

Re: Simple Sagnac

Source: <http://sci.tech-archive.net/Archive/sci.physics.relativity/2005-08/msg00356.html>

- *From:* "bsr3997@xxxxxxxxxxxxx" <bsr3997@xxxxxxxxxxxxx>
 - *Date:* 2 Aug 2005 21:32:21 -0700
-

sal wrote:

> Thanks for the informative response.

>

> On Sat, 30 Jul 2005 18:19:58 +0000, Daniel Cook wrote:

>

>> On Fri, 29 Jul 2005 10:43:19 -0400, sal <pragmatist@xxxxxxxxxxxxx> wrote:

>>>The problem here is really that the "classical" case is a squishy

>>>fiction without hard rules.

>>

>> True. There were many different "classical" theories of optics, and
>> many different ideas about how the "ether" interacted with ordinary
>> matter, if at all. In the context of a historical discussion about
>> optics, people often refer to first-order effects (in v/c) as
>> "classical", and to second-order effects as "relativistic". This is
>> because the "classical" ether theorists were more or less able to
>> account for all first-order effects (including Sagnac), and were not
>> forced to adopt the fully relativistic view until second-order
>> effects came under observation (e.g., Michelson and Morley).

>>

>>>.. in the absence of relativity (or some "aether clone" of
>>> relativity) I don't see any way to predict the correct Sagnac
>>> fringe shift when the signal is carried by an optical fiber with
>>> relatively high index of refraction, rather than by vacuum or air.

>>

>> Don't under-estimated the ingenuity of the classical theorists. To
>> account for all first-order effects, including the Fizeau experiment
>> (which showed how light propagates through a moving column of
>> water), it was necessary to adopt Fresnel's "partial dragging"
>> hypothesis.

>

> Oops ... I have a vague memory of reading about Fresnel's hypothesis
> but I had completely forgotten about it in this context. And I was
> never clear on quite what it was, either.

>

>

>> This meant the ether was neither totally stationary nor
>> totally dragged along by material bodies. Through a complicated
>> chain of classical reasoning, Fresnel actually predicted this

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>> partial dragging in 1818, three decades before Fizeau performed his
>> experiment. According to Fresnel, the speed of light in a medium
>> with refractive index n moving (along the same line) at speed $\pm v$
>> should be $c/n \pm v(1 - n^2)$, and of course Fizeau confirmed this (up
>> to first order). If you work out your Sagnac effect with this
>> partial dragging, you'll see it agrees up to first order with the
>> relativistic prediction, basically because Fresnel's partial
>> dragging formula mimics the relativistic speed composition rule up
>> to first order.
>>
>> Needless to say, Fresnel's interpretation of the extra term in the
>> velocity as due to partial dragging of the ether is not entirely
>> consistent, because the index of refraction in material media varies
>> with frequency, which means that Fresnel needs infinitely many
>> ethers, one for each frequency of light, being dragged at slightly
>> different speeds to account for the observed behavior at all
>> frequencies. This is the kind of detail that always nagged at ether
>> theorists, but in general they were happy to just have a theory that
>> more or less agreed with all the first-order experiments. It was the
>> second order experiments that made it clear to everyone that the
>> relativity principle itself, rather than the old mechanical
>> principles, was the more reliable guide to how things work.
>>
>>> Sagnac himself didn't address the presence of a medium; he assumed
>>> he could ignore the effect of the air in his apparatus, and just
>>> assume the light traveled at C relative to the "fixed frame" (I
>>> think he thought there was an aether but I'm not sure).
>>
>> Even as late as 1913, for some (particularly French) physicists the
>> two main competing theories of light were still the ether/wave
>> theory of Lorentz and the ballistic corpuscle theory of people like
>> Ritz. Those were the two main traditions, going back to Huygens and
>> Newton respectively. One major distinction between these theories
>> is that in an ether theory the speed of light is independent of the
>> speed of the source, whereas in a ballistic theory the speed of the
>> source is added to the speed of light. Sagnac's conclusion in his
>> 1913 paper was that (in his words) "the speed of light is
>> independent of the speed of the source". This, he declared, proves
>> the existence of an ether.
>
> Say, rather, that it disproves ballistic theory.
>
> Obviously, saying something "proves" a theory correct is an
> overstatement, as another experiment some time later may show some
> other problem with it. But when an experiment contradicts a theory's
> predictions, it's pretty safe to say it "disproves" it, and one must,
> at a minimum, find a band-aid for the theory if one is not to reject
> it completely.
>
> In any case, while I don't know the exact details of Sagnac's
> apparatus, if the air in the apparatus wasn't dragged along with the

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> disk, then Fox's variant on ballistic theory would still work (since
> the air acts as a sort of "ether" and light travels at C/n , $n \sim 1$,
> relative to the air). It's when the tubes carrying the light are
> evacuated or a glass fiber is used that ballistic theory really runs
> into trouble. I don't see how it can be saved in that case. I don't
> know if either of those variants on the experiment had been done when
> Fox did his work; I think that was in the '60s.

>

>

>> Needless to say, the independence of light speed from the speed of
>> the source is a fundamental property of Einstein's relativity theory
>> too, and this was well known, so no one but the supporters of
>> ballistic theories was ever bothered by Sagnac's
>> observations. Sagnac's paper didn't discuss the possibility of a
>> non-ether theory with invariant light speed. He simply equated the
>> invariance of light speed with proof of an ether/wave theory.

>>

>> Crackpots like to claim that Sagnac's result was originally widely
>> regarded as a refutation of special relativity, but this claim has
>> no basis in historical fact. Everyone familiar with special
>> relativity, even critics such as Michelson, always recognized that
>> the Sagnac effect is a (rather trivial) confirmation of special
>> relativity, not a refutation.

>>

>> I think your web page is good, because it points out that Sagnac
>> devices using fiber optic lines actually involve the Fizeau effect
>> as well as the Sagnac effect, because they run light in opposite
>> directions through a rotating medium with an index of refraction
>> differing significantly from 1. In order to account for the results
>> in this kind of device, an etherist needs to invoke, at the very
>> least, Fresnel's partial dragging hypothesis. This makes the device
>> a somewhat less trivial confirmation of special relativity, because
>> the Fizeau effect is not trivial. This is seldom mentioned in
>> discussions of the Sagnac effect, perhaps because people consider
>> the "pure" Sagnac effect to be represented by a closed loop path
>> through the vacuum, as distinct from the Fizeau effect of light
>> propagating in a moving medium. But your point is well taken, that
>> both of these effects are present in many real Sagnac devices.

>

> Hmm ... looks like I gotta revise that page yet again... :-)

>

>

> --

> Nospam becomes physicsinsights to fix the email

> I can be also contacted through <http://www.physicsinsights.org>

Nice web page. A very clear simple explanation of the Sagnac effect.
Just a few quibbles.

Your statement about the inability of Newtonian mechanics to explain
Sagnac is backwards. Sagnac has often been used in this group in

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attempts to show that light travels at $c+v$ or $c-v$ in a moving frame. Why else would it take different times to go in opposite directions around the ring ;) To claim that the single clock is out of sync with itself is really grasping at straws. Some might even say that is absurd ;)

Sagnac does not prove SR wrong because SR excludes rotations. In "Relativity" Einstein wrote,

"If, relative to K, K' is a uniformly moving co-ordinate system devoid of rotation, then natural phenomena run their course with respect to K' according to exactly the same general laws as with respect to K. This statement is called the principle of relativity (in the restricted sense)."

The signal is partially dragged in media for both classical and relativistic models, as it must be to agree with experiment. That is what Fizeau proposed and verified experimentally before SR existed. The media slows the signal to less than c , but slows it less when the media is moving in the same direction as the signal. The signal cannot be fully dragged or the signal speed could exceed c in the stationary frame with a fast moving media.

One error I noticed in your classical view of the stationary frame is that you used $2\pi r$ for the distance traveled by the signals. That is only true when there is no rotation. On the 28th Bilge wrote.

" Why not? If the ring rotates with an angular velocity, w , then the light in the direction of rotation has to travel a distance:

$$s = 2\pi r + wrt_1$$

Where t is the time required for the light to reach the point on the ring that it started, since the ring rotated by a distance wrt in that time. Similarly, in the opposite direction, the distance traveled is $s = 2\pi r - wrt_2$. The speed of light in the ring is $v = c/n$, so it travels a distance $s = vt_1$ in the direction of rotation and $s = vt_2$ in the opposite direction."

I'm sure the 2π is a typo for $2*\pi$. The important thing here is that he included the wrt factor. Leaving out the $+$ or $-$ wrt is what caused your time to come out the same in both directions.

Bruce

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 - ◇ *From:* sal

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 - ◆ **Re: Simple Sagnac**
 - ◇ *From:* Dirk Van de moortel
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