There Ain’t No Stealth in Space

- Cloaked ships show up in a lot of SF. # Star Trek has the Klingon Bird of Prey. # Stargate: Atlantis # has Puddle-Jumpers, # stealthed around a planet! # Starcraft II # has Banshees! # Invisible ships are a mainstay of science fiction.
- Invisible ships show up in other things that start with “Star”, like # Star Wars and # Star Doctor Who. They’re popular because they make space battles more exciting. # STAR TREK III SLIDE.
- Of course, if any overacting schlub can detect cloaked ships, that’s not much good, is it?
- So can you actually cloak a ship? Knowing what we know right now about physics, how possible is it?
    - # NO. So thanks for coming, and I hope you’ll come to some of my other talks.
    - # So why do I say you can’t make stealthy ships in space? What makes it all but impossible?
- Before I get to that, let’s talk about my assumptions.
    - I’m talking about SF-type ships that move from planet to planet, not satellites quietly orbiting around one planet.
    - I’m assuming that someone is actively looking for you, and you’re actively trying to hide your spaceship from them. It’s not like today, where we’re not really looking that seriously for other spaceships. # Even though we SHOULD BE.
    - I’m also assuming that we’re using physics we know about. Like, if you throw # faster-than-light ships or tachyon detection grids into the mix, my analysis doesn’t work.
- So what’s wrong with cloaking devices the way they’re shown in SF?
    - # We normally think of invisibility being a matter of bending light around us. We see objects because light bounces off of them. # Make light pass around something, and it becomes # invisible.
    - Here’s where you should think like someone who can see in infrared.. # WWPD? The trick isn’t to bend the sun’s light around us, or avoid sensor beams that another ship is sending out. They don’t have to, because spaceships, like everything else, # make their own light in the form of heat. See that light; # see the spaceship.
- Lemme esplain. Objects give off light depending on how hot they are. # Think about what happens as we heat up metal. It starts glowing dull red at around 800 K (about 525 C). Get it to 1000 K (725 C) and now it’s cherry red. Keep going and it’ll turn white. In fact, just about *any* solid will do that, and it’s mainly a function of temperature..
    - # This has to do w/the electromagnetic spectrum. POINT OUT IR, VISIBLE, UV. MORE ENERGY AS YOU MOVE TO UV. # Now here’s what happens when solids get hot. One, the light they give off starts out in the infrared and then it moves into the visible and then into the uv. That’s because hot stuff has more energy, and so it can emit higher energy light.. Two, the amount of light it gives off goes up. In fact, it goes up fast -- it’s proportional to the fourth power of its temperature.

    - This is blackbody radiation, and # Max Planck is the guy who first fully explained it.
    - We don't think about how stuff gives off light all the time because, at room temperature, everything gives off a visible photon every 41 seconds. Watch closely -- maybe you'll see me emit one. And no, light reflecting off of my head doesn't count # PIC OF ME W/LENS FLARE ON HEAD.
        - # But we're emitting plenty of infrared photons. In fact, you're giving off 100 W of infrared power ALL THE TIME. You're giving off almost as much infrared power as a 120 W lightbulb. #
        - That makes you easy to see on IR, in fact # Notice how the garbage bag totally doesn't hide the guy's hand in IR
- So what does this have to do with stealth in space? #
    - I'm going to see you because your ship is emitting light like crazy.
    - Space has a 3 K background. Your spaceship doesn't. And because of that, I'm going to see you with this # HgCdTe ARRAY.
        - It's like the sensor in your camera, only it sees infrared light -- exactly the light you're giving off right now. And with it, I can see you a long way aray. # Best of all, I can buy these sensors right now.
    - Got a crew? I trust they'd like to work in an environment that's not 3 K. # 62 F is about 290 K. Let's say you've got a Klingon Bird of Prey because, hey, why not. # Nose on to us, it'll give off about 375,000 W of infrared light. If I stick a 2 m telescope in front of my super detector, I can see this guy coming a long way away. # In fact, I can see it # 8 million kilometers away! That's 30 light seconds, which doesn't sound like much until you realize that's 18 times further than from the Earth to the moon. Without crazy awesome drives we don't know anything about yet, you're going to take days get to me. That's plenty of warning! # Curse you, Max Planck!
- Fine! I won't use squishy hu-mons. # I'll use robots so I don't have to have a heated crew compartment! Or I'll put the crew in suspended animation!
    - That's cool. But how are you getting around the solar system?
        - Chemical rockets? # You're burning stuff at up to 3500 K. # One of the Space Shuttle Main Engines produces about 5 GW of power when it's running. You know how far away I can see that when it's lit up? # 400 million kilometers. That's further than from the Sun to Mars! And that's just one of the drives! The Space Shuttle has three of them! And they're the shuttle's little engines! # Curse you, Max Planck!
        - Ion drives? # They spit out ionized atoms to push the spaceship. # The real ones are more fuel-efficient than chemical rockets but you don't get high thrust, so you'll have to run them for a long time. And they still use lots of power. Like, 1000 kW. # 50% of that goes out as waste heat, so your Twin Ion Engine fighter is visible at 6 million km. # So, you know, only 13 times as far as from here to the moon. # Curse you, Max Planck!
        - Plasma thruster like a # VASIMR drive? It's a kind of plasma drive, and plasma drives are neat, but you still have to use a lot of power. NASA looked at using 5 VASIMR drives to get cargo from the Earth to the Moon in, oh, about a month. They'll run at 1,000 kW, giving 400 kW of waste

heat. That's only visible # 3,500,000 km away; plenty of time for someone on the moon to see you coming. Or couple it with a nuclear reactor (which also generates heat!) to get from Earth to Mars in 40 days using 200 MW of power, so 80 MW of waste heat just from the engines! That's # 50,000,000 km! That's 1/3 of the way from the Sun to the Earth. # Curse you, Max Planck!

        - Project Orion? # Use 15 kT nuclear bombs to push your rocket around. Your pusher plate will heat up to about 600 K, not counting the 15% of your bomb's energy that escapes as soft x-rays and gamma rays. # At 600 K I'll see you coming from 4 million km away, plus I can use astronomy tricks to look for x-rays and gamma ray bursts coming from odd locations at a rate of one a second. # Curse you, Max Planck!
        - Lightsail? # Cool technology, as long as you're shipping a FedEx package and nothing more. Plus you'll start to occlude stars.
    - Here's the thing: moving astronomical distances takes astronomical amounts of energy. Know how much electricity New York City is using at its peak? 12 MW. The Shuttle with all engines firing? 81 **GW**.
- Fine! I'll turn off my engines and coast! # That way when I run my engines you won't see them!
    - Let's ignore the heat that your power supply is generating and that you have to get rid of. How long are you willing to coast? Months? Years?
    - Math's going to get you. Detection scales as the inverse square of the distance; it also scales as the square of the drive power. Want to start further out but take the same amount of time to arrive? The required drive power goes as the square of the distance. Go twice as far away and you'll be 1/4 as detectable, but you'll need 4 times the drive power and thus you're also 4 times as detectable. Stupid math! # Curse you, er, guy who invented math!
    - Plus, how are you going to stop?
- Fine! I'll refrigerate the whole thing and either store the heat until later or radiate it in a direction where you're not looking!
    - Sure, let's store the heat. You know what's great for that? # Water. It holds a lot of heat per kilogram if you take it from freezing to boiling. Take an Olympic swimming pool full of water. That'll let you cool your megawatt-producing power plants for less than 12 days. And when you turn on your gigawatt-producing drives you'll only be able to cool them for, oh, 17 minutes. Plus you've just added 2500 metric tons of weight just for the water. # That's more than the space shuttle weight at launch! You're gonna need a bigger drive, which needs a bigger cooling system, which means you're screwed.
    - Okay, so beam the heat away in a direction where no one's looking. Put a reflector around the bits that are giving off heat. # Except...you can't squeeze it down into a tiny cone thanks to thermodynamics. The smaller you make the area you're radiating into, the bigger a radiator you have to have to dissipate the same energy. Plus because of the second law of thermodynamics, your doggy cone that you use to re-direct the heat will get hot itself, which means you need to refrigerate the doggie cone and re-radiate that heat, which makes the doggie cone get hotter, etc. etc. Soon you're in a Red Queen's Race, # where you

have to run faster and faster just to stay in the same spot. # Curse you, Rudolph Clausius and your laws of thermodynamics!

- But space is big! # Really big! There's no way you can see me!
    - # O RLY?
    - Remember my 2000x2000 HgCdTe detector I talked about earlier? The one that's hooked up to a 2-meter f/2 Cassegrain telescope? If I'm taking pictures 30 times a second and moving it after each time, like on a gimbal, then I can cover the whole sky in under an hour! And these setups are cheap, relatively speaking.
- Well, crap. Is there nothing to be done?
    - Decoy ships. # Though that's tough to do. If you're using chemical rockets, I can look at the spectrum of your exhaust to guess your thrust and how fast you move. Given that, I can tell how much your ship weighs. So your decoys will probably need to weigh as much as your ship, and your drives are the expensive part, so you might as well make your decoys an actual ship.
    - # Break the laws of physics
    - Best bet: # bribe the guy who deals with the sensors