Title: EFT for EHT

Speakers: Markus Rummel

Collection: Echoes in Southern Ontario

Date: February 25, 2020 - 1:30 PM

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EFT for EHT

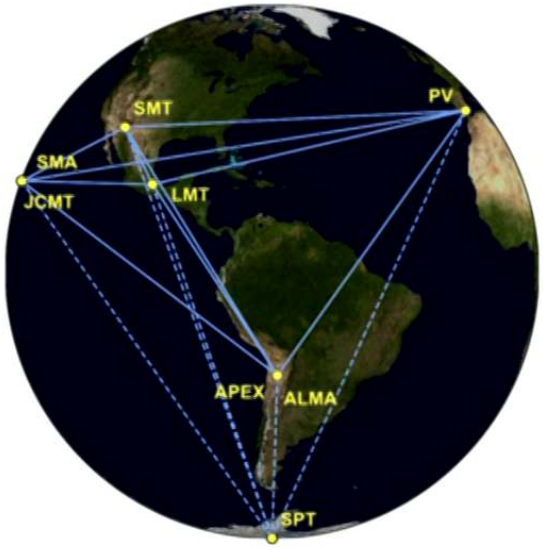
Markus Rummel

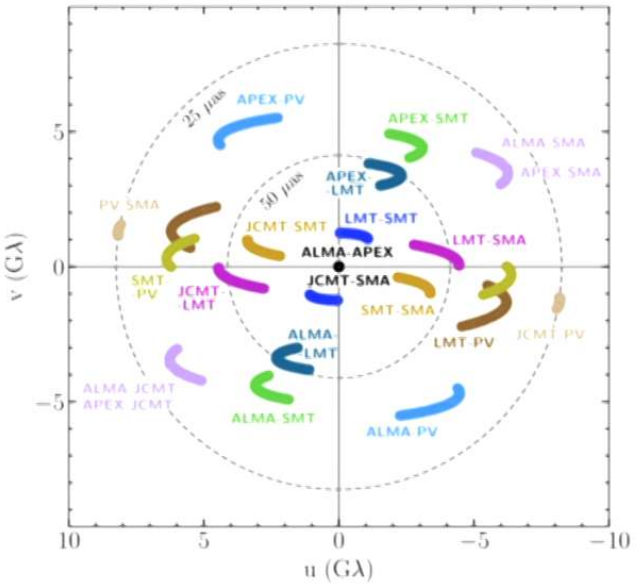
Echoes in Southern Ontario,
Feb 25 2020

Outline

- EHT observations
- Near-horizon EFT
- Methodology and Results

Event Horizon Telescope





$$\mathcal{V}(u,\,v) = \iint e^{-2\pi i(ux+vy)} I(x,\,y)\,dx\,dy$$

u, ν are in frequency space

x, y are angular coordinates

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EHT pipelines

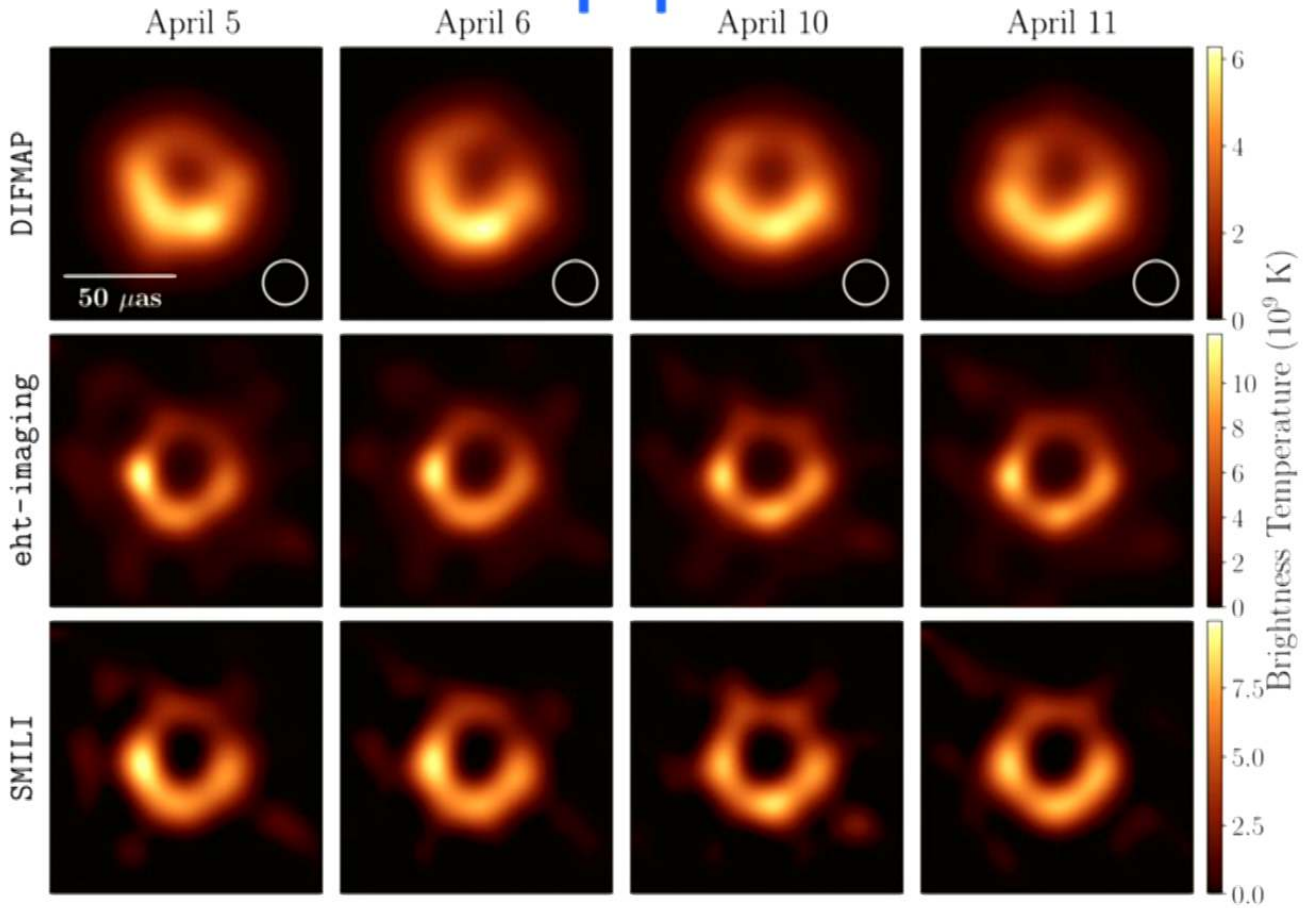
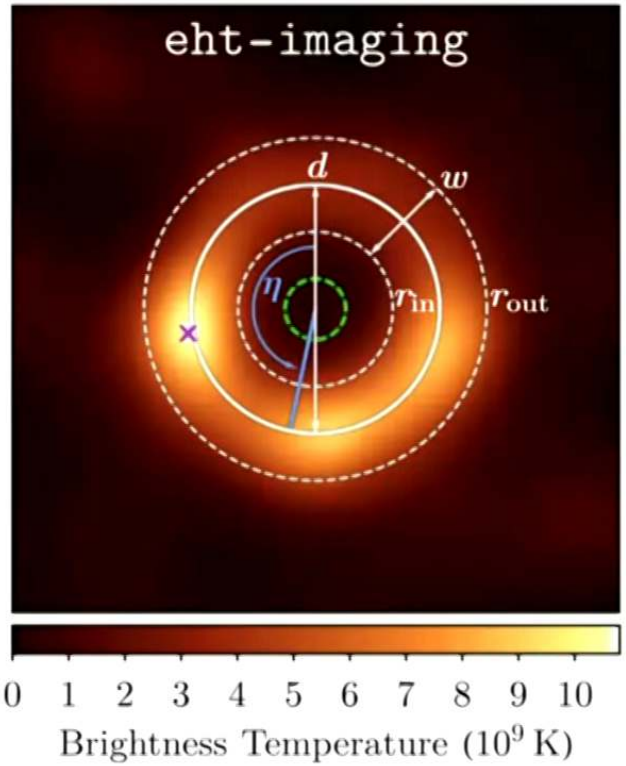


Image diagnostics



- diameter d
- width w
- orientation angle η
- azimuthal asymmetry A
- fractional central brightness f_c
- deviation from circularity $\Delta_c = \frac{\sigma_d}{d}$

Digitized EHT image

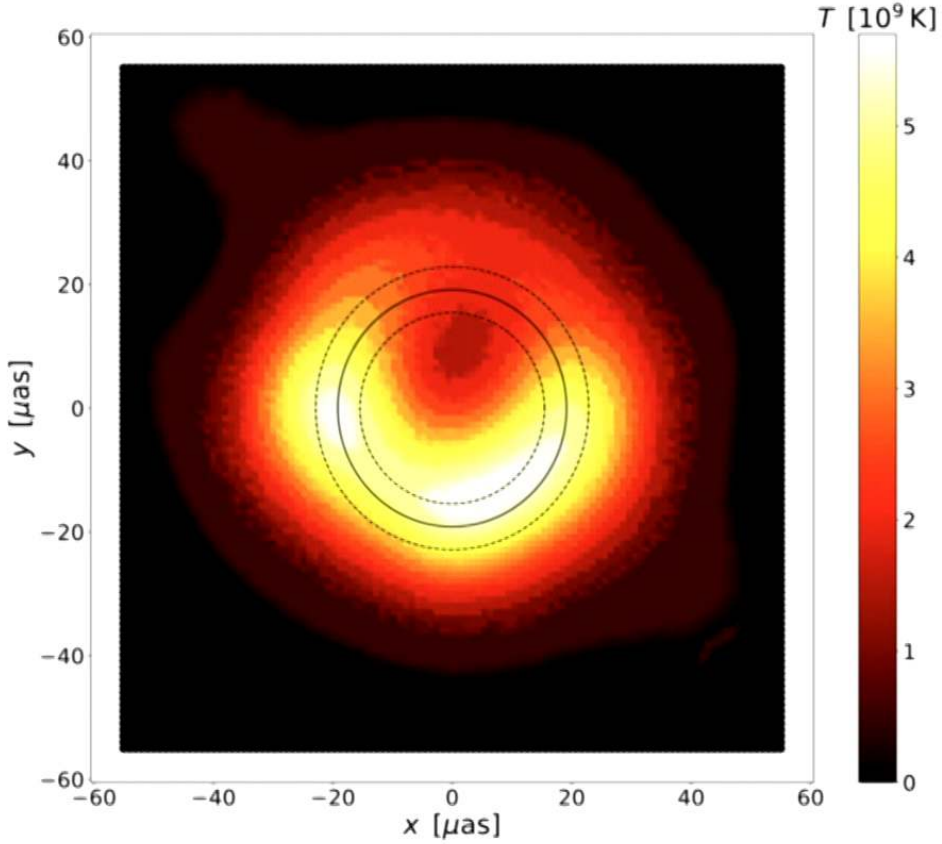


Image constraints

	d (μas)	w (μas)	η ($^\circ$)	A	Δ_c	f_c
Digitized	38.3 ± 7.4	28.4 ± 7.4	205.1 ± 83.7	0.15 ± 0.08	0.19	0.63
`DIFMAP`	40.7 ± 2.6	29.0 ± 3.0	173.3 ± 4.8	0.23 ± 0.04	0.06	0.5
`eht-imaging`	41.0 ± 1.4	15.5 ± 1.8	168.0 ± 6.9	0.20 ± 0.02	0.03	0.04
`SMILI`	42.3 ± 1.6	15.6 ± 2.2	167.6 ± 2.8	0.22 ± 0.03	0.04	$6 \cdot 10^{-6}$

Errors are about 2-3 times larger than DIFMAP

- EHT bound: $\Delta_c \lesssim 0.1$ and $f_c \lesssim 0.5$
- Digitized bound: $\Delta_c \lesssim 0.2$ and $f_c \lesssim 0.7$

EFT and reflection coefficient

see Cliff's talk

$$S_{\rm hor} = -\int_\Sigma \mathrm{d}^3x\,\sqrt{-\gamma}\,\left[h_0 + h_1\,\phi^*\phi + \cdots\right]$$

$$(\mathrm{d}/\mathrm{d}\epsilon)R[h_1(\epsilon),\epsilon] = 0$$

$$R = |R_N R_{\rm UV}| \qquad |R_{\rm UV}| = \left(\frac{\ell}{r_s}\right)^{2\,\mathrm{Im}(\xi)}$$

RG invariant length scale ℓ.

$$r_s = 2GM \qquad \xi \to \omega\, r_s - \frac{is}{2} \qquad \text{(Schwarzschild limit)}$$

Reflection coefficients

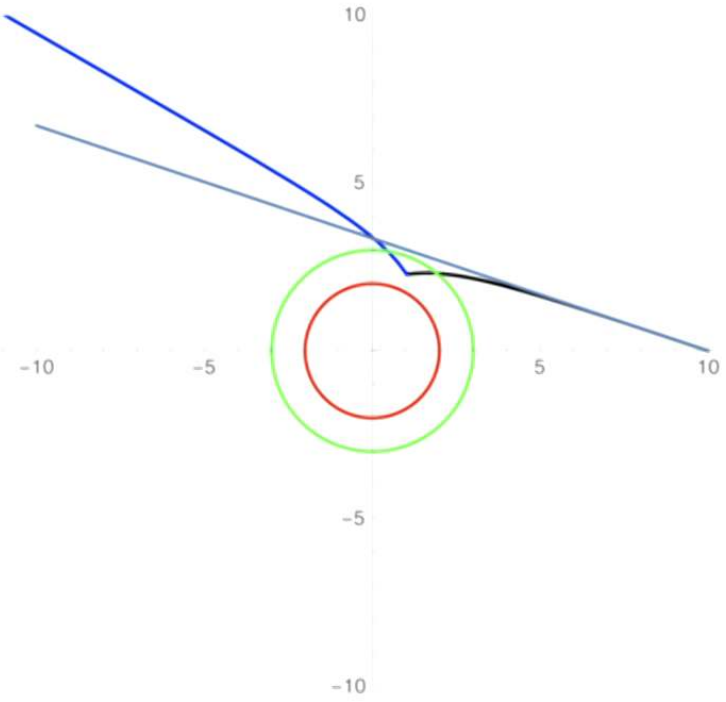
In practice:

$$
\begin{aligned}
l = 0: \quad & R(\theta, \phi) = R_0 \,, \\
l = 1: \quad & R(\theta, \phi) = R_0 \, |\cos(\theta)| \,, \\
l = 2: \quad & R(\theta, \phi) = R_0 \, |\sin(\theta) \cos(\theta)|
\end{aligned}
$$

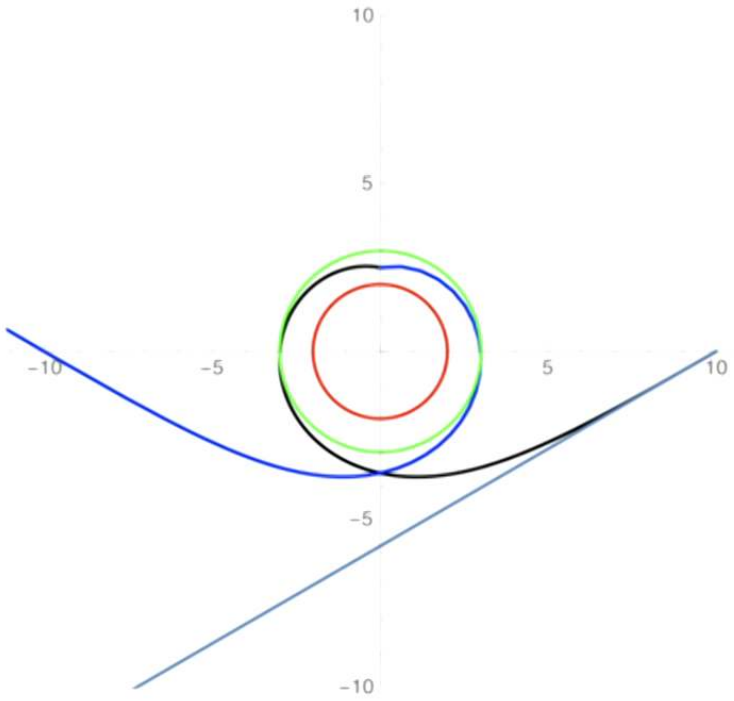
imposed at $r_R = r_H + \epsilon$

RG invariant R_0

Photon Trajectories



Photon Trajectories



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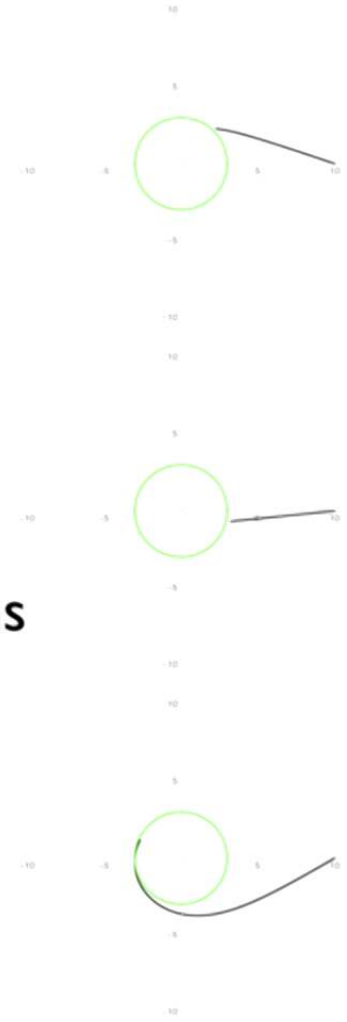
Methodology

Step 1:

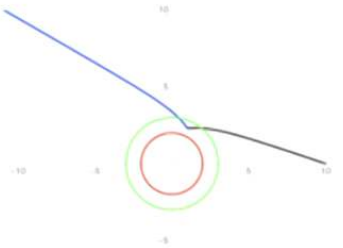
- Ray trace pixels in the *original* EHT image back to the photon ring
- Creates a map of "where the photons are coming from"

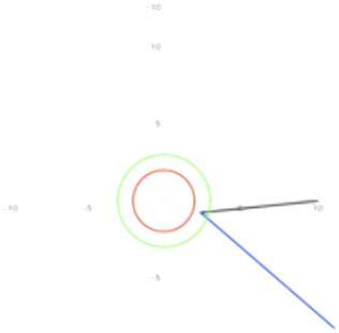


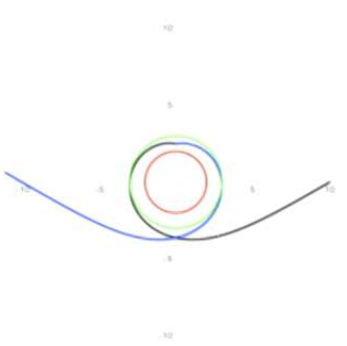
Methodology

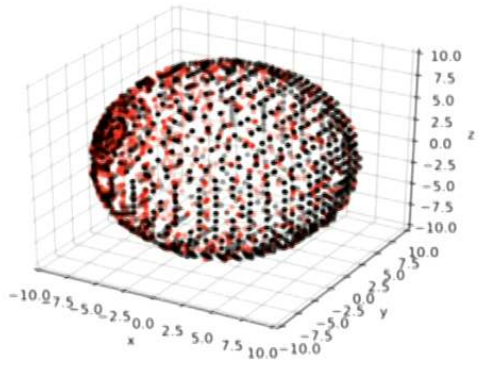
Step 2:

- Turn on reflection
- Assign intensities from Step 1 where ray crosses photon ring
- Add reflected to original image







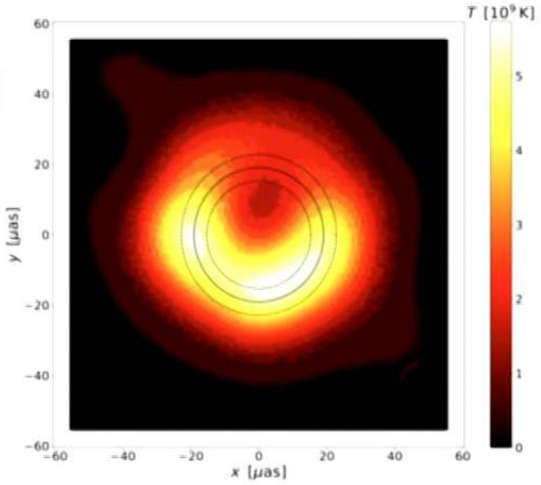


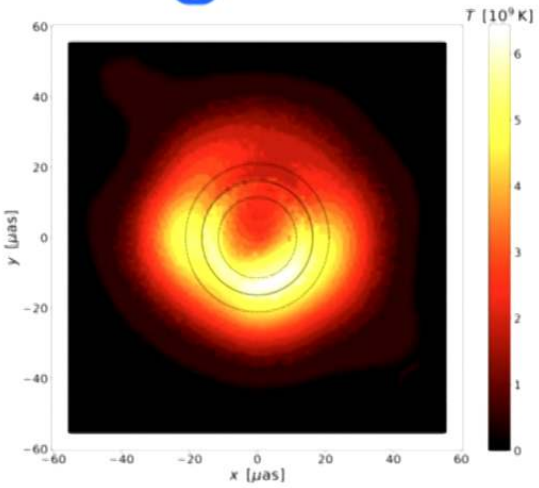
Assumptions/Caveats

- Perturbative approach as intensities are infered from original unperturbed image
- Accretion disk has to be optically thin - true for M87 [Narayan & Yi '94, '95; Reynolds et al. '96]
- Reference surface has to radiate with equal intensity in all directions

Reflection image l=0

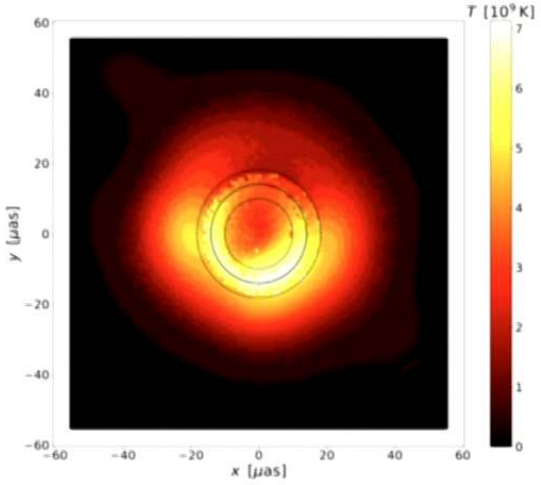
$R_0 = 0.01$

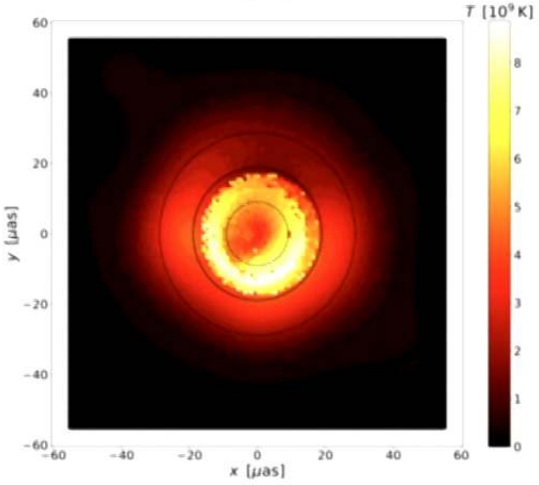




$R_0 = 0.2$

$R_0 = 0.4$





$R_0 = 1$

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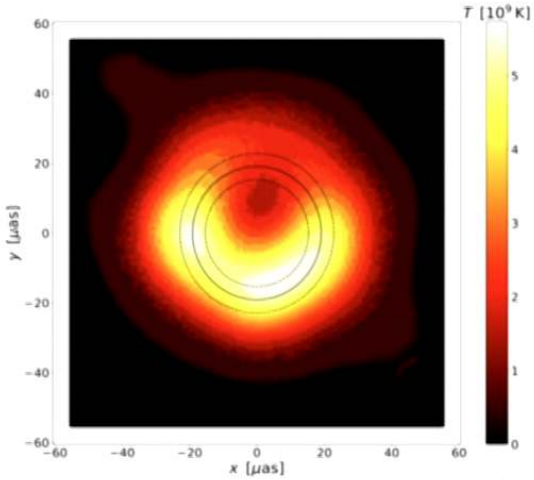
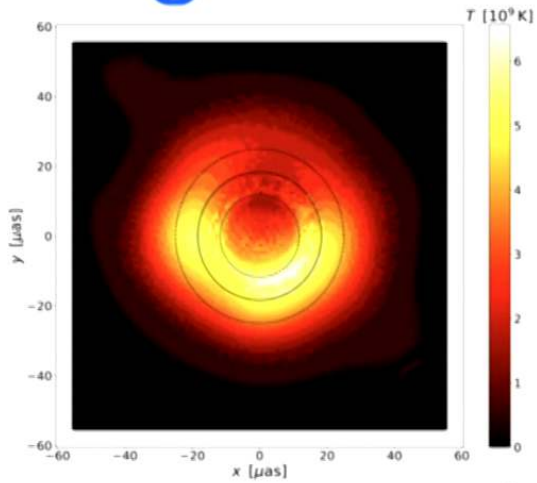
Reflection image l=1

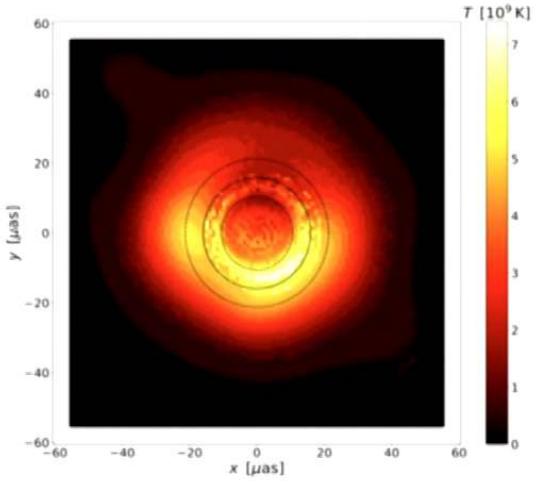
$R_0 = 0.01$

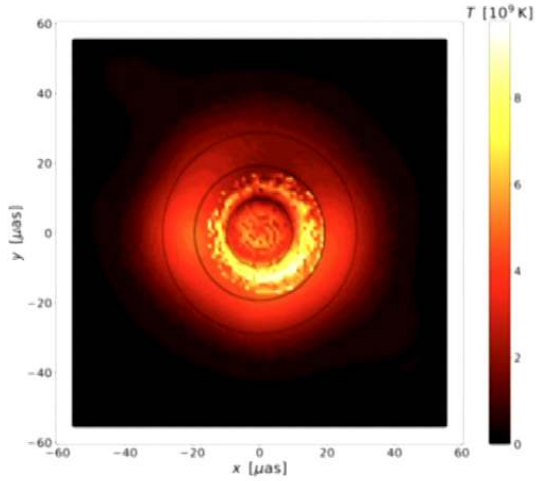




$R_0 = 0.2$

$R_0 = 0.4$





$R_0 = 1$

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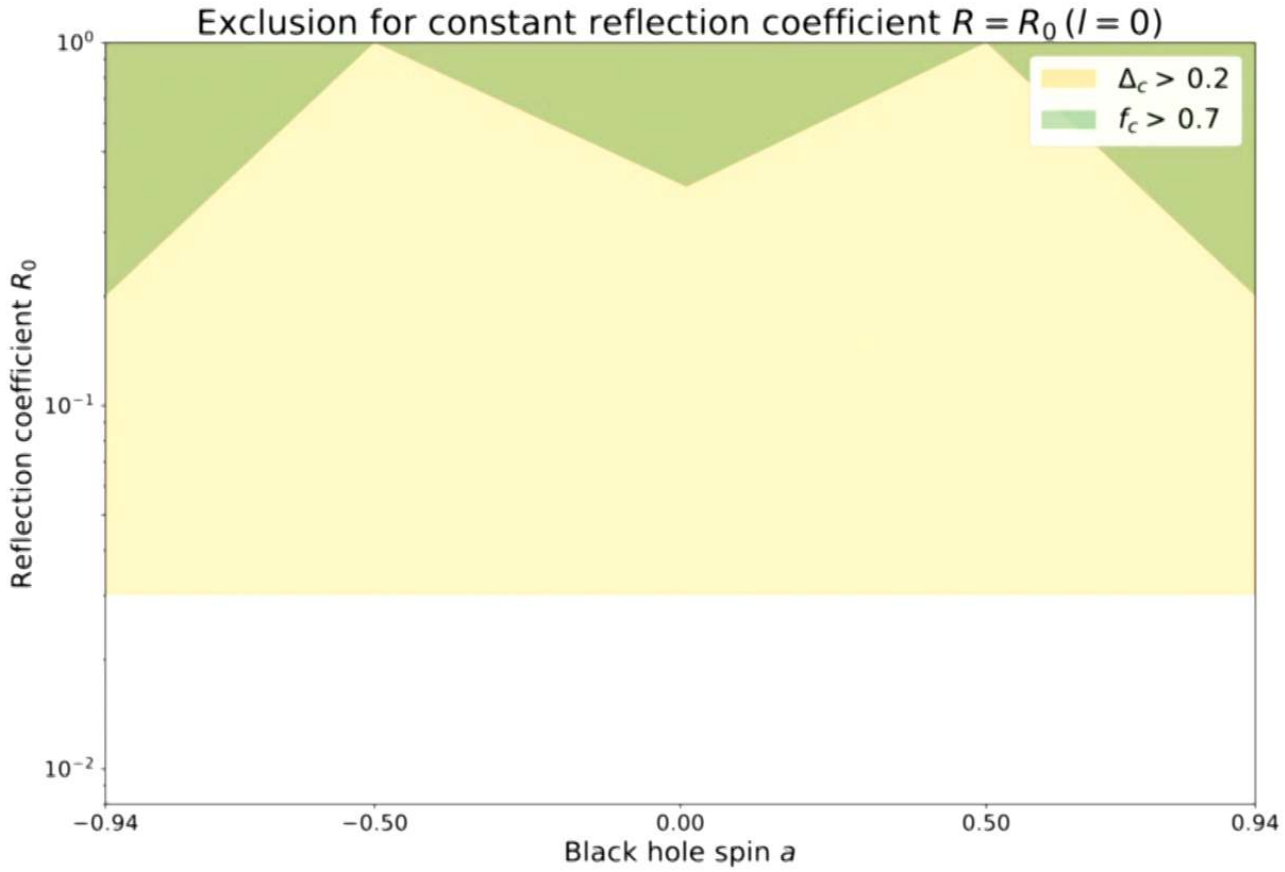
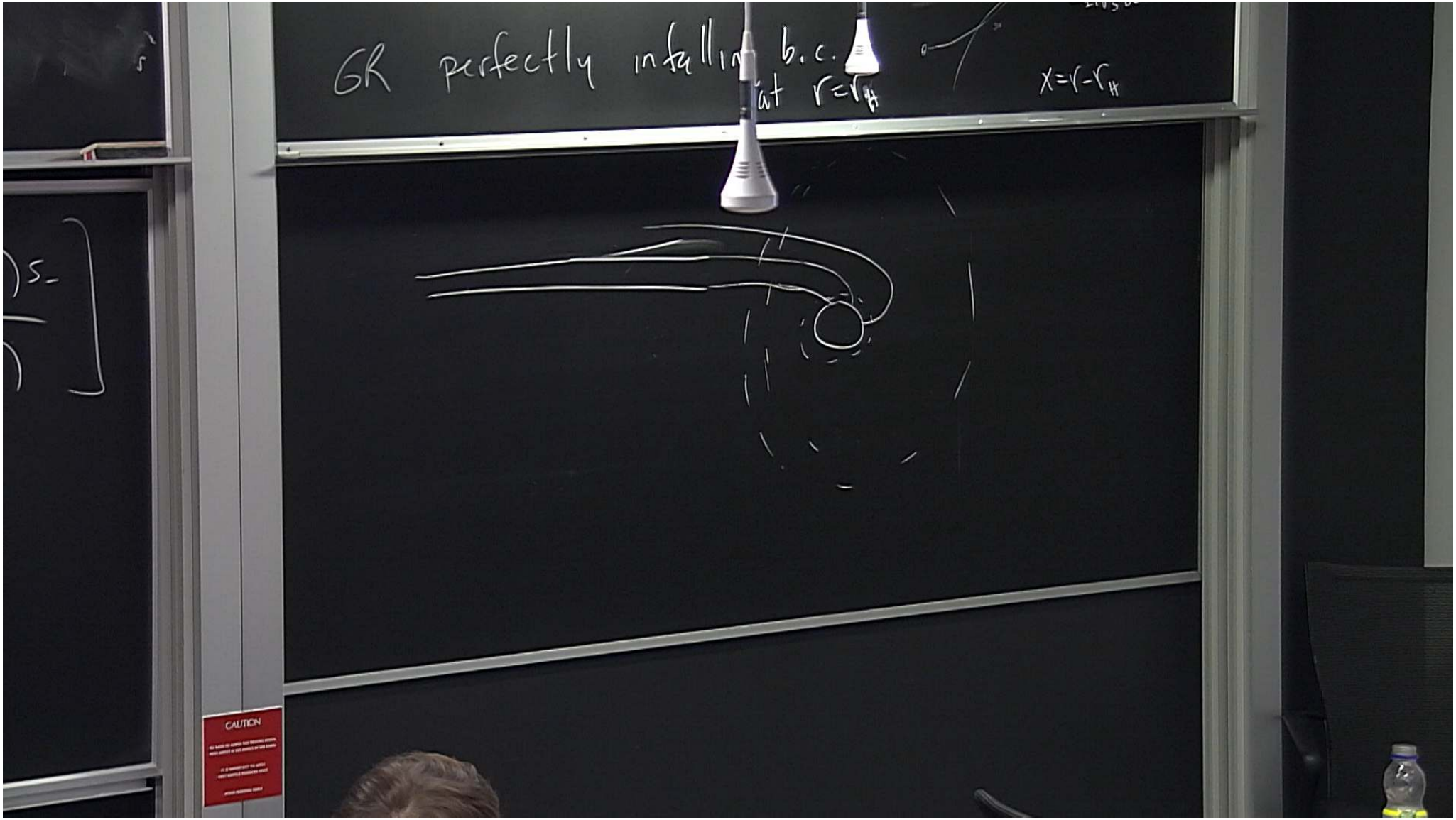
Exclusion l=0

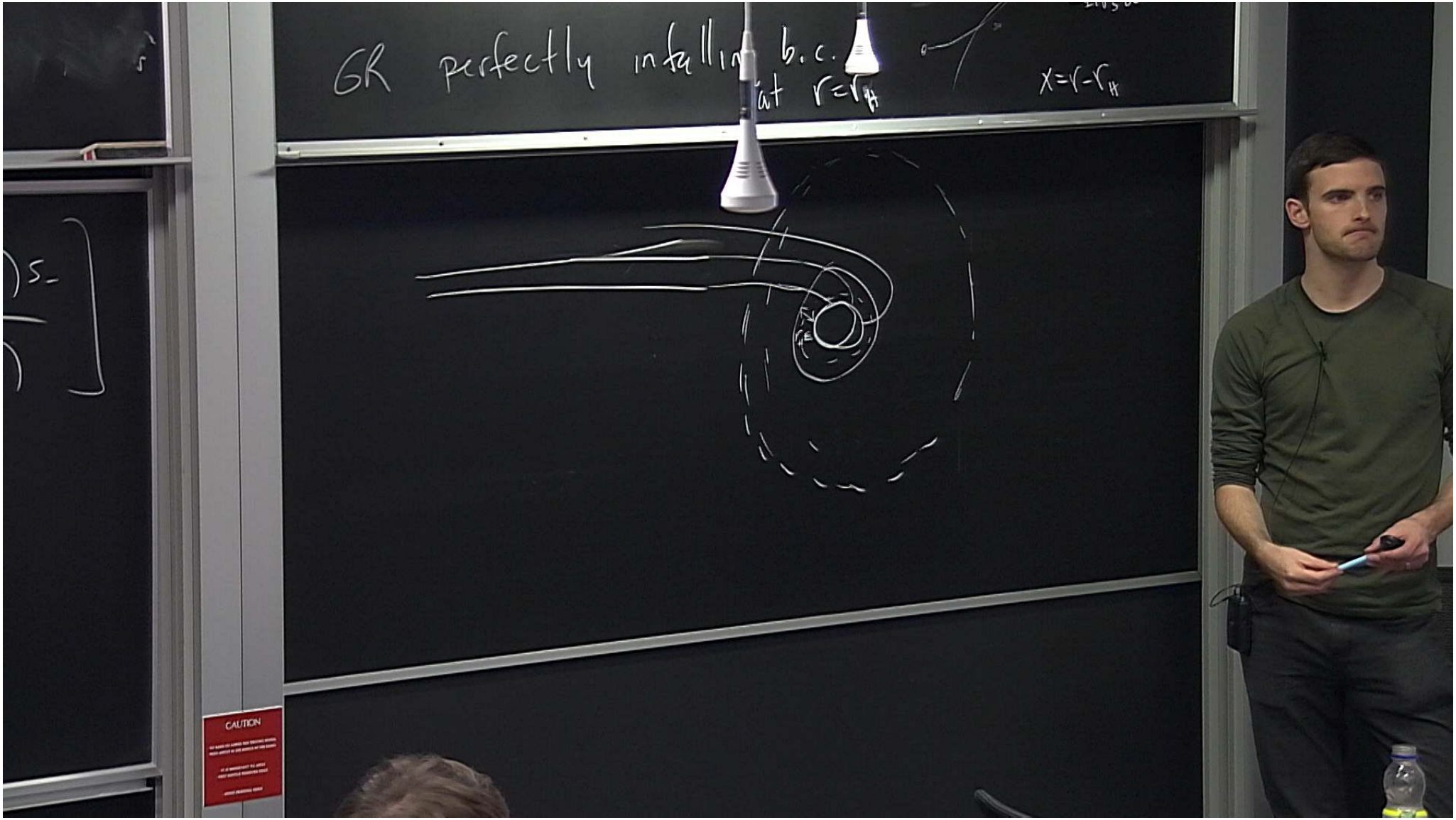


Conclusions

- EHT observations are consistent with GR Kerr black hole which can be used to constrain new physics
- Reflection coefficient is RG invariant and can be constrained to less than $1 - 10\%$ already
- Reflection should be included in GRMHD simulations and EHT data for full treatment and better constraints

Thank you!


GR perfectly infalling b.c.
at r=r_H
x=r-r_H
CAUTION


GR perfectly infalling b.c.
at r=r_H
x=r-r_H
CAUTION