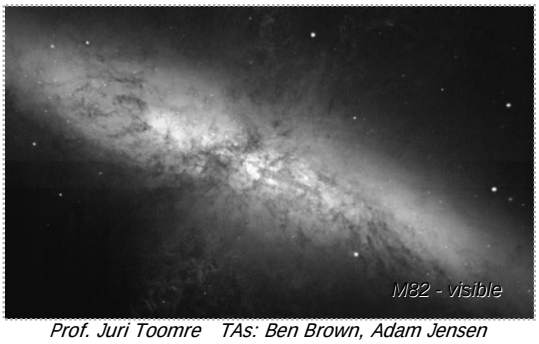
ASTR 1040 Accel Astro: Stars & Galaxies



Prof. Juri Toomre TAs: Ben Brown, Adam Jensen

Lecture 26 Thur 20 Apr 06

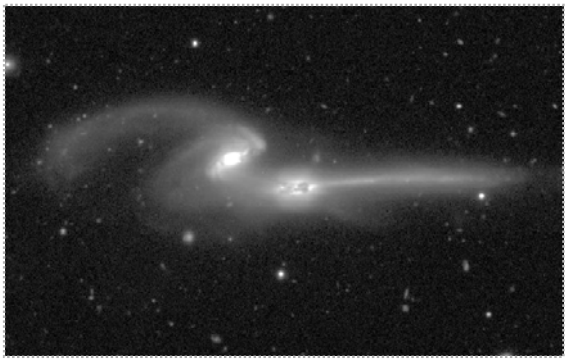
zeus.colorado.edu/astr1040-toomre

Today's "Ride to the Wild Side"

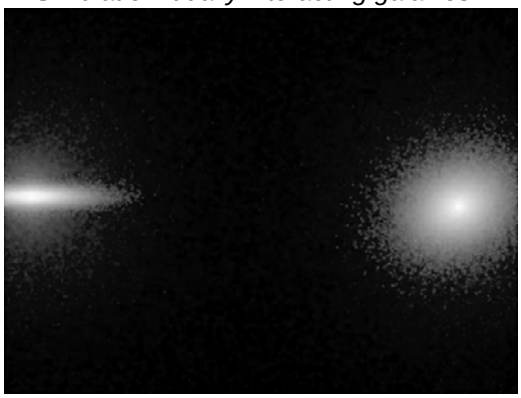
- Today discuss *active galaxies – quasars, starburst galaxies, radio galaxies*
- All from *Chap 21: Galaxy Evolution* – start overview reading *Chap 22: Dark Matter*

- *Third Mid-Term Exam on Mon 24 April*
- *Review Set 3* still available, Ben Brown runs *evening review* tonight 7-9pm

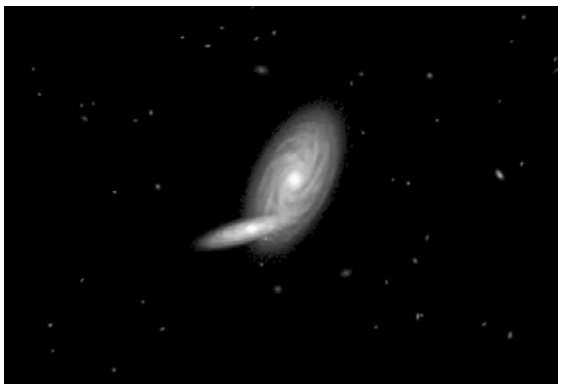
Revisit: "The Mice" NGC 4676



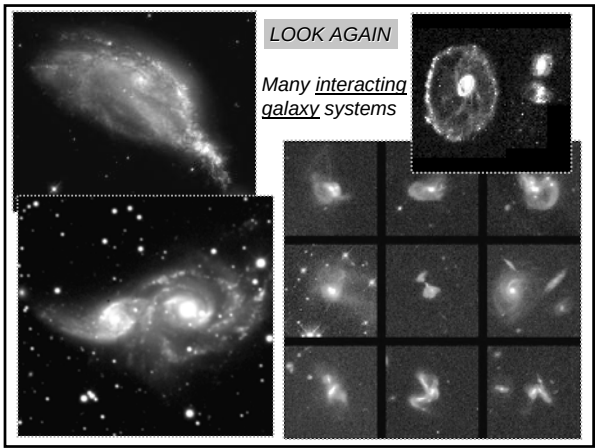
Simulation: tidally interacting galaxies Barnes



Revisit with critical eye: "Mice" simulation Dubinsky



Stefan's Quintet in HST detail



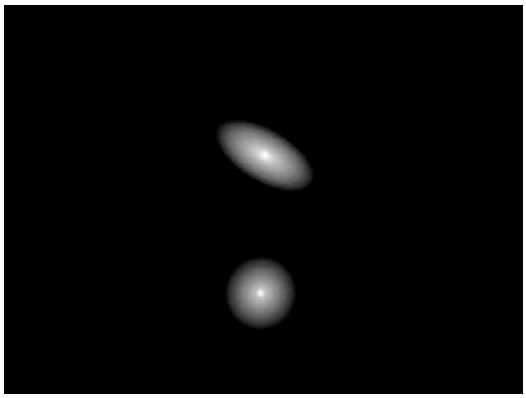
LOOK AGAIN

Many interacting galaxy systems

It may happen to us in future!

Andromeda (M31) in future

M31 and Milky Way in future collision *Dubinski*

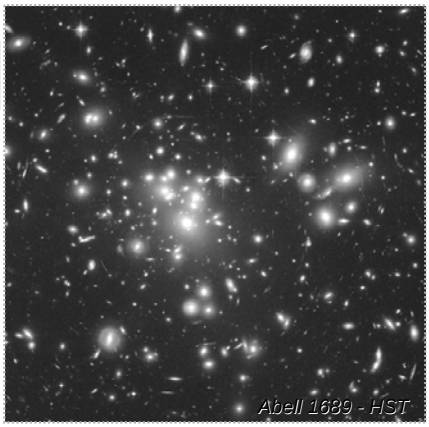


M31 heading in !

Rich galaxy cluster

Galaxies are not lonely -- many "interactions" most likely!

also curious arcs of light?



Abell 1689 - HST

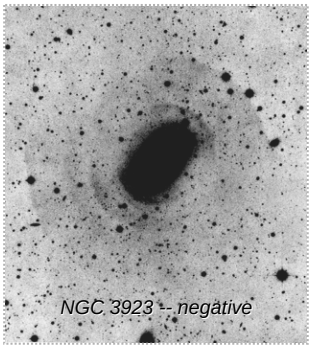
Reading clicker – the boss galaxy

- *Which of the following is NOT a feature of a central dominant galaxy ?*

A.

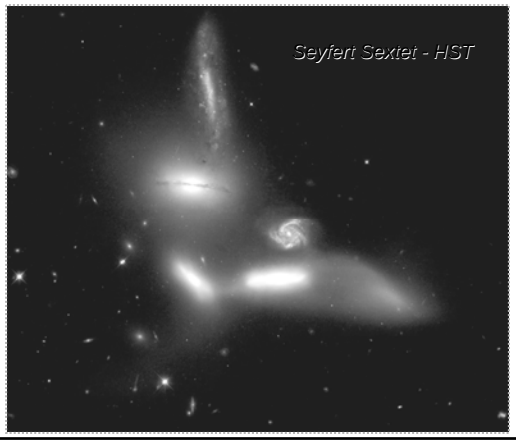
- *A.* They are often spiral galaxies
- *B.* They are found in clusters of galaxies
- *C.* They often have multiple galactic nuclei near their centers
- *D.* They are thought to form by the merger of several smaller galaxies

Signs of having collided: elliptical galaxy with shells



NGC 3923 -- negative

"Polar ring" galaxy

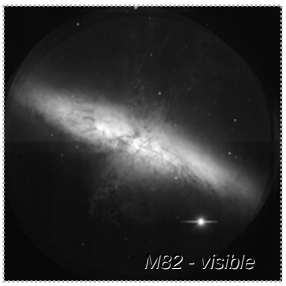


Seyfert Sextet - HST

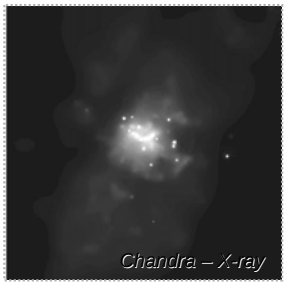
Messages from galaxy interactions

1. *In dense clusters, galaxy collisions (grazing or even head-on) must have been common*
2. *With successive passages, spiral galaxies can tumble together to form a big elliptical*
3. *Vastly increased star birth from shocking the gas and dust (star burst galaxies)*
4. *Start rapid feeding of supermassive black hole lurking at center of most galaxies (quasars)*

Starburst Galaxies



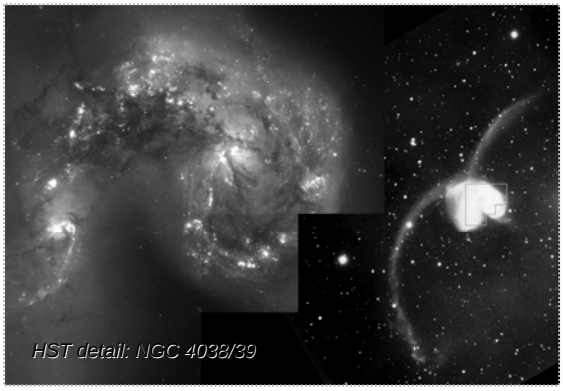
M82 - visible



Chandra – X-ray

- *Milky Way forms about 1 new star per year*
- *Starburst galaxies form 100's of stars per year*

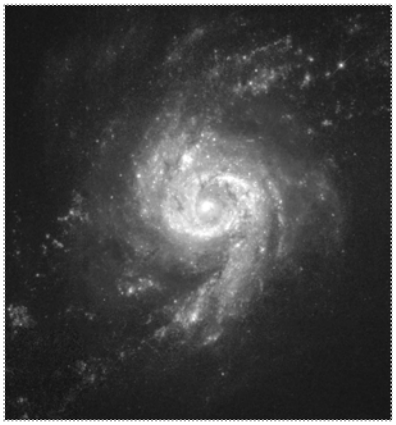
Vigorous star birth – "The Antennae"



HST detail: NGC 4038/39

Starburst galaxy in fine detail

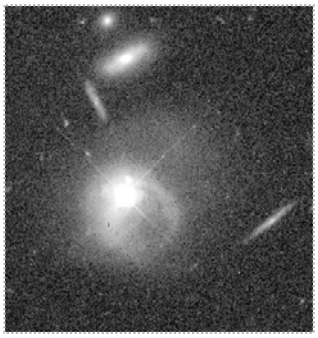
NGC 3310 - HST



Big open two-sided spiral structure --> tidal interaction

Quasars

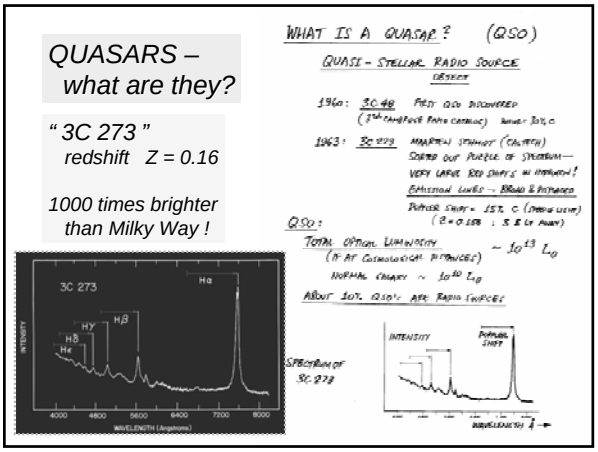
- *Quasi-stellar Radio Source (QSOs)*
- *Nuclei so bright that the rest of the galaxy is not easily seen*
- *First discovered as radio sources - then found to have high redshifts ! (far, far away?)*



QUASARS – what are they?

" 3C 273 "
redshift Z = 0.16

1000 times brighter than Milky Way !



Cosmological (Big) Redshifts
(from expansion of universe)

Alternative definition of redshift :

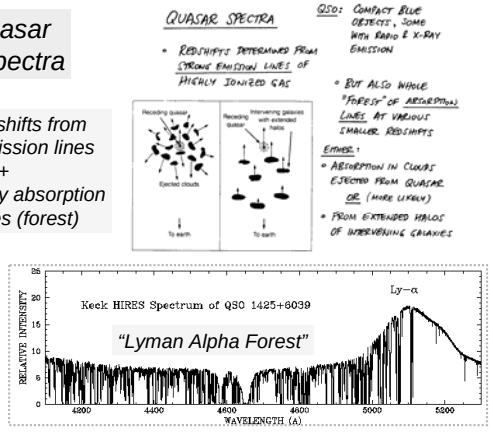
Z = redshift
= change in wavelength/ "normal" wavelength

1 + Z =
observed wavelength / "normal" wavelength

redshifts always have Z > 0
(redder light has larger wavelengths)

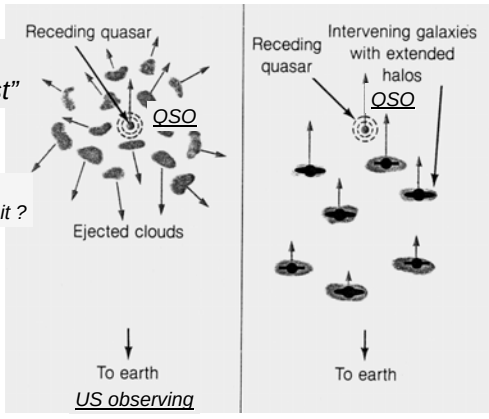
Quasar spectra

Redshifts from emission lines + Many absorption lines (forest)



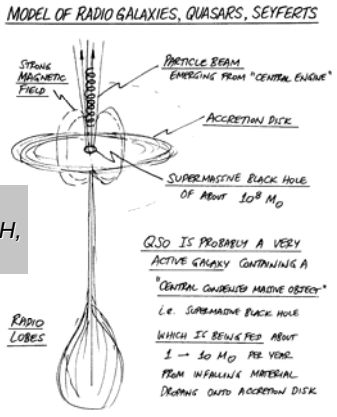
QSO "forest"

What causes it ?



Model for "active galaxies"

Accretion disk, supermassive BH, beams on axis



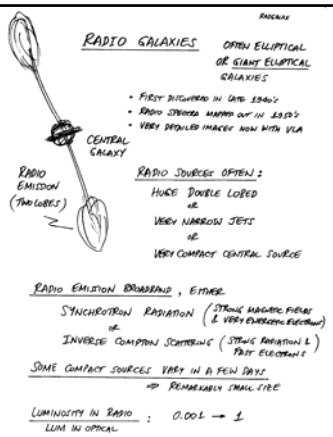
"Central Engine" -- artist's conception

- *Accretion disk around super-massive black hole*
- *Disk itself may or may not be obscured by dust*
- *If bright nucleus is visible, looks like a quasar, if not, then a radio galaxy*

Radio galaxies

Central elliptical galaxy, huge lobes of emission, compact central source

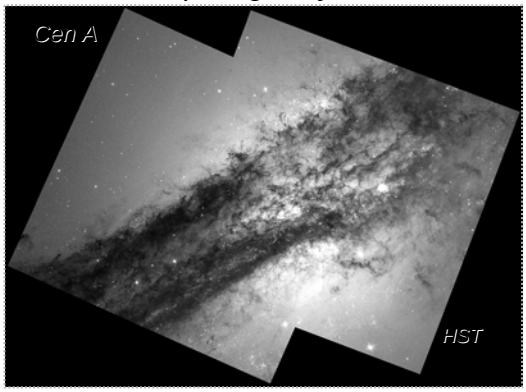
Synchrotron radiation



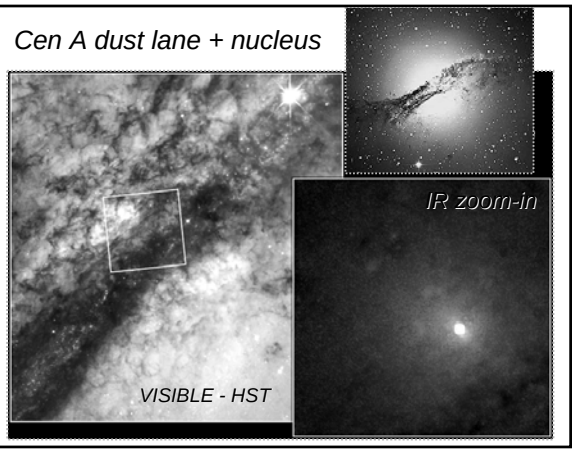
Prototypical "radio galaxy"

Giant elliptical galaxy NGC 5128 with dust lane (from spiral galaxy?)
+
Centaurus A radio source (color lobes)

Remains of spiral galaxy as dust lane ?



Cen A dust lane + nucleus



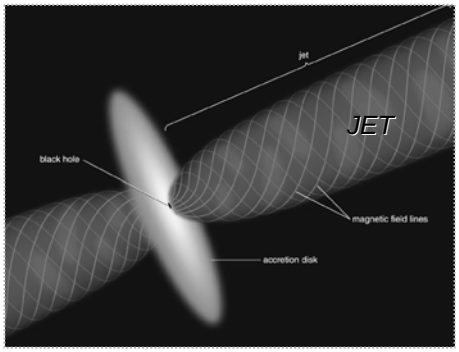
Clicker – what makes the light?

- *What is most likely source of light from bright nuclei (radio, visible, x-rays) in active galaxies?*

D.

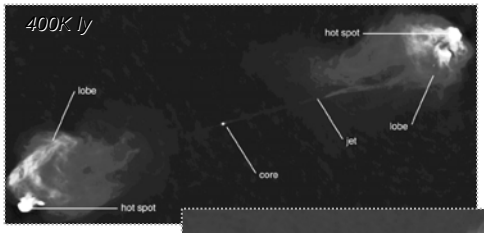
- *A.* Thermal radiation from a massive star cluster
- *B.* Emission lines from hot gas
- *C.* 21 cm from hydrogen
- *D.* Synchrotron radiation from a black hole

Synchrotron radiation from particles moving outward

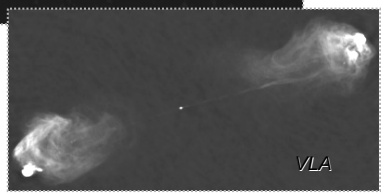


Spinning accretion disk drags along magnetic fields

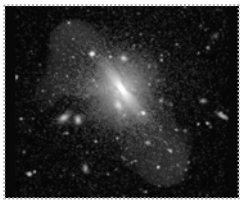
Cygnus A radio jets

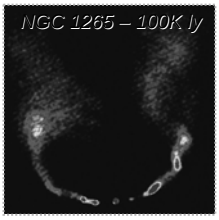


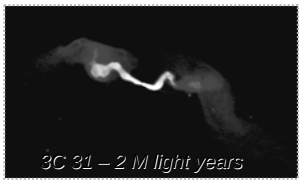
Jet as fine thread, big lobes at end, central hot spot

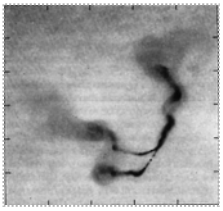


Radio tails: many shapes









Typical properties of "active galaxies"

synchrotron emission !

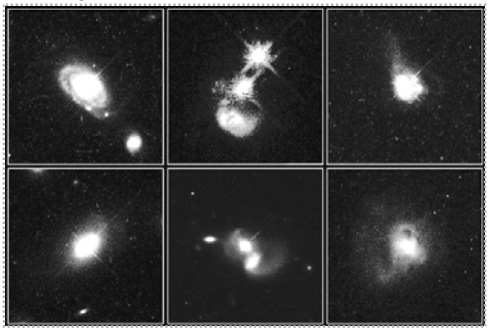
source very small in size

PROPERTIES OF "ACTIVE GALAXIES"

RADIO GALAXIES, SEYFERT GALAXIES, BL LACERTAE OBJECTS, QUASARS *"SOME HAVE MORE THAN OTHERS!"

1. HIGH LUMINOSITY
   - MUCH MORE LUMINOUS THAN NORMAL GALAXIES
2. NON-THERMAL EMISSION
   - EXCESS RADIATION IN UV, IR, RADIO, X-RAY
   - IMPLYING SYNCHROTRON EMISSION FROM RELATIVISTIC ELECTRONS SPIRALLING IN MAGNETIC FIELDS
3. SMALL, COMPACT SIZE OF INTENSE EMISSION
   - NUCLEUS VERY BRIGHT COMPARED TO REST OF GALAXY
4. RAPIDLY VARYING EMISSION
   - SOURCE MAY BE A FEW LIGHT HOURS OR DAYS IN SIZE
5. EXPLOSIVE FEATURES
   - JETLIKE EXTENSIONS, FILAMENTS
6. GRAVITATIONAL DISTURBANCES
   - VERY HIGH INTERNAL VELOCITIES DEDUCED FROM BROAD SPECTRAL EMISSION LINES
   - PECULIAR OPTICAL APPEARANCE
7. LARGE REDSHIFTS
   - IMPLYING HIGH RECESSIONAL VELOCITIES, VERY LARGE DISTANCES

Distant galaxies with "active nuclei" - HST



- *Galaxies with odd stuff going on in their cores*
- *Nuclei as bright as rest of galaxy*

Epochs for "active galaxies"

SEQUENCE OF EPOCHS (AGES) FOR ACTIVE GALAXIES

BASED ON LARGE REDSHIFTS z

SEYFERT GALAXIES	$0.0 \leq z \leq 0.2$
BL LAC OBJECTS	$0.1 \leq z \leq 0.5$
RADIO GALAXIES	$0.0 \leq z \leq 0.8$
QUASARS	$0.1 \leq z \leq 4.1$

Most quasars present when universe was young

WITH HIGHER z, "LOOKING BACK FURTHER IN TIME"

QUASARS SEEN NOW EMITTED LIGHT WHEN UNIVERSE WAS MUCH YOUNGER.

$z = 4.4 \Rightarrow$ 12 BILLION YEAR LIGHT TRAVEL TIME

(FLAT UNIVERSE, $H = 50$)

REMINDER

Cosmological Redshifts
(from expansion of universe)

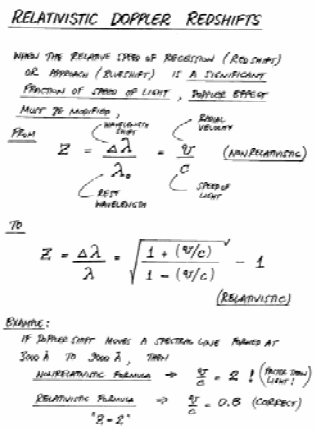
Definition of redshift :

Z = redshift
= change in wavelength/ "normal" wavelength

1 + Z =
observed wavelength / "normal" wavelength

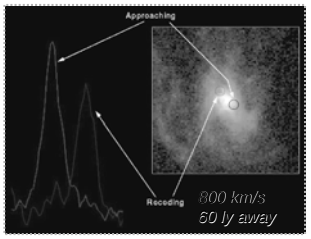
redshifts always have Z > 0
(redder light has larger wavelengths)

Relativistic redshifts



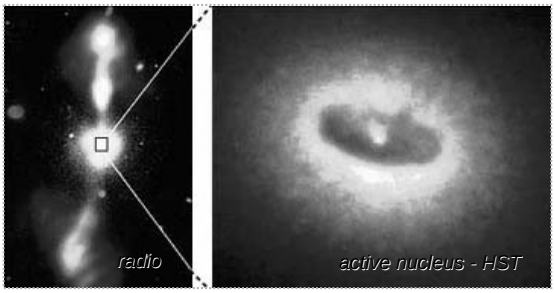
If Z is big (~2+), use relativistic formula to get velocity v

M87 – elliptical with jet



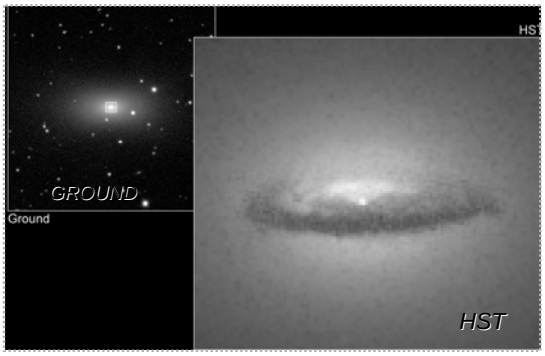
- *Active galactic nucleus beams out very narrow jet*
- *Accretion disk shows gas orbiting a 2.7 billion solar mass black hole – first real proof !*

Another example of "central beaming engine"



- *400 light year wide disk of material in core of elliptical galaxy with radio jets – looks like supermassive BH at work!*

Disk around 'black hole' in NGC 7052



Do ALL galaxies have supermassive black holes?

- *As of early 2006: probably YES !*
- *Part of normal galaxy formation ?*
- *More quasars seen in the distant (early) universe than now*
- *Black holes gradually grow, but can run out of available fuel and become relatively invisible (like in our Milky Way)*