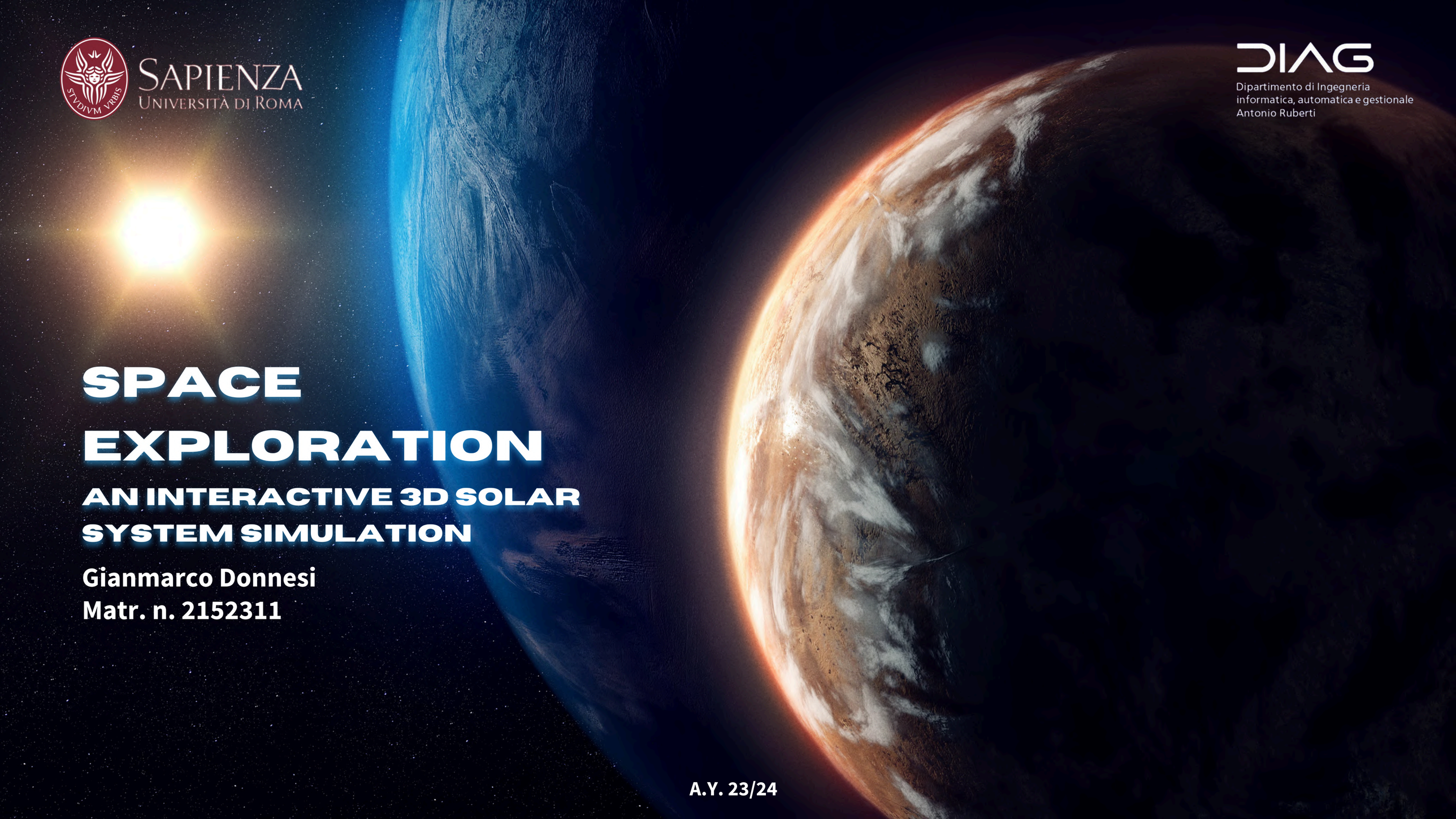

SAPIENZA
UNIVERSITÀ DI ROMA

DIAG
Dipartimento di Ingegneria informatica, automatica e gestionale Antonio Ruberti

# SPACE EXPLORATION

## AN INTERACTIVE 3D SOLAR SYSTEM SIMULATION

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## 01 PROJECT OVERVIEW

This project is a 3D simulation of a solar system and includes various celestial bodies such as the Sun, planets, asteroids, and the International Space Station (ISS).

## 02 PURPOSE

To provide a visually engaging and interactive representation of our solar system.
To allow users to explore and learn about different celestial bodies and their movements.

## 03 KEY FEATURES

- Realistic sun with dynamic lighting effects.
- Detailed planets with realistic textures and orbits.
- A belt of asteroids with random movements.
- An orbiting ISS with controllable view.

## 04 TECHNOLOGIES USED

- **Three.js**: A powerful JavaScript library for 3D graphics.
- **GLTFLoader**: For loading the 3D model of the ISS.
- **Custom Shaders**: For realistic visual effects on the sun and planets.

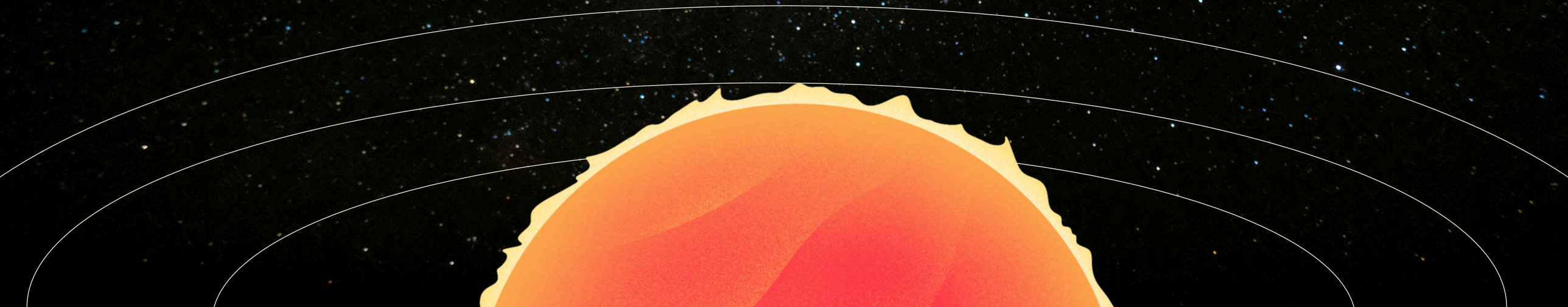
# SUN LIGHTING

The sun is the central light source in the solar system simulation. It is designed to be visually dynamic and realistic to enhance the overall experience.

**Lighting Techniques:**

- **Point Light**:
  - A high-intensity point light is placed at the sun's position.
  - This light casts shadows and illuminates other objects in the scene.
  - Configured with decay to simulate the natural falloff of light over distance.

- **Emissive Material**:
  - The sun's material is emissive, meaning it emits light and creates a glow effect around the sun, making it appear bright and radiant.



# SUN SHADERS

## Vertex Shader:

- The vertex shader modifies the positions of the vertices to create a pulsating effect.
- It uses a sine function based on time to simulate the dynamic surface of the sun.

## Fragment Shader:

- The fragment shader handles the color and lighting of the sun's surface.
- It blends a base texture with noise to create a realistic, turbulent surface.
- Uses a sine function to adjust the brightness over time, simulating solar activity.

## Noise for Realism:

- **Noise Function:**
  - A custom noise function is implemented to create irregularities on the sun's surface.
  - This noise adds small variations to the color and brightness, making the sun look more natural.
- **Parameters:**
  - Noise Frequency: Controls the scale of the noise patterns.
  - Noise Amplitude: Controls the intensity of the noise effect.

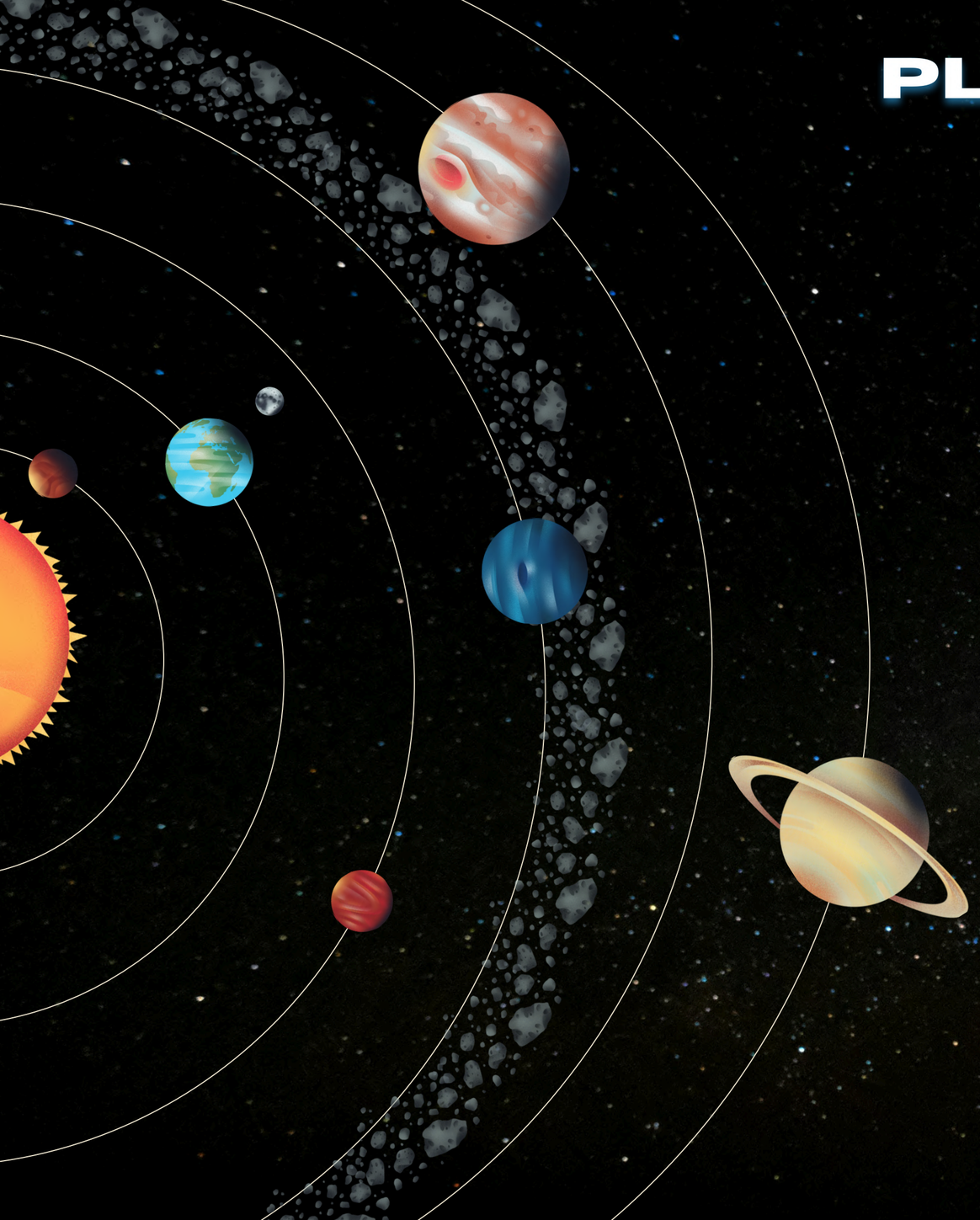
```
vertexShader: `
            varying vec2 vUv;
            varying vec3 vNormal;
            varying vec3 vPosition;

            void main() {
                vUv = uv; // Pass UV coordinates to fragment shader
                vNormal = normal; // Pass normal vector to fragment shader
                vPosition = position; // Pass position to fragment shader
                gl_Position = projectionMatrix * modelViewMatrix * vec4(position, 1.0);
            }
        `,

fragmentShader: `
            uniform float time;
            uniform sampler2D sunTexture;
            uniform float noiseFrequency;
            uniform float noiseAmplitude;
            varying vec2 vUv;
            varying vec3 vNormal;
            varying vec3 vPosition;

            // Simple noise function
            float noise(vec3 p) {
                return sin(p.x + p.y + p.z + time);
            }

            void main() {
                vec3 texColor = texture2D(sunTexture, vUv).rgb; // Sample sun texture
                float noiseValue = noise(vPosition * noiseFrequency + time * 0.5);
                float intensity = 0.5 + 0.5 * noiseValue * noiseAmplitude; // Calculate intensity
                vec3 color = mix(vec3(1.0, 0.3, 0.0), vec3(1.0, 1.0, 0.0), intensity);
                gl_FragColor = vec4(texColor * color, 1.0); // Set fragment color
            }
        `
```



# PLANETS

The simulation includes several planets with realistic textures and properties. Each planet orbits the sun based on its distance and revolution time.

**Planetary Data:**

- Each planet is modeled with specific data including distance from the Sun, eccentricity, revolution time, and surface temperature.
- This data provides realistic orbital paths and behaviors for each planet in the simulation.

**Dynamic Lighting:**

- Each planet has its own dynamic point light source, enhancing realism by simulating how light interacts with the planet's surface.

**Interactive Elements:**

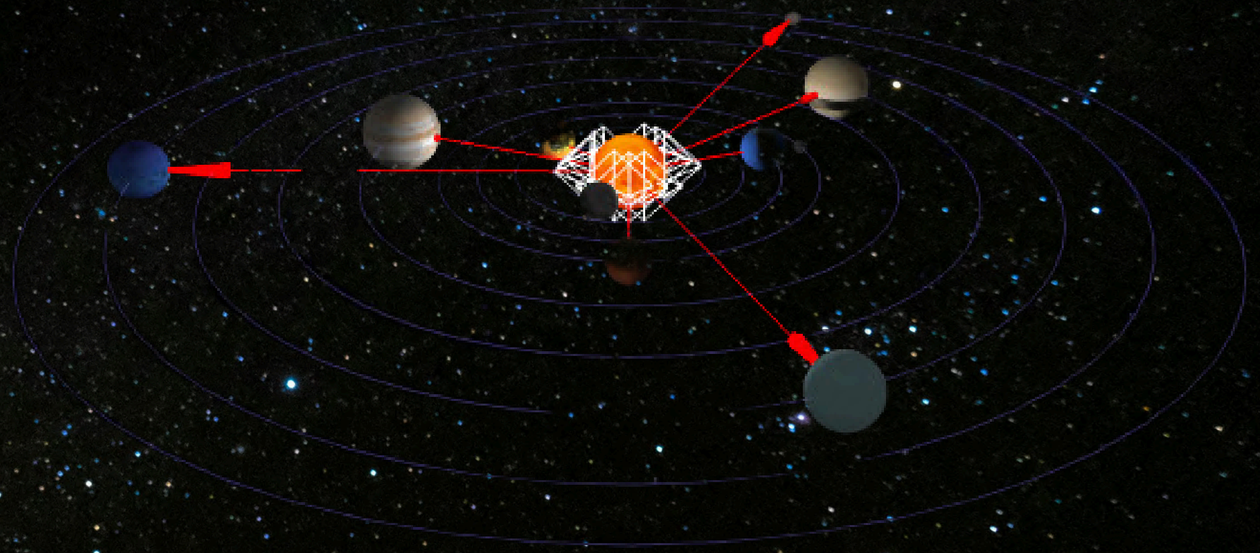
- Users can click on planets to get detailed information displayed in a tooltip.
- The camera can lock onto planets for close-up views, providing an interactive and educational experience.
- Planets move in their respective orbits (visually represented) around the Sun with varying speeds and eccentricities.

# DYNAMIC LIGHTING

Dynamic lighting plays a crucial role in enhancing the realism and visual appeal for the 3D Solar System Simulator.

**Point Lights for Planets:**

- The point lights simulate how sunlight interacts with each planet's surface, creating realistic lighting and shadow effects.
- Light intensity is calculated dynamically based on the distance of the planet from the Sun
- Planets farther from the Sun receive less light, mimicking real-world conditions.



**Visualization Helpers:**

- Light helpers and arrow helpers are used to visualize the direction and position of the lights.
- These tools are useful for development and debugging purposes, ensuring lights are correctly placed and oriented.

# SHADOW MAPPING

## Enabling Shadow Mapping:

- Implemented to create realistic and dynamic shadows for planets and other objects.
- Enabled in the Three.js renderer to allow shadows to be cast and received by objects in the scene.

```
renderer.shadowMap.enabled = true;
renderer.shadowMap.type = THREE.PCFSoftShadowMap; // Soft shadows for better quality
```

```
const pointLight = new THREE.PointLight(0xffffff, 3, 1000);
pointLight.castShadow = true;
pointLight.shadow.mapSize.width = 4096; // High-resolution shadow map
pointLight.shadow.mapSize.height = 4096; // High-resolution shadow map
pointLight.shadow.bias = -0.0001; // Shadow bias to reduce artifacts
scene.add(pointLight);
```

## Configuring Light Sources:

- Dynamic point lights for each planet are configured to cast shadows, enhancing the depth and realism of the scene.
- Shadow bias and shadow map quality are adjusted to minimize artifacts and ensure detailed and accurate shadows.

## Dynamic Shadows:

- Shadows dynamically change based on the position of the light source and objects. As planets orbit the Sun, their shadows shift accordingly, adding a layer of dynamism and realism to the simulation.

```
const time = Date.now() * 0.001;
planets.forEach((planet, index) => {
    const distance = planet.userData.distance;
    const angle = time * settings.orbitSpeed * (1 + index);
    planet.position.x = distance * Math.cos(angle);
    planet.position.z = distance * Math.sin(angle);

    // Update shadow position
    const pointLight = planet.userData.pointLight;
    if (pointLight) {
        const direction = new THREE.Vector3();
        direction.subVectors(planet.position, sun.position).normalize();
        const lightPosition = direction.clone().multiplyScalar(1).add(sun.position);
        pointLight.position.copy(lightPosition);
        pointLight.target.position.copy(planet.position);
    }
});
```

# SPACE STATION AND ASTEROIDS

### 3D Model of the ISS:

- The ISS is represented by a detailed 3D model positioned near Earth.
- The model is scaled realistically to fit the simulation environment.
- Users can lock the camera view onto the ISS for close-up observation.
- The station orbits Earth, mimicking real orbital mechanics.
- Users can press 'l' to lock/unlock the camera view on the ISS.

### Asteroid Belt:

- The asteroid belt is simulated with numerous small 3D models, each representing an asteroid.
- Positions and movements are randomized for a natural appearance.
- Asteroids move randomly within the belt, simulating the dynamic environment of space.
- Each asteroid has its own speed and path, creating a realistic belt.

ISS 3D Model: [Source:NASA](https://science.nasa.gov/resource/international-space-station-3d-model/)

# BACKGROUND AND ENVIRONMENT

### Ambient Lighting:

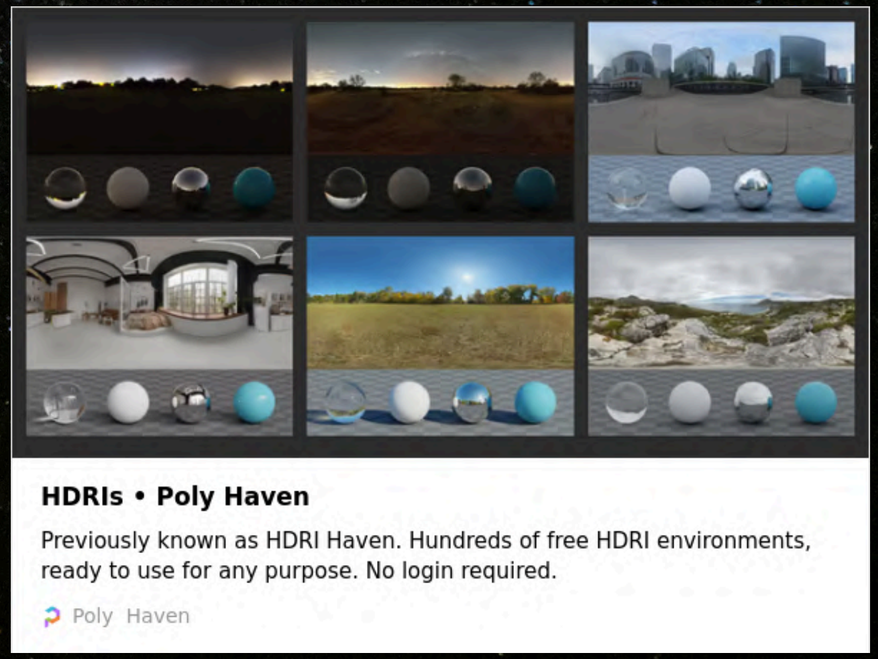
- Soft ambient lighting is added to simulate the faint light present in space.
- This helps in highlighting objects without creating harsh shadows.

### HDRI Environment for Realistic Lighting:

- An HDRI (High Dynamic Range Imaging) environment map is used to simulate realistic lighting conditions.
- This environment map ensures that light reflections and ambient lighting match the space setting.

```
function loadHDRIEnvironment(THREE, renderer, scene, textureLoader) {
    const pmremGenerator = new THREE.PMREMGenerator(renderer);
    pmremGenerator.compileEquirectangularShader();

    textureLoader.load('textures/space_hdr.hdr', (texture) => {
        const envMap = pmremGenerator.fromEquirectangular(texture).texture;
        scene.environment = envMap;
        scene.background = envMap;
        texture.dispose();
        pmremGenerator.dispose();
    });
}
loadHDRIEnvironment(THREE, renderer, scene, textureLoader);
```



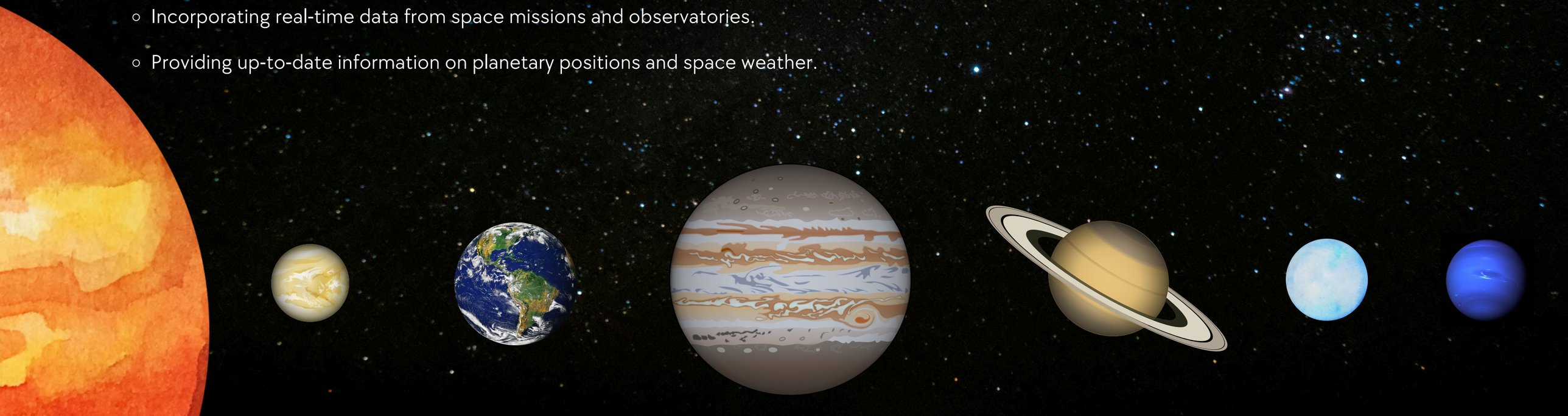
# CONCLUSION

## Future Improvements:

1. **Enhanced Planetary Details:**
   - Adding more surface details and features to planets and moons.
   - Implementing atmospheric effects for planets with atmospheres.
2. **Expanded Interactivity:**
   - Allowing users to take virtual tours on the surfaces of planets and moons.
   - Adding more interactive elements such as comets and additional spacecraft.
3. **Scientific Data Integration:**
   - Incorporating real-time data from space missions and observatories.
   - Providing up-to-date information on planetary positions and space weather.

## Key Achievements:

- Realistic 3D Models
- Dynamic Lighting and Shadows
- Interactive Elements



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# THANK YOU FOR LISTENING!

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