Dual Accretion Disks in Alternate Gravity Theories

James S. Graber*

* 407 Seward Square SE, Washington, DC 20003

Abstract. The interior of gravitationally collapsed objects in alternate theories of gravity in which event horizons and singularities do not occur in strong field gravity were generically investigated. These objects, called red holes, were found to contain dynamic configurations of matter, radiation and spacetime similar to inside out accretion disks well inside the photon orbit. Applications to astrophysical phenomena are briefly described.

NATURE MIGHT PREFER RED HOLES

Rather than general relativity, an alternate theory of gravity – in which event horizons do not form around collapsing compact bodies – might be true. In this case, black holes do not exist in nature. Instead, compact bodies that collapse gravitationally inside their photon orbit form a different configuration of matter, radiation and space-time, which can be called a red hole. The literature contains several theories, consistent with all known experimental evidence, in which red holes occur instead of black holes [1–3].

THREE PARADIGMS FOR GRAVITATIONAL COLLAPSE

The black hole paradigm for gravitational collapse is now well known. In the black hole paradigm, once a certain critical density is reached, a compact body collapses forever, reaching infinite redshift in a finite time and forming an event horizon, which is a one-way sink for matter, energy and radiation – a sort of bottomless pit. This is the most popular expectation today.

In the frozen star paradigm, which preceded the black hole paradigm, gravitational collapse ended with a super-hard kernel, sort of like a tougher, denser, more massive neutron star. Variants of this paradigm are still considered today. See, for example, Robertson [4].
In the less well known red hole paradigm, gravitational collapse results in a configuration of matter, energy and space-time that contains no solid surface, no singularities, and no event horizons. Unlike the frozen star paradigm, red holes do not stop collapsing and form a dense kernel that resembles a denser, tougher neutron star. Unlike the black hole paradigm, red holes do not collapse forever and form a bottomless pit with an event horizon as a one-way sink for matter, energy and radiation.

Instead, the matter and radiation inside a red hole form a dynamical configuration somewhat resembling a globular cluster or an accretion flow. Orbits inside a red hole are typically highly elliptical, deeply plunging, roseate shaped and at relativistic velocities. Space-time is highly stretched and distorted in a manner very similar to the parts of a black hole that are inside the photon orbit but outside the event horizon. As a result of this progressive space-time stretching, the density of a red hole decreases toward the center, and the center of a red hole can be – and usually is – a near-vacuum.

**WHEN WILL A RED HOLE STOP COLLAPSING?**

As a star collapses into a red hole, its locally apparent density increases until it crosses the photon orbit and then it starts to decrease. It reaches a density much greater than a neutron star’s, and then the density decreases again to that of a neutron star, then a white dwarf, then a normal star, and eventually to the density of a collisionless plasma. Once the density drops to a level appropriate to a collisional gas or plasma, a violent relaxation will take place, and the matter and radiation deep inside the red hole will assume a randomized near-equilibrium configuration similar to that of a globular cluster (an inside-out globular cluster, as the matter is denser on the outside than on the inside). Self-organizing criticality will keep the equilibrium near the point of marginal collisionality. Below the collisionality point, the matter will scatter to a more tightly bound configuration only very slowly. Above collisionality, scattering will rapidly bifurcate the red hole contents into a more energetic escaping fraction and a less energetic, less dense, more tightly bound remainder, which will thereafter evaporate only very slowly.

**WHY DOES A RED HOLE STOP COLLAPSING?**

In red hole theories, only infinite densities lead to infinite redshift and hence the possibility of an event horizon or a bottomless pit or an endless collapse. In red hole theories once gravitational forces have overcome all other forces and collapsed inside the photon orbit occurs, the space-stretching effects happen faster than the infall rate. Contrary to intuition, the density then begins to decrease rather than increase. This allows the collapse to eventually stop when the density is once again low enough to allow the particles to follow essentially independent trajectories.
In principle, there is no limit to how near a configuration can approach infinite density and infinite redshift. In fact, a hypothetical point particle will itself have infinite density and hence an infinite redshift and a point singularity. Thus, one may have to appeal to quantum uncertainty principle limits or string theory dualities to make singularities, infinite densities and infinite redshifts impossible.

In practice, however, if one begins with real electrons, baryons and photons in reasonably random thermal motion, no infinite density state will occur, even in gravitational collapse. The center of a red hole will have a nearly flat potential like the center of a spherical shell, and kinematics much like an inside-out globular cluster. Therefore, the density and hence the redshift and also the stoppage of the collapse will be determined by an equilibrium near the point of marginal collisionality.

WHAT DOES A RED HOLE LOOK LIKE?

From the outside, a red hole looks like a cross between a neutron star and a black hole: Like a black hole, a red hole has no solid surface, and a red hole is entirely within its photon orbit, as well as its innermost stable circular orbit. Like a neutron star, a red hole emits some of the matter and radiation that fall into it, and a red hole may be optically thick and have a visible last scattering surface. Mathematically, a red hole looks like a black hole with a cutoff. Think of the Thorne, et al., membrane approximation to a general relativity black hole [5]. Put a hollow sphere around the black hole, just outside the event horizon, and connect opposite points with a straight line. This is a good model of a red hole.

To understand what happens inside a red hole, think particularly of the loss cone model of Misner, Thorne and Wheeler [6]. Only matter moving at near-relativistic speeds can escape the red hole. Only matter and radiation directed near vertically can escape. The size of the loss cone decreases rapidly inside the photon orbit. Hence, only a small fraction of matter and radiation can escape. (Think of it as similar to Hawking evaporation.) Most matter and radiation are trapped inside the red hole for a long time.

THE INNER "ACCRETION DISK"

The inside of a red hole looks a lot like an inside-out accretion disk with a near-vacuum at the center. Since there is no singularity or event horizon to swallow up the matter and radiation falling into a red hole, it can only escape by reemerging from the red hole, of which there is only a very small probability. Since the gravitational force inside the photon orbit is too high for anything to remain static, all the contents are in motion, mostly at relativistic speeds. A nonrotating red hole might resemble a globular cluster or a spherical galaxy inside a deep potential well. A rotating red hole might resemble an accretion disk or a spiral galaxy similarly situated.
However, there are no circular orbits inside a red hole, only deeply plunging roseate shaped orbits. Also contrary to intuition, a red hole does not get denser and denser as the center is approached. As the center is approached, the space-bending and space-stretching effects increase faster than the rate of approach to the center, thus causing the density to decrease. Thus the center of a red hole is hollow – in fact resembling a near-vacuum – and the slope of the gravitational potential flattens, as is expected inside a spherical shell. This is why no singularity forms and why the redshift at the center stops at a finite value and does not approach infinity. Hence the matter inside a red hole near equilibrium is densest on the outside and least dense on the inside, which is why it resembles an inside-out accretion disk.

**RED HOLES WORK BETTER THAN BLACK HOLES**

Red holes can explain many astrophysical phenomena better than black holes of similar mass. Because more energy can escape from a red hole, there is more energy to power supernovae, jets, and gamma ray bursts. Because you can see inside a red hole, small size scale and rapid variability effects can be explained. Because accretion disks can have an active center – instead of a solid body or a bottomless pit – it is easier to form, power, and collimate jets.

If two particles of equal mass originate near the boundary of the red hole (i.e. just marginally bound or just marginally unbound), fall in, reach relativistic velocities, and scatter so that one particle is tightly bound and the other one escapes, the escaping particle will have excess kinetic energy of the same order of magnitude as its rest mass. Likewise if the two particles scatter inelastically and emit a photon that can escape, its energy upon emerging will be of the order of magnitude of the rest mass of the particles or of the binding energy at the level to which they have fallen when they scatter.

Hence it is possible that if roughly half the matter in an initial collapse is trapped in the red hole and half is scattered out, about one quarter to one half of the rest mass of the collapsing matter will be converted into escaping kinetic energy and radiation available to drive supernovae explosions, gamma ray burst fireballs, jets, superluminal ejected blobs, or other energetic phenomena.

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