Rojstvo črnih lukenj

Andreja Gomboc
Fakulteta za matematiko in fiziko
Univerza v Ljubljani

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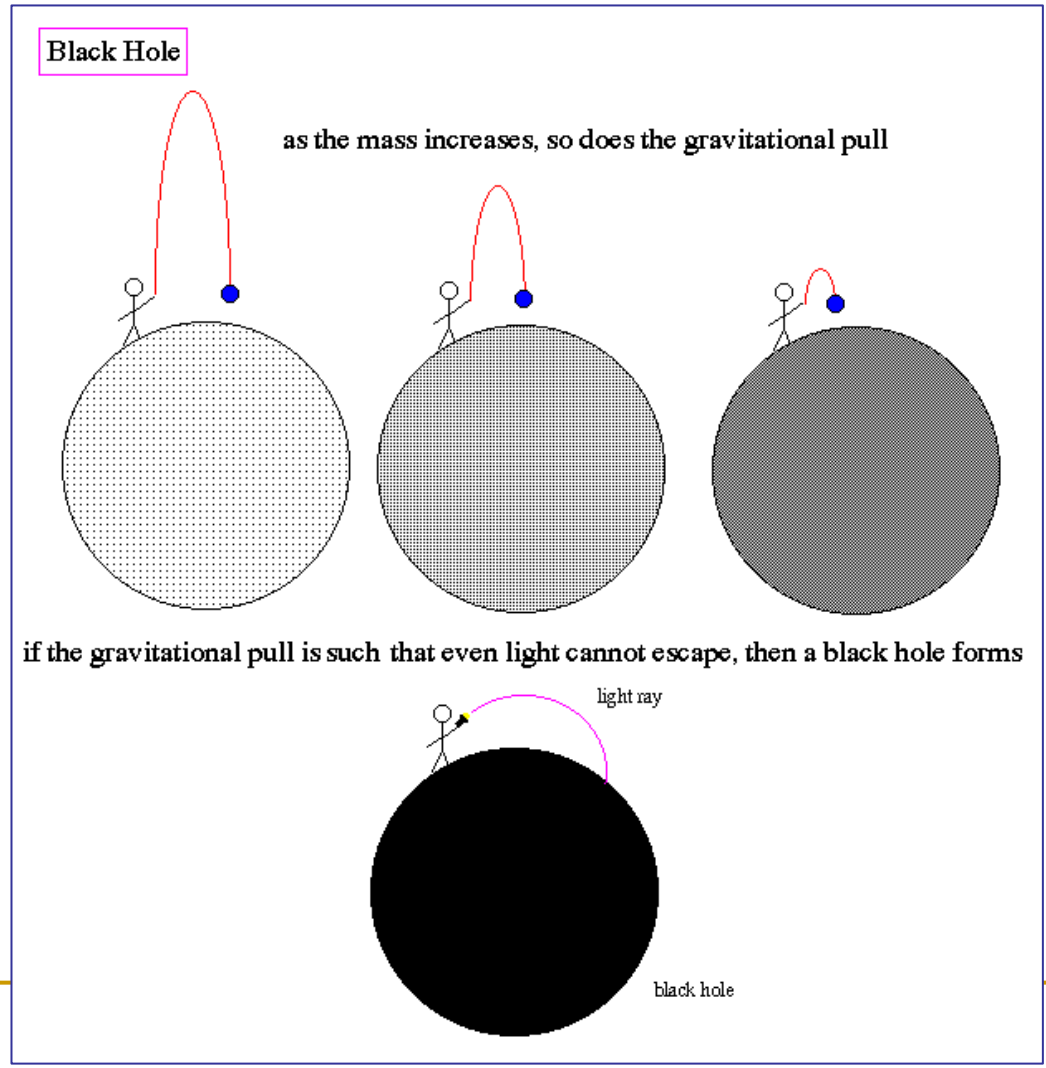
ideja ali teoretično rojstvo

John Mitchell in Pierre Simon de Laplace (1783, 1795)



"temne zvezde"

velikost?

$$\frac{mv^2}{2} - \frac{GMm}{r} = 0$$

$$v = c$$

$$r_{Sch} = \frac{2GM}{c^2}$$

Schwarzschildov radij - horizont

Sonce: r_{Sch}=3 km

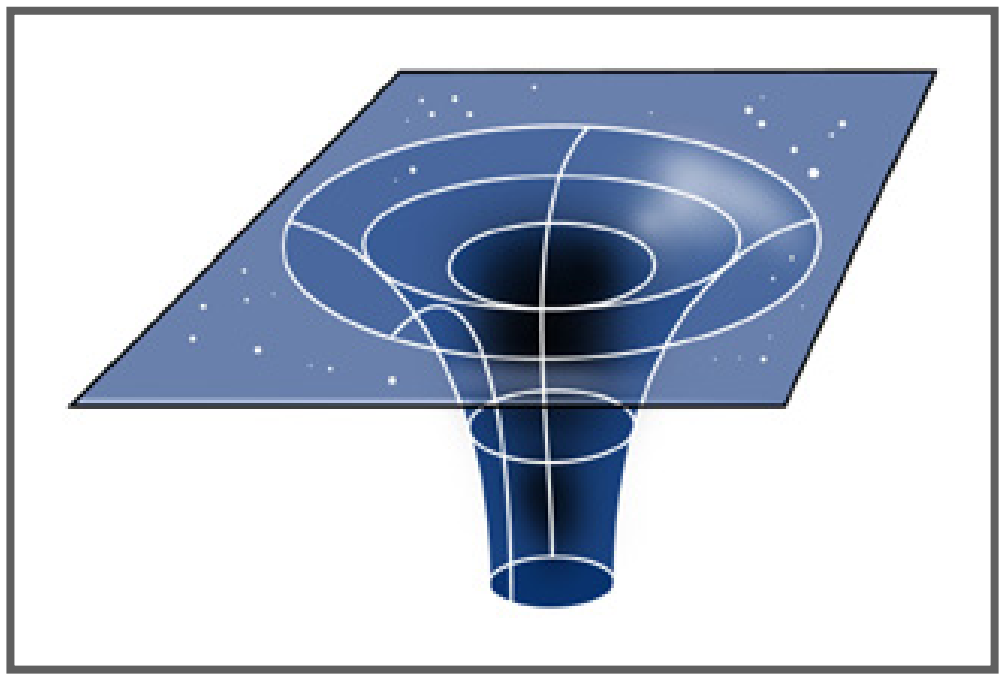
2 napaki!
- fotoni nimajo mase
- Einsteinova splošna teorija relativnosti

prava teorija

1915, 1916

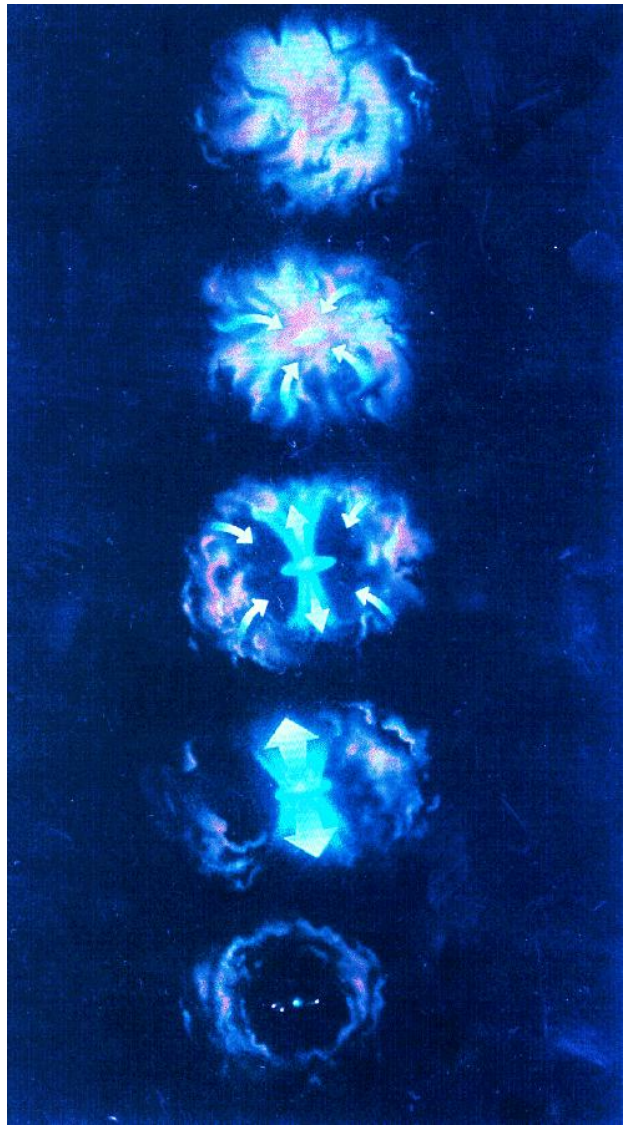
Einstein, Schwarzschild ⇒

rešitev enačb splošne teorije relativnosti



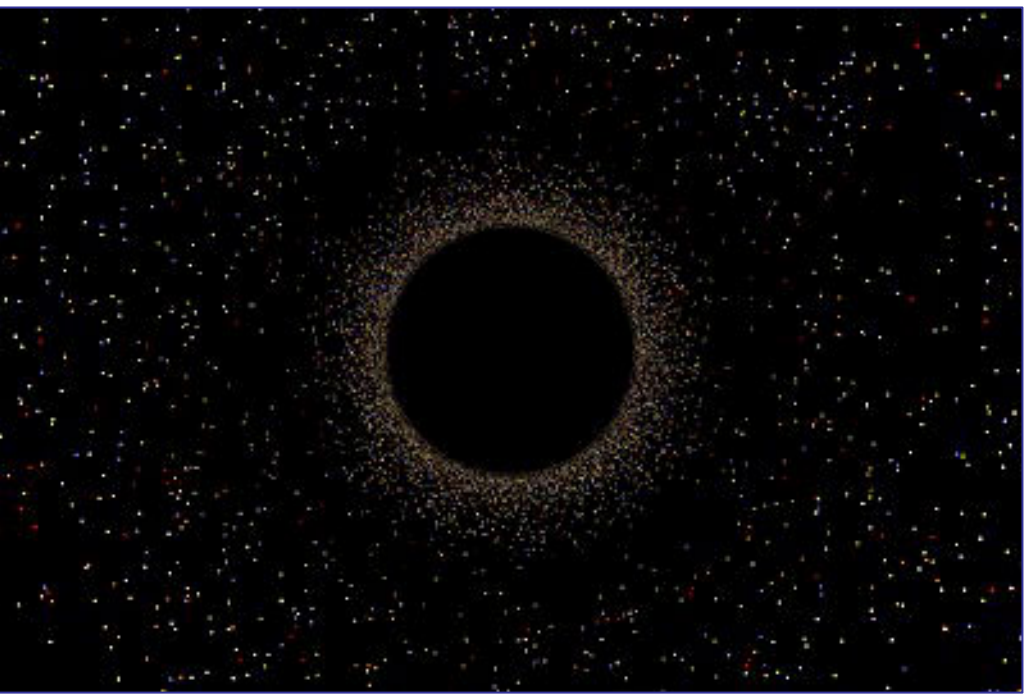
- **1939** Snyder, Oppenheimer

  $\Rightarrow$ napoved črnih lukenj



zlata doba

- **1967** Wheeler ⇒ ime črne luknje



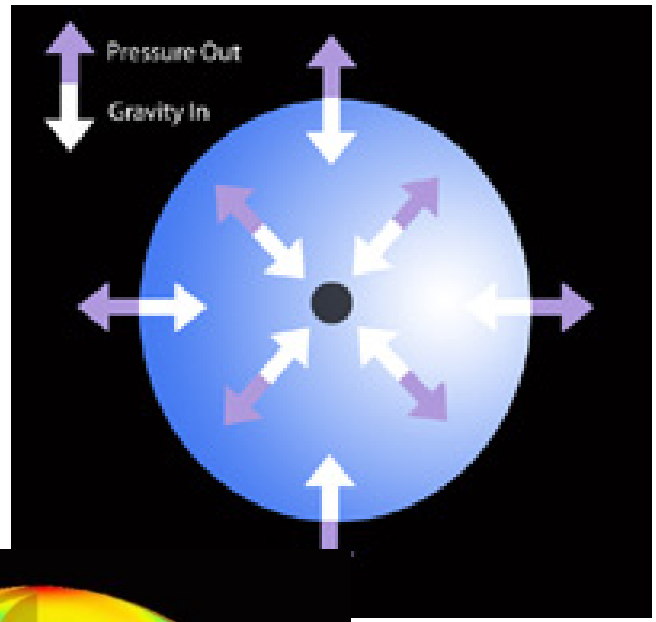
"črna luknja nima las"-
masa,
vrtilna količina,
električni naboj
(Schwarzschild,
Kerr,
Reissner-Nordström,
Kerr-Newman)

Opazovalno “rojstvo” črnih lukenj

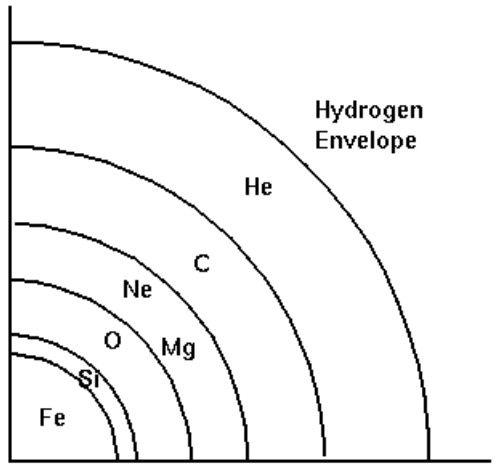
Ali v vesolju takšna telesa sploh obstajajo?

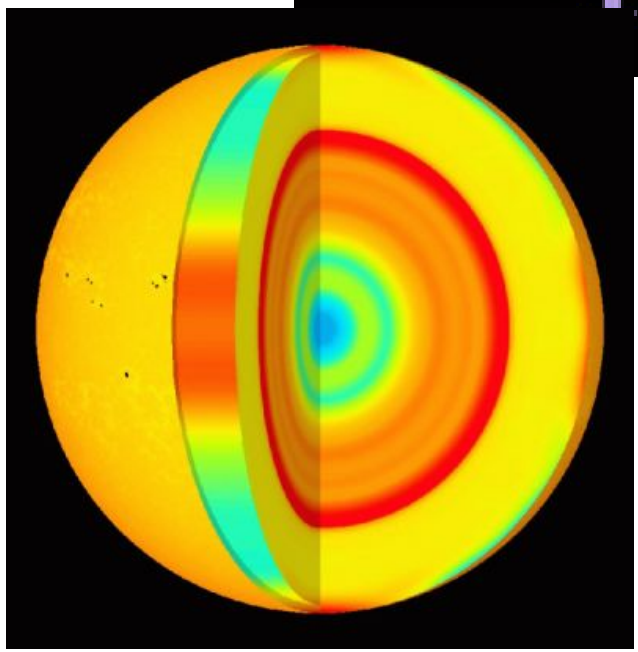
razvoj zvezd

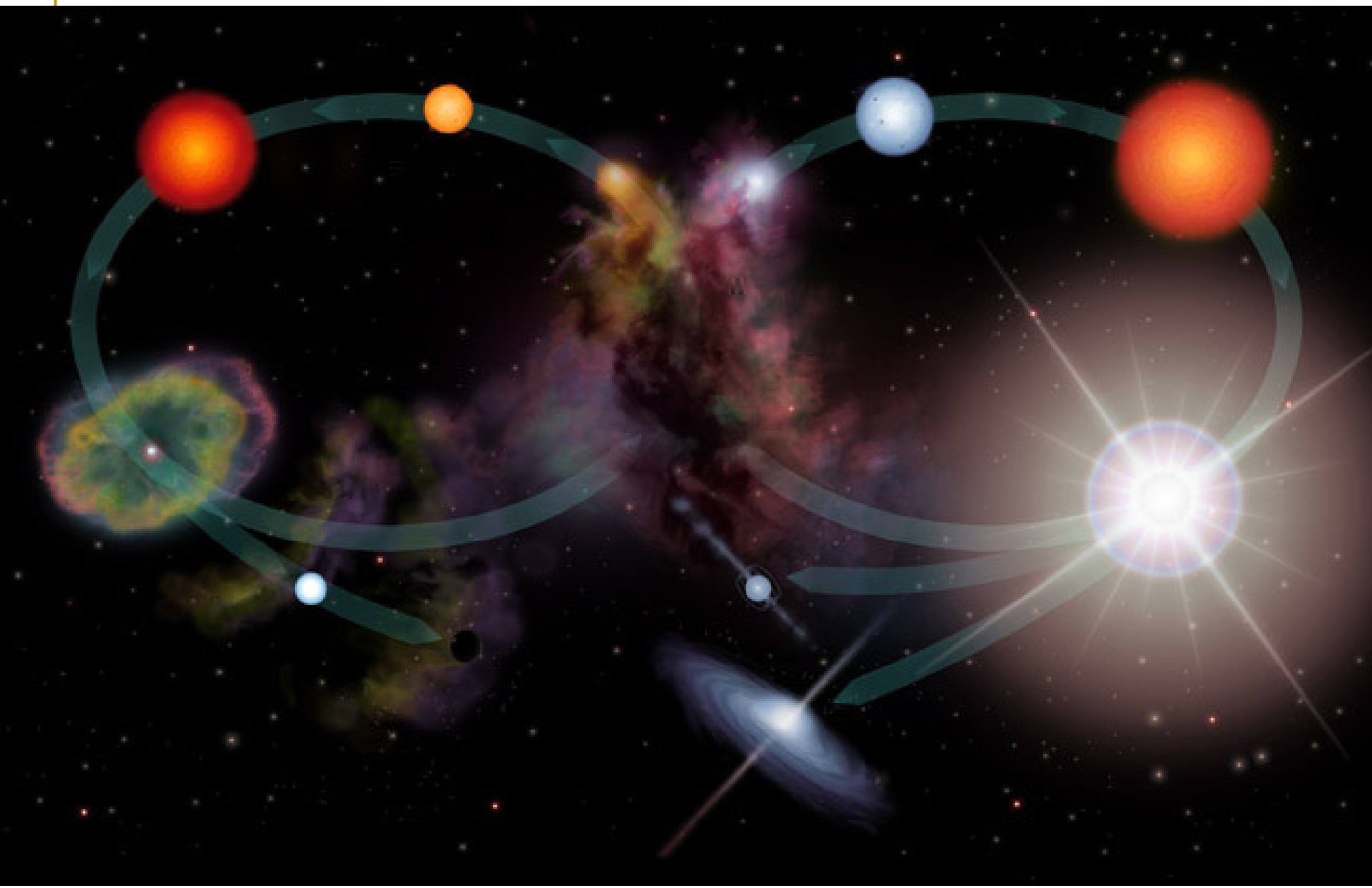
boj gravitacije proti tlaku:



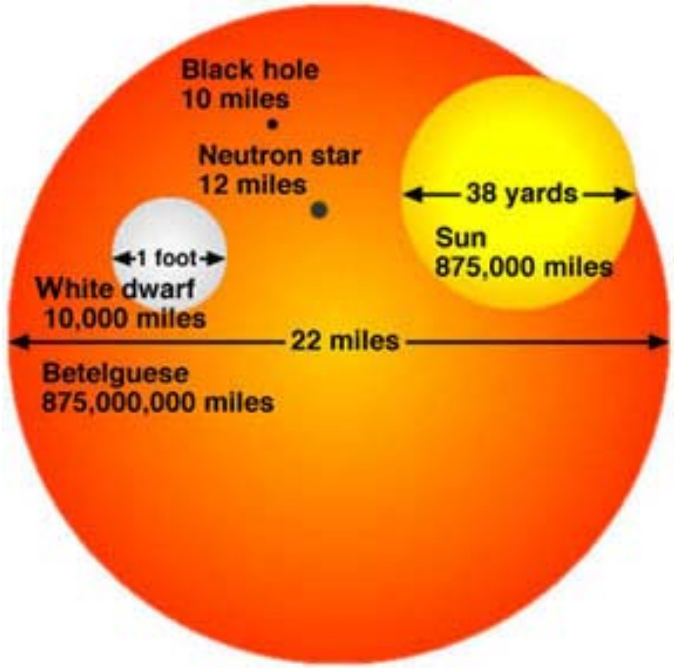
zlivanje atomskih jeder





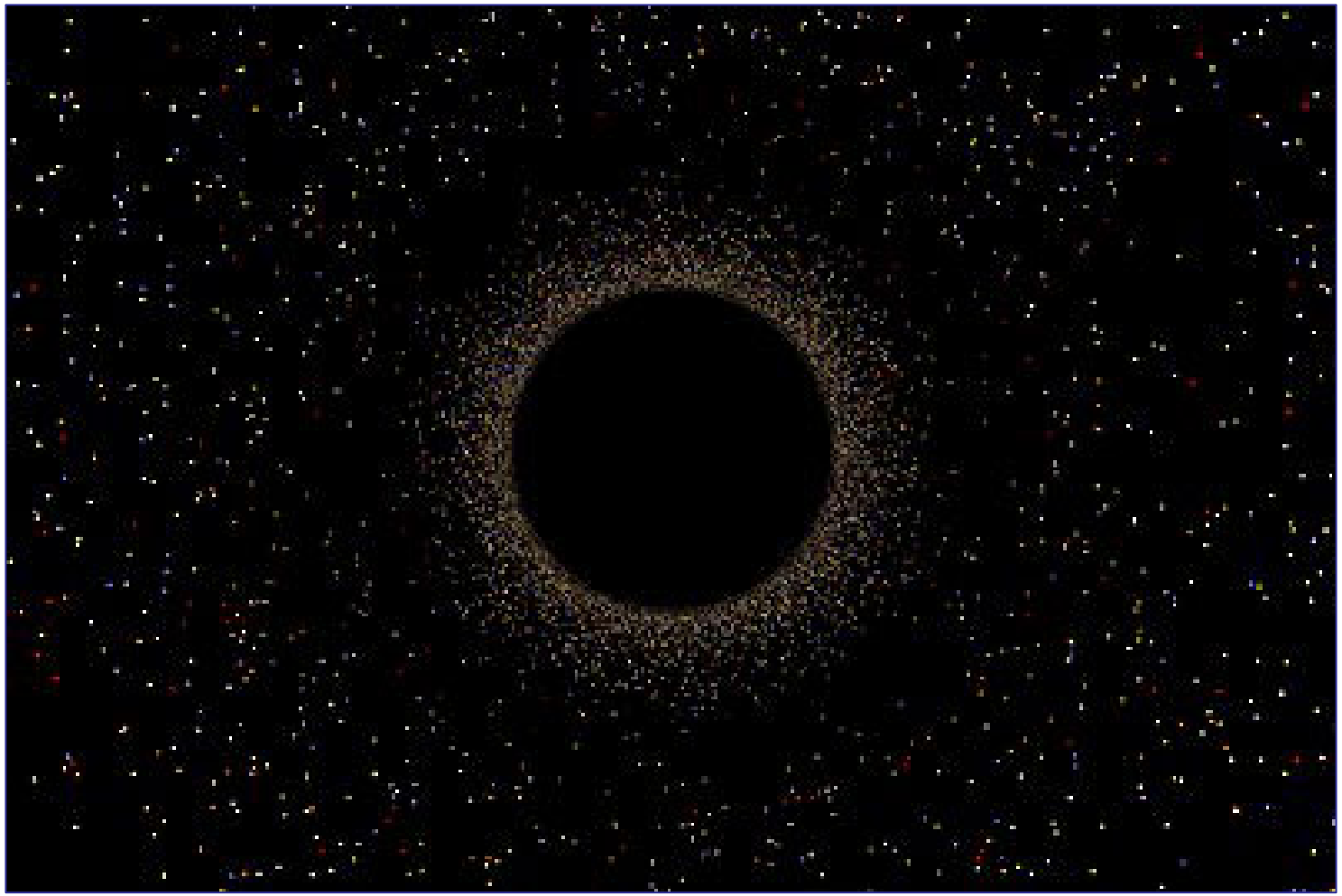


Velikosti in gostote



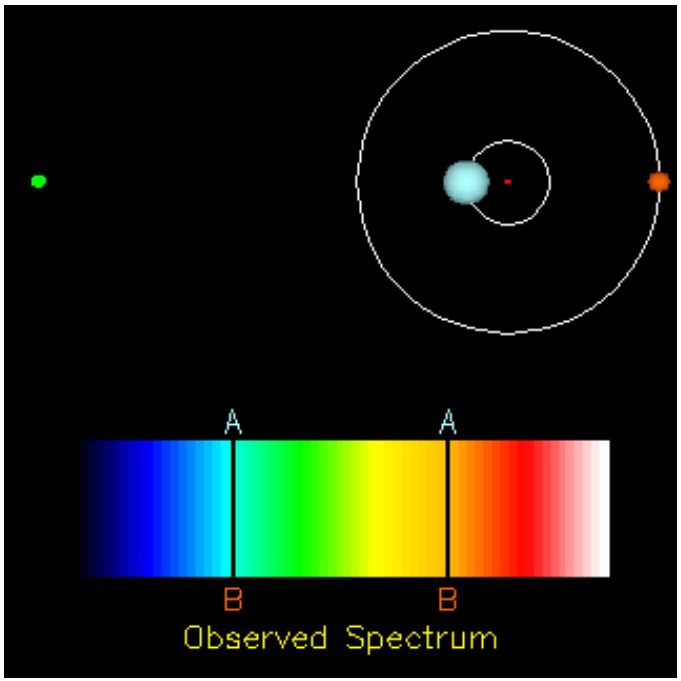
	premer	gostota
Sonce	1.400.000 km	1,4 kg/dm^3
bela pritlikavka	15.000 km	1000 ton/dm^3
nevtronska zvezda	20 km	10^{15} kg/dm^3 !!!
črna luknja	15 km	

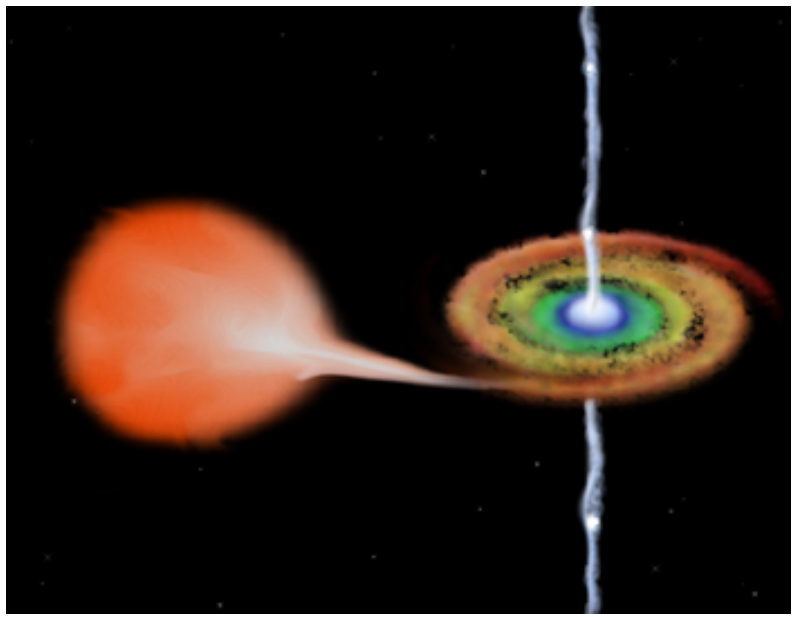
Kako opaziti črne luknje?



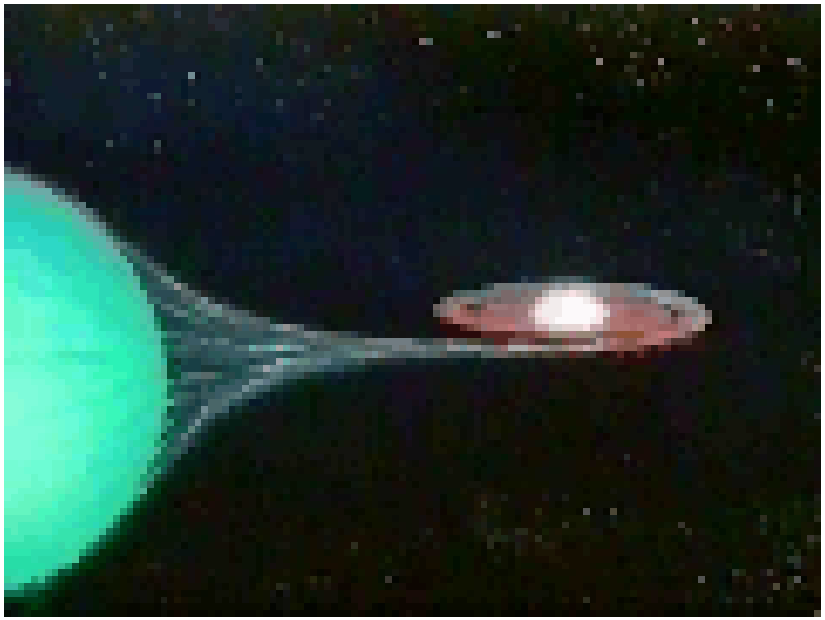
dvojni zvezdni sistemi

periodični Dopplerjev premik spektralnih črt

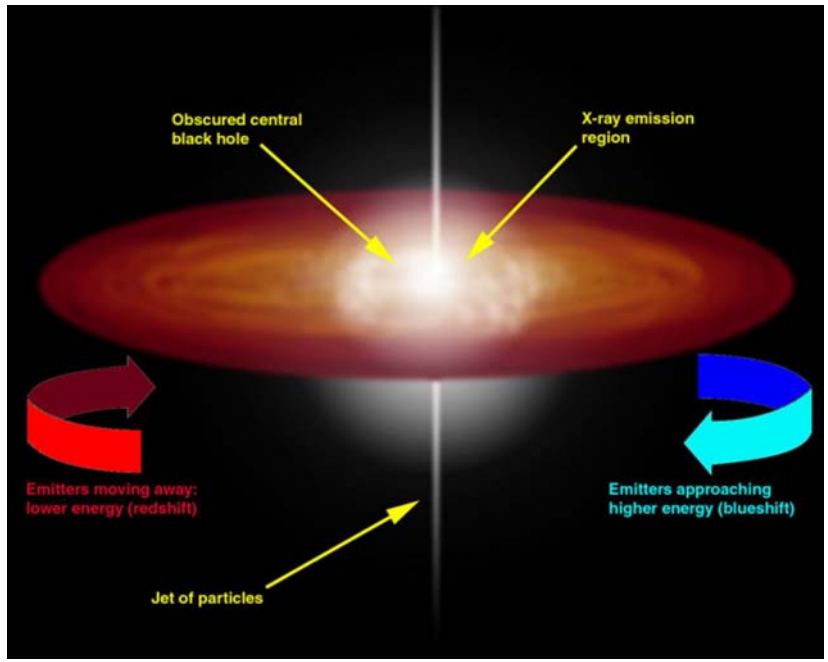




rentgenske dvojnice



- ena zvezda “nevidna”
- rentgentsko sevanje



stava – Labod X1

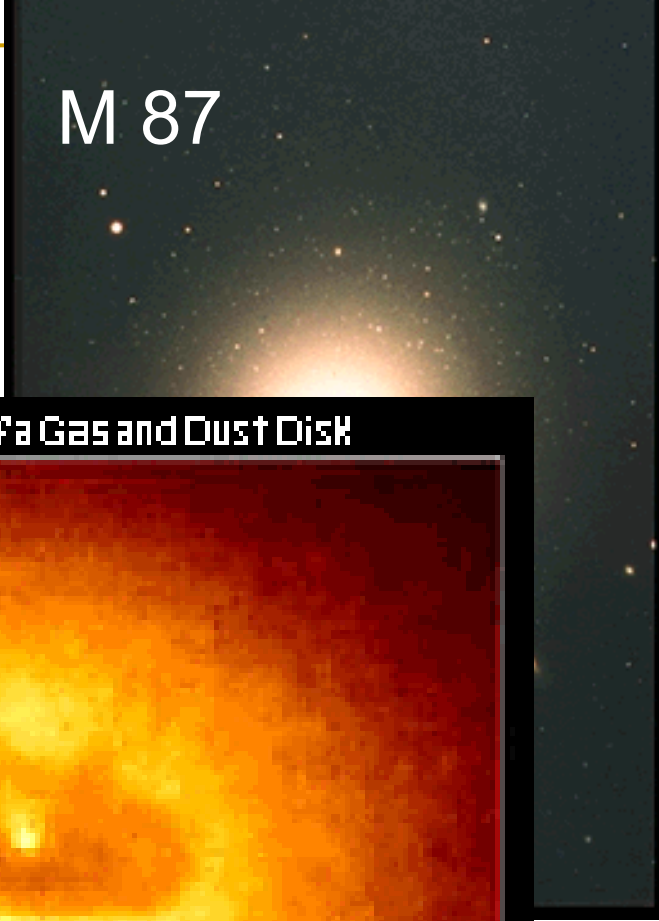
Whereas Stephen Hawking has such a large investment in General Relativity and Black Holes and desires an insurance policy, and whereas Kip Thorne likes to live dangerously without an insurance policy,

Therefore be it resolved that Stephen Hawking bets 1 year's subscription to "Penthouse" as against Kip Thorne's wager of a 4-year subscription to "Private Eye", that Cygnus X 1 does not contain a black hole of mass above the Chandrasekhar limit.

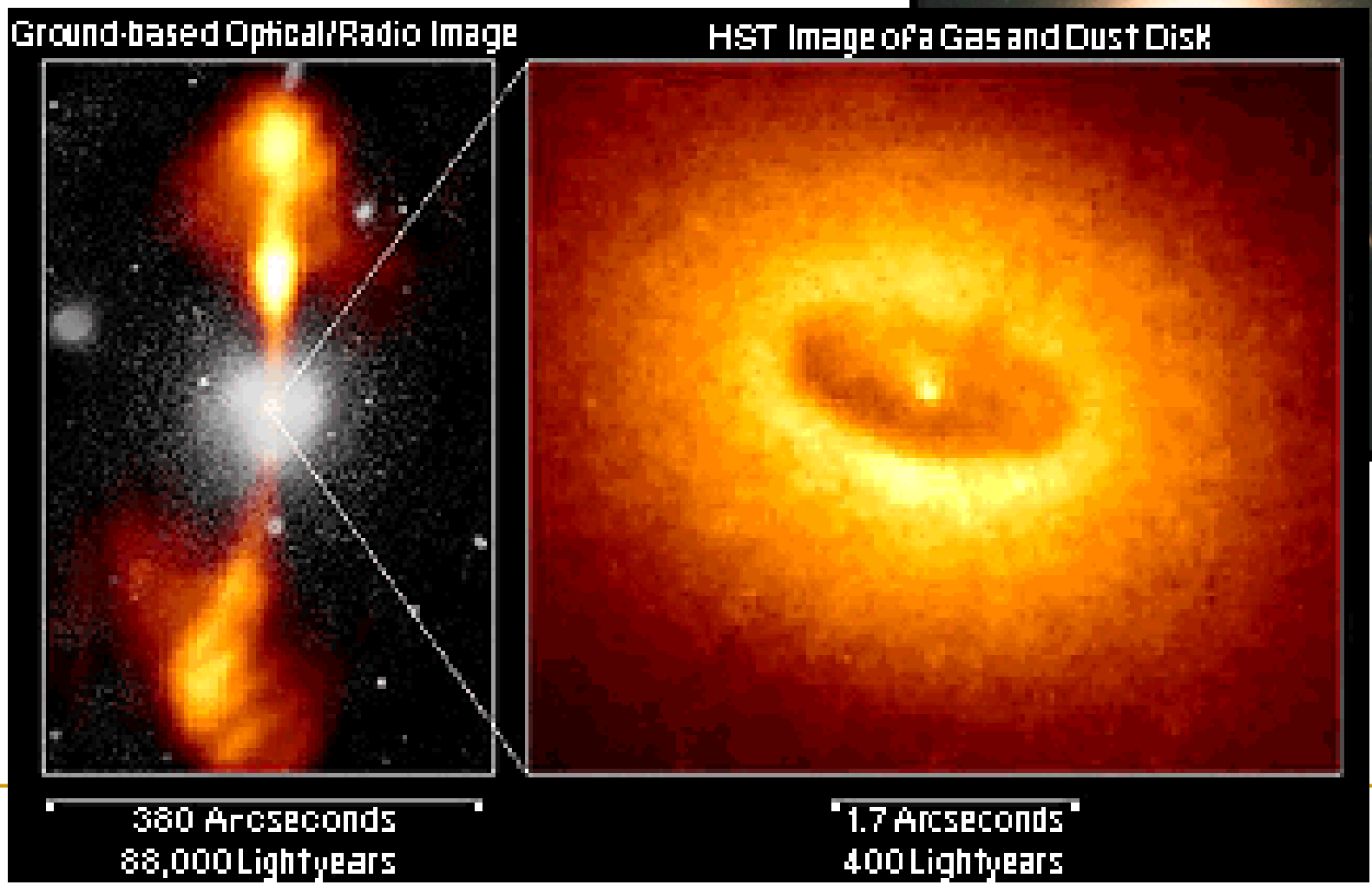
Witnessed this tenth day of December 1974

Kip S. Thorne

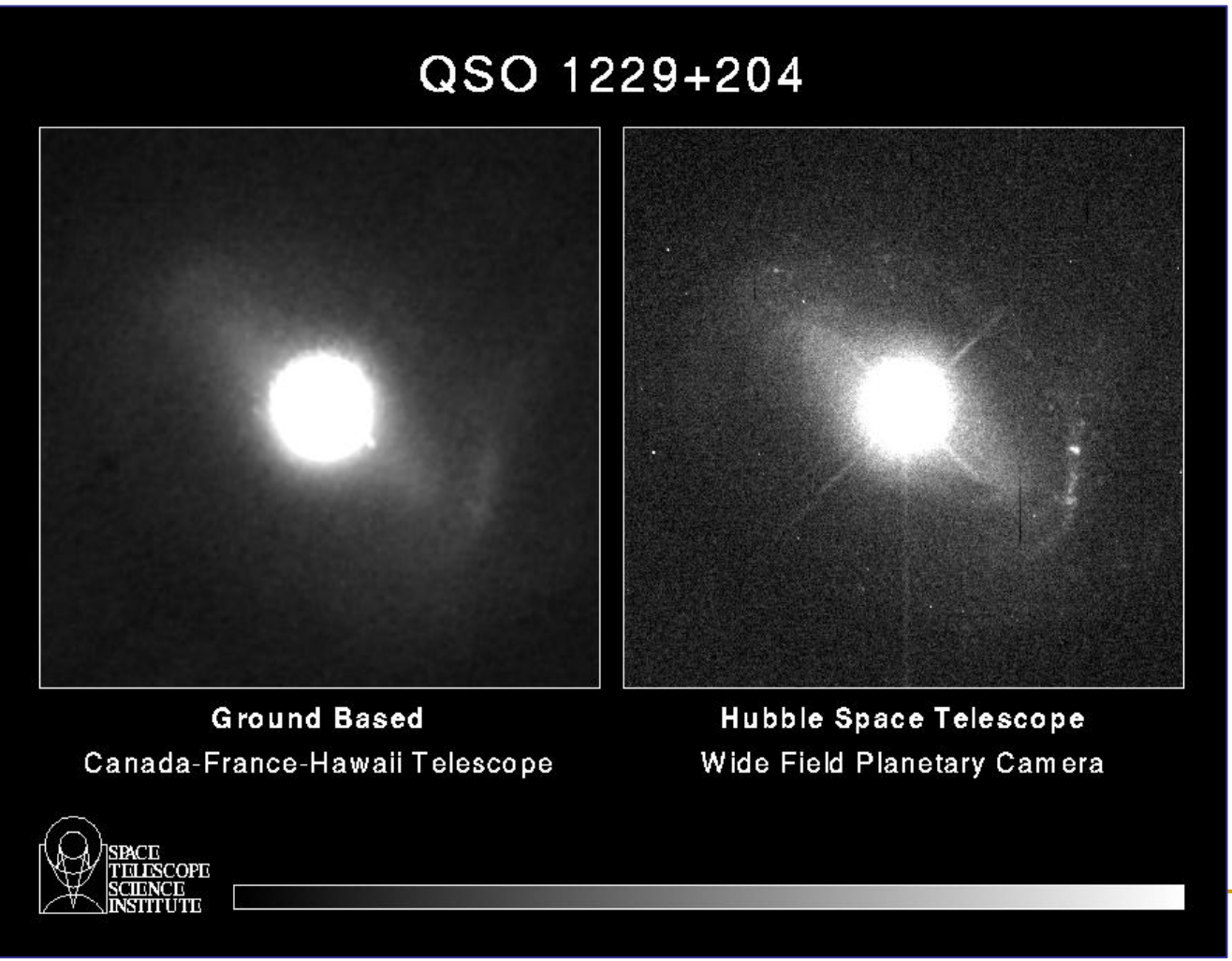
središča galaksij



aktivna galaktična jedra (AGJ)



kvazarji



quasi-stellar radio source (quasar)

- $L \sim 10^{40}$ W
- hitre spremembe izseva

energija?

- jedrsko zlivanje H → He :

$$\Delta E \sim \underline{0.007}\ mc^2$$

- padanje snovi na telo z maso M in radijem r:

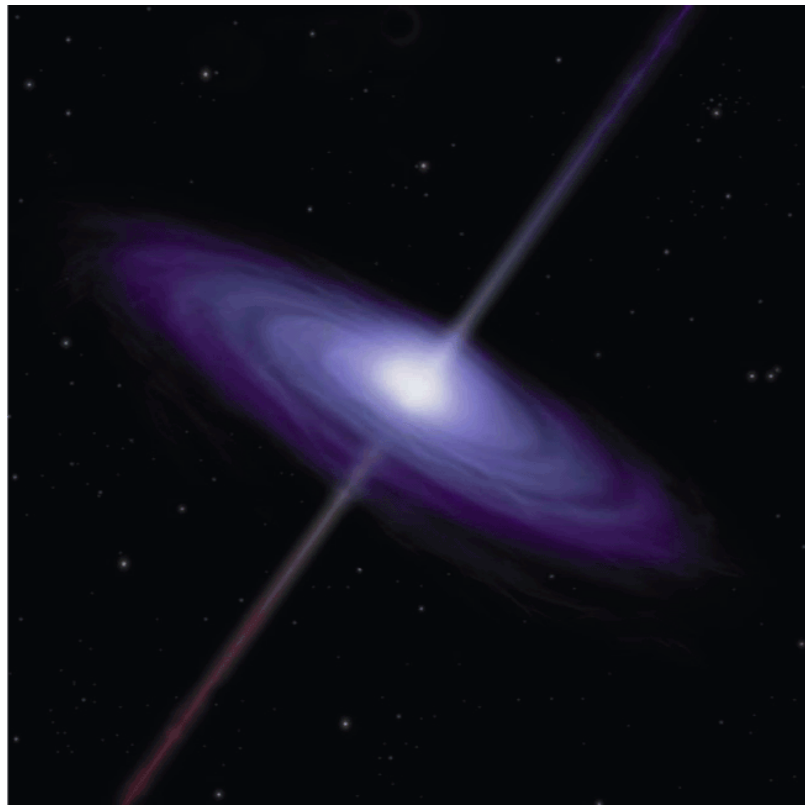
$$\Delta E \approx \frac{GMm}{r}$$

črna luknja $r=r_{Sch}$: $\Delta E \sim \underline{0.15}\ mc^2$

} 20 × !

model AGJ s črno luknjo

model AGJ



10^6 M_{Sonca}< $M_{č.l}$< 10^9 M_{Sonca}

Lastnosti AGJ:

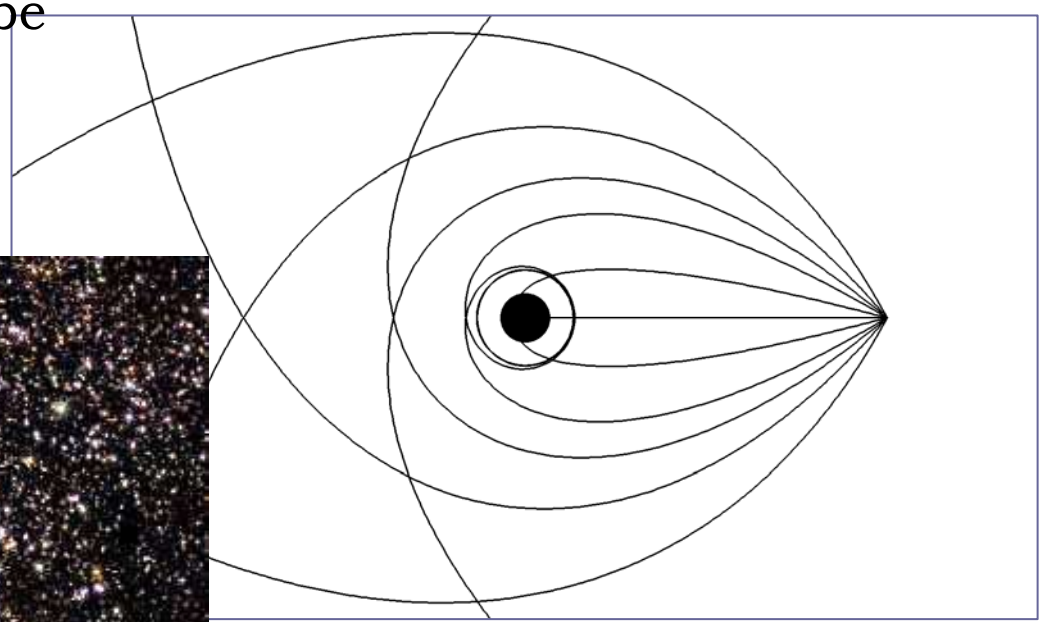
1. L~10^{40} W : 1 M_{Sonca}/mesec

2. majhnost: $M_{č.l}$=10^9 M_{Sonca} $\Rightarrow$ r_{Sch} = 3 sv. ure

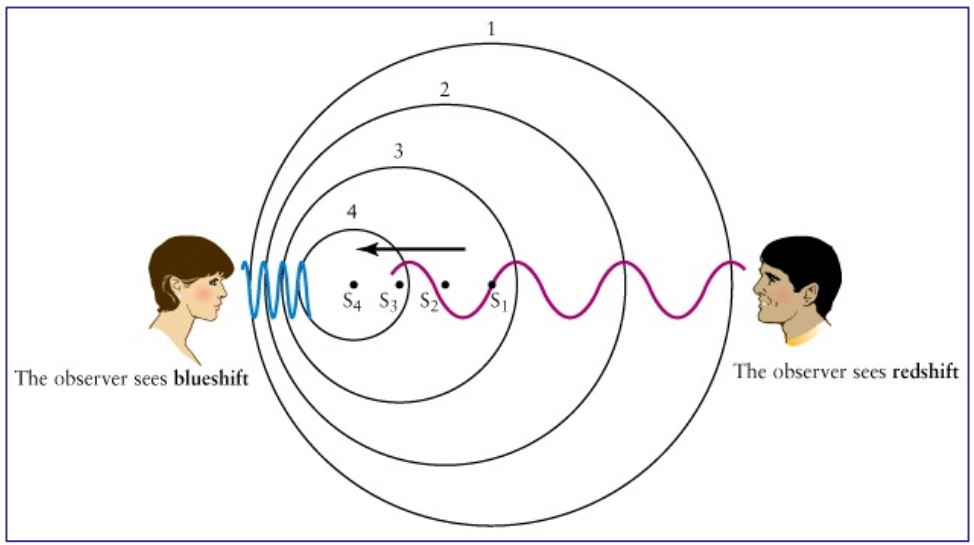
3. $M_{galaksije}$ = 100 milijard M_{Sonca} $\Rightarrow$ 10 milijard let

blizu črne luknje

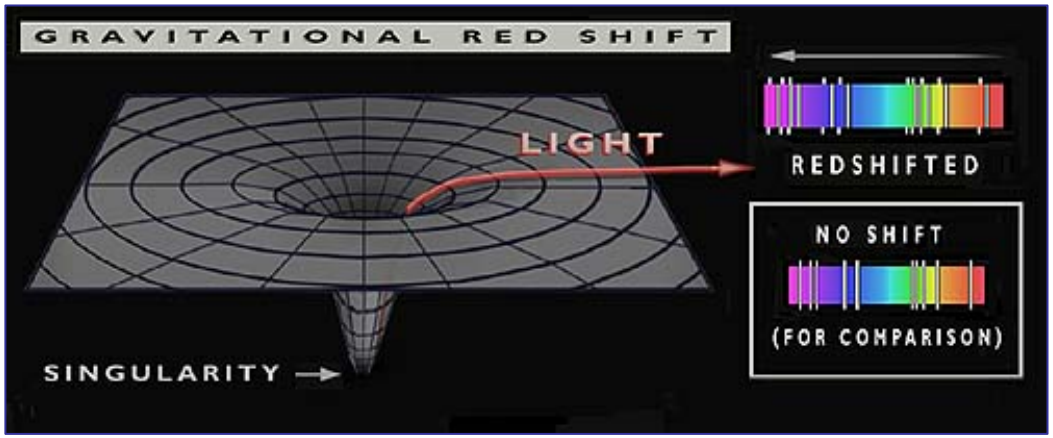
gravitacijsko lečenje svetlobe

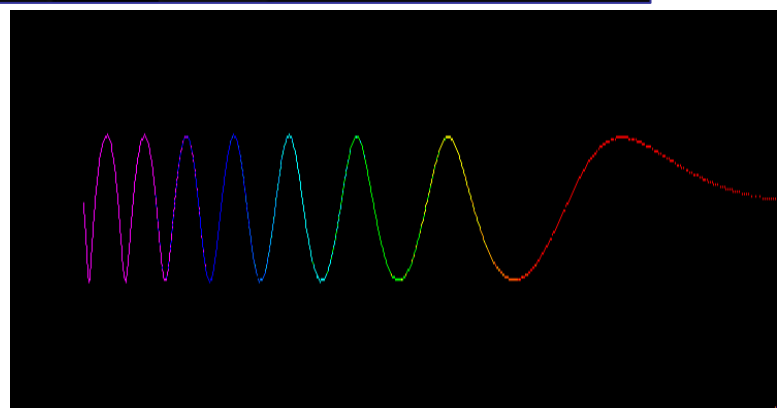


v → c : Dopplerjev pojav



gravitacijski rdeči premik

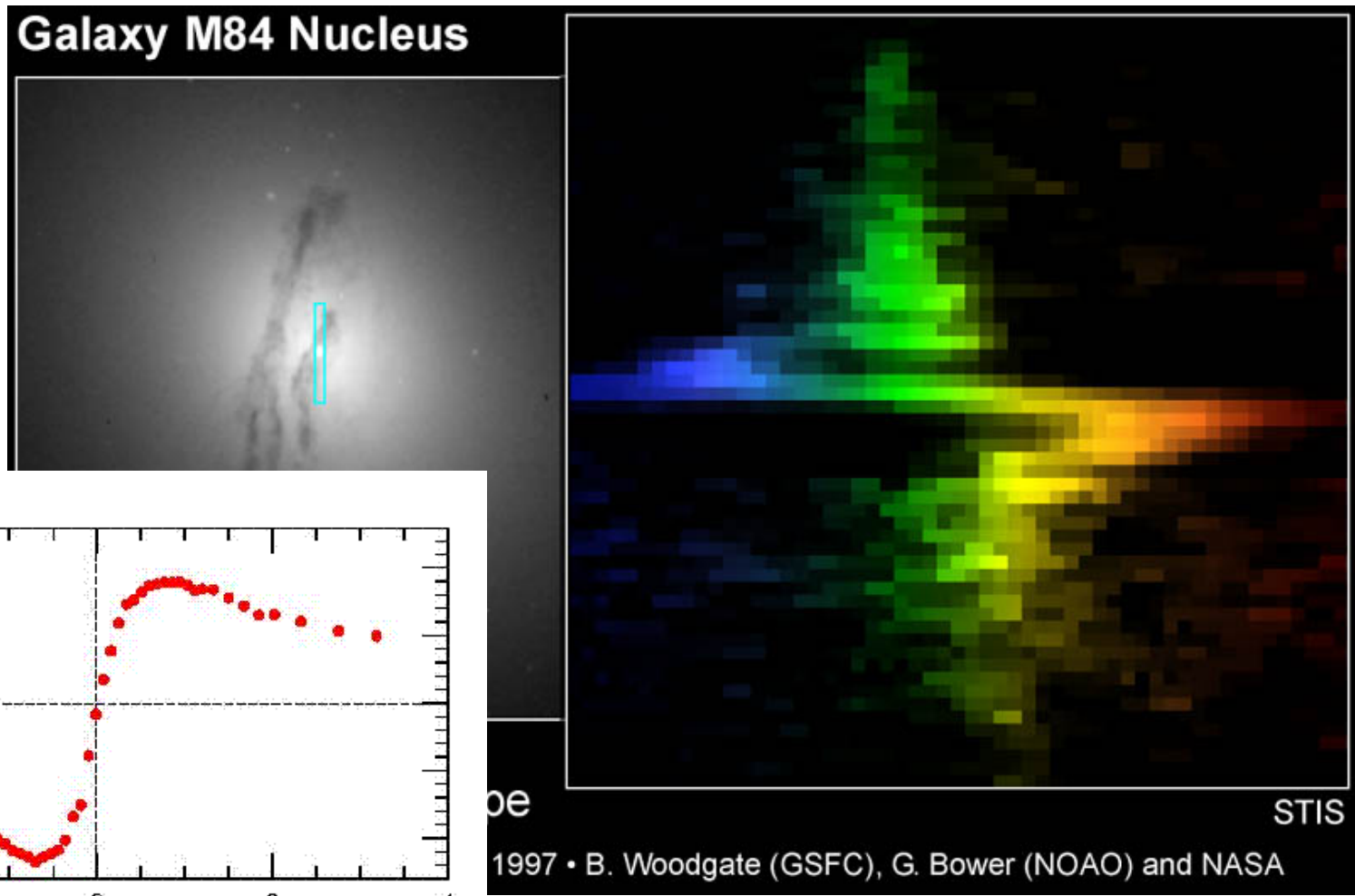


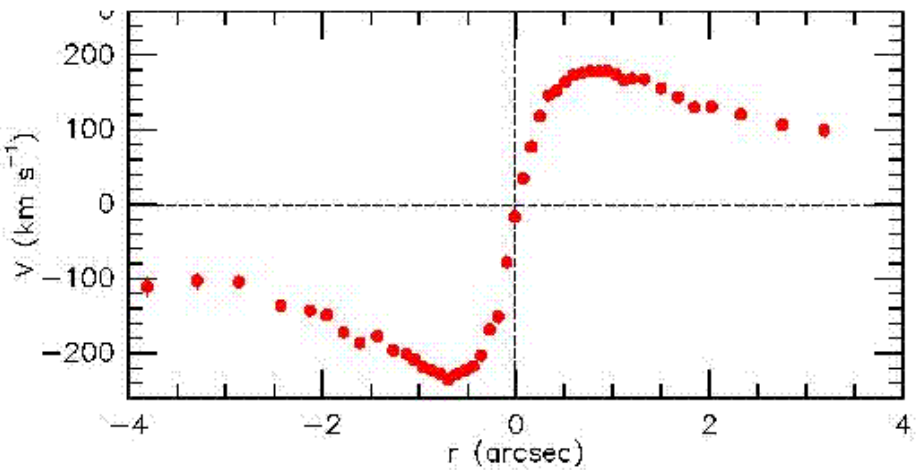


tudi v neaktivnih galaksijah

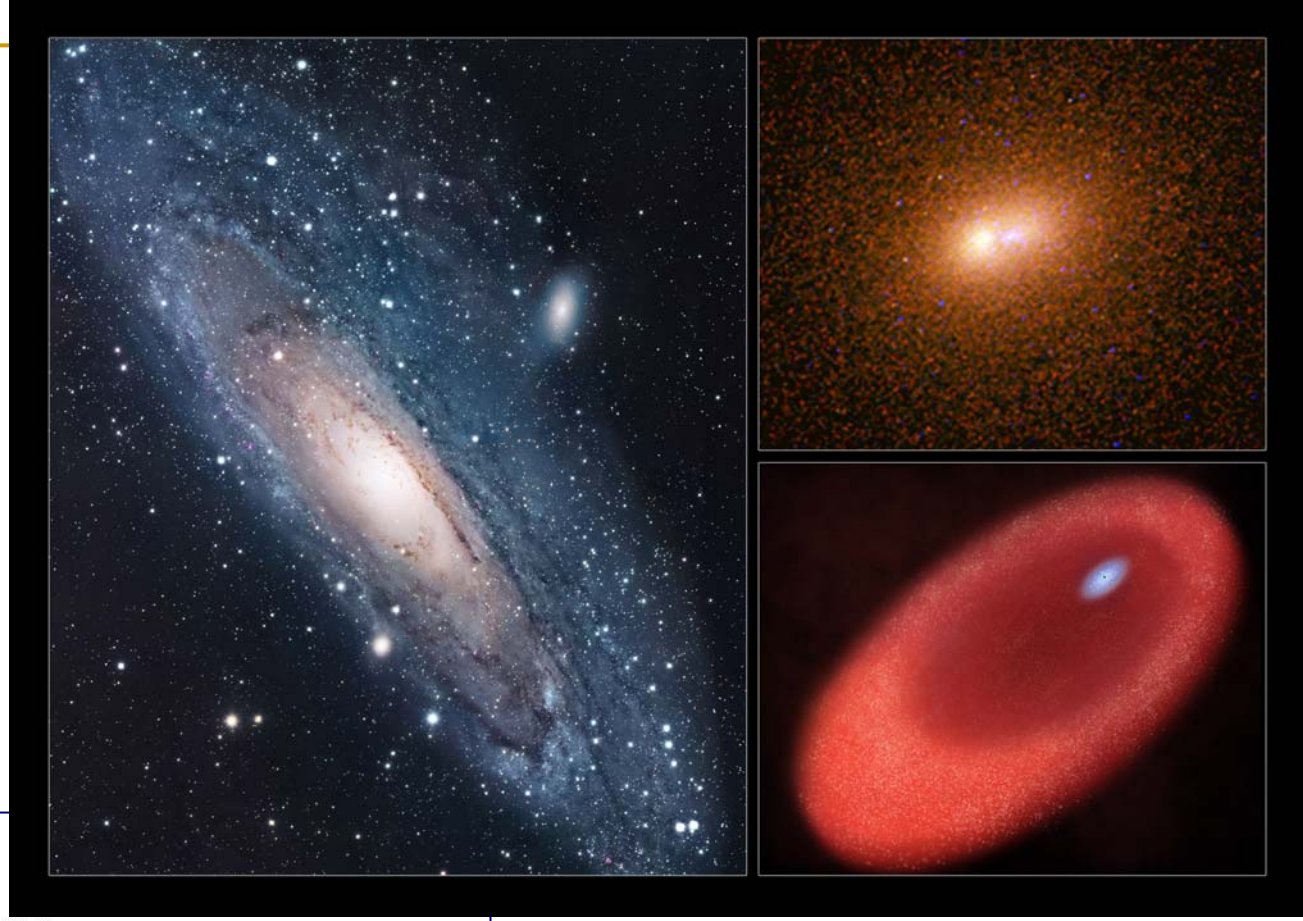
- gibanje zvezd in plina

$$v = \sqrt{\frac{GM}{r}}$$

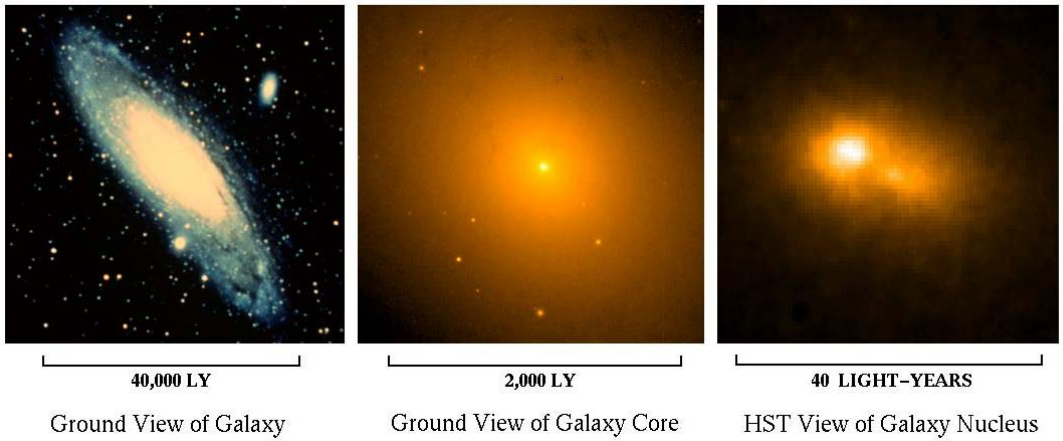




M 31



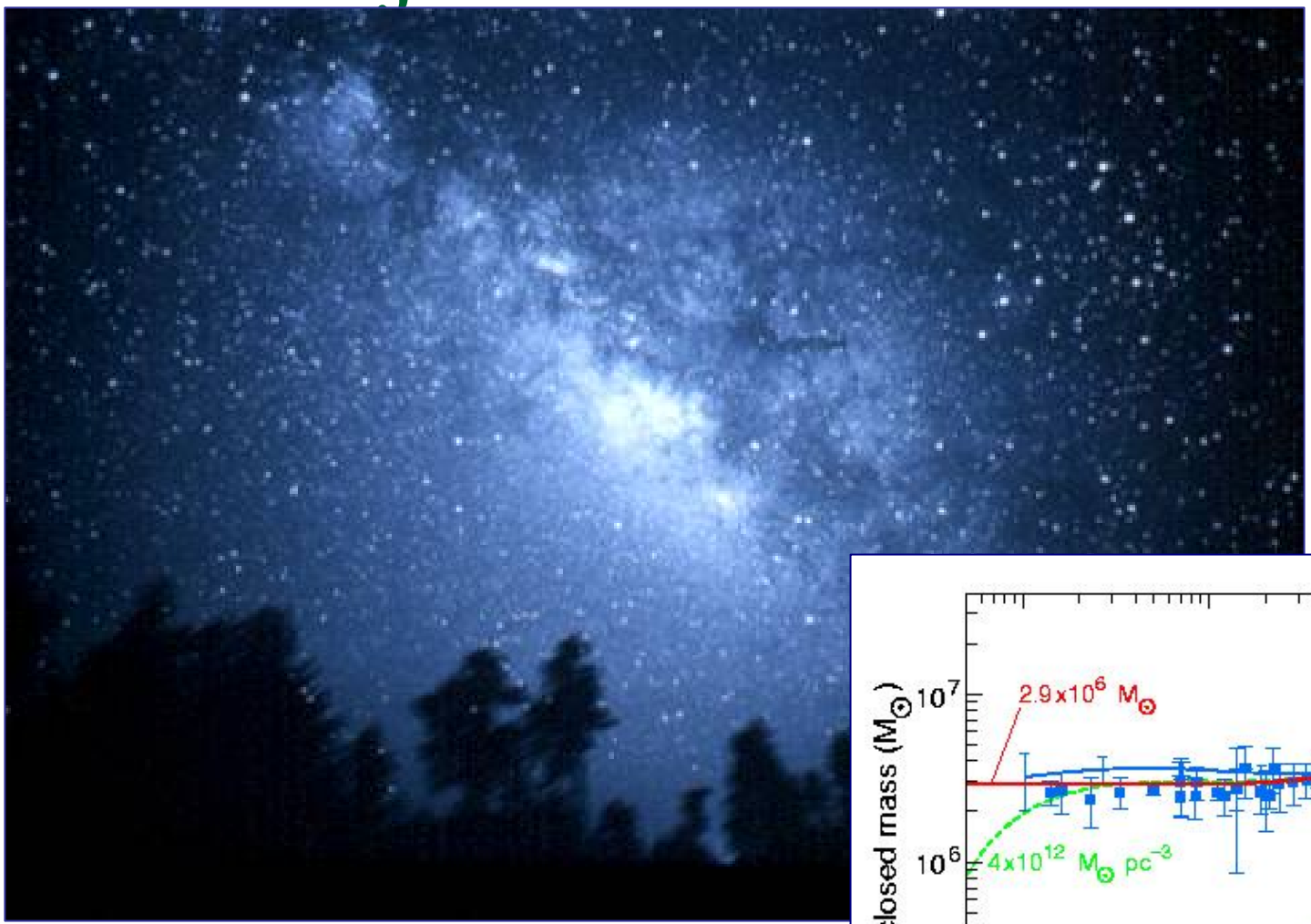
M 31
The Andromeda Galaxy

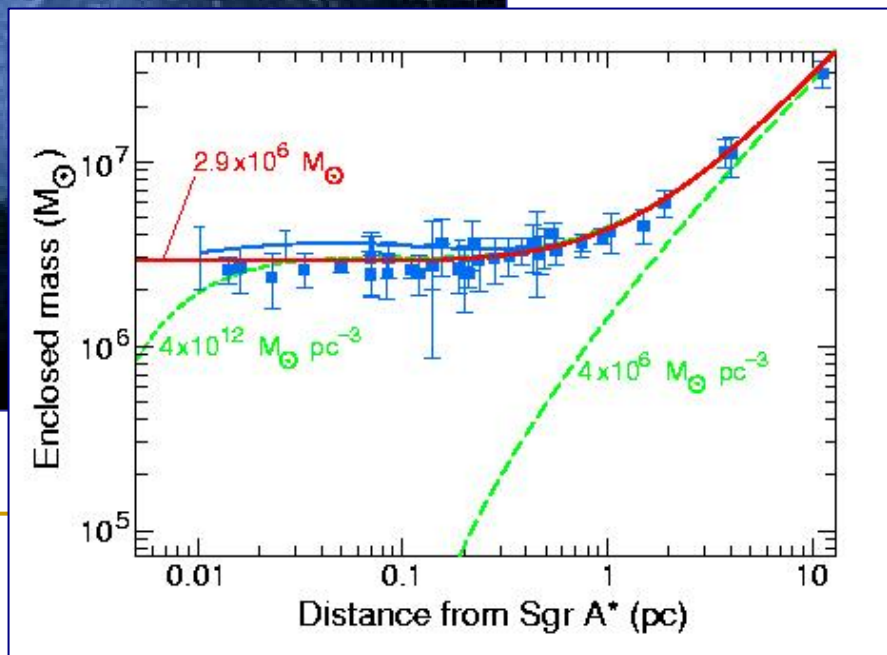


$M_{\bullet} \sim 3 \times 10^7 M_{Sonca}$

3 milijone sv. let

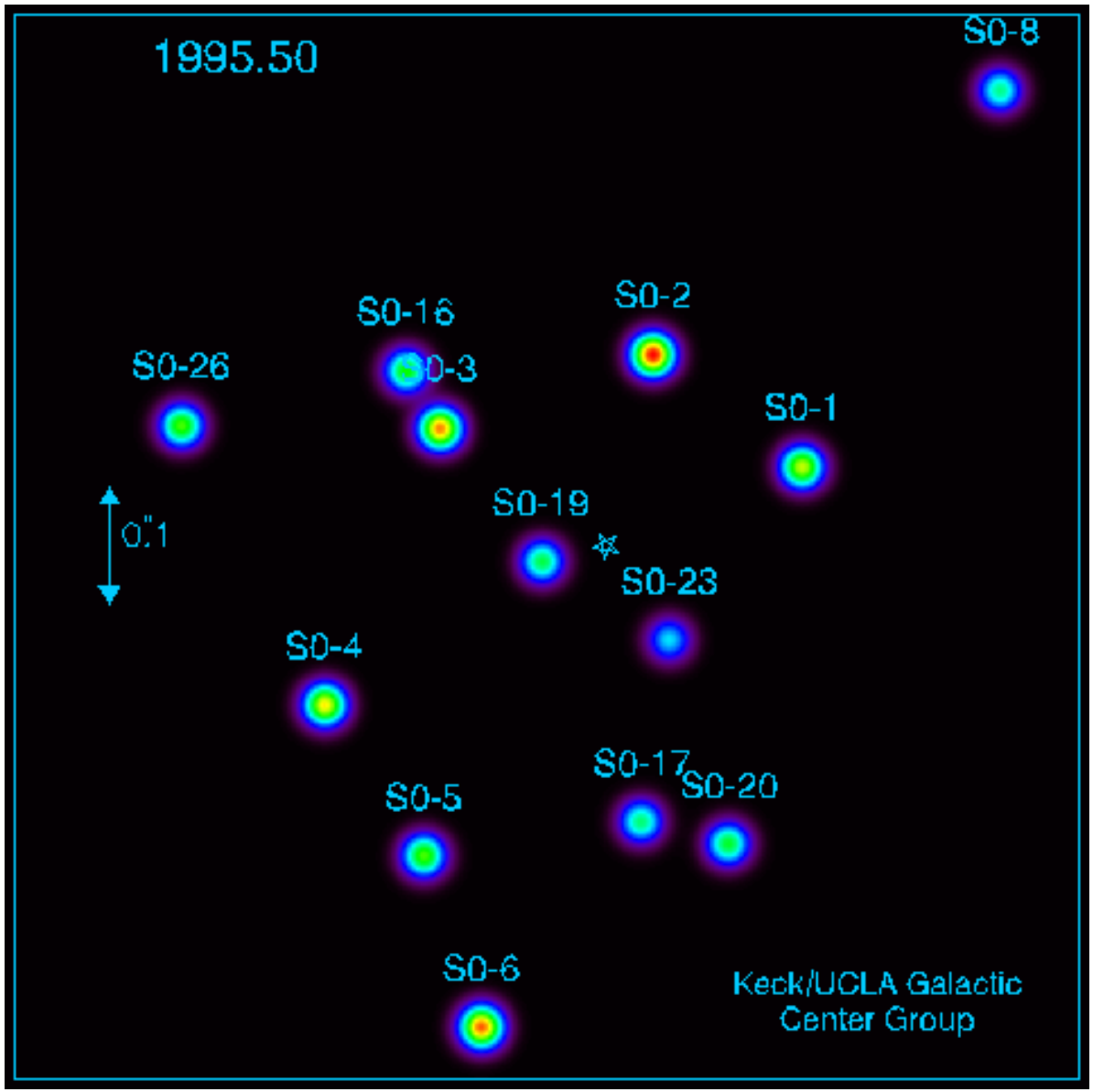
Galaksija





$M_{\bullet} \sim 3 \times 10^6 M_{Sonca}$

30.000 sv. let



zvezda s periodo 15.2 let
in periastronom
17 sv. ur ~ 1500 r_{Sch}

Plimska sila

Sonce, Luna - plima

gravitacijska sila: $F_g = -\frac{G m_1 m_2}{r^2}$

plimska sila: $\propto \frac{m_1 m_2}{r^3}$

plimska sila na horizontu črne luknje:

$$\frac{M}{M^3} \propto \frac{1}{M^2}$$

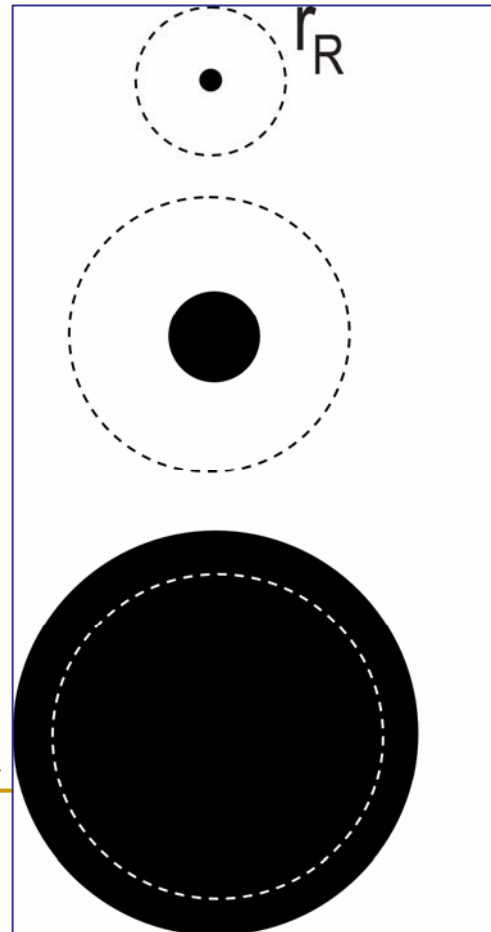
Kaj se zgodi z astronavtom?

odvisno od velikosti črne luknje:

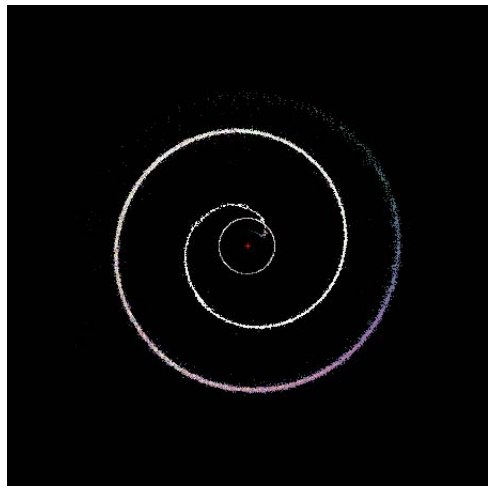
$M_{č.l.} < 10.000\ M_{Sonca}$

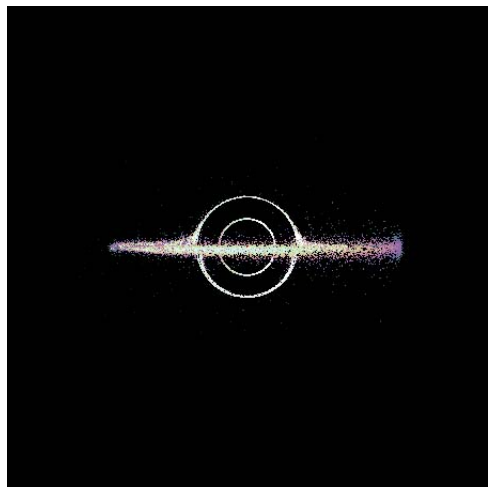
$M_{č.l.} \sim$ milijon M_{Sonca}

$M_{č.l.} > 100$ milijonov M_{Sonca}



Kaj se zgodi z zvezdo?





“vmesne” črne luknje

- masa :

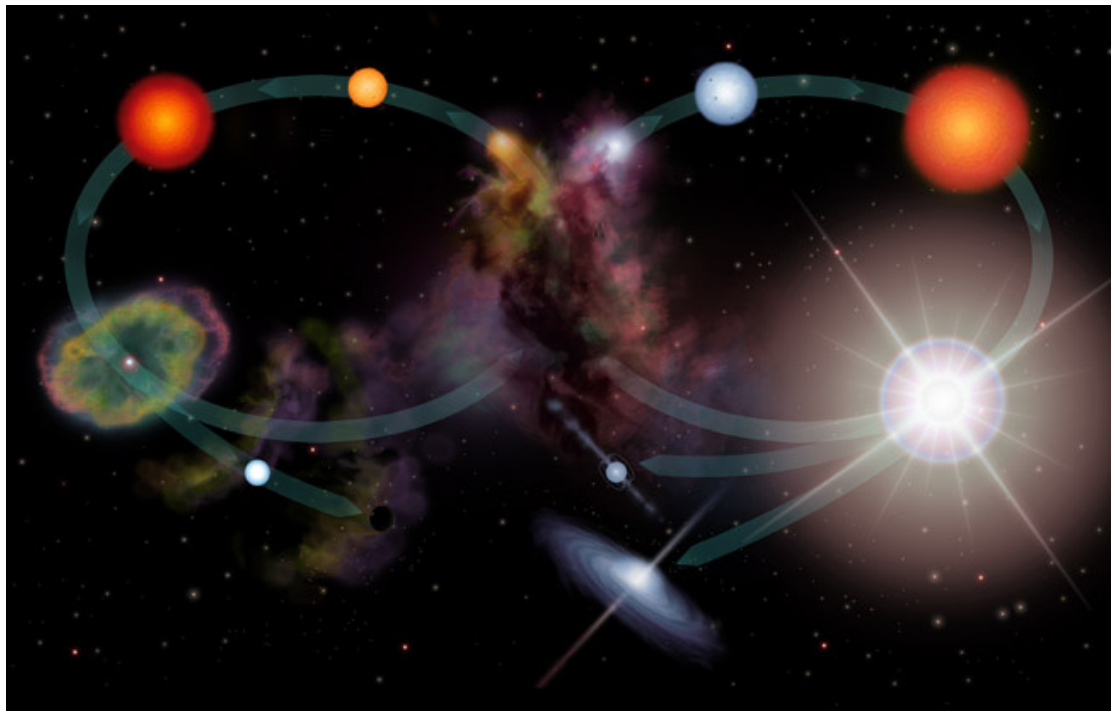
$$100\ M_{Sonca} < M_{č.l.} < 100.000\ M_{Sonca}$$

izven središč galaksij, nastajajo v gostih zvezdnih kopicah - ?

Nastanek masivnih črnih lukenj v središčih galaksij

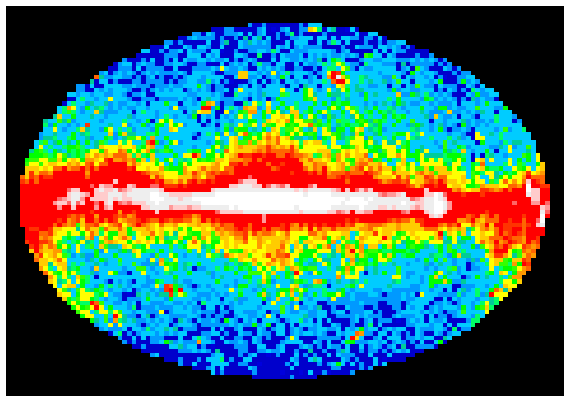
- nastanejo skupaj z galaksijo – že velike
- nastanejo kasneje – hitro rastejo
- trk dveh galaksij

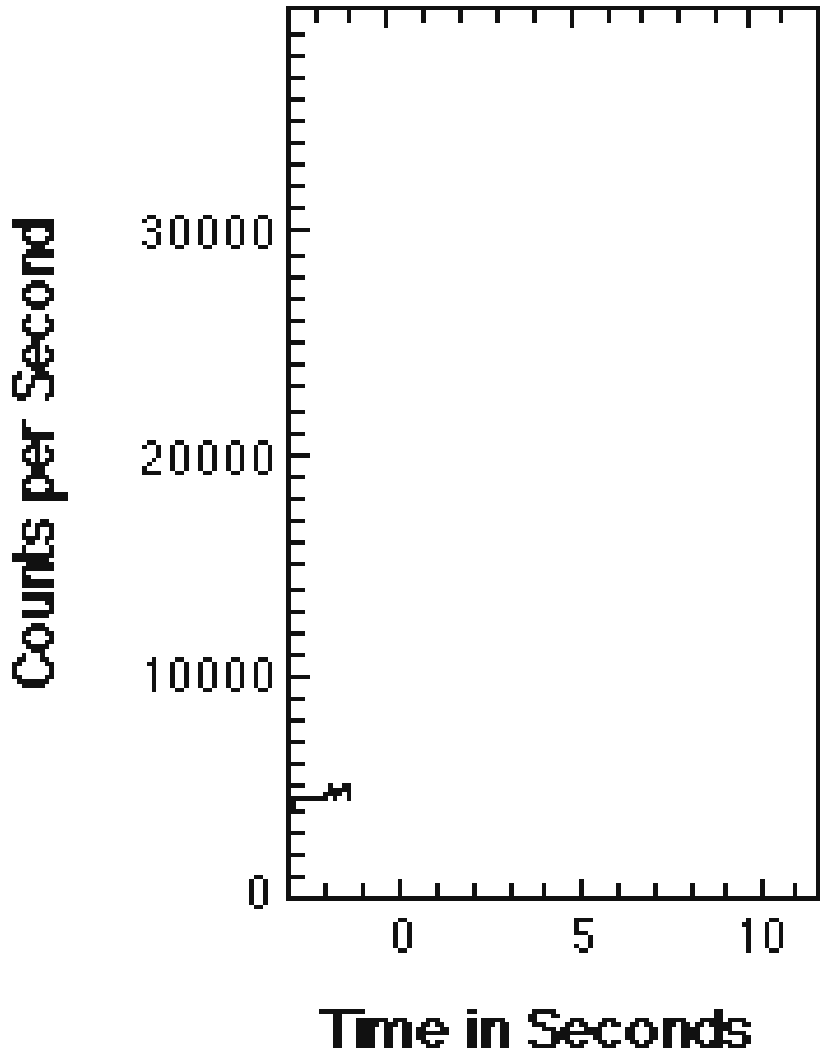
Nastanek majhne črne luknje

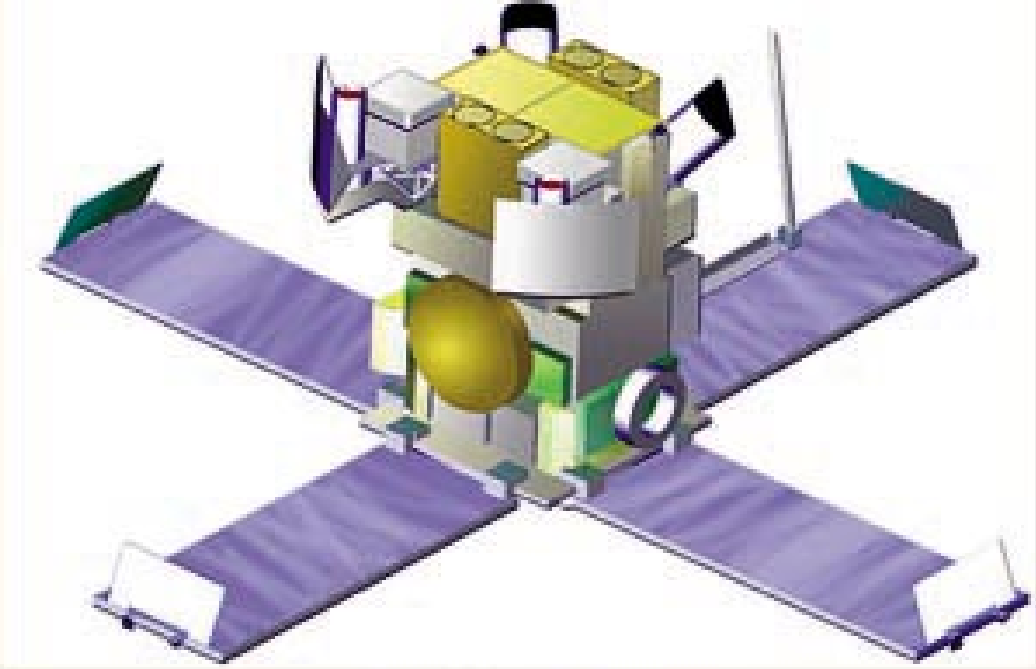


- končna faza v življenju zvezd, zvezda eksplodira, jedro → črno luknjo
- eksplozije supernov
- bolj pogosto ~1/dan – izbruhi žarkov gama!

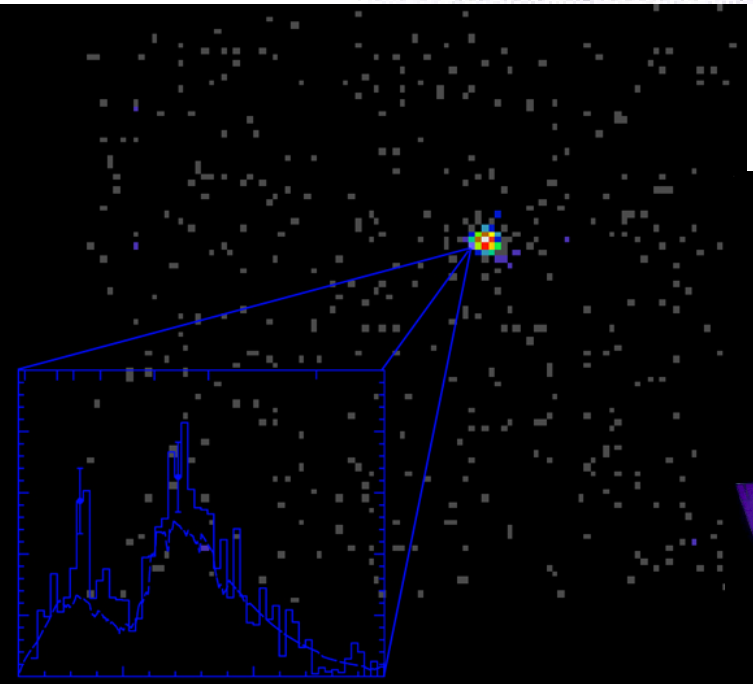
Izbruhi Žarkov gama



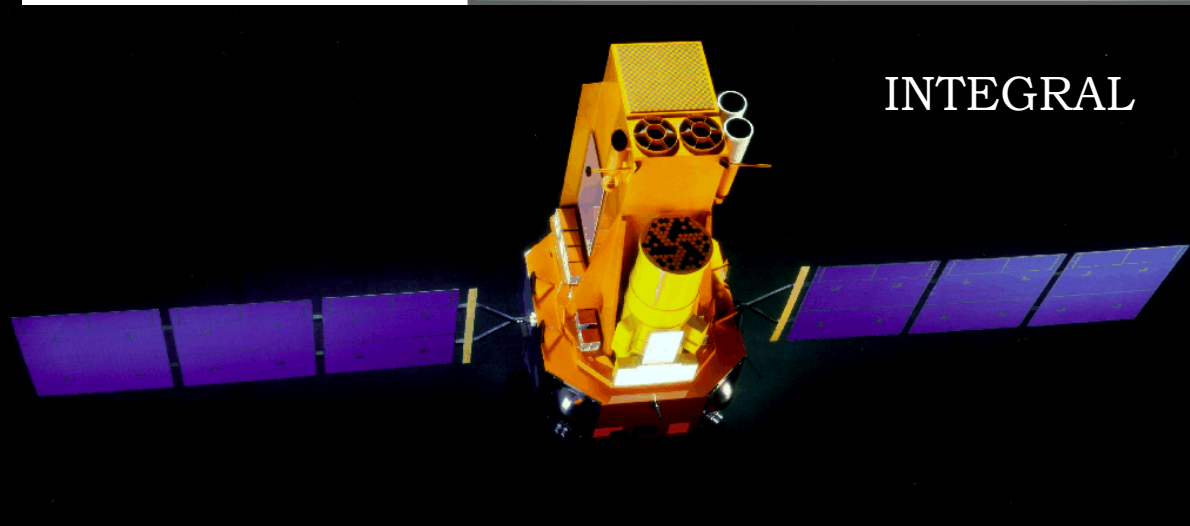




HETE-2 Satellite

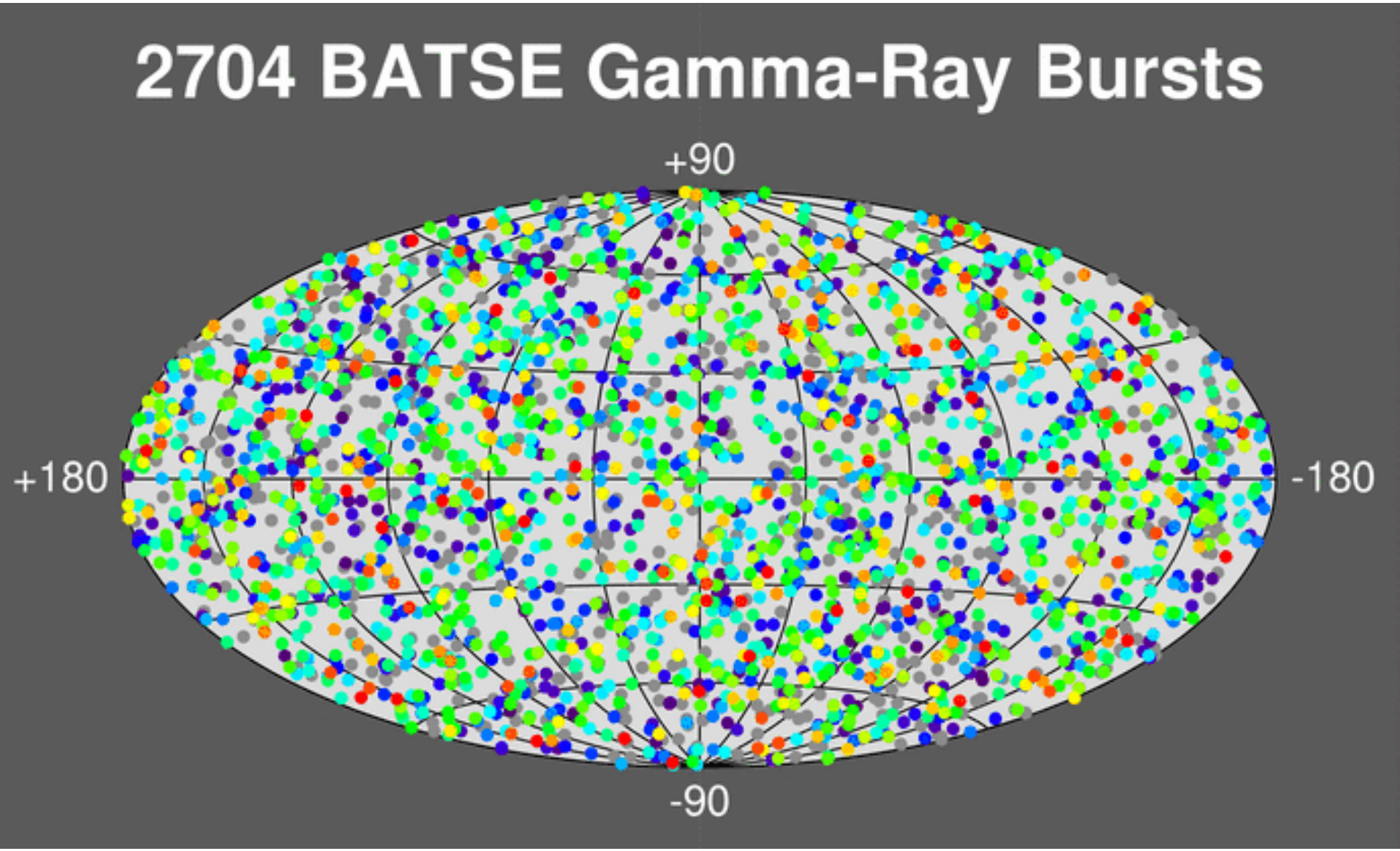


Swift



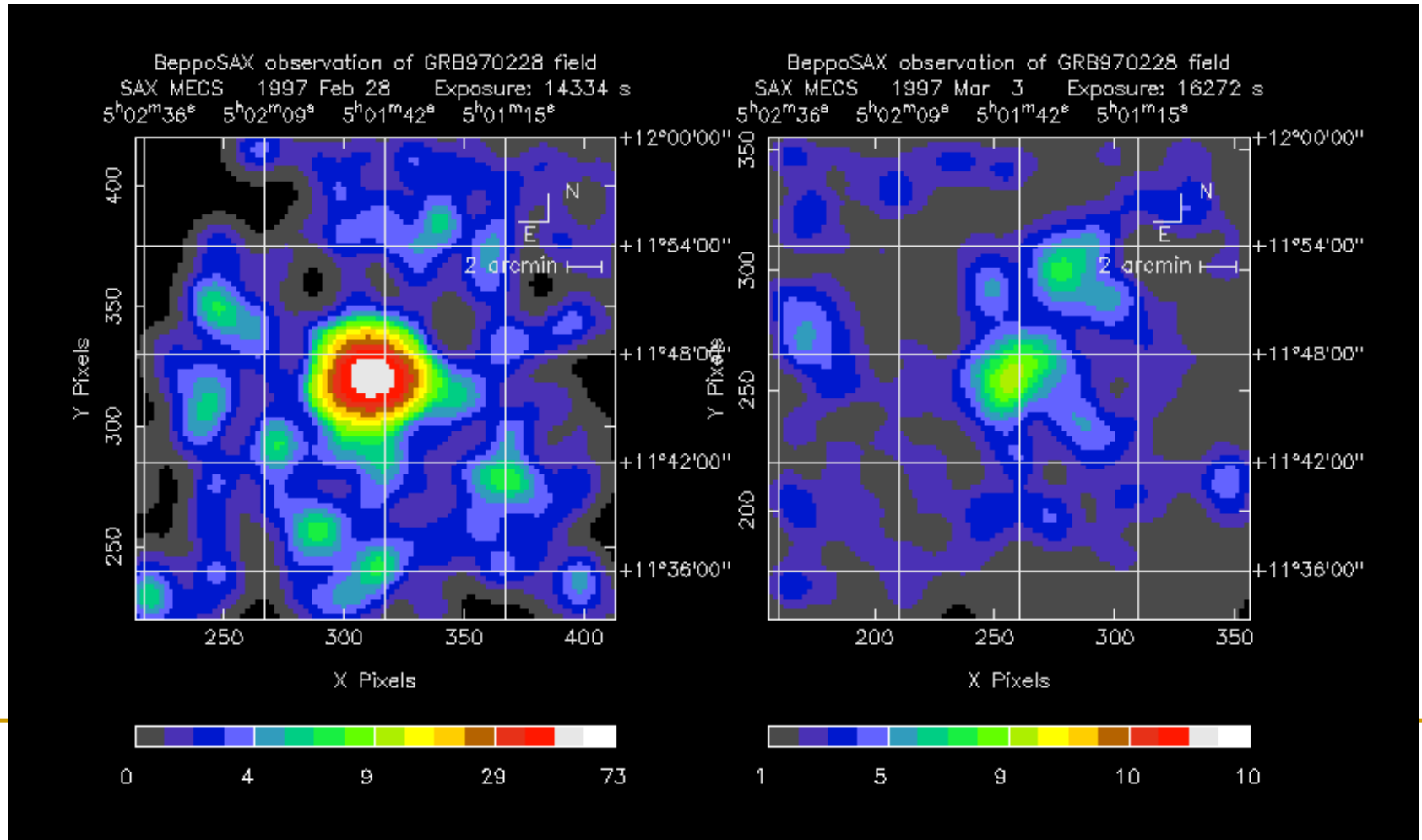
INTEGRAL

porazdelitev po nebu

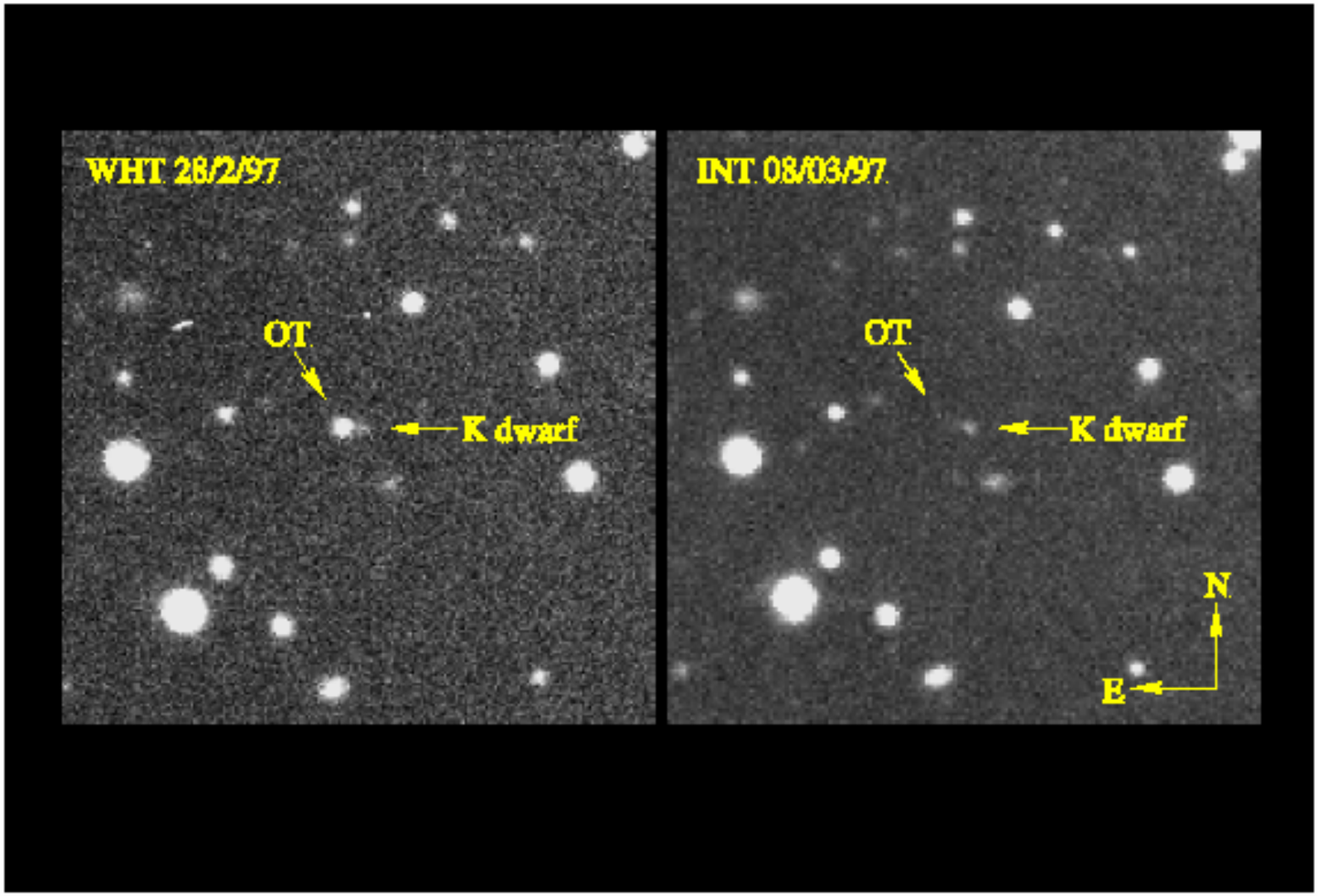


po 30. letih: Beppo-SAX

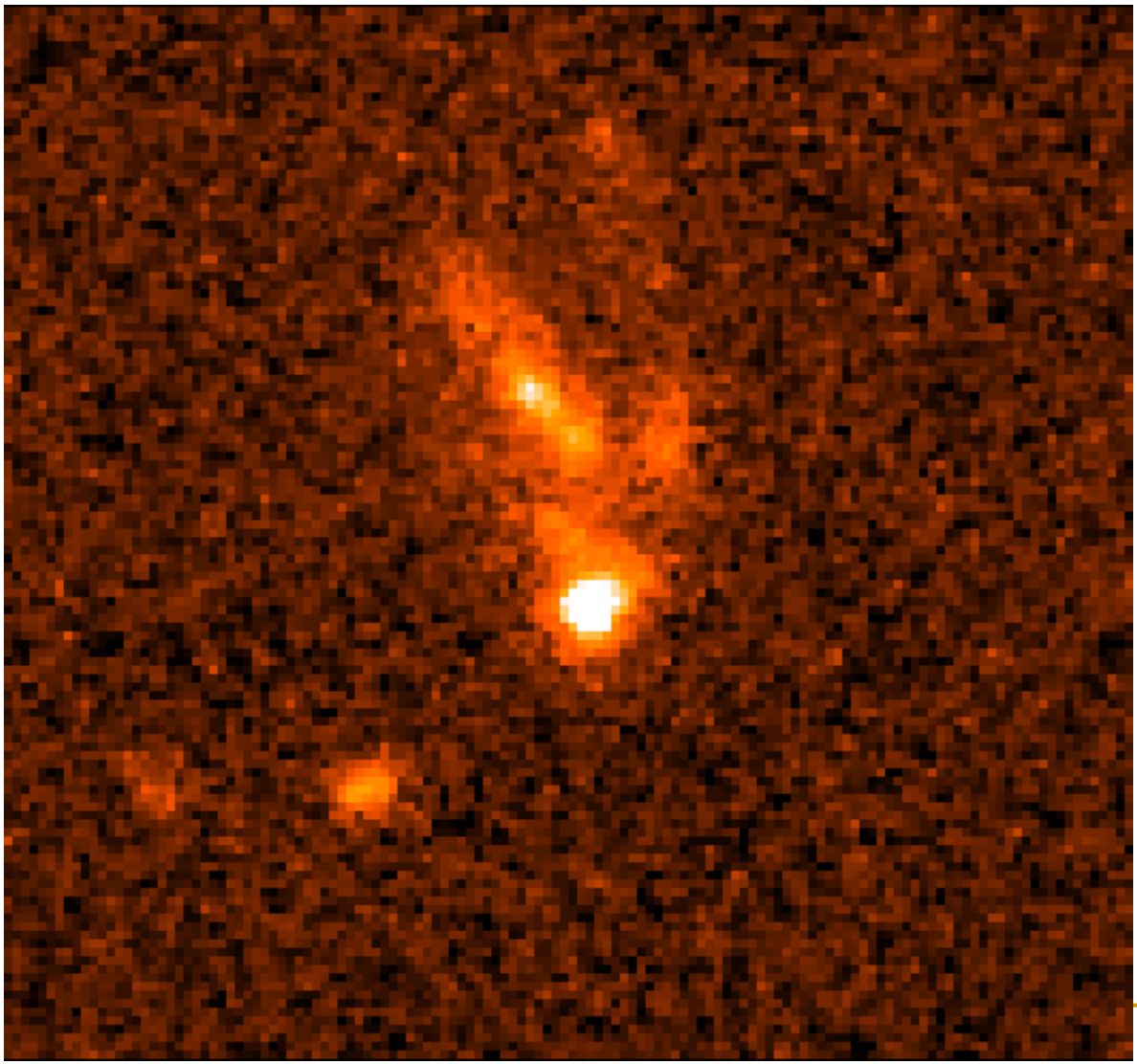
- 1997 – odkritje afterglow-ov dolgih GRB-jev
- GRB 970228: v rentgentskih žarkih:



v vidni svetlobi



v galaksijah



-izmerijo z galaksije
-kozmološke
oddaljenosti
-rekord z=6.3

-oddaljenost $\Longrightarrow$ E

E

$\sim M_{Sonca}c^2$ v času

0.01 do 100 s!

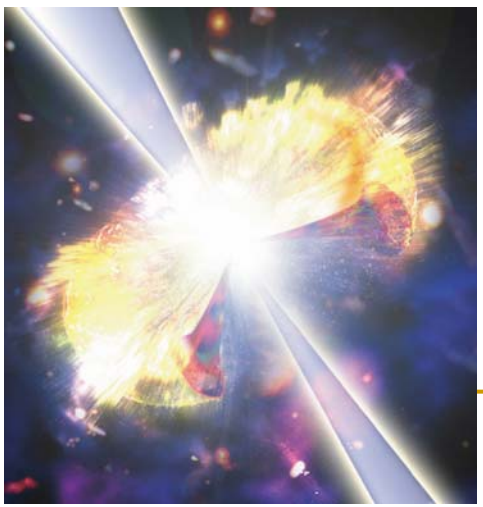
$\sim 10^{47}$

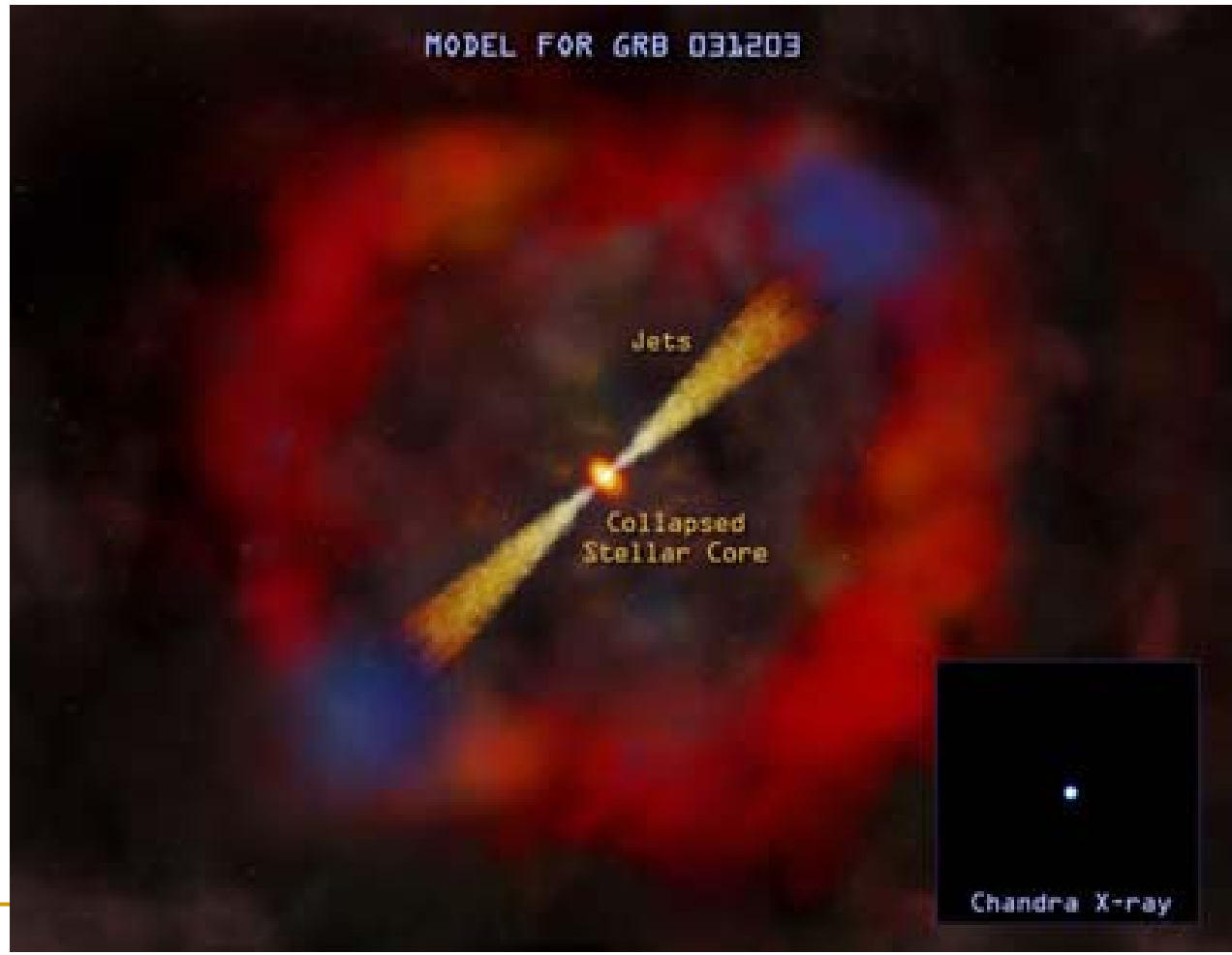
dolgi GRB-ji

- $t_\gamma > 2$ s

supernova

grb



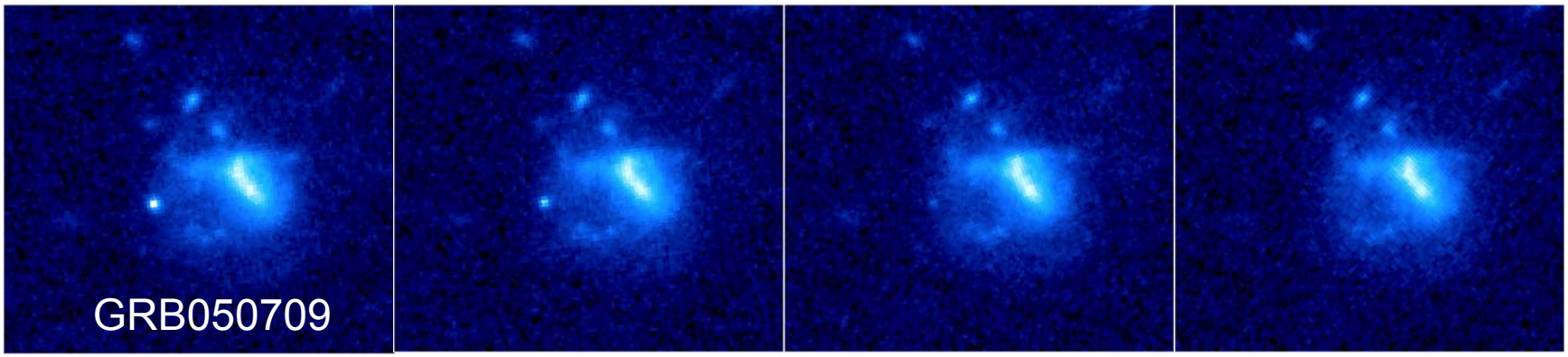


>10 milijard sv. let daleč

kratki GRB-ji

- $t_\gamma < 2$ s

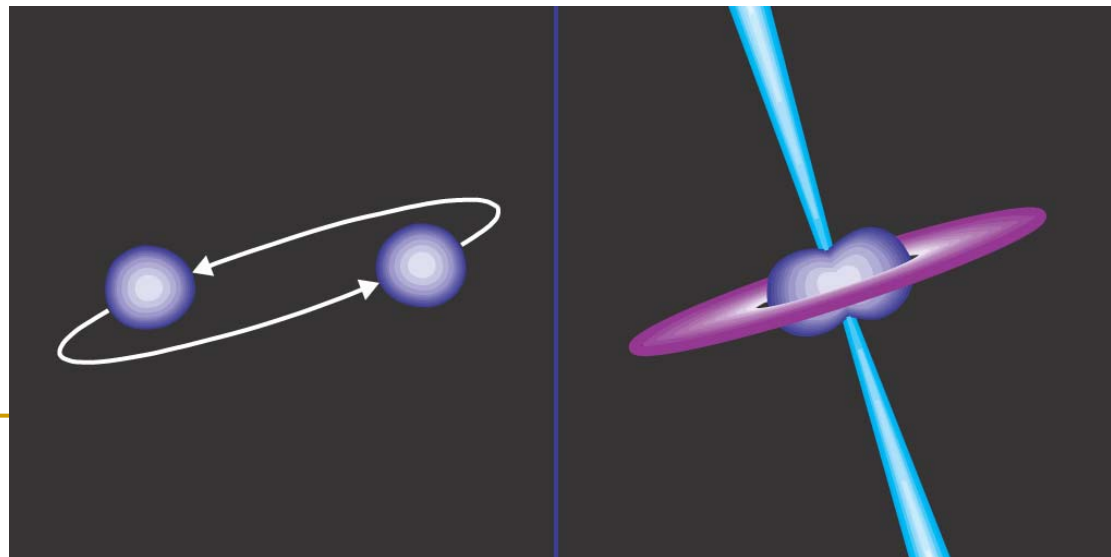
HST, 2 milijardi svetlobnih let daleč

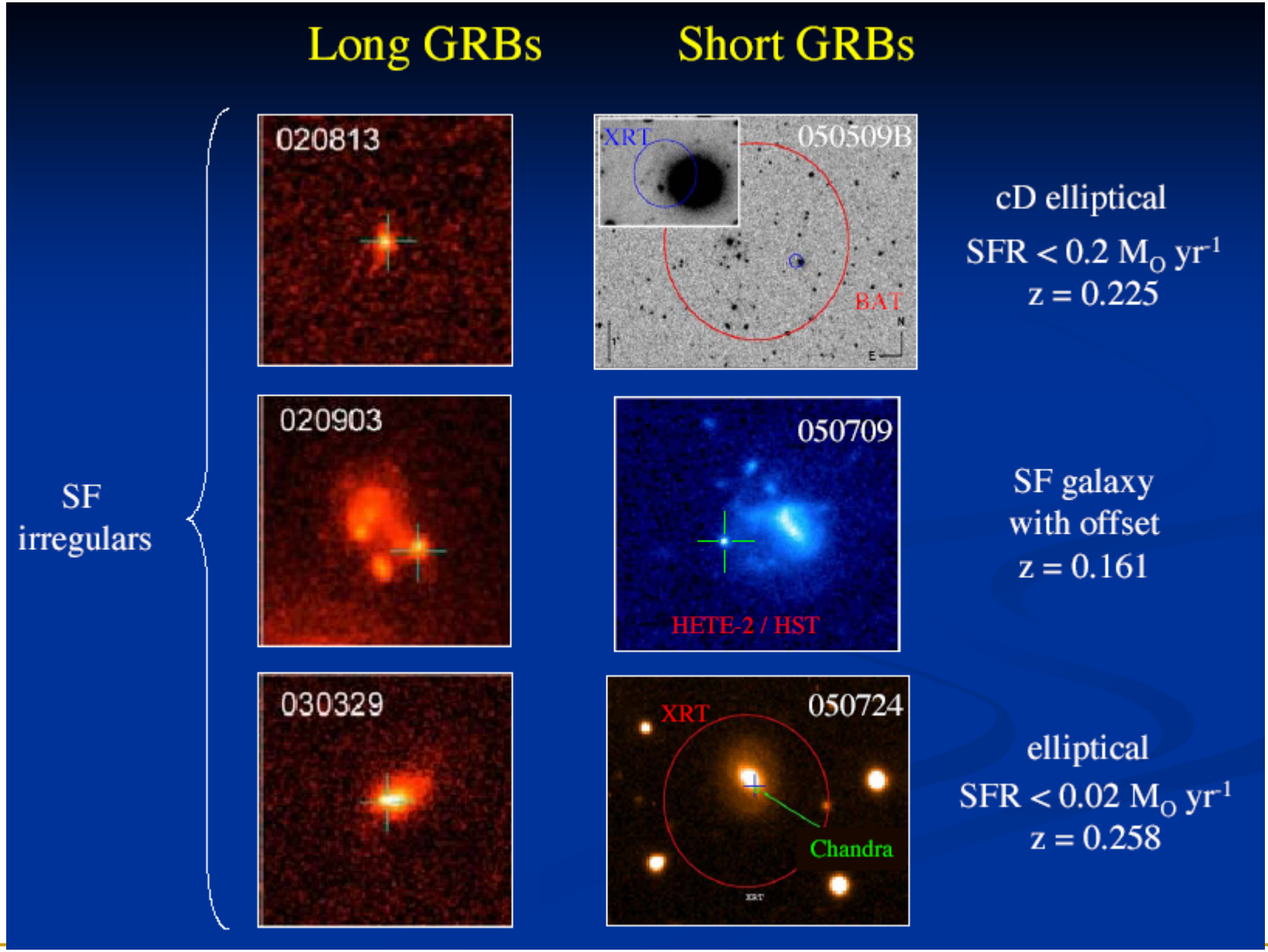


- mergerji

mergerji-ns

mergerji- bh




Long GRBs
Short GRBs
SF irregulars
020813
XRT
050509B
BAT
cD elliptical
SFR < 0.2 M$_O$ yr^{-1}
z = 0.225
020903
050709
HETE-2 / HST
SF galaxy with offset
z = 0.161
030329
XRT
050724
Chandra
elliptical
SFR < 0.02 M$_O$ yr^{-1}
z = 0.258


Nov. 20, 2004

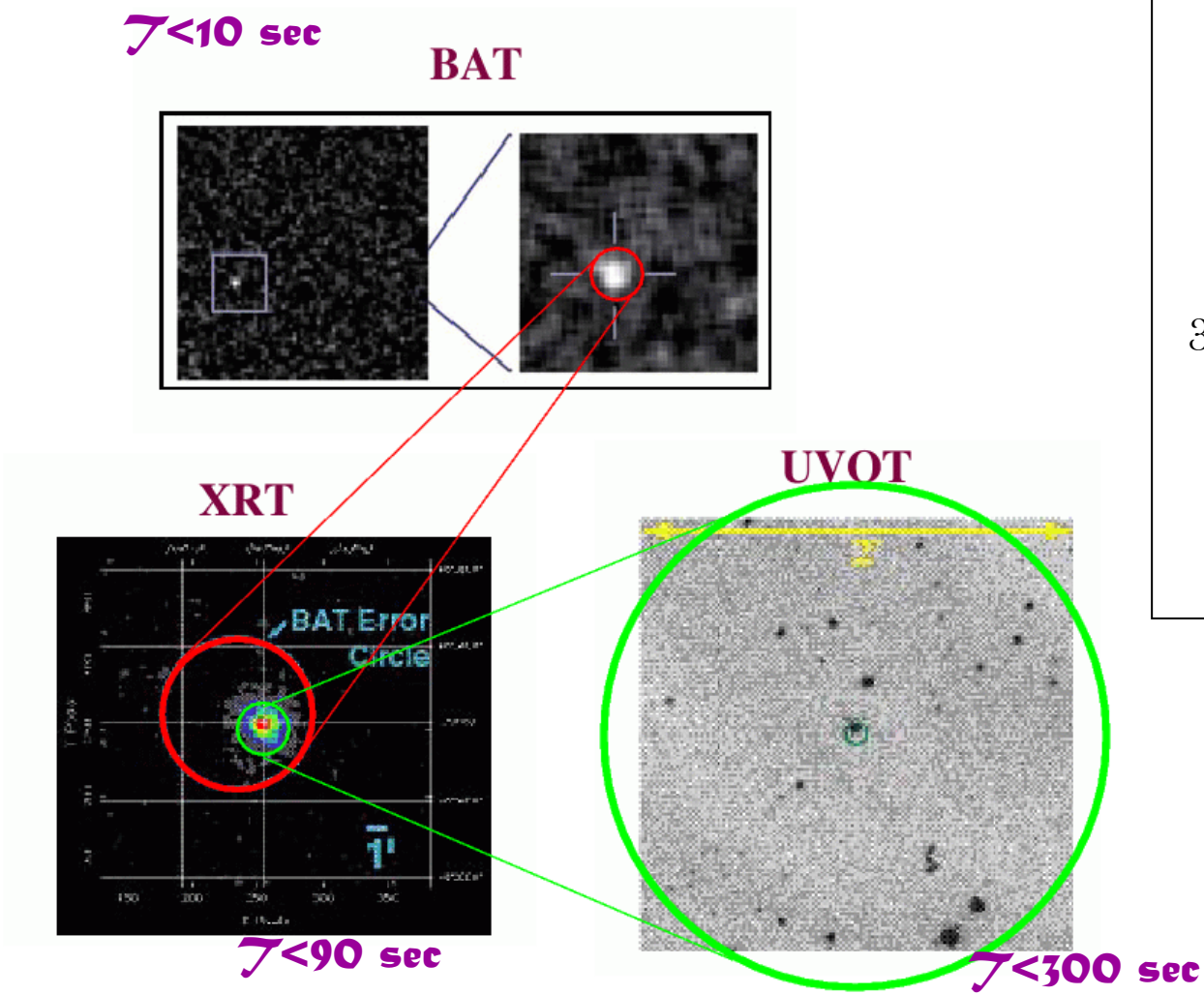
Swift

NASA
izstreljen konec 2004,
začetek 2005

detektorji:
-BAT - γ
-XRT - rentgentski
-UVOT – UV in optični

hitro in točno določen položaj!

Swift procedura



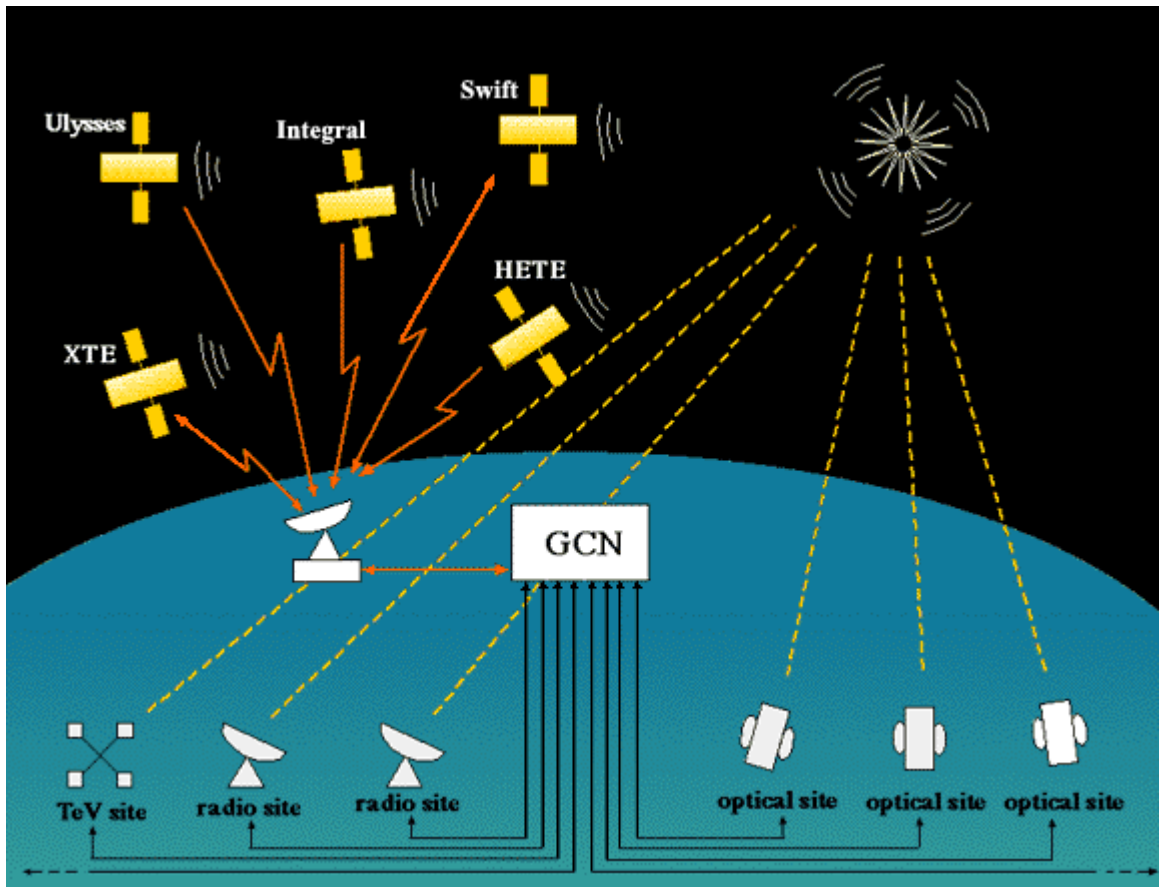
1. BAT triggers on GRB and calculates position to within 4 arcmin
2. Spacecraft autonomously slews to GRB position in 20-70 sec.
3. XRT determines position to within ~5 arcsec.
4. UVOT images field and transmit finding chart to ground

GCN

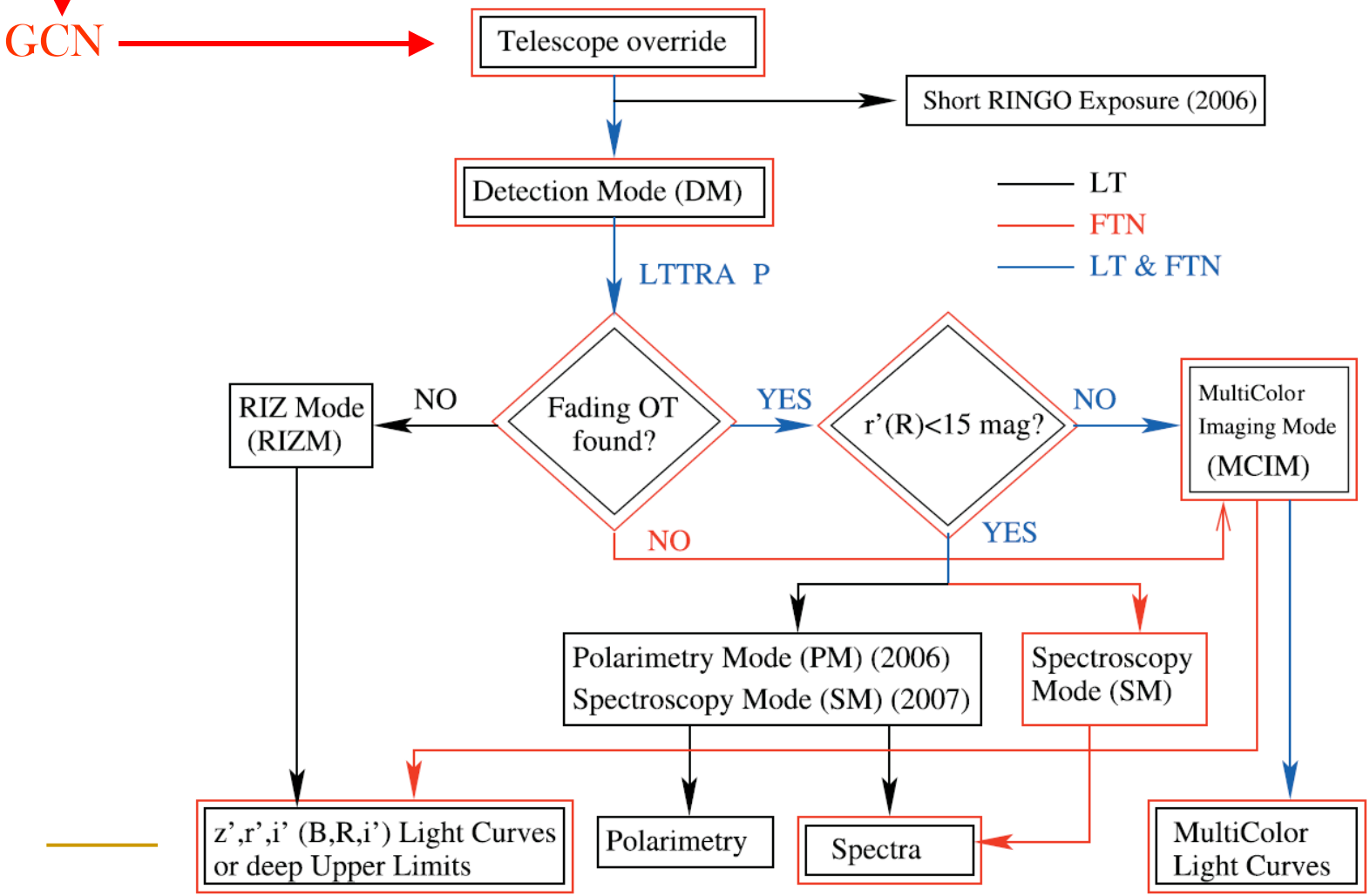
Gamma ray bursts Coordinates Network

http://gcn.gsfc.nasa.gov/

sporočilo na e-mail ali SMS!



opazovalna strategija



LT, La Palma, Kanarski otoki

FTN, Mauna Kea, Hawaii

FTS, Siding Spring, Avstralija

za konec...

Črne luknje :

- obstajajo – v dvojnih sistemih zvezd, v središčih galaksij
- Čeprav "Črne", so "najsvetlejše" – AGJ in GRB

Konec

- mini črne luknje:

  $M_{č.l.}$ ~10^{12} kg < 3 M_{Sonca} nastajale naj bi v začetku vesolja

- izhlapevanje – Hawkingovo sevanje

$$T = \frac{hc^3}{16\pi^2 kGM} \qquad S = \frac{8\pi^2 kGM^2}{hc} \propto A$$

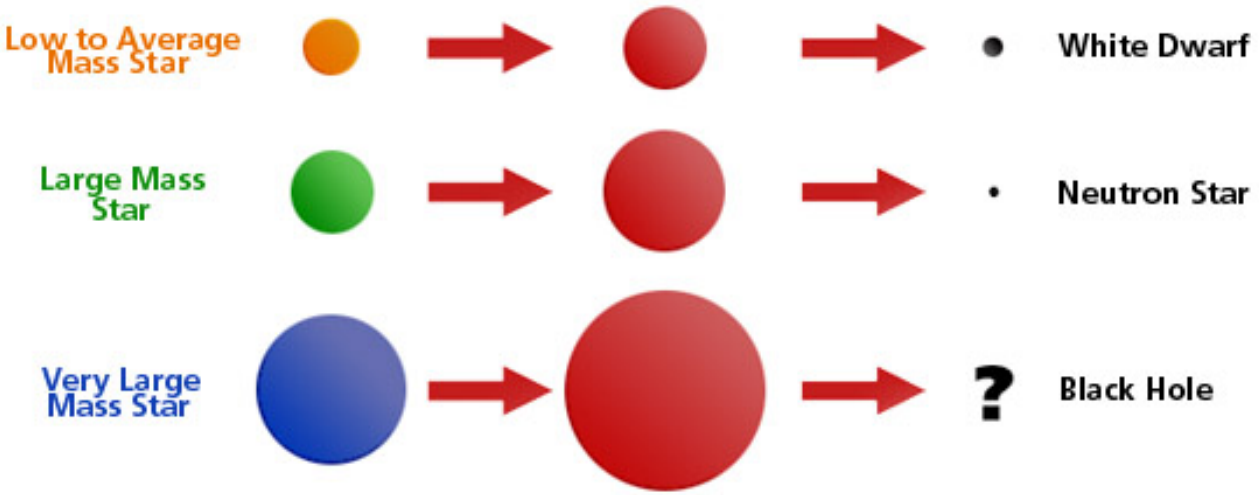
$$t = \frac{10240\pi^2 G^2 M^3}{hc^4}$$

$M_{č.l.}$< 10^{11} kg (gora) izhlapi v ~ starost vesolja

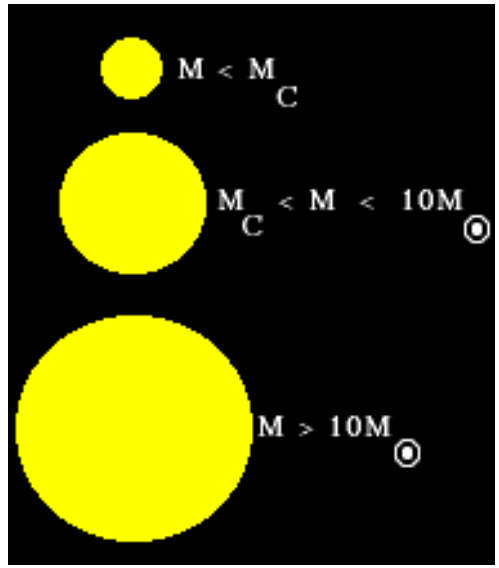
$M_{č.l.}$ = M_{Sonca} izhlapi v ~ 10^{58} × starost vesolja

- .....

…in konec



The fate of a star depends on its mass (size not to scale)



zgornja meja za maso:
- bele pritlikavke: Chandrasekharjeva limita =1.4 M_S
- nevtronske zvezde: 2-10 M_S