Cosmic Collisions

March 8, 2006

1. INTRODUCTION

The audience is seated and the houselights FADE TO BLACK. A beautiful CANOPY OF STARS fills the dome. We are floating in space with only distant stars visible.

Hello. I'm Robert Redford.

Out here in space, the stars look peaceful, don't they?

Through good times and bad, we've always found comfort in their reassuring light…a sense that there is order in the universe.

Comet rises inconspicuously from the lip of the dome.

When something new suddenly appears in the night sky, it makes us wonder.

Comet gets larger.

See that big rock? It's really a comet.

People used to believe that comets like this one were bad omens… warnings that trouble was on the way.

Today, we know that comets begin as chunks of ice and rock that orbit around the sun, far beyond the planets of our solar system. If one of them is pulled into an orbit closer to the sun's heat, its icy surface changes from solid to gas, unleashing an enormous tail of rock and dust that's millions of miles long.

But knowing what a comet is doesn't mean it can't cause trouble.

We move into the comet, so that we're almost inside the matter that is flowing off it.

Then…EARTH COMES INTO VIEW. The COMET looks like it's going to hit for a minute.

That comet is heading toward Earth.

Will it hit?

The comet swings away from Earth. Earth is caught in its debris.

Not this one. Like most comets, it will pass us by.

But bits of rock from the comet's tail, called meteoroids, will collide with Earth's atmosphere.

When they hit, they'll burn up…

…creating a brilliant meteor shower.

We see Earth up close…the CITY LIGHTS of NORTH AMERICA, the AURORA above ALASKA, and as our planet plows through the comet's remains, we begin to see them as METEOR STREAKS.

MUSIC SWELLS along with the celestial display. We settle into the landscape, and the meteor showers FADE DOWN.

These days, down here on Earth, it sometimes feels that things are changing far too much…and far too quickly.

And it's not just Earth. You see, change is a constant in the universe. Stars, planets, even galaxies are always on the move… tugged this way and that by the powerful, ever-present force of gravity.

At times, they even collide.

This may sound alarming. But collisions can actually be beneficial… and sometimes beautiful.

Come with me now, on a journey to places near Earth and beyond the distant reaches of our galaxy…to see how cosmic collisions have created our past…affect our present…and continue to shape our future.

There used to be a number of theories about how our moon was formed. Not long ago, scientists proposed a new one.

Let's travel back in time…four and a half billion years into the past… to find out what they think happened.

FADE TO BLACK

2. THE FORMATION OF THE MOON

FADE UP: We are floating in space. A PROTO-EARTH, cratered and molten, rises dramatically up over the lip of the dome.

What you're seeing is the young Earth. It was a planet still forming….

….where life had not yet begun.

In those early days, our solar system was swarming with large chunks of rock, some as big as planets. A number of them had orbits that brought them close to Earth.

A partially-formed planet approximately the size of Mars heads towards the young Earth.

This one got a little *too* close…

And WHAM! Music reaches a dramatic peak and the seats shake as the rock slams Earth. Molten debris sprays everywhere.

The collision nearly destroyed the Earth, spraying molten rock out into space.

Most of this rock fell back onto our shattered planet.

Transition to accretion epoch: Earth is now surrounded by a SWIRLING MASS OF MOLTEN DEBRIS, which flashes here and there, as pieces stick together. A glowing yellow-red band hugs Earth's equator.

The rest of the rock stayed in orbit.

The force of gravity kept it from escaping out into space.

DISSOLVE TO NEXT EPOCH

As these jagged rocks revolved around Earth, gravity drew them towards one another. They began to collide, fusing together into larger chunks.

Within weeks, these chunks combined with others, growing bigger and bigger.

DISSOLVE TO NEXT EPOCH

And in less than a month… incredible as it may seem…

TRANSITION to a FULLY-FORMED MOON…

…our moon was formed.

That's right. It took only one month to create our moon.

CROSS-DISSOLVE to the PRESENT-DAY EARTH AND MOON. Earth is tiny in the distance beyond it.

This is the Moon today. It's strange to think that the comforting sphere in our night sky was formed by a violent collision.

But it was.

In a thousand different ways, this collision made life on Earth possible. The force of it tilted our planet's axis, giving us our seasons. And the moon's gravitational pull causes our tides.

We PULL AWAY, losing the moon entirely, and we HEAD TOWARDS Earth.

Our solar system has settled down a lot since then, so we don't have to worry about another planet colliding with Earth.

But other collisions affect us each and every day.…

THE SUN begins to COME INTO VIEW.

3. ***DOMAIN OF THE SUN***

Some of the most important ones involve our sun.

Don't worry. Earth isn't going to collide with the Sun anytime soon. Our orbit is stable, and it should stay that way for billions of years.

But all life on the surface of Earth depends on collisions that happen *inside* the sun.

The Sun begins to move towards us, and as it does, it morphs through different wavelength images of the Sun. It begins as a simple glow. The MUSIC turns more INTENSE.

The Sun is a star, like the other stars we see in the night sky. It's much closer, though, so it looks different to us—like a gently glowing golden ball.

Moving close, the Sun MORPHS from a simple glow to yellow sphere (image from SOHO MDI – visible wavelength).

But there's nothing "gentle" about the sun.

SUNSPOTS become visible on the face of the Sun.

Those dark patches just coming into view are sunspots. Each of them is about the size of Earth.

Sunspots look dark because they're the coolest places on the sun… only about 8,000 degrees Fahrenheit.

That's thirty-seven times hotter than boiling water.

As the Sun reaches the apex of the dome, it MORPHS again into a more dramatic aspect, with fiery knows and complex features (image from SOHO EIT – ultraviolet wavelength).

And the rest of the Sun is even hotter.

The Sun's energy—like that of all stars—is created by collisions between tiny particles called protons.

The Sun moves closer. Loops and prominences shoot out from the chaotic surface. MUSIC is DRAMATIC.

Every second, countless numbers of protons collide and fuse within the Sun's core, releasing incomprehensible amounts of energy.

Most of this energy leaves the Sun as light.

The SUN MORPHS into an image that includes a DRAMATIC CORONA flowing out.

Some of it leaves the Sun's surface in a continuous stream of charged particles known as the Solar Wind, which blows out into the solar system at almost a million miles an hour…

…or in less frequent but faster solar storms that blast particles out into space.

We're looking at actual images of solar storms, taken by a NASA satellite.

STATIC splatters across the dome.

See that static?

That's a solar storm cloud hitting the satellite and overwhelming its imaging device.

We pull back, revealing blasts from the solar storm spreading out across the ORBITS OF THE INNER PLANETS.

The Solar Wind blasts across the planets in the Solar System every second of every day.

The orbits FADE DOWN, as we fly in towards Earth.

It's so powerful that contact with it would sweep away a large portion of our upper atmosphere, removing much of our water and dramatically altering the development of life on Earth.

But fortunately, Earth is protected by an invisible, natural shield.

We move in closer to see Earth surrounded by what looks like a SHIELD or COCOON, moving and morphing dynamically.

What you're seeing is a visualization of Earth's magnetic field.

This field arises from Earth's iron core, which makes our planet act like a big magnet—attracting some things and repelling others.

Wrapped in this cocoon, Earth is sheltered from the Solar Wind.

We see PARTICLES COLLIDING with Earth's atmosphere.

But some of the particles make it through this magnetic barrier, eventually reaching the North and South Poles. The results are spectacular…

We keep flying down, revealing a full view of Earth with A GREEN, GLOWING AURORA sitting atop the planet like a crown.

…glorious, shimmering curtains of color. This one is called the Aurora Borealis…the Northern Lights.

Auroras occur when charged particles from the Solar Wind and solar storms collide with the upper atmosphere of Earth, causing atmospheric gases to glow.

We fly past the INTERNATIONAL SPACE STATION.

That's the International Space Station, circling the globe in low Earth orbit, about 250 miles up.

Not many people have seen the Aurora from out in space.

AN AIRPLANE flies overhead with a great WHOOSH.

The collisions that cause Auroras happen between 60 and 300 miles above the surface of Earth…far above where airplanes fly…and create one of the greatest natural light shows on our planet.

But as we've already seen, not all collisions have beautiful and harmless results. One of them was a major factor in an extraordinary event that changed the course of life on Earth.

We fly through the aurora and away from Earth. The aurora FADES DOWN as we pull away.

4. ASTEROIDS

It began out here… where asteroids orbit the Sun.

FADE UP a graphic of the ASTEROID BELT between Mars and Jupiter.

Asteroids are pieces of rock and metal left over from the first few million years of our solar system, when the planets were forming. Most of these asteroids orbit within that belt you're seeing, located between Mars…

FLASH ON MARS

…and Jupiter.

FLASH ON JUPITER

FADE UP SEVERAL ORBITS of NEAR-EARTH ASTEROIDS.

Some can be even closer.

There's only a one-in-a-million chance in any given year that a large asteroid will hit Earth.

All orbits and graphics FADE DOWN.

But 65 million years ago, one did.

FADE TO BLACK.

5. KT IMPACT

FADE UP: We are floating in space. MUSIC is TENSE. A LARGE ASTEROID ASCENDS menacingly up over the lip of the dome, looming over us.

It was about seven miles wide, traveling at 40,000 miles an hour. And it was headed straight for Earth.

The asteroid recedes as Earth also comes into view.

But not the Earth we know today. This was long before humans existed, when the great dinosaurs roamed the planet.

Unfortunately for them, that was about to change.

The asteroid punches through Earth's atmosphere. It collides, followed by a SUPER-BRIGHT FIREBALL and a MASSIVE SPLASH OF MATERIAL. We let this scene "breathe" before picking up narration.

SHOCK WAVES move out around the planet. ROCK and DEBRIS are flung out into space…

The asteroid hit near what is now Mexico. The impact created a fireball that scorched everything in sight.

Vaporized earth and rock were blasted into space.

Then re-enter the atmosphere. The sky is filled with SHOOTING STARS.

As this material rained back down, it heated the atmosphere. Glowing debris slammed into Earth, hitting again and again.

Everything that could, caught fire.

BURNING DEBRIS rains back down on the planet and GLOBAL SCALE FOREST FIRES spread around Earth.

For an hour, temperatures across the globe rose to more than 500 degrees Fahrenheit—literally as hot as an oven.

DEBRIS and SMOKE encircles the planet. MUSIC evokes SADNESS.

Smoke and soot filled the atmosphere. For six months, it would be too dark for most plants to grow.

We pull back gradually to see Earth in perspective.

Between massive destruction caused by the collision and damage done by volcanic eruptions and changing sea levels, nearly three-quarters of all life on Earth went extinct.

The age of the dinosaurs was over.

But life is resilient, and there were survivors. A few dinosaurs made it through, eventually evolving into our present-day birds. And some mammals survived as well, giving them a chance to evolve.

In fact, without this collision, we might not be here today.

FADE TO BLACK.

6. MITIGATION

FADE UP: We are floating in space. The MUSIC is OMINOUS.

Could a collision like this happen again?

Asteroids are still out there. If one came our way…what could we do?

Blowing it up wouldn't work…we'd just end up with a swarm of rocks heading our way.

AN ASTEROID floats into frame, seeming to menace Earth just as another asteroid did 65 million years ago.

But scientists have been studying and tracking asteroids for years, and they've come up with an ingenious idea…

As the asteroid comes closer, we see that A ROCKET flies nearby. MUSIC becomes just a little OPTIMISTIC.

We could use the force of gravity to alter the asteroid's path.

It might work like this.

If you flew a spacecraft alongside an asteroid, the spacecraft's tiny gravitational pull might be enough to change the asteroid's orbit, tugging it a little off course.

The asteroid and rocket pass close to earth.

It would take years, but slowly, over time, the asteroid would move into a slightly different orbit…eventually ending up hundreds of miles away from Earth.

A few hundred miles isn't much…but it's all we'd need to keep us safe.

The asteroid and rocket pass by, leaving Earth unharmed. MUSIC is TRIUMPHANT.

Right now, this is only an idea…but it's a promising one. Many scientists think it may be our best bet.

Some day, perhaps one of you will come up with an even better idea…an idea that will help protect Earth from these cosmic wanderers.

7. STELLAR COLLISION

We pull away from Earth.

We now know that a collision created our moon, and that collisions fuel our sun each and every day. We've seen the collision that destroyed the dinosaurs. We've learned how we might prevent future collisions by using the force of gravity.

All of this happened right here… in our own cosmic neighborhood….

We pull out through the stars.

But what of the rest of the Universe?

And what of the future? What other cosmic collisions might be in store for us?

We pull out of the galaxy, keeping it in view.

We're leaving the Milky Way Galaxy now…home to our solar system.

The Milky Way is also home to hundreds of billions of stars and possibly trillions of other planets, as well as vast collections of gas and dust.

Most stars in galaxies are so far apart, they hardly ever collide.

But there are rare exceptions.

Let's slow down for a moment on the outskirts of our galaxy.

The STARS of a GLOBULAR CLUSTER rapidly surround us.

Those stars streaming past us are part of a globular cluster—a place in which stars are crammed together so tightly that they sometimes smash into one another—

TWO STARS RISE UP above us from opposite ends of the dome and… SMASH TOGETHER before receding rapidly into the distance.

***That* was unusual. Even here, stars only collide once every hundred thousand years.**

As we pull out quickly from the Milky Way, it's time to fast-forward into the future to see what the outlook is for our galaxy…and our universe.

FADE TO BLACK.

8. GALAXY COLLISION

FADE IN: OUR MILKY WAY is SPINNING in TIME-LAPSE fashion. Behind it, ANOTHER SPIRAL GALAXY is winding its way toward ours.

We're now billions of years in the future and a half a million light years away from Earth.

What you're seeing has been speeded up so that every second, forty million years pass by.

Galaxies, like everything else in the universe, are constantly on the move. Even though they're very far apart, the powerful force of gravity pulls them together.

The two galaxies continue moving towards one another.

This is the Milky Way Galaxy on a collision course with our nearest neighbor, the galaxy Andromeda.

In a ballet-like motion, the two galaxies STRIKE each other with a glancing blow.

The two galaxies remain intact, gracefully retreating to a distance before again moving towards each other.

These two great galaxies will swirl around each other in a graceful cosmic dance, glancing off one another and then drifting apart again.

Stars and planets in these galaxies won't actually collide. They're much too far apart. Scientists think they'll simply slide past one another.

What *will* collide are the gas and dust that fill each galaxy.

And from these collisions…

They strike again, this time merging into ONE GREAT ELLIPTICAL GALAXY. MUSIC SWELLS…

…countless stars and planets will be born.

Eventually…billions of years from now…the Milky Way and Andromeda will become one vast new galaxy.

Galactic collisions are a normal part of all galaxies' lives. In fact, our own Milky Way was formed by collisions among many small galaxies.

Without these collisions, the Milky Way wouldn't exist. And probably, neither would we.

9. CONCLUSION

We pull away from the swirling new elliptical galaxy, and out into a whole UNIVERSE OF GLAXIES surrounding us.

Cosmic collisions—dynamic and dazzling--have created so many things we take for granted—the glowing moon, the sun's warmth and light, our changing seasons, waves washing up on a sandy shore.

They've ended the age of the dinosaurs and changed the very map of the cosmos, reforming galaxies and giving birth to new stars and new worlds.

We humans occupy a tiny part of a vast and evolving cosmic landscape. Sometimes, it feels like we're merely voyagers on a brief journey.

But we are explorers…striving to understand the ever-changing nature of the cosmos. And there's no telling what our boundless curiosity will reveal to us next, in a universe made and remade in a story of cosmic collisions.