

Jets Schwarzer Löcher

Astro- und Teilchenphysik-Seminar

Maria Obst

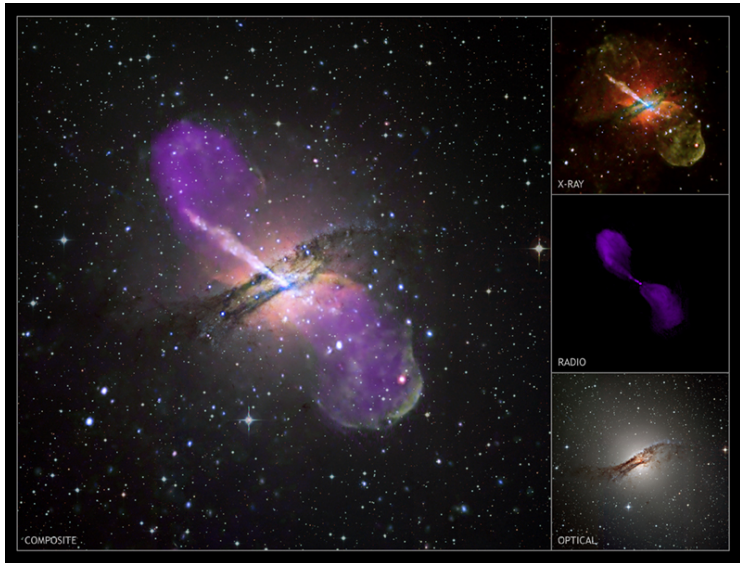
Dr. Karl Remeis-Sternwarte / ECAP

06. Juni 2011



<http://apod.nasa.gov/apod/ap000706.html>

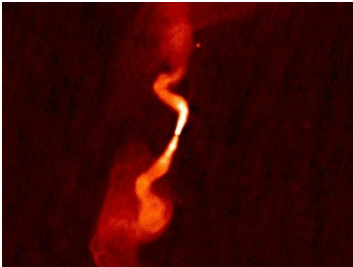




<http://chandra.harvard.edu/photo/2008/cena/>

Fanaroff-Riley-Klassifikation

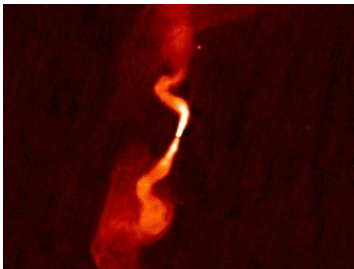
FR I: 3C 31



<http://www.astro.virginia.edu/class/whittle/>

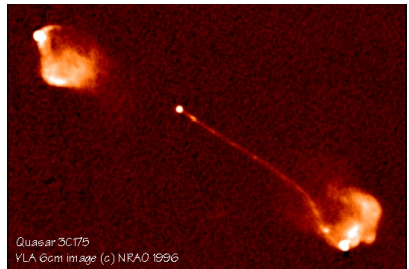
Fanaroff-Riley-Klassifikation

FR I: 3C 31



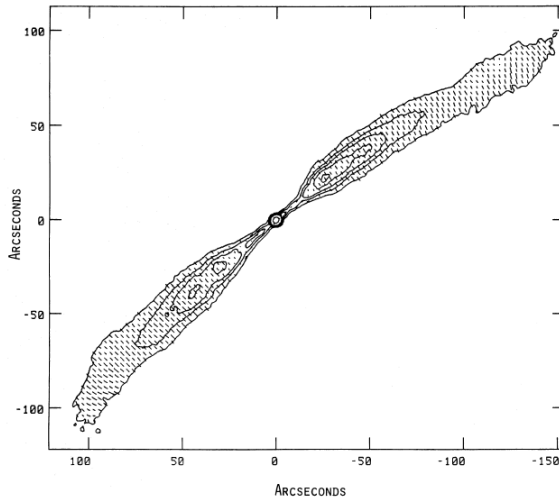
<http://www.astro.virginia.edu/class/whittle/>

FR II: 3C 175



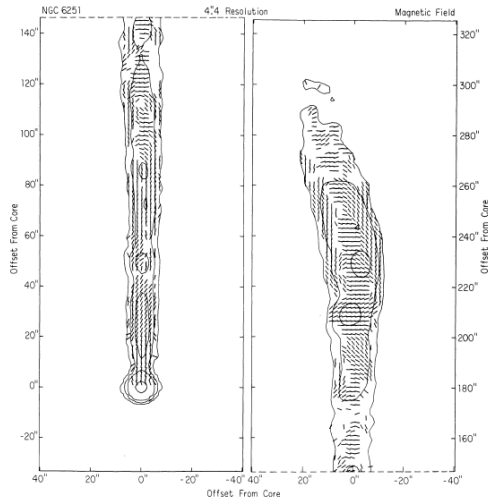
<http://apod.nasa.gov/apod/ap010905.html>

Polarisation in FR I: IC 4296

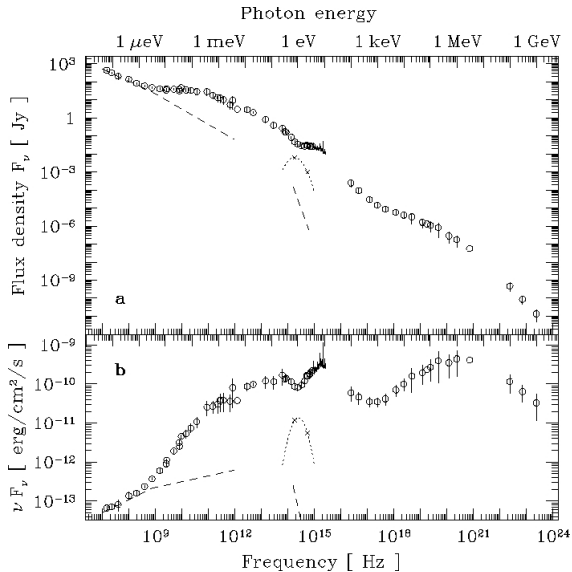


Killeen et al., 1986

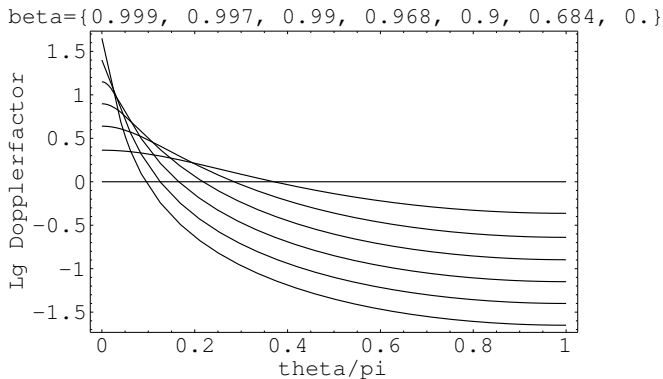
Polarisation in FR II: NGC 6251



Perley et al., 1984

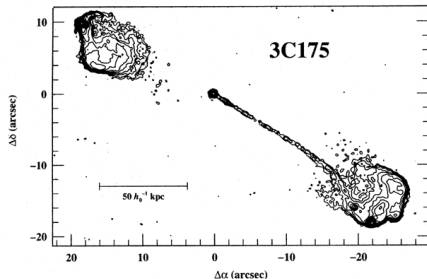


3C 273: Türlér et al., 1999



Vorlesung: Galaxien und Kosmologie, WS 2009/2010

Relativistic Doppler factor:
$$\mathcal{D} = \frac{1}{\gamma \left(1 - \frac{v}{c} \cos \phi\right)}$$
 (1)



http://ned.ipac.caltech.edu/level5/Cambridge/Cambridge1_3_1.html

Lorentz-Invarianz:

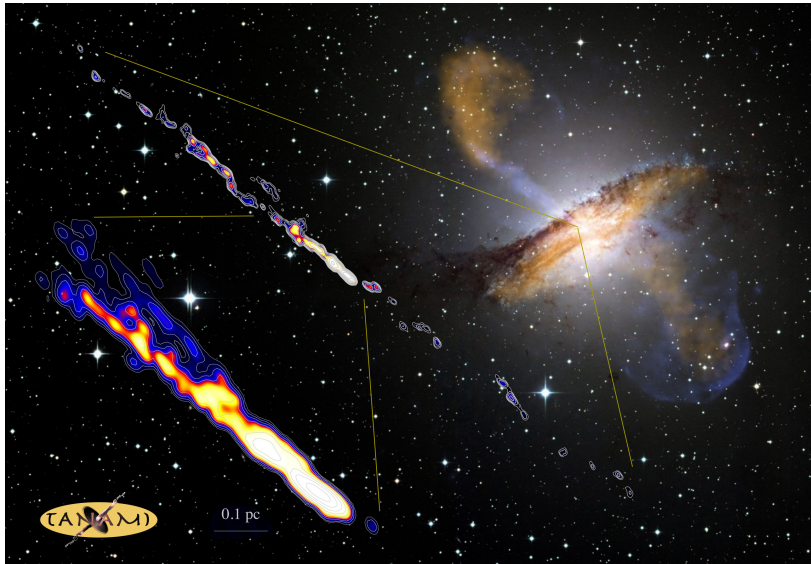
$$\frac{S(\nu_o)}{\nu_o^3} = \frac{S(\nu_e)}{\nu_e^3}$$

daraus folgt

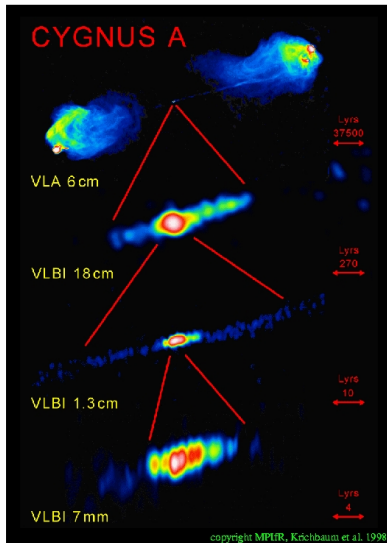
$$S(\nu_o) = \frac{\nu_o^3}{\nu_e^3} S(\nu_e) = \mathcal{D}^3 S(\nu_e)$$

Für ein powerlaw-Spektrum
($S(\nu) = A\nu^\alpha$):

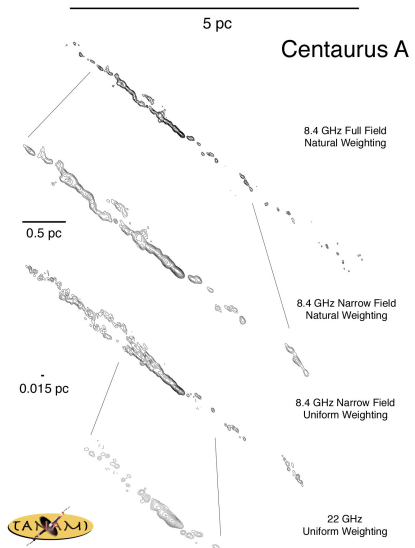
$$\begin{aligned} S(\nu_o) &= \mathcal{D}^3 A \nu_e^\alpha \\ &= \mathcal{D}^3 A \mathcal{D}^{-\alpha} \nu_o^\alpha \\ &= \mathcal{D}^{3-\alpha} A \nu_o^\alpha \end{aligned}$$



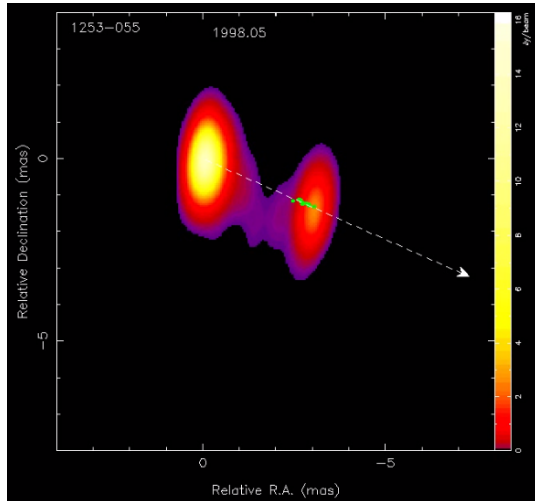
Credit: Cornelia Müller



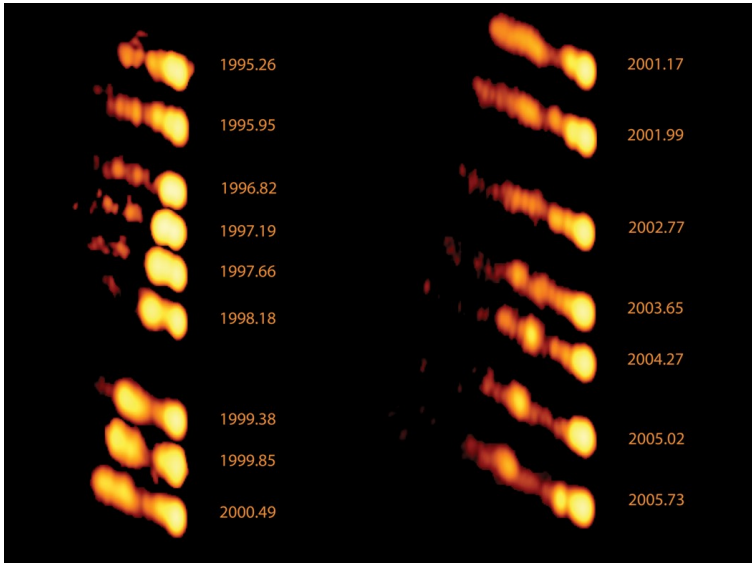
<http://www.mpifr-bonn.mpg.de/staff/tkrichbaum/>



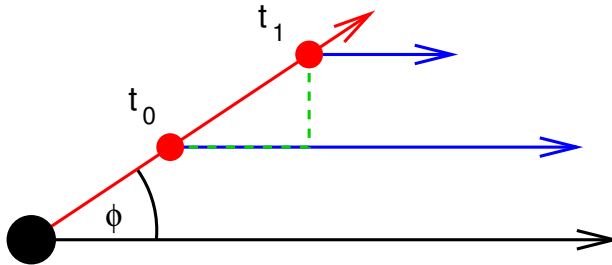
Credit: Cornelia Müller



Movie Time:
1253-055.i.mpg



Credit: Matthias Kadler



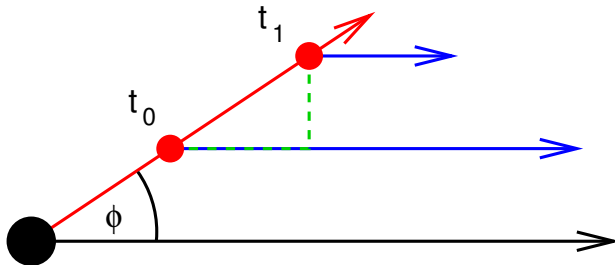
Vorlesung: Galaxien und Kosmologie, WS2009/2010

Weg ℓ den der Blob vom Beobachter aus gesehen zurücklegt:

$$\ell = v_e \Delta t_e \sin \phi$$

Zeitlicher Abstand zwischen Beobachtung des ersten und zweiten Blobs:

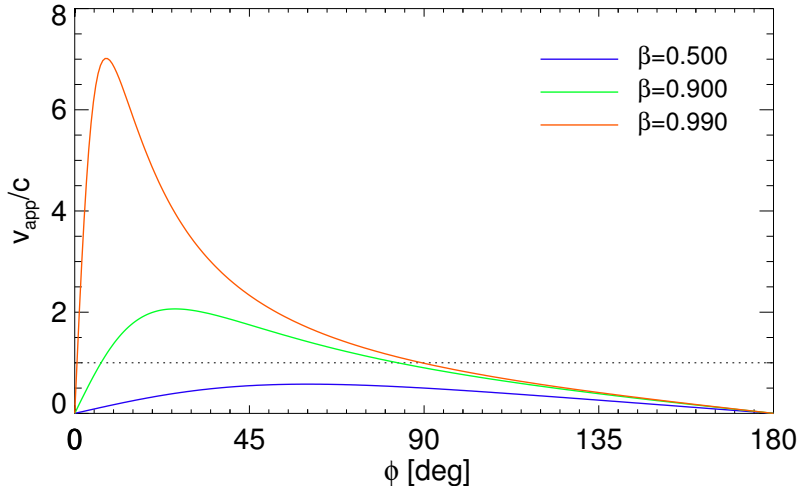
$$\Delta t_o = \Delta t_e - \frac{x}{c} = \Delta t_e - \frac{v_e \Delta t_e}{c} \cos \phi = \left(1 - \frac{v_e}{c} \cos \phi\right) \Delta t_e$$



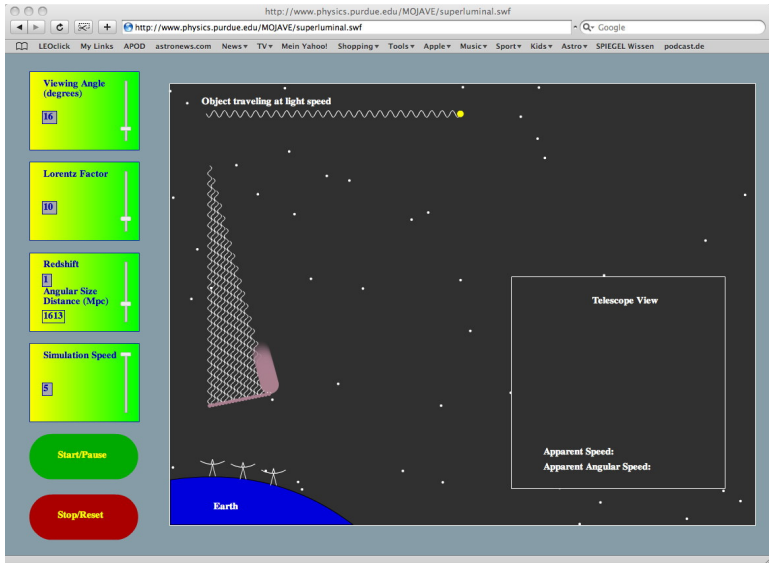
Vorlesung: Galaxien und Kosmologie, WS2009/2010

Beobachtete, scheinbare Geschwindigkeit des Blobs:

$$v_{app} = \frac{\ell}{\Delta t_o} = \frac{v_e \Delta t_e \sin \phi}{\left(1 - \frac{v_e}{c} \cos \phi\right) \Delta t_e} = \frac{v_e \sin \phi}{1 - \frac{v_e}{c} \cos \phi}$$



Vorlesung: Galaxien und Kosmologie, WS2009/2010



www.physics.purdue.edu/MOJAVE/superluminal.swf

Offene Fragen



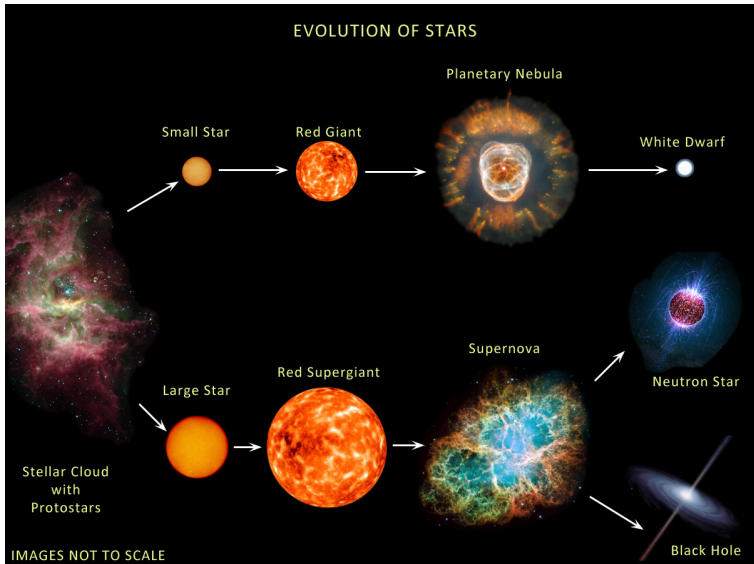
<http://apod.nasa.gov/apod/ap000706.html>

- Gut kollimiert
- Magnetisiert aber nicht gestört
- hohe Temperaturen
- Relativistische Geschwindigkeiten
- Synchrotronstrahlung
- Radiolobes



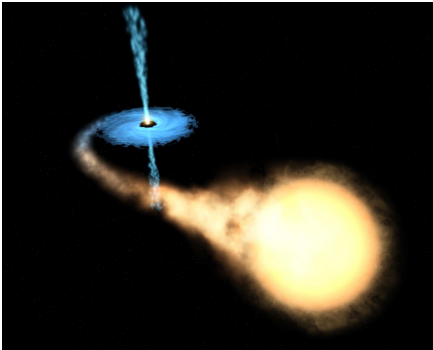
"It's black, and it looks like a hole. I'd say it's a black hole."

Begelman/Rees, p. 20



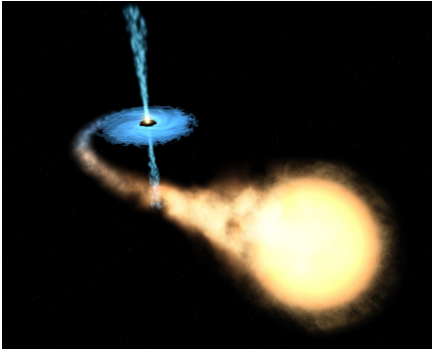
<http://essayweb.net/astronomy/blackhole.shtml>

Binaries



[http://essayweb.net/
astronomy/blackhole.shtml](http://essayweb.net/astronomy/blackhole.shtml)

Binaries

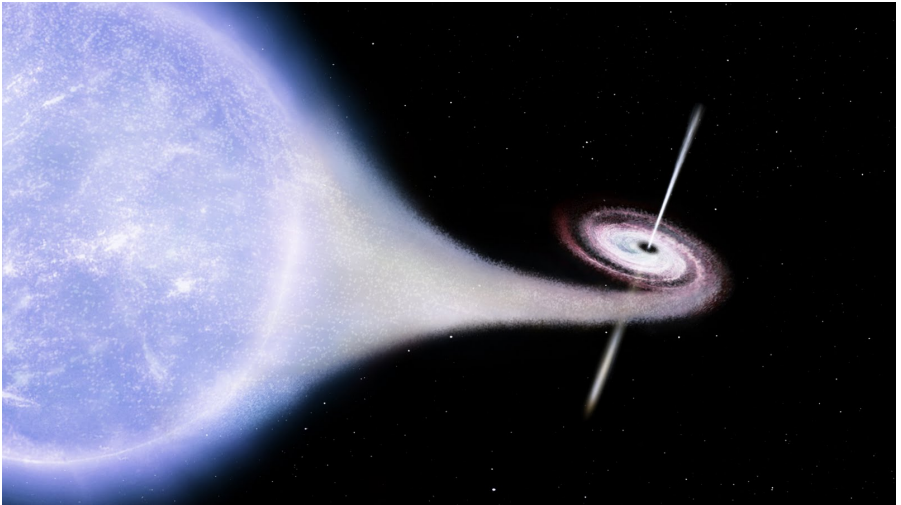


[http://essayweb.net/
astrophysics/blackhole.shtml](http://essayweb.net/astrophysics/blackhole.shtml)

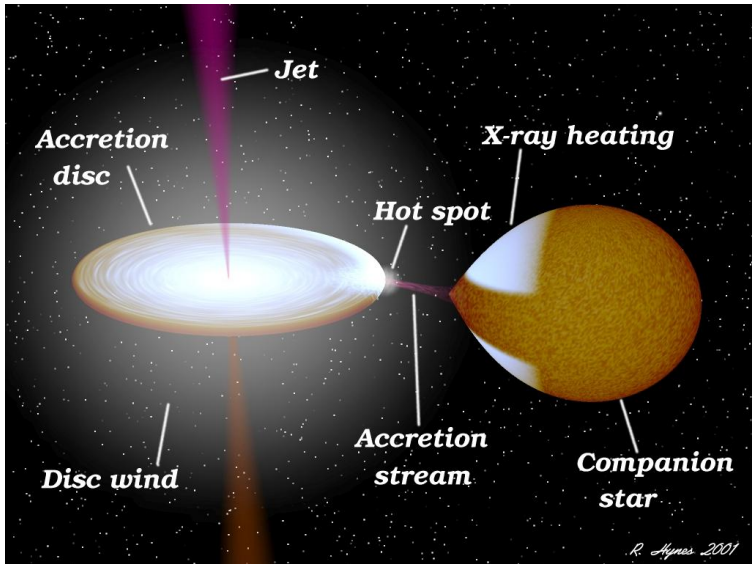
AGN



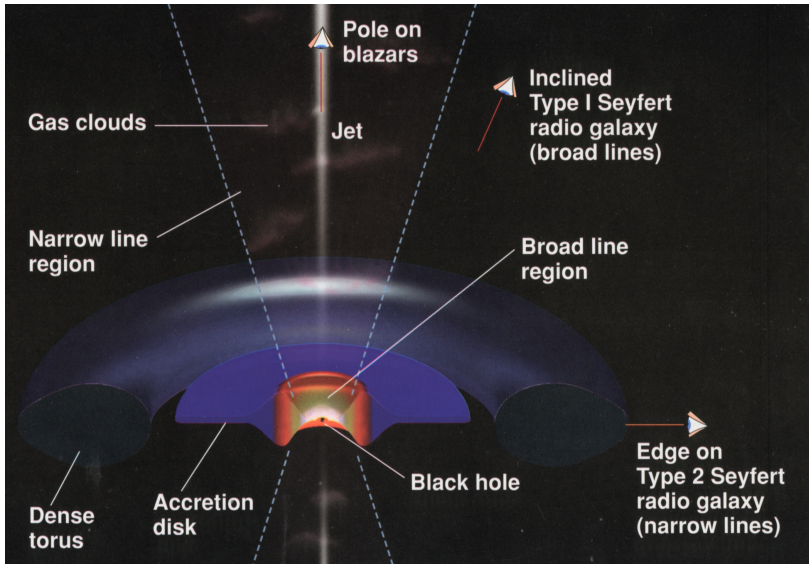
[http://web.hallym.ac.kr/
~physics/course/a2u/agn/agn.htm](http://web.hallym.ac.kr/~physics/course/a2u/agn/agn.htm)



<http://minsex.blogspot.com/>

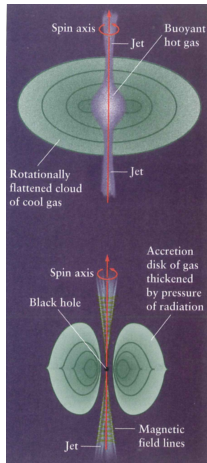


<http://www.vikdhillon.staff.shef.ac.uk/>



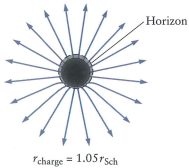
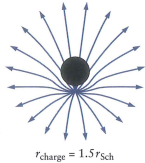
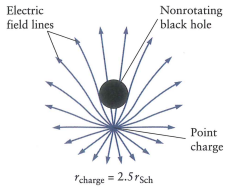
<http://crab0.astr.nthu.edu.tw/~hchang/ga2/ch27-03.htm>

Klassische Beschleunigungsmechanismen

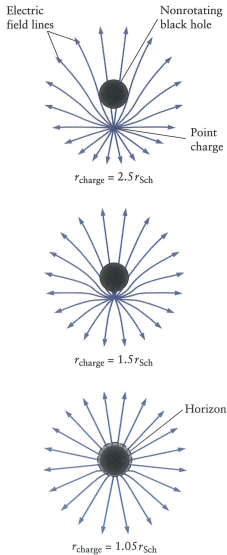


Begelman/Rees, p. 153

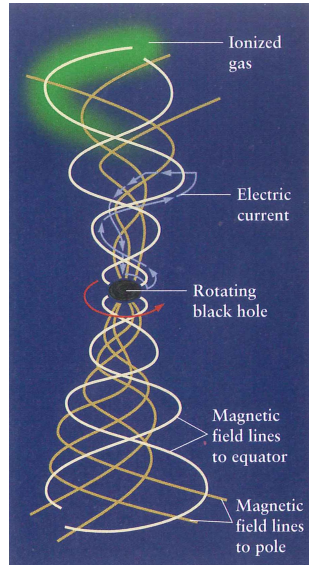
- Beschleunigung durch Druck (adiabatische Expansion)
 - erreichte Geschwindigkeiten:
Schallgeschwindigkeit im heißen Medium
 - für hohe Temperaturen instabil (Paarbildung, ν)
- Beschleunigung durch Strahlungsdruck
 - Geschwindigkeit begrenzt durch Anfangsenergie der Strahlung
 - räumliche Dispersion bremst zusätzlich



Begelman/Rees, p. 154

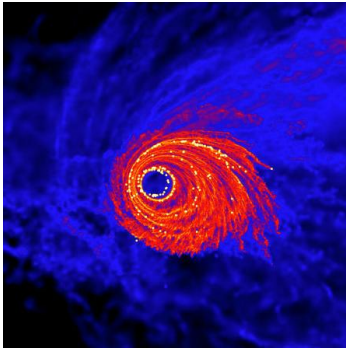


Begelman/Rees, p. 154



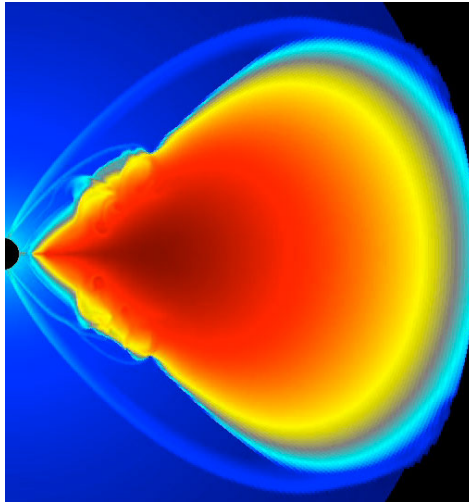
Begelman/Rees, p. 155

Allgemein Relativistische Magnetohydrodynamik



<http://www.newscientist.com>

- Magnetohydrodynamische Näherung für Akkretion
- GRMHD Jet-Simulationen
 - masseabhängig
 - radiativ



Movie Time:
rho3.mpg
rout400new.lrho.3.mpg

Zusammenfassung



<http://apod.nasa.gov/apod/ap000706.html>

- Große Skalen:
 - Fanaroff-Riley-Klassifikation
 - Relativistic Beaming
 - Spektrum
- Kleine Skalen:
 - Radiobeobachtungen
 - Blobs
 - Scheinbare Überlichtgeschwindigkeit
- Entstehung von Jets:
 - Schwarze Löcher
 - Blandford-Znajek-Mechanismus
 - Relativistische MHD-Simulationen

Literatur

- Bücher

Begelman M., Rees M., Gravity's Fatal Attraction

Clark D. H., The Quest for SS 433

Müller C., Diplomarbeit

Thorne K. S., Black Holes & Time Warps

- Paper

Krolik J. H., Hawley J. F., VI. Microquasar Workshop Proceedings (2006)

Krolik J. H., Hawley J. F., arXiv:0909.2580v1 (2009)

McKinney J. C., MNRAS, 386, 1561-1582 (2006)

- Vorlesungen

Wilms J., Kadler M., Active Galactic Nuclei, SS 2010

Wilms J., Kadler M., Galaxien und Kosmologie, WS 2009/2010

Wilms J., Kadler M., Multiwavelength Astronomy, SS 2009