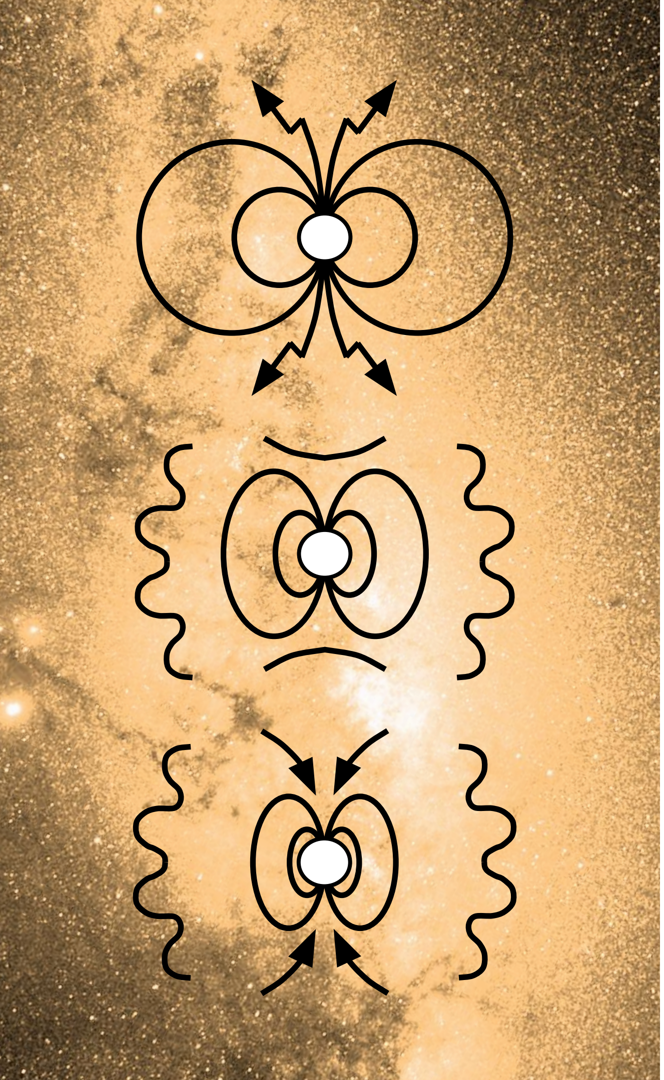


Can accreting isolated neutron stars be detected?

Marina Afonina,
Anton Biryukov, Sergei Popov
Sternberg Astronomical Institute

Kyoto, Japan
February 2026

2512.10666
arXiv

Results

eROSITA

An estimation of an upper bound on the number of potentially observed eROSITA **isolated accreting neutron stars**

2512.10666

arXiv

One-phase ISM		
Propeller model	Constant field	Exponential decay
A	4700 ± 110	3200 ± 80
B	4700 ± 110	3100 ± 80
C	1300 ± 60	1600 ± 60
Two-phase ISM		
Propeller model	Constant field	Exponential decay
A	1300 ± 60	840 ± 40
B	1200 ± 60	760 ± 40
C	270 ± 30	280 ± 30

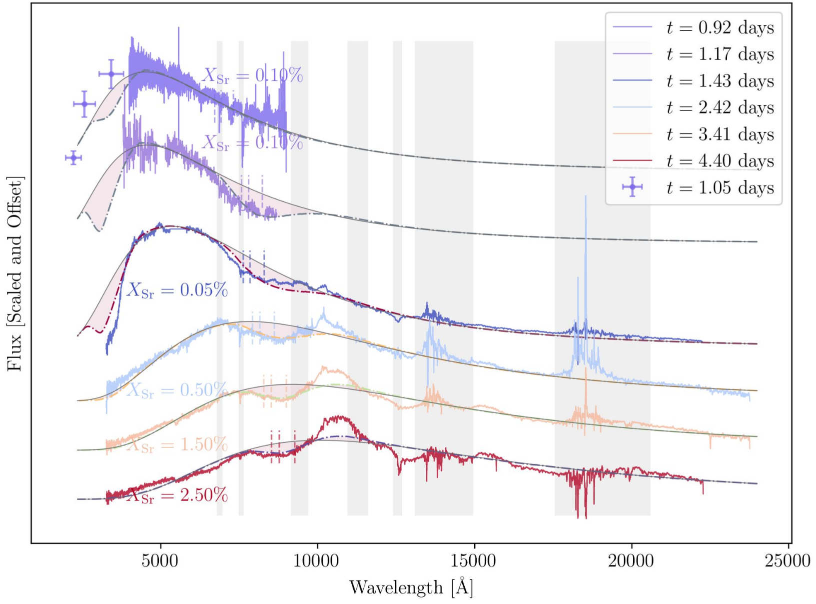
most realistic model

With 300 million NSs in the Galaxy, if the accretion efficiency is high and the accretor stage can be reached, hundreds to thousands low-velocity NSs are potentially observable soft X-ray sources

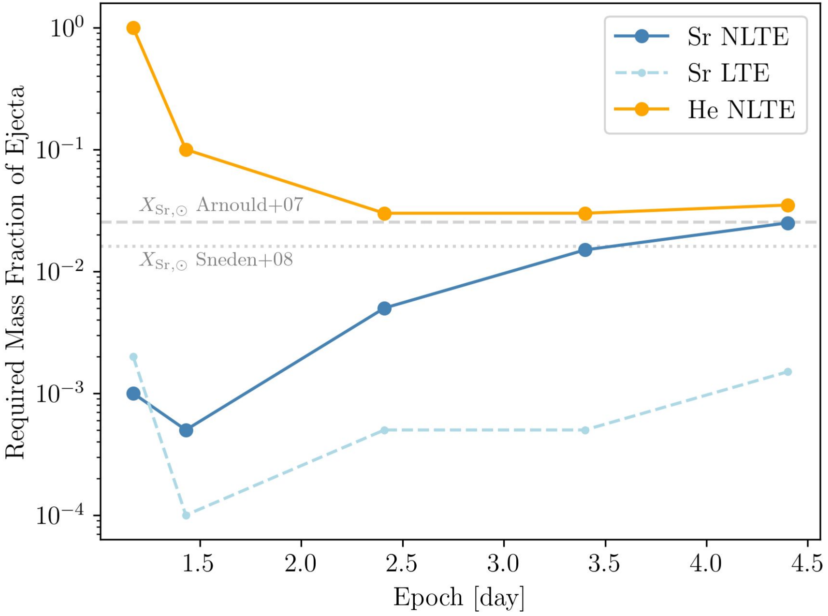
Strontium vs. helium spectral lines in the kilonova AT2017gfo

Aayush Arya
Niels Bohr Institute, University of Copenhagen, Denmark
with Rasmus Damgaard, Albert Sneppen, Stuart Sim, David Dougan, Connor Ballance, and Darach Watson

1μm feature with NLTE radiative transfer



Strontium vs. Helium: What is it?



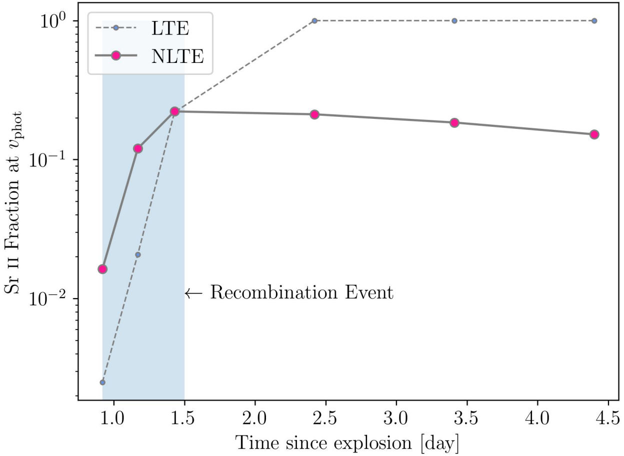
Strontium vs. helium spectral lines in the kilonova AT2017gfo

Aayush Arya

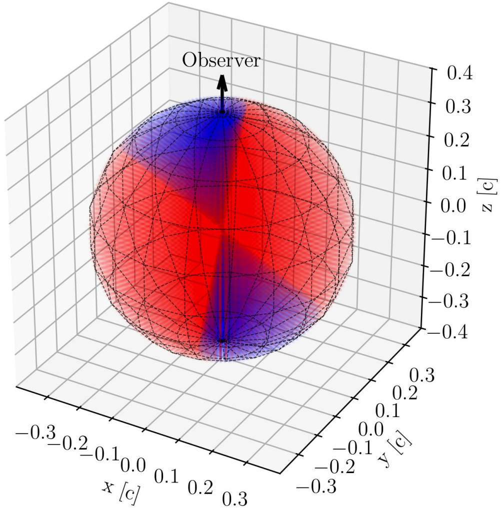
Niels Bohr Institute, University of Copenhagen, Denmark

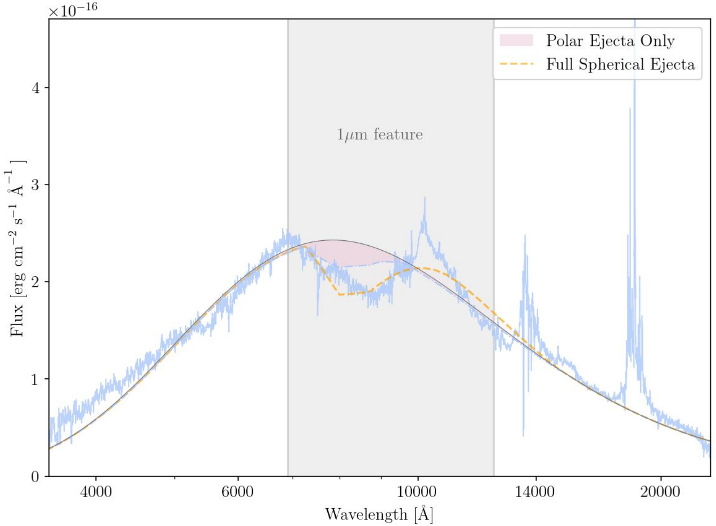
with Rasmus Damgaard, Albert Sneppen, Stuart Sim, David Dougan, Connor Ballance, and Darach Watson

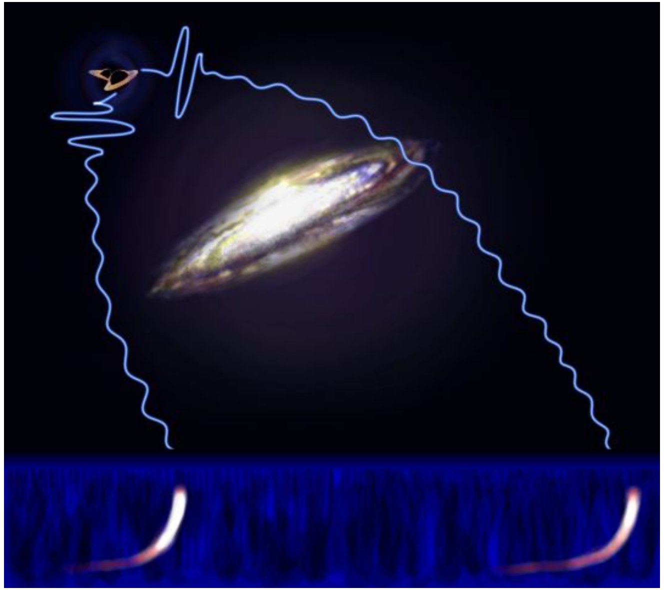
Emergence of the feature: Recombination Event



Helium in polar ejecta cannot form a full P Cygni





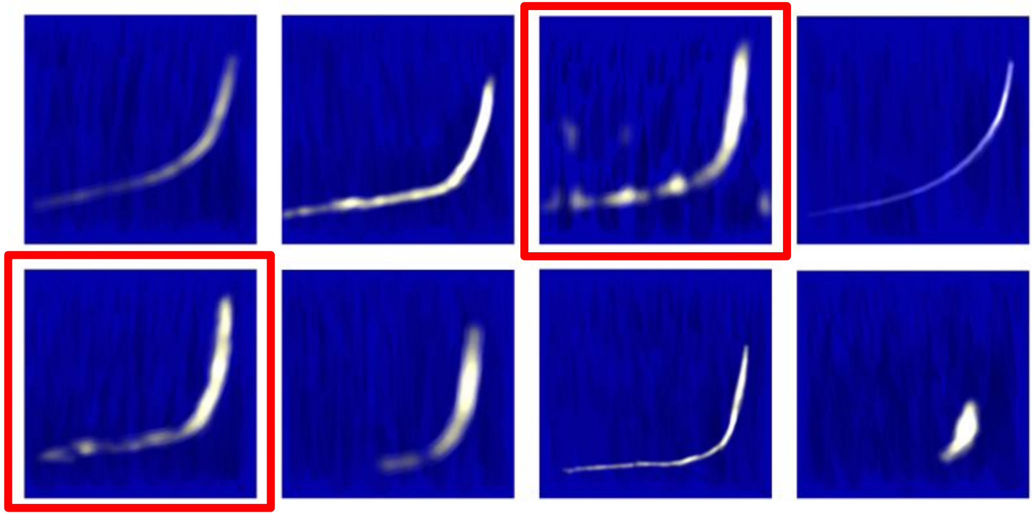


AB, Koustav

Strongly lensed gravitational waves

➔ Multiple copies of the same signal

➔ Useful probe of dark matter, cosmology, testing GR



Number of lensed signals ~ **0.001 x N**

Number of unlensed pairs ~ **N^2 / 2**

False positives grow faster!

Lensing, or luck?

3

Detection prospects of strongly lensed gravitational waves

arXiv:2510.23238

Ankur Barsode*, Koustav N. Maity, Parameswaran Ajith

International Centre for Theoretical Sciences, Tata Institute of Fundamental Research, Bangalore

*ankur.barsode@icts.res.in

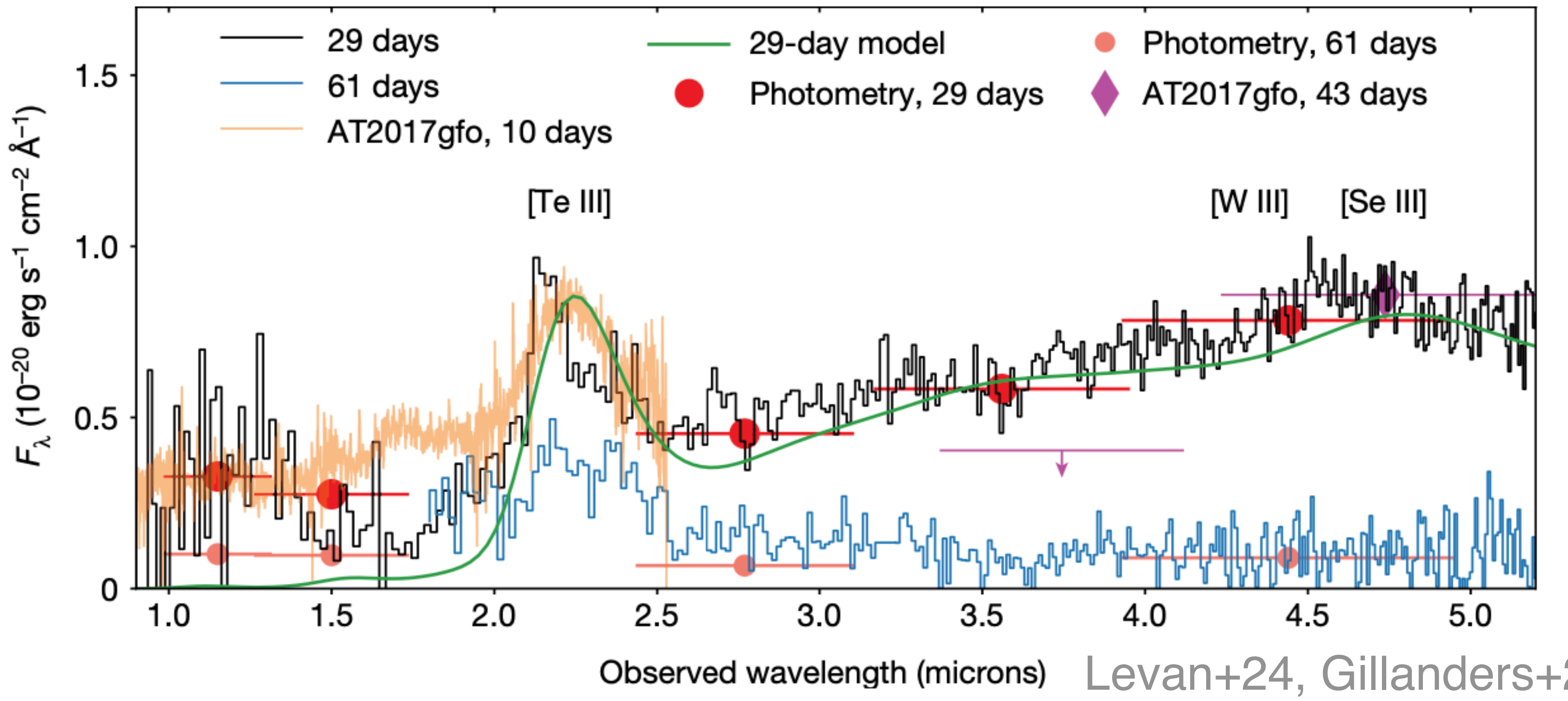
- First significant detection likely in LVK's O5!
- Routine detections thereafter

Lensing, not luck!

Dust formation in kilonovae

Nanae Domoto (U. Tokyo, RESCEU), Kenta Hotokezaka (RESCEU), Daniel Kasen (UC Barkley)

Late-time emission of observed kilonovae



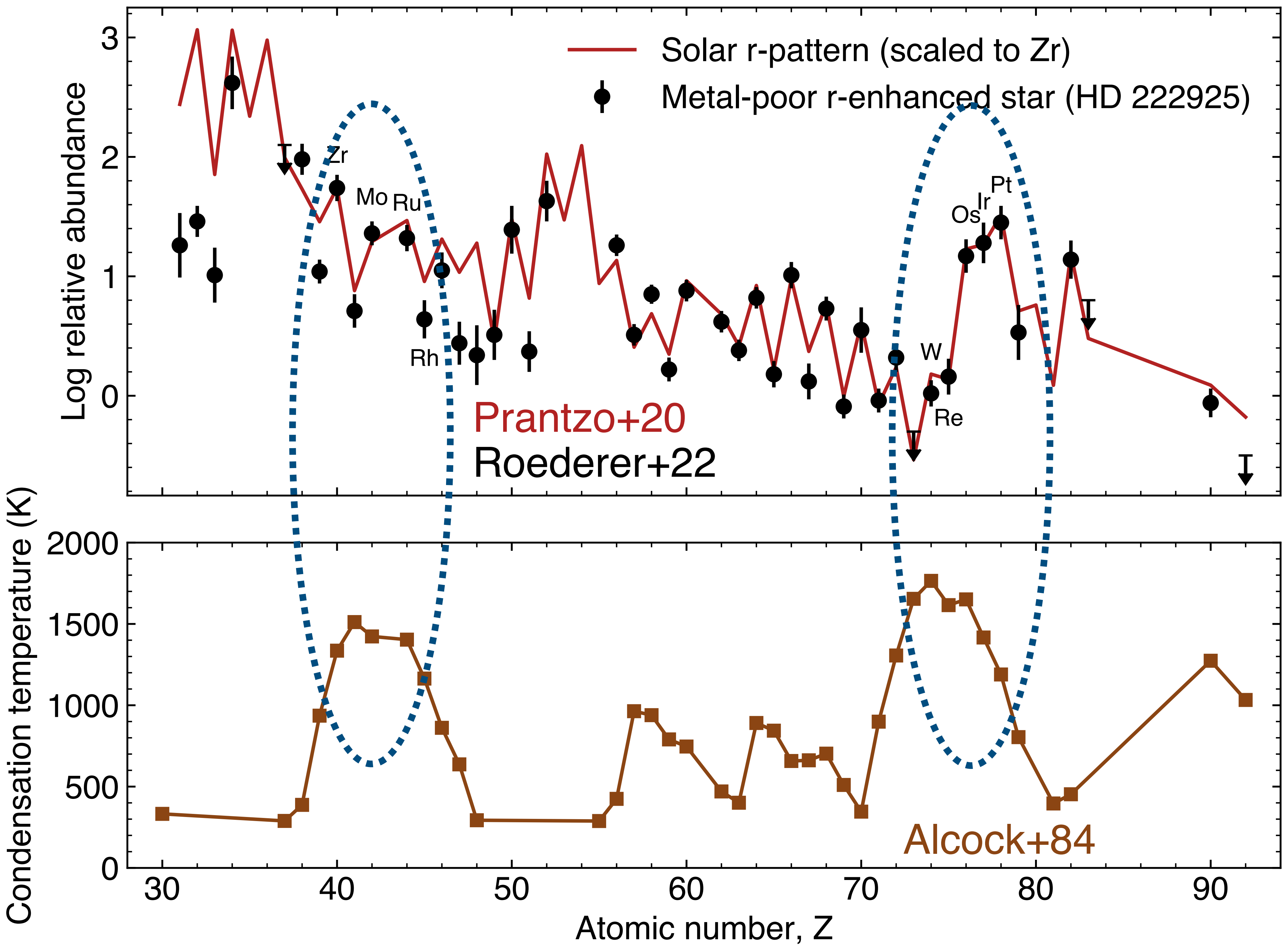
Levan+24, Gillanders+25

- AT2017gfo (GW170817) and AT2023vfi (GRB 230307A) revealed prominent red emission at late time
- Continuum-like emission is difficult to explain by atomic processes

→ **R-process dust grains?**

Refractory element

Palme & Wlotzka 1987, Wood et al. 2019

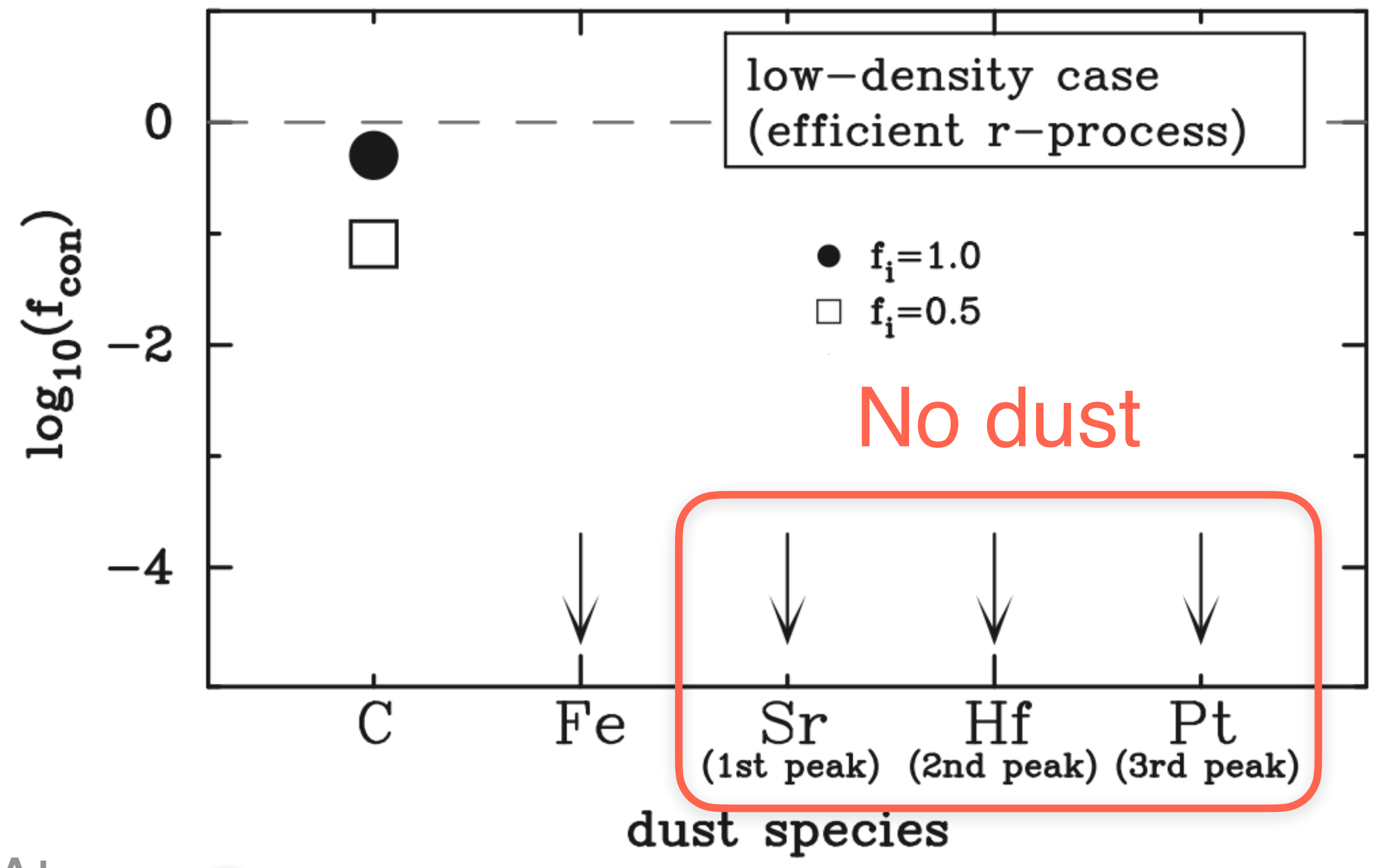


- Zr, W, Os, … have high condensation temperatures ~1800 K
- Ejecta temperature drops below this at ~10 days after the merger
- “Refractory metal nuggets” has been observed in meteorites (considered to form in early solar system)

Dust formation in kilonovae

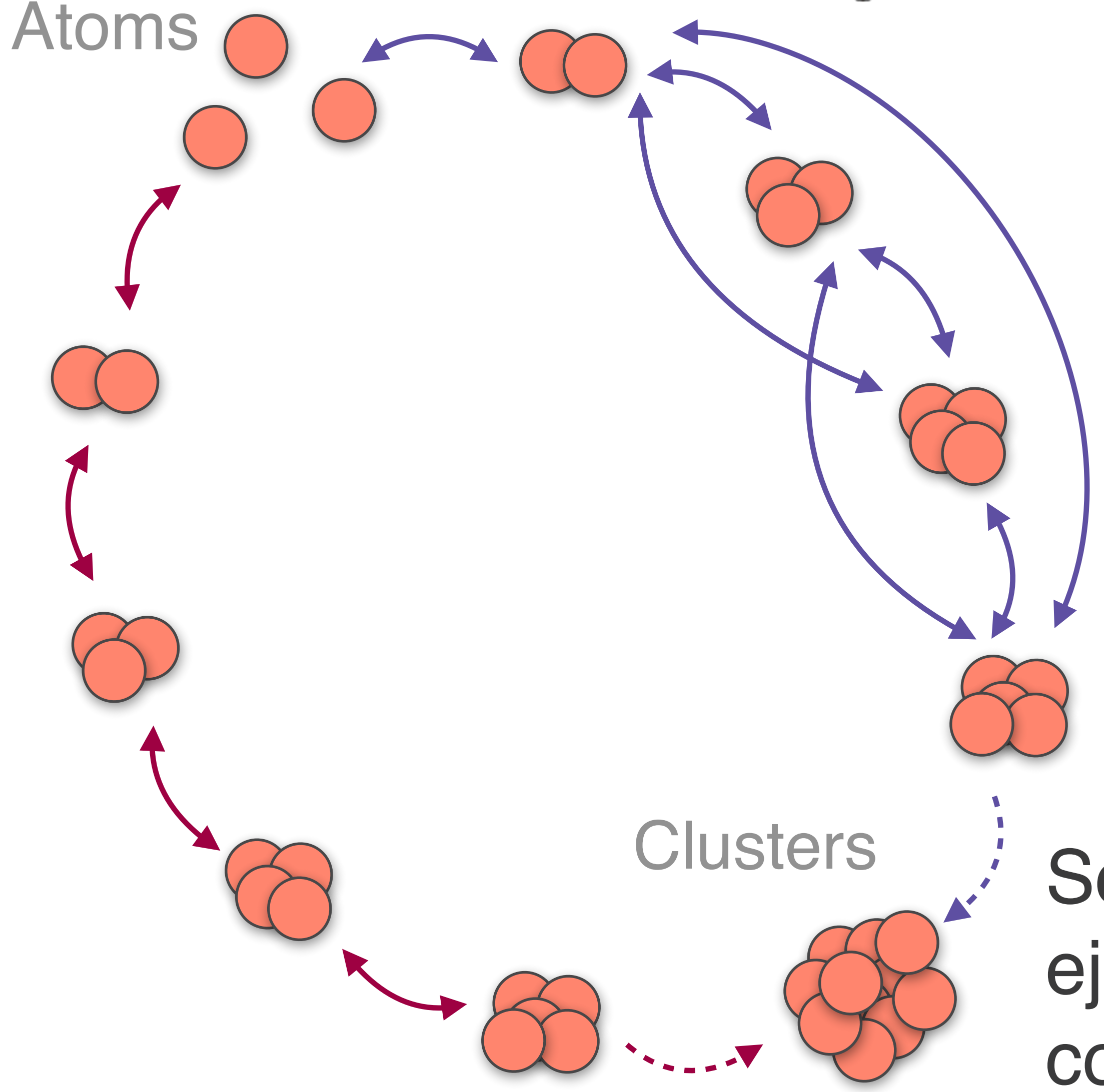
Nanae Domoto (U. Tokyo, RESCEU), Kenta Hotokezaka (RESCEU), Daniel Kasen (UC Barkley)

Methodology



Previous study has concluded that dust formation is unlikely (Takami+14)

However… **only low density ejecta was considered**; **the nucleation theory** was used



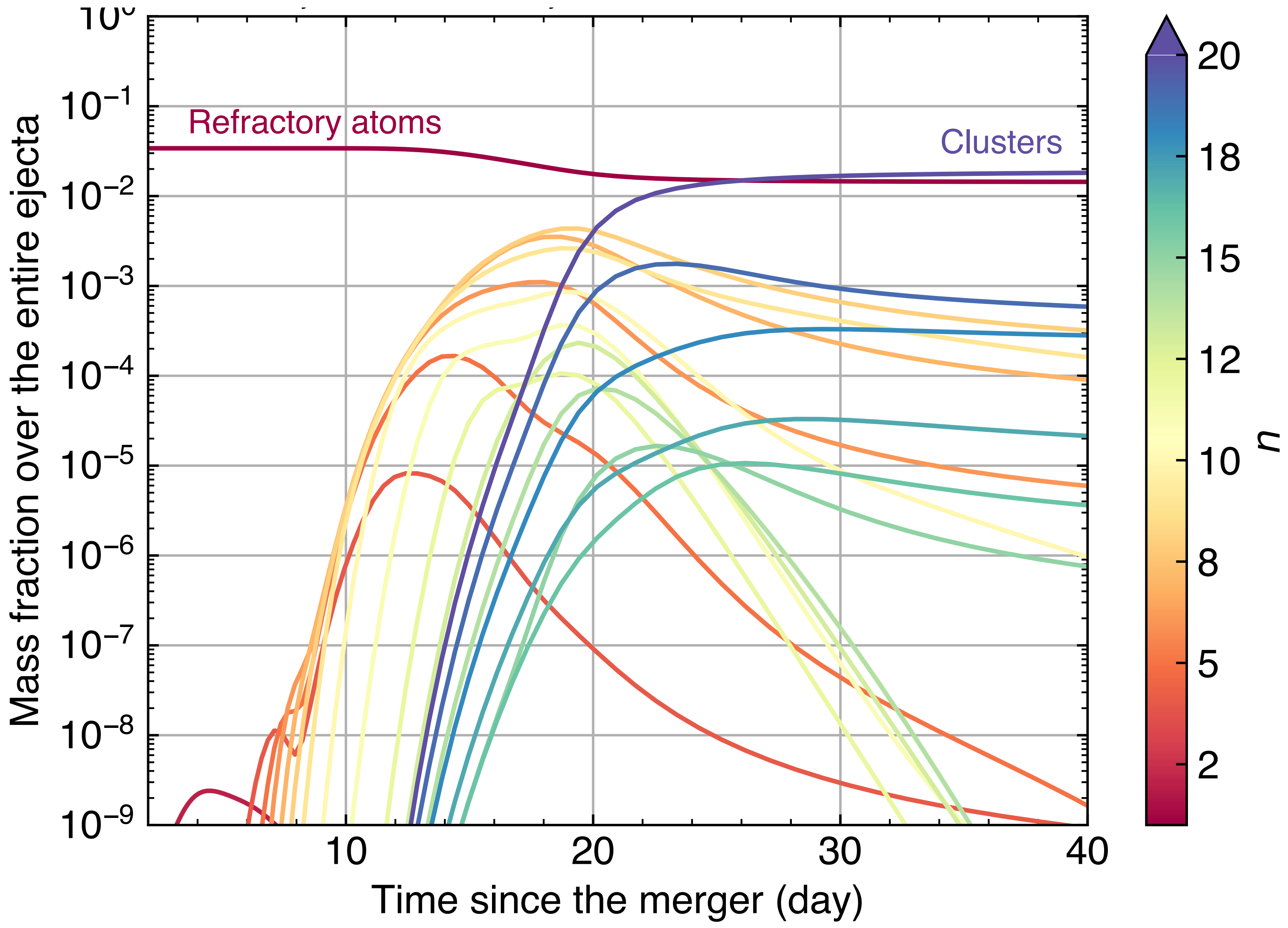
“classical” picture

“molecular” picture

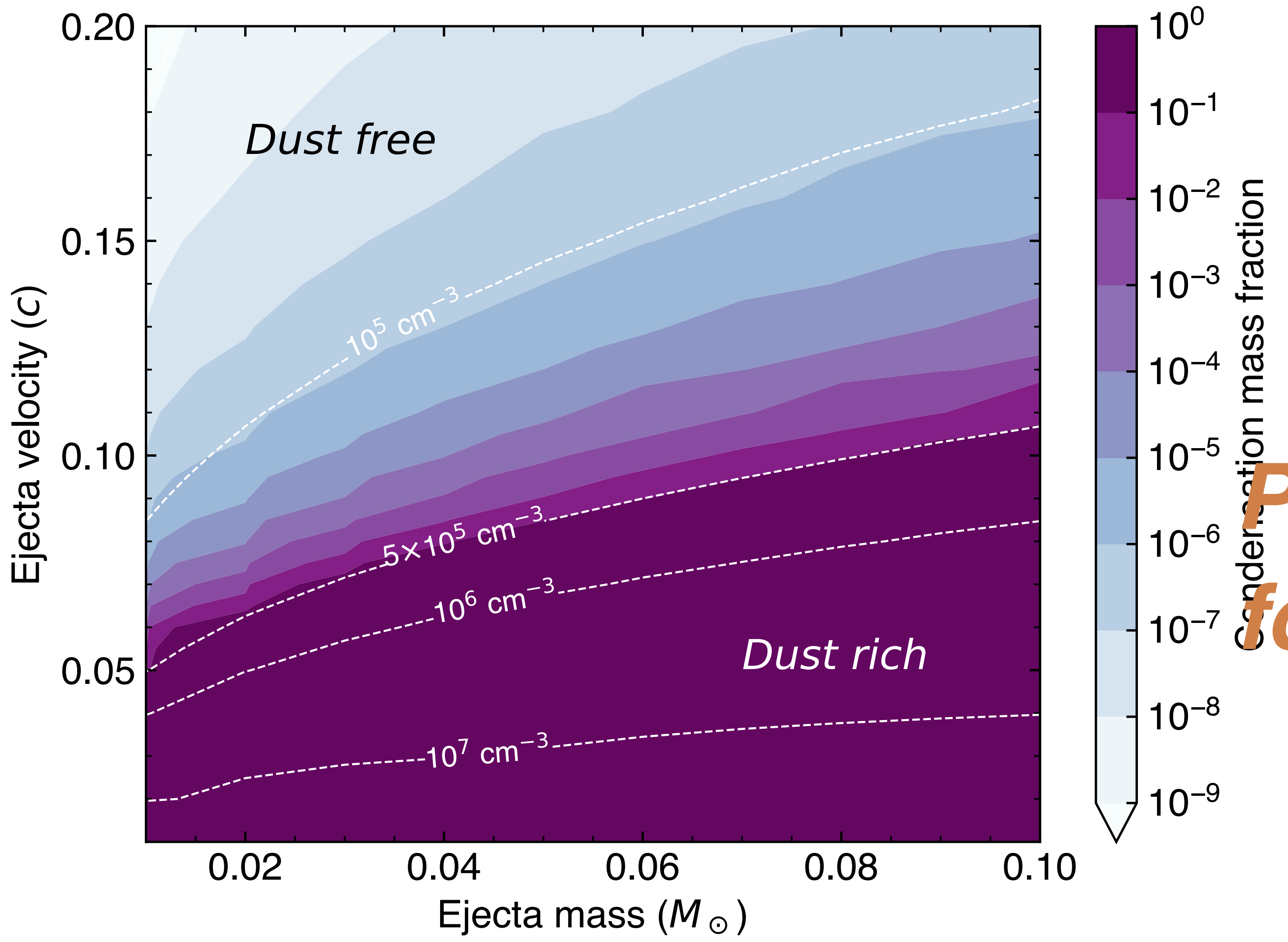
Cherchneff & Lilly 08,
Cherchneff & Dwek 09, 10,
Lazzati & Heger 16, Sluder+18, …

Solving rate equations in expanding ejecta using the theoretical rate coefficients from Matúška+19

Results & Discussions



Refractory element grains may form at ~10 days after the merger.
Resulting grain mass in this case is ~10^{-3} M_{sun}.
This may produce thermal red emission.



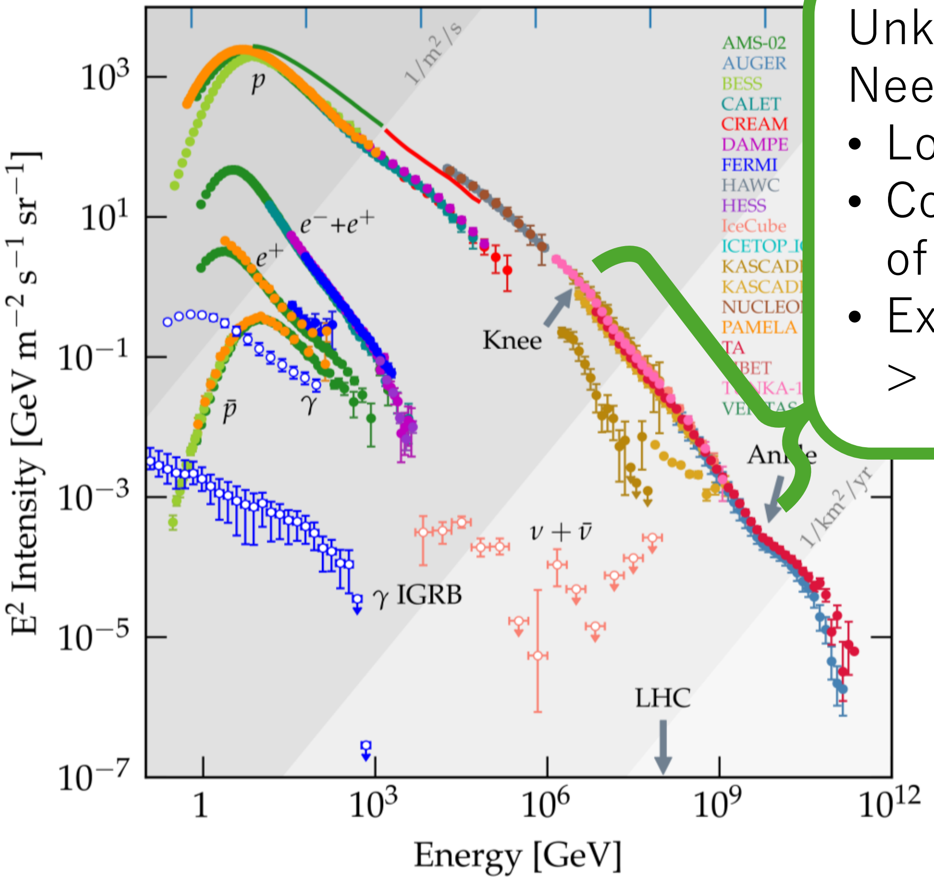
Condensation mass fraction is strongly sensitive to the velocity (density) of ejecta.

More data of molecular and cluster formation of r-process elements are needed.

Please visit the poster No.4 for more details!

Interacting SNe: super-PeV candidates that explain the composition trends

Nick Ekanger (Tohoku University), with Shigeo S. Kimura, Kazumi Kashiyama



Unknown!
Need:
- Local
- Composed of nuclei
- Explain flux $> 10^{15} eV$

- Typical SNRs cannot reach PeV
- *Interacting SNe?*

$$E_{max} \sim r_L ZeB$$
$$B^2/8\pi \sim \epsilon_B \rho_w V_w^2/2$$
$$\rho_w \sim \dot{M}/4\pi R_0^2 V_w$$
$$* \boldsymbol{E_{max}} \sim Ze(\epsilon_B \dot{M} V_w)^{1/2} \sim \mathbf{5 \times 10^{16}}\ \boldsymbol{eV}$$

$$L_{CR}|_{GeV}/L_{CR}|_{PeV} \sim 10^3$$
$$L_{CR} \sim \epsilon_{CR} M V^2 \mathcal{R}/2$$
$$\boldsymbol{L_{CR}|_{SNR}/L_{CR}|_{ISN}} \sim \frac{M_{ej}\mathcal{R}_{SN}}{M_{CSM}\mathcal{R}_{ISN}/\ln(\boldsymbol{E_{max}}/E_{min})} \sim \mathbf{10^3}$$

For parameters:
- $Z = 2$
- $\epsilon_B = 10^{-3}$
- $\dot{M} = 10^{-2}\ M_\odot\ yr^{-1}$
- $V_w = 100\ km\ s^{-1}$
- $M_{ej} = 10\ M_\odot$
- $M_{CSM} = 1\ M_\odot$
- $\mathcal{R}_{SN}/\mathcal{R}_{ISN} \sim 10$
- $E_{min} \sim 1\ GeV$

$*\ E_{max}$, also:
- Spallation, pp
- Photodisintegration
- Adiabatic loss
- Escape

Magnetic field amplification

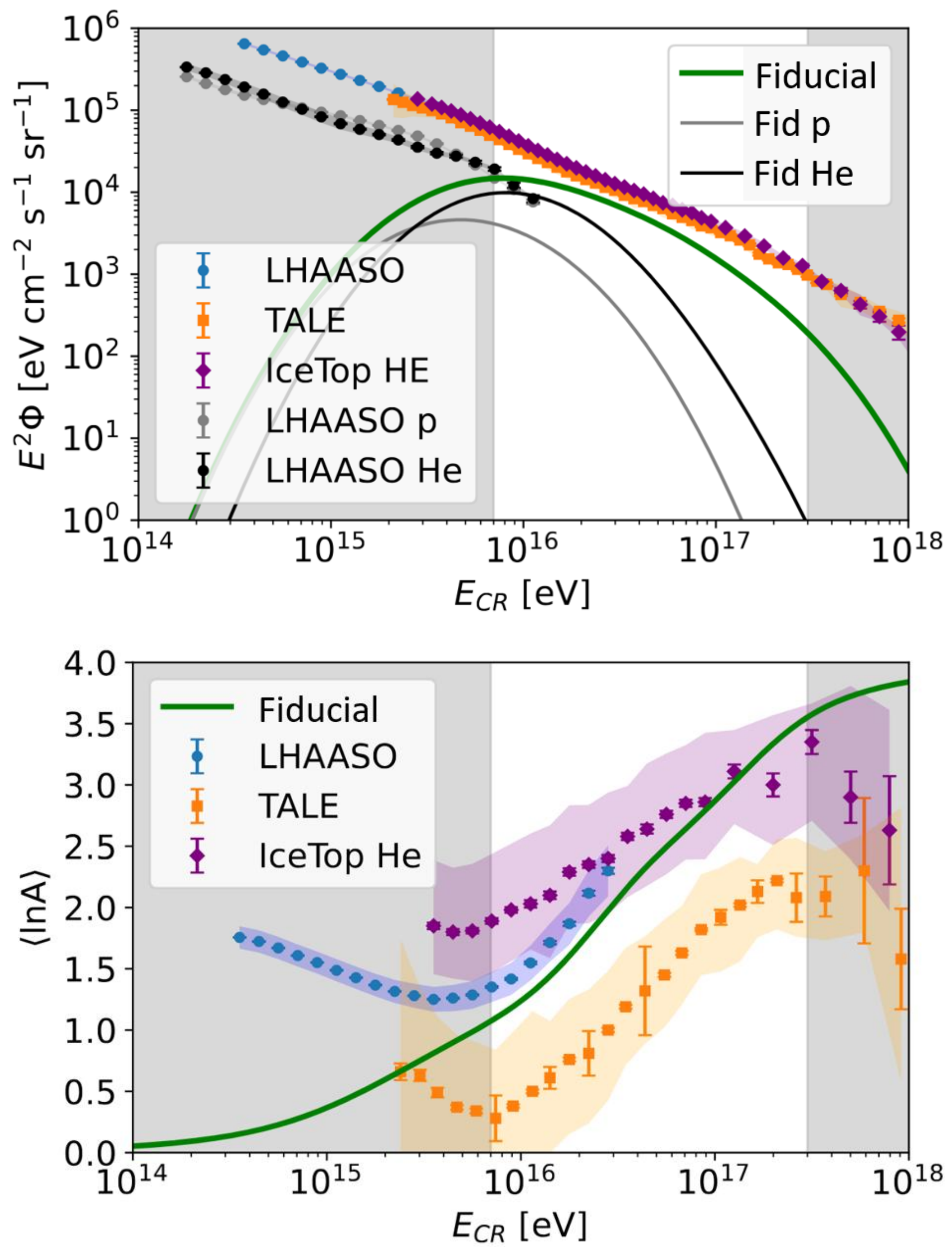
- CRs escape, producing a current
- Excite modes $< r_L$ *(non-resonant streaming or Bell instability)*
- $A \sim 3-5$ for IIn parameters

$$A = max\left(\frac{B_{sat,NRS}}{B_w}, 1\right)$$

Heavy ion abundance enhancement

- Simulations show $f_{inj} \sim (A/Z_{ion})^{5/2}$
- Z_{ion} from photoionization code, $T \sim 15000\ K$

		$f_{inj} \sim (A/Z_{ion})^{5/2}$
H	$\sim$ 90%	$\rightarrow$ 24%
He	$\sim$ 9%	$\rightarrow$ 53%
CNO	$\sim$ 0.1%	$\rightarrow$ 20%
Fe	$\sim$ 0.002%	$\rightarrow$ 2%

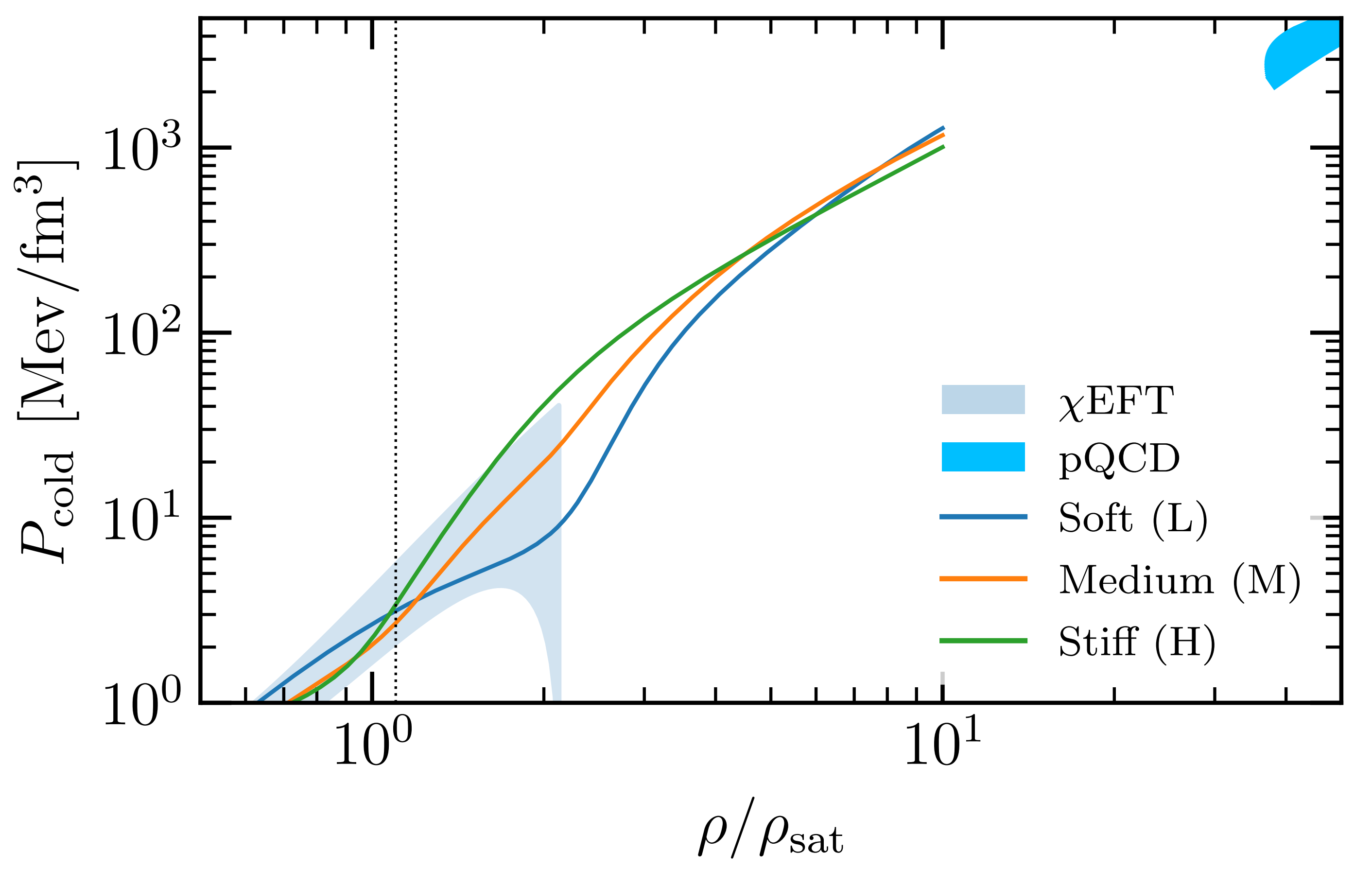


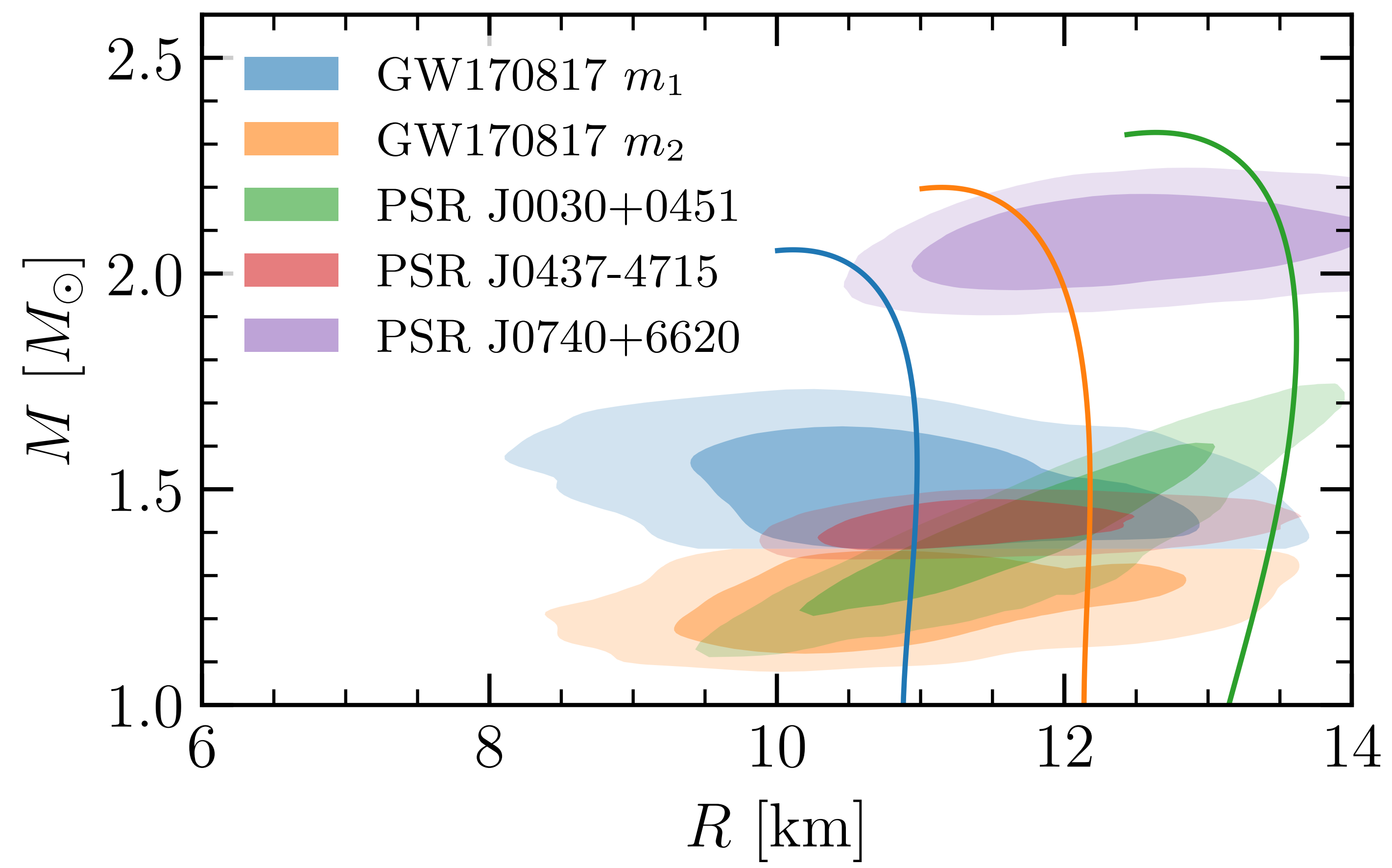
Dependence of postmerger properties on the thermal heating efficiency in neutron star mergers

Ming-zhe Han, Yong Gao, Kenta Kiuchi, Masaru Shibata

DOI: 10.1103/p6s8-khkw arxiv: 2504.08514

EOS





EOS constraints

χEFT at low density (up to $\sim 1.1\rho_{\rm sat}$)

pQCD at high density

M-Λ measurements of **GW170817**

M-R measurements of

PSR J0030+0451,

PSR J0740+6620,

and **PSRJ0437-4715**

Thermal effect

$$\varepsilon = \varepsilon_{\rm cold} + \varepsilon_{\rm th}$$

$$P = P_{\rm cold} + P_{\rm th}$$

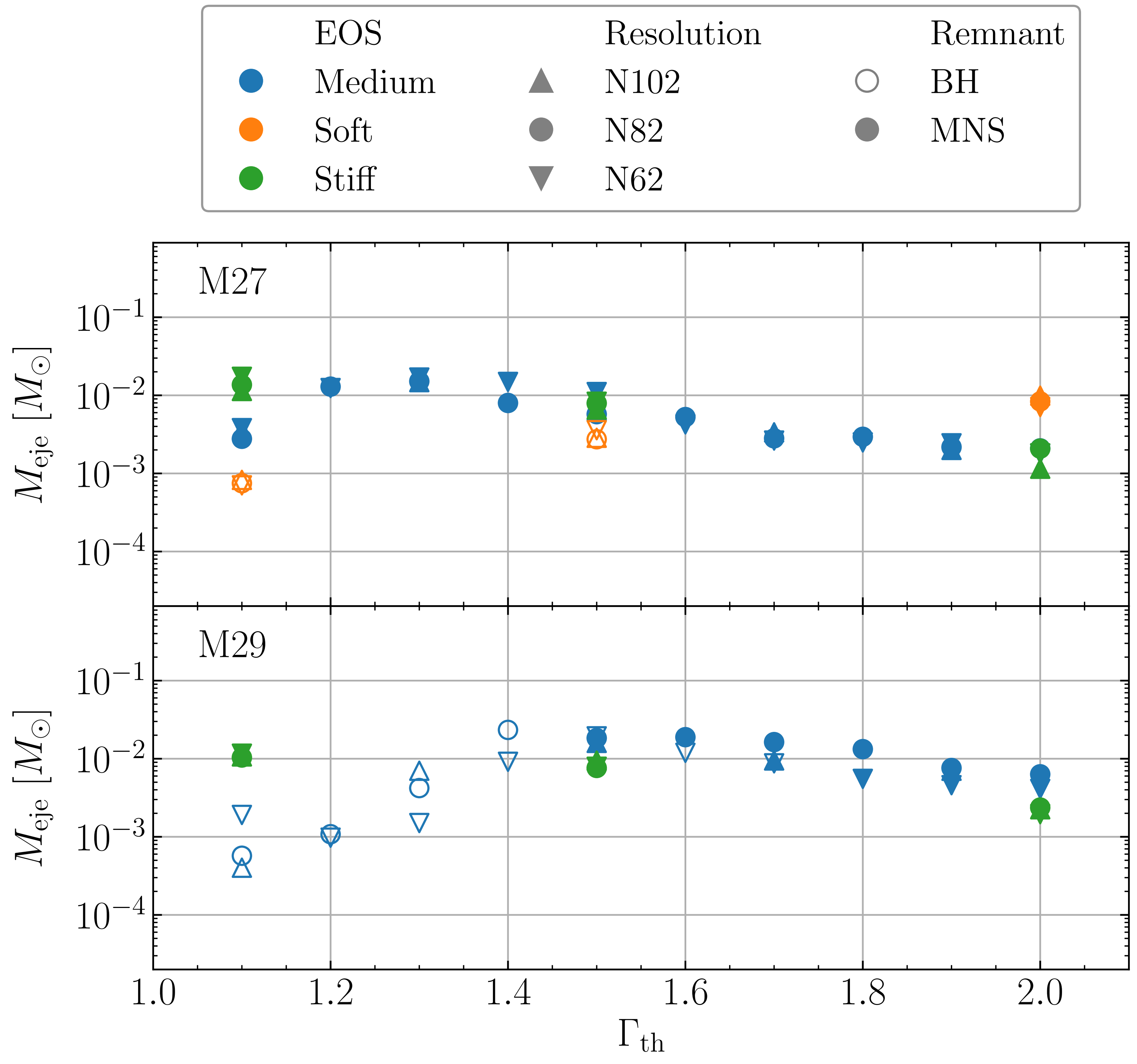
$$P_{\rm th} = (\Gamma_{\rm th} - 1)\rho\varepsilon_{\rm th}$$

Numerical Setups

ID solver	FUKA
Evolution	SACRA
EOS	Soft, Medium, Stiff
Mass	Equal mass with total mass $m_0 = 2.7, 2.9\ M_\odot$
Thermal index	$\Gamma_{\rm th} = 1.1, 1.2, 1.3, \ldots, 2.0$
Separation	~ 45 km
eccentricity	$\lesssim 0.001$
Simulation time	~ 30 ms after merger
Resolution	N62 ~ 150 m, N82 ~ 180 m, N102 ~ 240 m

Main results

Dynamical ejecta



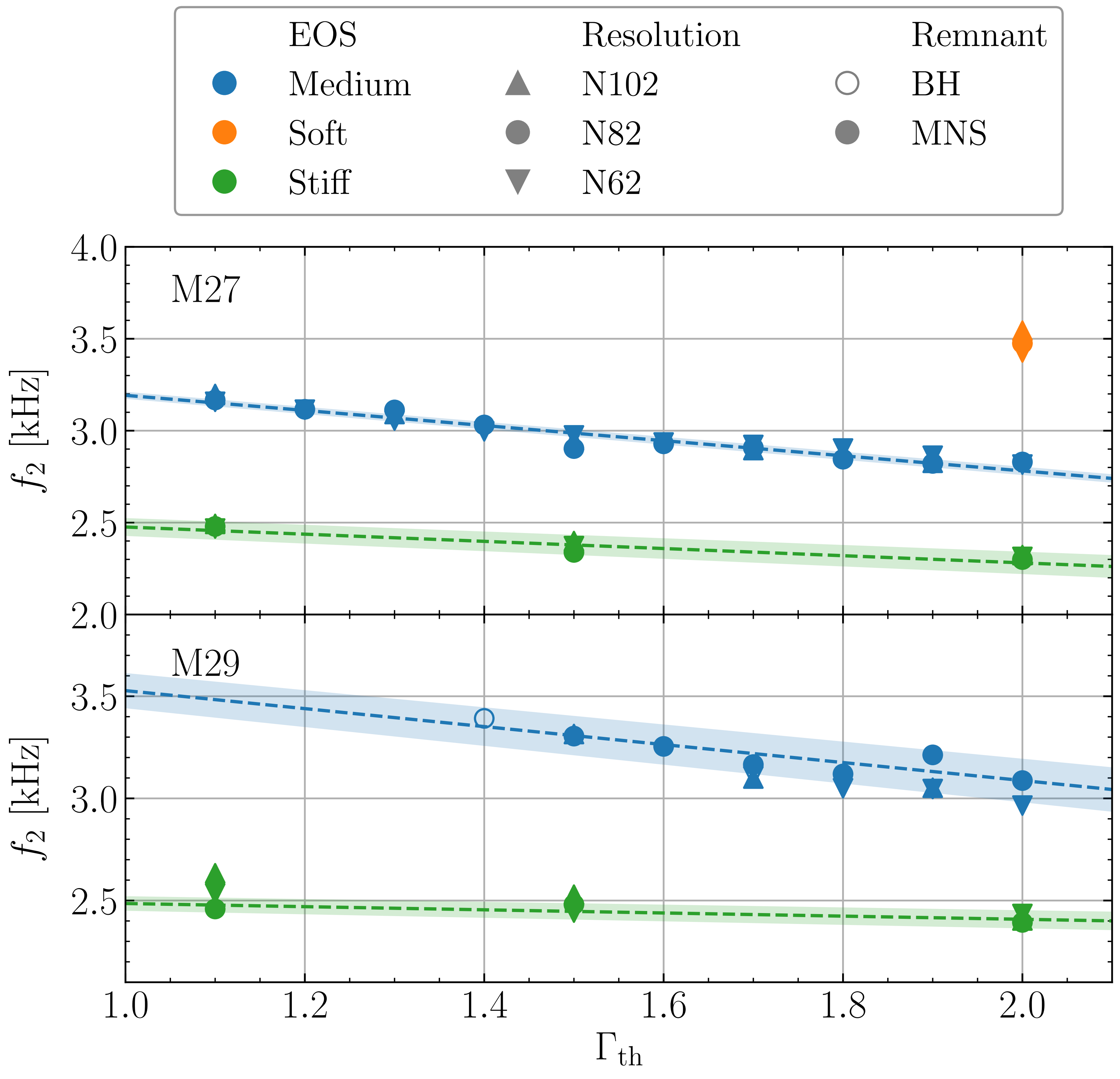
Three behaviors with different EOSs:

Soft, **monotonically** increase with $\Gamma_{\rm th}$

Medium, **peak structure**, increase first then decrease

Stiff, **monotonically** decrease with $\Gamma_{\rm th}$

f_2 peak



Fitting with:

$$f_2 = a\,\Gamma_{\rm th} + b$$

Model	a [kHz]	b [kHz]	$(\sigma_a,\ \sigma_b)$
M-M27	−0.411	3.603	(0.0019, 0.0046)
M-M29	−0.440	3.967	(0.0103, 0.0301)
H-M27	−0.195	2.671	(0.0061, 0.0152)
H-M29	−0.077	2.563	(0.0043, 0.0108)

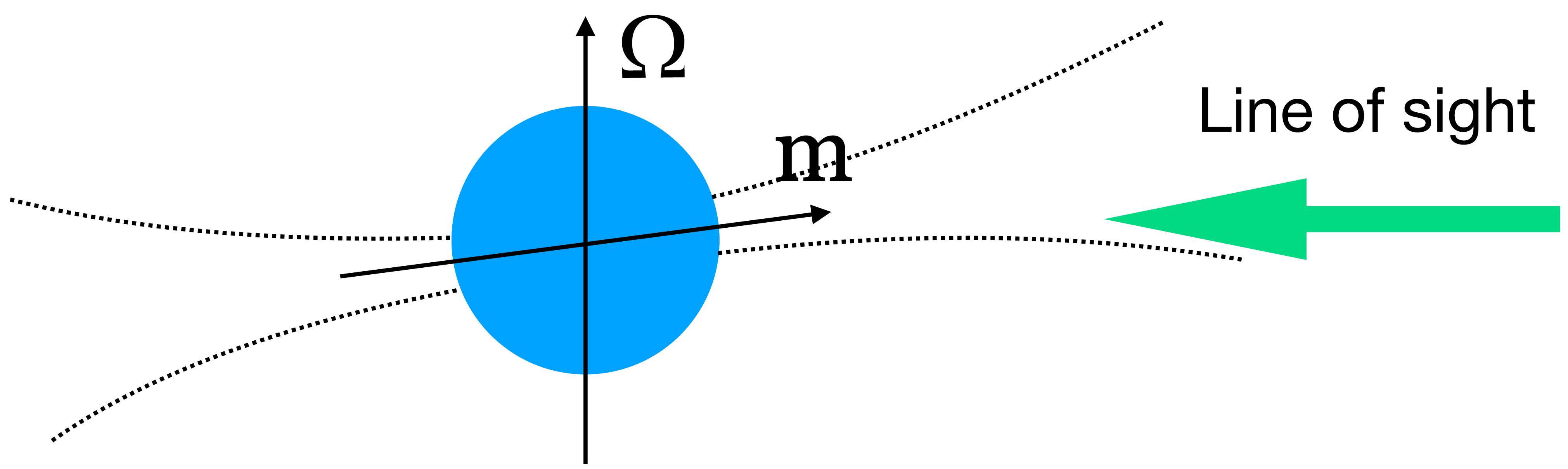
f_2 **monotonically decrease** with $\Gamma_{\rm th}$,

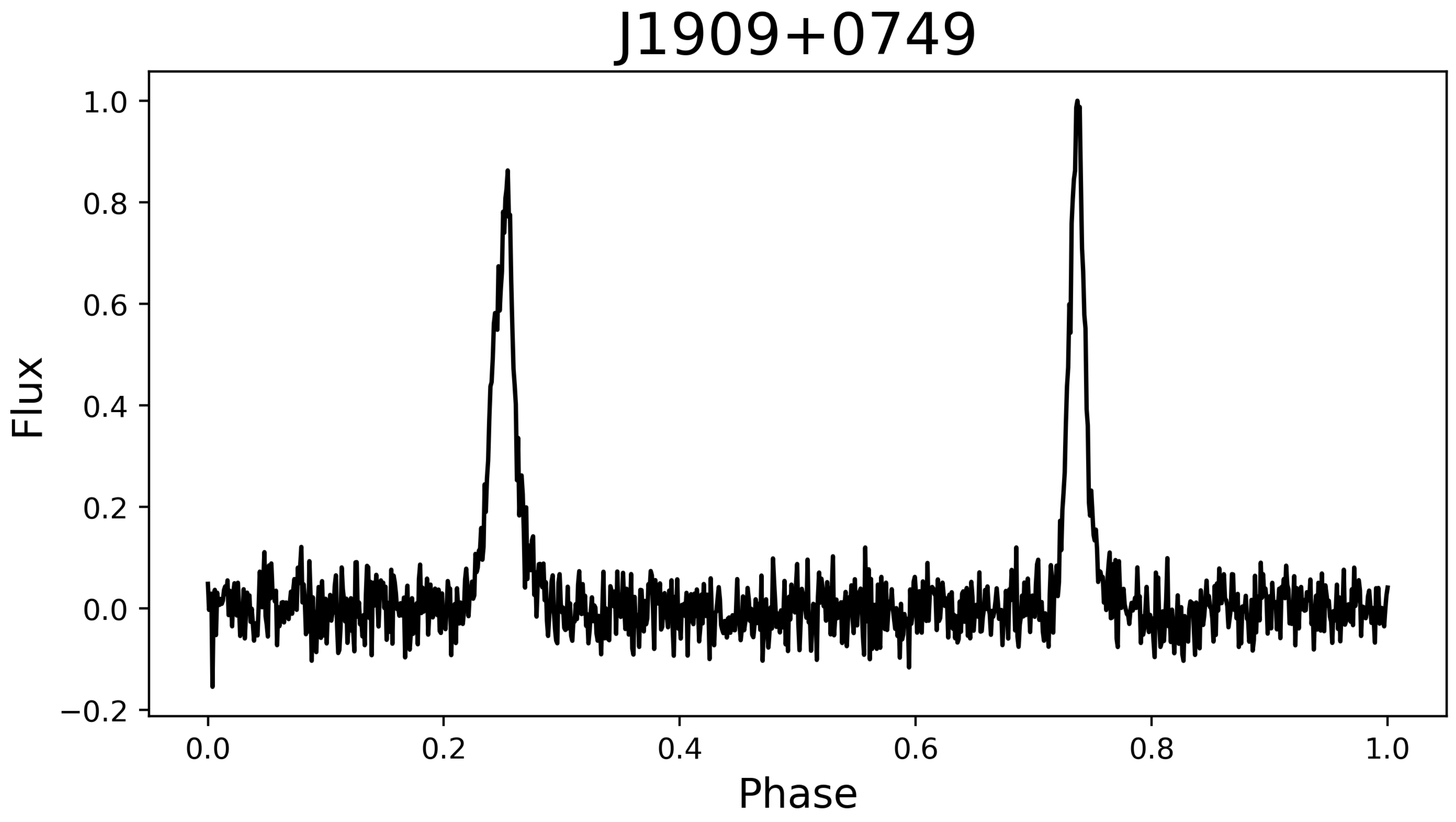
where f_2 is the dominant peak of the post-merger frequencies.

Orthogonal radio pulsars — theory and observations

Istomin A. Yu.[1,2,✉], Kniazev F. A.[1,2], Beskin V. S.[1,2]

Orthogonal radio pulsars





Data from Posselt et. al., MNRAS, 2023

Magnetosphere structure and «death line»

- «Classical» approach — accelerating potential is determined by Goldreich-Julian charge density
- «Modern» approach —accelerating potential is determined by the current, required for a smooth MHD-like solution

«Classical» death line

$$\dot{P} > P^{11/4} k^{7/4} \cos^{-7/4}\chi \qquad k \sim 1$$

For orthogonal radiopulsars: $\cos\chi \sim \sqrt{\frac{\Omega R}{c}}$

$$\dot{P} > P^{29/8} k^{7/4} \left(\frac{2\pi R}{c}\right)^{-7/4}$$

Kniazev F. A., Istomin A. Yu., Beskin V. S., Astron. Let. 2025

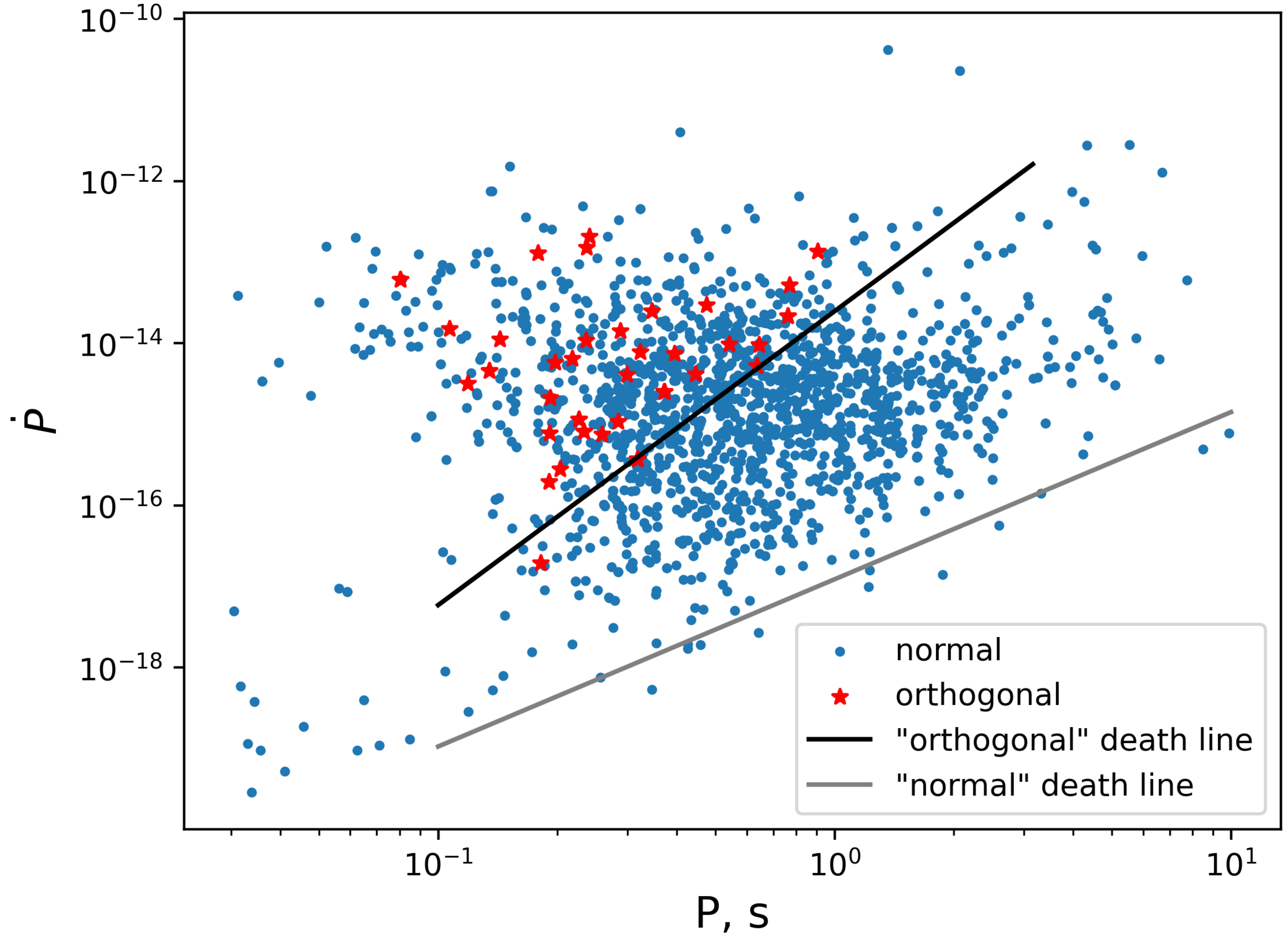
✉ — *istomin15arseniy@gmail.com*

[1] *- Lebedev Physical Institute*
[2] *-Moscow Institute for Physics and Technology*

Orthogonal radio pulsars — theory and observations

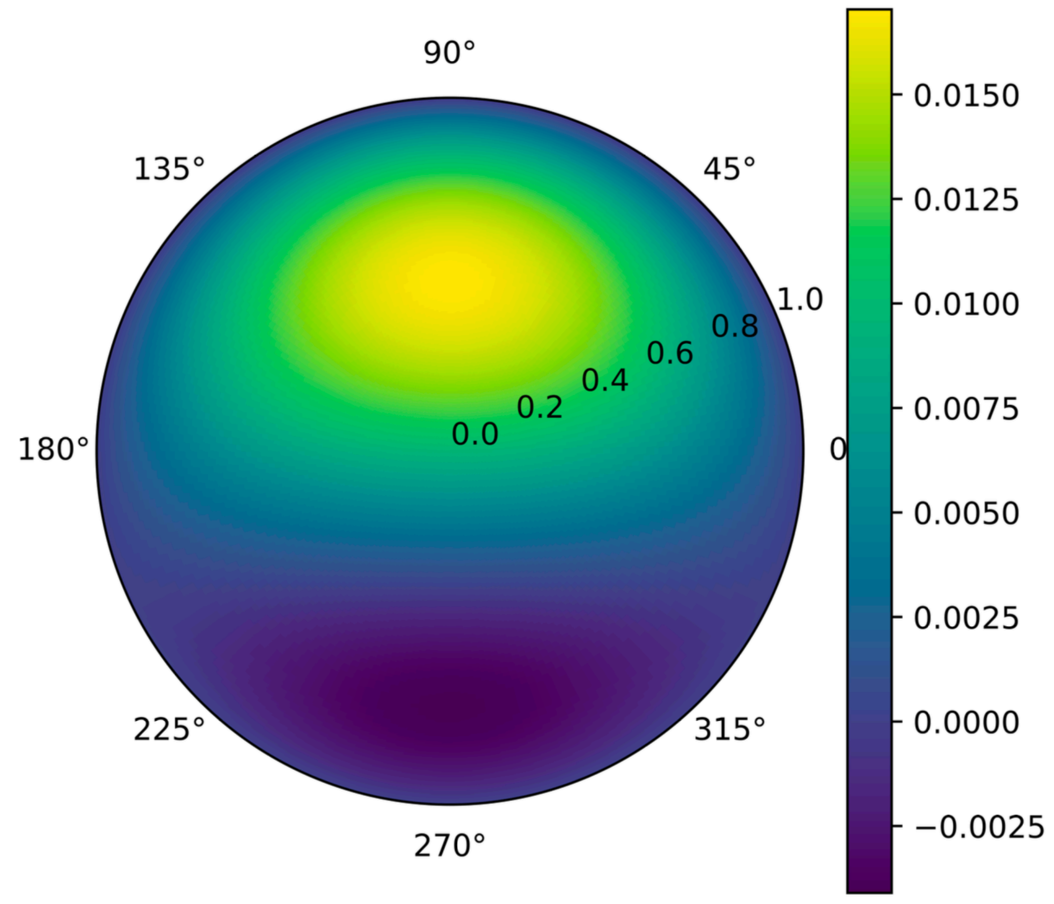
Istomin A. Yu.[1,2,✉], Kniazev F. A.[1,2], Beskin V. S.[1,2]

FAST and MeerKAT observations



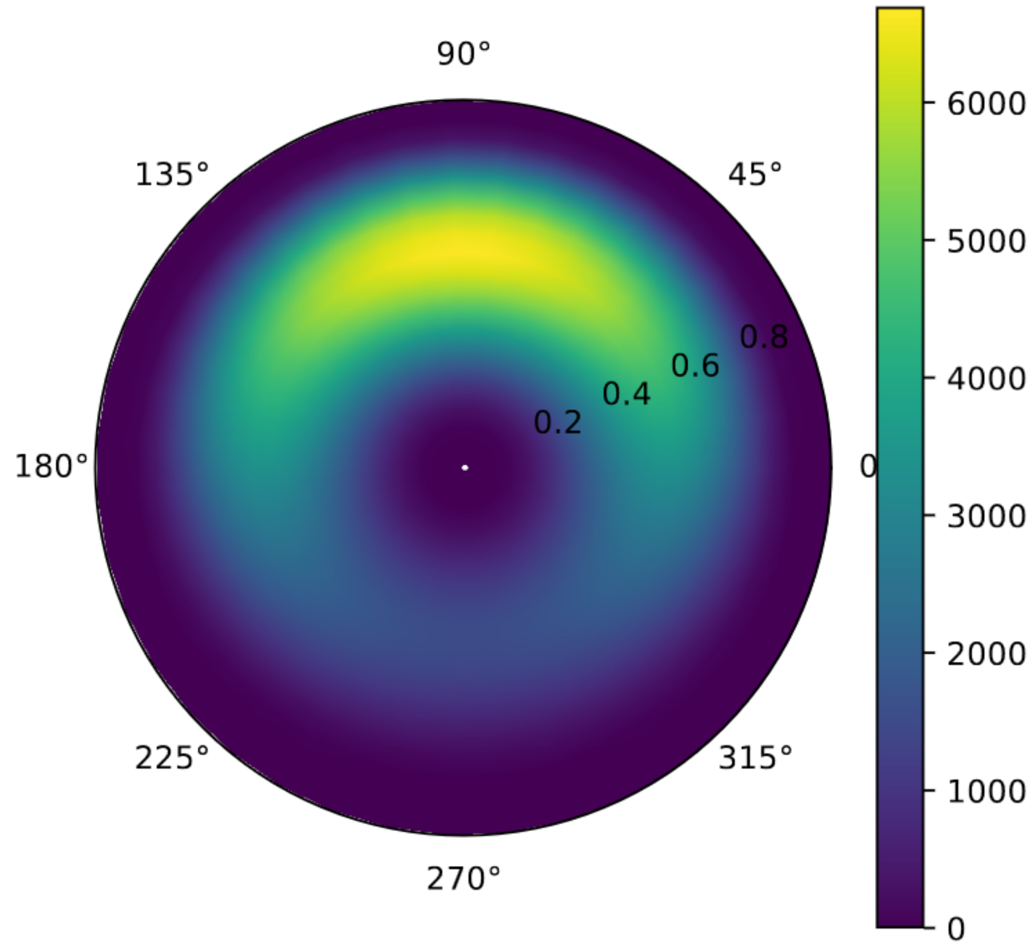
Data from Posselt et. al., MNRAS, 2023 and Wang et. al., RAA 2023

More on the theory of orthogonal pulsars



Example of accelerating potential calculation

Example of plasma number density calculation



Istomin A. Yu., Kniazev F. A., Beskin V. S., Astron. Rep. 2024

✉ — *istomin15arseniy@gmail.com*

[1] - Lebedev Physical Institute
[2] -Moscow Institute for Physics and Technology

Modeling of Little Red Dots and open challenges

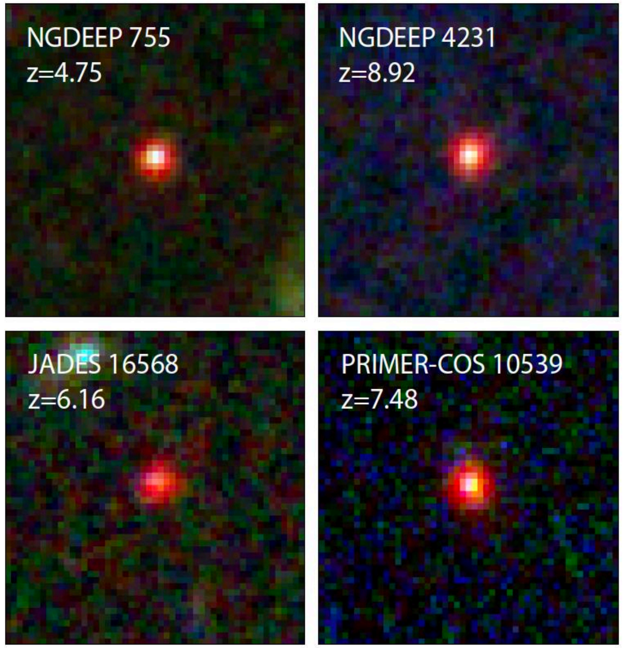
Daisaburo Kido@RESCEU, UTokyo
Collaborators: Kunihito Ioka, Kenta Hotokezaka, Kohei Inayoshi, Christopher Irwin

3 main characteristics of LRDs

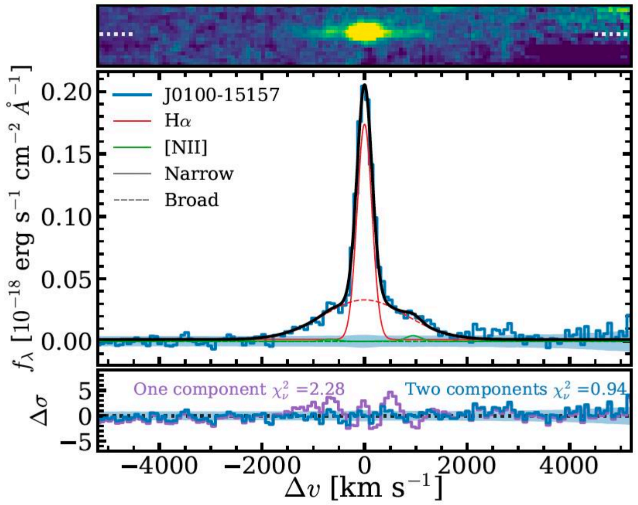
1. Very compact morphology (<100 pc)
2. Broad hydrogen Balmer emission lines (>1000 km/s)
3. Red in NIRCam, showing a “V-shaped” SED

+X-ray, mid IR weak, 1~10 years variability, strong Balmer break…

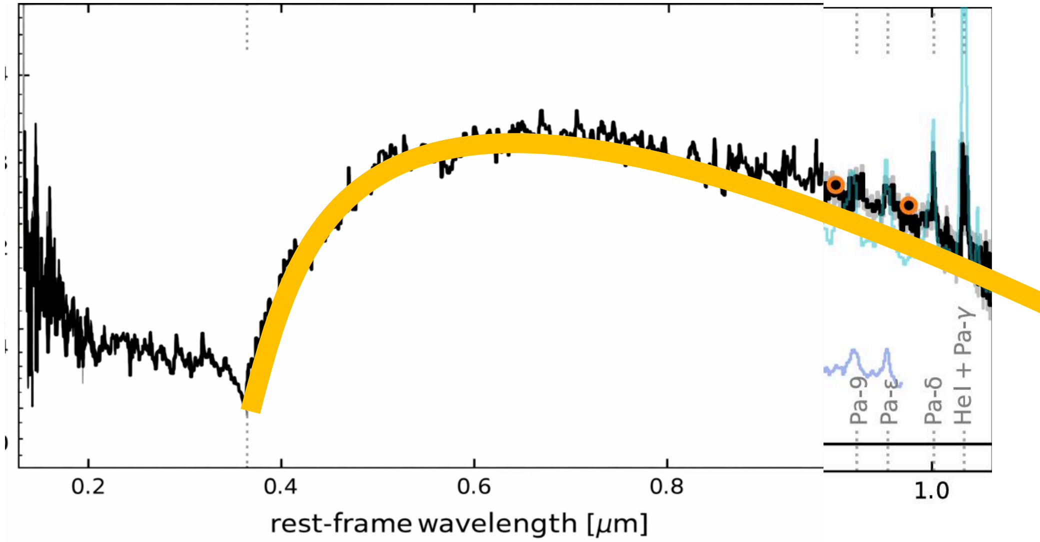
Matthee+24



Kocevski+24



de Graaff +25



Our work: BH envelopes

Very gas envelope around BH

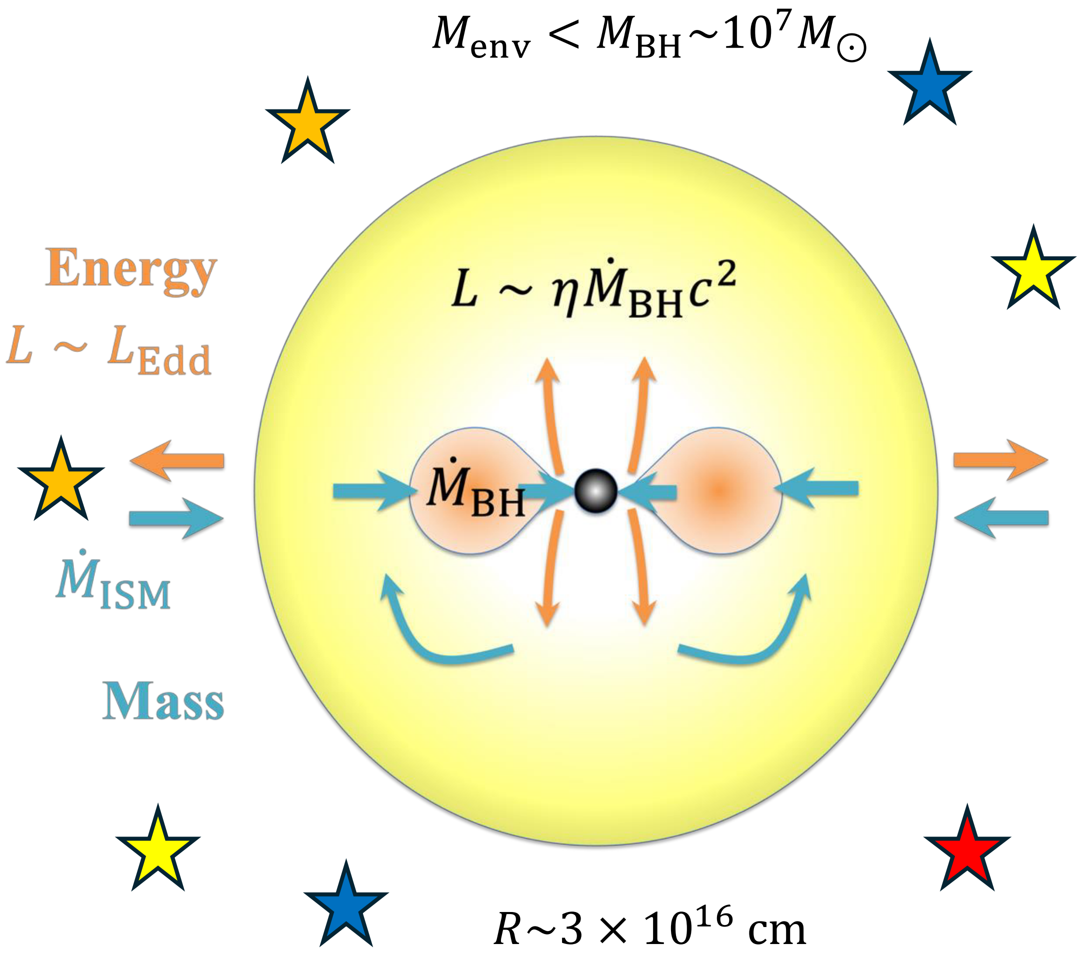
1. **Hide X-ray, outflow**
2. **Reproduce red optical continuum**
3. **Dynamical timescale of 1-10 years**

Reprocess outflow energy via radiation and convection

Finally, $T_{\rm ph} \sim 5000\ {\rm K}$ blackbody radiation is emitted from surface

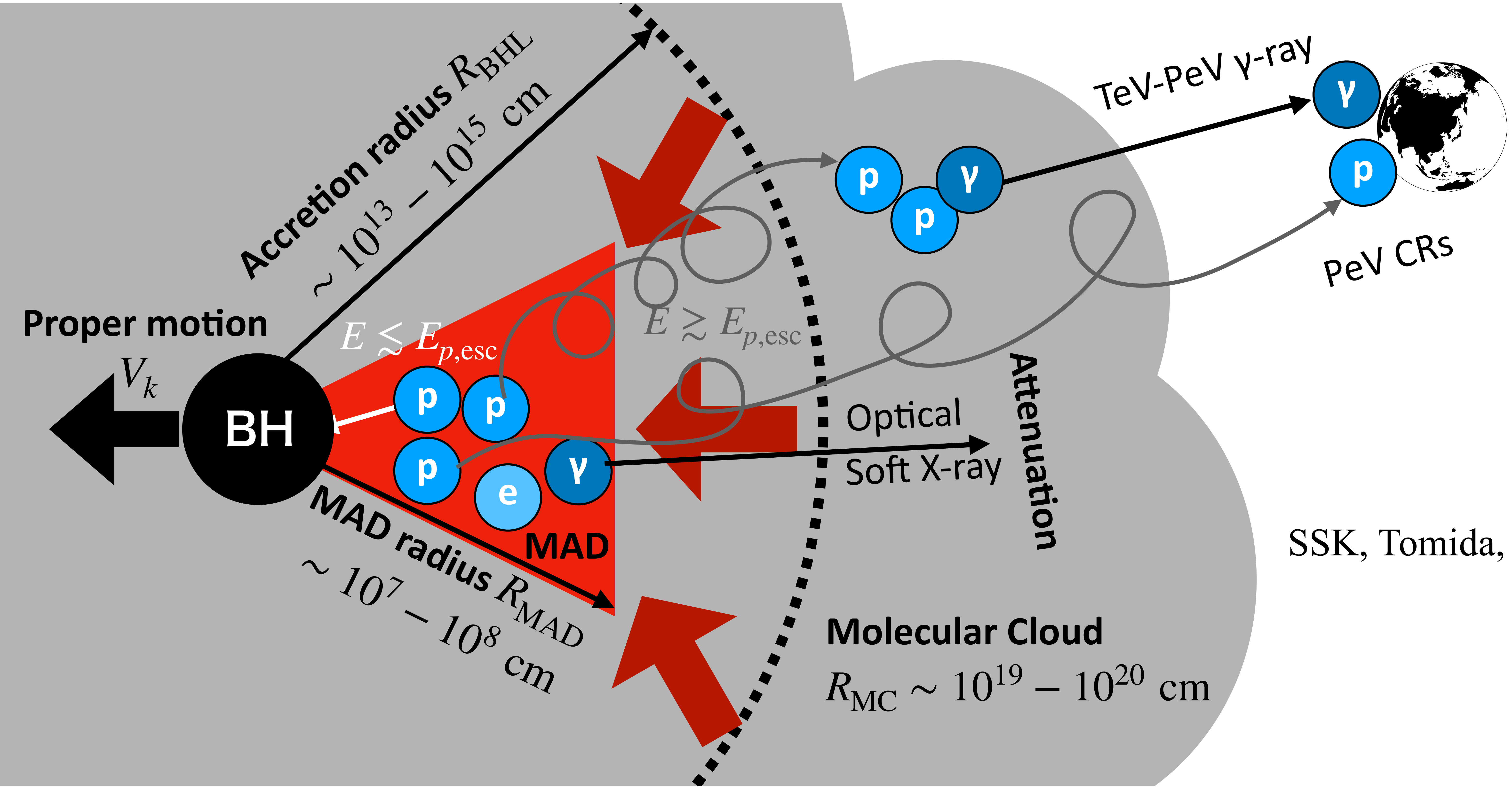
$$r_{\rm ph} = 10^{16} \left(\frac{L}{10^{45}\ {\rm erg\ s^{-1}}}\right)\left(\frac{T_{\rm ph}}{5000\ {\rm K}}\right)^{-2}\ {\rm cm}$$

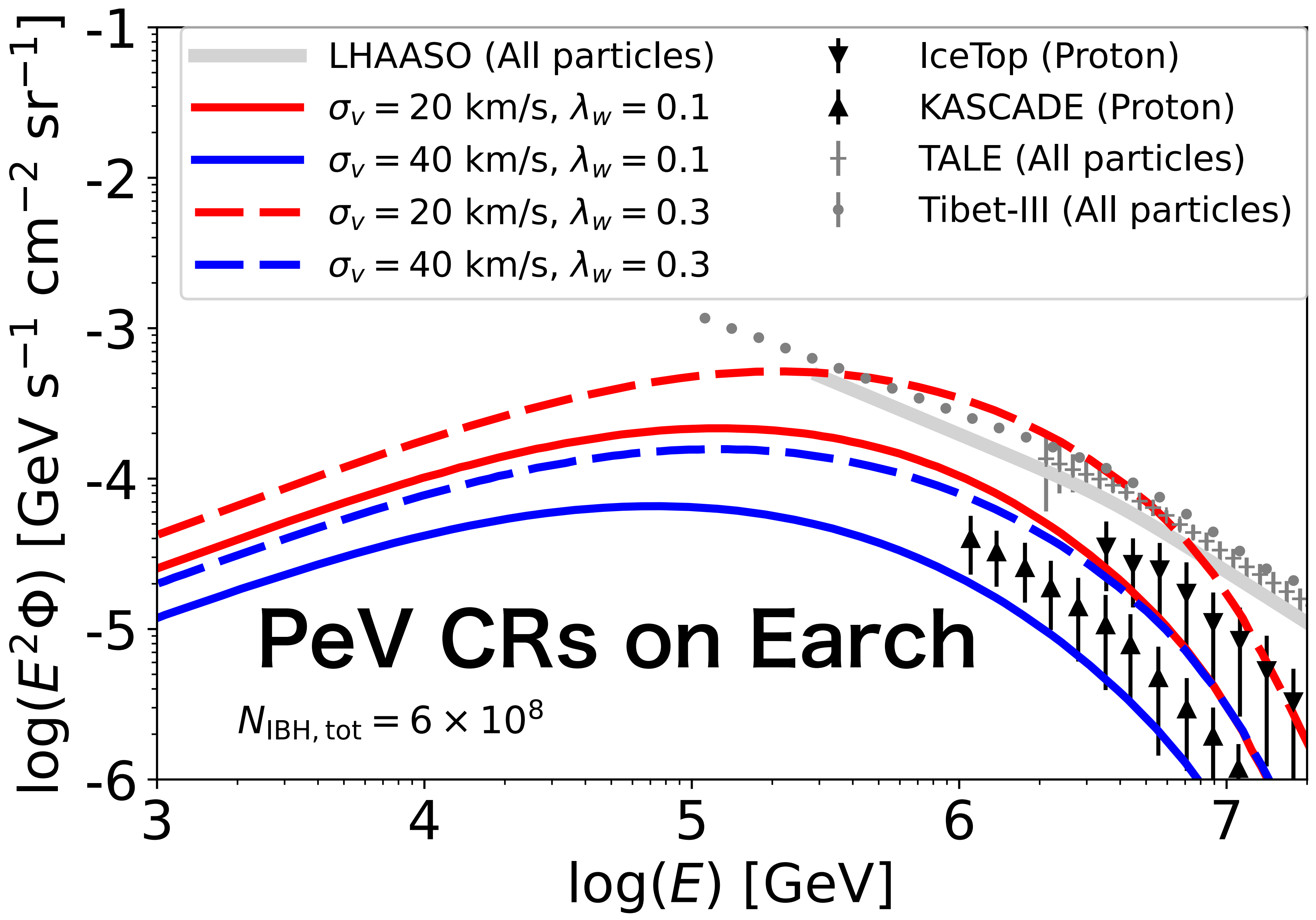
Required mass is 1~10% of BH mass



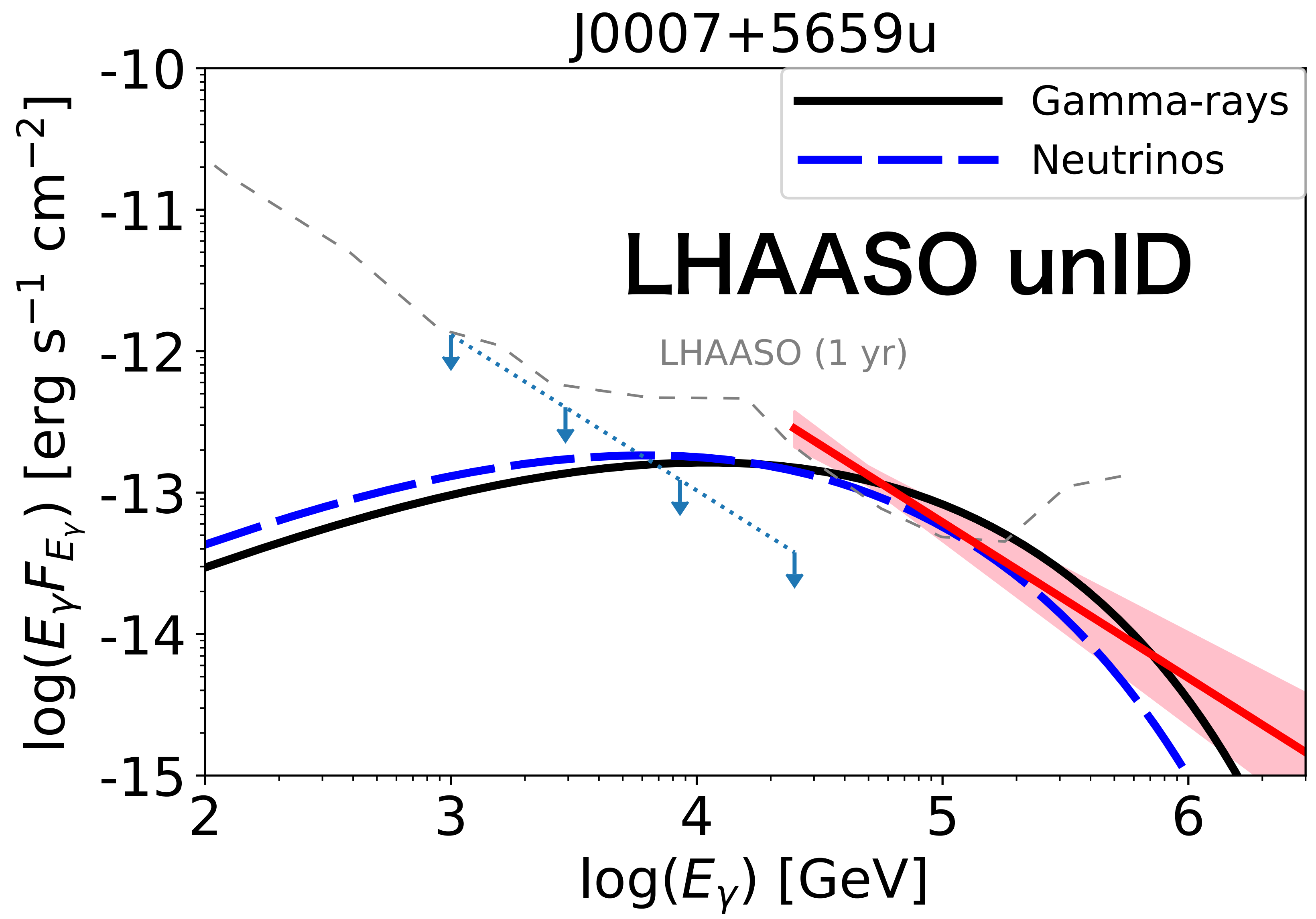
Isolated Black Holes as Potential PeVatrons

Tohoku University Shigeo S. Kimura





SSK, Tomida, et al. 2025 ApJL



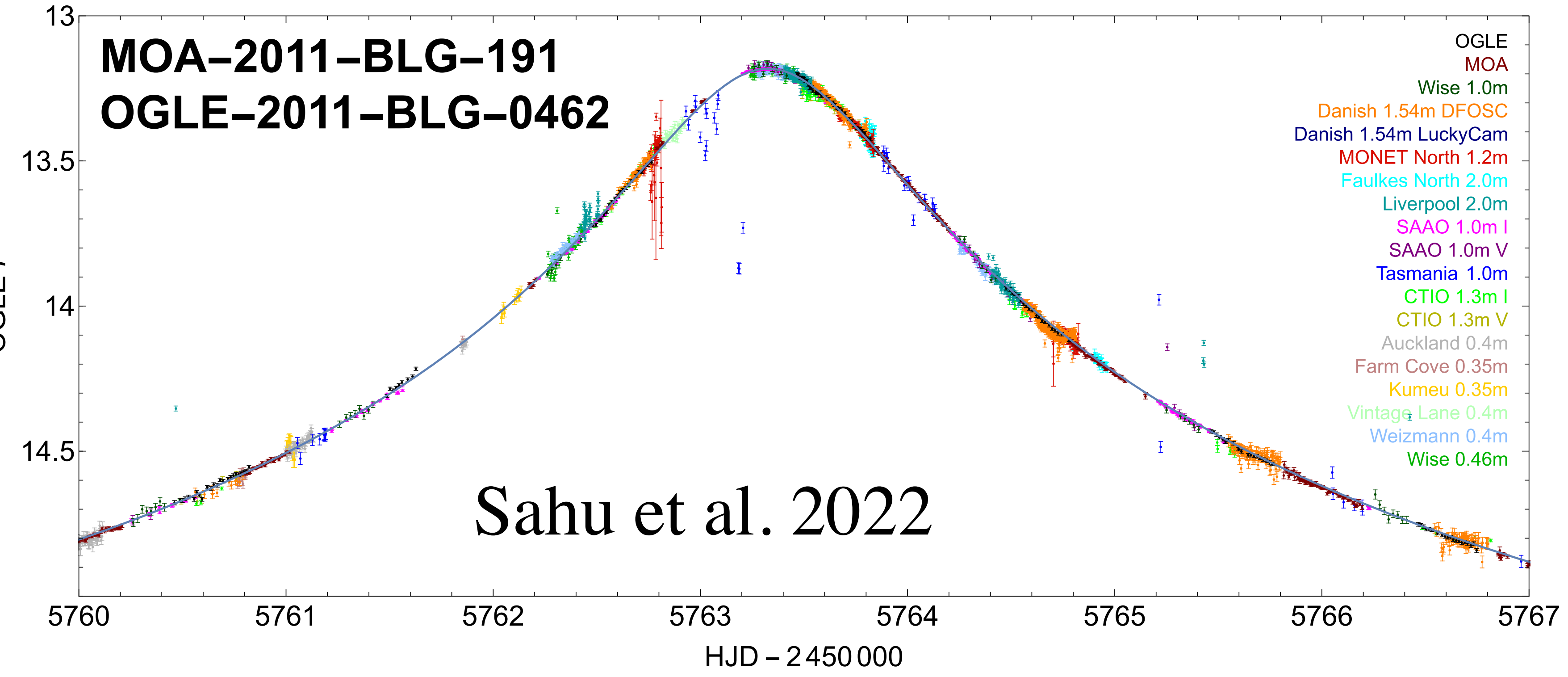
References

SSK, Kashiyama, Hotokezaka, 2021, ApJL, 922, L15

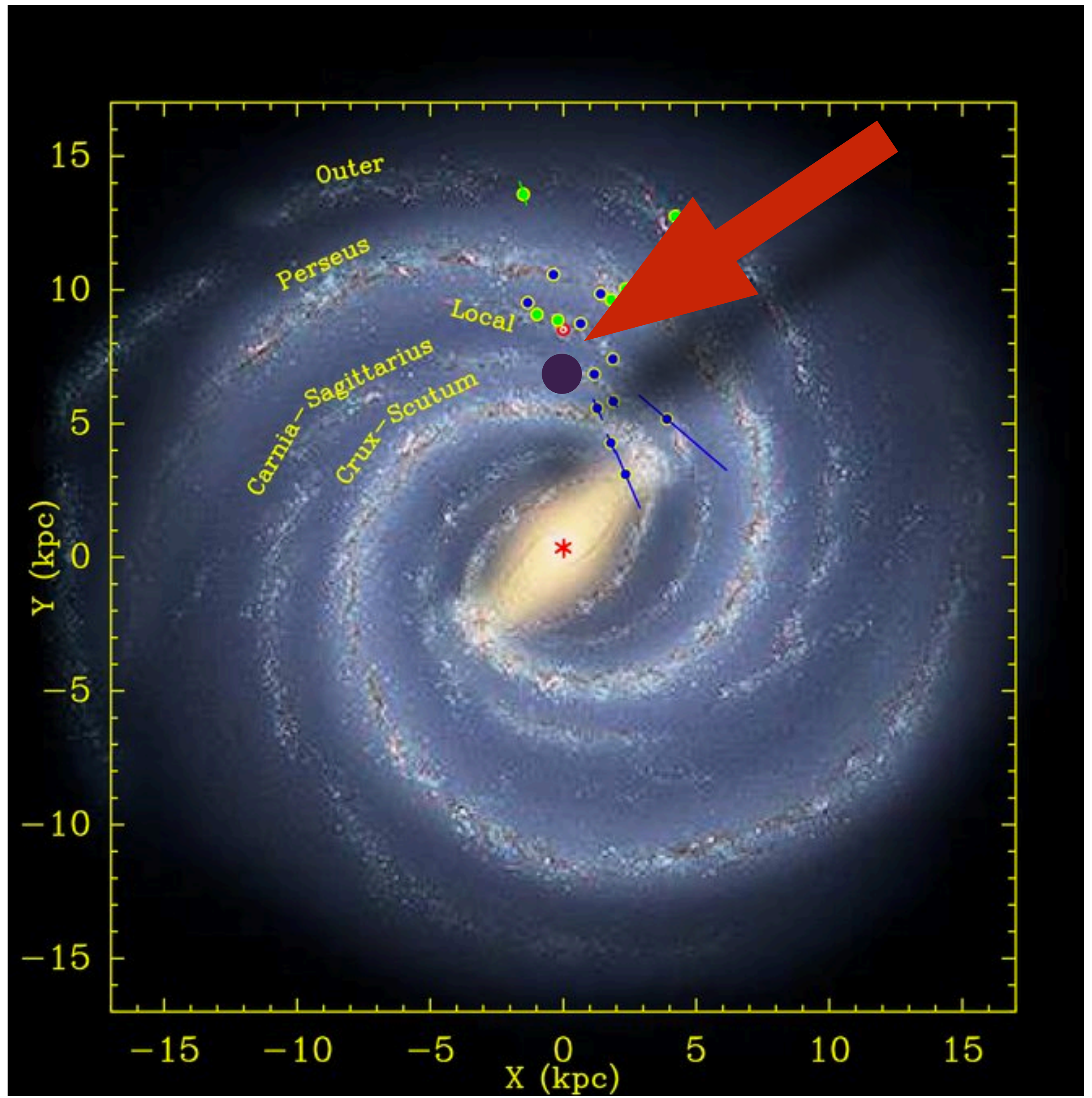
SSK, Tomida, Kobayashi, Kin, Zhang 2025, ApJL, 981, L36

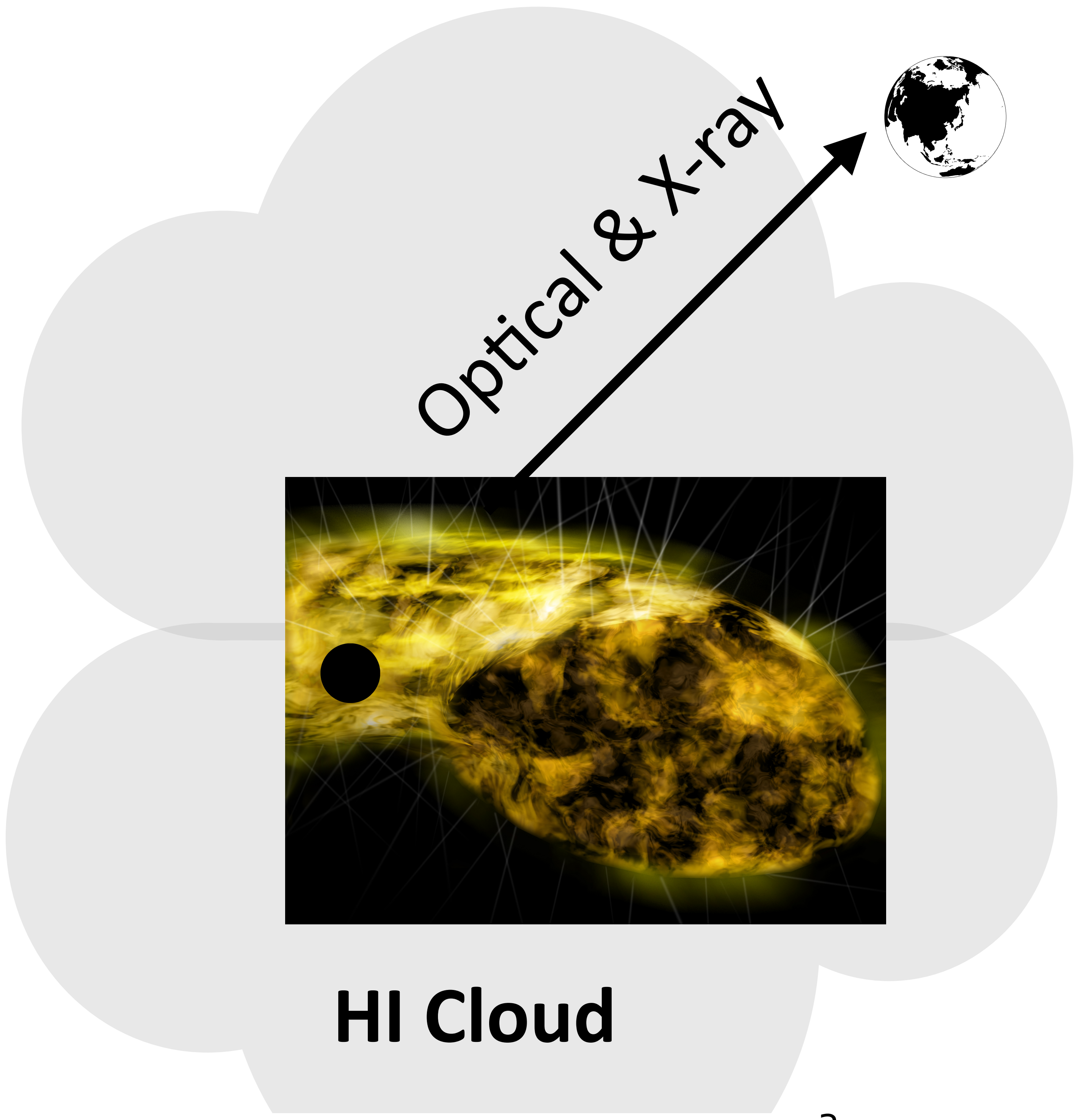
SSK, Murchikova, Sahu, 2025, ApJ, 986, 135

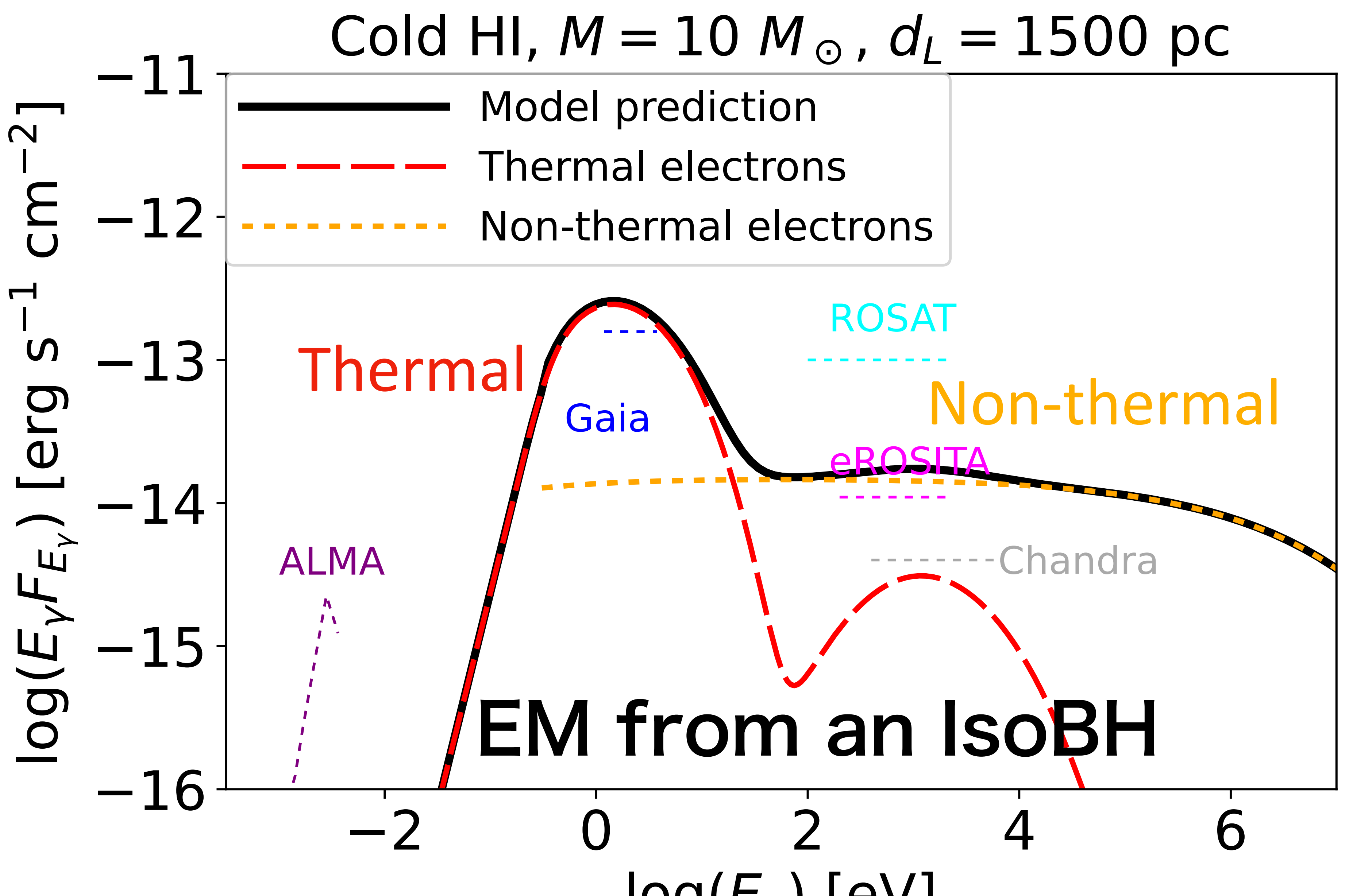
EM emission from Isolated Black Holes



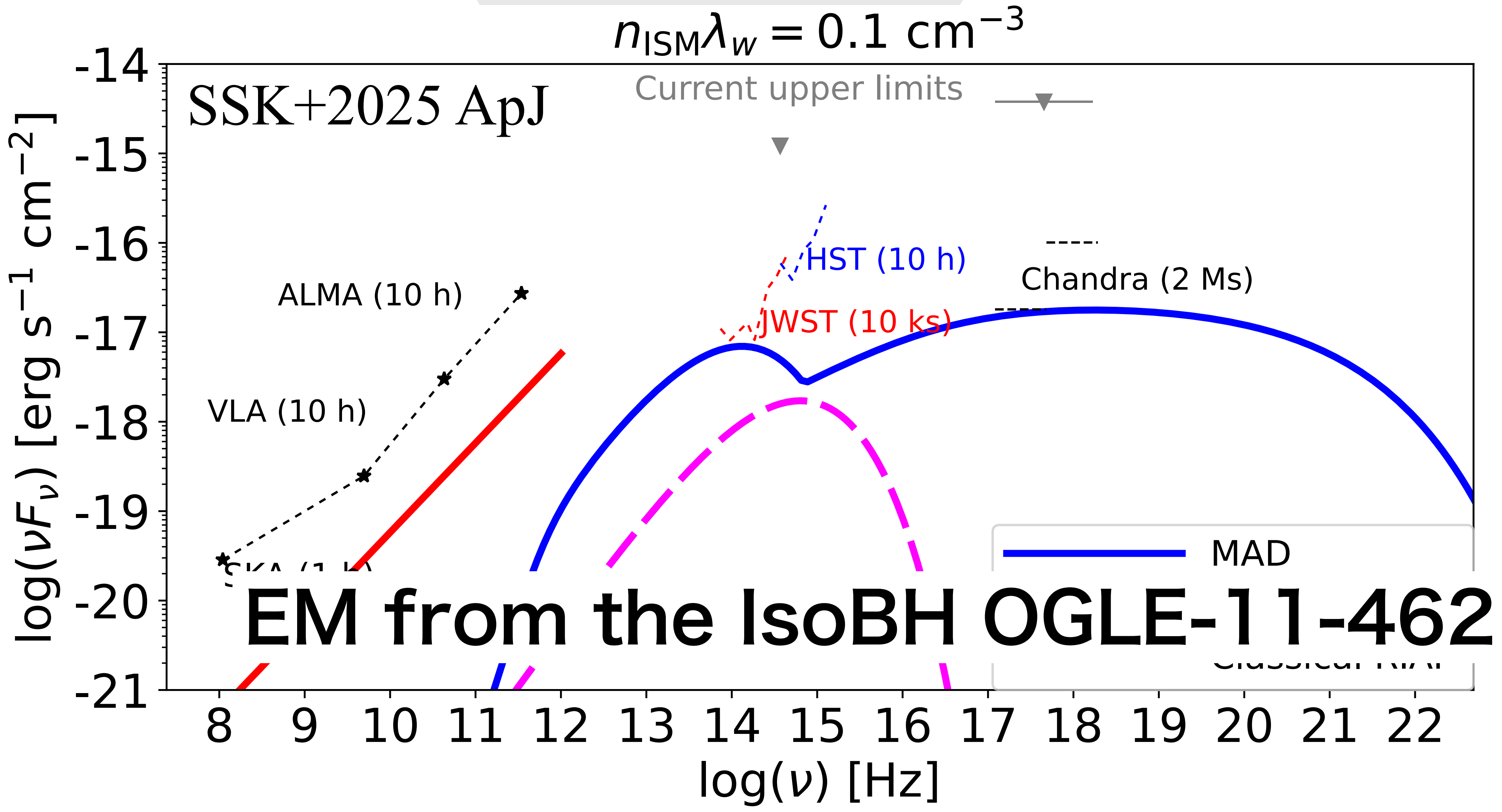
IsoBH OGLE-2011-BLG-0462



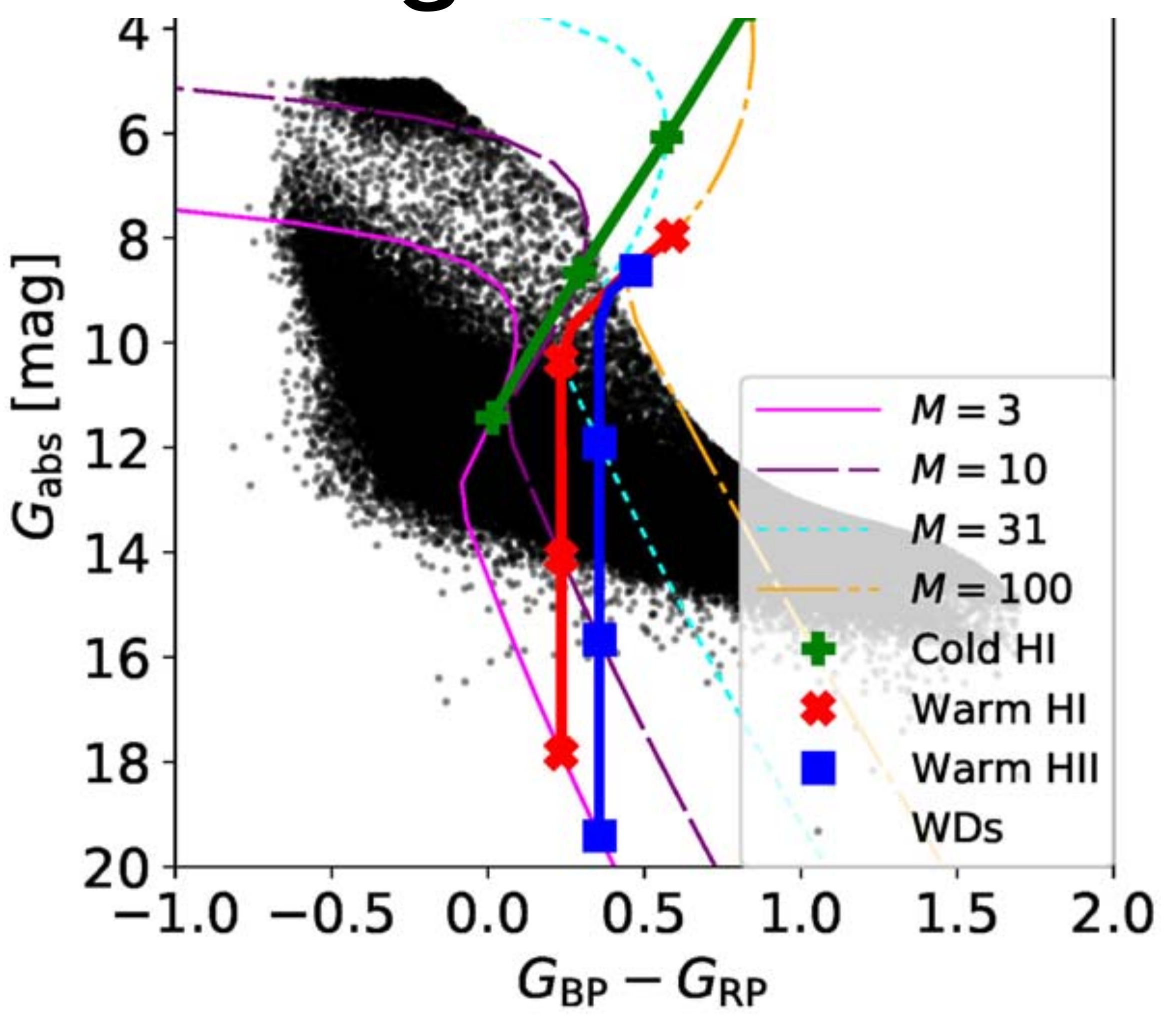




SSK+ 2021 ApJL



HR diagram for IsoBH

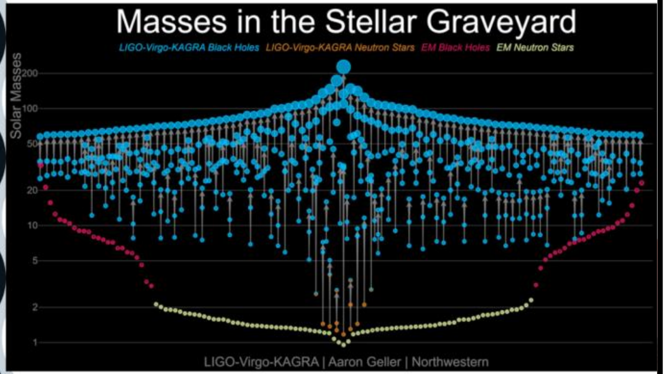


First star remnants for gravitational sources

Tomoya Kinugawa (Shinshu University)

Masses of GW events

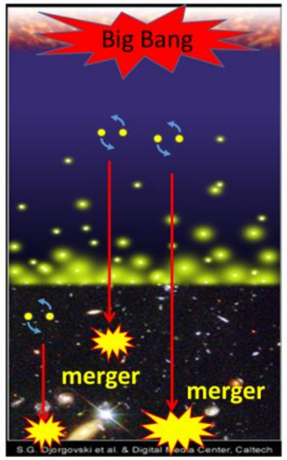
- GW events show that there are many massive BHs (≳30 Msun).
- On the other hand, the typical mass of BHs in X-ray binaries is ~10 Msun.



Pop III BBH remnants for gravitational wave

- Pop III stars were born and died at z≳10.
- The typical merger time of compact binaries ~$10^{8\text{-}10}$yr
  dN/dt∝t^{-1} (Kinugawa et al .2014,2020 Inayoshi et al. 2017)
- We can see Pop III BBH at the present day!

time



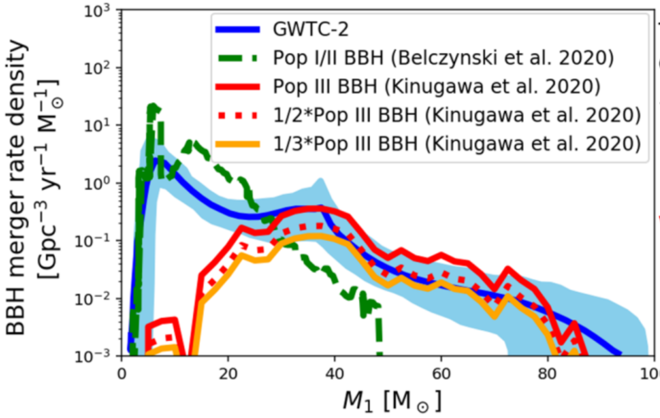
Djorgovski et al.&Degital Media Center

Wind mass loss & IMF

- Pop I (=Solar metal stars)
  Typical mass is small (IMF∝$M^{-2.35}$, 0.1Msun<M<100Msun)
  Stars lose a lot of mass due to the strong stellar wind
- Pop II (Metal<0.1SolarMetal)
  Typical mass is same as Pop I
  But, week wind mass loss

- Pop III (No metal)
  Pop III stars are ***the first stars*** after the Big Bang.
  Typical mass is more massive than Pop I, II
  MpopIII~10-100Msun
  No wind mass loss due to no metal.

Comparison with mass distributions of observed BBHs



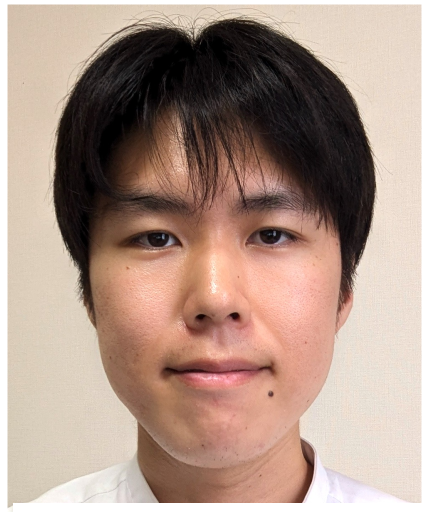
(Kinugawa, Nakamura& Nakano 2021)

The mass distribution might distinguish Pop III from Pop I/II

→The evidence of Pop III？
Not yet

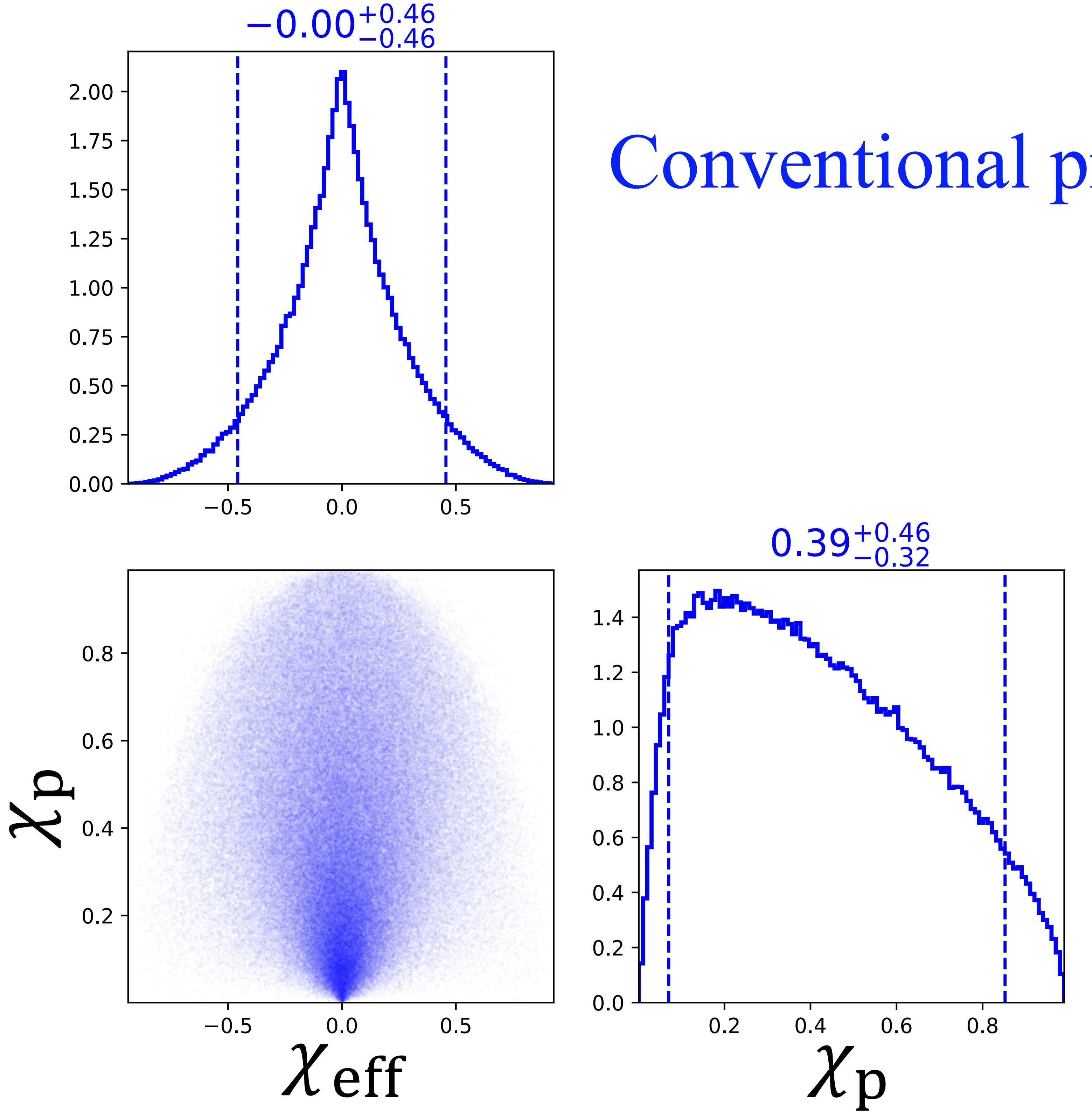
What is the smoking gun of Pop III?
→High redshift mergers
(ET, CE, DECIGO)
Peak of BBH merger rate
Pop III :z~10
Pop I/II: z~2-3

Reducing Spin-Prior Bias in Population Inference of Binary Black Holes



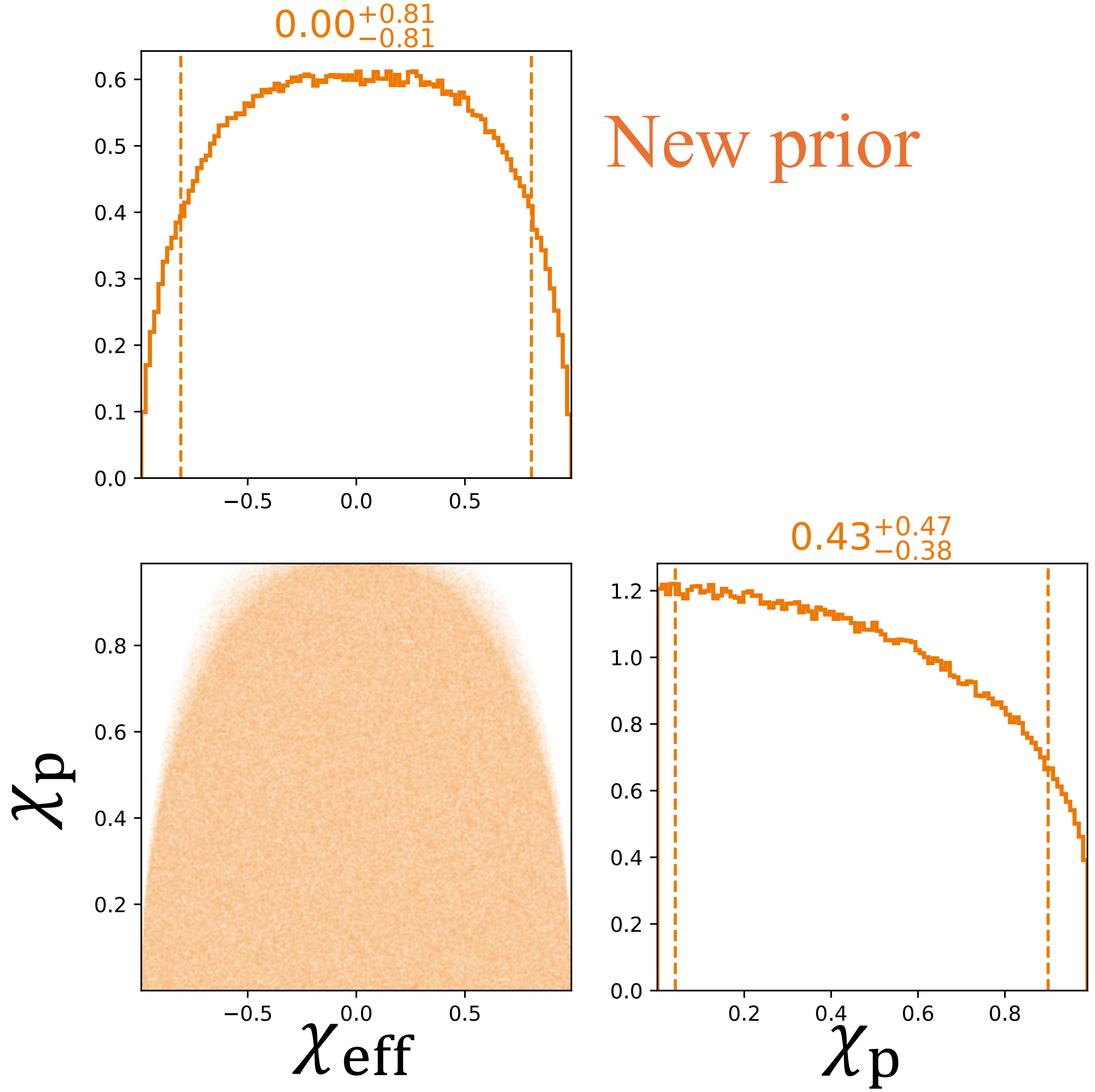
Kazuya Kobayashi[A], Masaki Iwaya[B,A], Soichiro Morisaki[A], Kenta Hotokezaka[C], Tomoya Kinugawa[D,C]

ICRR[A], GEI Cardiff University[B], RESCEU[C], Shinshu University[D]



Conventional prior

Change

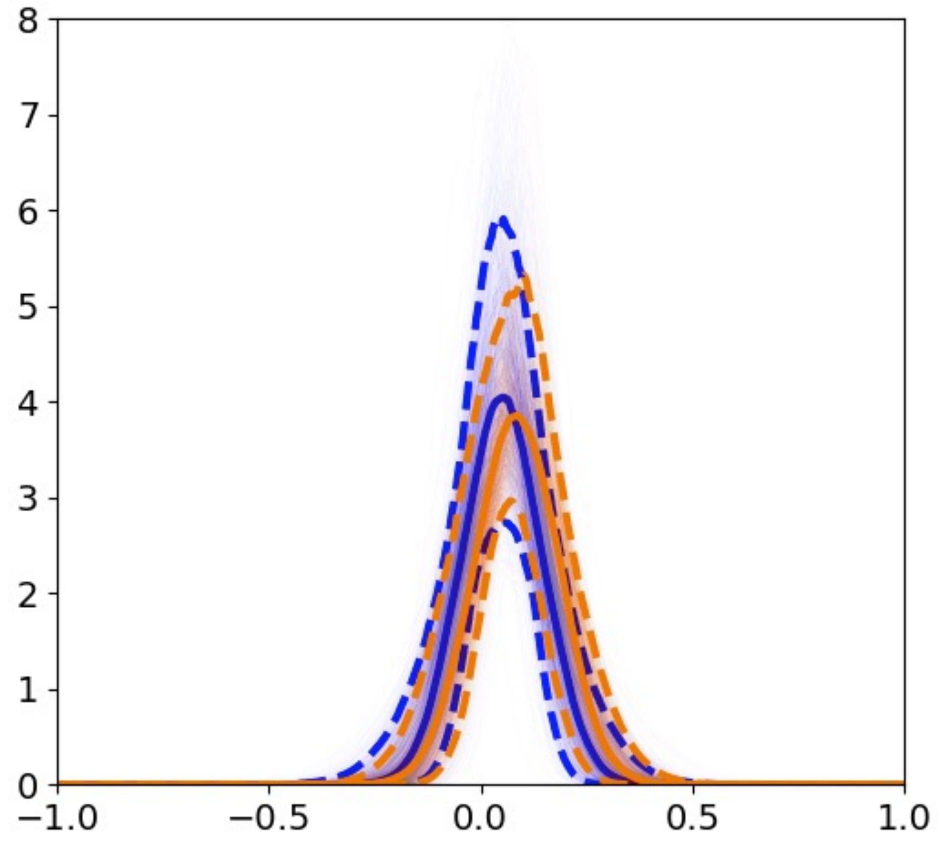


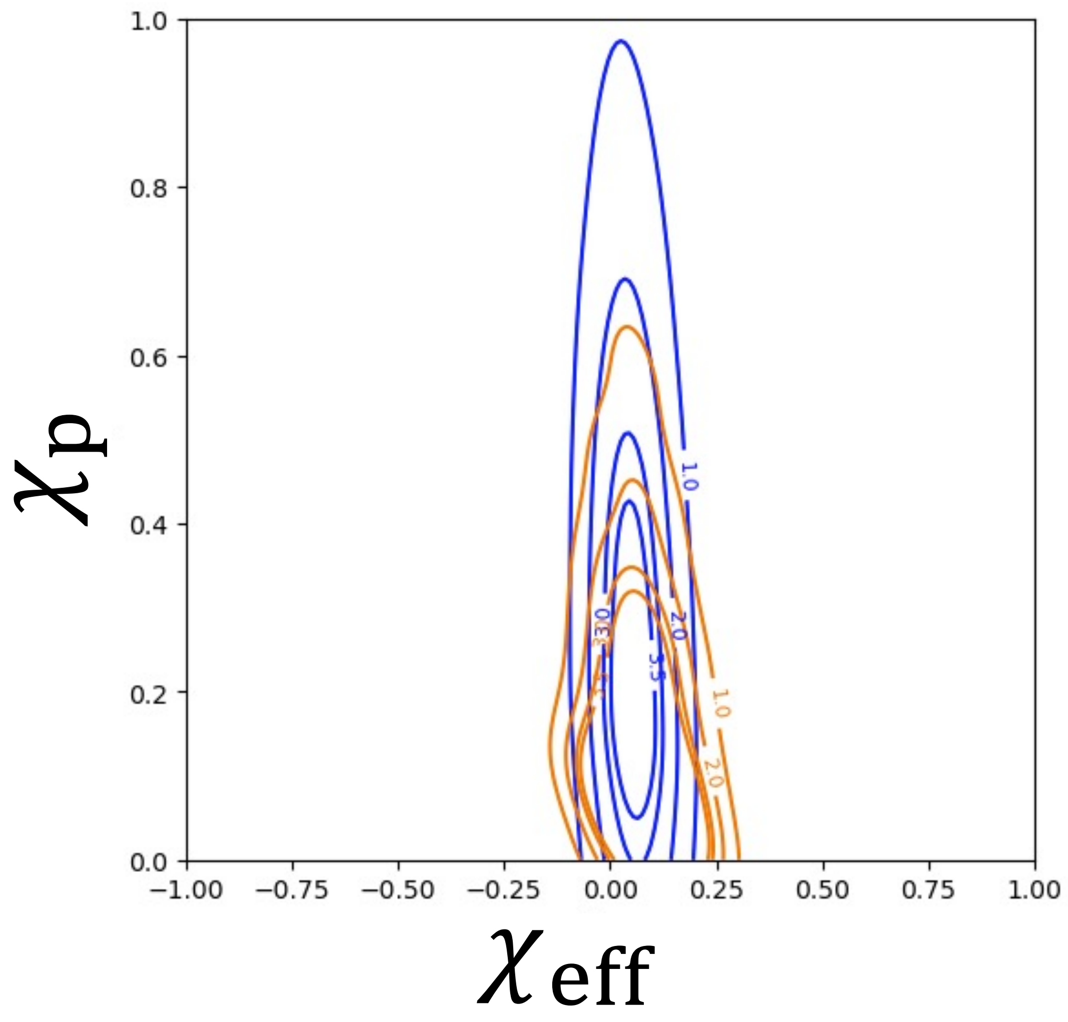
New prior

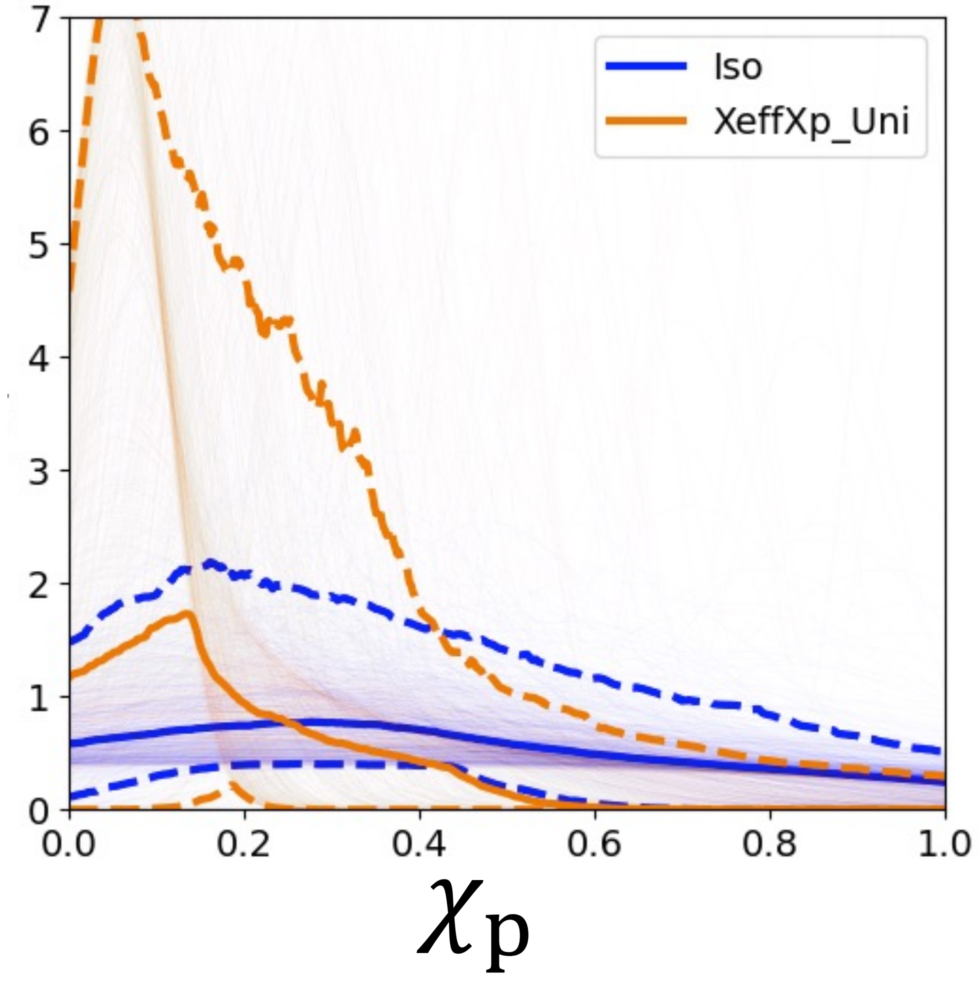
Effective spins population distribution for binary black holes observed in O3

Blue: conventional prior

Orange: new prior



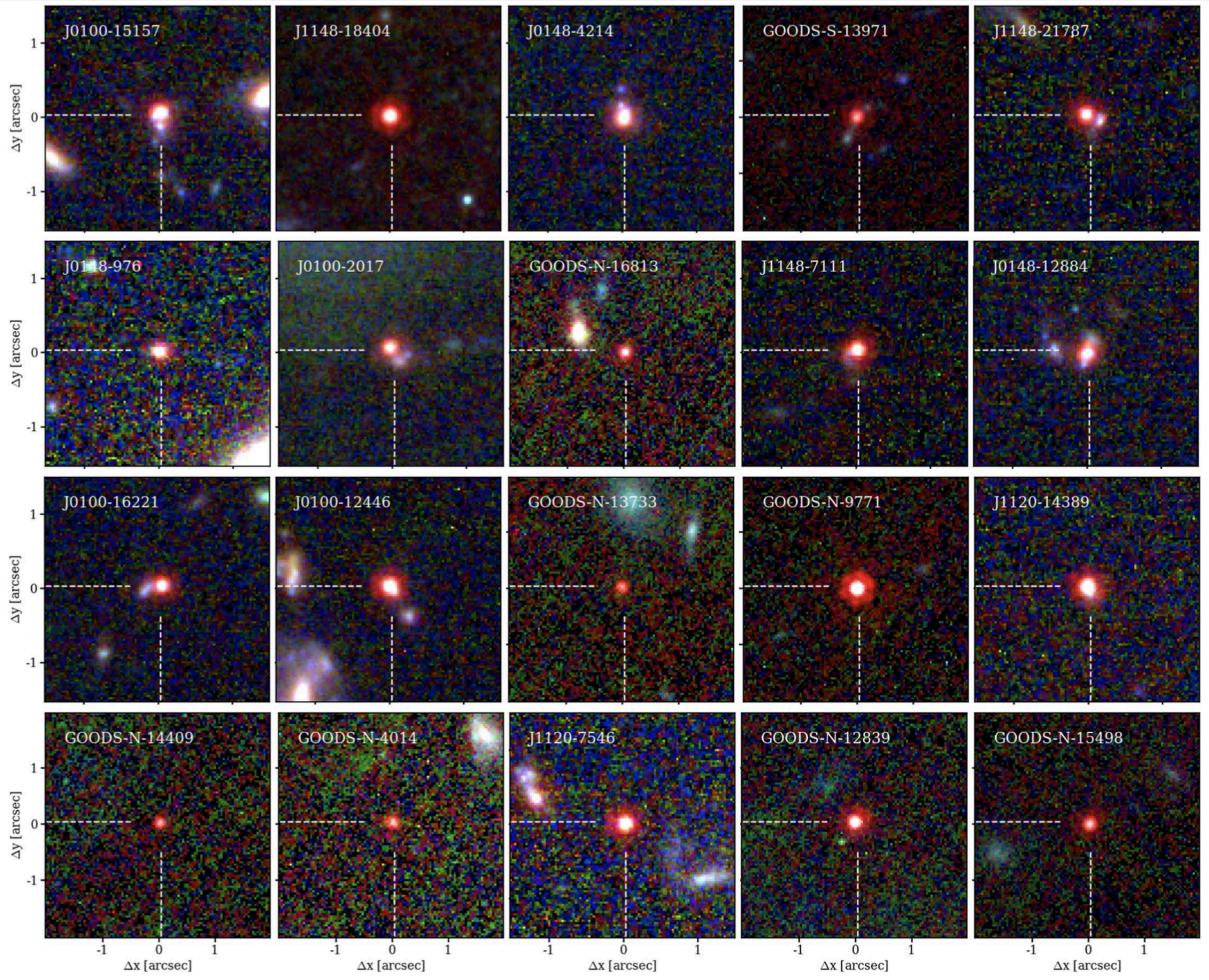




P14: Little Red Dots as Potential High-energy Neutrino Sources

arXiv: 2601.11203

Riku Kuze (YITP), Kunihito Ioka (YITP), Kohta Murase (Penn state), Shigeo S. Kimura (Tohoku), Kohei Inayoshi (Peking)



Matthee+2024

Little Red Dots (LRDs)

- Red & Compact galaxies ($R \lesssim 100$ pc)
- Population: $\Phi(z \sim 4) \simeq 10^{-4.5}$ cMpc^{-3}
- **No counterparts in radio and X-ray bands**
- Broad emission lines: $\sigma_v \sim 1000$ km s^{-1}

$L_{\rm Bol} \simeq 10^{44-45}$ erg s^{-1} -> $M_{\rm BH} \sim 10^{6-7} M_\odot$?

SMBH embedded with dense gaseous envelope

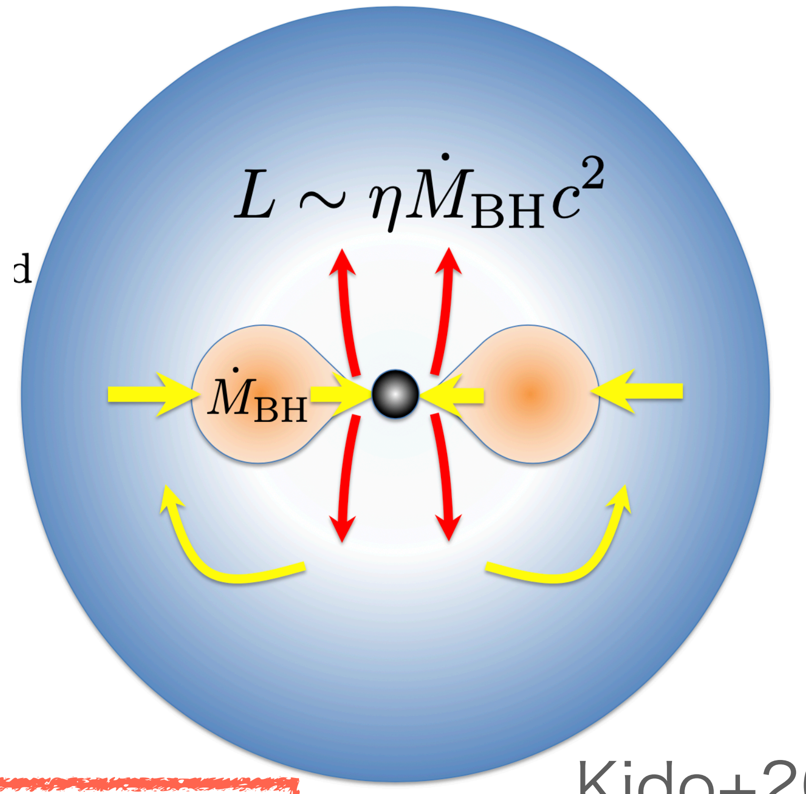
Dense envelope

- Efficient neutrino emission
- Gamma rays cannot escape

×

$n \sim 10^{-4.5}$ cMpc^{-3},

$L \sim 10^{44-45}$ erg s^{-1}



Kido+2025

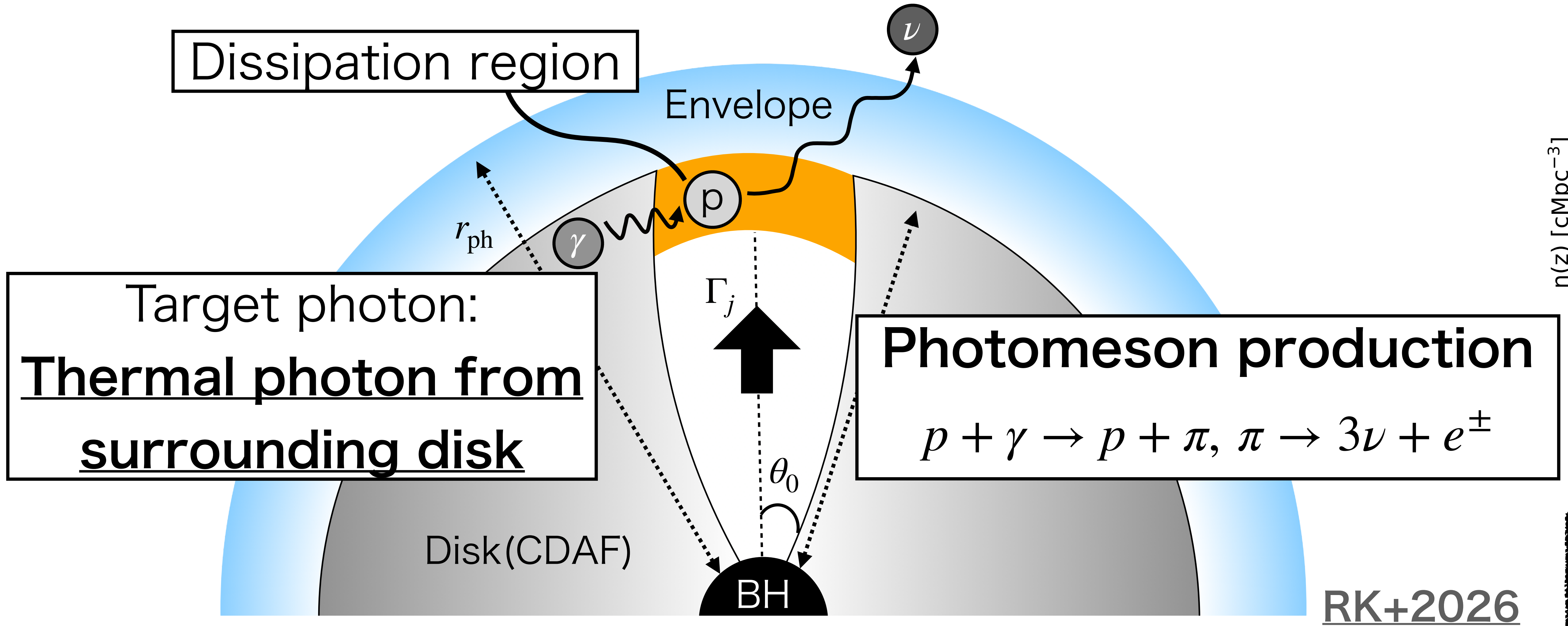
Compatible with the observed diffuse neutrino background

P14: Little Red Dots as Potential High-energy Neutrino Sources

arXiv: 2601.11203

Riku Kuze (YITP), Kunihito Ioka (YITP), Kohta Murase (Penn state), Shigeo S. Kimura (Tohoku), Kohei Inayoshi (Peking)

Jets or outflows launched from the central BH **propagate and dissipate within the BH polar funnel.**



RK+2026

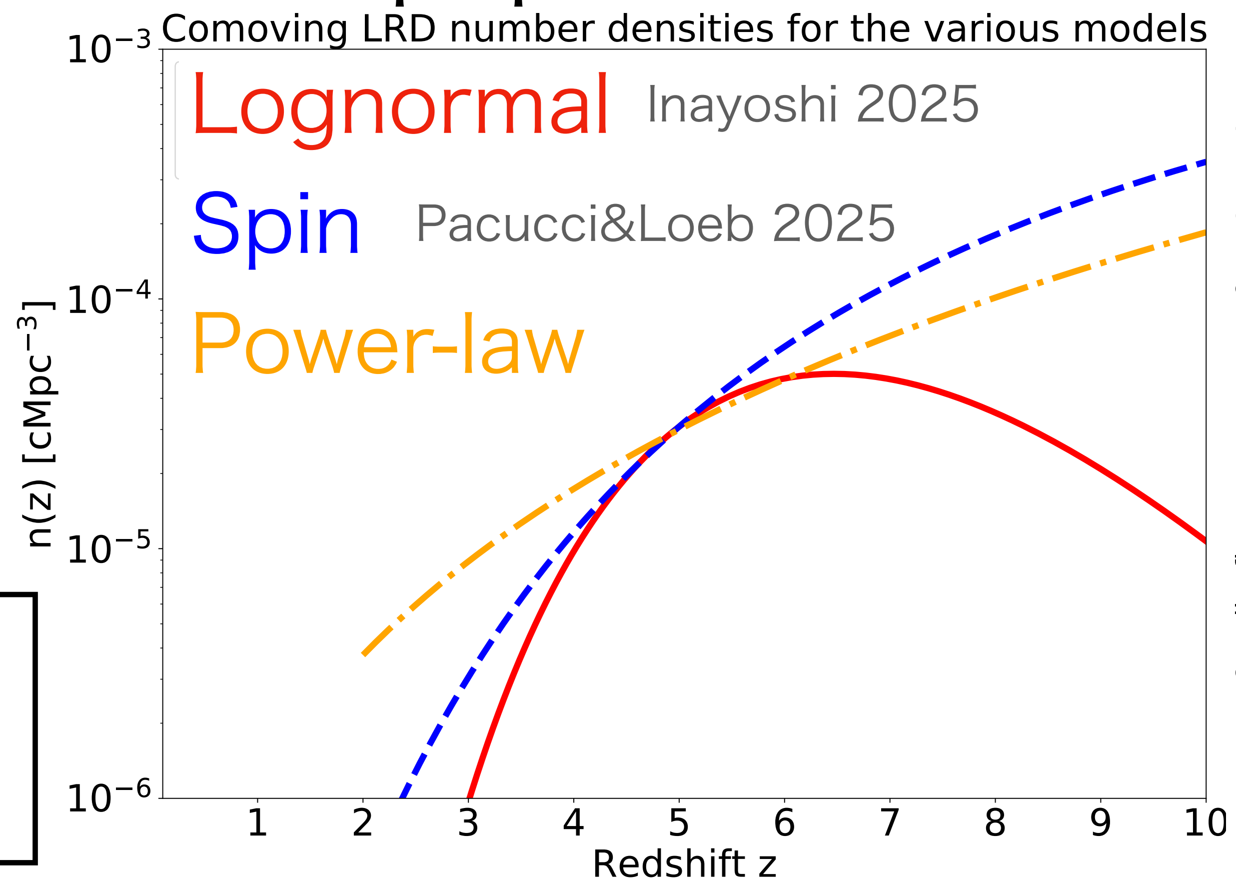
We estimate the contribution to the diffuse neutrino background.

3 types of LRD population model ✕

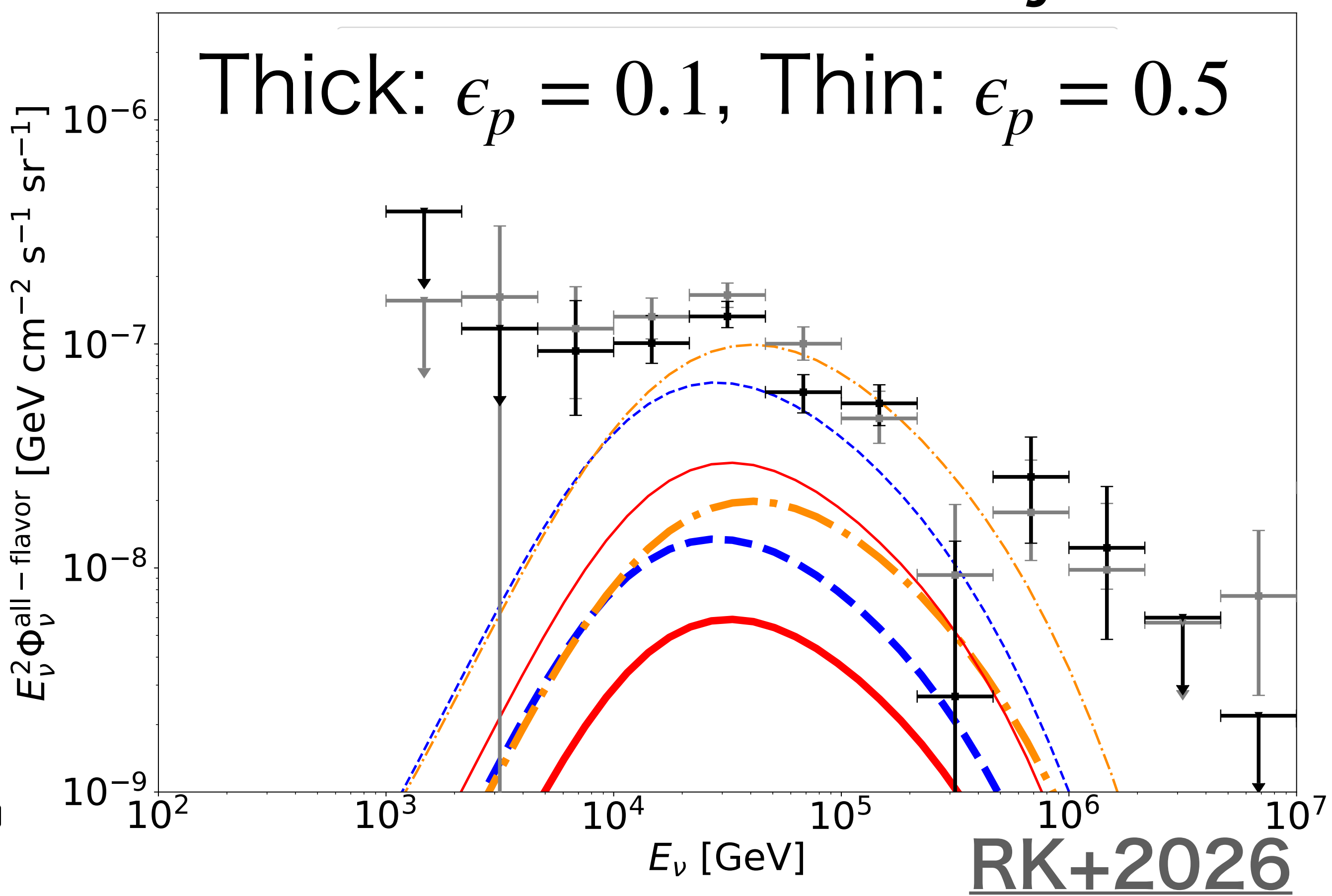
$$L_\nu \sim \frac{1}{8} f_{\rm bol}\epsilon_p L_j \sim 10^{41}\ {\rm erg\ s^{-1}}\ f_{{\rm bol},-1}\epsilon_{p,-1}L_{j,44}$$

Results

3 LRD population models



Diffuse intensity



RK+2026

Conclusion:

・A dense BH-envelope provides the environment for efficient neutrino production and prevents gamma rays from escaping.

・LRDs can contribute to a non-negligible fraction of the diffuse neutrino background in the TeV–sub-PeV energy range.

Binary strange quark star merger in fully general-relativistic simulation

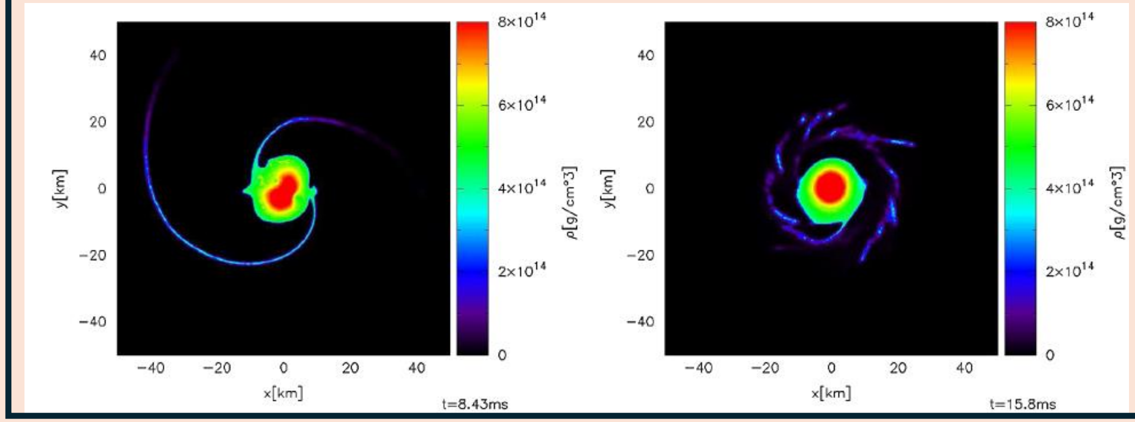
Ho Ching Luk, Lap Ming Lin Chinese University of Hong Kong

Quark eos: $P = B\left[\left(\frac{\rho}{\rho_s}\right)^{1+c_{ss}} - 1\right]$ ⟶ Extremely sharp surface

Previous quark star merger simulation

SPH

- A. Bauswein, R. Oechslin, and H. Janka (2010)

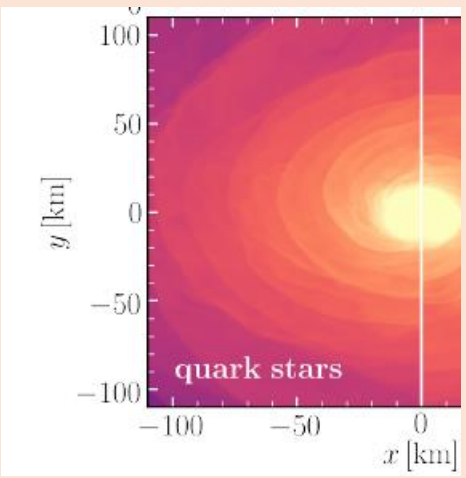


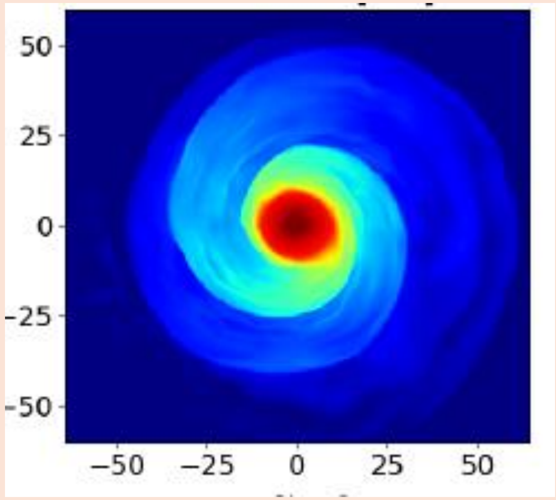
Prompt collapse: explore M_{th} but no GW extracted

- E. Zhou, K. Kiuchi, M. Shibata, A. Tsokaros, and K. Uryu (2022)

Grid base but add polytropic tail

- Z. Zhu and L. Rezzolla (2021)
- F. Grippa, A. Prakash, D. Logoteta, D. Radice, and I. Bombaci (2025)

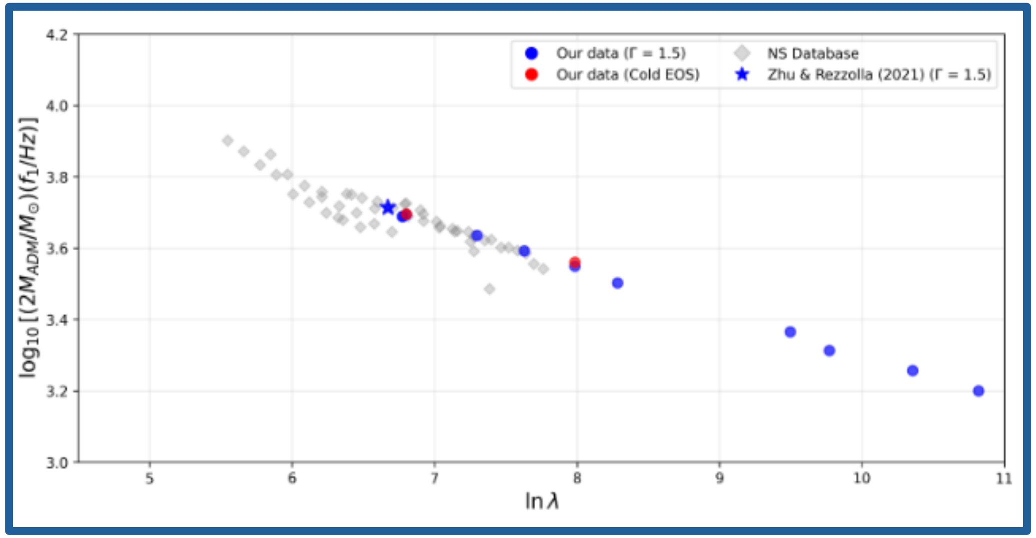


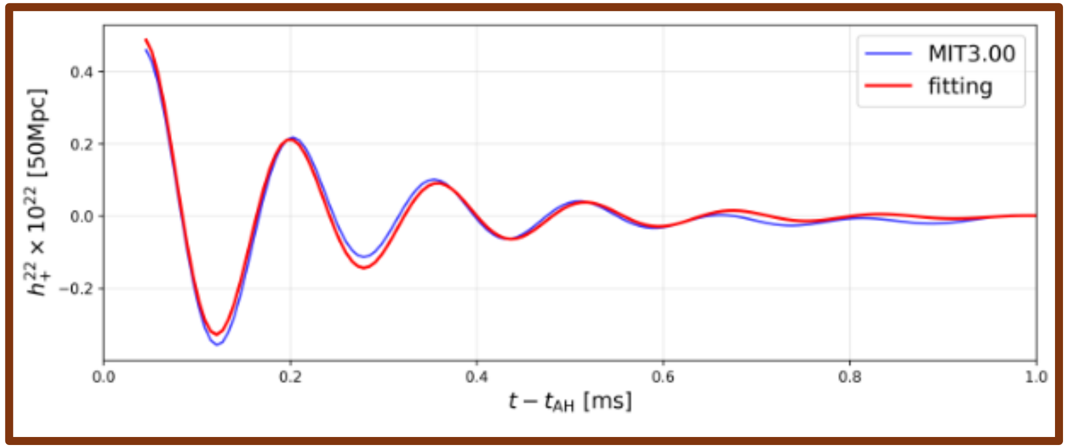


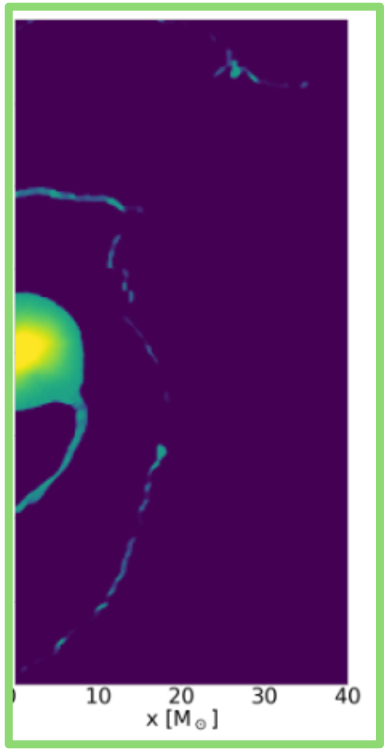
Our result

What’s different?

- Positively preserving Riemann solve
- Piecewise parabolic method reconstruction
- Hydro excision inside apparent horizon
- Dust atmosphere
- Modified AMR







What’s new result?

- Spiral arm and quark droplet in grid base code
- Larger mass range f_{max}, f_1 and f_2 $(0.5M_\odot$ to $1.5M_\odot)$
- Prompt collapse waveform (Compared to BH qnm)

大阪大学
THE UNIVERSITY OF OSAKA

YITP 2026

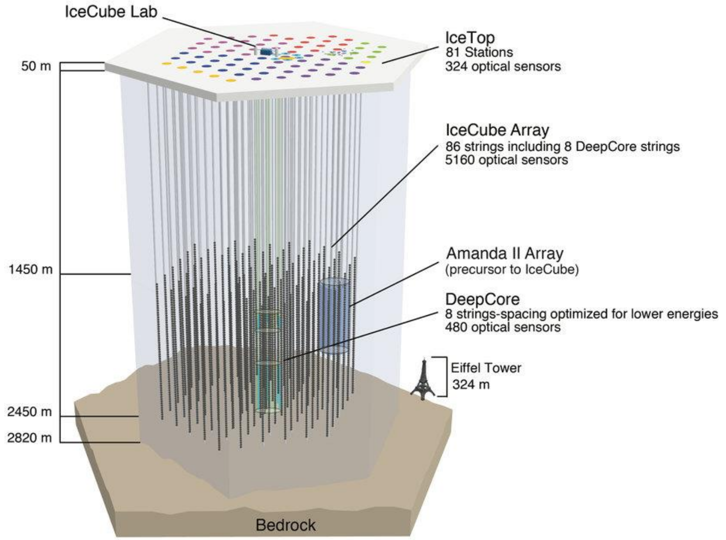
Particle-in-Cell (PIC) Simulations on Collisionless Shocks and Particle Acceleration in Black Hole Coronae

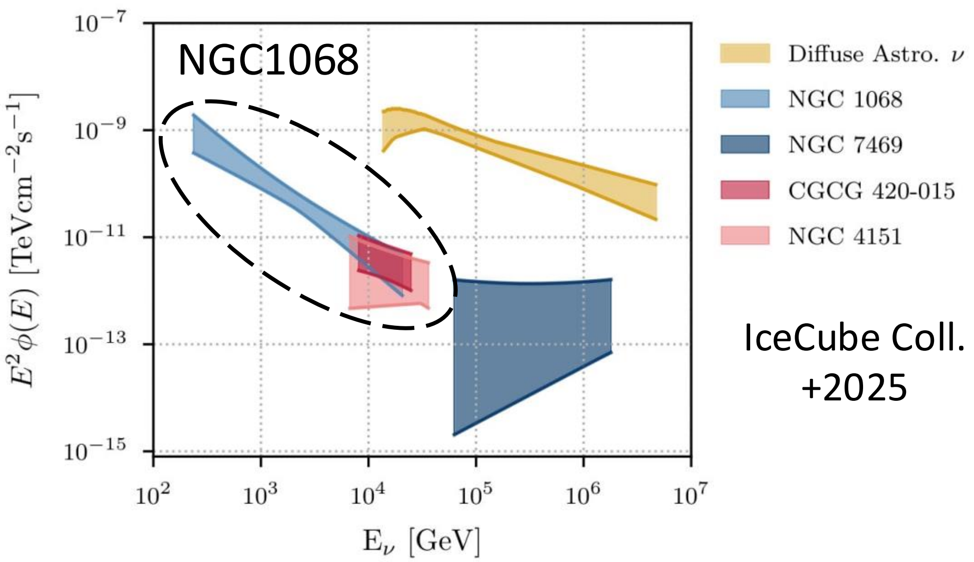
Nhat-Minh Ly[1], Takayoshi Sano[1,2], Yoshiyuki Inoue[2], Yasuhiko Sentoku[1]

1. Institute of Laser Engineering, The University of Osaka
2. Department of Earth and Space Science, Graduate school of Science, The University of Osaka

(In Press) M. N. Ly, Y. Inoue, Y. Sentoku, and T. Sano, *Proton Acceleration by Collisionless Shocks in Supermassive Black Hole Coronae: Implications for High-Energy Neutrinos*, arXiv:2601.01999.

High-energy neutrinos from BH Coronae





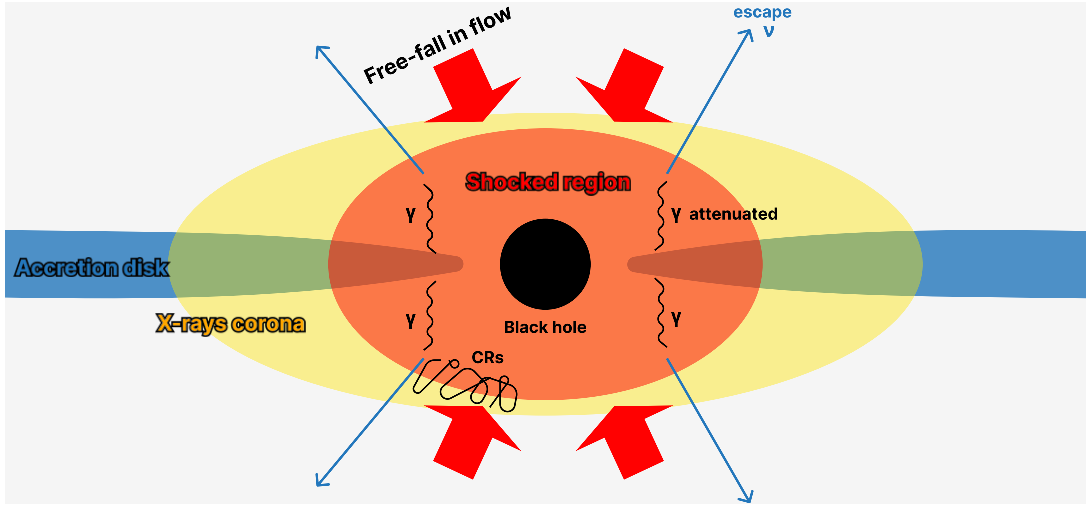
IceCube Coll. +2025

IceCube survey of high-energy ν from Radio Quiet (RQ) AGNs

NGC1068:
Neutrino ~10 TeV; Proton ~100 TeV

No γ-rays
→ ν produce in BH Coronae

Schematic shocks picture in BH coronae



Can shocks accelerate proton to 100 TeV in BH coronae?

- **Astrophysics: could be** (Inoue et al. 2019, 2020)
- **Plasma physics: Not sure**
  - Trans-Sonic may not be efficient in accelerate protons
  - Dynamics of accelerated protons and electrons are implied by plasma physics

Agencia Nacional de Investigación y Desarrollo
Ministerio de Ciencia, Tecnología, Conocimiento e Innovación
Gobierno de Chile

EX UMBRA IN SOLEM

Coupling Electromagnetism to Torsion: Black Holes and Spin-Charge Interactions

arXiv:2507.02362 — To appear in *Phys. Rev. D*

Jorge Maggiolo Tapia
Universidad Técnica Federico Santa María, Chile
Email: `jorge.maggiolo.t@gmail.com`

Theory

We consider the minimal gravitational theory that consistently couples electromagnetism to torsion while preserving $U(1)$ gauge invariance. The lagrangian density is

$$\mathcal{L} = -R - k_1 F_{\mu\nu} F^{\mu\nu} + k_2 \tilde{R}^2 + k_3 F_{\mu\nu} \tilde{R}^{\mu\nu}.$$

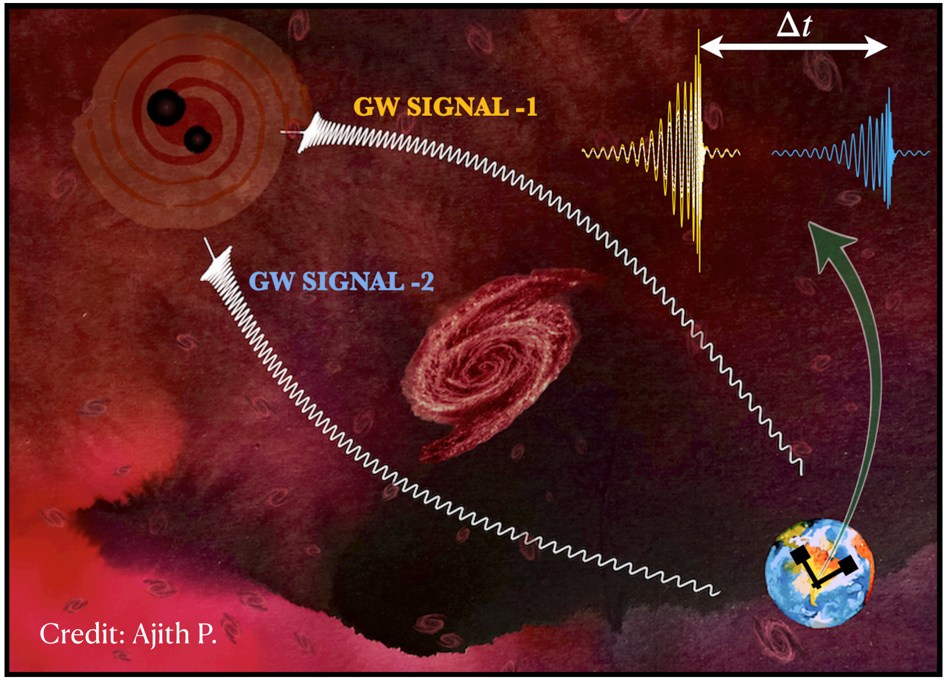
$$ds^2 = \Psi_1(r)\, dt^2 - \Psi_2(r) dr^2 - r^2 \left(d\theta^2 + \sin^2\theta\, d\phi^2 \right)$$

$\Psi_1(r) = ?$

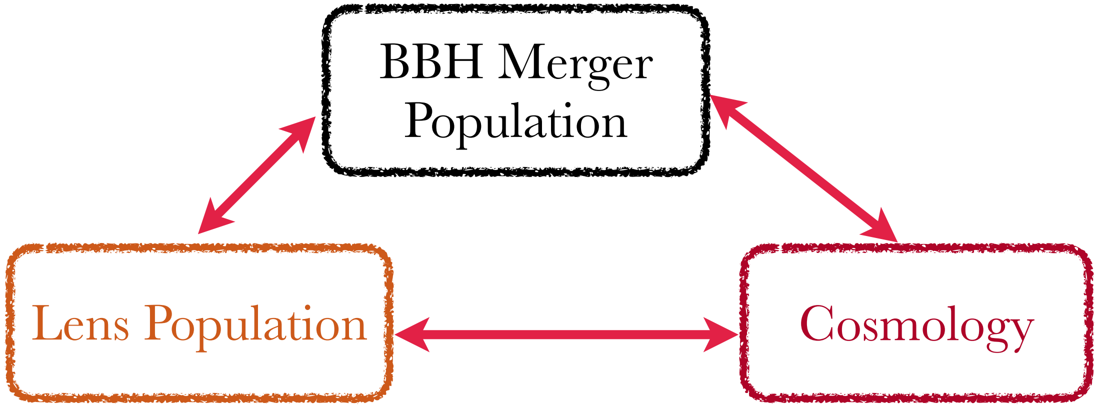
$\Psi_2(r) = ?$

18 Inferring Cosmology and Nature of Dark Matter using Strongly Lensed Binary-Black-Hole mergers: Prospects for the Near Future

Koustav N. Maity, Souvik Jana, Tejaswi Venumadhav, Ankur Barsode & Parameswaran Ajith : arXiv:2512.15168



~ similar copies of GW signals arrive at us at different times

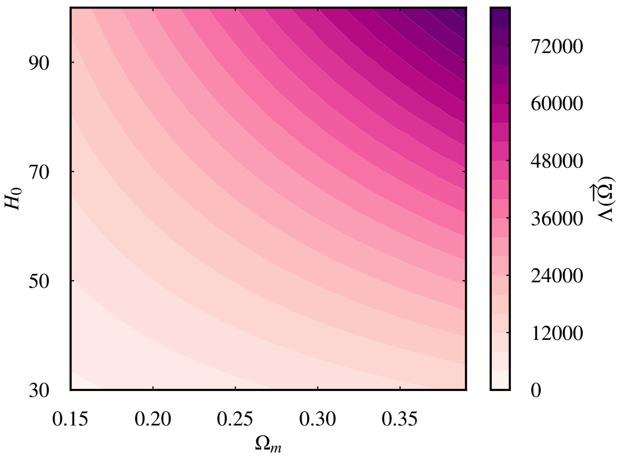


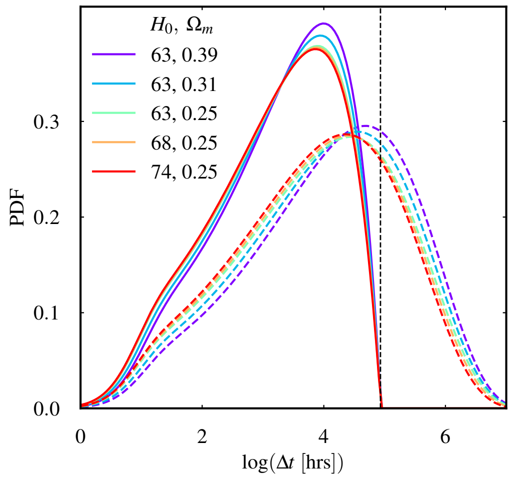
- Changing cosmology affects structure formation and the distances.
- The lens population changes if we change our dark matter model.

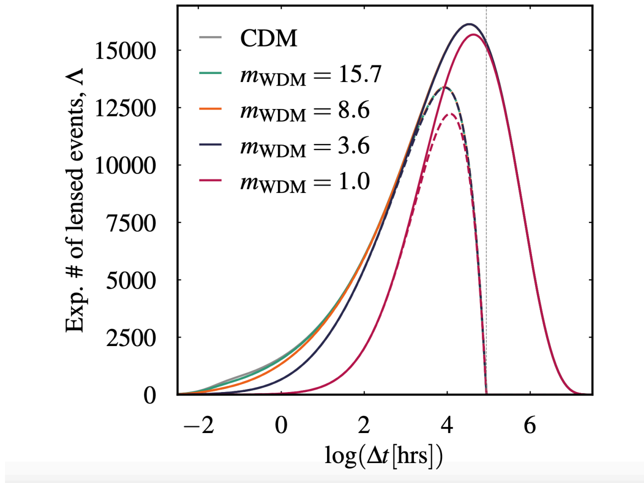
Both affect the delay-time distribution and lensing fraction.

18 Inferring Cosmology and Nature of Dark Matter using Strongly Lensed Binary-Black-Hole mergers: Prospects for the Near Future

Potential realization was already shown in XG, but **what could be done with immediate upgrades** ?







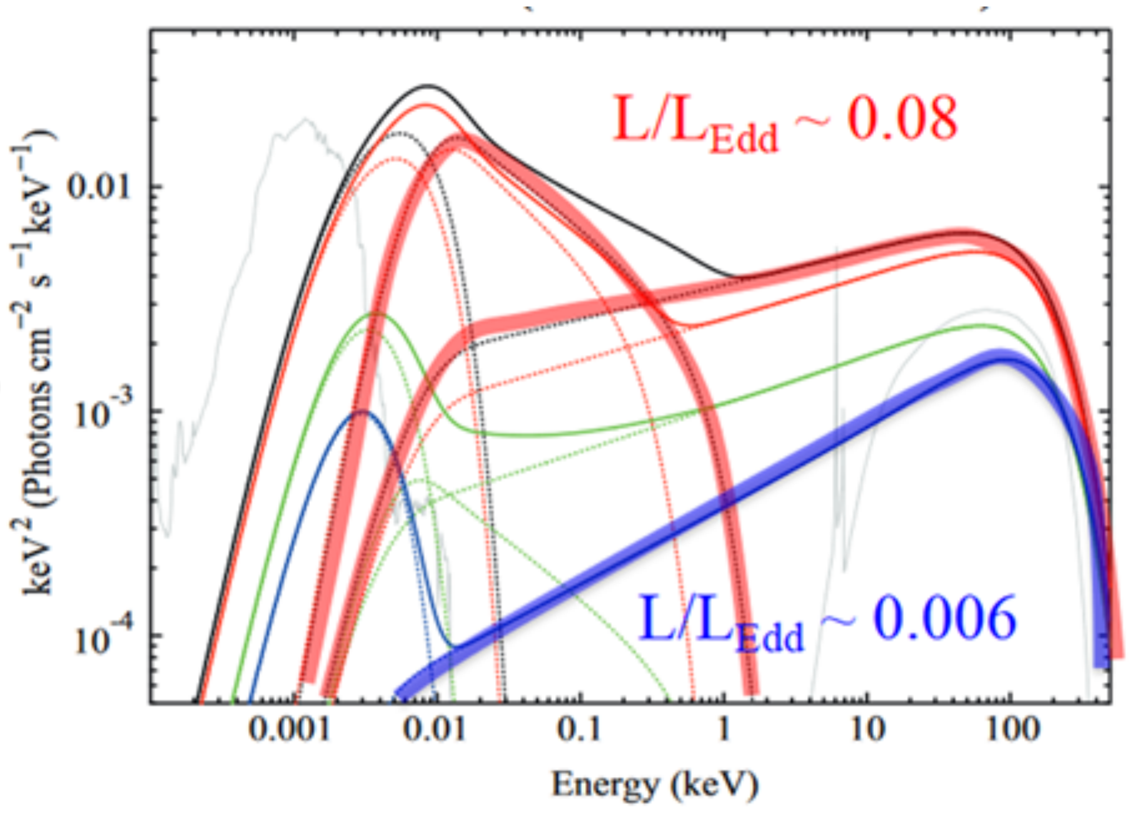
Credit: Jana. et al. (2023, 2025)

Precisely accounts for observing windows, enforces a joint SNR detectability criterion for multiple images, and incorporates time-varying detector-network sensitivity.

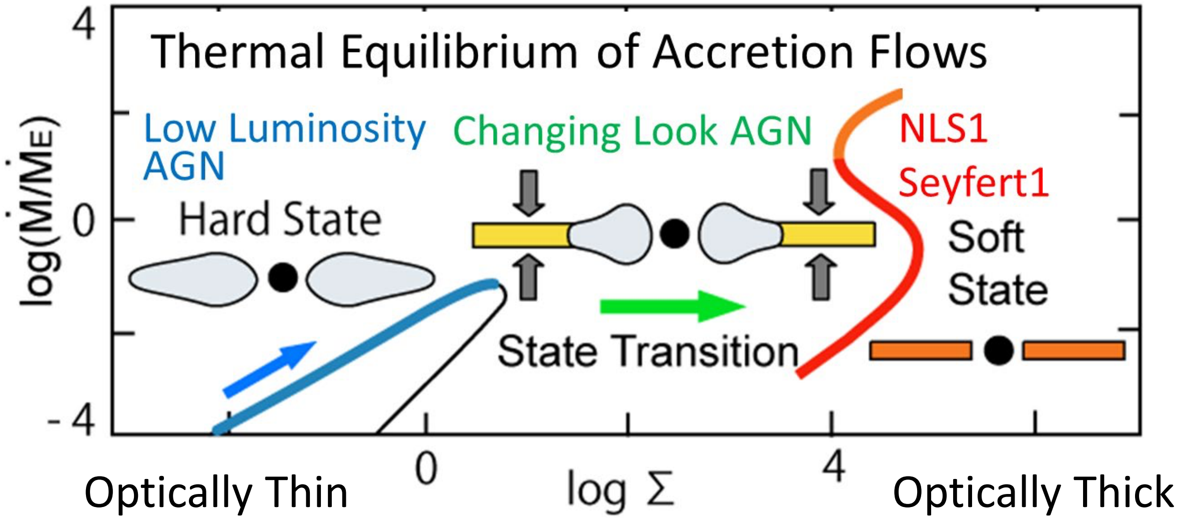
P19

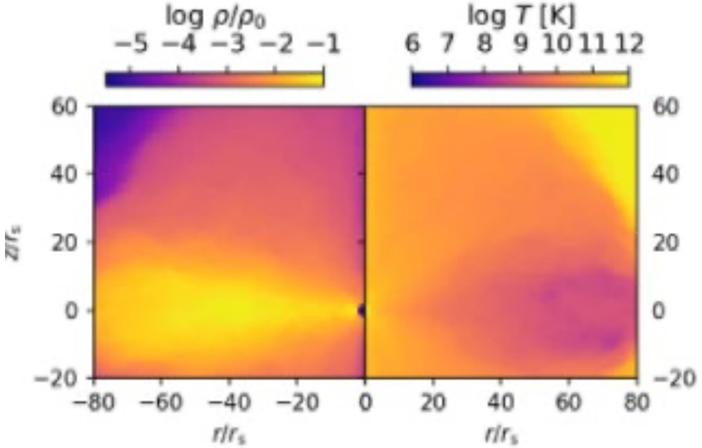
Global Radiation Magnetohydrodynamic Simulations of Black Hole Accretion Flows during State Transitions in AGN

Ryoji Matsumoto(Chiba Univ.), T. Igarashi(NAOJ/Rikkyo Univ.), H.R. Takahashi(Komazawa Univ.), T. Kawashima(NIT Ichinoseki), K. Ohsuga(Tsukuba Univ.), and Y. Matsumoto(Chiba Univ.)



Radiation Spectra of a changing look AGN Mrk1018 (Noda and Done 2018)





$M_{BH} = 10^7 M_\odot$

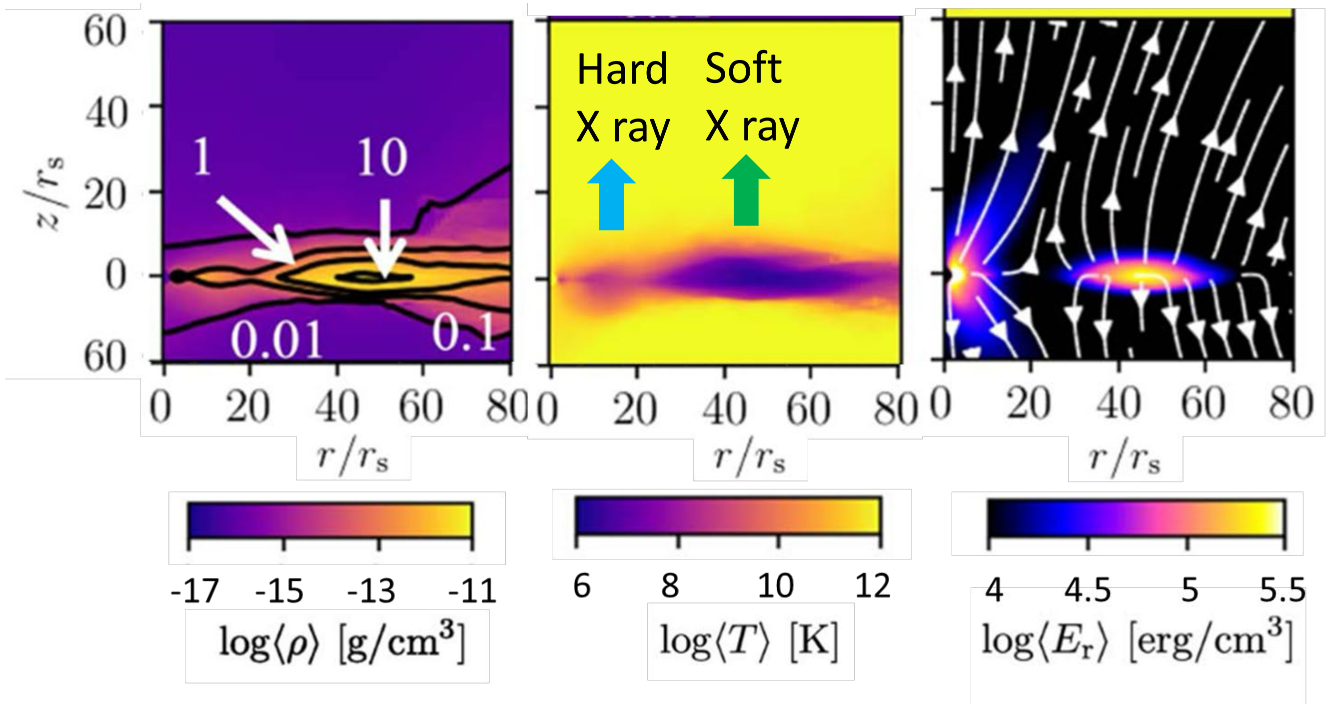
Unit Length $r_s = 3\times10^{12}$cm

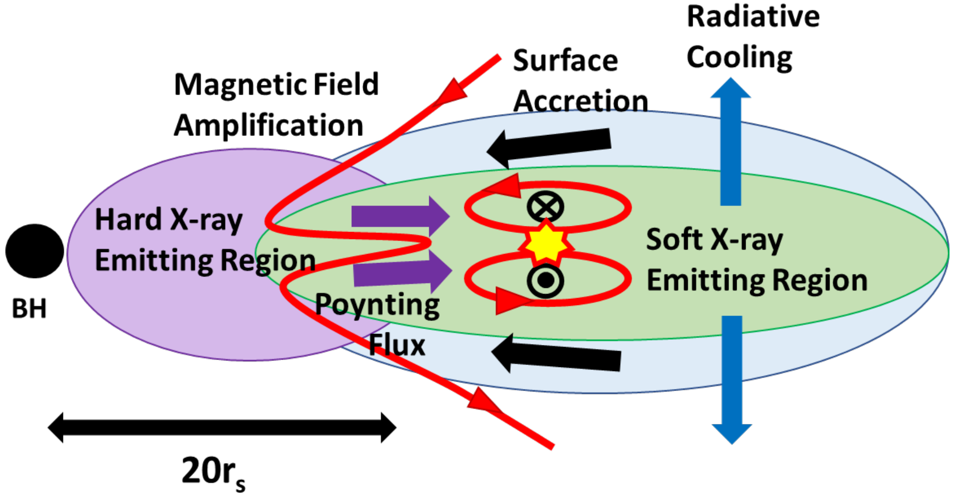
Cooling terms are turned on after RIAF is formed.

CANS+R （M1 code）

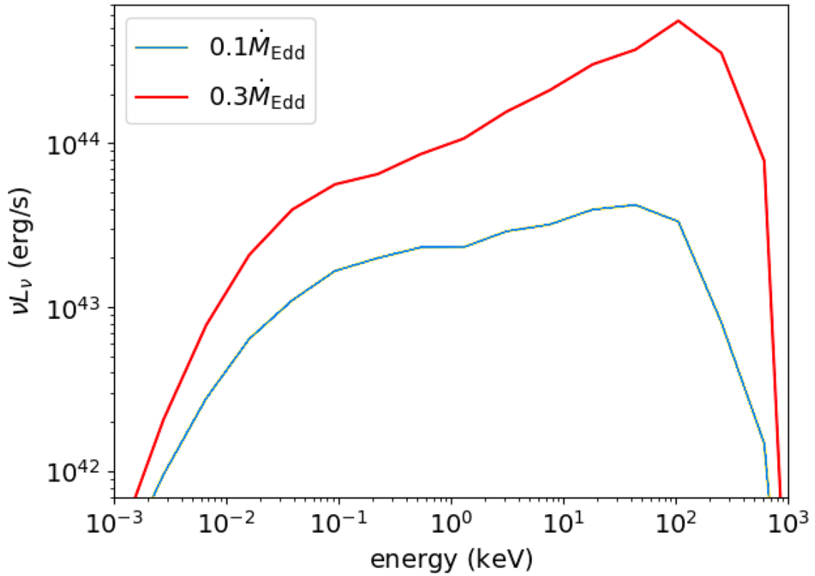
(N_r, N_φ, N_z)=(464.32.464)

Numerical Results and Radiation Spectra





- Results of radiation MHD simulation when the accretion rate is $0.1\dot{M}_{Edd}$ (Igarashi et al. 2024)
- Solid curves in the left panel show the contour of Thomson optical depth.
- Right panel shows the radiation energy density (color) and radiation flux (arrows)
- Soft X-ray emitting region is formed around $40r_s$



Radiation Spectra obtained by RAIKOU code

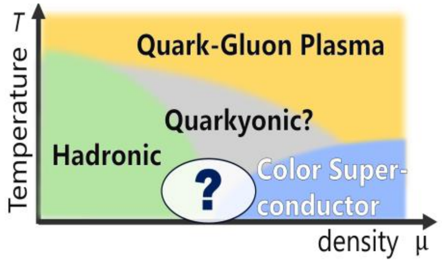
Constrain EoS from Binary Neutron Star GW

BH or NS ?

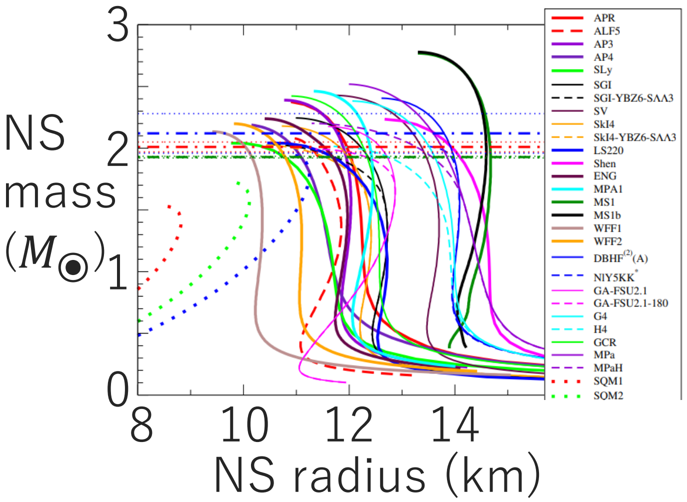
$\sim 2.4 M_\odot$

short GRB mechanism ?

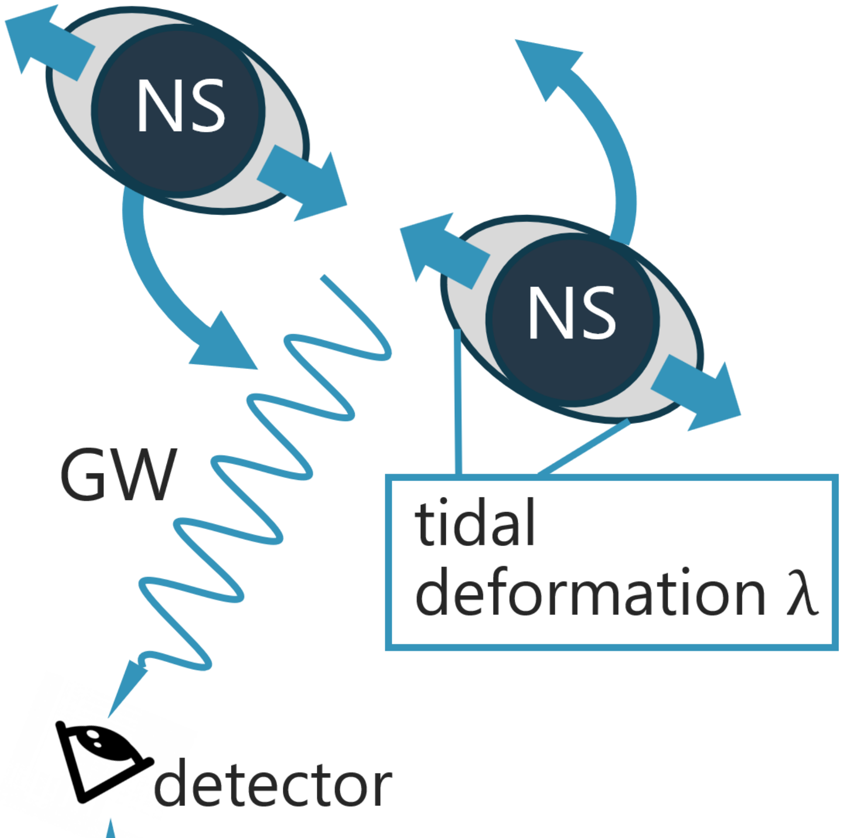
QCD phase diagram ?



Constrain Neutron Star Equation of State (EoS) !



K. Yagi and N. Yunes, *Phys. Rept.*, 681, 1 (2017) (modified)

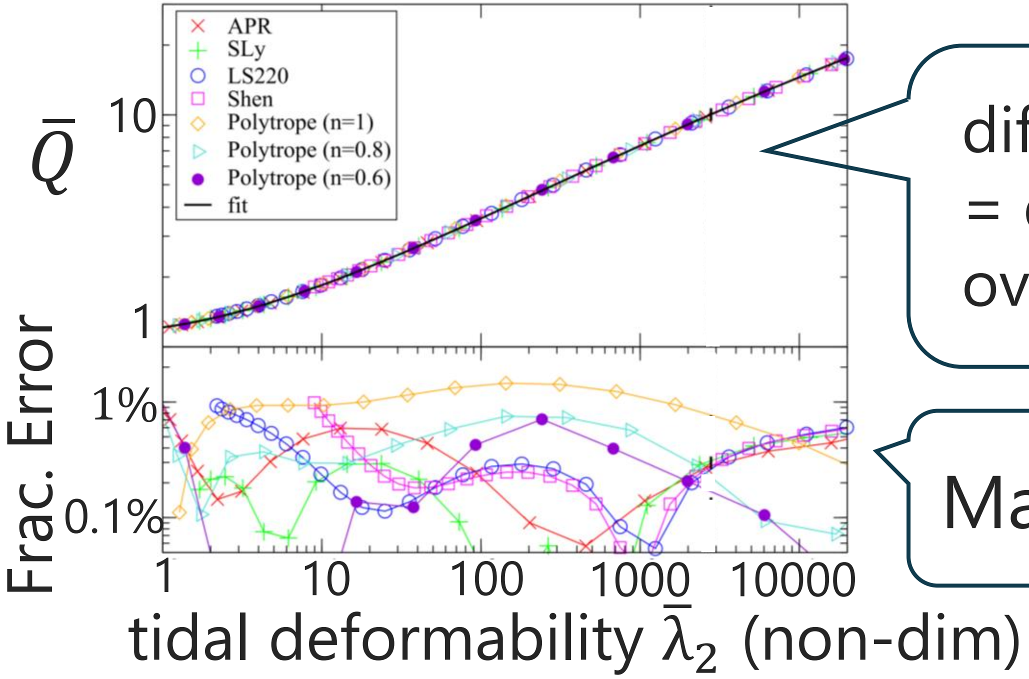


estimate params (star mass, λ, ...)

more # of params → more error

EoS-independent Universal Relations (URs)

$\bar{Q}$: spin-induced mass quadrupole (non-dim)



different colors = different EoS overlap

Max. error~1 %

K. Yagi and N. Yunes Phys. (2013)

Reduce # of params

→ Improved param estimation accuracy

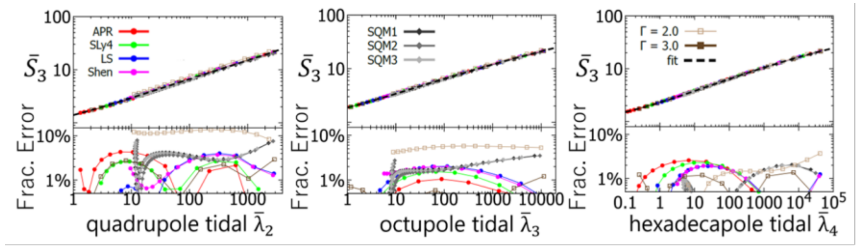
B. P. Abbott et al. *Phys. Rev. X*, 9:011001, (2019)

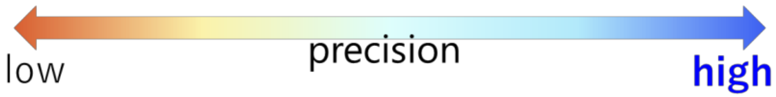
Reason of URs?

→ No definitive explanation yet.

What's New:

O(1)% URs among **higher-order multipoles** for future observations





+

characteristic behavior of universal relations