properties of Milky Way Satellites

[3] Ade, P. A. R.; et al., Bicep2 Collaboration, *Phys. Rev. Letters* **112**, id.241101 (2014); arXiv:1403.3985; Title: Detection of B-Mode Polarization at Degree Angular Scales by BICEP2

[4] Ade, P. A. R., et al., Polarbear Collaboration, *Phys. Rev. Letters* **113**, id.021301 (2014); Title: Measurement of the Cosmic Microwave Background Polarization Lensing Power Spectrum with the POLARBEAR Experiment

[5] Appenzeller, I., & Fricke, K., *Astron. & Astroph.* **18**, 10 (1972a); Title: Hydrodynamic Model Calculations for Supermassive Stars I. The Collapse of a Nonrotating $0.75 \times 10^6 \, M_\odot$ Star

[6] Appenzeller, I., & Fricke, K., *Astron. & Astroph.* **21**, 285 (1972b); Title: Hydrodynamic Model Calculations for Supermassive Stars. II. The Collapse and Explosion of a Nonrotating $5.2 \times 10^5 \, M_\odot$ Star

[7] Biermann, P. L., & Kusenko, A., *Phys. Rev. Let-*

ters **96**, id. 091301 (2006); Title: Relic keV Sterile Neutrinos and Reionization

[8] Biermann, P.L., & Harms, B.C., eprint arXiv:1305.0498 (2013); Title: Can dark energy be gravitational waves?,

[9] Bulbul, E., et al., *Astrophys. J.* **789**, id.13 (2014); Title: Detection of an Unidentified Emission Line in the Stacked X-Ray Spectrum of Galaxy Clusters

[10] Caramete, L.I., & Biermann, P.L., *Astron. & Astroph.* **521**, id.A55 (2010); arXiv:0908.2764; Title: The mass function of nearby black hole candidates

[11] Condon, J.J., et al., *Astrophys. J.* **758**, id.23 (2012); eprint arXiv:1207.2439 (2012); Title: Resolving the

Radio Source Background: Deeper Understanding Through Confusion,

[12] Conselice, C. J., et al., *Month. Not. Roy. Astr. Soc.* **417**, 2770 - 2788 (2011); Title: The tumultuous formation of the Hubble sequence at $z > 1$ examined with HST/Wide-Field Camera-3 observations of the Hubble Ultra Deep Field

[13] Conselice, C. J., et al., *Month. Not. Roy. Astr. Soc.* **430**, 1051 - 1060 (2013); Title: Gas accretion as a dominant formation mode in massive galaxies from the GOODS NICMOS Survey

[14] Dalcanton, J. J., & Hogan, C. J., *Astrophys. J.* **561**, 35 (2001); Title: Halo Cores and Phase-Space

Densities: Observational Constraints on Dark Matter Physics and Structure Formation

[15] Destri, C., de Vega, H. J., & Sanchez, N. G., eprint arXiv:1204.3090 (2012); Title: Fermionic warm dark matter produces galaxy cores in the observed scales

[16] Dole, H., Lagache, G., Puget, J., *The Spitzer Space Telescope: New Views of the Cosmos*, . Eds. L. Armus & W.T. Reach. ASP Conf. Ser. **357**, 290 (2006); arXiv:astro-ph/0503017; Title: The Cosmic Infrared Background: Resolved, Unresolved and Spitzer Contribution

[17] Fixsen, D.J., et al., *Astrophys. J.* **734**, id.5 (2011); Title: ARCADE 2 Measurement of the Absolute Sky Brightness at 3-90 GHz,

[18] Frieman, J. A., Turner, M. S., & Huterer, D., *Annual Rev. of Astron. & Astrophys.* **46**, 385 - 432 (2008); Title: Dark Energy and the Accelerating Universe

[19] Gentile, G., et al., *Nature* **461**, 627 (2009); Title: Universality of galactic surface densities within one dark halo scale-length

[20] Gergely L., Biermann, P.L., *Astrophys. J.* **697**, 1621 - 1633 (2009); arXiv:0704.1968; Title: Super-massive black hole mergers,

[21] Heger, A., et al., *Astrophys. J.* **591**, 288 - 300 (2003); Title: How Massive Single Stars End Their Life

[22] Hogan, C. J., & Dalcanton, J. J., *Phys. Rev.* **D 62**, id.063511 (2000); Title: New dark matter physics:

Clues from halo structure

[23] Holder, G. P., *Astrophys. J.* **780**, id. 112, 4 pp. (2014); Title: The Unusual Smoothness of the Extragalactic Unresolved Radio Background

[24] Kogut, A., et al., *Astrophys. J.* **734**, id. 4 (2011); Title: ARCADE 2 Observations of Galactic Radio Emission

[25] Kollmeier, Juna A., et al., *Astrophys. J. Letters* **789**, id. L32 (2014); Title: The Photon Underproduction Crisis

[26] Kormendy, J., et al. *Astrophys. J.* **723**, 54 - 80 (2010); Title: Bulgeless Giant Galaxies Challenge Our Picture of Galaxy Formation by Hierarchical Clustering

[27] Kormendy, J., Bender, R., & Cornell, M. E., *Nature* **469**, 374 - 376 (2011); Title: Supermassive black holes do not correlate with galaxy disks or pseudobulges

[28] Kormendy, J., Bender, R., *Nature* **469**, 377 - 380 (2011); Title: Supermassive black holes do not correlate with dark matter haloes of galaxies

[29] Kotera, K., Olinto, A. V., *Annual Rev. of Astron. & Astrophys.* **49**, 119-153 (2011); Title: The Astrophysics of Ultrahigh-Energy Cosmic Rays

[30] Lagache, G., Puget, J.-L., Dole, H., *Annual Rev. of Astron. & Astrophys.* **43**, 727 - 768 (2005); Title: Dusty Infrared Galaxies: Sources of the Cosmic Infrared Background

[31] Lucy, L. B., Solomon, P. M., *Astrophys. J.* **159**, 879 (1970); Title: Mass Loss by Hot Stars

[32] Milgrom, M., eprint arXiv:1404.7661 (2014): in special issue of the Canadian Journal of Physics dedicated to MOND. Title: MOND theory

[33] Mirabel, I.F., et al., *Astron. & Astroph.* **528**, id.A149 (2011); Title: Stellar black holes at the dawn of the universe

[34] Munyaneza, F., & Biermann, P. L., *Astron. & Astroph.* **436**, 805 (2005); Title: Fast growth of supermassive black holes in galaxies

[35] Munyaneza, F., & Biermann, P. L., *Astron. & Astroph. Letters* bf 458, L9 (2006); Title: Degenerate sterile neutrino dark matter in the cores of galaxies

[36] Planck Collaboration; Ade, P.A.R., et al., eprint arXiv:1303.5078 (2013); Title: Planck 2013 results. XVI. Cosmological parameters

[37] Salucci, P., *Month. Not. Roy. Astr. Soc.* **420**, 2034 (2012); Title: Dwarf spheroidal galaxy kinematics and spiral galaxy scaling laws

[38] Sanders, R. H., *Astrophys. J.* **162**, 791 (1970); Title: The Effects of Stellar Collisions in Dense Stellar Systems

[39] Seiffert, M., et al., *Astrophys. J.* **734**, id.6 (2011); Title: Interpretation of the ARCADE 2 Absolute Sky Brightness Measurement,

[40] Spitzer, L., Jr., *Astrophys. J. Letters* **158**, L139 (1969); Title: Equipartition and the Formation of

Compact Nuclei in Spherical Stellar Systems

[41] Strigari, Louis E., et al., *Nature* **454**, 1096 (2008); Title: A common mass scale for satellite galaxies of the Milky Way

[42] de Vega, H. J., Salucci, P., & Sanchez, N. G., *Month. Not. Roy. Astr. Soc.* **442**, 2717 (2014); Title: Observational rotation curves and density profiles versus the Thomas-Fermi galaxy structure theory

[43] Yang, Y., et al. *Month. Not. Roy. Astr. Soc.* **442**, 2419 (2014); Title: Reproducing properties of MW dSphs as descendants of DM-free TDGs

[44] Yungelson, L.R., et al., *Astron. & Astroph.* **477**, 223 - 237 (2008); Title: On the evolution and fate of super-massive stars