Black ringoids: new higher dimensional black objects with non-spherical horizon topology

Eugen Radu

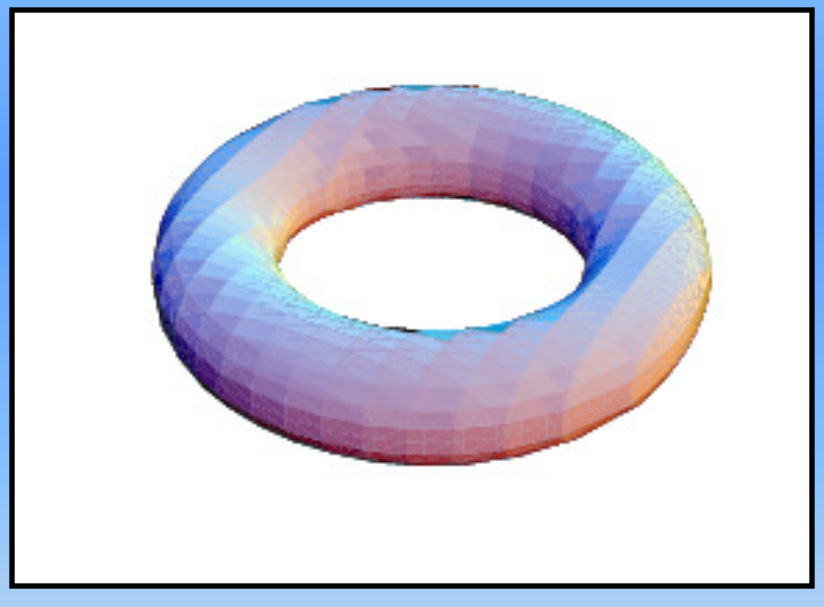
Physics Department,
Aveiro University

based on ***arXiv:1410.0581 --*** *work done together with*
B. Kleihaus and ***J. Kunz*** *(Oldenburg University, Germany)*

Black Holes in higher dimensions *d>4:*

(asymptotically flat +vacuum+ single black objects*)*

- important field of research
- rapid progress following the discovery of the ***d=5 Black Ring***

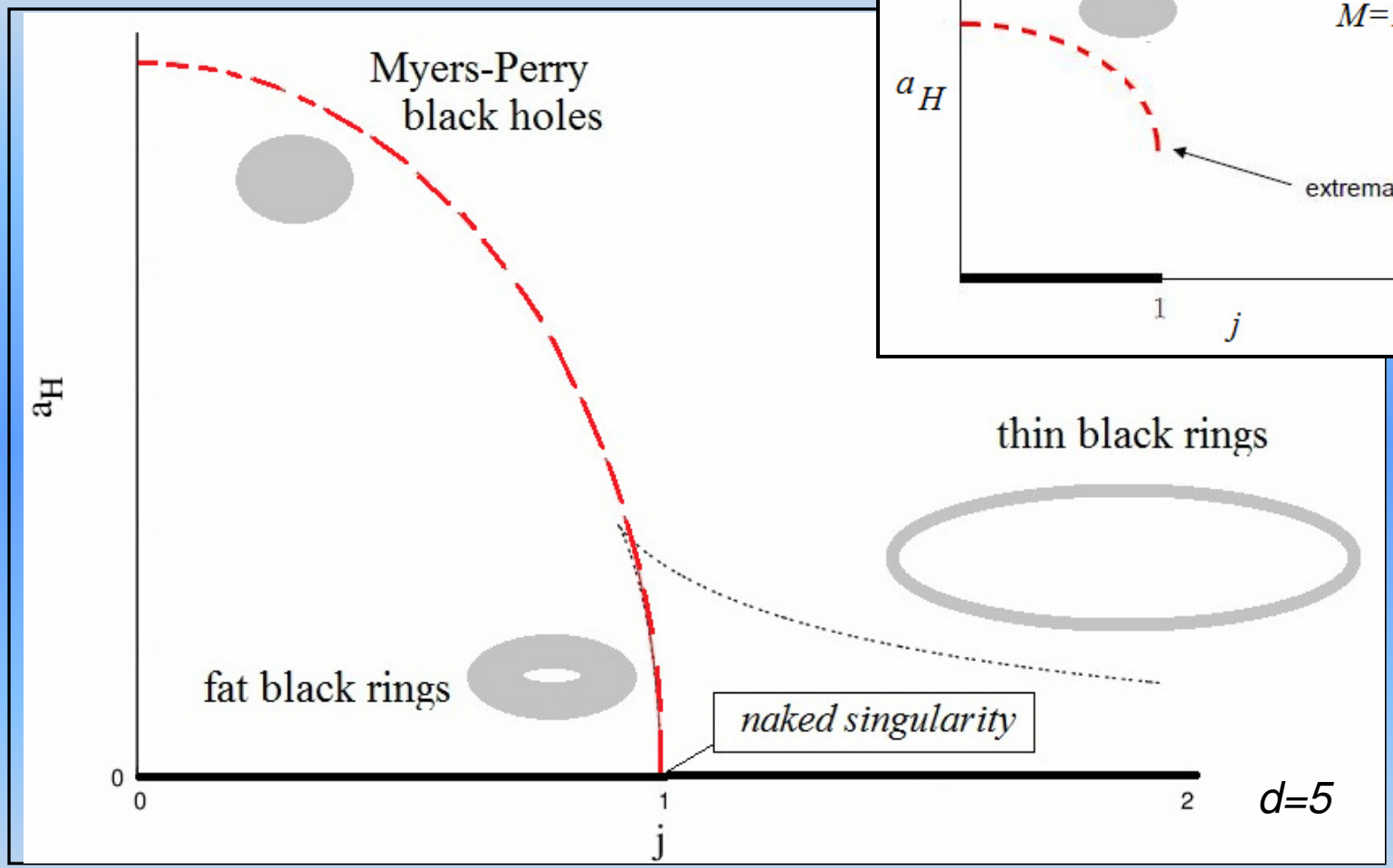


$S^2 x S^1$
horizon topology

- *exact solution!*
- *has led to a reconsideration of a number of basic results in black hole physics*

One-black hole phases in five dimensions:

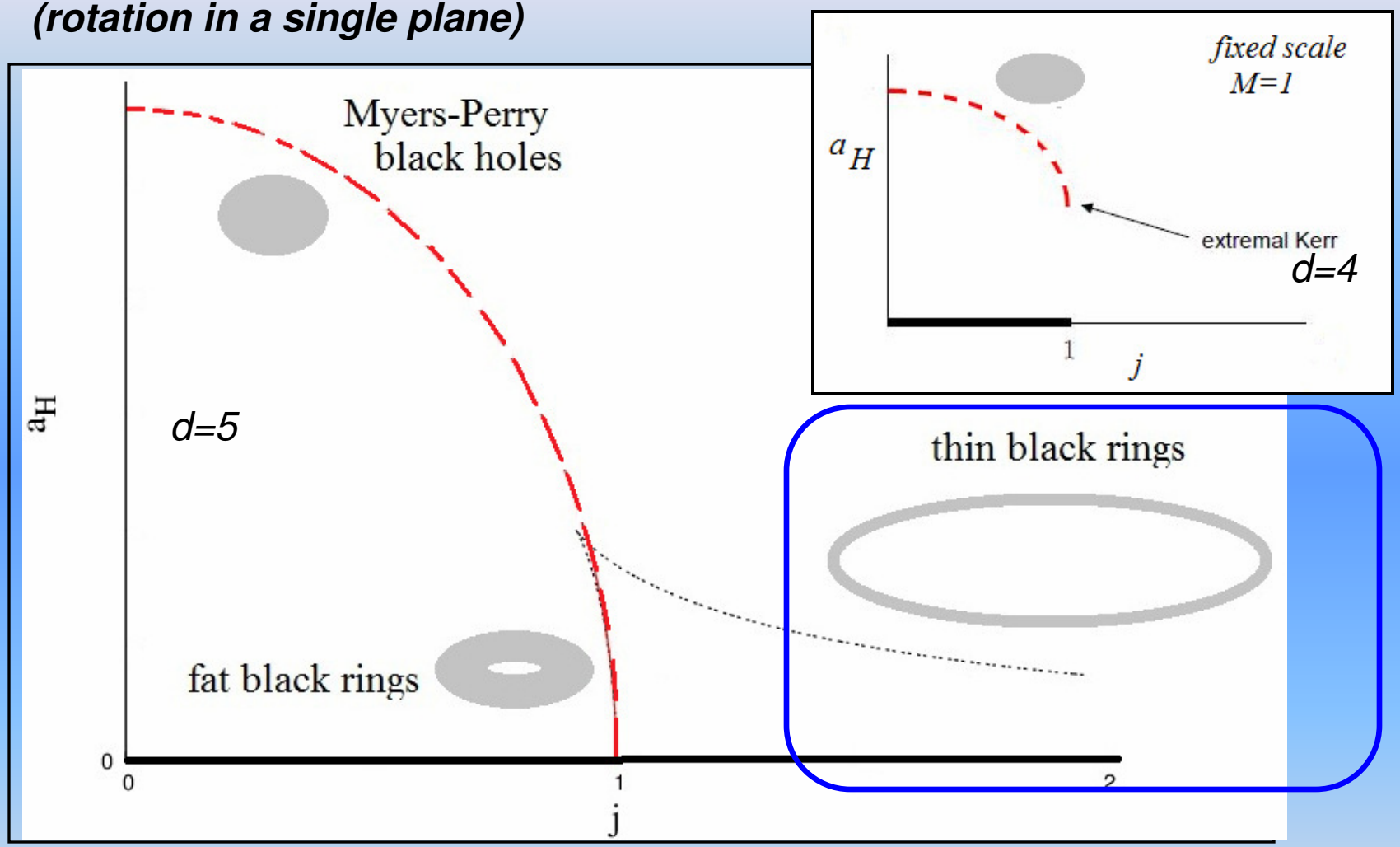
(rotation in a single plane)



- ***three different black holes with the same value of (M,J)***
- ***non uniqueness!***

One-black hole phases in five dimensions:

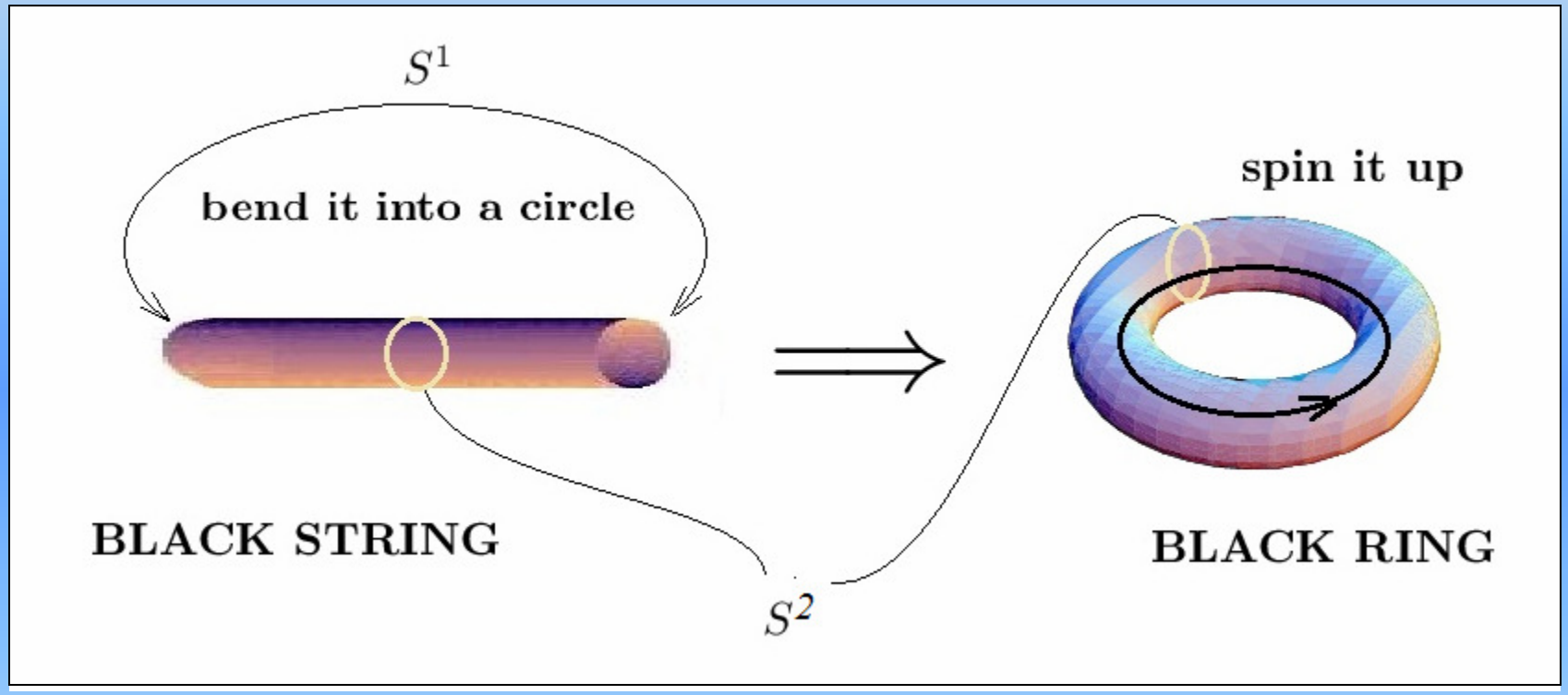
(rotation in a single plane)



- ***three different black holes with the same value of (M,J)***
- ***non uniqueness!***

thin black rings: heuristic construction

Schwarzschild black hole in 4-dimensions ⇨ *black string in 5-dimensions*



- there is an explicit realisation
- the same construction holds for d>5: $\mathbf{S^{d-3}xS^1}$
- predicts also other horizon topologies

⇨ ***blackfold approach*** (Emparan et al.)

also other arguments: <u>a large spectrum of d>5 exotic BHs</u>

however, <u>no exact solutions</u>:

- only the Myers-Perry BHs are known in closed form
- the d=4,5 formalism+generation techniques do not work for d>5

d>5 non-spherical horizon topology

all knowledge: from **blackfolds**

also other arguments: <u>a large spectrum of d>5 exotic BHs</u>

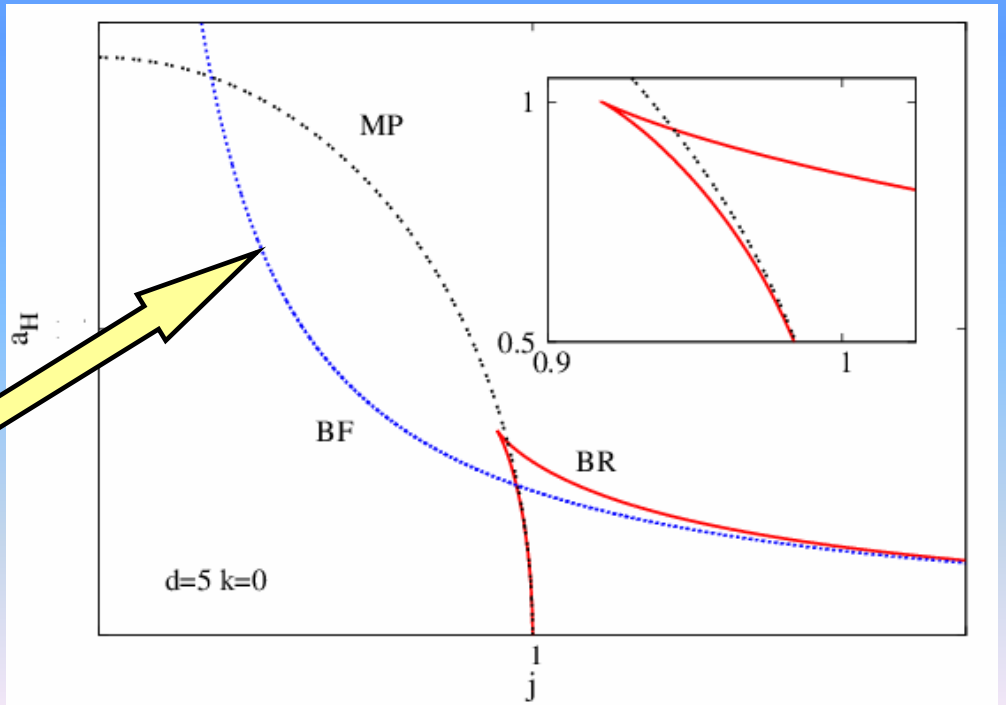
however, <u>no exact solutions</u>:

- only the Myers-Perry BHs are known in closed form
- the d=4,5 formalism+generation techniques do not work for d>5

d>5 non-spherical horizon topology: **blackfolds**

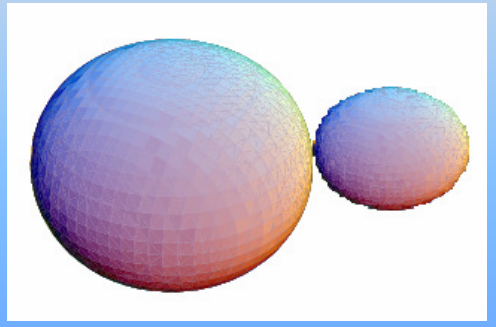
however, clear limits
e.g. d=5 black rings

blackfold predictions



our proposal: ***NON-PERTURBATIVE NUMERICAL APPROACH***

general framework for black holes with $S^p \times S^q$ horizon topology



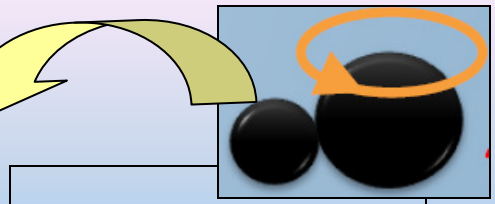
i) vacuum, spinning solutions: $S^{d-(2k+3)} \times S^{2k+1}$

ii) static black holes:
(Einstein-Maxwell theory) $S^{d-4} \times S^2$

what one can study: $S^{d-(2k+3)} \times S^{2k+1}$

	spherical horizon	*black rings*	*black ringoids*		
	MP/'pinched'	$k=0$	$k=1$	$k=2$	$k=3$
$d=5$	S^3	$\mathbf{S}^2 \times \mathbf{S}^1$			
$d=6$	S^4	$S^3 \times S^1$			
$d=7$	S^5	$S^4 \times S^1$	$\mathbf{S}^2 \times \mathbf{S}^3$		
$d=8$	S^6	$S^5 \times S^1$	$S^3 \times S^3$		
$d=9$	S^7	$S^6 \times S^1$	$S^4 \times S^3$	$\mathbf{S}^2 \times \mathbf{S}^5$	
$d=10$	S^8	$S^7 \times S^1$	$S^5 \times S^3$	$S^3 \times S^5$	
$d=11$	S^9	$S^8 \times S^1$	$S^6 \times S^3$	$S^4 \times S^5$	$\mathbf{S}^2 \times \mathbf{S}^7$

what one can study: $S^{d-(2k+3)} \times S^{2k+1}$



spinning part

	spherical horizon	*black rings*	*black ringoids*		
	MP/'pinched'	$k=0$	$k=1$	$k=2$	$k=3$
$d=5$	S^3	$\mathbf{S}^2 \times \mathbf{S}^1$			
$d=6$	S^4	$S^3 \times S^1$			
$d=7$	S^5	$S^4 \times S^1$	$\mathbf{S}^2 \times \mathbf{S}^3$		
$d=8$	S^6	$S^5 \times S^1$	$S^3 \times S^3$		
$d=9$	S^7	$S^6 \times S^1$	$S^4 \times S^3$	$\mathbf{S}^2 \times \mathbf{S}^5$	
$d=10$	S^8	$S^7 \times S^1$	$S^5 \times S^3$	$S^3 \times S^5$	
$d=11$	S^9	$S^8 \times S^1$	$S^6 \times S^3$	$S^4 \times S^5$	$\mathbf{S}^2 \times \mathbf{S}^7$

regular solutions!

(no (conical) singularities etc)

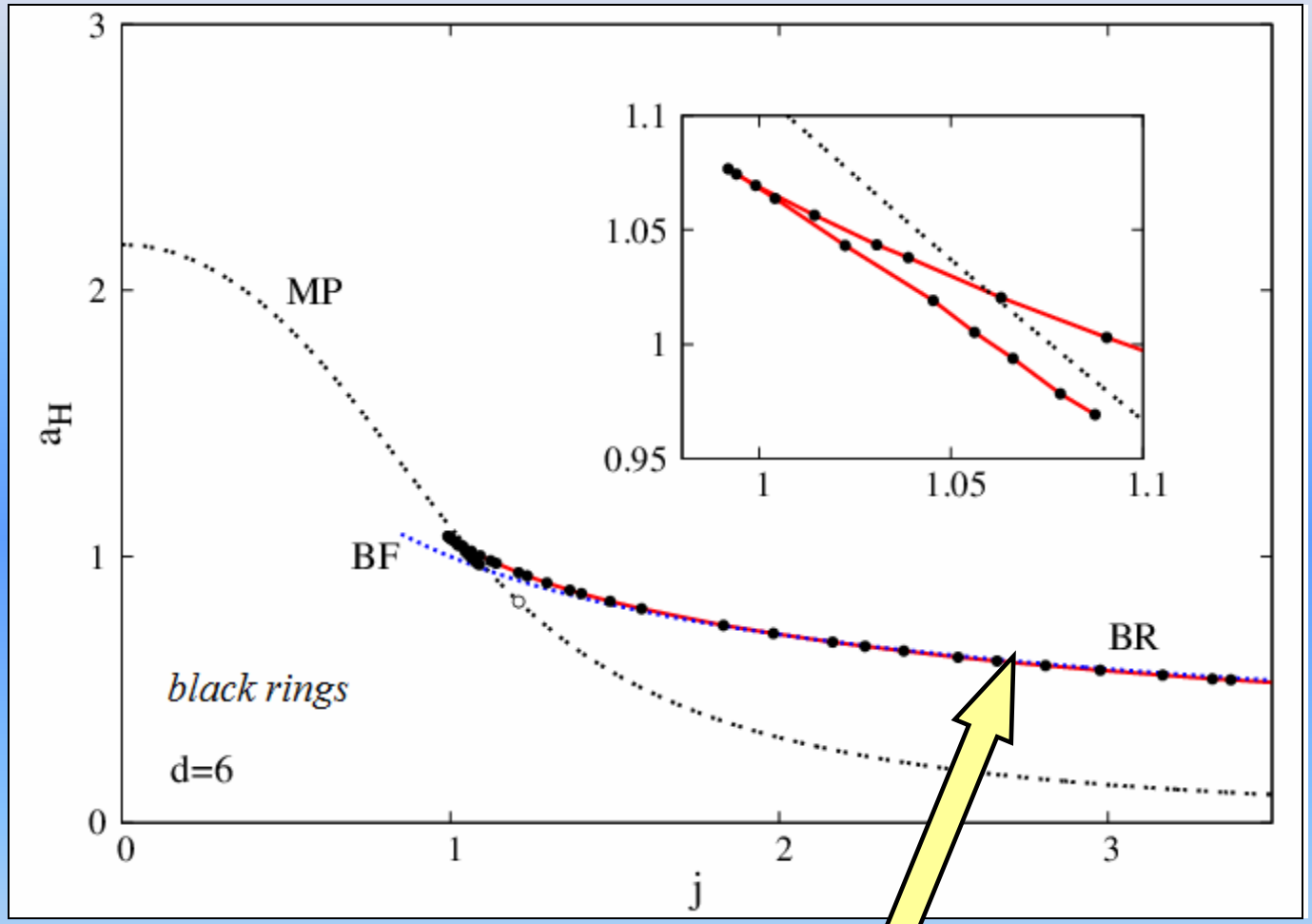
our results (i):

- cases we have considered so far:

	black rings	*black ringoids*		
	$k=0$	$k=1$	$k=2$	$k=3$
$d=5$	$\mathbf{S}^2 \times \mathbf{S}^1$			
$d=6$	$S^3 \times S^1$			
$d=7$	$S^4 \times S^1$	$\mathbf{S}^2 \times \mathbf{S}^3$		
$d=8$	$S^5 \times S^1$	$S^3 \times S^3$		
$d=9$	$S^6 \times S^1$	$S^4 \times S^3$	$\mathbf{S}^2 \times \mathbf{S}^5$	
$d=10$	$S^7 \times S^1$	$S^5 \times S^3$	$S^3 \times S^5$	
$d=11$	$S^8 \times S^1$	$S^6 \times S^3$	$S^4 \times S^5$	$\mathbf{S}^2 \times \mathbf{S}^7$

(details in ***arXiv:1410.0581***)

our results (ii):

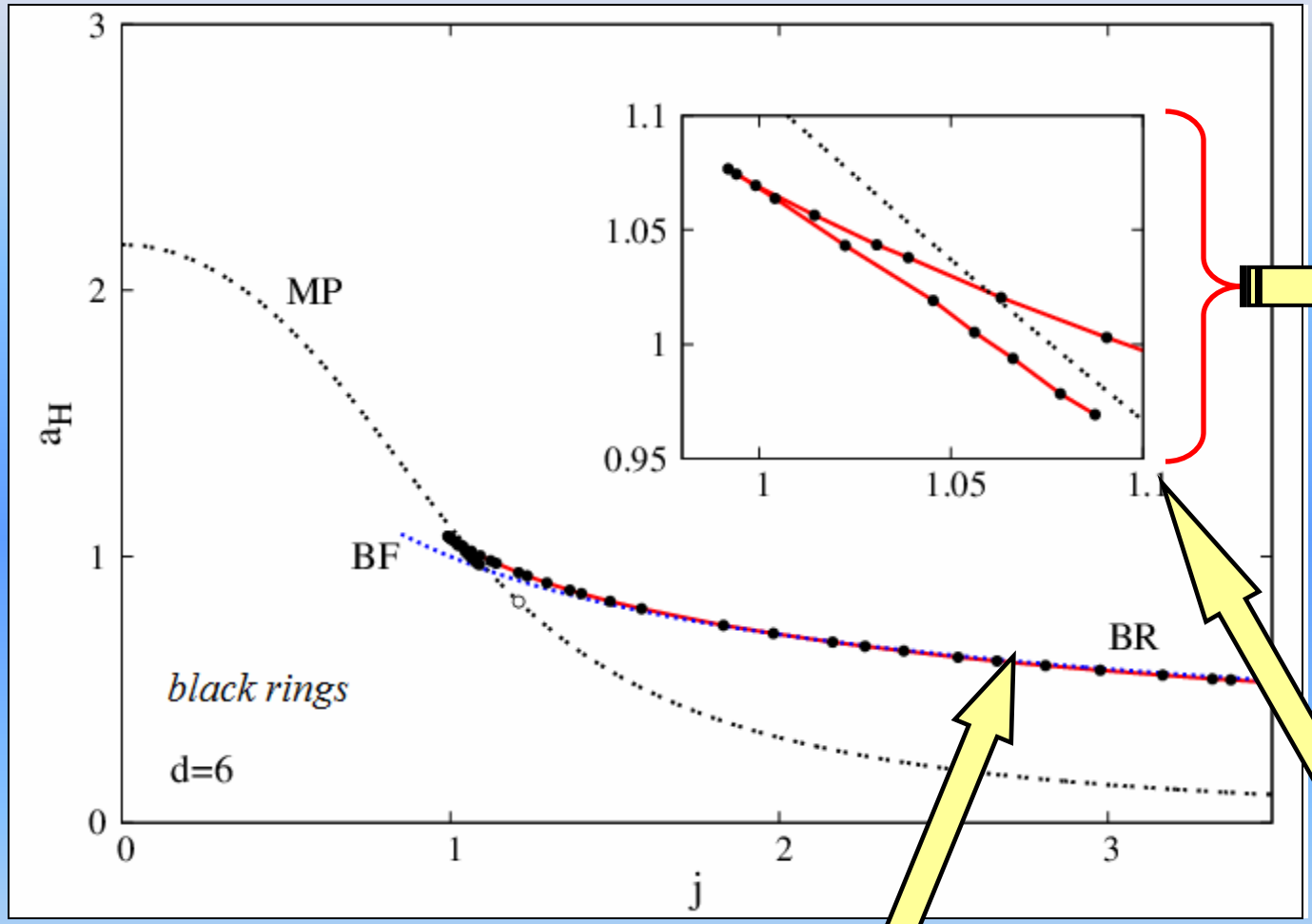


always:

very good agreement with the blackfolds

(for large j)

our results (ii):



2nd branch always

$j > j_{min}$

very good agreement with the blackfolds

however, new features

our results (iii):

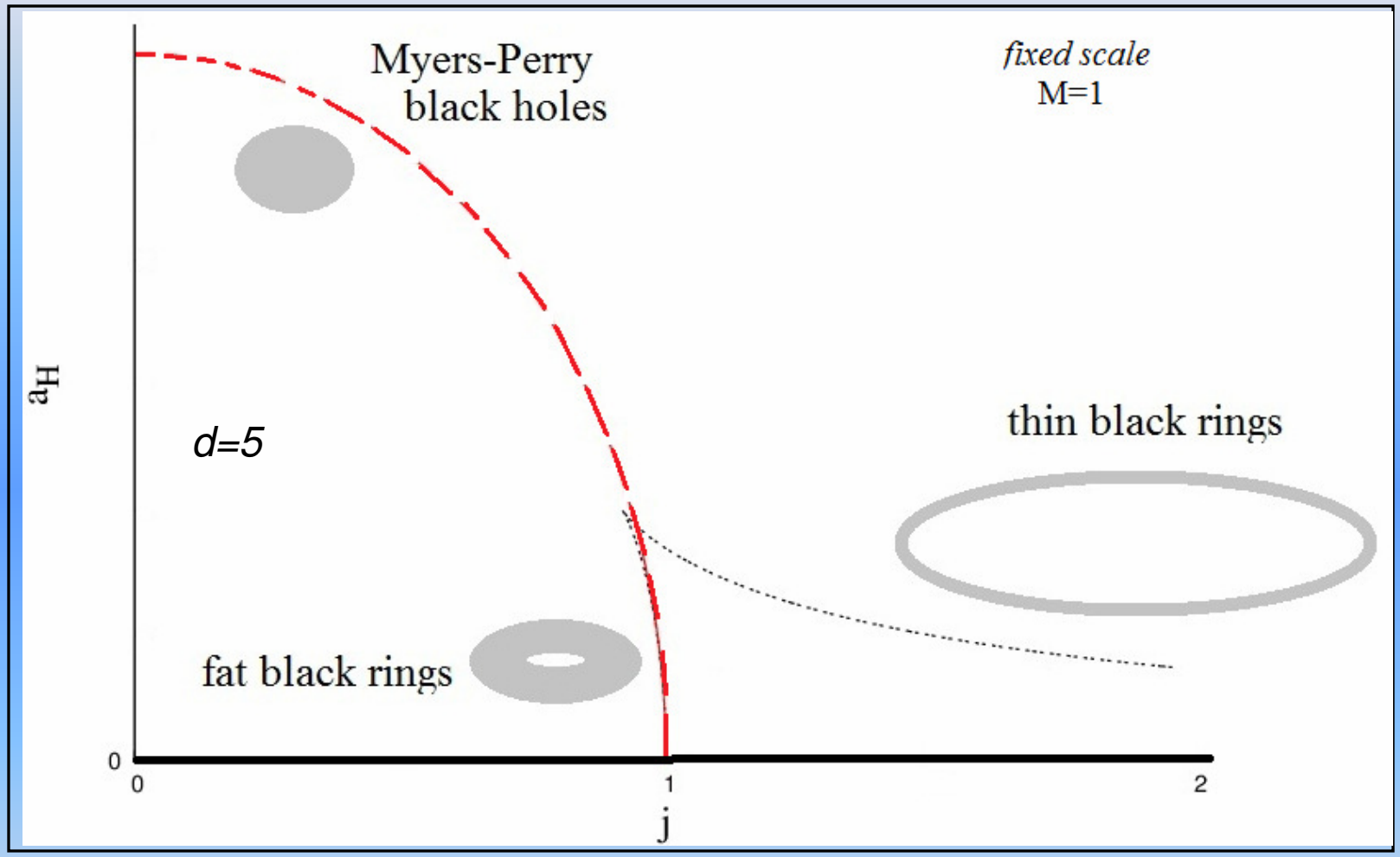
emerging picture (+ *Myers-Perry solutions*)

	black rings	*black ringoids*		
	$k=0$	$k=1$	$k=2$	$k=3$
$d=5$	$\mathbf{S}^2 \times \mathbf{S}^1$			
$d=6$	$S^3 \times S^1$			
$d=7$	$S^4 \times S^1$	$\mathbf{S}^2 \times \mathbf{S}^3$		
$d=8$	$S^5 \times S^1$	$S^3 \times S^3$		
$d=9$	$S^6 \times S^1$	$S^4 \times S^3$	$\mathbf{S}^2 \times \mathbf{S}^5$	
$d=10$	$S^7 \times S^1$	$S^5 \times S^3$	$S^3 \times S^5$	
$d=11$	$S^8 \times S^1$	$S^6 \times S^3$	$S^4 \times S^5$	$\mathbf{S}^2 \times \mathbf{S}^7$

$S^2 \times S^{d-4}$: *special properties*

the pattern of d=5 black rings+MP

emerging picture:



$S^2 \times S^{d-4}$: *special properties*

the pattern of d=5 black rings+MP

our results (iii):

emerging picture (+ *Myers-Perry solutions*)

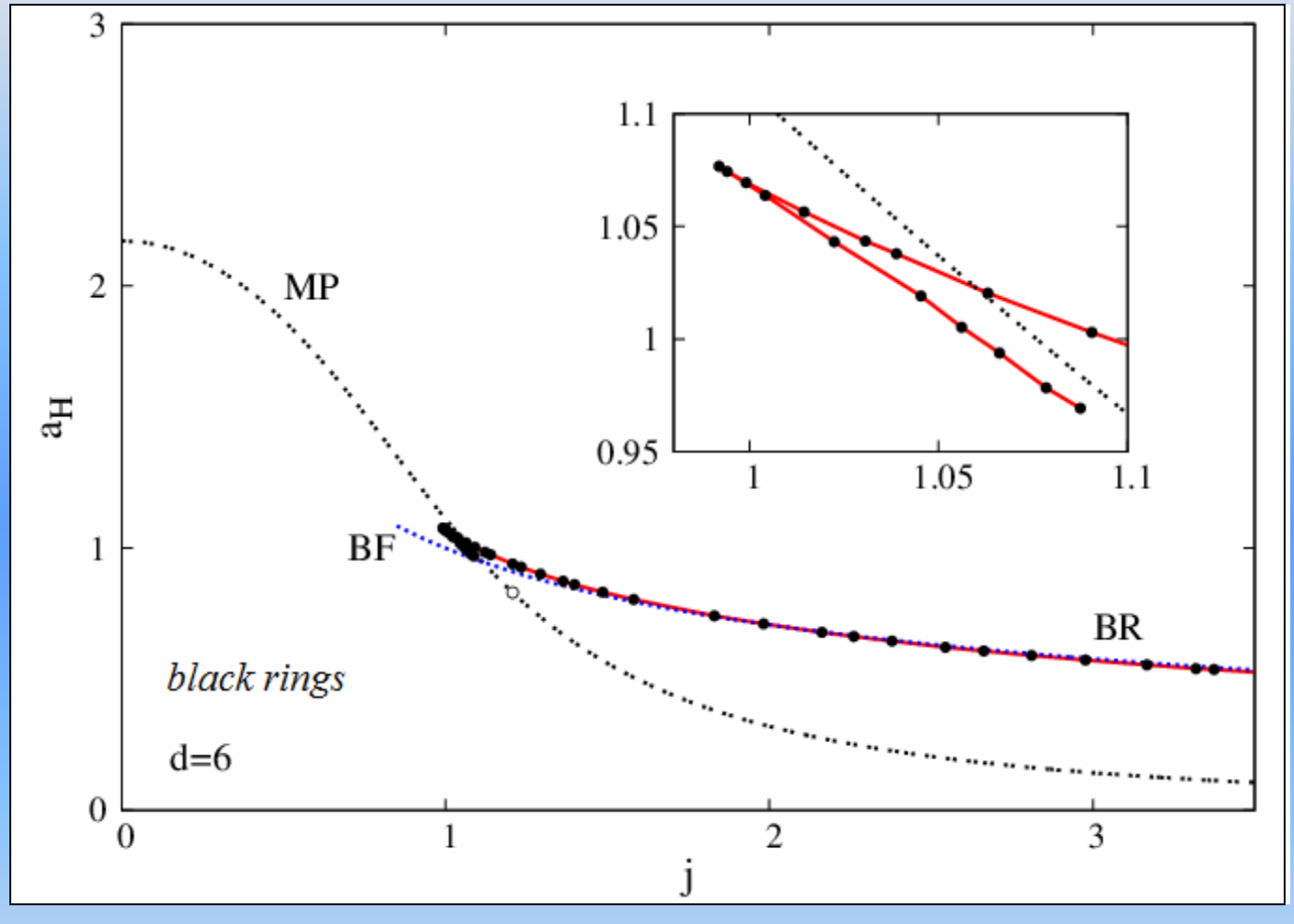
	black rings	*black ringoids*		
	$k=0$	$k=1$	$k=2$	$k=3$
$d=5$	$\mathbf{S}^2 \times \mathbf{S}^1$			
$d=6$	$S^3 \times S^1$			
$d=7$	$S^4 \times S^1$	$\mathbf{S}^2 \times \mathbf{S}^3$		
$d=8$	$S^5 \times S^1$	$S^3 \times S^3$		
$d=9$	$S^6 \times S^1$	$S^4 \times S^3$	$\mathbf{S}^2 \times \mathbf{S}^5$	
$d=10$	$S^7 \times S^1$	$S^5 \times S^3$	$S^3 \times S^5$	
$d=11$	$S^8 \times S^1$	$S^6 \times S^3$	$S^4 \times S^5$	$\mathbf{S}^2 \times \mathbf{S}^7$

$generic\ S^p \times S^q\ solutions:$

p>2

the pattern of d=6 black rings+MP

emerging picture:



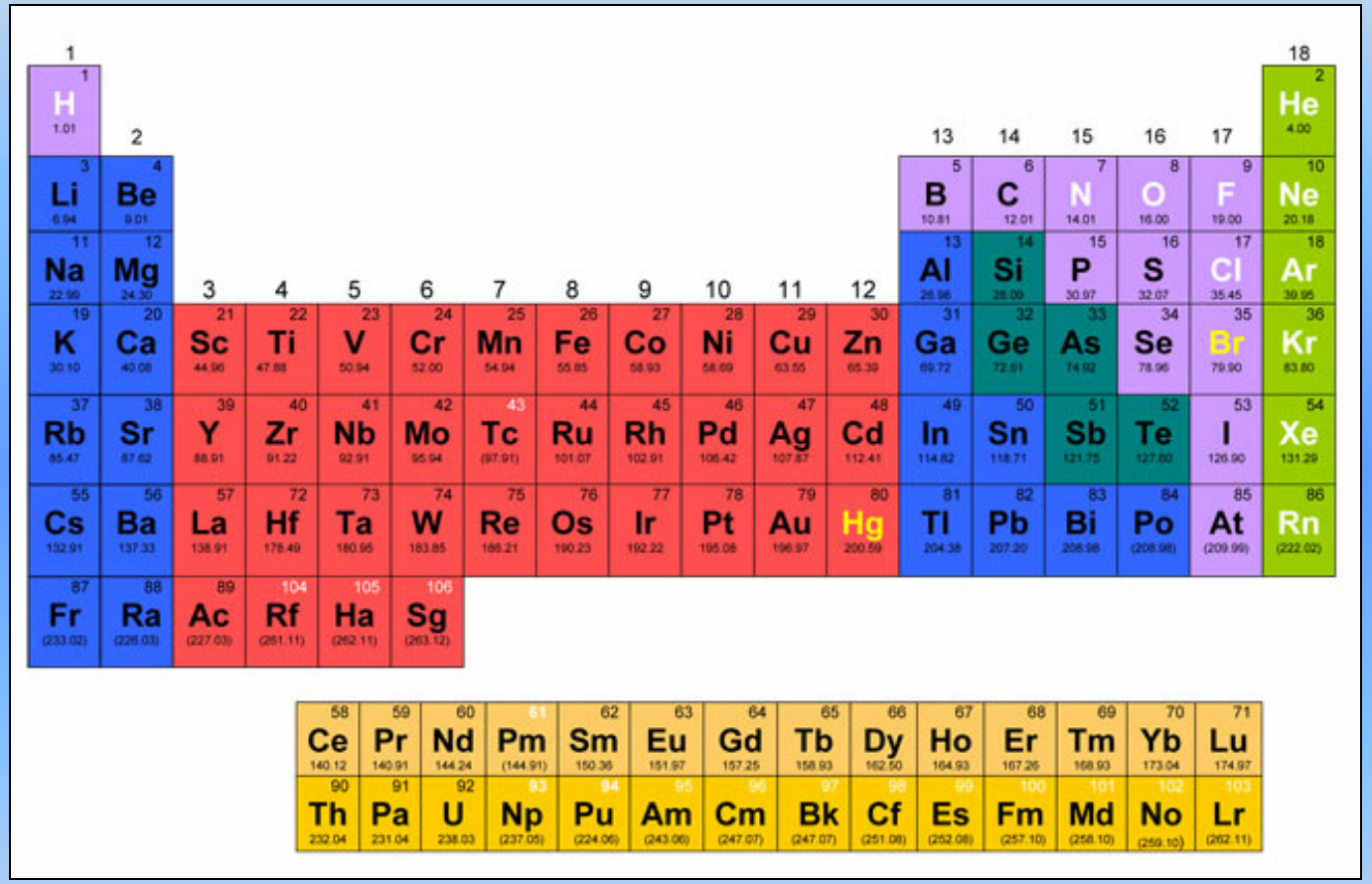
$generic\ S^p \times S^q\ solutions:$

p>2

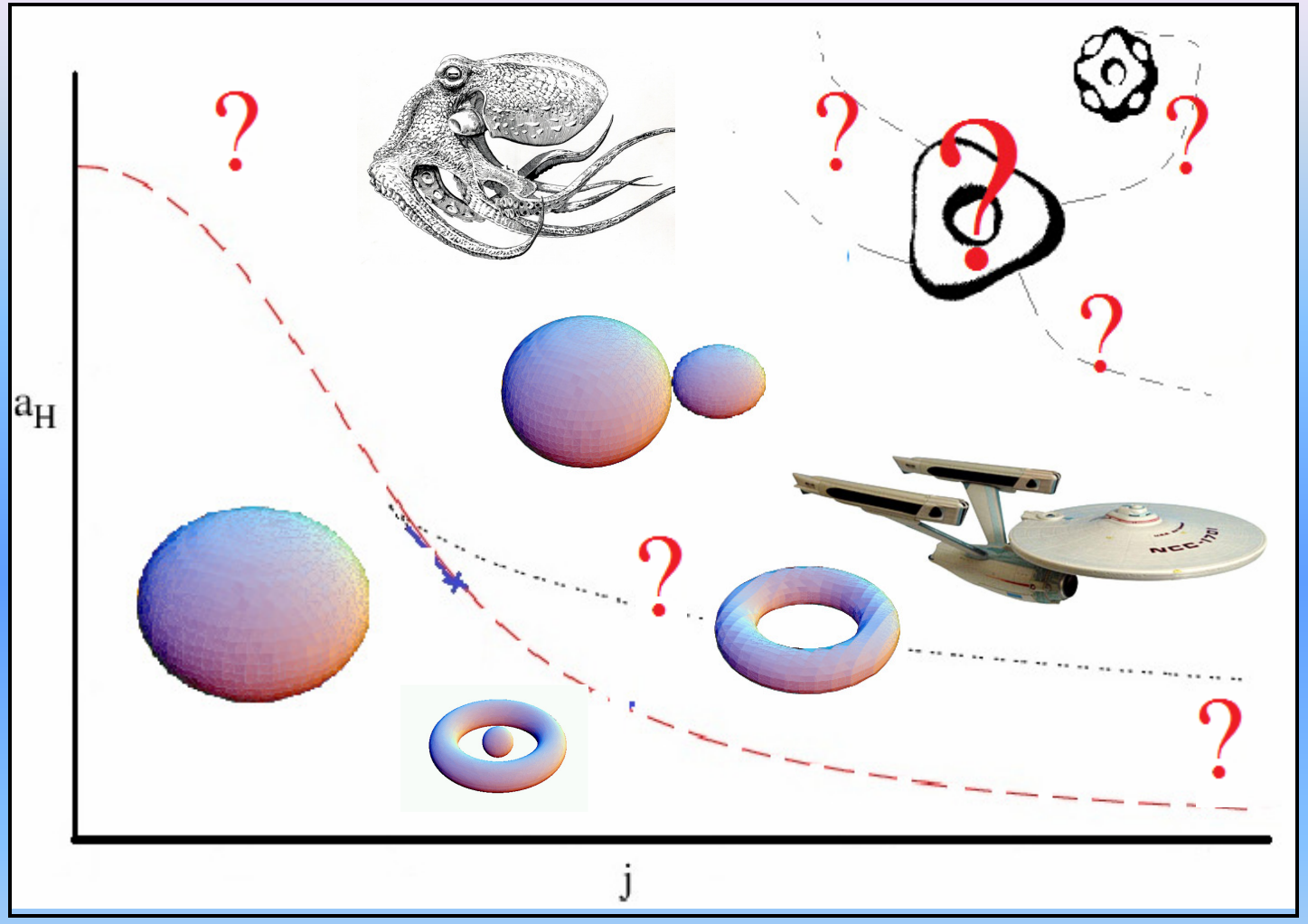
the pattern of d=6 black rings+MP

finally (speculation!):

towards a periodic table of black objects?



a black holes classification based on a finite number of simple features ?



THANK YOU VERY MUCH
FOR YOUR ATTENTION!